

SERI/SP-220-3548  
DE89009494

# **Sourcebook of Methods of Analysis for Biomass and Biomass-Conversion Processes**

T.A. Milne  
A.H. Brennan  
B.H. Glenn

February 1990

Produced by the Solar Technical Information Program, U.S. Department of Energy,  
with joint funding from the International Energy Agency;  
Energy, Mines and Resources Canada; and  
the Solar Energy Research Institute

## Acknowledgments

This sourcebook was published by the Solar Technical Information Program (STIP), U.S. Department of Energy. The contents are the result of contributions by many nations and individuals. Financial support came from IEA member countries Canada, Finland, Italy, New Zealand, and the United States; from the Solar Energy Research Institute's Director's Development Fund; from Energy, Mines and Resources Canada; and from STIP. Special thanks are due the Technical Advisory Board members, Dan Asplund, the late Doug Hayes, and Keith Mackie, and the IEA Biomass Conversion Annex Leader, Don Stevens. The following were most helpful in the working group panels and in the round-robin interlaboratory comparisons: Peter Dare, Doug Elliott, Hermann Esterbauer, Karel Grohmann, Barbel Hahn-Hagerdahl, Ted Hillis, James Linden, Jim McKinley, Keith Mackie, Ralph Overend, Michael Paice, Vic Phillips, Roger Sutcliffe, Olof Theander, and K. K. Wu, among others. Assistance in planning for standard reference materials was generously provided by Jerry Cherney, Janet Cushman, Gene Domalski, Keith Mackie, Jack Ranney, Stan Rasberry, Bill Reed, and Olof Theander. The staff at the National Center for Standards and Certification at the National Institute for Standards and Technology (NIST, formerly National Bureau of Standards) were most helpful in locating relevant standards. Heikki Oravainen contributed the special report on combustor efficiencies. Thanks also go to the members of the working group who met in Denver, to Diane Christodaro who arranged the meeting, and to the many correspondents who responded to questionnaires, sent in methods, and joined the round-robin tests. Finally, we are especially indebted to Helena Chum for her technical guidance and contributions throughout the project.

## Notice

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Printed in the United States of America  
Available from:  
National Technical Information Service  
U.S. Department of Commerce  
5285 Port Royal Road  
Springfield, VA 22161

Price: Microfiche A01  
Printed Copy A19

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issue of the following publications which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

## Preface

Since the oil embargo of the 1970s, researchers around the world have made tremendous progress in developing and improving methods for converting biomass--trees, plants, and organic wastes--to useful fuels and chemicals. However, the lack of relevant standards and analytical methods has made comparison of results between laboratories and nations difficult. This *Sourcebook of Methods of Analysis for Biomass and Biomass-Conversion Processes* is the result of an international effort to begin to fill this gap.

In 1986, the International Energy Agency began sponsorship of a "Voluntary Standards Activity," designed to provide comparability of research results, increase research efficiency, and provide quality assurance to both researchers and industry. Canada, Finland, New Zealand, and the United States supported the activity initially; Italy joined in 1988. Major support also came from Energy, Mines and Resources Canada (E,M&R); the U.S. Department of Energy's Solar Technical Information Program (STIP); and the Solar Energy Research Institute (SERI).

The sourcebook presents titles and abstracts (when available) of methods relevant to all aspects of biomass conversion--from analyzing feedstocks to evaluating performance of biofuels. The authors assembled the sourcebook at SERI by searching the literature, reviewing industrial standards, and soliciting suggestions from scientists in the field. In addition, Finland prepared a special report on measuring the efficiencies of small boilers and biomass stoves and furnaces.

## Contents

Introduction .....	
Key to Standards Organizations Cited .....	
Standards and Analytical Methods .....	
Feedstock Sampling and Preparation .....	
Physical and Thermal Properties .....	
Density and Specific Gravity .....	
Particle Size Determination and Sieving .....	
Pore Size and Capacity .....	
Heats of Combustion .....	
Thermal Properties .....	
Elemental Analyses .....	
Ultimate Analysis .....	
Oxygen Analysis .....	
Nitrogen Analysis .....	
Sulfur Analysis .....	
Halogen Analysis .....	
Metals and Other Inorganics .....	
Chemical Component and Group Analyses .....	
Proximate Analysis .....	
Moisture .....	
Ash, Mineral Matter and Dirt .....	
Cellulose and Hemicellulose .....	
Hemicelluloses .....	
Lignins .....	
Extractives .....	
Functional Groups and Compound Classes .....	
Sugars and Other Carbohydrates .....	
Proteins .....	
Special Categories of Biomass Materials .....	
Forage Analysis .....	
Microalgae .....	
Oilseeds and Crops .....	
Peat .....	
Miscellaneous Analyses of Biomass Materials .....	
Fuel Product Analyses .....	
Solid Fuels .....	
Petroleum-Derived Liquid Fuels .....	
Lignocellulosic and Oxygenated Liquid Fuels .....	
Gaseous Fuels .....	
Non-Fuel Products .....	
Waste Product Analyses .....	
Solid Waste .....	
Liquid Waste .....	
Atmospheric Analysis .....	

## Contents (Concluded)

	Page
Conversion System Performance and Specifications .....	269
Combustion .....	271
Gasification .....	279
Bioconversion .....	283
Enzymatic Assays .....	287
Fire and Flammability .....	293
Measurements, Units, Quality Assurance, and Round-Robin Tests .....	303
Temperature, Pressure, and Flow .....	315
Chromatography .....	323
Spectrometry .....	331
Appendix I. Working Group Members .....	I-1
Appendix II. Standards Organizations .....	II-1
Appendix III. Combustion Equipment: Finland Report .....	III-1
Appendix IV. Round-Robin Tests .....	IV-1
Appendix V. Reference Biomass Materials .....	V-1
Appendix VI. Other Sources of Information .....	VI-1
Appendix VII. Glossary of Useful Terms .....	VII-1
Index I. Standards by Organization .....	Index I-1
Index II. Subject .....	Index II-1

## Introduction

Earth has a huge diversity of biomass feedstocks, including trees, crops, liquid and solid municipal wastes, oil-producing plants, waste wood, and agricultural residues. Today's options for converting these feedstocks range from direct burning for heat and electricity to chemical, thermochemical, and biochemical processes for making liquid fuels and chemicals. These processes, combined with sustainable management of the biomass resource, can be part of the solution to the world's energy supply and environmental problems.

Scientists and engineers have made great progress from the basic conversion technology available 15 to 20 years ago. Similar advances have taken place in analytical techniques and equipment. There is a growing consensus that establishing standard methods for analyzing biomass and its conversion products would speed research and improve its quality.

Several groups and nations have shown interest in establishing biomass standards. A 1984 workshop organized by the Solar Energy Research Institute (SERI) and supported by the U.S. National Bureau of Standards (NBS, now National Institute of Standards and Technology, NIST), the Pacific Northwest Laboratory (PNL), Oak Ridge National Laboratory (ORNL), the National Research Council of Canada (NRCC), the International Energy Agency (IEA), and the National Science Foundation (NSF) was a major step in discussing the need for standards. The American Society for Testing and Materials (ASTM) has expressed strong interest in continuing to issue biomass standards. Energy, Mines, and Resources (E,M&R) of Canada is pursuing the issue as well by establishing standard materials or feedstocks for conversion research and by coordinating common analyses of pyrolysis oils and enzymatic assays.

In 1986, the International Energy Agency (IEA) began a program to start to address the need for voluntary standards. Sponsored initially by Canada, Finland, New Zealand, and the United States, the program has three tasks: (1) to carry out selected analysis comparisons between laboratories, (2) to establish standard reference materials for both woody and herbaceous plants, and (3) to assemble a sourcebook of relevant analytical methods and standards now being used by laboratories and industry.

The IEA standards activity has benefited from the contributions of many scientists from around the world. An International Advisory Board has provided broad guidance to the program. A Working Group of about 30 scientists was established in 1987 to help plan and conduct specific activities. Advisory Board and Working Group members are listed in Appendix I. Another 250 scientists (correspondents) have received regular information on the project, and many have contributed methods for the sourcebook.

Preparation of the sourcebook has been the major task within the IEA activity. Methods selected were primarily those adopted as voluntary standards by private associations. A number of literature citations are included as well. These represent newer instrumental methods and those relevant to conversion processes such as fermentation and pyrolysis.

Standards specific to biomass energy exist in only a few cases, for example, municipal solid waste and wood fuels. Most of the standard methods come from related industries such as pulp and paper, agriculture, and fossil fuels. In fact, many biomass researchers have adopted these methods as interim standards. However, the applicability to biomass of some of these is limited, as is noted in the literature.

Each section of the sourcebook includes citations of both standard methods and literature methods. The sourcebook lists only citations and abstracts (where available) to save space and abide by copyright limitations. Citations include information on availability. Complete addresses of sources of standards are provided in Appendix II.

Reports on other tasks within the IEA Standards Activity are included in the appendices. The Finland report on small combustor efficiency is Appendix III. Reports on the round-robin tests are included in Appendix IV. Recommendations on selection and pretreatment of standard reference materials are presented in Appendix V.

The last two appendices may also be helpful. Appendix VI lists additional sources of information. Appendix VII presents a glossary of terms related to biomass.

We recognize that the collection of citations in the sourcebook is far from complete and covers predominantly U.S. standards. We hope that those who use the sourcebook will suggest additional methods, comment on limitations of those included, and provide feedback on the usefulness of the publication. The IEA Voluntary Standards Activity will continue through 1991 to allow for conducting more round-robin tests, establishing reference biomass materials, and issuing additional methods for the sourcebook. Please send comments and suggestions for the sourcebook to:

Thomas A. Milne  
Chemical Conversion Research Branch  
Solar Energy Research Institute  
1617 Cole Boulevard  
Golden, CO 80401-3393

### **Key to Standards-Setting Bodies Cited**

<b>AFNOR</b>	Association Francaise de Normalisation
<b>AGA</b>	American Gas Association
<b>AIChE</b>	American Institute of Chemical Engineers
<b>ANSI</b>	American National Standards Institute
<b>AOAC</b>	Association of Official Analytical Chemists
<b>APFI</b>	Association of Pellet Fuel Industries
<b>APHA</b>	American Public Health Association
<b>API</b>	American Petroleum Institute
<b>Appita</b>	Australian and New Zealand Pulp and Paper Industry Technical Association
<b>ASAE</b>	American Society of Agricultural Engineers
<b>ASHRAE</b>	American Society of Heating, Refrigerating and Air-Conditioning Engineers
<b>ASME</b>	American Society of Mechanical Engineers
<b>ASTM</b>	American Society for Testing and Materials
<b>AWWA</b>	American Water Works Association
<b>BSI</b>	British Standards Institution
<b>CBS</b>	Canadian Boiler Society
<b>CFR</b>	Code of Federal Regulations
<b>CGA</b>	Canadian Gas Association
<b>CPPA</b>	Canadian Pulp and Paper Association
<b>CSA</b>	Canadian Standards Association
<b>DIN</b>	Deutsches Institut fur Normung
<b>EN</b>	European Committee for Standardization
<b>EPA</b>	U.S. Environmental Protection Agency
<b>FPL</b>	U.S. Forest Products Laboratory
<b>GOST</b>	USSR State Committee for Standards
<b>ISO</b>	International Standards Organization

<b>IUPAC</b>	International Union of Pure and Applied Chemistry
<b>JIS</b>	Japanese Industrial Standards
<b>NFPA</b>	National Fire Protection Association
<b>SAA</b>	Standards Association of Australia
<b>SANZ</b>	Standards Association of New Zealand
<b>SCAN</b>	Scandinavian Pulp, Paper and Board
<b>SFS</b>	Suomen Standardisoimisliitto
<b>TAPPI</b>	Technical Association of the Pulp and Paper Industry
<b>UL</b>	Underwriters' Laboratories, Inc.
<b>ULC</b>	Underwriters' Laboratories of Canada





## FEEDSTOCK SAMPLING AND PREPARATION (STANDARDS)

**Title:** Wood: General Requirements for Tests; Physical and Mechanical Tests

**Citation:** NF B 51-003-85

**Content:**

**Availability:** AFNOR

---

**Title:** Sampling of Peat

**Citation:** AOAC 2.198

**Content:** For moss, humus, and reed-sedge types.

**Availability:** AOAC

---

**Title:** Preparation of Peat Sample

**Citation:** AOAC 2.199

**Content:** Place representative field sample on square rubber sheet, paper, or plastic. Reduce sample to amount required by quartering and place in moisture-proof container. Work rapidly to prevent moisture losses.

**Availability:** AOAC

---

**Title:** Sampling of Plants

**Citation:** AOAC 3.001

**Content:** When more than one plant is sampled, include enough plants in sample to ensure that it adequately represents average composition of entire lot of plants sampled. (This number depends upon variability in composition of the plants.) Determine details of sampling by purpose for which sample is taken.

**Availability:** AOAC

---

**Title:** Preparation of Plant Sample

**Citation:** AOAC 3.002

**Content:** For mineral constituents and carbohydrates.

**Availability:** AOAC

---

**Title:** Sampling of Animal Feed: Procedure

**Citation:** AOAC 7.001

**Content:**

**Availability:** AOAC

---

**Title:** Methods of Test for Pulp and Paper (metric units); Preparation of Wood Samples for Chemical Analysis

**Citation:** AS 1301, P2m:1973 and Appita P2m-73

**Content:** This standard prescribes the procedure for reducing wood samples to a suitable state of subdivision for chemical analysis.

**Availability:** Appita, SAA

---

**Title:** Methods of Test for Pulp and Paper (metric units); Sampling Paper and Board for Testing

**Citation:** AS 1301, P417m:1973 and Appita P417m-73

**Content:** Specifies a method of obtaining a representative sample of a lot of paper for test purposes.

**Availability:** Appita, SAA

---

**Title:** Standard Method of Collection and Preparation of Coke Samples for Laboratory Analysis<sup>1</sup>

**Citation:** ASTM D 346-78

**Content:** Coke, especially run of oven coke, or foundry coke, or both, is a difficult

## FEEDSTOCK SAMPLING AND PREPARATION (STANDARDS)

material to sample. It is imperative that every sample be collected and handled carefully and conscientiously and in strict accordance with the standard procedure described herein.

Gross samples of not less than the quantities designated in this method must be taken, whether the coke to be sampled consists of a few tons or several hundred tons.

This method covers procedures for the collection of samples of coke to be used for physical tests, chemical analyses, and the determination of total moisture.

Methods for the determination of total moisture of the coke and for the reduction and preparation of samples for chemical analyses are included.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D 05.23 on Sampling.

---

**Title:** Standard Method for Preparation of Extractive-Free Wood<sup>1</sup>

**Citation:** ASTM D 1105-84

**Content:** This method covers the preparation of extractive-free wood and is applicable to all North American woods. Extractives in wood consist of materials that are soluble in neutral solvents and that are not a part of the wood substance.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.14 on Chemical Tests.

---

**Title:** Standard Method of Preparing Coal Samples for Analysis<sup>1</sup>

**Citation:** ASTM D 2013-72 (1986)

**Content:** This method covers the reduction and division of gross samples, collected in accordance with Method D 2234, up to and including the individual portions for laboratory analysis.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke.

---

**Title:** Standard Methods for Collection of a Gross Sample of Coal<sup>1</sup>

**Citation:** ASTM D 2234-82 (1986)

**Content:** Data obtained from coal samples are used in establishing price, controlling mine and cleaning plant operations, allocating production costs, and determining plant or component efficiency. The task of obtaining a sample of reasonable weight to represent an entire lot presents a number of problems and emphasizes the necessity for using standard sampling procedures.

Coal is one of the most difficult of materials to sample, varying in composition from non-combustible particles to those which can be burned completely, with all gradations in between. The task is further complicated by the use of the analytical results, the sampling equipment available, the quantity to be represented by the sample, and the degree of precision required.

These standard methods give the overall requirements for the collection of coal samples. The wide varieties of coal handling facilities preclude the publication of detailed procedures for every sampling situation. The

proper collection of the sample involves an understanding and consideration of the physical character of the coal, the number and weight of increments, and the overall precision required.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke.

---

**Title:** Standard Recommended Practice for Probability Sampling of Materials<sup>1</sup>

**Citation:** ASTM E 105-58 (1975)

**Content:** This recommended practice is primarily a statement of principles for the guidance of ASTM technical committees and others in the preparation of a sampling plan for a specific material.

**Availability:** ASTM

---

<sup>1</sup>This recommended practice is under the jurisdiction of ASTM Committee E-11 on Statistical Methods.

---

**Title:** Standard Recommended Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process<sup>1</sup>

**Citation:** ASTM E 122-72 (1979)

**Content:** This recommended practice presents simple methods for calculating how many units to include in a sample in order to estimate, with a prescribed precision, the average of some characteristic for all the units of a lot of material, or the average produced by a process.

**Availability:** ASTM

---

<sup>1</sup>This recommended practice is under the jurisdiction of ASTM Committee E-11 on Statistical Methods.

---

**Title:** Standard Recommended Practice for Acceptance of Evidence Based on the Results of Probability Sampling<sup>1</sup>

**Citation:** ASTM E 141-69 (1975)

**Content:** This recommended practice presents and defines a rule by which to accept or to reject evidence based on samples. Statistical evidence is usually in the form of an estimate of a proportion, average, total, or other numerical characteristic of a lot. More specifically, it is an estimate of what would be the result of investigating the entire lot under the same rules and with the same care as were used for the samples.

**Availability:** ASTM

---

<sup>1</sup>This recommended practice is under the jurisdiction of ASTM Committee E-11 on Statistical Methods.

---

**Title:** Standard Method of Preparing RDF-3 Laboratory Samples for Analysis<sup>1</sup>

**Citation:** ASTM E 829-81

**Content:** This method covers the preparation of RDF-3 laboratory samples for analysis, the laboratory samples having been previously obtained from representative RDF-3 samples.

The method given may also be used for other RDF types but additional sample preparation steps may be necessary prior to the application of this method.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

## FEEDSTOCK SAMPLING AND PREPARATION (STANDARDS)

**Title:** Standard Test Method for Composition or Purity of a Solid Waste Materials Stream<sup>1</sup>

**Citation:** ASTM E 889-82 (1988)

**Content:** This method covers the determination of the composition of a materials stream in a solid waste resource recovery processing facility. The composition is determined with respect to one or more defined components. The results are used for determining the purity resulting from the operation of one or more separators, and in conjunction with Proposed Method for the Determination of the Recovery of a Product in a Materials Separation Device, is used to measure the efficiency of a materials separation device.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.08 on Processing Equipment and Unit Operations.

---

**Title:** Standard Method for Packaging and Shipping of Laboratory Samples of Refuse-Derived Fuel-3<sup>1</sup>

**Citation:** ASTM E 954-83 (1988)

**Content:** This method covers a procedure for packaging a refuse-derived fuel-3 sample at its point of origin for shipping this sample to the laboratory for subsequent analyses.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Test Method of Air Drying RDF-5 for Further Analysis<sup>1</sup>

**Citation:** ASTM E 1183-87

**Content:** This test method covers the process of air drying a gross or laboratory sample of RDF-5. The air-dry loss is determined by air drying on a drying floor.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery.

---

**Title:** Definition of Solid Forms of Refuse-Derived Fuels from which Appropriate Analytical Samples May Be Prepared

**Citation:** ASTM STP 832

**Content:** Definition is:

RDF-1 - wastes used as a fuel in as-discarded form with only bulky wastes removed.

RDF-2 - wastes processed to coarse particle size with or without ferrous metal separation.

RDF-3 - combustible waste fraction processed to particle sizes-95% passing 2-in.-square screening.

RDF-4 - combustible waste fraction processed into powder form-95% passing 10-mesh screening.

RDF-5 - combustible waste fraction densified (compressed) into the form of pellets, slugs, cubettes, or briquettes.

**Availability:** ASTM

---

**Title:** Methods for Sampling Animal and Vegetable Fats and Oils

**Citation:** BS 627:1982

**Content:** Methods for bulk (land tanks, ships' tanks, tank wagons and cars), packages

(barrels, drums, cases, tins, bags), weigh tanks and pipe lines; descriptions and illustrations of equipment; temperature limits; sizes, packages, and labeling of samples.

**Availability:** BSI

---

**Title:** Methods for Sampling of Coal and Coke

**Citation:** BS 1017:1977 (Parts 1 and 2)

**Content:** Fundamentals, preparation of laboratory samples for moisture determination, general analysis and size analysis. Appendices: precision, equipment, introduction to samples.

**Availability:** BSI

---

**Title:** Preparation of Wood for Chemical Analysis

**Citation:** CPPA G.31P

**Content:** Wood is milled and screened to particles of a definite size range and extracted with ethanol/benzene mixture to remove waxes, fats, resins, and certain other extractables. The procedure is applicable also to straw, flax, and other natural fibrous materials.

**Availability:** CPPA

---

**Title:** Introduction to Sampling Procedures for Materials and Manufactured Products

**Citation:** CSA Z90-1975

**Content:**

**Availability:** CSA

---

**Title:** Testing of Solid Fuels; Sampling and Sample Preparation

**Citation:** DIN 51701 Part 2

**Content:**

**Availability:** DIN

---

**Title:** Paper and Board: Sampling to Determine Average Quality

**Citation:** ISO 186:1985

**Content:**

**Availability:** ISO

---

**Title:** Hard Coal: Sampling

**Citation:** ISO 1988:1975

**Content:**

**Availability:** ISO

---

**Title:** Wood-Sampling Methods and General Requirements for Physical and Mechanical Tests

**Citation:** ISO 3129-75

**Content:**

**Availability:** ISO

---

**Title:** Wood: Sampling Sample Trees and Logs for Determination of Physical and Mechanical Properties of Wood in Homogeneous Stands

**Citation:** ISO 4471-82

**Content:**

**Availability:** ISO

---

## FEEDSTOCK SAMPLING AND PREPARATION (STANDARDS)

**Title:** Brown Coals and Lignites--Principles of Sampling--Part 1: Sampling for Determination of Moisture Content and for General Analysis

**Citation:** ISO 5069-1:1983

**Content:**

**Availability:** ISO

---

**Title:** Brown Coals and Lignites--Principles of Sampling--Part 2: Sample Preparation for Determination of Moisture Content and for General Analysis

**Citation:** ISO 5069-2:1983

**Content:**

**Availability:** ISO

---

**Title:** Pulp: Sampling for Testing

**Citation:** ISO 7213:1981

**Content:**

**Availability:** ISO

---

**Title:** Sampling and Preparation Method for Analysis of Pulpwood

**Citation:** JIS P 8001-1976 (1985)

**Content:**

**Availability:** JIS

---

**Title:** Sampling of Paper and Paperboard from Lots

**Citation:** SCAN-P 1:61

**Content:** This method covers the drawing of a composite sample for test purposes. Certain tests call for special sampling precautions, which are described in the methods concerned.

**Availability:** SCAN

---

**Title:** Sampling of Wood Chips from Conveyor

**Citation:** TAPPI Useful Method 4

**Content:**

**Availability:** TAPPI

---

**Title:** Sampling and Preparing Wood for Analysis

**Citation:** TAPPI T 257 cm-85

**Content:** This method is applicable to the sampling of wood for all chemical tests.

The procedures given describe the sampling of wood in all forms, i.e., logs, chips, or sawdust.

Two sampling plans are described: A probability sampling plan which provides test units from which some property of the wood may be determined within known and controlled limits at a minimum total cost; an economic or engineered sampling plan which minimizes errors due to variations in the raw material or the quality of the lot.

The particle size to which wood should be reduced for the purpose of certain analyses has been the subject of differences of opinion and complete agreement with respect to the most suitable size has not yet been reached.

**Availability:** TAPPI

---

**Title:** Preparation of Wood for Chemical Analysis

**Citation:** TAPPI T 264 om-88

**Content:** This method describes a procedure for further preparation of wood that has been sampled for analysis in accordance with TAPPI T 257 "Sampling and Preparing Wood for Analysis."

**Availability:** TAPPI

---

**Title:** Taking Relevant Samples

**Citation:** Taylor, John K. *Chemtech* 294  
(May 1988).

**Content:** The more one looks at sampling, the more one is convinced that sampling is not a trivial exercise. Accordingly, in all but the simplest situations, one is well advised to carefully plan all aspects of sampling, utilizing sampling experts and/or statistical advisors as necessary, if meaningful and defensible conclusions are to be realized.

---

**Title:** Sampling for Biofuel Analysis

**Citation:** Persson, J. Aa. Report  
#STEV-TORV-85-2. (In Swedish)  
1984, 36 pp. Available from NTIS,  
Order #DE85752525.

**Content:** This project reviews methods for sampling biofuels, i.e., wood chips, crushed wood wastes, sod peat and milled peat. A Swedish standard for sampling will later be worked out from this material. It was found that the fuel can be very inhomogeneous--variations in dry matter content of up to 20 percent were noticed--which means that it is very hard to get high precision in the analysis of one shipment.

---

**Title:** Definition of Biomass Samples  
Involving Wood, Bark, and Foliage

**Citation:** Barton, G. M. *Biomass* 4:311-314  
(1984).

**Content:** In recent years there has been a growing interest in using wood, bark and foliage for chemical biomass conversion studies. The reasons are understandable since forests represent one of the largest sources of renewable biomass still available to mankind. Also, the forest product industries concentrate at a single location potential thermochemical conversion materials such as tops, limbs, bark, and foliage not required for lumber or pulp. This potential will increase dramatically if plans to introduce whole-tree logging materialize. Unfortunately, many scientists who have been attracted to this

area are unfamiliar with the wide variation among and between tree species. To many, wood is wood and little attempt is made to define the sample on which valuable scientific research is done. Borrowing a sentence from the *Basic Coal Sciences Project Advisory Report*, and substituting wood for coal, the following describes the current situation concisely: "Considerable basic research has been done on a wide range of wood samples for various purposes, yet much of this previous research cannot be correlated since little, if any, comparisons can be drawn from the samples used."

---

**Title:** Sampling of Wood Resources for  
Pulpwood Quality Assessment; Part 1:  
Sampling Theory

**Citation:** Balodis, V. and I. R. James.  
*Appita* 34(2):113 (Sept. 1980).

**Content:** Sampling theory for the assessment of pulpwood quality is developed and illustrated with practical examples. From theoretical considerations, completely random sampling, without reference to forest composition, is very inefficient, because a large number of trees need to be sampled to ensure the correct volumetric representation of the major species and tree sizes in the final chip mixture.

Sampling efficiency can be significantly improved by the use of pulpwood inventory data to stratify the forest by species and/or diameter classes. For a stratified forest it is necessary to sample only a few trees from each stratum to ensure that the major species are present in the pulpwood sample; the correct volumetric proportions of different species and tree sizes in the representative chip mixture is determined by the inventory data. Efficiency can be further improved by considering sampling costs. If the diameter classes are chosen relative to unit sampling costs, then it is possible to design a scheme so that the same number of trees is sampled in each diameter class. In addition to being efficient, such a scheme is also easy to implement in the field.

---

## FEEDSTOCK SAMPLING AND PREPARATION (LITERATURE)

**Title:** The Sampling of Species for Pulpwood Evaluation

**Citation:** Balodis, V., A. F. Logan, I. R. James, I. A. Crawford, and C. H. Turner. 30th Annual Conference, Technical Association of the Australian and New Zealand Pulp and Paper Industry, April 26-30, 1976.

**Content:** The aim of sampling is to collect the best representative sample from a pulpwood resource at the minimum cost. The design of an optimum sampling plan is based on (a) the relative costs of locating, cutting, and removing a sample from a tree, (b) the anticipated variability of pulpwood quality between and within trees, (c) the size distribution of trees in the sampling area.

Theoretical aspects of sampling are presented and illustrated by considering the effect of sampling costs and pulpwood quality on the design of an optimum sampling plan.

Experimental results on the variability of pulping properties, pulp yield, and pulp quality, between and within trees, are presented for temperate zone and tropical hardwoods. These results are incorporated in charts showing changes in the expected accuracy of the estimates of pulpwood quality with the number of sample trees and the number of sampling positions in a tree.

The practical aspects of selection of sample trees are briefly discussed and illustrated by the procedures adopted in some actual sampling operations.

A method has been developed for the preparation of representative composite chip mixtures from individual chip samples when these have to be combined in predetermined volumetric proportions.

---

**Title:** Sampling and Preparation of Samples

**Citation:** Chapter 3 in Browning, B. L. *Methods of Wood Chemistry*, Vol. 1. New York: Interscience Publishers, 1967.

**Content:** 1) The problem of sampling; 2) Selection of the sample; 3) Reduction of the sample to a subsample (test sample); 4) Preparation of the test sample; 5) Reduction of particle size; 6) Screening; 7) TAPPI method for sample preparation; 8) Drying and storing of samples; 9) Sampling from standing trees; 10) Sampling of pulp; 11) Grinding and defiberizing of pulp; 12) Fine grinding of wood.

---

**Title:** Sampling Problems for the Chemical Analysis of Sludge, Soils, and Plants

**Citation:** Edited by A. Gomez, R. Leschber, and P. L'Hermite. London and New York: Elsevier Applied Science Publishers, 1986.

**Content:** Proceedings of a round-table seminar organized by the Commission of the European Communities, Directorate-General Science, Research and Development, Environmental Research Programme, held in Bordeaux, France, 6-7 November 1985.

---

**Title:** Need for Standardization in Short-Rotation Energy Feedstock Research

**Citation:** Wright, Lynn L. Proceedings of 22nd Annual Meeting of Poplar Council of the United States, Lawrence, Kansas, June 25-27, 1985.

**Content:**

---

## FEEDSTOCK SAMPLING AND PREPARATION (LITERATURE)

**Title:** New Methods of Measuring Wood and  
Fiber Properties in Small Samples

**Citation:** Technical Association of the  
Pulp and Paper Industry,  
Technology Park, P.O. Box 105113,  
Atlanta, GA. 79 pp.

**Content:**  

---

---

**Title:** Revised Protocol for Preparing and  
Submitting Samples for Analysis in the  
IFAS Gasification Bioconversion  
Laboratories

**Citation:** GRI/IFAS Publication 82-2.  
Inst. of Food and Ag. Sciences  
Methane from Biomass and Waste  
Program, Univ. of Florida,  
Gainesville, FL.

**Content:**  

---

---





## DENSITY AND SPECIFIC GRAVITY (STANDARDS)

**Title:** Wood: Determination of Density

**Citation:** NF B 51-005-85

**Content:**

**Availability:** AFNOR

---

**Title:** Methods of Test for Pulp and Paper (metric units); Basic Density of Wood Chips

**Citation:** SA 1301, Pls-79 and Appita Pls:79

**Content:** Basic density as measured according to this standard is more accurately defined as moisture-free mass per unit soaked volume.

The method described here differs from previous methods in that two matched parallel samples are used, one for the determination of moisture-free mass and the other for the determination of soaked volume. This procedure eliminates errors introduced either by the leaching out of water-soluble extractives or by changes in swelling characteristics brought about by oven drying.

Volume determination: on-balance method.

**Availability:** Appita, SAA

---

**Title:** Density, Specific Gravity, and Weight-Moisture Relationships of Grain for Storage

**Citation:** ASAE D241.3

**Content:**

**Availability:** ASAE

---

**Title:** Density Determinations of Solids and Liquids

**Citation:** ASME PTC 19.16-65

**Content:**

**Availability:** ASME

---

**Title:** Standard Test Method for Specific Gravity and Density of Semi-Solid Bituminous Materials<sup>1</sup>

**Citation:** ASTM D 70-82 (1986)

**Content:** This method covers the determination of the specific gravity and density of semi-solid bituminous materials, asphalt cements, and soft tar pitches by use of a pycnometer.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-4 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.47 on Miscellaneous Asphalt Tests.

---

**Title:** Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)<sup>1</sup>

**Citation:** ASTM D 287-82 (Reapproved 1987)

**Content:** This test method covers the determination by means of a glass hydrometer of the API gravity of crude petroleum and petroleum products normally handled as liquids and having a Reid vapor pressure of 26 psi (180 kPa) or less. Gravities are determined at 60°F (15.56°C), or converted to values at 60°F, by means of standard tables. These tables are not applicable to nonhydrocarbons or essentially pure hydrocarbons such as the aromatics.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

## DENSITY AND SPECIFIC GRAVITY (STANDARDS)

**Title:** Standard Test Methods for Relative Density (Specific Gravity) of Gaseous Fuels<sup>1</sup>

**Citation:** ASTM D 1070-85

**Content:** These test methods cover the determination of relative density (specific gravity) of gaseous fuels, including liquefied petroleum gases, in the gaseous state at normal temperatures and pressures. The test methods specified are sufficiently varied in nature so that one or more may be employed for laboratory, control, reference, or gas measurement, or in fact for any purpose where one desires to know the relative density of gas or gases as compared to the density of dry air at the same temperature and pressure.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and are the direct responsibility of Subcommittee D 03.04 on Determination of Specific Gravity and Density of Gaseous Fuels.

---

**Title:** Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method<sup>1</sup>

**Citation:** ASTM D 1298-85

**Content:** This test method covers the laboratory determination, using a glass hydrometer, of the density, relative density (specific gravity), or API gravity of crude petroleum, petroleum products, or mixtures of petroleum and nonpetroleum products normally handled as liquids, and having a Reid vapor pressure (Test Method D 323, or IP 69) of (179 kPa) 26 lb or less. Values are measured on a hydrometer at convenient temperatures, readings of density being reduced to 15°C, and readings of relative density (specific gravity) and API gravity of 60°F, by means of international standard tables. By means

of these same tables, values determined in any one of the three systems of measurement are convertible to equivalent values in either of the other two so that measurements may be made in the units of local convenience.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants, the API Central Committee on Petroleum Measurement, and the IP Standardization Committee.

---

**Title:** Standard Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer<sup>1</sup>

**Citation:** ASTM D 1481-81

**Content:** This test method covers the determination of the density of oils more viscous than 15 cSt at 20°C (mm<sup>2</sup>/s), and of viscous oils and melted waxes at elevated temperatures, but not at temperatures at which the sample would have a vapor pressure of 100 mm Hg (13 kPa) or above.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

**Title:** Standard Test Methods for Specific Gravity of Wood and Wood-Base Materials<sup>1</sup>

**Citation:** ASTM D 2395-83

**Content:** These methods cover the determination of the specific gravity of wood and wood-based materials to generally desired degrees of accuracy and for specimens of different sizes, shapes, and moisture content.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-7 on Wood and are the direct responsibility of Subcommittee D07.09 on Methods of Testing.

---

**Title:** Standard Test Method for Apparent Density of Activated Carbon<sup>1</sup>

**Citation:** ASTM D 2854-83

**Content:** This test method covers the determination of the apparent density of granular activated carbon. For purposes of this test method, granular activated carbon is defined as a minimum of 90% being larger than 80 mesh.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-28 on Activated Carbon and is the direct responsibility of Subcommittee D28.04 on Gas Phase Evaluation Tests.

---

**Title:** Standard Test Method for Density and Relative Density of Liquids by Digital Density Meter<sup>1</sup>

**Citation:** ASTM D 4052-86

**Content:** This method covers the determination of the density or relative density of petroleum distillates and viscous oils that can be handled in a normal fashion as liquids at test temperatures between 15° and 35°C. Its application is restricted to liquids with vapor pressures below 600 mm Hg (80 kPa) and viscosities below about 15,000 cSt (mm<sup>2</sup>/s) at the temperature of test. It should not be applied to samples so dark in color that the absence of air bubbles in the sample cell cannot be established with certainty.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Bulk Density of Densified Particulate Biomass Fuels<sup>1</sup>

**Citation:** ASTM E 873-87

**Content:** This test method covers the procedure for the determination of bulk density (or bulk specific weight) of densified particulate biomass fuels with a maximum particle volume of 16.39 cm<sup>3</sup> (1 in.<sup>3</sup>).

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-48 on Biotechnology and is the direct responsibility of Subcommittee E48.05 on Biomass Conversion Systems.

---

**Title:** Standard Test Method for Determining the Bulk Density of Solid Waste Fractions<sup>1</sup>

**Citation:** ASTM E 1109-86

**Content:** This test method determines the bulk density of various fractions from the resource recovery processing of municipal solid waste. It is intended as a means of characterizing such fractions and for providing data useful to designers of solid waste processing plants.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.08 on Processing Equipment and Unit Operations.

---

**Title:** Basic Density of Wood

**Citation:** CPPA A.1H

**Content:** The methods described are suitable for routine mill determinations of basic density on samples from wood chips and disks.

The basic density is defined as the oven-dry weight per unit of maximum or green volume

## DENSITY AND SPECIFIC GRAVITY (STANDARDS)

of wood and is expressed in grams per cubic centimeter. The green volume does not change above the fiber saturation point which, for most species, lies between a moisture content of 23% and 30% of the oven-dry weight of the wood. Moistures below this point are seldom encountered in mill woods.

**Availability:** CPPA

---

**Title:** Basic Density of Wood

**Citation:** CPPA A.8P<sup>1</sup>

**Content:** The basic density of wood is defined as the oven-dry weight per unit of maximum, or "green" volume of wood. It is expressed as grams per cubic centimeter.

By modifying the size of the sample to fit the container, this procedure may be used to determine the basic density of wood in the form of disks, billets, or chips.

**Availability:** CPPA

---

<sup>1</sup>Supersedes Standard A.1

---

**Title:** Density of Pulpwood (Submersion with Correction for Cracks, etc.)

**Citation:** TAPPI Useful Method 2

**Content:**

**Availability:** TAPPI

---

**Title:** Density of Wood Chips (Sheet Machine Mold)

**Citation:** TAPPI Useful Method 9

**Content:**

**Availability:** TAPPI

---

**Title:** Specific Gravity of Wood Disks

**Citation:** TAPPI Useful Method 12

**Content:**

**Availability:** TAPPI

---

**Title:** Density and Moisture of Chips  
(Presoak Before Immersion)

**Citation:** TAPPI Useful Method 16

**Content:**

**Availability:** TAPPI

---

**Title:** Density and Moisture of Chips  
(Submersion with Correction for Cracks, etc.)

**Citation:** TAPPI Useful Method 20

**Content:**

**Availability:** TAPPI

---

**Title:** Bulk Density of Wood Chips<sup>1</sup>

**Citation:** TAPPI T 21 wd-82

**Content:** Became Useful Method 23.

**Availability:** TAPPI

---

<sup>1</sup>Withdrawn 1982

---

**Title:** Bulk Density of Wood Chips<sup>1</sup>

**Citation:** TAPPI Useful Method 23

**Content:** This method is used to determine the weight per unit volume of wood chips, the bulk density. For purposes of reference, a standard pressure of 11 kPa (225 lb/ft<sup>2</sup>) has been chosen. The principles of the test can be applied to the pressure of any digester or chip bin by making appropriate adjustments to the pressure of the test.

**Availability:** TAPPI

---

<sup>1</sup>Replaces TAPPI T 21

---

**Title:** Density and Specific Gravity

**Citation:** Chapter 18 in Browning, B. L.  
*Methods of Wood Chemistry*,  
Vol. 1. New York: Interscience  
Publishers, 1967.

**Content:** Density or specific gravity is important in investigations related to the growth and properties of wood, in utilization of wood as a structural material, in processing such as the manufacture of chemical wood pulps, and in uses where porosity and similar properties are significant. The utilization of cellulose fibers from wood is also affected by many fiber properties that are closely related to specific gravity. I. Specific Gravity of Wood; II. Density of Wood and Cellulose; III. Density of Cell-Wall Substance.

---



**Title:** Sieves and Sieving: Terminology

**Citation:** NF X 11-500-85

**Content:**

**Availability:** AFNOR

---

**Title:** Sieves and Sieving: Particle Size Analysis; Test Sieving

**Citation:** NF X 11-507-70

**Content:**

**Availability:** AFNOR

---

**Title:** Particle Size Analysis: Particle Size Analysis of Powders; Diffraction Method

**Citation:** NF X 11-666-84

**Content:**

**Availability:** AFNOR

---

**Title:** Particle Size Analysis: Apparatus for Particle Size Analysis of Particles in Suspension in an Electrolyte Based on Resistance Variation

**Citation:** NF X 11-671-81

**Content:**

**Availability:** AFNOR

---

**Title:** Particle Size Range of Peat: Mechanical Analysis Procedure

**Citation:** AOAC 2.202

**Content:**

**Availability:** AOAC

---

**Title:** Method of Determining and Expressing Fineness of Feed Materials by Sieving

**Citation:** ASAE S319.1

**Content:** The purpose of this standard is to define a test procedure to determine the fineness of feed ingredients and to define a method of expressing the particle size of the material. The particle size determined can be used to calculate surface area and number of particles per unit weight.

This standard shall be used to determine the fineness of feed ingredients where the reduction process yields particles which are essentially spherical or cubical. It is not adequate to define the particle size of materials such as steamed and rolled grains which are a flaked product, or products, such as chopped hay, in which a substantial fraction consists of elongated particles.

**Availability:** ASAE

---

**Title:** Method of Determining and Expressing Particle Size of Chopped Forage Materials by Screening

**Citation:** ASAE S424

**Content:** The purpose of this standard is to define a test procedure to determine the particle size of chopped forage materials and to define a method of expressing the particle length of the material. The determined particle size can be used to evaluate forage harvesting machine and handling equipment variables and to define forage physical length in animal feeding trials.

This standard shall be used to determine the particle size of chopped forage materials where the reduction process yields particles such as that material produced by shear-bar-type forage harvesters. It is not intended for use on material produced by flail-type harvesters where substantial fractions of the material may be extremely long.

## PARTICLE SIZE DETERMINATION AND SIEVING (STANDARDS)

This standard is intended for use in the field as well as in the laboratory. It is intended to separate chopped forage samples without drying them first.

**Availability:** ASAE

---

**Title:** Standard Method of Sampling and Fineness Test of Pulverized Coal<sup>1</sup>

**Citation:** ASTM D 197-82 (1987)

**Content:** This method covers the determination of the fineness by sieve analysis of coal sampled from a dry pulverizing operation. It is not applicable to products of wet milling or to fines that have clustered into an agglomerated mass.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characteristics of Coal.

---

**Title:** Standard Method of Sieve Analysis of Coke<sup>1</sup>

**Citation:** ASTM D 293-69 (1980)

**Content:** This method covers the separation of a coke sample into defined size fractions and expressing said fractions as a weight percent of the gross sample.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke.

---

**Title:** Standard Method for Sieve Analysis of Crushed Bituminous Coal<sup>1</sup>

**Citation:** ASTM D 311-84

**Content:** This method covers the sieve analysis of rather coarsely crushed bituminous coal, less than 1-1/2 in. (37.5 mm) in size,

such as is charged into coke ovens. It is not applicable to the testing of powdered coal as used in boiler plants.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characteristics of Coal.

---

**Title:** Standard Method for Sieve Analysis of Coal<sup>1</sup>

**Citation:** ASTM D 410-84

**Content:** This method for sieve analysis is applicable to all coal except anthracite, powdered coal as used in boiler plants, and crushed coal as charged into coke ovens.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characteristics of Coal.

---

**Title:** Standard Test Method for Designating the Size of Coal from Its Sieve Analysis<sup>1</sup>

**Citation:** ASTM D 431-84

**Content:** This test method covers the designation of coal sizes from the results of sieve analysis tests of samples taken to represent the condition of the coal as sold. This test method applies only to natural continuous ranges of sizes as produced by mining, handling, crushing, screening, etc. In the case of special mixtures, or where the sieve analysis indicates a substantial deviation from a normal gradation of sizes, a sufficiently complete sieve analysis to properly describe the size composition shall be made and reported in accordance with Method D 410.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characteristics of Coal.

---

**Title:** Standard Test Method for Particle Size Distribution of Granular Activated Carbon<sup>1</sup>

**Citation:** ASTM D 2862-82 (1987)

**Content:** This test method covers the determination of the particle size distribution of granular activated carbon. For purposes of this test, granular activated carbon is defined as a minimum of 90% retained on a 180- $\mu\text{m}$  standard sieve.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-28 on Activated Carbon and is the direct responsibility of Subcommittee D28.04 on Gas Phase Evaluation Tests.

---

**Title:** Test Method for Performing the Sieve Analysis of Coal and for Designating the Size of Coal<sup>1</sup>

**Citation:** ASTM D 4749-87

**Content:** This test method covers procedures for determining the sieve analysis of coal and designating the size of coal from sieve analysis data. Raw as well as prepared (crushed, cleaned, or screened) coals can be tested by this test method.

This test method explains how to designate coal sizes from the results of sieve analysis data in order to represent the condition of the coal as sold. In the case of special mixtures or coals with noncontinuous ranges of sizes, a sufficiently complete sieve analysis must be made to properly describe the size distribution.

This test method is not applicable for determining the sieve analysis nor for designating the size of pulverized coal. Size fractions down to and including 38  $\mu\text{m}$  (No. 400 U.S.A. Standard Series) can be treated by the methods discussed in this test method. Methods for handling size fractions below 38  $\mu\text{m}$  (No. 400) will be developed by this committee.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of Subcommittee D-5 on Coal and Coke.

---

**Title:** Standard Specification for Wire-Cloth Sieves for Testing Purposes<sup>1</sup>

**Citation:** ASTM E 11-87

**Content:** This specification covers the design and construction of sieves wherein a screening medium of woven wire cloth is mounted in a frame for use for precision testing in the classification of materials according to designated nominal particle size.

Methods of checking and calibrating sieves are included as information in the appendix.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee E-29 on Particle Size Measurement and is the direct responsibility of Subcommittee E29.01 on Sieves, Sieving Methods, and Screening Media.

---

**Title:** Standard Specification for Precision Electroformed Sieves (Square Opening Series)<sup>1</sup>

**Citation:** ASTM E 161-87

**Content:** This specification covers the design, construction, and use of square-holed electroformed sieves. These sieves are used to perform precise particle-sized distribution analysis and in preparing narrowly designated particle-size fractions. They may also be used as reference standards when suitably calibrated. A method of calibrating these

## PARTICLE SIZE DETERMINATION AND SIEVING (STANDARDS)

sieves is included as information in Appendix XI.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee E-29 on Particle Size Measurement and is the direct responsibility of Subcommittee E29.01 on Sieves, Sieving Methods, and Screening Media.

---

**Title:** Standard Specification for Perforated-Plate Sieves for Testing Purposes<sup>1</sup>

**Citation:** ASTM E 323-80 (1985)

**Content:** This specification covers perforated plate with either round or square apertures, normally mounted in a frame for use as sieves in precision testing in the classification of materials according to designated nominal particle size. A method for checking the accuracy of perforated sieve plates is included as information in Appendix XI.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee E-29 on Particle Size Measurement.

---

**Title:** Standard Specification for Industrial Wire Cloth and Screens (Square Opening Series)<sup>1</sup>

**Citation:** ASTM E 437-85

**Content:** This specification covers the sizes of square opening wire cloth and screens for general industrial uses, including the separating or grading of materials according to designated nominal particle size, and lists standards for openings from 5 in. (125 mm) and finer, woven with wire diameters for various grades of service. Methods of checking and calibrating industrial wire cloth and screens are included as information in the Appendices.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee E-29 on Particle Size Measurement and is the direct responsibility of Subcommittee E29.01 on Sieves, Sieving Methods, and Screening Media.

---

**Title:** Standard Specification for Industrial Perforated Plate and Screens (Square Opening Series)<sup>1</sup>

**Citation:** ASTM E 454-80 (1985)

**Content:** This specification covers the sizes of square opening perforated plate and screens for general industrial uses, including the separating or grading of materials according to designated nominal particle size, and lists standards for openings from 5 in. (125 mm) to 0.127 (1/8) in. (3.35 mm) punched with bar sizes and thicknesses of plate for various grades of service. Methods of checking industrial perforated plate and screens are included as information in the Appendix.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee E-29 on Particle Size Measurement and is the direct responsibility of Subcommittee E29.01 on Sieves, Sieving Methods, and Screening Media.

---

**Title:** Standard Method for Designating the Size of RDF-3 from Its Sieve Analysis<sup>1</sup>

**Citation:** ASTM E 828-81

**Content:** This method of designating the size of refuse-derived fuel from its sieve analysis is applicable to the classified light fraction (RDF-3) of shredded municipal or industrial waste materials less than 0.15 m (6 in.) in size.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Method for Measuring Particle Size Distribution of RDF-5

**Citation:** ASTM E 1037-84

**Content:** This method is used to determine the size distribution of a RDF-5 sample. Size is defined as the maximum length of the particle, where length is determined by the RDF-5 manufacturing process. That is, a pellet, cubette, or briquette all have a recognizable length.

An air-dried RDF-5 sample is separated into categories of differing particle sizes. The size distribution is measured as the weight percentage of each size category. A graph of a function of the cumulative fraction of material by weight finer than particle size versus particle size is plotted. From this plot are taken values which describe the size distribution--the uniformity constant and the characteristic particle size.

**Availability:** ASTM

---

**Title:** Test Method for Determining Liquid Drop Size Characteristics in a Spray Using Optical Non-Imaging Light-Scattering Instruments<sup>1</sup>

**Citation:** ASTM E 1260-88

**Content:** The purpose of this test method is to obtain data which characterizes the sizes of liquid particles or drops such as are produced by a spray nozzle or similar device under specified conditions using a specified liquid. The drops will generally be in the size range from 5  $\mu\text{m}$  to the order of 1000  $\mu\text{m}$  diameter; they will occur in sprays which may be as small as a few cubic centimeters or as large as several cubic meters. Typically the number density of the particles can vary significantly from one point to another.

This test method is intended primarily for use in standardizing measurements of the performance of spray-producing devices. It is limited to those techniques and instruments which operate by passing a beam of light through the spray and analyzing the light scattered by the droplets to derive size information. Such techniques do not produce images of individual drops, and therefore are known as "optical (non-imaging) instruments."

The measurements made, when referred to the entire spray being sampled, may be temporal or spatial, as defined in Practice E 799, depending on the techniques used with a particular instrument.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-29 on Particle Size Measurement.

---

**Title:** Specification for Test Sieves

**Citation:** BS 410:1986

**Content:** Specifies size requirements for sieves used for testing the size distribution of granular products in the particle size range from 125 mm down to 32  $\mu\text{m}$ .

**Availability:** BSI

---

**Title:** Methods for the Size Analysis of Coal and Coke

**Citation:** BS 1293 and 2074:1965

**Content:** Adopted by SANZ as NZS 535 and 2175:1967.

**Availability:** BSI

---

## PARTICLE SIZE DETERMINATION AND SIEVING (STANDARDS)

**Title:** Methods for the Determination of Particle Size Distribution: Guide to Powder Sampling

**Citation:** BS 3406--Part 1:1986

**Content:** Recommended methods for the subdivision of laboratory powder samples into test portions suitable for analysis by methods for the determination of particle size distribution described in other parts of this standard and for particle characterization analysis described in other British Standards.

**Availability:** BSI

---

**Title:** Rapid Sieve Analysis of Pulpwood Chips

**Citation:** CPPA Useful Method D.12U-77

**Content:** This method can be satisfactorily used for the determination of chip "size" classification and uniformity using standard laboratory sieving equipment or portable units. Sieving time and sample size are both reduced to a minimum to permit this test to give a reasonably accurate measure of chipping equipment operation for control purposes.

**Availability:** CPPA

---

**Title:** Fractionation of Pulpwood Chips for the Kraft Process

**Citation:** CPPA Useful Method D.25U

**Content:** This method enables a separation of any given sample of comminuted wood (chips) into five fractions which have an effect on pulp yield and pulp quality in the Kraft process.

The procedure developed is based on the fact that chip thickness is the most critical parameter of chip geometry in the Kraft pulping process. Pin chips are effectively separated from accept chips and fines by means of the difference in hole geometry of the two lower screens. The analytical procedure comprises determination of the following:

- Oven-dry content
- Loose chip packing density
- Bark content, and chip size classification by mechanical separation into five fractions on an air-dry basis.
- This method does not measure chip length.

**Availability:** CPPA

---

**Title:** Classification of Pulpwood Chips (The Domtar Chip Classifier Method)

**Citation:** CPPA Useful Method D.26U

**Content:** This is a method for separating samples of wood chips into distinct thickness fractions, while simultaneously extracting a number of size or length fractions (usually two) from all the thickness fractions. This procedure is suitable for classifying all types of wood chips ranging in thickness from 2 to 18 mm in increments of 2 mm.

**Availability:** CPPA

---

**Title:** Sieve Analysis of Pulpwood Chips

**Citation:** CPPA Standard D.27H

**Content:** The chip "size" distribution of pulpwood chips, as determined by screen analysis, is one criterion of chip quality.

Test sieves are also in general use for controlling the efficiency of chip screens and size reduction machinery such as chippers, chip breakers, and rechippers.

This test method is a procedure for determining "size" distribution and uniformity of chips. It is not to be construed as a measure of chip length.

**Availability:** CPPA

---

**Title:** Test Sieves--Woven Metal Wire Cloth,  
Perforated Plate and Electroformed  
Sheet--Nominal Sizes of Openings

**Citation:** ISO 565-83

**Content:**

**Availability:** ISO

---

**Title:** Hard Coals--Size Analysis

**Citation:** ISO 1953:1972

**Content:**

**Availability:** ISO

---

**Title:** Test Sieves and Test Sieving--  
Vocabulary

**Citation:** ISO 2395-72

**Content:**

**Availability:** ISO

---

**Title:** Methods for the Size Analysis of Coal  
and Coke

**Citation:** NZS 535, NZS 2175:1967  
(Identical to BS 1293 and  
2074:1965)

**Content:** Attainable precision, sampling and  
sieving, reporting results, preparation of  
samples for special purposes. Appendices:  
checks on precision, sieving techniques and  
apparatus, reporting mean size and size  
range.

**Availability:** SANZ

---

**Title:** Chip Length Analysis (Measurement)

**Citation:** TAPPI Useful Method 5

**Content:**

**Availability:** TAPPI

---

**Title:** Chip Length Analysis (Two-Screen)

**Citation:** TAPPI Useful Method 6

**Content:** Screen a 10-kg composite sample  
through a screen having 1/4-in. openings or  
3 meshes/in. Then screen the fines so ob-  
tained on a screen of 3/32-in. openings or  
8 meshes/in. Report the retained portions as  
percent fines in the first case, and as percent  
sawdust in the second case, based on the  
total weight of the sample screen.

**Availability:** TAPPI

---

**Title:** Chip Classification (Hand Screen)

**Citation:** TAPPI Useful Method 13

**Content:**

**Availability:** TAPPI

---

**Title:** Sieve Analysis of Pulpwood Chips

**Citation:** TAPPI Useful Method 21

**Content:** This method measures the propor-  
tions of different sized aggregates in pulp-  
wood chips by means of sieves.

**Availability:** TAPPI

---



**Title:** Classifying Chips by Size  
Automatically

**Citation:** Marrs, Gevan R. *Tappi Journal*  
143 (April 1987).

**Content:** A limiting factor in obtaining a sound characterization of the particle-size distribution of a chip flow is the extensive amount of labor required to test the samples. A new classifier has been developed that can reproduce the results of a conventional "manual" chip classifier. The automated technique reduces sample classification time and labor, almost eliminates the possibility of error arising from data handling, and allows more tests to be run, improving statistical reliability. Test results are rapidly available, and unattended operation will allow "real-time" process control decisions to be made based on chip size.

---

**Title:** Determination of Fractions for Wood  
Fuels

**Citation:** Stridsberg, S. 1984, 55 pp.  
Available from NTIS, Order No.  
DE85752523.

**Content:** Methods and equipment for screening biofuels are discussed in this report. The following fuels are studied: Wood chips, crushed wood wastes, bark, and peat. A modified CCL sieve is found to be well suited for these fuels. (The CCL sieve was developed for screening wood chips in the paper industry.) Drying to 80-90 percent dry content is necessary before the screening can take place. Recommendations are made for the procedures and reports of the analyses.

---



**Title:**

**Citation:** Stone, J. E. and A. M. Scallan.  
*TAPPI* 50(10):496-501 (1967).

**Content:** Discusses pore size distribution .  

---

---

**Title:**

**Citation:** Stone, J. E. and A. M. Scallan.  
*Cellulose Chem. Technol.* 2:343  
(1968).

**Content:** Discusses pore size distribution.  

---

---

**Title:** Microstructure and Thermal Analysis  
of Solid Surfaces

**Citation:** Mikhail, Raouf Sh. and  
Erich Robens. New York: John  
Wiley and Sons.

**Content:**  

---

---

**Title:** Enzymatic Hydrolysis of Cellulose--  
A Kinetic Study

**Citation:** Van Dyke, B. H. Chapter 9.  
"Solute Exclusion Technique,"  
pp. 164-181. Ph.D. Dissertation.  
Massachusetts Institute of  
Technology, Cambridge, Mass.

**Content:** Discusses pore size distribution.  

---

---

**Title:** The Fine Structure of Wood Cell Wall  
Postulated in View of the Pore  
Structure

**Citation:** Sawabe, O. *Mokuzai Gakkaishi* 26  
(10):641-646, 1986.

**Content:** Has English summary and diagram.  

---

---



**Title:** Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter<sup>1</sup>

**Citation:** ASTM D 240-87

**Content:** This test method covers the determination of the heat of combustion of liquid hydrocarbon fuels ranging in volatility from that of light distillates to that of residual fuels.

Under normal conditions, this test method is directly applicable to such fuels as gasolines, kerosines, Nos. 1 and 2 fuel oil, Nos. 1-D and 2-D diesel fuel and Nos. 0-CT, 1-CT, and 2-CT gas turbine fuels.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.05 on Properties of Fuels, Petroleum, Coke, and Oil Shale.

---

**Title:** Standard Test Method for Calorific Value of Gases in Natural Gas Range by Continuous Recording Calorimeter<sup>1</sup>

**Citation:** ASTM D 1826-88

**Content:** This test method covers the determination with the continuous recording calorimeter of the total calorific value of fuel gas produced or sold in the natural gas range from 900 to 1200 Btu/standard ft<sup>3</sup>.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.03 on Determination of Calorific Value of Gaseous Fuels.

---

**Title:** Standard Test Method for Gross Calorific Value of Coal and Coke by the Adiabatic Bomb Calorimeter<sup>1</sup>

**Citation:** ASTM D 2015-85

**Content:** This test method covers the determination of the gross calorific value of coal and coke by the adiabatic bomb calorimeter.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Method for Heat of Combustion of Hydrocarbon Fuels by Bomb Calorimeter (High-Precision Method)<sup>1</sup>

**Citation:** ASTM D 2382-83

**Content:** This test method covers the determination of the heat of combustion of hydrocarbon fuels. It is designed specifically for use with aviation turbine fuels when the permissible difference between duplicate determinations is of the order of 0.1%. It can be used for a wide range of volatile and non-volatile materials where slightly greater differences in precision can be tolerated.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.05 on Physical Analysis of Fuels and Light Distillates.

---

## HEATS OF COMBUSTION (STANDARDS)

**Title:** Standard Test Method for Gross Calorific Value of Coal and Coke by the Isoperibol Bomb Calorimeter<sup>1</sup>

**Citation:** ASTM D 3286-85

**Content:** This test method covers the determination of the gross calorific value of coal and coke by the isoperibol bomb calorimeter.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Intermediate Precision Method)

**Citation:** ASTM D 4809-88

**Content:** The heat of combustion is a measure of the energy available from a fuel. A knowledge of this value is essential when considering the thermal efficiency of equipment for producing either power or heat. This test method covers the determination of the heat of combustion of hydrocarbon fuels. It is designed specifically for use with aviation turbine fuels when the permissible difference between duplicate determinations is of the order of 0.2 percent. Under normal conditions, the method is directly applicable to such fuels as gasolines, kerosines, Nos. 1 and 2 fuel oil, Nos. 1-D and 2-D diesel fuel, and Nos. 0-CT, 1-CT, and 2-CT gas turbine fuels.

**Availability:** ASTM

---

**Title:** Standard Recommended Practice for Safe Use of Oxygen Combustion Bombs<sup>1</sup>

**Citation:** ASTM E 144-64 (1987)

**Content:** This recommended practice covers methods for judging the soundness of new and used oxygen combustion bombs, and describes

the precautions to be observed in oxygen bomb combustion methods.

**Availability:** ASTM

---

<sup>1</sup>This recommended practice is under the jurisdiction of ASTM Committee E-41 on Laboratory Apparatus and is the direct responsibility of Subcommittee E41.02 on Metalware.

---

**Title:** Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter<sup>1</sup>

**Citation:** ASTM E 711-81

**Content:** This method covers the determination of the gross calorific value of refuse-derived fuel (RDF-3) by the bomb calorimeter.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Gross and Net Calorific Values; Terms

**Citation:** DIN 5499

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid and Liquid Fuels; Determination of the Gross Calorific Value by the Bomb Calorimeter and Calculation of the Net Calorific Value

**Citation:** DIN 51900 Parts 1-3

**Content:**

**Availability:** DIN

---

**Title:** Solid Mineral Fuels--Determination  
of Gross Calorific Value by the  
Calorimeter Bomb Method and Calcula-  
tion of Net Calorific Value

**Citation:** ISO 1928:1976

**Content:**

**Availability:** ISO

---



**Title:** Thermodynamic Data for Biomass  
Materials and Waste Components

**Citation:** Edited by E. S. Domalski,  
T. L. Jobe, Jr., and T.A. Milne.  
New York: The American Society  
of Mechanical Engineers, 1987.

**Content:** Heats of combustion and some  
compositional data.

---

**Title:** Calculation of the Heat Value of Solid  
and Liquid Fuels

**Citation:** Colombo, B., M. Baccanti, and  
B. Dutko. *American Laboratory* 51  
(August 1987).

**Content:** Heat value, the only quantitative  
measure of the energy output of a fuel, can  
be determined rapidly and easily using an  
elemental analyzer. The method described  
here is a so-called "indirect" method since it  
calculates the heat value based on the per-  
centages of carbon, hydrogen, nitrogen, oxy-  
gen, and sulfur in the fuel rather than by a  
direct combustion of the fuel.

---

**Title:** Heating Value of Municipal Solid  
Waste

**Citation:** Finet, C. *Waste Management and  
Research* 5:141-145 (1987).

**Content:** This paper describes the processes  
that are used to calculate the heating value  
of municipal solid waste in France. The cal-  
culation can be done either by using the  
thermal-balance method of a furnace or a  
furnace-boiler unit, or by sorting the refuse  
and calculating the heating value of the  
homogeneous components. Both methods are  
described in this paper. The first method  
measures the heating value of the refuse that  
is injected into the furnace; the furnace  
becomes a calorimeter in which thermal bal-  
ance is achieved on measuring the input and  
output heats. The second method consists of  
sorting a 100-kg refuse sample into piles that  
are as homogeneous as possible so that it can  
be considered as unchanging. The heating  
value is determined for each component and  
the lower heating value of the whole sample  
is calculated. The advantages and drawbacks  
of both methods are discussed.

---



**Title:** Thermal Properties of Grain and Grain Products

**Citation:** ASAE D243.3

**Content:** Contains data on specific heat, conductivity, and diffusivity.

**Availability:** ASAE

---

**Title:** Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus<sup>1</sup>

**Citation:** ASTM C 177-85

**Content:** This test method covers the achievement and measurement of steady-state heat flux through flat-slab specimens using a guarded-hot-plate apparatus. The method encompasses both the single-sided and the double-sided mode of measurement. Both distributed and line source guarded-heating-plate designs are included, in principle, in this test method. The reader should consult the standard practices on the single-sided mode of operation and on the line source apparatus for further details on these variations of the method.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee C-16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

---

**Title:** Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus<sup>1</sup>

**Citation:** ASTM C 518-85

**Content:** This test method covers the measurement of steady-state thermal transmission through flat-slab specimens using a heat flow meter apparatus.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee C-16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

---

**Title:** Standard Test Method for Expansion or Contraction of Coal by the Sole-Heated Oven<sup>1</sup>

**Citation:** ASTM D 2014-85

**Content:** This test method covers a large-scale laboratory test for obtaining information on the expansion or contraction of coal or coal blends during carbonization under specified conditions. This test method is applicable in the examination of coals or coal blends intended for use in the manufacture of coke.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.15 on Plasticity and Swelling of Coal.

---

**Title:** Standard Test Method for Thermal Conductivity of Liquids<sup>1</sup>

**Citation:** ASTM D 2717-86

**Content:** This test method covers the determination of the thermal conductivity of non-metallic liquids. It is applicable to liquids that (1) are chemically compatible with borosilicate glass and platinum, (2) are moderately transparent or absorbent to infrared radiation, and (3) have a vapor pressure less than 200 torr at the temperature of test.

## THERMAL PROPERTIES (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.11 on Engineering Science and High-Performance Fluids and Solids.

---

**Title:** Standard Test Method for Specific Heat of Liquids and Solids<sup>1</sup>

**Citation:** ASTM D 2766-86

**Content:** This test method covers the determination of the heat capacity of liquids and solids. It is applicable to liquids and solids that are chemically compatible with stainless steel, that have a vapor pressure less than 13.3 kPa (100 torr), and that do not undergo phase transformation throughout the range of test temperatures. The specific heat of materials with higher vapor pressures may be determined if their vapor pressures are known throughout the range of test temperatures.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.11 on Engineering Science and High-Performance Fluids and Solids.

---

**Title:** Standard Test Method for Calculation of Liquid Heat Capacity of Petroleum Distillate Fuels<sup>1</sup>

**Citation:** ASTM D 2890-87

**Content:** This test method describes the calculation of liquid heat capacity, Btu/lb·°F (kJ/kg·K), at atmospheric pressure, of petroleum fuels for which distillation data may be obtained in accordance with Method D 86 without reaching a decomposition point prior to obtaining 90 volume % distilled.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

**Title:** Standard Practice for Reporting Thermoanalytical Data<sup>1</sup>

**Citation:** ASTM E 472-86

**Content:** This practice is for general use in reporting experimental information from differential thermal analysis, thermogravimetry, evolved gas analysis or detection, and thermomechanical analysis studies. It incorporates laboratory practice with some of the specific needs in thermal analysis. These specific needs account for possible variation of the observed curve with the several parameters reported. Without changing the observed data, reporting in full the conditions under which the data were taken will enable another worker to reconcile differences which may be apparent in another study.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.01 on Test Methods and Recommended Practices.

---

**Title:** Standard Definitions of Terms Relating to Thermal Analysis<sup>1</sup>

**Citation:** ASTM E 473-85

**Content:** This standard is a compilation of definitions used in thermal analysis. Terms that are generally understood or adequately defined in other readily available sources are not included.

Definitions that are identical to those published by another standards body are identified with the abbreviation of the name of the

organization: for example, ICTA is the International Confederation for Thermal Analysis.

A definition is a single sentence with additional information included in notes. It is reviewed every five years, and the year of the last review or revision is appended.

**Availability:** ASTM

---

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee E-37 on Thermal Measurements and are the direct responsibility of Subcommittee E37.03 on Nomenclature and Definition.

---

**Title:** Standard Test Method for Assessing the Thermal Stability of Chemicals by Methods of Differential Thermal Analysis<sup>1</sup>

**Citation:** ASTM E 537-86

**Content:** This test method covers the ascertainment of the presence of enthalpic changes, using a minimum quantity of sample, normally in the milligram range, and approximates the temperature at which these enthalpic changes occur.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-27 on Hazard Potential of Chemicals and is the direct responsibility of Subcommittee E27.02 on Thermal Stability.

---

**Title:** Standard Test Method for Heats of Fusion and Crystallization by Differential Scanning Calorimetry<sup>1</sup>

**Citation:** ASTM E 793-81 (1985)

**Content:** This method covers the determination of the heat of fusion and crystallization by differential scanning calorimetry.

This method is applicable to solid samples in granular form or in any fabricated shape from which an appropriate specimen can be cut or to liquid samples that crystallize within the range of the instrument.

The normal operating temperature range is from -120° to 600°C. The temperature range can be extended depending upon the instrumentation used.

This method is generally applicable to thermally stable materials with well defined endothermic or exothermic behavior.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.01 on Test Methods and Recommended Practices.

---

**Title:** Standard Test Method for Thermal Characteristics of Refuse-Derived Fuel-3 Macrosamples<sup>1</sup>

**Citation:** ASTM E 955-83 (1988)

**Content:** This test method covers the determination of moisture, noncombustibles and combustibles and the calculation of higher heating value content of a large mass of refuse-derived fuel three (RDF-3).

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Standard Test Method for Compositional Analysis by Thermogravimetry<sup>1</sup>

**Citation:** ASTM E 1131-86

**Content:** This test method is intended to provide a general technique incorporating thermogravimetry to determine the amount of highly volatile matter, medium volatile matter, combustible material, and ash content of compounds. This test method will be useful in performing a compositional analysis in cases where agreed upon by interested parties.

## THERMAL PROPERTIES (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.01 on Test Methods and Recommended Practices.

---

---

**Title:** Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique

**Citation:** ASTM E 1225-87

**Content:**

**Availability:** ASTM

---

---

**Title:** Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry

**Citation:** ASTM E 1269

**Content:**

**Availability:** ASTM

---

---

**Title:** Development of Standard Operating Procedures for Differential Scanning Calorimeters

**Citation:** Callanan, Jane E. and Sandra A. Sullivan. *Rev. Sci. Instrum.* 57 (10):2584 (1986).

**Content:** This paper describes an assessment of the behavior of a differential scanning calorimeter and the development of satisfactory calibration, operation, and data reduction procedures, which depend on performance characteristics of the individual instrument. Factors that contribute to thermal lag are identified; suggestions for evaluating and compensating for it are given.

---

---

**Title:** Compositional Analysis by Thermogravimetry

**Citation:** STP997-Compositional Analysis by Thermogravimetry. New York: American Society of Testing and Materials.

**Content:** Defines the technique of thermogravimetry (TG) and describes the instrumentation and the principles on which the technique is based. The text is divided into four sections: General papers; compositional analysis of polymeric materials; compositional analysis using TG techniques and new instrumental concepts; and compositional analysis of inorganics, fuels, minerals, and raw materials. The wide range of materials presented for analysis include rubber, polymers, coal, sheet molding materials, clays, cement, oil shales, and solid waste.

---

---





**Title:** Standard Test Method for Hydrogen in Petroleum Fractions<sup>1</sup>

**Citation:** ASTM D 1018-87

**Content:** This test method covers the determination of hydrogen in petroleum fractions that can be burned completely.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.03 on Elemental Analysis.

---

**Title:** Standard Method for Ultimate Analysis of Coal and Coke<sup>1</sup>

**Citation:** ASTM D 3176-84

**Content:** This method covers the term "ultimate analysis" as it is applied to the analysis of coal and coke. The information derived is intended for general use by applicable industries, to provide the basis for evaluation or beneficiation or for other purposes.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Methods for Carbon and Hydrogen in the Analysis Sample of Coal and Coke<sup>1</sup>

**Citation:** ASTM D 3178-84

**Content:** These test methods cover the determination of total carbon and hydrogen in samples of coal or coke. Both the carbon and hydrogen are determined in one operation. This test method yields the total percentages of carbon and hydrogen in the coal as analyzed, and the results include not only the carbon and hydrogen in the organic matter but also the carbon present in mineral

carbonates and the hydrogen present in the free moisture accompanying the sample as well as hydrogen present as water hydration of silicates.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-5 on Coal and Coke and are the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Method for Hydrogen Content of Aviation Turbine Fuels by Low-Resolution Nuclear Magnetic Resonance Spectrometry<sup>1</sup>

**Citation:** ASTM D 3701-87

**Content:** This test method covers the determination of the hydrogen content of aviation turbine fuels.

This test method may be extended to other liquids containing hydrogen but as only aviation turbine fuels were included in the precision evaluation, the precision may be different from that shown.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.03 on Elemental Analysis.

---

**Title:** Test Methods for Hydrogen Content of Light Distillates, Middle Distillates, Gas Oils, and Residua by Low-Resolution Nuclear Magnetic Resonance Spectroscopy

**Citation:** ASTM D 4808-88

**Content:** The hydrogen content represents a fundamental quality of a petroleum product that has been correlated with many of the performance characteristics of that product. These test methods cover the determination of the hydrogen content of petroleum

## ULTIMATE ANALYSIS (STANDARDS)

products ranging from atmospheric distillates to vacuum residua using a continuous wave, low-resolution nuclear magnetic resonance spectrometer. Test methods are included that account for the special characteristics of different petroleum products: Test Method A for light distillates; Test Method B for middle distillates and gas oils; and Test Method C for residua.

**Availability:** ASTM

---

**Title:** Standard Test Method for Carbon and Hydrogen in the Analysis Sample of Refuse-Derived Fuel<sup>1</sup>

**Citation:** ASTM E 777-87

**Content:** This method covers the determination of total carbon and hydrogen in a sample of refuse-derived fuel (RDF-3). Both carbon and hydrogen are determined in one operation. This method yields the total percentages of carbon and hydrogen in RDF-3 as analyzed, and the results include not only the carbon and hydrogen in the organic matter but also the carbon present in mineral carbonates and the hydrogen present in the free moisture accompanying the analysis sample as well as hydrogen present as water of hydration.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Coal and Coke--Determination of Carbon and Hydrogen--High-Temperature Combustion Method

**Citation:** ISO 609:1975

**Content:**

**Availability:** ISO

---

**Title:** Coal and Coke--Determination of Carbon and Hydrogen--Liebig Method

**Citation:** ISO 625:1975

**Content:**

**Availability:** ISO

---

**Title:** Combustion Train Method for Carbon  
and Hydrogen (Draft)

**Citation:** *Pittsburgh Energy Technology  
Center (PETC) Methods Manual.*  
Vol. 1. PETC, P.O. Box 10940,  
Pittsburgh, PA 15236.

**Content:**

---

---



**Title:** Hard Coal: Determination of Oxygen  
Content

**Citation:** ISO 1994:1976

**Content:**

**Availability:** ISO

---



**Title:** Beitrag Zur Mikrobestimmung Von Sauerstoff in Organischen Substanzen in Gegenwart Von Metallen Sowie in Metallorganischen Verbindungen and Automatische Endbestimmung der Kohlensaure

**Citation:** Merz, W. *Anal. Chem. Acta* 50:305 (1970).

**Content:** The direct determination of oxygen in organic substances in the presence of metals is described. For complete removal of oxygen from metal oxides, the addition of a mixture of ammonium chloride, silver chloride, and hexamethylenetetramine was found to give the best results. The carbon dioxide is finally determined by fully automatic titration with colorimetric end-point detection.

---

**Title:** Determination of Oxygen in Nonvolatile Organic Materials

**Citation:** Gevert, S. B. Paper presented at Pittsburgh Conference, Atlantic City, N.J., March 1986.

**Content:** In the analysis of inhomogenous materials like coal and biomass it is important to take samples as large as possible since it is difficult to obtain representative samples. The LECO RO-116 instrument was used for the direct determination of oxygen. For comparison, oxygen was also determined indirectly by analyzing for sulfur with a LECO SC-132 instrument and for carbon, hydrogen, and nitrogen using a LECO CHN-600.

---

**Note:** In connection with an ongoing round-robin test of pyrolysis and liquefaction oils, about a dozen laboratories are doing ultimate analyses. Those that carry out direct oxygen determination will indicate the method used. This will be reported under the continuing IEA Voluntary Standards project.

.

**Title:** Nitrogen (Total) in Peat

**Citation:** AOAC 2.211

**Content:**

**Availability:** AOAC

---

**Title:** Organic Nitrogen in Paper

**Citation:** Appita P408m-70

**Content:**

**Availability:** Appita

---

**Title:** Standard Test Method for Organic Nitrogen in Paper and Paperboard

**Citation:** ASTM D 982-65 (1971)  
Discontinued

**Content:** This method covers the determination of glue, casein, urea-formaldehyde resins, melamine resin, and other nitrogenous organic materials in paper and paperboard.

Formerly under the jurisdiction of ASTM Committee D-6 on Paper and Paper Products, this method was discontinued in 1984.

As a service to ASTM users, an industry standard, TAPPI T 418, developed under the auspices of the Technical Association of the Pulp and Paper Industry, is also included.

**Availability:** ASTM

---

**Title:** Standard Test Method for Total Nitrogen in Peat Materials<sup>1</sup>

**Citation:** ASTM D 2973-71 (1981)

**Content:** This is a chemical method for the determination of the weight percent of nitrogen in peat material.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock.

---

**Title:** Standard Test Methods for Nitrogen in the Analysis Sample of Coal and Coke<sup>1</sup>

**Citation:** ASTM D 3179-84

**Content:** These test methods cover the determination of total nitrogen in samples of coal and coke. The analytical data from these test methods are to be reported as part of ultimate analysis where ultimate analysis is requested. If ultimate analysis is not requested, the value is to be reported according to the request.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-5 on Coal and Coke and are the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Methods for Total Kjeldahl Nitrogen in Water<sup>1</sup>

**Citation:** ASTM D 3590-84

**Content:** These test methods cover the determination of total Kjeldahl nitrogen. The following methods are included: Method A--Manual Digestion/Distillation and Method B--Semiautomated Colorimetric Bertholt.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-19 on Water and are the direct responsibility of Subcommittee D19.05 on Methods for Analysis for Organic Substances in Water.

---

## NITROGEN ANALYSIS (STANDARDS)

**Title:** Standard Test Method for Organically Bound Trace Nitrogen in Liquid Petroleum Hydrocarbons by Oxidative Combustion and Chemiluminescence Detection<sup>1</sup>

**Citation:** ASTM D 4629-86

**Content:** This test method covers the determination of the trace total nitrogen naturally found in liquid hydrocarbons boiling in the range from approximately 50°C to 400°C, with viscosities between approximately 0.2 and 10 cSt (mm<sup>2</sup>/s) at room temperature. This test method is applicable to naphthas, distillates, and oils containing 0.3 to 100 mg/kg total nitrogen.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.03 on Elemental Analysis.

---

**Title:** Standard Test Method for Total Nitrogen in Organic Materials by Modified Kjeldahl Method<sup>1</sup>

**Citation:** ASTM E 258-67 (1987)

**Content:** This method covers the determination of total nitrogen in nitrogen-containing organic compounds. The method is not applicable for materials containing N-O, N-N linkages.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-15 on Industrial Chemicals and is the direct responsibility of Subcommittee E15.21 on Elements.

---

**Title:** Standard Test Methods for Nitrogen in the Analysis Sample of Refuse-Derived Fuel<sup>1</sup>

**Citation:** ASTM E 778-87

**Content:** These methods cover the determination of total Kjeldahl nitrogen in samples of refuse-derived fuel (RDF-3). The procedures measure free ammonia or ammonia formed from the conversion of organic nitrogenous compounds such as amino acids and proteins. However, the procedures may not convert the nitrogenous compounds of some wastes to ammonia. Examples of such compounds that may not be measured are nitro compounds, hydrozones, oxines, nitrates, semicarbazones, pyridines, and some refractory tertiary amines.

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee E-38 on Resource Recovery and are the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Coal--Determination of Nitrogen--Macro Kjeldahl Method

**Citation:** ISO 332:1981

**Content:**

**Availability:** ISO

---

**Title:** Coal--Determination of Nitrogen--Semi-Micro Kjeldahl Method

**Citation:** ISO 333:1983

**Content:**

**Availability:** ISO

---

**Title:** Organic Nitrogen by the Kjeldahl Method--Modified Starch Products

**Citation:** SCAN-P 56:86

**Content:** This SCAN-test standard specifies a procedure for the determination of organically bound nitrogen in starch and its derivatives used in the manufacture of papers or boards. The results may be used to calculate the degree of substitution in starch derivatives, provided that the chemical structure of the nitrogen-containing substituent is known. The standard, as described, is not applicable to water-soluble starches. For these, total Kjeldahl nitrogen is determined without washing. Neither inorganic nitrogen, which is water soluble, nor the nitrogen contained in nitro, nitroso, and azo groups is included in the value yielded by this determination.

**Availability:** SCAN

---

**Title:** Organic Nitrogen in Paper and Paperboard

**Citation:** TAPPI T 418 om-85

**Content:** This method is used for the determination of nitrogen from glue, casein, urea- and melamine-formaldehyde resins, amine and amide polymers, and other nitrogenous organic materials in paper and paperboard.

The determination does not include all the nitrogen in nitro compounds, nitrates, nitrites, azo, hydrazine, cyanide, or pyridine ring-type compounds, which are not normally found in paper and paperboard.

**Availability:** TAPPI

---

---



**Title:** Modified Kjeldahl Method for Nitrogen (Draft)

**Citation:** *Pittsburgh Energy Technology Center Methods Manual*, Vol. 1. PETC, P.O. Box 10940, Pittsburgh, PA 15236

**Content:**

---

**Title:** Total Nitrogen Determination of Various Sample Types: A Comparison of the Hach, Kjelttec, and Kjeldahl Methods

**Citation:** Watkins, Kevin L., Trugve L. Veum, and Gary F. Krause. *J. Assoc. Off. Anal. Chem.* 70(3):6073 (1987).

**Content:** Conventional Kjeldahl analysis with modifications, Kjelttec analysis with block digestion and semiautomated distillation, and the Hach method for determining nitrogen (N) were compared using a wide range of samples. Twenty different sample

types were ground and mixed. Each sample type was divided into 5 subsamples which were analyzed for N by each of the 3 methods. In each sample type, differences ( $P < 0.05$ ) were detected among the 3 N determination methods in 5 of the 20 N sources analyzed. The mean N content over all 20 samples was higher with Kjeldahl analysis ( $P < 0.05$ ) than with Kjelttec, while Hach analysis produced intermediate results. Results also indicated that the Hach procedure most accurately detected differences in N content among sample types, being more sensitive than either other method ( $P < 0.05$ ).

---

**Title:** Determination of Nitrogen by the Kjeldahl Method

**Citation:** Moore, Wayne E. and David B. Johnson. *Procedures for the Chemical Analysis of Wood and Wood Products* (As used at the U.S. Forest Products Laboratory.) Revised Dec. 1967. (Unpublished.)

**Content:**

---



**Title:** Sulfur in Plants--Sodium Peroxide Method

**Citation:** AOAC 3.108 (Preparation of Solution)  
AOAC 3.109 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Sulfur in Plants--Magnesium Nitrate Method

**Citation:** AOAC 3.110 (Preparation of Solution)  
AOAC 3.111 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Standard Test Method for Sulfur in Petroleum Products (General Bomb Method)<sup>1</sup>

**Citation:** ASTM D 129-64 (1978)

**Content:** This test method covers the determination of sulfur in petroleum products, including lubricating oils containing additives, additive concentrates, and lubricating greases, that cannot be burned completely in a wick lamp. The method is applicable to any petroleum product sufficiently low in volatility that it can be weighed accurately in an open sample boat and containing at least 0.1% sulfur.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Total Sulfur in Fuel Gases<sup>1</sup>

**Citation:** ASTM D 1072-80

**Content:** This method covers the determination of total sulfur in combustible fuel gases, when present in concentrations between 1.0 and 30 grains of sulfur per 100 cubic feet (25 and 700 mg/m<sup>3</sup>). It is applicable to natural gases, manufactured gases, and mixed gases, such as are distributed by gas utility companies.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and is the direct responsibility of D03.01 on Collection and Measurement of Gaseous Samples.

---

**Title:** Standard Test Methods for Carbon Black--Sulfur Content<sup>1</sup>

**Citation:** ASTM D 1619-86

**Content:** These test methods cover the determination of the sulfur content of carbon black. The following methods are included: Method A--Oxygen Bomb Calorimeter; Method B--High-Temperature Combustion with Iodimetric Detection Procedures; and Method C--High-Temperature Combustion with Infrared Absorption Detection Procedures.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-24 on Carbon Black and are the direct responsibility of Subcommittee D24.31 on Non-Carbon-Black Components of Carbon Black.

---

## SULFUR ANALYSIS (STANDARDS)

**Title:** Standard Test Methods for Sulfur in Ash from Coal and Coke<sup>1</sup>

**Citation:** ASTM D 1757-86

**Content:** These test methods cover three optional gravimetric procedures for determining sulfur in coal or coke ash prepared in accordance with Methods D 2795 or Test Method D 3174. The sulfur content is reported as SO<sub>3</sub>.

The procedures appear in the following order: Method A--Modified British Method; Method B--Eschka Method; and Method C--Sodium Carbonate Fusion Method.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-5 on Coal and Coke and are the direct responsibility of Subcommittee D05.29 on Major Elements in Ash and Trace Elements of Coal.

---

**Title:** Standard Test Method for Forms of Sulfur in Coal<sup>1</sup>

**Citation:** ASTM D 2492-84

**Content:** This test method covers the determination of the three commonly recognized forms of sulfur in coal: sulfate sulfur, pyritic sulfur, and organic sulfur. This test method is not applicable to coke or other carbonaceous materials containing sulfur as a monosulfide (pyrites, FeS<sub>2</sub>, are disulfides).

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Method for Sulfur Content of Cellulosic Materials by X-Ray Fluorescence<sup>1</sup>

**Citation:** ASTM D 2929-70 (1985)

**Content:** This test method covers determination of sulfur content of cellulosic materials by X-ray fluorescence. Using appropriate standards, the range of the procedure is from approximately 10 ppm to 20% sulfur.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives and is the direct responsibility of Subcommittee D23.20 on Cellulose.

---

**Title:** Standard Test Methods for Total Sulfur in the Analysis Sample of Coal and Coke<sup>1</sup>

**Citation:** ASTM D 3177-84

**Content:** These test methods cover two alternative procedures for the determination of total sulfur in samples of coal and coke. Sulfur is included in the ultimate analysis of coal and coke.

The procedures are Method A--Eschka Method and Method B--Bomb Washing Method.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-5 on Coal and Coke and are the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Methods for Sulfur in the Analysis Sample of Coal and Coke Using High-Temperature Tube Furnace Combustion Methods<sup>1</sup>

**Citation:** ASTM D 4239-85

**Content:** These test methods cover three alternative procedures using high-temperature tube furnace combustion methods for the rapid determination of sulfur in samples of coal and coke.

These test methods appear in the following order: Method A--High-Temperature Combustion Method with Acid Base Titration Detection Procedures; Method B--High-Temperature Combustion Method with Iodimetric Titration Detection Procedures; and Method C--High-Temperature Combustion Method with Infrared Absorption Detection Procedures.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-5 on Coal and Coke and are the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Methods for Total Sulfur in the Analysis Sample of Refuse-Derived Fuel<sup>1</sup>

**Citation:** ASTM E 775-87

**Content:** These methods cover two alternative procedures for the determination of total sulfur in samples of refuse-derived fuel three (RDF-3). Sulfur is included in the ultimate analysis of RDF-3. The methods are Eschka Method and Bomb Washing Method.

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee E-38 on Resource Recovery and are the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Total Sulfur in Pulp

**Citation:** CPPA G.28

**Content:**

**Availability:** CPPA

---

**Title:** Testing of Solid Fuels

**Citation:** DIN 51724 Parts 1-2

**Content:** 1. Determination of sulfur content; total sulfur. 2. Determination of forms of sulfur.

**Availability:** DIN

---

**Title:** Determination of Sulfur in Mineral Oils by Wickbold Combustion Method

**Citation:** EN 41

**Content:** Equivalent to DIN 51400

**Availability:** EN

---

**Title:** Coal and Coke--Determination of Total Sulfur--Eschka Method

**Citation:** ISO 334:1975

**Content:**

**Availability:** ISO

---

**Title:** Solid Mineral Fuels--Determination of Total Sulfur--High Temperature Combustion Method

**Citation:** ISO 351:1984

**Content:**

**Availability:** ISO

---

## SULFUR ANALYSIS (STANDARDS)

**Title:** Water-Soluble Sulfates in Pulp and Paper

**Citation:** TAPPI T255 om-84

**Content:**

**Availability:** TAPPI

---

**Title:** Water-Soluble Sulfates and Chlorides in Pulp

**Citation:** TAPPI T229 wd-76  
(Became Useful Method 254)

**Content:**

**Availability:** TAPPI

---

**Title:** Chloride in Plants; Gravimetric Method

**Citation:** AOAC 3.069 (Preparation of Solution)  
AOAC 3.070 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Chloride in Plants; Volumetric Method I

**Citation:** AOAC 3.071 (Reagents)  
AOAC 3.072 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Chloride in Plants; Volumetric Method II

**Citation:** AOAC 3.073 (Reagents)  
AOAC 3.074 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Fluoride in Plants; Potentiometric Method

**Citation:** AOAC 3.075

**Content:**

**Availability:** AOAC

---

**Title:** Fluoride in Plants; Willard-Winter Distillation Method

**Citation:** AOAC 3.081

**Content:**

**Availability:** AOAC

---

**Title:** Fluoride in Plants; Semiautomated Method

**Citation:** AOAC 3.082

**Content:**

**Availability:** AOAC

---

**Title:** Chlorine (Soluble) in Animal Feed; Titrimetric Method

**Citation:** AOAC 7.104

**Content:**

**Availability:** AOAC

---

**Title:** Chlorine (Soluble) in Animal Feed; Potentiometric Method

**Citation:** AOAC 7.106

**Content:**

**Availability:** AOAC

---

**Title:** Fluorine in Animal Feed

**Citation:** AOAC 7.114

**Content:**

**Availability:** AOAC

---

**Title:** Iodine in Mineral Mixed Feeds

**Citation:** AOAC 7.119

**Content:**

**Availability:** AOAC

---

## HALOGEN ANALYSIS (STANDARDS)

**Title:** Standard Test Method for Total Chloride Content of Paper and Paper Products

**Citation:** ASTM D 1161-70 (1974)  
Discontinued

**Content:** This method covers the determination of the chloride content of paper, pulp, and paper products. Formerly under the jurisdiction of ASTM Committee D-6 on Paper and Paper Products, this method was discontinued in 1984.

As a service to ASTM users, an industry standard, TAPPI 256, developed under the auspices of the Technical Association of the Pulp and Paper Industry, is also included.

**Availability:** ASTM

---

**Title:** Standard Test Method for Chlorine in Coal<sup>1</sup>

**Citation:** ASTM D 2361-85

**Content:** This test method covers the determination of the total chlorine content of coal.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D 05.21 on Methods of Analysis.

---

**Title:** Standard Test Method for Chlorine in Cellulose<sup>1</sup>

**Citation:** ASTM D 2641-70 (1985)

**Content:** This test method covers the determination of chlorine in cellulose. Procedures for total chlorine, water-insoluble chlorine, and alcohol-benzene-insoluble chlorine are described. The range is 5 to 1000 ppm on cellulose. Total chlorine determinations (including ashing) can be performed at a rate of one determination every 30 min.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of the ASTM Committee D-23 on Cellulose and Cellulose Derivatives and is the direct responsibility of Subcommittee D-23.20 on Cellulose.

---

**Title:** Standard Test Method for Water-Soluble Halide Ion in Halogenated Organic Solvents and Their Admixtures<sup>1</sup>

**Citation:** ASTM D 2988-86

**Content:** This method covers the determination of water-extractable halide ion in halogenated organic solvents and their admixtures. Fluoride ion is not measured due to the solubility of silver fluoride.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of Committee D-26 on Halogenated Organic Solvents.

---

**Title:** Standard Test Method for Total Chlorine in Coal by the Oxygen Bomb Combustion/Ion Selective Electrode Method<sup>1</sup>

**Citation:** ASTM D 4208-88

**Content:** This test method covers the analysis of total chlorine in coal. Total chlorine is determined in this test method by combusting a weighed sample in an oxygen bomb with dilute base absorbing the chlorine vapors. The bomb contents are rinsed into a beaker with water and following the addition of an ionic strength adjuster, the chloride is determined by ion-selective electrode.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Method for Forms of Chlorine in Refuse-Derived Fuel<sup>1</sup>

**Citation:** ASTM E 776-87

**Content:** This method covers the determination of the forms of chlorine in refuse-derived fuel three (RDF-3): total chlorine, water-soluble chloride, and water-insoluble chlorine.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E 38.01 on Energy.

---

**Title:** Solid Mineral Fuels--Determination of Chlorine--High Temperature Combustion Method

**Citation:** ISO 352:1981

**Content:**

**Availability:** ISO

---

**Title:** Chloride Content--Starch

**Citation:** SCAN-P 54:84

**Content:** This SCAN-test standard specifies a method for the determination of the chloride content in samples of starch used in the manufacture of papers and boards. It is applicable both to native starches and starch derivatives and is primarily intended for quality control purposes. The chloride content is important for corrosion in the paper mill and for the quality of the manufactured paper.

The lower limit of chloride content that can be determined is 0.02%.

**Availability:** SCAN

---

**Title:** Water-Soluble Sulfates and Chlorides in Pulp

**Citation:** TAPPI T 229 wd-76  
(Became Useful Method 254)

**Content:**

**Availability:** TAPPI

---

**Title:** Water-Soluble Chlorides in Pulp and Paper

**Citation:** TAPPI T 256 cm-85

**Content:**

**Availability:** TAPPI

---



**Title:** The Determination of the Total Content of Organic Halogen and Sulphur Compounds

**Citation:** Lammi, T. *Paperi ja Puu—Papper och Trä* 10:605 (1981).

**Content:** An occupationally safe method of analyzing organically bound halogen and sulfur has been presented. The compound was burned with an igniting substance in a steel container containing excess pressure of oxygen. The halides formed were analyzed gravimetrically or volumetrically.

---

**Title:** Determination of Chlorine in Wood, Pulp and Paper

**Citation:** Bethge, P.O. and T. Troëng. *Svensk Papperstidning* 69(17):598 (1979).

**Content:** Small amounts of chlorine in wood, pulp, and paper can be determined by combustion of the material in oxygen of atmospheric pressure, absorption of the chloride formed in water, and potentiometric titration. This method is suitable for chlorine contents of more than 0.1 mg/g and is more accurate than conventional procedures.

---

**Title:** Determination of Soluble Halides in Wood

**Citation:** Moore, Wayne E. and David B. Johnson. *Procedures for the Chemical Analysis of Wood and Wood Products* (As used at the U.S. Forest Products Laboratory.) Revised Dec. 1967. (Unpublished.)

**Content:**

---

4

**Title:** Metals in Plants: Emission Spectrographic Methods

**Citation:** AOAC 3.006

**Content:** Applicable to aluminum, barium, boron, calcium, copper, iron, magnesium, manganese, molybdenum, phosphorus, potassium, sodium, strontium, and zinc.

**Availability:** AOAC

---

**Title:** Metals in Plants: Atomic Absorption Spectrophotometric Method

**Citation:** AOAC 3.013

**Content:**

**Availability:** AOAC

---

**Title:** Aluminum and Iron in Plants: Titrimetric Method

**Citation:** AOAC 3.017

**Content:**

**Availability:** AOAC

---

**Title:** Calcium in Plants: Titrimetric Macro Method

**Citation:** AOAC 3.018

**Content:**

**Availability:** AOAC

---

**Title:** Calcium in Plants: Titrimetric Method

**Citation:** AOAC 3.019

**Content:**

**Availability:** AOAC

---

**Title:** Cobalt in Plants: Nitroso-R-Salt Method

**Citation:** AOAC 3.029

**Content:**

**Availability:** AOAC

---

**Title:** Copper in Plants: Colorimetric Method

**Citation:** AOAC 3.033

**Content:**

**Availability:** AOAC

---

**Title:** Iron in Plants: Colorimetric Method

**Citation:** AOAC 3.035

**Content:**

**Availability:** AOAC

---

**Title:** Iron in Plants: Titrimetric Method

**Citation:** AOAC 3.038

**Content:**

**Availability:** AOAC

---

**Title:** Magnesium in Plants: Gravimetric Method

**Citation:** AOAC 3.039

**Content:**

**Availability:** AOAC

---

**Title:** Manganese in Plants: Colorimetric Method

**Citation:** AOAC 3.040

**Content:**

**Availability:** AOAC

---

## METALS AND OTHER INORGANICS (STANDARDS)

**Title:** Molybdenum in Plants: Colorimetric Method

**Citation:** AOAC 3.041

**Content:**

**Availability:** AOAC

---

**Title:** Potassium and Sodium in Plants: Gravimetric Method

**Citation:** AOAC 3.044

**Content:**

**Availability:** AOAC

---

**Title:** Potassium and/or Sodium in Plants: Flame Photometric Method

**Citation:** AOAC 3.045

**Content:**

**Availability:** AOAC

---

**Title:** Potassium in Plants

**Citation:** AOAC 3.049

**Content:**

**Availability:** AOAC

---

**Title:** Sodium in Plants: Uranyl Acetate Method

**Citation:** AOAC 3.052

**Content:**

**Availability:** AOAC

---

**Title:** Zinc in Plants: Mixed-Color Method

**Citation:** AOAC 3.054

**Content:**

**Availability:** AOAC

---

**Title:** Zinc in Plants: Single-Color Method

**Citation:** AOAC 3.061

**Content:**

**Availability:** AOAC

---

**Title:** Arsenic in Plants: Titrimetric Method

**Citation:** AOAC 3.066

**Content:**

**Availability:** AOAC

---

**Title:** Boron in Plants: Quinalizarin Method

**Citation:** AOAC 3.067 (Reagents)  
AOAC 3.068 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Phosphorus in Plants: Gravimetric Quinolinium Molybdophosphate Method

**Citation:** AOAC 3.095

**Content:**

**Availability:** AOAC

---

**Title:** Phosphorus in Plants: Macro Method

**Citation:** AOAC 3.097

**Content:**

**Availability:** AOAC

---

**Title:** Phosphorus in Plants: Micro Method

**Citation:** AOAC 3.098

**Content:**

**Availability:** AOAC

---

**Title:** Selenium in Plants: Gravimetric Method

**Citation:** AOAC 3.101

**Content:**

**Availability:** AOAC

---

**Title:** Selenium in Plants: Fluorometric Method

**Citation:** AOAC 3.102

**Content:**

**Availability:** AOAC

---

**Title:** Calcium in Animal Feed: Dry Ash Method

**Citation:** AOAC 7.101 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Cobalt in Animal Feed: Colorimetric Method

**Citation:** AOAC 7.109 (Reagents)  
AOAC 7.110 (Preparation of Standard Curve)  
AOAC 7.111 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Copper in Animal Feed: Colorimetric Method

**Citation:** AOAC 7.112 (Preparation of Standard Curve)  
AOAC 7.113 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Manganese (Acid Soluble) in Animal Feed: Colorimetric Method

**Citation:** AOAC 7.121

**Content:**

**Availability:** AOAC

---

**Title:** Phosphorus in Animal Feed: Alkalimetric Ammonium Molybdophosphate Method

**Citation:** AOAC 7.123

**Content:**

**Availability:** AOAC

---

**Title:** Phosphorus in Animal Feed: Photometric Method

**Citation:** AOAC 7.125

**Content:**

**Availability:** AOAC

---

## METALS AND OTHER INORGANICS (STANDARDS)

**Title:** Standard Methods of Chemical  
Analysis of Chromated Zinc Chloride<sup>1</sup>

**Citation:** ASTM D 1033-76 (1987)

**Content:** These methods cover the chemical analysis of chromated zinc chloride, either granulated or in commercial concentrated solutions, for use in the preservative treatment of wood.

The analytical procedures appear in the following order: zinc (calculated as ZnO) and hexavalent chromium (calculated as CrO<sub>3</sub>).

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-7 on Wood.

---

**Title:** Standard Methods for Chemical  
Analysis of Fluor-Chrome-Arsenate-  
Phenol<sup>1</sup>

**Citation:** ASTM D 1035-76 (1987)

**Content:** These methods cover the determination of the chemical analysis of commercial fluor-chrome-arsenate-phenol.

The analytical procedures appear in the following order: fluorine (calculated as F), arsenic (calculated as As<sub>2</sub>O<sub>5</sub>), chromium (calculated as CrO<sub>3</sub>), and dinitrophenol or sodium pentachlorophenate.

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-7 on Wood.

---

**Title:** Standard Methods for Chemical  
Analysis of Ammoniacal Copper  
Arsenate<sup>1</sup>

**Citation:** ASTM D 1326-76 (1987)

**Content:** These methods cover the determination of the chemical analysis of commercial solutions of ammoniacal copper arsenate.

The analytical procedures appear in the following order: ammonia (calculated as anhydrous ammonia), arsenic (calculated as As<sub>2</sub>O<sub>5</sub>), and copper (calculated as CuO).

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-7 on Wood and are the direct responsibility of Subcommittee D07.06 on Wood Preservatives.

---

**Title:** Standard Methods for Chemical  
Analysis of Acid Copper Chromate<sup>1</sup>

**Citation:** ASTM D 1627-71 (1987)

**Content:** These methods cover the chemical analysis of solid acid copper chromate and solutions of this material.

The analytical procedures appear in the following order: copper (calculated as CuO), hexavalent chromium (calculated as CrO<sub>3</sub>), and pH of solution.

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-7 on Wood.

---

**Title:** Standard Methods for Chemical  
Analysis of Chromated Copper  
Arsenate<sup>1</sup>

**Citation:** ASTM D 1628-83

**Content:** These methods cover the chemical analysis of solid chromated copper arsenate and solutions of this material.

The analytical procedures occur in the following order: pentavalent arsenic (calculated as As<sub>2</sub>O<sub>5</sub>), copper (calculated as CuO), hexavalent chromium (calculated as CrO<sub>3</sub>).

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-7 on Wood and are the direct responsibility of Subcommittee D07.06 on Wood Preservatives.

---

**Title:** Standard Test Methods for Major and Minor Elements in Coal and Coke Ash by Atomic Absorption<sup>1</sup>

**Citation:** ASTM D 3682-87

**Content:** This test method covers the analysis of the commonly determined major and minor elements in coal ash and coke ash.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.29 on Major Elements in Ash and Trace Elements in Coal.

---

**Title:** Standard Test Method for Trace Elements in Coal and Coke Ash by Atomic Absorption<sup>1</sup>

**Citation:** ASTM D 3683-78 (1983)

**Content:** This test method covers the determination of beryllium, chromium, copper, manganese, nickel, lead, vanadium, and zinc in coal ash or coke ash.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.29 on Major Elements in Ash and Trace Elements in Coal.

---

**Title:** Standard Test Method for Metals in Cellulose by Atomic Absorption Spectrophotometry<sup>1</sup>

**Citation:** ASTM D 4085-81 (1987)

**Content:** This method covers the determination of the iron, copper, manganese, and calcium content of cellulose pulp from wood or cotton.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives.

---

**Title:** Standard Test Method for Wet Ashing Procedure for Preparing Wood Samples for Inorganic Chemical Analysis<sup>1</sup>

**Citation:** ASTM D 4278-83

**Content:** This test method consists of a procedure for decomposition of wood as an initial step for analysis for the constituents arsenic, chromium, copper, phosphate, and zinc, all of which may then be analyzed according to Methods D 1033, D 1035, D 1326, D 1627, and D 1628.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.06 on Wood Preservatives.

---

**Title:** Standard Test Method for Major and Minor Elements in Coal and Coke Ash by X-Ray Fluorescence<sup>1</sup>

**Citation:** ASTM D 4326-84

**Content:** This test method covers the analysis of the commonly determined major and minor elements in ash from coal or coke using X-ray fluorescence techniques.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.29 on Major Elements in Ash and Trace Elements in Coal.

---

## METALS AND OTHER INORGANICS (STANDARDS)

**Title:** Standard Test Methods for Analysis of Metals in Refuse-Derived Fuel by Atomic Absorption Spectrophotometry<sup>1</sup>

**Citation:** ASTM E 885-88

**Content:** These methods cover the determination of metals in solution by atomic absorption spectroscopy (AAS).

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee E-38 on Resource Recovery and are the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Standard Test Methods for Dissolution of Refuse-Derived Fuel (RDF-3) Ash Samples for Analysis of Metals<sup>1</sup>

**Citation:** ASTM E 886-88

**Content:** The methods described herein cover the preparation of RDF-3 ash, fly ash, bottom ash, or slag for analyses of metals by atomic absorption spectroscopy or inductively coupled plasma spectroscopy, or both.

These methods may be applicable to any waste material from which a laboratory analysis sample can be prepared.

Three methods are described in this standard: Method A--Lithium Tetraborate ( $\text{Li}_2\text{B}_4\text{O}_7$ ) Fusion, Method B--Aqua Regia Dissolution, and Method C--Bomb, Acid Digestion Method.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee E-38 on Resource Recovery and are the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Standard Methods for Preparing Refuse-Derived-Fuel (RDF-3) Samples for Analyses of Metals<sup>1</sup>

**Citation:** ASTM E 926-88

**Content:** The methods described herein cover the preparation of milled refuse-derived fuel three (RDF-3) sample for analyses of metals by atomic absorption spectroscopy or inductively coupled plasma spectroscopy, or both.

These methods may be applicable to any waste material from which a laboratory analysis sample can be prepared.

Four methods are described in this standard: Method A--Nitric-Hydrofluoric-Perchloric Acid Digestion, Method B--Nitric-Sulfuric-Hydrofluoric Acid Digestion, Method C--Bomb, Acid Digestion Method, and Method D--Oxygen Bomb Combustion Method.

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee E-38 on Resource Recovery and are the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Trace Metal Contents of Pulps

**Citation:** BS 4897:1983

**Content:**

**Availability:** BSI

---

**Title:** Solid Fuels, Phosphorus Content

**Citation:** DIN 8429-80

**Content:**

**Availability:** DIN

---

**Title:** Calcium in Pulp

**Citation:** SCAN-C 10:62

**Content:** The sample is ashed and the ash is dissolved in nitric acid. Calcium is determined volumetrically with EDTA solution. Other metal ions are masked with potassium cyanide.

**Availability:** SCAN

---

**Title:** Sodium Content of Wet Pulp

**Citation:** SCAN-C 30:73

**Content:** The sodium content of wet pulp is defined as the amount of sodium that can be extracted from a sample of the pulp with hydrochloric acid under specified conditions.

**Availability:** SCAN

---

**Title:** Determination of Sodium, Calcium, Copper, Iron, and Manganese in Pulp and Paper by Atomic Absorption Spectroscopy

**Citation:** TAPPI T 266 om-88

**Content:**

**Availability:** TAPPI

---



**Title:** The Inorganic Content of Wood

**Citation:** Fossum, Terje, Nils Hartler, and Jan Libert. *Svensk Papperstioning* 75:305 (1972).

**Content:** Pine wood has been shown to contain a relatively large amount of calcium--between 600 and 800 mg/kg of wood--and 100 mg of both magnesium and manganese per kilogram. The inorganic content varied slightly from one geographical area to another.

An analysis of the distribution of the metals in a cross section showed that the amounts increased from the outer edge of the sapwood toward the heartwood. The cambium contained much more of all three types of ions than did the adjacent sapwood and bark layers.

The thin wood sections were ashed in such a way that the inorganic components in the wood remained in their original position as a lattice. It was found that the inorganic substances accumulated in the resin ducts and rays.

---

**Title:** Determination of Trace Metals in Pulp by Atomic-Absorption Spectrophotometry

**Citation:** Bethge, Per Olof and Rune Rådeström, *Svensk Papperstioning* 69(22):772 (1966).

**Content:** Atomic-absorption spectrophotometry has been applied in the determination of trace metals (copper, iron, manganese, calcium, magnesium, and sodium) in pulp. The technique has been tested on eight SCAN reference pulps. The results indicate that precision and accuracy are of the same order as for conventional methods. The method is time saving when large numbers of samples are analyzed and when several trace metals are to be determined on the same sample.

---

**Title:** Special Methods

**Citation:** Chapter 16 in Browning, B.L. *Methods of Wood Chemistry*, Vol. 1. New York: Interscience Publishers, 1967.

**Content:** Inorganic constituents, analysis for elements: arsenic; boron; mercury; zinc; chromium; chlorine; fluorine.

---

**Title:** Determination of Silica in Organics

**Citation:** Moore, Wayne E. and David B. Johnson. *Procedures for the Chemical Analysis of Wood and Wood Products* (As used at the U.S. Forest Products Laboratory.) Revised Dec. 1967. (Unpublished.)

**Content:**

---





**Title:** Standard Method for Proximate Analysis of Coal and Coke<sup>1</sup>

**Citation:** ASTM D 3172-73 (1984)

**Content:** This method covers the determination of moisture, volatile matter, and ash and the calculation of fixed carbon on coals and cokes sampled and prepared by prescribed methods and analyzed according to ASTM-established procedures.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke<sup>1</sup>

**Citation:** ASTM D 3175-82

**Content:** This method determines the percentage of gaseous products, exclusive of moisture vapor, in the analysis sample that are released under the specific conditions of the test.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Method for Volatile Matter in the Analysis of Particulate Wood Fuels<sup>1</sup>

**Citation:** ASTM E 872-82 (1987)

**Content:** This test method determines the percentage of gaseous products, exclusive of moisture vapor, in the analysis sample of particulate wood fuel that is released under

the specific conditions of the test. The particulate wood fuel may be sanderdust, sawdust, pellets, green tree chips, hogged fuel, or other type particulate wood fuel having a maximum particle volume of 16.39 cm<sup>3</sup> (1 in.<sup>3</sup>). Volatile matter, when determined as herein described, may be used to indicate yields on processes to provide the basis for purchasing and selling or to establish burning characteristics.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-44 on Solar Energy Conversion and is the direct responsibility of Subcommittee E44.12 on Biomass Conversion Systems.

---

**Title:** Standard Test Method for Volatile Matter in the Analysis Sample of Refuse-Derived Fuel-3<sup>1</sup>

**Citation:** ASTM E 897-88

**Content:** This method covers the determination of the percentage of gaseous products, exclusive of moisture vapor, in the analysis sample which is released under specific conditions of the test. The knowledge of the volatile matter content assists in predicting burning characteristics of RDF-3.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Testing of Solid Fuels; Determination of Volatile Matter

**Citation:** DIN 51720

**Content:**

**Availability:** DIN

---



**Title:** Semiautomatic Proximate Analysis of Fossil Fuels

**Citation:** Nadkarni, R.A. and J.M. Brewer.  
*American Laboratory*, November 1987, p. 87.

**Content:** The proximate analysis is a routine test carried out on coal or oil shale samples for the purpose of determining the moisture, ash, volatile matter, and by difference the fixed carbon content of these solid fuels. These analyses are used to establish the coal ranks, to show the ratio of combustible-to-incombustible constituents in the sample, to provide the basis for buying and selling, and to evaluate for beneficiation or for other purposes.

---

**Title:** Determination of Combustible Volatile Matter in Fuels

**Citation:** Eklund, G., J.R. Pedersen, and B. Stroemberg. *Fuel* 66(1):13-16 (Jan. 1987).

**Content:** A method for determination of combustible volatile matter by flash-pyrolysis has been developed. The analysis is applicable to fuels with H/C values ranging from 0.2 to 2.05. This range includes hard coals, lignites, peats, biomass, and fuel oil. The precision is similar to traditional gas chromatography, i.e. 6-8%. Combustible volatile matter should be better correlated to ignitability of solid fuels than ASTM volatile matter.

---

**Title:** Proximate Analysis of Some Western Wood and Bark

**Citation:** Mingle, J.G. and R.W. Boubel.  
*Wood Science* 1(1):29-36 (1968).

**Content:**

---



**Title:** Wood: Determination of Moisture Content

**Citation:** NF B 51-004-85

**Content:**

**Availability:** AFNOR

---

**Title:** Moisture in Peat: Method I

**Citation:** AOAC 2.200

**Content:**

**Availability:** AOAC

---

**Title:** Moisture in Peat: Method II

**Citation:** AOAC 2.201

**Content:**

**Availability:** AOAC

---

**Title:** Water Capacity and Volumes for Peat

**Citation:** AOAC 2.212 (Apparatus)  
AOAC 2.213 (Preparation of Sample)  
AOAC 2.214 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Moisture in Plants

**Citation:** AOAC 3.003

**Content:**

**Availability:** AOAC

---

**Title:** Moisture in Animal Feed: I. Drying in Vacuo at 90°-100°

**Citation:** AOAC 7.003

**Content:**

**Availability:** AOAC

---

**Title:** Moisture in Animal Feed: II. By Distillation with Toluene

**Citation:** AOAC 7.004 (Apparatus)  
AOAC 7.005 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Moisture in Animal Feed: III. Drying without Heat over Sulfuric Acid

**Citation:** AOAC 7.006

**Content:**

**Availability:** AOAC

---

**Title:** Moisture in Animal Feed: IV: Drying at 135°

**Citation:** AOAC 7.007

**Content:**

**Availability:** AOAC

---

**Title:** Methods of Test for Pulp and Paper (metric units); Determination of Moisture in Wood Chips--Distillation Method

**Citation:** AS 1301, P10rp: 1986,  
Appita P10rp-86

**Content:** Details a procedure used as a rapid control test in the mill, for the determination of moisture in wood chips and the calculation of the oven-dry value. It is based on the distillation of water from a known mass of chips, using a water-immiscible organic liquid as the distilling medium. An all-metal still is used for this purpose, specially designed to give maximum heat transfer efficiency. As this is a mill control method, it should be regularly checked against the reference standard, using the oven-drying procedure.

**Availability:** Appita, SAA

---

## MOISTURE (STANDARDS)

**Title:** Methods of Test for Pulp and Paper (metric units); Determination of Moisture in Pulp for Calculation of the Delivered Mass of a Shipment

**Citation:** AS 1301, P200m: 1977 and Appita P200m-77

**Content:** Details the procedure for the determination of the moisture content of baled sheet pulp irrespective of the quantity of moisture present. The method is based on the "Rules" accepted by the British and Scandinavian Association.

**Availability:** Appita, SAA

---

**Title:** The Sampling and Testing of Paper for Moisture Content

**Citation:** Appita P401s-78

**Content:**

**Availability:** Appita

---

**Title:** Density, Specific Gravity, and Weight-Moisture Relationships of Grain for Storage

**Citation:** ASAE D241.3

**Content:**

**Availability:** ASAE

---

**Title:** Moisture Relationships of Grains

**Citation:** ASAE D245.4

**Content:** Contains nomograph for converting moisture from wet to dry basis.

**Availability:** ASAE

---

**Title:** Wafers, Pellets, and Crumbles--Definitions and Methods for Determining Density, Durability, and Moisture Content

**Citation:** ASAE S269.3

**Content:**

**Availability:** ASAE

---

**Title:** Moisture Measurement--Unground Grain and Seeds

**Citation:** ASAE S352.2

**Content:** This standard is to provide a uniform method for determining the moisture content of unground samples of agricultural seeds. Only those seeds are included for which documented comparisons with the Karl Fischer method are available. These techniques should become common practice and their use referenced in all technical presentations where moisture content determinations have been a factor. Deviations from these methods should be reported.

**Availability:** ASAE

---

**Title:** Moisture Measurement--Forages

**Citation:** ASAE S358.2

**Content:** This standard establishes uniform methodology for determining the moisture content of forage products in their various forms.

**Availability:** ASAE

---

**Title:** Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation<sup>1</sup>

**Citation:** ASTM D 95-83

**Content:** This test method covers the determination of water in petroleum products, tars, and other bituminous materials by the

distillation method. For bituminous emulsions refer to Method D 244. This method, along with ASTM Test Method D 4006 (API Chapter 10.2 and IP 358), supersedes the previous edition of ASTM Test Method D 95 (API Standard 2560, IP 74).

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants. In the Institute of Petroleum this method is under the jurisdiction of the Standardization Committee.

---

**Title:** Standard Test Methods for Water and Sediment in Crude Oils<sup>1</sup>

**Citation:** ASTM D 96-73 (1984)

**Content:** This standard defines a primary centrifuge method and two alternatives for determining the amount of water and sediment in crude oil. It further specifies a base method to be used when centrifuging is not suitable or when the accuracy of a centrifuge method is to be confirmed.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and are the direct responsibility of Subcommittee D02.02 on Static Petroleum Measurement (Joint ASTM-API).

---

**Title:** Test Method for Moisture Content of Paper and Paperboard by Oven Drying

**Citation:** ASTM D 644-88

**Content:**

**Availability:** ASTM

---

**Title:** Standard Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature<sup>1</sup>

**Citation:** ASTM D 1142-86

**Content:** This test method covers the determination of the water vapor content of gaseous fuels by measurement of the dew-point temperature and the calculation therefrom of the water vapor content.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.05 on Determination of Special Constituents of Gaseous Fuels.

---

**Title:** Standard Test Method for Moisture in Cellulose<sup>1</sup>

**Citation:** ASTM D 1348-61 (1985)

**Content:** These test methods cover the determination of moisture in cellulose using two oven-drying procedures and one Karl Fischer procedure.

The test procedures appear in the following order: Method A--Sample Weighed in Oven, Method B--Sample Weighed Outside of Oven, and Method C--Karl Fischer Method.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives and are the direct responsibility of Subcommittee D23.20 on Cellulose.

---

**Title:** Standard Test Method for Water in Liquid Petroleum Products by Karl Fischer Reagent<sup>1</sup>

**Citation:** ASTM D 1744-83

**Content:** This test method covers the determination of water in the concentration from 50 to 1000 ppm in liquid petroleum products.

## MOISTURE (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.03 on Elemental Analysis.

---

**Title:** Standard Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)<sup>1</sup>

**Citation:** ASTM D 1796-83

**Content:** This test method covers the laboratory test for determination of water and sediment in fuel oils by using the centrifuge method. This chapter, along with API Chapter 10.3 (Test Method D 4007, IP 359), supersedes the previous edition of ASTM Test Method D 1796 (API Standard D 2548, IP 75).

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Methods for Moisture Content of Wood<sup>1</sup>

**Citation:** ASTM D 2016-74 (1983)  
(Withdrawn 1988)

**Content:** These methods cover the determination of the moisture content of wood. The methods provide a means whereby producers, fabricators, processors, and users of wood and wood products can facilitate inspection for adherence to moisture quality-control specifications. The requirements, advantages, and limitations of the different methods are outlined.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-7 on Wood.

---

**Title:** Standard Test Method for Moisture in Paper and Paperboard by Toluene Distillation

**Citation:** ASTM D 2044-68 (1974)  
Discontinued

**Content:** This method covers rapid determination of moisture in paper and paperboard by toluene distillation. Formerly under the jurisdiction of ASTM Committee D-6 on Paper and Paper Products, this method was discontinued in 1984.

As a service to ASTM users, an industry standard, TAPPI T 208, developed under the auspices of the Technical Association of the Pulp and Paper Industry is also included.

**Availability:** ASTM

---

**Title:** Standard Test Methods for Moisture in Activated Carbon<sup>1</sup>

**Citation:** ASTM D 2867-83

**Content:** These test methods provide two procedures for the determination of the moisture content of activated carbon. The procedures may also be used to dry samples required for other tests. The oven-drying method is used when water is the only volatile material present and is in significant quantities, and the activated carbon is not heat sensitive (some activated carbons can ignite spontaneously at temperatures as low as 150°C). The xylene-extraction method is used when a carbon is known or suspected to be heat sensitive or to contain nonwater-miscible organic compounds instead of or in addition to water.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-28 on Activated Carbon and are the direct responsibility of Subcommittee D28.04 on Gas Phase Evaluation Tests.

---

**Title:** Standard Test Method for Total Moisture in Coal Reduced to No. 8 (2.38 mm) Top Sieve Size (Limited-Purpose Method)<sup>1</sup>

**Citation:** ASTM D 2961-87

**Content:** This method is a single-stage procedure for the determination of total moisture in coal reduced to No. 8 mesh (2.38 mm). It is recognized that, under the conditions of test, certain coals will give results that reflect varying levels of oxidation; therefore its use should be limited to prior agreement between the parties involved. The method shall not be construed as the standard method for total moisture.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke.

**Title:** Standard Test Method for Moisture in the Analysis Sample of Coal and Coke<sup>1</sup>

**Citation:** ASTM D 3173-87

**Content:** This test method covers the determination of moisture in the analysis sample of coal or coke. It is used for calculating other analytical results to a dry basis. When used in conjunction with the air drying loss as determined in accordance with Method D 2013 or Method D 346, each analytical result can be calculated to an as-received basis.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

**Title:** Standard Test Method for Total Moisture in Coal<sup>1</sup>

**Citation:** ASTM D 3302-82

**Content:** This method covers the measurement of the total moisture in coal as it exists at the site, at the time, and under the conditions it is sampled. It is applicable to coals as mined, processed, shipped, or utilized in normal commercial pursuits. It is not applicable to coal-water slurries, sludges, or pulverized products under 0.5-mm diameter sieve size. It is applicable to coals of all ranks within the recognized limitations imposed by oxidation and decomposition characteristics of lower rank coals. Because of its empirical nature, strict adherence to basic principles and permissive procedures is required for valid results. This complete standard is available to producers, sellers, and consumers as a total moisture method when other procedures or modifications are not mutually agreed on.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

**Title:** Standard Test Method for Water in Crude Oil by Distillation<sup>1</sup>

**Citation:** ASTM D 4006-81 (1987)

**Content:** This method covers the determination of water in crude oil by distillation.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

## MOISTURE (STANDARDS)

**Title:** Standard Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure)<sup>1</sup>

**Citation:** ASTM D 4007-81 (1987)

**Content:** This method describes the laboratory determination of water and sediment in crude oils by means of the centrifuge procedure. This centrifuge method for determining water and sediment in crude oils is not entirely satisfactory. The amount of water detected is almost always lower than the actual water content. When a highly accurate value is required, the revised procedures for water by distillation (Method D 4006) and sediment by extraction (Method D 473) must be used.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Water in Crude Oils (Karl Fischer) Titration<sup>1</sup>

**Citation:** ASTM D 4377-86

**Content:** This test method covers the determination of water in the range from 0.02% to 2% in crude oil containing less than 150 ppm sulfur as either mercaptan sulfur or sulfide sulfur, or both.

This test method is intended for use with standard Karl Fischer reagent or pyridine-free Karl Fischer reagents.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.03 on Elemental Analysis.

---

**Title:** Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials

**Citation:** ASTM D 4442-84

**Content:**

**Availability:** ASTM

---

**Title:** Standard Test Method for Water Using Karl Fischer Reagent<sup>1</sup>

**Citation:** ASTM E 203-86

**Content:** This test method is intended as a general guide for the application of the Karl Fischer reagent method for determining free water and water of hydration in most solid or liquid organic and inorganic compounds. Samples that are gaseous at room temperature are not covered. By proper choice of sample size, Karl Fischer reagent concentration, and apparatus, the method is suitable for the measurement of water over a wide concentration range, that is, parts per million to pure water. Both visual and electro-metric methods are described for ascertaining the end point.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-15 on Industrial Chemicals and is the direct responsibility of Subcommittee E15.24 on Water.

---

**Title:** Standard Test Method for Residual Moisture in a Refuse-Derived Fuel Analysis Sample<sup>1</sup>

**Citation:** ASTM E 790-81 (1987)

**Content:** This method covers the measurement of the residual moisture in an analysis sample of RDF-3. It is used to calculate to the dry basis other determinations performed on the analysis sample. It is used with the air-dry moisture results to calculate total moisture. The total moisture is used to calculate as-received values or other analyses performed on the sample.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Standard Method for Moisture Analysis of Particulate Wood Fuels<sup>1</sup>

**Citation:** ASTM E 871-82 (1987)

**Content:** This method covers the determination of total weight basis moisture in the analysis sample of particulate wood fuel. The particulate wood fuel may be sanderdust, sawdust, pellets, green tree chips, hogged fuel, or other type particulate wood fuel having a maximum particle volume of 16.39 cm<sup>3</sup> (1 in.<sup>3</sup>). It is used for calculating other analytical results to a dry basis. Moisture, when determined as herein described, may be used to indicate yields on processes, to provide the basis for purchasing and selling, or to establish burning characteristics.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-44 on Solar Energy Conversion and is the direct responsibility of Subcommittee E44.12 on Biomass Conversion Systems.

---

**Title:** Standard Test Method for Total Moisture in a Refuse-Derived Fuel Laboratory Sample<sup>1</sup>

**Citation:** ASTM E 949-88

**Content:** This test method covers the measurement of the total moisture in RDF-3 as it exists at the time it is sampled. Because of its empirical nature, strict adherence to test procedures are required for valid results. The standard is available to producers, vendors, and consumers as a total, two-stage moisture method.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Test Method of Air Drying Refuse Derived Fuel-5 for Further Analysis

**Citation:** ASTM E 1183 (1987)

**Content:** According to the procedure described in E 1183, a laboratory sample is air dried in order to yield a RDF-5 sample with moisture content near to equilibrium with the atmosphere. Such equilibrium is necessary to ensure uniform conditions throughout subsequent analysis of the RDF-5 laboratory sample for density, size distribution, hydrophilia, breakage, and similar tests.

**Availability:** ASTM

---

**Title:** Methods for the Determination of Water (Karl Fischer Method)

**Citation:** BS 2511:1970

**Content:** Preparation and standardization of Fischer reagent; its application to determination of water in various substances including ketones; double- and single-burette method with electrometric end points; single-burette method with visual end point; determination of microgram quantities of water. Notes on sampling for determination of low water contents.

**Availability:** BSI

---

**Title:** Air-Dry Weight Determination of Wood Pulp

**Citation:** CPPA A.2

**Content:** Exact air-dry shipment weight as determined by the receiver depends on proper sampling, careful wet weight determination, and accurate moisture measurement. Since the determination of moisture in wood

## MOISTURE (STANDARDS)

pulp varies with the form in which it is manufactured, this procedure outlines methods for determining air-dry shipment weight of (1) baled sheeted pulp, (2) roll pulp, and (3) wet lap pulp.

**Availability:** CPPA

---

**Title:** Moisture in Wood Chips, Sawdust, and Pulp by the Toluene Method

**Citation:** CPPA G.1

**Content:** This method is a rapid and accurate procedure for the determination of moisture in comparatively small laboratory samples but is not intended to be used in acceptance tests of pulp shipments. It usually gives slightly higher results than oven drying since cellulose can be completely dried only with difficulty, if at all, and then must be weighed in a dry atmosphere. It does not give, as water, any other volatile impurities such as turpentine, unless they are soluble in water. It is especially valuable for wood chips, sawdust, or groundwood pulp, and for these has been claimed to be much superior to oven drying.

**Availability:** CPPA

---

**Title:** Moisture in Paper

**Citation:** CPPA G.3

**Content:** The moisture content of paper is assumed to be the loss of weight in a test specimen when it is dried to constant weight in an oven maintained at the temperature of  $105 \pm 2^\circ\text{C}$ .

This method does not apply to papers which contain appreciable quantities of volatile constituents, other than water, which would be lost, oxidized, or decomposed by oven drying at  $105 \pm 2^\circ\text{C}$ .

**Availability:** CPPA

---

**Title:** Solid Fuels: Determination of Water Content

**Citation:** DIN 51718

**Content:**

**Availability:** DIN

---

**Title:** Turf. Methods for Determination of Moisture

**Citation:** GOST 11305-83

**Content:** The standard covers peat (fuel peat for agriculture and peat products of all kinds) and establishes general and accelerated methods of determination of moisture fraction of total mass.

**Availability:** GOST

---

**Title:** Coal--Determination of Moisture in the Analysis Sample--Direct Gravimetric Method

**Citation:** ISO 331:1983

**Content:**

**Availability:** ISO

---

**Title:** Determination of Water--Karl Fischer Method

**Citation:** ISO 760:1978

**Content:**

**Availability:** ISO

---

**Title:** Testing Method for Moisture in Woodchips and Sawdusts by the Toluene Method

**Citation:** JIS P 8015-1976 (1985)

**Content:** This Japanese Industrial Standard specifies the testing method for moisture in woodchips and sawdusts by the toluene method.

This method is intended for measuring the moisture content, which is separated when the test specimen is distilled by evaporation together with toluene and cooled. Volatile contents insoluble in water such as turpentine oil may not vary the test values by this method.

**Availability:** JIS

---

**Title:** Moisture in Paper and Paperboard

**Citation:** SCAN-P 4:63

**Content:** The moisture content of paper is defined as the loss of weight of a sample, dried under specified conditions to constant weight at a temperature of  $103^{\circ}\text{C} \pm 2^{\circ}\text{C}$  and is expressed as a percentage of the weight of the moist sample.

This method applies to papers that do not contain appreciable quantities of materials, other than water, that will escape from the paper at the temperature specified for the test. The method does not cover sampling procedure.

**Availability:** SCAN

---

**Title:** Moisture in Wood Chips (Steam Oven)

**Citation:** TAPPI Useful Method 7

**Content:**

**Availability:** TAPPI

---

**Title:** Moisture in Chips (Moisture Teller)

**Citation:** TAPPI Useful Method 8

**Content:**

**Availability:** TAPPI

---

**Title:** Moisture in Wood Chips (Two-Liter Graduate)

**Citation:** TAPPI Useful Method 10

**Content:**

**Availability:** TAPPI

---

**Title:** Moisture in Wood, Pulp, Paper, and Paperboard by Toluene Distillation

**Citation:** TAPPI T 208 om-84

**Content:** This method can be applied to wood chips, sawdust, groundwood, pulp, paper, paperboard, and nonwood fibers. It is especially useful for determination of moisture content in materials containing volatile substances such as turpentine and resins in wood and groundwood or easily melting waxes and varnishes in paper and paperboard. These substances, by volatilization or melting, interfere with moisture determination by oven-drying methods.

In addition, water cannot be expelled completely on oven drying of cellulosic materials. Therefore, the moisture content, as determined by this method of distillation, is a better measure of the true water content than that provided by oven-drying procedures for some materials.

**Availability:** TAPPI

---

**Title:** Basic Density and Moisture Content of Pulpwood

**Citation:** TAPPI T 258 om-85

**Content:** This method describes the measurement of the basic density (bone-dry weight per unit of maximum volume) of pulpwood in the form of chips or disks from the cross section of logs. The method also gives procedures for determining the moisture content of wood in either form.

**Availability:** TAPPI

---

## **MOISTURE (STANDARDS)**

**Title:** Moisture in Paper and Paperboard

**Citation:** TAPPI T 412 om-88

**Content:** The following procedure applies to paper, paperboard, and paper products, except those containing significant quantities of materials other than water that are volatile at  $105^{\circ} \pm 2^{\circ}\text{C}$ . Moisture control is significant not only from the economic aspects but also as it affects such properties as printability, shrinkage, dimensional stability, and physical strength.

**Availability:** TAPPI

---

**Title:** Comparison of Microwave Drying and Conventional Drying Techniques for Reference Materials

**Citation:** Beary, E. S. *Analytical Chemistry* 60(8):742 (1988).

**Content:**

---

**Title:** The Determination of Water in Biomass-Derived Liquid Fuels

**Citation:** Roy, Christian and Bruno De Caumia. *Fuel Science and Technology Int'l.* 4(5):531-539 (1986).

**Content:** The Dean and Stark distillation is an appropriate method for the determination of water in coal tar, bitumen, and petroleum-like products. This article shows, however, that a direct application of the Dean and Stark method for the determination of water in biomass-derived liquid fuels results in incorrect estimates. Inaccuracies are due to the presence of soluble organics in the aqueous phase, which apparently form azeotropic mixtures with water and xylene and which condense and are trapped as distillate in the graduated cylinder. Instead, a Karl Fischer determination of water is recommended in the case of biomass-derived liquid fuels.

---

**Title:** Hydranal®-Composite 5 K Hydranal®-Working Medium for the Determination of Water in Ketones and Aldehydes According to Eugen Scholz

**Citation:** Available from Riedel-de Haën, Aktiengesellschaft, Wunstorfer Strabe 40, D-3016 Seelze I, Hannover, West Germany.

**Content:**

---

**Title:** Karl Fischer Titration: Determination of Water; Chemical Laboratory Practice

**Citation:** Scholz, Eugen. New York: Springer-Verlag, 1984.

**Content:**

---

**Title:** Rapid Determination of Wood Fuel Moisture Content Using a Microwave Oven for Drying

**Citation:** Harris, Robert A. *Forest Products Journal* 32:56 (1982).

**Content:** A method of determining moisture content (MC) of wood fuel using a microwave oven for drying the wood was evaluated by drying paired samples of five different wood fuel types in a microwave oven and a conventional oven. When compared to the conventional oven drying method, the microwave technique produces consistently lower MC determinations, although the differences are less than 1 percent. The advantage of the microwave technique is the speed at which MC determinations can be determined (less than 15 minutes). Schedules for drying five wood fuel types are presented.

---

**Title:** Determination of Water

**Citation:** Chapter 4 in Browning, B.L. *Methods of Wood Chemistry*, Vol. 1. New York: Interscience Publishers, 1967.

**Content:** I. The Hygroscopicity of Wood; II. Determination of the Water (Moisture) Content of Wood; III. Oven Drying; IV. Vacuum Drying; V. Distillation; VI. Karl Fischer Titration; VII. Other Methods for Determination of Water.

---

**MOISTURE  
(LITERATURE)**

**Title:** Sorption and Swelling

**Citation:** Chapter 17 in Browning, B.L.  
*Methods of Wood Chemistry*,  
Vol. 1. New York: Interscience  
Publishers, 1967.

**Content:** I. Sorption of Water Vapor; II. Swel-  
ling; III. Measurement of Surface Area.

---

**Title:** Determination of Moisture in Wood  
and Wood Pulp

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Pulps: Determination of Silica  
Content

**Citation:** NF T 12-028-87

**Content:**

**Availability:** AFNOR

---

**Title:** Ash of Peat

**Citation:** AOAC 2.207

**Content:**

**Availability:** AOAC

---

**Title:** Sand in Peat

**Citation:** AOAC 2.208 (Preparation of  
Sample)  
AOAC 2.209 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Ash of Plants

**Citation:** AOAC 3.004

**Content:**

**Availability:** AOAC

---

**Title:** Sand and Silica in Plants--Gravimetric  
Method

**Citation:** AOAC 3.005

**Content:**

**Availability:** AOAC

---

**Title:** Ash of Animal Feed

**Citation:** AOAC 7.009

**Content:**

**Availability:** AOAC

---

**Title:** Mineral Salts in Animal Feed

**Citation:** AOAC 7.093 (Ferrous Salts)  
AOAC 7.094 (Copper Salts)  
AOAC 7.095 (Potassium Iodide)

**Content:**

**Availability:** AOAC

---

**Title:** Minerals in Animal Feed--Atomic  
Absorption Spectrophotometric  
Method

**Citation:** AOAC 7.096 (Apparatus)  
AOAC 7.097 (Operating  
Parameters)  
AOAC 7.098 (Reagents)  
AOAC 7.099 (Preparation of  
Sample Solution)  
AOAC 7.100 (Determination and  
Calculation)

**Content:**

**Availability:** AOAC

---

**Title:** Calcium in Animal Feed--Wet Ash  
Method

**Citation:** AOAC 7.102

**Content:**

**Availability:** AOAC

---

**Title:** Dirt in Pulp

**Citation:** Appita P204m-56

**Content:**

**Availability:** Appita

---

**Title:** Dirt in Paper

**Citation:** Appita P410m-56

**Content:**

**Availability:** Appita

---

## ASH, MINERAL MATTER AND DIRT (STANDARDS)

**Title:** Methods of Test for Pulp and Paper (metric units); Ash Content of Wood Pulp

**Citation:** AS 1301, P3s:1978 and Appita P3s:78

**Content:** The ash content of wood and pulp is determined by heating prepared specimens at a controlled temperature ( $575^{\circ} \pm 125^{\circ}\text{C}$ ) at which the usual mineral constituents are not volatilized until all the carbon is consumed.

**Availability:** Appita, SAA

---

**Title:** Methods of Test for Pulp and Paper (metric units); Ash Content of Paper and Paperboard

**Citation:** AS 1301, P418s:1978 and Appita P418s:78

**Content:** The ash content of paper is defined as the residue remaining after combustion of a sample at  $925^{\circ} \pm 125^{\circ}\text{C}$ .

**Availability:** Appita, SAA

---

**Title:** Standard Test Method for Ash from Petroleum Products<sup>1</sup>

**Citation:** ASTM D 482-87

**Content:** This test method covers the determination of ash from distillate and residual fuels, gas turbine fuels, crude oils, lubricating oils, waxes, and other petroleum products, in which any ash-forming materials present are normally considered to be undesirable impurities or contaminants. The method is limited to petroleum products that are free from added ash-forming additives, including certain phosphorus compounds.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D 02.03 on Elemental Analysis.

---

**Title:** Standard Test Method for Ash in Paper

**Citation:** ASTM D 583-63  
Discontinued

**Content:** This method covers the determination of the ash content of paper and paper products, which is defined as the residue after complete combustion of the paper at  $925^{\circ} \pm 25^{\circ}\text{C}$  ( $1967^{\circ} \pm 45^{\circ}\text{F}$ ).

Formerly under the jurisdiction of ASTM Committee D-6 on Paper and Paper Products, this method was discontinued in 1984.

As a service to ASTM users, an industry standard, TAPPI T 413, developed under the auspices of the Technical Association of the Pulp and Paper Industry is also included.

**Availability:** ASTM

---

**Title:** Standard Test Method for Ash in Wood<sup>1</sup>

**Citation:** ASTM D 1102-84

**Content:** This test method covers the determination of ash, expressed as the percentage of residue remaining after dry oxidation (oxidation at  $580^{\circ}$  to  $600^{\circ}\text{C}$ ) of wood or wood products.

**Availability:** ASTM

---

<sup>1</sup>This test method is currently under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.14 on Chemical Tests.

---

**Title:** Standard Test Method for Carbon Black--Ash Content<sup>1</sup>

**Citation:** ASTM D 1506-85

**Content:**

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-24 on Carbon Black and is the direct responsibility of Subcommittee D24.31 on Non-Carbon-Black Components of Carbon Black.

---

**Title:** Standard Test Method for Dirt in Paper and Paperboard

**Citation:** ASTM D 2019-65 (1970)  
Discontinued

**Content:** This method is adapted to the numerical estimation of dirt in paper or paperboard in terms of equivalent black area.

Formerly under the jurisdiction of ASTM Committee D-6 on Paper and Paper Products, this method was discontinued in 1984.

As a service to ASTM users, an industry standard, TAPPI T 437, developed under the auspices of the Technical Association of the Pulp and Paper Industry is also included.

**Availability:** ASTM

---

**Title:** Standard Test Method for Silica in Cellulose<sup>1</sup>

**Citation:** ASTM D 2438-68 (1985)

**Content:** This test method covers the determination of silica in cellulose and is applicable to all pulps. It is designed to measure up to 200 µg of silica (SiO<sub>2</sub>) in 50 mL of solution.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives and is the direct responsibility of Subcommittee D23.20 on Cellulose.

---

**Title:** Standard Test Methods for Analysis of Coal and Coke Ash<sup>1</sup>

**Citation:** ASTM D 2795-86

**Content:** These test methods cover the rapid and inexpensive analysis of coal and coke ash for the commonly determined major elements.

The test methods cover silicon dioxide (SiO<sub>2</sub>), aluminum oxide (Al<sub>2</sub>O<sub>3</sub>), ferric oxide (Fe<sub>2</sub>O<sub>3</sub>), titanium dioxide (TiO<sub>2</sub>), phosphorus pentoxide (P<sub>2</sub>O<sub>5</sub>), calcium oxide (CaO), sodium oxide (Na<sub>2</sub>O), and potassium oxide (K<sub>2</sub>O).

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-5 on Coal and Coke and are the direct responsibility of Subcommittee D05.29 on Major Elements in Ash and Trace Elements of Coal.

---

**Title:** Standard Test Method for Total Ash Content of Activated Carbon<sup>1</sup>

**Citation:** ASTM D 2866-83

**Content:** This test method describes a procedure for the determination of total ash content of activated carbon.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-28 on Activated Carbon and is the direct responsibility of Subcommittee D28.04 on Gas Phase Evaluation Tests.

---

## ASH, MINERAL MATTER AND DIRT (STANDARDS)

**Title:** Standard Test Method for Ash in the Analysis Sample of Coal and Coke from Coal<sup>1</sup>

**Citation:** ASTM D 3174-88

**Content:** This method covers the determination of the inorganic residue as ash in the analysis sample of coal or coke as prepared in accordance with Method D 2013 or Method D 346. The results obtained can be applied as the ash in the proximate analysis, Method D 3172, and in the ultimate analysis, Method D 3176. For the determination of the constituents in ash, reference is made to Method D 2795 and D 3682. See Definitions D 121 for definition of ash.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Practices for Ashing Cellulose<sup>1</sup>

**Citation:** ASTM D 3516-76 (1985)

**Content:** These practices cover four ashing methods for cellulose. These are intended for use on unbleached and bleached cellulose in sheeted or bulk fiber form. Each one of the methods has advantages, so that preference applications exist for all four.

**Availability:** ASTM

---

<sup>1</sup>These practices are under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives.

---

**Title:** Test Method for Wet Ashing Procedure for Preparing Wood Samples for Inorganic Chemical Analysis

**Citation:** ASTM D 4278-88

**Content:** This test method consists of a procedure for decomposition of wood as an

initial step for analysis for the constituents arsenic, chromium, copper, phosphate, and zinc, all of which may then be analyzed according to Methods D 1033, D 1035, D 1326, D 1627, and D 1628.

**Availability:** ASTM

---

**Title:** Standard Test Method for Ash in the Analysis Sample of Refuse-Derived Fuel<sup>1</sup>

**Citation:** ASTM E 830-87

**Content:** This method covers determination of the ash content in the analysis sample of refuse-derived fuel (RDF-3). The results obtained can be applied as the weight percent ash in the proximate analysis and in the ultimate analysis.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Standard Test Method for Silica in Refuse-Derived Fuel-3 (RDF-3) and RDF-3 Ash<sup>1</sup>

**Citation:** ASTM E 887-88

**Content:** This test method covers the determination of silica in RDF, RDF ash, fly ash, bottom ash, or slag. The test method is an acid dehydration gravimetric procedure and is independent of interferences.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Method for Determination of Ash of Paper and Board

**Citation:** BS 3631:1984

**Content:** Specifies a method for determining the ash of paper and board which is suitable for most loading materials and coating pigments.

**Availability:** BSI

---

**Title:** Method for Determination of Acid-Insoluble Ash of Pulp

**Citation:** BS 4496:1984

**Content:** Specifies a method for the determination of the acid-insoluble ash of all kinds of pulp.

**Availability:** BSI

---

**Title:** Method for the Determination of Ash of Pulp

**Citation:** BS 4896:1973

**Content:** Specifies a method for the determination of ash of all kinds of papermaking and dissolving pulps.

**Availability:** BSI

---

**Title:** Dirt in Chips

**Citation:** CPPA Useful Method D.3U-77

**Content:**

**Availability:** CPPA

---

**Title:** Ash in Pulp and Wood

**Citation:** CPPA G.10

**Content:** The ash content of wood or pulp is defined as the residue remaining after

burning all the carbon and igniting to constant weight as  $575^{\circ} \pm 25^{\circ}\text{C}$ .

**Availability:** CPPA

---

**Title:** Ash of Paper and Paperboard

**Citation:** CPPA G.11

**Content:** This method deals with the determination of ash, which is defined as the residue after combustion of paper. The mineral content of paper may consist of (1) the natural ash of the pulp and various residues from chemicals used in its manufacture; (2) metallic matter from piping and machinery; and (3) filling, coating, and pigmenting materials. Generally, if the ash content does not exceed about 2%, no filling, coating, or pigmenting material has been used; but this is not always the case, as pigments such as the titanium pigments are sometimes used in very small amounts.

When filling or coating minerals are present which do not change much on ignition, such as clay, the ash is an approximate measure of the amount present.

**Availability:** CPPA

---

**Title:** Acid-Insoluble Ash in Pulp

**Citation:** CPPA G.33P

**Content:** This method describes a procedure for the determination of the acid-insoluble ash content of pulp.

The acid-insoluble ash in pulp is made up primarily of silica and silicates. This material, when present in the finished paper or paperboard, can have an abrasive effect on punches, knives, slitters, dies, etc., which come in contact with the paper during finishing operations. Paper made from pulps with more than 400 mg/kg of acid-insoluble ash may cause premature dulling of such equipment.

**Availability:** CPPA

---

## ASH, MINERAL MATTER AND DIRT (STANDARDS)

**Title:** Testing of Solid Fuels; Determination of Ash Content

**Citation:** DIN 51719

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Generalities, Preparation of Test Samples

**Citation:** DIN 51729 Part 1

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Silica (SiO<sub>2</sub>) Content

**Citation:** DIN 51729 Part 2

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Aluminum Oxide (Al<sub>2</sub>O<sub>3</sub>) Content

**Citation:** DIN 51729 Part 3

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Titanium Dioxide (TiO<sub>2</sub>)

**Citation:** DIN 51729 Part 4

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Ferric Oxide (Fe<sub>2</sub>O<sub>3</sub>) Content

**Citation:** DIN 51729 Part 5

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Calcium Oxide (CaO) Content

**Citation:** DIN 51729 Part 6

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Magnesium Oxide (MgO) Content

**Citation:** DIN 51729 Part 7

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Soda and Potash (Na<sub>2</sub>O, K<sub>2</sub>O) Contents

**Citation:** DIN 51729 Part 8

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash, Phosphoric Oxide (P<sub>2</sub>O<sub>5</sub>) Content

**Citation:** DIN 51729 Part 9

**Content:**

**Availability:** DIN

---

**Title:** Turf. Methods of Ash Content Determination

**Citation:** GOST 11306-83

**Content:** The standard covers fuel, lump and milled peat, peat and coal breaks, and peat products of all kinds for agriculture and establishes general and accelerated methods of ash content determination.

**Availability:** GOST

---

**Title:** Coal--Determination of Mineral Matter

**Citation:** ISO 602:1983

**Content:**

**Availability:** ISO

---

**Title:** Pulps--Determination of Acid-Insoluble Ash

**Citation:** ISO 776:1982

**Content:**

**Availability:** ISO

---

**Title:** Solid Mineral Fuels--Determination of Ash

**Citation:** ISO 1171:1981

**Content:**

**Availability:** ISO

---

**Title:** Pulps--Determination of Ash

**Citation:** ISO 1762:1974

**Content:**

**Availability:** ISO

---

**Title:** Testing Method for Ash of Pulpwood

**Citation:** JIS P 8003-1976 (Reaffirmed 1985)

**Content:**

**Availability:** JIS

---

**Title:** Ash in Paper and Paperboard

**Citation:** SCAN-P 5:63

**Content:** The ash content of paper is defined as the weight of the residue after complete combustion of a sample at a temperature of  $925^{\circ}\text{C} \pm 25^{\circ}\text{C}$  under specified conditions and is expressed as a percentage of the weight of the oven-dry paper.

The ash content of paper gives an estimate of the content of mineral salts, loading materials, and other inorganic matter, but is not quantitatively equal to this content because the weight of some of these substances is altered during ignition.

**Availability:** SCAN

---

**Title:** Ash in Pulp

**Citation:** SCAN-C 6:62

**Content:** The ash content of a pulp sample is defined as the weight of the residue after complete combustion at a temperature of  $575^{\circ}\text{C} \pm 25^{\circ}\text{C}$  under specified conditions and is expressed in percent of the weight of the oven-dry sample.

The ash content of pulp gives an estimation of the content of mineral salts and other inorganic matter in the pulp, but is not quantitatively equal to it.

**Availability:** SCAN

---

**Title:** Silicates and Silica in Pulp

**Citation:** SCAN-C 9:62

**Content:** The sample is ashed and the ash is treated with hydrochloric acid. The insoluble

## ASH, MINERAL MATTER AND DIRT (STANDARDS)

residue is filtered, washed, ignited, and weighed.

**Availability:** SCAN

---

**Title:** Ash in Wood and Pulp

**Citation:** TAPPI T 211 om-85

**Content:** This method for determination of ash can be applied to wood and to all types and grades of wood pulp. For the determination of ash in paper and paperboard, T 413 must be used.

**Availability:** TAPPI

---

**Title:** Dirt in Pulp

**Citation:** TAPPI T 213 om-85

**Content:** This method is adapted to the numerical estimation of dirt in pulp in terms of equivalent black area. The results will differ from those obtained by T 246 in that it is the contrasting color of foreign matter rather than its opaqueness that affects the result.

**Availability:** TAPPI

---

**Title:** Acid-Insoluble Ash in Pulp

**Citation:** TAPPI T 244 om-88

**Content:** This method describes a procedure for determining the acid-insoluble ash content of pulp.

The pulp is dry-ashed and the residue treated with hydrochloric acid. The insoluble residue is filtered, washed, ignited, and weighed.

This method measures all acid-insoluble material. For a more accurate but time-consuming wet-ash procedure for determining the silicates and silica content of pulp, see TAPPI T 245, "Silicates and Silica in Pulp (Wet Ash Method)."

**Availability:** TAPPI

---

**Title:** Silicates and Silica in Pulp (Wet Ash Method)

**Citation:** TAPPI T 245 om-88

**Content:** This method describes a procedure for determining the silicates and silica content of pulp.

The pulp is wet-ashed using nitric and sulfuric acids. The insoluble residue is filtered, washed, ignited, and weighed as silicon dioxide.

For a faster but less accurate procedure for measuring all acid-insoluble material see TAPPI T 244, "Acid-Insoluble Ash in Pulp."

**Availability:** TAPPI

---

**Title:** Natural Dirt in Wood Chips

**Citation:** TAPPI T 265 om-87

**Content:** This method is used to estimate the amount of natural (wood-derived) dirt in chips. The amount of dirt in the chips may be reflected in the level of dirt in the finished pulp or in bleaching and screening steps needed to produce an acceptable product. The determination is made by examining and classifying chips into categories defined by the ultimate contribution to dirt levels in the final product. For sulfite pulps from certain species, a dirt contribution values table is provided, which allows the results to be expressed in terms of an index based on square millimeters or equivalent area of black dirt.

**Availability:** TAPPI

---

**Title:** Ash in Paper and Paperboard

**Citation:** TAPPI T 413 om-85

**Content:** This method for determination of ash can be applied to all types of paper and paperboard.

Paper or paperboard is ignited in a muffle furnace at  $900^{\circ} \pm 25^{\circ}\text{C}$ . The resulting ash is weighed and calculated as percentage of the moisture-free paper or paperboard.

**Availability:** TAPPI

---

**Title:** Dirt Count of Wood Chips

**Citation:** TAPPI Useful Method 11

**Content:**

**Availability:** TAPPI

---

**Title:** Ash in Paper (Oxygen and Electric Furnace)

**Citation:** TAPPI Useful Method 496

**Content:**

**Availability:** TAPPI

---



**Title:** Determination of Ash in Wood

**Citation:** Moore, Wayne E. and David B. Johnson. *Procedures for the Chemical Analysis of Wood and Wood Products* (As used at the U.S. Forest Products Laboratory.) Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Determination of Ash in Pulp

**Citation:** Moore, Wayne E. and David B. Johnson. *Procedures for the Chemical Analysis of Wood and Wood Products* (As used at the U.S. Forest Products Laboratory.) Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---



**Title:** Standard Test Method for Alpha-, Beta-, and Gamma-Cellulose in Paper

**Citation:** ASTM D 588-42 (1971)  
Discontinued

**Content:** This method covers the determination of alpha-, beta-, and gamma-cellulose. Formerly under the jurisdiction of ASTM Committee D-6 on Paper and Paper Products, this method was discontinued in 1984.

As a service to ASTM users, an industry standard, TAPPI T 429, developed under the auspices of the Technical Association of the Pulp and Paper Industry is also included.

**Availability:** ASTM

---

**Title:** Standard Test Method for Alpha-Cellulose in Wood<sup>1</sup>

**Citation:** ASTM D 1103-60 (1977)  
Discontinued

**Content:** This method covers the determination of alpha-cellulose in wood.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-7 on Wood.

---

**Title:** Standard Test Method for Holocellulose in Wood<sup>1</sup>

**Citation:** ASTM D 1104-56 (1978)  
Discontinued

**Content:** This method covers the determination of holocellulose (hemicellulose plus cellulose) in wood.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-7 on Wood.

---

**Title:** Standard Definitions of Terms Relating to Cellulose and Cellulose Derivatives<sup>1</sup>

**Citation:** ASTM D 1695-77 (1983)

**Content:** These definitions are divided into three classes of terminology as follows: (A) cellulosic materials and constituents, (B) chemical modifications and derivatives of cellulose, and (C) properties of cellulose and associated concepts that are applicable to both (A) and (B).

**Availability:** ASTM

---

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives and are the direct responsibility of Subcommittee D23.02 on Nomenclature.

---

**Title:** Standard Test Method for Solubility of Cellulose in Sodium Hydroxide<sup>1</sup>

**Citation:** ASTM D 1696-61 (1985)

**Content:** This test method is intended for application to dissolving-type cellulose pulps prepared from cotton or wood. The procedure is not directly applicable to pulps that have not been refined for use in chemical conversion processes because solubility equilibrium may not be attained within the specified extraction time.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives and is the direct responsibility of Subcommittee D23.20 on Cellulose.

---

## CELLULOSE AND HOLOCELLULOSE (STANDARDS)

**Title:** Standard Test Method for Cellulose Chain Length Uniformity by Fractional Precipitation of Cellulose Nitrate<sup>1</sup>

**Citation:** ASTM D 1716-82 (1987)

**Content:** This method covers the determination of the chain length uniformity of cellulose by fractional precipitation of cellulose nitrate. It is recognized that this method does not give absolute delineation of chain length; however, the curves obtained by this method afford a useful basis for comparing the relative chain length uniformity of different cellulose samples. It is applicable primarily to purified celluloses.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives.

---

**Title:** Standard Test Method for Intrinsic Viscosity of Cellulose<sup>1</sup>

**Citation:** ASTM D 1795-62 (1985)

**Content:** This test method covers the determination of the intrinsic viscosity of purified celluloses such as bleached wood pulps, cotton linters, and regenerated cellulose. It is applicable to all cellulose samples with an intrinsic viscosity of 15 dl/g or less. Most native (unpurified) celluloses have intrinsic viscosity values too high for measurement by this method.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives and is the direct responsibility of Subcommittee D23.20 on Cellulose.

---

**Title:** Standard Method for Chromatographic Analysis of Chemically Refined Cellulose<sup>1</sup>

**Citation:** ASTM D 1915-63 (1985)

**Content:** This method covers the determination of the composition of chemically refined cellulose by chromatographic analysis. The method is suitable for rapid and routine testing of large numbers of samples with high accuracy and precision.

Quantitative paper chromatographic analysis of polysaccharides by the chemical method involves the following operations: (1) total hydrolysis, (2) neutralization, (3) concentration, (4) chromatographic separation, (5) elution, (6) analysis of separated sugars, and (7) calibration and calculation.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives and is the direct responsibility of Subcommittee D23.20 on Cellulose.

---

**Title:** Degree of Polymerization of Cellulose Materials

**Citation:** CPPA G-24P

**Content:** Equivalent to TAPPI T 230 SU-6C

**Availability:** CPPA

---

**Title:** Determination of Holocellulose

**Citation:** CPPA Useful Method G. 9U-77

**Content:**

**Availability:** CPPA

---

**Title:** Alkali Solubility of Pulp

**Citation:** CPPA G. 26

**Content:**

**Availability:** CPPA

---

**Title:** Alkali-Resistant Cellulose in Pulp

**Citation:** CPPA G. 27P

**Content:** This method gives a rapid and reproducible determination of the alkali-resistant cellulose in pulp, using 10%, 18%, and 21.5% sodium hydroxide solutions. With some modifications, using the 21.5% sodium hydroxide solution, this method gives the yield to be expected from a pulp in the classical viscose process.

**Availability:** CPPA

---

**Title:** Alpha-, Beta- and Gamma-Cellulose in Bleached Pulp

**Citation:** CPPA G. 29P

**Content:** Division of the cellulose in pulp into alpha-, beta- and gamma-cellulose fractions is an empirical procedure originally devised by Cross and Bevan around 1900 and since used widely to evaluate pulps for various purposes.

**Availability:** CPPA

---

**Title:** Testing Method for Cellulose in Wood for Pulp

**Citation:** JIS P 8007-1976 (1984)

**Content:**

**Availability:** JIS

---

**Title:** Testing Method for Holocellulose in Pulpwood

**Citation:** JIS P 8012-1976 (1984)

**Content:**

**Availability:** JIS

---

**Title:** Cross and Bevan Cellulose in Wood

**Citation:** AS 1301, P9m:1968 and Appita P9m-68

**Content:**

**Availability:** SAA, Appita

---

**Title:** Fiber Analysis of Pulp and Paper--  
General Procedure

**Citation:** SCAN-G 3:71

**Content:** In this method qualitative fiber analysis consists in the identification of individual fibers in a fiber mixture as regards their origin and the methods applied for their processing.

The object of quantitative fiber analysis is to estimate the weight fraction of the different kinds of fibers.

The weight factor of a given type of fiber is the ratio of the mean mass per unit length of such fibers to that of rag fibers.

**Availability:** SCAN

---

**Title:** Fiber Analysis of Pulp and Paper--  
Herzberg's Stain

**Citation:** SCAN-G 4:72

**Content:** This method, which is intended for use in conjunction with SCAN-G 3, Fiber Analysis of Pulp and Paper--General Procedure, describes the preparation and use of Herzberg's stain. For equipment, preparation of slides and their examination under the microscope, and for the calculation and report, see SCAN-G 3.

## CELLULOSE AND HOLOCELLULOSE (STANDARDS)

Herzberg's stain, which is a mixture of aqueous solutions of zinc chloride and of iodine and potassium iodide, is used to differentiate fibers from chemical, mechanical, and rag pulp. Fibers from semichemical pulp may also be identified with this stain.

**Availability:** SCAN

---

**Title:** Cellulose in Wood

**Citation:** TAPPI T 17 wd-70 (Withdrawn)

**Content:** The procedure here described isolates the total cellulose in wood by a process of chlorination. The cellulose thus obtained is sometimes referred to as Cross and Bevan cellulose. As the method is empirical, details must be carefully followed.

**Availability:** TAPPI

---

**Title:** Cellulose in Pulp (Cross and Bevan Method)

**Citation:** TAPPI T 201 wd 76 (Withdrawn, Became Useful Method 249)

**Content:** This is an empirical method for determining cellulose in pulp. Its results are not comparable to those obtained by other methods. This method was developed by Cross and Bevan about 1885 and its use is now limited.

**Availability:** TAPPI

---

**Title:** Alpha-, Beta-, and Gamma-Cellulose in Pulp

**Citation:** TAPPI T 203 om-88

**Content:** This method for determination of alpha-, beta-, and gamma-cellulose can be applied to bleached or delignified pulps only. Unbleached and semibleached pulps must be delignified before testing.

**Availability:** TAPPI

---

**Title:** Cellulose Chain Length Uniformity by Fractional Precipitation of Cellulose Nitrates

**Citation:** TAPPI T 238 wd-75 (Withdrawn)

**Content:**

**Availability:** TAPPI

---

**Title:** Alpha-Cellulose in Paper

**Citation:** TAPPI T 429 om-84

**Content:** This method describes a procedure for determining the alpha-cellulose in paper. Alpha-cellulose is empirically defined as the fraction that can be filtered out of a mixture consisting of the fibrous material and sodium hydroxide solution (7.3%) of maximum dissolving power, after the fibers have previously been swollen with sodium hydroxide solution (17.5%). This method is applicable to and is intended primarily for papers made from rags or chemical wood fibers. It is not suitable for papers containing large amounts of lignin, such as newsprint.

**Availability:** TAPPI

---

**Title:** ESCA Analysis of Cellulosic Materials

**Citation:** Ahmed, A., A. Adnot, J.L. Grandmaison, S. Kaliaguine, and J. Doucet. *Cellulose Chem. Technol.* 21:483-492 (1987).

**Content:** The feasibility of application of the ESCA technique to the surface analysis of various cellulosic materials subject to different treatments was studied. First an investigation was made of the changes in surface composition of Whatman Paper No. 1 exposed to the x-ray source of an ESCA spectrometer for various times. The continuous change of the components  $C_1$ ,  $C_2$ , and  $C_3$  in the  $C_{1s}$  signal expressed in % area, and of the O/C ratio calculated from ESCA intensity ratio with exposure time, were satisfactorily monitored with the ESCA technique. The results indicate that when the sample is maintained for some time under the x-ray source, it undergoes important degradation, which must be taken into consideration in the analysis of ESCA data.

The surface modifications of cotton linters submitted to the acid treatment producing hydrocellulose and to an oxidative treatment leading to oxycellulose were also followed by means of ESCA, as well as the changes in surface composition of raw cotton linters with extraction in various organic solvents.

**Title:** Modern Analytical Methods--  
Application to Cellulose and Its  
Derivatives

**Citation:** Stephenson, P.J. Chapter 1 in *Wood and Cellulosics: Industrial Utilization, Biotechnology Structures, and Properties*. Edited by J.F. Kennedy, G.O. Phillips, and P.A. Williams. New York: John Wiley and Sons, 1987.

**Content:** Chemical analytical methods applied to the characterization of polymers have traditionally been destructive in nature

with their roots in pyrolysis and related techniques. Fundamental advances, particularly over the last decade, have armed the analyst with an array of nondestructive methods for the analysis of solids, allowing a much more detailed elucidation of structure.

**Title:** The Isolation and Determination of Cellulose

**Citation:** Chapter 19 in Browning, B.L. *Methods of Wood Chemistry*, Vol. 2. New York: Interscience Publishers, 1967.

**Content:** I. The Nature of Cellulose; II. The Laboratory Isolation of Cellulose; A. Isolation of Cellulose Preparations; B. Holocellulose Preparations; C. Other Laboratory Cellulose Preparations; III. Isolation of the Cellulose Component; A. Isolation of Cellulose from Cellulose Preparations and the Determination of Cellulose; B. Determination of Cellulose by Nitration; IV. The Preparation of Wood Pulps; V. The Evaluation of Cellulose Preparations.

**Title:** Cellulose and Cellulose Derivatives

**Citation:** Ott, E., H.M. Spurlin, and M.W. Grafflin. 3 parts. London: Interscience, 1954. See also Parts IV and V (N.H. Bikales and L. Segal, Eds.), 1971.

**Content:**



**Title:** Pulps: Determination of the Pentosans Content by the Furfural Method

**Citation:** NF T 12-008-87

**Content:**

**Availability:** AFNOR

---

**Title:** Pentosans in Animal Feed

**Citation:** AOAC 7.090

**Content:**

**Availability:** AOAC

---

**Title:** Standard Test Method for Pentosans in Cellulose<sup>1</sup>

**Citation:** ASTM D 1787-62 (1985)

**Content:** This test method covers the determination of pentosans in cellulose by the orcinol colorimetric method, in the range from less than 1% to about 16%.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives and is the direct responsibility of Subcommittee D23.20 on Cellulose.

---

**Title:** Pentosans in Pulp

**Citation:** CPPA G.12

**Content:** This method is suitable for highly refined pulps with low pentosan content. With suitable variation in size of test specimen or dilution of the distillate, or both, the method is applicable to pulps with high pentosan content and to wood.

Furfural is formed from the xylan in the pulp by the action of hot hydrochloric acid and is distilled from the mixture. The amount of furfural in the distillate is determined as the

colored orcinol complex by a spectrophotometric method.

**Availability:** CPPA

---

**Title:** Testing of Pulp; Determination of Pentosan Content, Furfural Method

**Citation:** DIN 54361

**Content:**

**Availability:** DIN

---

**Title:** Testing Method for Pentosan in Pulpwood

**Citation:** JIS P 8011-1976

**Content:**

**Availability:** JIS

---

**Title:** Pentosans in Pulp

**Citation:** SCAN-C 4:61

**Content:** This method is suitable for all types of pulp.

The pentosans are determined by Tollens's method of heating the pulp sample with hydrochloric acid of a fixed concentration, thereby converting the pentosans into furfural, which is distilled off. In order to keep the concentration of the hydrochloric acid constant, the distillation is carried out in the presence of sodium chloride. The furfural formed is determined colorimetrically with orcinol.

**Availability:** SCAN

---

**Title:** Pentosans in Wood and Pulp

**Citation:** TAPPI T 223 cm-84

**Content:** This method for determination of pentosan content can be applied both to wood and to unbleached or bleached pulps.

## HEMICELLULOSE (STANDARDS)

In boiling 3.85-N hydrochloric acid, pentosans are transformed to furfural, which is collected in the distillate and determined colorimetrically with orcinol-ferric chloride reagent.

**Availability:** TAPPI

---

**Title:** Pentosans in Pulp

**Citation:** TAPPI Useful Method 236

**Content:** This method is based on volumetric determination of furfural by bromination and can be applied only to unbleached pulps with pentosan content higher than about 2%. TAPPI Standard T 223 (colorimetric) is more precise and accurate, and can be applied to wood and pulps over the entire range of pentosan content.

**Availability:** TAPPI

---

**Title:** Isolation and Separation of the  
Hemicelluloses

**Citation:** Chapter 26 in Browning, B. L.  
*Methods of Wood Chemistry*,  
Vol. 2. New York: Interscience  
Publishers, 1967.

**Content:** I. Nature of the Hemicelluloses;  
II. Isolation and Determination of the Hemi-  
celluloses; III. Extraction from Wood;  
IV. Extraction from Cellulose Preparations;  
V. Alkaline Solvents; VI. Extraction of Acetyl  
Hemicelluloses; VII. Fractionation and Puri-  
fication; VIII. Characterization of the Hemi-  
celluloses. See also Chapter 30, Deter-  
mination of Structure, and Chapter 31,  
Molecular Weight.

---



**Title:** Pulps: Determination of the Permanganate Number

**Citation:** NF T 12-007-87

**Content:**

**Availability:** AFNOR

---

**Title:** Pulps, Bleached Wood Pulp; Quantitative Determination of Matter Insoluble in Sulphuric Acid

**Citation:** NF T 12-010-87

**Content:**

**Availability:** AFNOR

---

**Title:** Cellulose: Raw Vegetable Matter: Quantitative Determination of Matter Insoluble in 72% Sulphuric Acid

**Citation:** NF T 12-014-61

**Content:**

**Availability:** AFNOR

---

**Title:** Cellulose: Degree of Delignification During Bleaching

**Citation:** NF T 12-019-87

**Content:**

**Availability:** AFNOR

---

**Title:** Lignin in Plants: Direct Method

**Citation:** AOAC 3.130 (Preparation of Sample)  
AOAC 3.131 (Apparatus)  
AOAC 3.132 (Reagent)  
AOAC 3.133 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Lignin in Plants: Indirect Method

**Citation:** AOAC 3.134

**Content:**

**Availability:** AOAC

---

**Title:** Fiber (Acid Detergent) and Lignin in Animal Feed

**Citation:** AOAC 7.074 (Reagents)  
AOAC 7.075 (Apparatus)  
AOAC 7.076 (Determination of Acid-Detergent Fiber)  
AOAC 7.077 (Determination of Lignin)

**Content:**

**Availability:** AOAC

---

**Title:** Methods of Test for Pulp and Paper (metric units); Halse Lignin in Wood and Pulp

**Citation:** AS 1301, P6rp:1978 and Appita P6rp-78

**Content:** The acid-insoluble lignin in wood or pulp is the fraction that remains undissolved after the material has been treated with concentrated mineral acid under prescribed conditions. Two methods are available for determining this property. The method described in this standard is the Halse procedure, in which the sample is treated with cold 38% hydrochloric acid and cold concentrated sulphuric acid. The other method is the Klason method which is described in Appita Standard P11.

**Availability:** Appita, SAA

---

**Title:** Klason Lignin in Wood and Pulp

**Citation:** Appita P11s:1978

**Content:** Lignin is the aromatic amorphous material found in the cell wall and middle lamella of a wood fiber. Its removal is the

## LIGNINS (STANDARDS)

main objective of chemical pulping and bleaching processes.

For the purpose of this standard, Klason lignin is defined as those components of wood or pulp which are insoluble after treatment with 72% *m/m* sulfuric acid followed by boiling in 3% sulfuric acid. This standard describes a method for determination of Klason lignin. The lignin content should not be less than 1% to provide a sufficient amount of lignin, about 20 mg for accurate weighing. It is not applicable to bleached pulps containing small amounts of lignin.

**Availability:** Appita

---

**Title:** Methods of Test for Pulp and Paper (metric units); Kappa Number of Pulp

**Citation:** AS 1301, P201m:1986 and Appita P201m-86

**Content:** This method provides an indirect measure of the relative bleachability or residual lignin content of pulp. It may be used for all types and grades of chemical and semichemical unbleached and semibleached wood pulps obtained in yields under 60%. The method may also be used as a laboratory control technique for well screened pulps obtained in higher yields up to 70%. It should be noted that reproducibility is less for high-yield pulps than for low-yield pulps.

**Availability:** Appita, SAA

---

**Title:** Standard Test Method for Acid-Insoluble Lignin in Wood<sup>1</sup>

**Citation:** ASTM D1106-84

**Content:** This test method covers the determination of the acid-insoluble lignin content of wood.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.14 on Chemical Tests.

---

**Title:** Method for Determination of the Kappa Number of Pulp (Degree of Delignification)

**Citation:** BS 4498:1982

**Content:** Specifies a method of determining the Kappa number of the pulp, which is an indication of the lignin content (hardness) or bleachability of the pulp.

**Availability:** BSI

---

**Title:** Acid-Insoluble Lignin in Wood

**Citation:** CPPA G.8

**Content:** This method is for the determination of acid-insoluble lignin in wood. The lignin determined by this method is also defined as "Klason lignin" or "sulfuric acid lignin."

**Availability:** CPPA

---

**Title:** Acid-Insoluble Lignin in Wood Pulp

**Citation:** CPPA G.9

**Content:** This method is for the determination of acid-insoluble lignin in unbleached pulp. The lignin determined by this method is also defined as "Klason lignin" or "sulfuric acid lignin."

**Availability:** CPPA

---

**Title:** Chlorine Number of Pulp

**Citation:** CPPA G.16

**Content:**

**Availability:** CPPA

---

**Title:** Permanganate Number of Pulp

**Citation:** CPPA G.17H

**Content:** This method is adapted to the determination of the relative "hardness" or bleachability of pulp. It may be used on all ordinary types and grades of chemical wood pulp (sulfite, soda, or sulfate) sampled in any condition of dryness and at any stage of processing.

The permanganate number is, by definition, the number of milliliters of tenth normal potassium permanganate solution (0.1 N  $\text{KMnO}_4$ ) which is absorbed by 1 g of oven-dry pulp under certain specified and carefully controlled conditions.

**Availability:** CPPA

---

**Title:** Kappa Number of Pulp

**Citation:** CPPA G.18

**Content:** The Kappa Number test is used for evaluation of pulps with regard to the degree of delignification and bleachability.

The method can be applied to pulps produced in yields up to about 65% and giving Kappa Numbers not higher than 100 on hardwood pulps and not higher than 120 on softwood pulps.

The Kappa Number is the number of milliliters of 0.02 M potassium permanganate consumed by 1 g of pulp corrected to an assumed 50% consumption using an empirical correction factor.

**Availability:** CPPA

---

**Title:** Testing of Pulp; Determination of the Kappa Number

**Citation:** DIN 54357

**Content:**

**Availability:** DIN

---

**Title:** Pulps--Determination of Kappa Number

**Citation:** ISO 302:1981

**Content:**

**Availability:** ISO

---

**Title:** Testing Method for Lignin in Wood for Pulp

**Citation:** JIS P 8008-1976 (1984)

**Content:**

**Availability:** JIS

---

**Title:** Methods of Test for Pulp and Paper (metric units)--Halse Lignin in Wood and Pulp

**Citation:** AS 1301, P6rp:1978

**Content:**

**Availability:** SAA

---

**Title:** Methods of Test for Pulp and Paper (metric units)--Klason Lignin in Wood and Pulp

**Citation:** AS 1301, P11s:1978

**Content:**

**Availability:** SAA, TAPPI

---

## LIGNINS (STANDARDS)

**Title:** Kappa Number

**Citation:** SCAN-C 1:77 R

**Content:** This standard specifies the method for determining the kappa number, which is used to describe the degree of delignification obtained in a chemical pulping process. However, it should be noted that there is no general and unambiguous relationship between the kappa number and the lignin content. This relation varies according to wood species and delignification procedure. This standard is applicable to all kinds of chemical and semichemical unbleached pulps within the kappa number range from 5 to 100. For pulps with a kappa number in the range from 1 to 5, a method for determining a modified kappa number is presented in Appendix C. For pulps with a kappa number over 100, use the chlorine consumption (SCAN-C 29) to describe the degree of delignification.

**Availability:** SCAN

---

**Title:** Chlorine Consumption of Pulp

**Citation:** SCAN-C 29:72

**Content:** The chlorine consumption of a pulp is the amount of active chlorine it consumes under the conditions specified in this method. It is expressed in grams of chlorine per 100 g of oven-dry pulp.

This method for determining the chlorine consumption of pulp is applicable to any type or grade of chemical, semichemical, unbleached or semibleached pulp.

**Availability:** SCAN

---

**Title:** Permanganate Number of Pulp (For Highly Lignified Pulps)

**Citation:** TAPPI Useful Method 201

**Content:**

**Availability:** TAPPI

---

**Title:** Permanganate Number of Pulp (Rapid Volumetric)

**Citation:** TAPPI Useful Method 228

**Content:**

**Availability:** TAPPI

---

**Title:** Permanganate Number of Pulp

**Citation:** TAPPI Useful Method 229

**Content:**

**Availability:** TAPPI

---

**Title:** Rapid Kappa Number

**Citation:** TAPPI Useful Method 245

**Content:**

**Availability:** TAPPI

---

**Title:** Micro Kappa Number

**Citation:** TAPPI Useful Method 246

**Content:**

**Availability:** TAPPI

---

**Title:** Acid-Soluble Lignin in Wood and Pulp

**Citation:** TAPPI Useful Method 250

**Content:** This method describes a procedure which can be applied to the determination of acid-soluble lignin in wood and pulp, supplementing the determination of acid-insoluble lignin described in T 222.

The sum of the acid-soluble lignin in percent, as determined by this method, and of the acid-insoluble lignin according to T 222, should represent the *total* lignin content in a wood or pulp sample.

**Availability:** TAPPI

---

**Title:** Permanganate Number of Pulp

**Citation:** TAPPI Useful Method 251

**Content:** This method provides for the determination of the relative "hardness" or bleachability of chemical pulps having lignin content below 6%.

**Availability:** TAPPI

---

**Title:** Acid-Insoluble Lignin in Wood and Pulp

**Citation:** TAPPI T 222 om-88

**Content:** This method describes a procedure which can be applied to the determination of acid-insoluble lignin in wood and in all grades of unbleached pulps. In semibleached pulp the lignin content should not be less than about 1% to provide a sufficient amount of lignin, about 20 mg, for an accurate weighing. The method is not applicable to bleached pulps containing only small amounts of lignin.

**Availability:** TAPPI

---

**Title:** Kappa Number of Pulp

**Citation:** TAPPI T 236 cm-85

**Content:** This method applies to the determination of the relative hardness, bleachability, or degree of delignification of pulp. It may be used for all types and grades of chemical and semichemical, unbleached and semibleached pulps obtained in yields under 60%. This method may also be used for pulps obtained in yields up to 70%, provided the pulp has been well screened.

**Availability:** TAPPI

---



**Title:** An Improved Acetyl Bromide Procedure for Determining Lignin in Woods and Wood Pulps

**Citation:** Iiyama, K. and A.F.F. Wallis. *Wood Sci. Technol.* 22:271-280 (1988).

**Content:** The acetyl bromide procedure for spectrophotometrically determining lignin in wood and wood pulp samples has been modified by adding perchloric acid to the digestion medium. This enables faster dissolution of the materials and the use of coarser samples. Subsequent treatment of the digestion mixtures with larger amounts of sodium hydroxide than those used in the conventional procedure has obviated the need for treatment with hydroxylamine. The modified method has been successfully applied to woodmeals and pulps from *Pinus radiata* and *Eucalyptus* species.

---

**Title:** Relationship Between Kappa Number and Lignin Content of Unscreened Straw Pulp

**Citation:** Oreopoulou, Vassiliki. *Cell. Chem. and Techn.* 22(1):53-57 (1988)

**Content:** The relationship between total lignin (acid-insoluble plus acid-soluble) and Kappa number of unscreened straw pulp was investigated. Straw was prehydrolyzed and then pulped by high-consistency chlorination, followed by alkaline extraction. A linear relationship was found to exist, having a constant slope (Kappa coefficient) independent of prehydrolysis and pulping conditions. The intercept of this relationship--expressing the lignin content of shives and knots of the unscreened pulp, which cannot be oxidized easily--varies with the prehydrolysis conditions, as the percentage of shives and knots in pulp seems to depend on these conditions.

---

**Title:** Lignin Analysis for the Industrial Practitioner

**Citation:** Glasser, W.G. Presented at the 194th American Chemical Society National Meeting. New Orleans, La., August 30-September 4, 1987.

**Content:** Much lignin research is motivated by the desire to improve the raw material value of biomass via the utilization of lignin in higher value products than fuel. Lignin candidates for use in structural materials need to be evaluated in terms of their chemical, molecular, and end-use characteristics. Suitable quantitative analysis techniques must become available as standard methods for employment by both potential lignin suppliers and lignin consumers. Analytical procedures must be rated in terms of information content, practicality, and cost-effectiveness. This paper reviews available lignin analysis techniques from the standpoint of the industrial practitioner. Attempts are presented which identify a series of methods capable of characterizing chemical, molecular, and network-formation properties as candidates for a standard lignin classification instrument.

---

**Title:** Estimation of Lignin in Wood Pulp by Diffuse Reflectance Fourier-Transform Infrared Spectrometry

**Citation:** Berben, Sally A., John P. Rademacher, Lowell O. Sell, and Dwight B. Easty. *Tappi Journal*, November 1987, p. 129.

**Content:** A method has been developed for estimating lignin in unbleached pulps using diffuse reflectance Fourier-transform infrared spectrometry. The procedure is based on linear relationships found to exist between the area of the 1510-cm<sup>-1</sup> infrared band, measured on diffuse reflectance difference spectra, and kappa number and Klason lignin.

## LIGNINS (LITERATURE)

These relationships, which serve as calibration lines for lignin estimation, apply to a range of hardwood and softwood pulps from high-yield and conventional kraft processes (1-20% lignin, 10-120 in kappa no.) and from the alkaline sulfite anthraquinone process. An unknown sample's 1510-cm<sup>-1</sup> band area is referenced against the calibration line to estimate its lignin content. This method is nondestructive, it requires no sample preparation other than drying, it employs no calculations, and it may be used on samples as small as 0.5 mg.

---

**Title:** Some Aspects of Lignin Characterization by High-Performance Size-Exclusion Chromatography Using Styrene Divinylbenzene Copolymer Gels

**Citation:** Chum, Helena L., David K. Johnson, Melvin P. Tucker, and Michael E. Himmel.  
*Holzforschung* 41(2):97-108 (1987).

**Content:** The molecular weight distributions (MWD) of alkaline-extracted steam-exploded aspen (*Populus tremuloides* L.) lignin and organosolv black cottonwood (*Populus trichocarpa* L.) lignin are compared with those of milled wood lignin from aspen. High-performance size-exclusion chromatography (HPSEC) of these acetylated lignins on styrene-divinylbenzene copolymer gels was investigated as a function of the organic solvent elution system from tetrahydrofuran to dimethylformamide (DMF) alone or in the presence of 0.1 M LiBr. In the mixed solvent and DMF the three types of lignin reported in this study displayed multimodal elution behavior indicative of associative phenomena. Addition of LiBr to DMF reduced the observed apparent associative behavior of the lignins. The interpretation of calibration standard elution in these solvent systems is discussed with reference to the behavior of polystyrenes, Igepal polymers, and lignin model compounds. Deconvolution of the elution profile of a lignin into acetylated monomers, dimers, and mixtures of trimers was performed.

---

**Title:** Rapid Determination of Lignocellulose by Diffuse Reflectance Fourier Transform Infrared Spectrometry

**Citation:** Schultz, Tor P., M. Curry Templeton, and Gary D. McGinnis.  
*Anal. Chem.* 57:2867-2869 (1985).

**Content:** Analysis of solid lignocellulose is a lengthy, multistep procedure. This study was initiated to determine if an FTIR procedure is feasible. Sweetgum and white oak were pretreated to obtain 26 samples with a wide range of compositions. FTIR spectra were collected by using a DRIFT cell. On the basis of the spectra of lignin, cellulose, and hardwood samples, 18 peaks in the 1600-700 cm<sup>-1</sup> region were selected. The absorbances at the selected peaks were first baseline corrected and then normalized by using nine internal peaks to give nine data sets of absorbance ratios. The lignin, glucose, and xylose contents, determined by conventional methods, were separately regressed against each data set using stepwise elimination regression. This procedure gave an equation for lignin (five variables, R<sup>2</sup> = 0.949), glucose (five variables, R<sup>2</sup> = 0.921), and xylose (three variables, R<sup>2</sup> = 0.973).

---

**Title:** Quantitative Structural Analysis of Lignin by Diffuse Reflectance Fourier Transform Infrared Spectrometry

**Citation:** Schultz, Tor P. and Wolfgang G. Glasser. *Holzforschung* 40:Suppl. 37-44 (1986).

**Content:** Empirical quantitative relationships were established between infrared (IR) spectral information and several structural features in lignins as determined by conventional methods. The structural composition of average phenylpropane (C<sub>9</sub>) units which significantly correlated (0.01 level) with IR peak intensities included methoxy content, aromatic hydrogen content, phenolic hydroxy content, guaiacyl/syringyl ratio, and "hydrolysis" and "condensation" ratios. The two latter ratios are quantitative expressions for

the degree of aryl-alkyl ether interunit linkages and for the content of carbon-carbon interunit bonds as measured by degradative permanganate oxidation analysis. Insignificant relationships were found for carbonyl, total hydroxy (acetylated lignins), and aliphatic hydroxy content (acetylated and nonacetylated). The IR spectra were collected using a diffuse reflectance infrared Fourier transform (DRIFT) cell. Absorbance values and peak areas were normalized using three peak intensities (1600, 1513, and 1425  $\text{cm}^{-1}$ ), and three peak areas (1636-1553, 1545-1482, and 1441-1404  $\text{cm}^{-1}$ ). Each normalized data set was regressed against the lignin structure data using stepwise regression. Of the different internal standards, the absorbance at 1600  $\text{cm}^{-1}$  generally gave a more accurate correlation than the other reference absorbances or areas. Spectra were also obtained by the KBr pellet technique. While the pellet cell had a higher throughput than the DRIFT cell, the pellet spectra also had ramping baselines and moisture-related noise.

**Title:**

**Citation:** Connors, W.J., S. Sarkannen, and J.L. McCarthy. *Holzforschung* 34:801 (1980).

**Content:****Title:**

**Citation:** Walsh, A.R. and A.G. Campbell. *Holzforschung* 40:263 (1986).

**Content:** Molecular weights and their distribution for lignins/carbohydrates.

**Title:** Lignin Analysis by Pyrolysis-GC-MS

**Citation:** Fullerton, Terry J. and Robert A. Franich. *Holzforschung* 37:267-269 (1983).

**Content:** Pyrolysis-gas chromatography-mass spectrometry (py-gc-ms) is a relatively new technique which has been demonstrated to be a useful aid in the characterization of

lignins, providing considerable information about the structure of lignins, including the ratio of guaiacyl to syringyl phenylpropane units they contain.

This note describes how the technique has been used to characterize lignins isolated by ethanol-water pulping and to compare these lignins with milled wood lignins (MWLs) from the same species.

**Title:**

**Citation:** Connors, W.J., S. Sarkannen, and J.L. McCarthy. *Holzforschung* 34:80-85 (1980).

**Content:** Molecular weight distribution of lignin.

**Title:**

**Citation:** Faix, O., W. Lange, and O. Beinhoff. *Holzforschung* 34:174-176 (1980).

**Content:** Molecular weight distribution of lignin.

**Title:**

**Citation:** Himmel, M.E., K.K. Oh, D.W. Sopher, and H.L. Chum. *J. Chrom.* 267:247-265 (1983).

**Content:** Molecular weight distribution of lignin.

**Title:**

**Citation:** Concin, R.E., E. Burtscher, and O. Bobleter. *Holzforschung* 35:3-9 (1981).

**Content:** Molecular weight distribution of lignin.

## LIGNINS (LITERATURE)

**Title:**

**Citation:** Van Zyl. *Wood Sci. Technol.* 12: 251 (1978).

**Content:** Determination of lignin by UV spectrophotometry of acetyl bromide-digested samples.

---

**Title:** Modified Procedure to Determine Acid-Insoluble Lignin in Wood and Pulp

**Citation:** Effland, Marilyn J. *Tappi* 60(10):143 (1977).

**Content:** If wood is treated with strong acid, carbohydrates are hydrolyzed and solubilized. The insoluble residue is by definition lignin and can be measured gravimetrically. The standard method of analysis requires samples of 1 or 2 g of wood or pulp. In research at this laboratory these amounts of sample are often not available for analytical determinations. Thus we developed a modification of the standard procedure suitable for much smaller sample amounts. The modification is based on the procedure of Saeman *et al.*

Wood samples require extraction prior to lignin analysis to remove acid-insoluble extractives that will be measured as lignin. Usually this involves only a standard extraction with ethanol-benzene. However, woods high in tannin must also be subjected to extraction with alcohol. Pulps seldom require extraction.

---

**Title:** Determination of Total Lignin and Polyphenol in Eucalypt Woods

**Citation:** Bland, D.E. and M. Menshun. *Appita* 25(2):110 (1971).

**Content:** It has been shown that the customary sulfuric acid determination of lignin in *Eucalyptus* wood does not include all the lignin but that an appreciable amount remains in the acid solution. Serious doubt has been cast on the validity of spectroscopic determination of lignin at 280 nm because of the effect of interfering substances. In this work reference compounds have been investigated and it has been found that the band at

206 nm is much less variable than that at 280 nm and much less influenced by the most likely interfering substance (furfural). Milled wood lignin has been used to determine the absorptivity of several eucalypt lignins. These do not obey Beer's Law but evidence is given that the absorptivity of milled wood lignin at infinite dilution is equal to the absorptivity of acid-soluble lignin. Although acid-soluble lignin itself does not obey Beer's Law precisely, it approximates to it so that over a certain range of absorption concentration can be calculated with sufficient accuracy for its estimation in connection with the acid-insoluble lignin determinations.

By determining the sulfuric acid-insoluble lignin values on the wood both before and after alkali extraction, the ultraviolet absorption of the filtrates from the above determinations, and the methoxyl contents of the sulphuric acid-insoluble lignins, estimates can be made of total lignin as acid-insoluble lignin plus acid-soluble lignin and total polyphenol in the same way.

---

**Title:** Isolation of Lignin Preparations

**Citation:** Chapter 32 in Browning, B.L. *Methods of Wood Chemistry*, Vol. 2. New York: Interscience Publishers, 1967.

**Content:** I. Materials and Methods; II. Isolation by Extraction; III. Isolation as a Residue; IV. Isolation as Derivatives.

---

**Title:** Investigation of Lignin Preparations

**Citation:** Chapter 33 in Browning, B.L. *Methods of Wood Chemistry*, Vol. 2. New York: Interscience Publishers, 1967.

**Content:** I. Elementary Composition; II. Absorption Spectra; III. Methoxyl Groups; IV. Methylation Techniques; V. Hydroxyl Groups.

---

**Title:** Determination of Lignin

**Citation:** Chapter 34 in Browning, B.L. *Methods of Wood Chemistry*, Vol. 2. New York: Interscience Publishers, 1967.

**Content:** I. Principles; II. Acid Hydrolysis Methods; III. Lignin in Pulps; IV. Indirect Methods for Lignins in Pulps; V. Lignin in Processing Liquors and Wastes; VI. Detection of Lignin.

---

**Title:** Pyrolysis Field Ionization Mass Spectrometry of Lignins, Soil Humic Compounds and Whole Soil

**Citation:** Haider, Konrad and Hans-Rolf Schulten. *Journal of Analytical and Applied Pyrolysis* 8:317-331 (1985).

**Content:** Pyrolysis, followed by field ionization mass spectrometry (FI-MS) of lignins, revealed a regular pattern of phenolic products related to the building blocks of these compounds. The signals were found to be related to dimers of the respective lignin alcohols in addition to their methylated derivatives. However, overlapping was observed in the signals from ionized subunits having the same mass numbers but different structures. Although lignins play an important role in the formation of terrestrial humic compounds, their thermal fragments, analysed by FI-MS, are largely different from those of lignins. Correlation with the chemical structure of lignins is only indicated by some phenol-related signals in the lower mass range ( $m/z$  90-160). These also became more obvious in hydrolyzed humic acids. The higher mass range from  $m/z$  300 to 350 showed a regular pattern of signals apparently indicating complex aliphatic hydrocarbon structures. Pyrolysates from typical soil humic acids also showed additional thermal fragments resulting from polysaccharides, which were even more prominent in pyrolysates from whole soil samples. The analysis of humic compounds by pyrolysis and FI-MS led to the conclusion that the compact phenolic framework of lignin becomes substantially altered and dispersed

during its transformation into humic compounds. These results are discussed together with recently obtained solid-state  $^{13}\text{C}$  NMR measurements on soil organic matter fractions. They are further compared with the results of studies of microbial attack on lignin, which were carried out by  $^{14}\text{C}$  NMR measurements of specifically  $^{13}\text{C}$ -enriched lignins after incubation with several ligninolytic organisms. A first direct isotopic determination of the subunits in the biotransformation product using pyrolysis in combination with soft ionization mass spectrometry confirmed the label content in the dehydropolymer-lignin.

---

**Title:** Quantitative Determination of Phenolic and Total Hydroxyl Groups in Lignins

**Citation:** Mansson, Per. *Holzforschung* 37:143-146 (1983).

**Content:** A rapid method has been developed for the determination of phenolic hydroxyl groups in lignins. The method comprises acetylation, selective aminolysis of the phenolic acetyl groups by pyrrolidine (aminolysis), and determination of the resulting 1-acetylpiperidine (I) by gas chromatography. A number of lignin model compounds and lignins have been studied by the method.

The total amount of hydroxyl groups in lignin was estimated by complete saponification (NaOH) of the acetylated sample followed by GC-determination of the liberated acetic acid as its benzyl ester.

---

**Title:** Qualitative and Quantitative Analysis of Solid Lignin Samples by Carbon-13 Nuclear Magnetic Resonance Spectrometry

**Citation:** Hatfield, Galen R., Gary E. Maciel, Oktay Erbatur, and Gaye Erbatur. *Anal. Chem.* 59:172-179 (1987).

**Content:** The solid lignin preparations from two common woods, red oak and lodgepole pine, have been methylated and acetylated in order to examine the relationships between

## LIGNINS (LITERATURE)

the  $^{13}\text{C}$  nuclear magnetic resonance chemical shift and molecular structure in solid lignin samples. Comparison of the untreated and chemically modified lignins results in a detailed set of chemical shift assignments, many of which directly reflect previously reported solution-state studies on model compounds and lignin extracts. The present study also demonstrates the ability of solid-state  $^{13}\text{C}$  cross polarization magic angle spinning nuclear magnetic resonance (CP/MAS NMR) spectrometry to identify many of the key functionalities in lignin and to probe lignin chemistry. Finally, the ability of  $^{13}\text{C}$  CP/MAS NMR spectrometry to yield quantitative results in lignin and wood spectra is discussed.

---

**Title:** Acid-Insoluble Lignin in Pulp--  
Standard Method

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Acid-Insoluble Lignin in Pulp--  
Modified Hydrolysis Method

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Acid-Insoluble Lignin in Wood--  
Standard Method

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Spectrophotometric Determination of  
Lignin in Small Wood Samples

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Acid-Insoluble Lignin in Wood--  
Modified Hydrolysis Method

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Important Reference Books

**Citation:** Brauns, F.E. *The Chemistry of  
Lignin*. New York: Academic  
Press, 1952.

Pearl, I.A. *The Chemistry of Lignin*,  
New York: M. Dekker, 1967.

Sarkanen, K.V. and C. Ludwig.  
*Lignins*. New York: Wiley  
Interscience, 1971.

Kirk, T.K., T. Higuchi, and H.M.  
Chang. *Lignin Biodegradation*.  
Vols. I-II, CRC Press, 1980.

**Content:**

---

**Title:** Alkali Solubility of Pulp

**Citation:** Appita P210m-69

**Content:**

**Availability:** Appita

---

**Title:** Solubility of Wood in Boiling Water

**Citation:** Appita P4m-61 (Revised 1981)

**Content:** This determination is a measure of the materials in wood (or pulp) which are soluble in boiling water. They may include tannins, kinos, colouring matter, sugars, free acids and free mineral matter. The values obtained are arbitrary because departures from the conditions laid down can cause more or less material to be extracted. Since hot water has a limited hydrolytic effect on wood which increases with time of extraction, some water soluble hydrolysis products are extracted along with the soluble material initially present.

**Availability:** Appita

---

**Title:** Alcohol Benzene Solubility of Wood

**Citation:** Appita P7m-70

**Content:**

**Availability:** Appita

---

**Title:** Ether Solubility of Wood

**Citation:** Appita P8m-59

**Content:**

**Availability:** Appita

---

**Title:** Organic Solvent Extractives in Wood and Pulp

**Citation:** Appita P12s-79, AS 1301

**Content:** This standard prescribes a method for the determination of those wood and pulp

materials which are soluble in organic solvents. They consist primarily of resin and fatty acids, their esters, waxes and unsaponifiable substances. No single solvent is capable of removing all of these substances and different solvents remove different combinations. Therefore, this standard leaves the choice of solvent open and the properties of various solvents need to be taken into consideration.

**Availability:** Appita, SAA

---

**Title:** Methods of Test for Pulp and Paper (metric units); Solubility of Wood in Boiling Tenth Molar Sodium Hydroxide

**Citation:** AS 1301, 005s-1967 and Appita P5m-68 (Revised 1981)

**Content:** This determination is a measure of the materials in wood which are soluble in boiling, dilute sodium hydroxide solution. They include tannins, kinos, coloring matter, some carbohydrate material, and some lignin.

**Availability:** Appita, SAA

---

**Title:** Standard Methods of Testing Tall Oil<sup>1</sup>

**Citation:** ASTM D 803-82 (1987)

**Content:** These methods cover the test procedures to be applied to whole tall oils or refined tall oils.

The procedures appear in the following order: Physical Tests - Viscosity: Brookfield Method (Preferred Method); Gardner-Holdt Method (Alternate Method); Pour Point; Flash Point Color; Moisture; Ash. Chemical Analysis - Acid Number: Potentiometric Method (Referee Method); Colorimetric Method (Alternate Method); Saponification Number: Potentiometric Method (Referee Method); Colorimetric Method (Alternate Method); Rosin Acids: Potentiometric Method (Referee Method); Modified Wolff Method; Qualitative Test for Rosin; Unsaponifiable Matter (Sterols, Higher Alcohols, etc.); Fatty Acids.

## EXTRACTIVES (STANDARDS)

**Availability:** ASTM

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and are the direct responsibility of Subcommittee D01.34 on Naval Stores.

---

**Title:** Standard Definitions of Terms Relating to Naval Stores and Related Products<sup>1</sup>

**Citation:** ASTM D 804-79 (1987)

**Content:**

**Availability:** ASTM

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and are the direct responsibility of Subcommittee D01.34 on Naval Stores.

---

**Title:** Standard Test Methods for Sampling and Testing Pine Tars and Pine-Tar Oils<sup>1</sup>

**Citation:** ASTM D 856-49 (1987)

**Content:** These test methods cover procedures for sampling and testing pine tars, both kiln and retort, and pine-tar oils, together with compounded tar products of naval stores origin.

**Availability:** ASTM

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and are the direct responsibility of Subcommittee D01.34 on Naval Stores.

---

**Title:** Standard Method for Preparation of Extractive-Free Wood<sup>1</sup>

**Citation:** ASTM D 1105-84

**Content:** This method covers the preparation of extractive-free wood and is applicable to

all North American woods. Extractives in wood consist of materials that are soluble in neutral solvents and that are not a part of the wood substance.

**Availability:** ASTM

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-7 on Wood.

---

**Title:** Standard Test Method for Alcohol-Benzene Solubility of Wood<sup>1</sup>

**Citation:** ASTM D 1107-84

**Content:** This test method covers the determination of the alcohol-benzene soluble content of wood, which is a measure of the waxes, fats, resins, and oils, plus tannins and certain other ether-insoluble components.

**Availability:** ASTM

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.14 on Chemical Tests.

---

**Title:** Standard Test Method for Dichloromethane Solubles in Wood<sup>1</sup>

**Citation:** ASTM D 1108-84

**Content:** This test method covers the determination of the dichloromethane soluble content of wood, which is a measure of the waxes, fats, resins, oils, and similar materials.

**Availability:** ASTM

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.14 on Chemical Tests.

---

**Title:** Standard Test Method for 1% Sodium Hydroxide Solubility of Wood<sup>1</sup>

**Citation:** ASTM D 1109-84

**Content:** This test method covers the determination of the solubility of wood in a hot dilute alkali solution. A 1% solution of sodium hydroxide (NaOH) is used. One application is in determining the degree of fungus decay that has taken place in a given wood sample.

**Availability:** ASTM

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.14 on Chemical Tests.

---

**Title:** Standard Test Methods for Water Solubility of Wood<sup>1</sup>

**Citation:** ASTM D 1110-84

**Content:** These test methods cover the determination of the water solubility of wood. Two methods are given: Method A, Cold-Water Solubility, provides a measure of the tannins, gums, sugars, and coloring matter in the wood. Method B, Hot-Water Solubility, provides a measure of the tannins, gums, sugars, coloring matter, and starches in the wood.

**Availability:** ASTM

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-7 on Wood and are the direct responsibility of Subcommittee D07.14 on Chemical Tests.

---

**Title:** Standard Test Method for Alcohol-Benzene Soluble Matter in Cellulose<sup>1</sup>

**Citation:** ASTM D 1794-62 (1985)

**Content:** This method covers the determination of alcohol-benzene soluble matter in celluloses and is applicable to dissolving-type cellulose pulps prepared from cotton or wood.

**Availability:** ASTM

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives.

---

**Title:** Standard Test Method for Dichloromethane-Soluble Matter in Cellulose<sup>1</sup>

**Citation:** ASTM D 3971-80 (1985)

**Content:** This method covers the determination of dichloromethane-soluble matter in cellulose and is applicable to dissolving-type cellulose pulps prepared from cotton or wood.

**Availability:** ASTM

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-23 on Cellulose and Cellulose Derivatives.

---

**Title:** Method for Determination of Alkali Solubility of Pulp

**Citation:** BS 4499:1984

**Content:** Specifies a method for determining the solubility of pulp in cold sodium hydroxide solutions of various and fixed concentrations.

**Availability:** BS I

---

**Title:** Hot and Cold Water Solubility of Wood and Pulp

**Citation:** CPPA G. 4 and G. 5

**Content:** This test method is used to determine the solubility of wood and pulp by hot and cold water extraction.

**Availability:** CPPA

---

## EXTRACTIVES (STANDARDS)

**Title:** One Percent Sodium Hydroxide Solubility of Wood and Pulp

**Citation:** CPPA G. 6 and G. 7

**Content:** This test is used to determine the solubility of wood and pulp in 1% sodium hydroxide solution.

An application is the determination of the degree of fungus decay that has taken place in wood. As the wood decays, the percentage of alkali-soluble material increases, and the pulp yield, as a result of the decay, decreases. The test is useful to indicate such yields only when applied to a composite sample representative of the wood supply.

**Availability:** CPPA

---

**Title:** Solvent Extractives in Pulp

**Citation:** CPPA G. 13

**Content:** This standard describes a method for determination of the amount of materials in pulp which are extractible with organic solvents. The solvent used is ethanol, dichloromethane or a mixture of ethanol and benzene.

This method may be applied to all types and grades of wood pulp.

The extractible substances in pulps are mainly resins, waxes, fatty acids and similar components of wood not removed in pulping and bleaching processes. Some of the material, especially those extractible with ethanol and dichloromethane, are responsible for pitch deposition in the papermaking process.

**Availability:** CPPA

---

**Title:** Pitch and Rosin in Paper

**Citation:** CPPA G. 14

**Content:**

**Availability:** CPPA

---

**Title:** Paraffin in Paper and Paperboard

**Citation:** CPPA G. 15

**Content:**

**Availability:** CPPA

---

**Title:** Solvent Extractives in Wood

**Citation:** CPPA G. 20

**Content:** This standard describes a method for determination of the amount of material in wood which is extractible with organic solvents. The solvent used is dichloromethane or a mixture of ethanol and benzene.

The extractives of wood are mainly resins, fats, waxes, tannins, and other similar materials.

**Availability:** CPPA

---

**Title:** Alkali Solubility of Pulp

**Citation:** CPPA G. 26

**Content:** This method for determination of the alkali solubility is applicable to bleached or delignified pulps.

**Availability:** CPPA

---

**Title:** Testing of Pulp; Determination of the Alkali Solubility of Pulp

**Citation:** DIN 54356

**Content:**

**Availability:** DIN

---

**Title:** Pulps: Determination of Alkali Solubility

**Citation:** ISO 692:1982

**Content:**

**Availability:** ISO

---

**Title:** Testing Method for Cold-Water Solubility of Pulpwood

**Citation:** JIS P 8004-1976

**Content:**

**Availability:** JIS

---

**Title:** Testing Method for Hot-Water Solubility of Pulpwood

**Citation:** JIS P 8005-1976 (1985)

**Content:**

**Availability:** JIS

---

**Title:** Testing Method for 1% Sodium Hydroxide Solubility of Pulpwood

**Citation:** JIS P 8006-1976 (1985)

**Content:**

**Availability:** JIS

---

**Title:** Testing Method for Ether Solubility of Wood for Pulp

**Citation:** JIS P 8009-1976 (1984)

**Content:** The ether soluble content contains wax, fat, resin, phytosterol, and nonvolatile hydrocarbon.

**Availability:** JIS

---

**Title:** Testing Method for Alcohol-Benzene

**Citation:** JIS P 8010-1976 (1984)

**Content:** The alcohol-benzene solubility herein described contains wax, fat, resin, and some kinds of ether-insoluble materials (wood rubber and parts of water soluble materials).

**Availability:** JIS

---

**Title:** Methods of Test for Pulp and Paper-- Solubility of Wood in Boiling Water

**Citation:** AS P4m-61

**Content:**

**Availability:** SAA

---

**Title:** Methods of Test for Pulp and Paper (Metric Units); Organic Solvent Extractives in Wood and Pulp

**Citation:** AS 1301, P12s-79

**Content:**

**Availability:** SAA

---

**Title:** Alkali Solubility of Pulp

**Citation:** SCAN-C 2:61

**Content:** This is a method for determining the cold alkali solubility of pulp in various and fixed concentrations of sodium hydroxide. The concentrations of sodium hydroxide most frequently used are 18% and 10%. Pulp is treated with sodium hydroxide solution and dissolved organic matter is oxidized with dichromate. Excess dichromate is determined volumetrically.

**Availability:** SCAN

---

**Title:** Dichloromethane Extract of Pulp

**Citation:** SCAN-C 7:62

**Content:** This method may be used for all kinds of chemical and semichemical pulp.

The pulp is extracted with dichloromethane in a Soxhlet apparatus. After at least 24 extraction cycles the solvent is evaporated and the residue is dried at a temperature of  $103^{\circ}\text{C} \pm 2^{\circ}\text{C}$  for 16 h and subsequently weighed.

**Availability:** SCAN

---

## EXTRACTIVES (STANDARDS)

**Title:** Ethanol Extract of Pulp

**Citation:** SCAN-C 8:62

**Content:** This method may be used for all kinds of chemical and semichemical pulp.

The pulp is extracted with ethanol in a Soxhlet apparatus. After at least 24 extraction cycles the solvent is evaporated and the residue is dried at a temperature of  $103^{\circ}\text{C} \pm 2^{\circ}\text{C}$  for 16 h and subsequently weighed.

**Availability:** SCAN

---

**Title:** Refractive Index of Tall Oil and Turpentine Oil

**Citation:** SCAN-T 1:65

**Content:** In this method the refractive index of a substance is defined as the ratio of the speed of light of a specified wavelength in air to the speed in the substance.

This method applies to distilled tall oil, tall oil fatty acids, tall light oil, and crude and distilled sulphate turpentine oil.

**Availability:** SCAN

---

**Title:** Density of Tall Oil and Turpentine Oil

**Citation:** SCAN-T 2:65

**Content:** This method applies to the determination of the density of crude and distilled tall oil, tall oil fatty acids, tall light oil, and crude and distilled sulphate turpentine oil.

The density of the sample is given by the difference between the weight loss of a glass plummet, submerged in the sample and the weight loss of the same plummet, when submerged in water.

**Availability:** SCAN

---

**Title:** Traces of Water in Distilled Tall Oil and Turpentine Oil

**Citation:** SCAN-T 3:66

**Content:** This is a method for determining traces of water, dissolved or not, present in distilled tall oil, tall oil fatty acids, tall light oil and distilled turpentine oil. It also applies to rosin or tall oil pitch and similar products, provided that they are soluble in the solvent mixture used for the determination and do not form dark solutions.

**Availability:** SCAN

---

**Title:** Ash in Tall Oil

**Citation:** SCAN-T 4:66

**Content:** The ash content of tall oil is defined as the weight of the residue after complete combustion at a temperature of  $625^{\circ}\text{C} \pm 25^{\circ}\text{C}$  under specified conditions and is expressed as a percentage of the weight of the moisture-free sample.

This method applies to crude and distilled tall oil, tall oil fatty acids, tall oil rosin, tall light oil and tall oil pitch.

**Availability:** SCAN

---

**Title:** Pour Point of Tall Oil

**Citation:** SCAN-T 5:67

**Content:** The pour point of a tall oil is the lowest temperature at which the oil will pour or flow when it is chilled under the conditions specified in this method.

This method applies to crude and distilled tall oil, tall oil fatty acids and tall light oil.

**Availability:** SCAN

---

**Title:** Flash and Fire Points of Tall Oil

**Citation:** SCAN-T 6:67

**Content:** The flash point of tall oil is the lowest temperature at which it will flash and its fire point is the lowest temperature at which it will burn for at least 5 s, the tests in both cases carried out as specified in this method.

This method applies to crude and distilled tall oil, tall oil fatty acids and tall light oil.

**Availability:** SCAN

---

**Title:** Water in Crude Tall Oil

**Citation:** SCAN-T 7:67

**Content:** The crude tall oil is distilled with xylene and the distillate collected in a graduated tube. After cooling to 20°C the volume of the water phase is read off.

**Availability:** SCAN

---

**Title:** Sampling of Crude Tall Oil

**Citation:** SCAN-T 8:68

**Content:** This sampling procedure relates to a sample, either single or one of a set, that, while being suitable for testing, still constitutes an average sample as regards composition and properties of the lot of crude tall oil from which it has been drawn.

Crude tall oil is often a heterogeneous mixture of two liquid phases, tall oil and water, and a solid phase, crystallized rosin. All three phases may contain flocculated lignin, which prevents their separation but allows the formation of two or more layers. Special care is therefore indicated in the sampling procedure.

**Availability:** SCAN

---

**Title:** Viscosity of Tall Oil

**Citation:** SCAN-T 9:68

**Content:** This method applies to distilled tall oil, tall light oil and tall oil fatty acids.

In a Hoeppler viscometer a glass or steel ball is allowed to fall a fixed distance in the inclined tube containing the sample. The time required is a measure of the viscosity.

**Availability:** SCAN

---

**Title:** Softening Point of Tall Oil Rosin and Pitch Determined with a Ring and Ball Apparatus

**Citation:** SCAN-T 10:69

**Content:** In this method the softening point is defined as the temperature at which a disk of the sample, held within a horizontal ring, is forced downwards a distance of 25.4 mm under the weight of a steel ball. The sample is heated at a prescribed rate in a water or glycerol bath.

This method applies to tall oil rosin and other resins derived from tall oil and turpentine oil. It also applies to tall oil pitch.

**Availability:** SCAN

---

**Title:** Acid Number of Tall Oil

**Citation:** SCAN-T 11:72

**Content:** The acid number of tall oil is the number of milligrammes of potassium hydroxide required to neutralize the free acids of one gramme of the oil.

This method applies to crude and distilled tall oil, tall oil rosin, tall oil fatty acids, tall light oil and tall oil pitch.

**Availability:** SCAN

---

## EXTRACTIVES (STANDARDS)

**Title:** Saponification Number of Tall Oil

**Citation:** SCAN-T 12:72

**Content:** The saponification number of tall oil is the number of milligrammes of potassium hydroxide required to saponify the esters present in one gramme of the oil.

This method applies to crude and distilled tall oil, tall oil rosin, tall oil fatty acids, tall light oil and tall oil pitch.

**Availability:** SCAN

---

**Title:** Unsaponifiable Matter in Tall Oil

**Citation:** SCAN-T 13:74

**Content:** In this standard unsaponifiable matter is defined as the substance that remains unsaponified when a sample of tall oil is treated with alkali as specified.

This standard applies in the first place to distilled tall oil and tall oil fatty acids. For other tall oil products, such as crude tall oil, tall oil rosin, tall oil pitch and tall light oil, the results of the determination may be less accurate.

**Availability:** SCAN

---

**Title:** Tall Oils Resin Acids

**Citation:** SCAN-T 14:78

**Content:** This SCAN-test Standard specifies a method for the determination of resin acids. It applies to crude and distilled tall oils, tall oil rosins, tall oil fatty acids, tall light oils and tall oil pitch.

**Availability:** SCAN

---

**Title:** Determination of Water-Soluble Acids in Crude Tall Oils

**Citation:** SCAN-T 15:78

**Content:** This SCAN-test Standard describes the determination of small amounts of

water-soluble acids, such as sulphuric acid, that may be present in crude tall oils. It is applicable to all kinds of crude tall oils except those containing considerable amounts of unsplit soap.

**Availability:** SCAN

---

**Title:** Distillation Yield--Crude Tall Oils

**Citation:** SCAN-T 16:82

**Content:** This SCAN-test Standard describes a distillation test applicable to crude tall oil. The results will give an idea of the possible yield of distillates in a tall oil fractionating plant using a vacuum distillation process at a working pressure of about 300-400 Pa or lower.

**Availability:** SCAN

---

**Title:** Water Solubility of Wood

**Citation:** TAPPI T 1 wd-75  
(Became part of T 207)

**Content:**

**Availability:** TAPPI

---

**Title:** Alcohol-Benzene and Dichloromethane Solubles in Wood and Pulp

**Citation:** TAPPI T 204 om-88

**Content:** This method describes a procedure for determining the amount of soluble material in wood and pulp in each of two different solvents, dichloromethane and a mixture of 1/3 ethanol and 2/3 benzene.

**Availability:** TAPPI

---

**Title:** Water Solubility of Wood and Pulp

**Citation:** TAPPI T 207 om-88

**Content:**

**Availability:** TAPPI

---

**Title:** Analysis of Crude Tall Oil

**Citation:** TAPPI T 689 om-88

**Content:** In the alkaline pulping processes using resinous woods, the rosin and fatty acids in the wood are saponified and dissolved in the spent liquor. As the black liquor is concentrated by evaporation, some of the organic acid soaps plus some unsaponifiable material become insoluble and may be skimmed from the surface of the liquor. Many alkaline pulp mills today have acidulation plants for converting these tall oil skimmings to crude tall oil; therefore, many mills market this product to chemical manufacturers.

**Availability:** TAPPI

---

**Title:** Analysis of Tall Oil Skimmings

**Citation:** TAPPI T 635 om-82

**Content:**

**Availability:** TAPPI

---

**Title:** Estimating Alcohol-Benzene  
Extractives Content in Wood  
Increment Cores by Cold-Soaking

**Citation:** TAPPI Useful Method 257

**Content:**

**Availability:** TAPPI

---



**Title:** Extraneous Components

**Citation:** Browning, B.L. *Methods of Wood Chemistry*. Vol. I, Part 2. New York: Interscience Publishers, 1967.

**Content:**

- Ch 5. Extraneous Components of Wood  
 6. Examination of Volatile Components  
 7. Examination of Components Soluble in Organic Solvents  
 8. Examination of the Fatty Acid Fraction  
 9. Examination of the Resin Acid Fraction  
 10. Tall Oil  
 11. The Unsaponifiable Substances  
 12. Phenolic Substances  
 13. Components Soluble in Water
- 

**Title:** Determination of the Resin Content of Wood from Softwoods

**Citation:** Nelson, P.J., P.I. Murphy, and F.C. James. *Appita* 30(6):503 (1977).

**Content:** For some purposes the petroleum solubles are a more useful measure of the resin content of softwoods than the ethanol/benzene solubles as obtained by Appita P7m-70. A sample of *P. radiata* wood was dried in four different ways to assess the effect of the procedures on the amount of resin extractable with petroleum. Freeze drying was the most satisfactory method followed by short term air drying, whereas oven drying and prolonged air drying resulted in marked reduction in the amounts of extractable resin.

---

**Title:** Feedstock Analyses: Extractives - Amount and Nature

**Citation:** Hillis, W. E. Private Communication as Member of Working Group. 3 pp. 1987.

**Content:** When the correct solvent is chosen, the gross amount of extractives (e.g., resins) can be useful in characterizing biomass for some purposes such as for heating. In other

cases this information alone is inadequate, as it does not indicate the full influence that extractives may have. Most extractives are mainly located in the penetration routes of the woody material where they are the first to react with the penetrating substances and reduce their effectiveness as pulping reagents, enzymic treatments and so on. Extractives can have an effect out of proportion with their gross amount. In addition, as pointed out by O. Theander, extractable materials formed during hydrolytic and heat treatments can also inhibit microbial and enzymatic processes and cause corrosion. The amounts and nature of extractives vary in all woody plants and within the one plant.

---

**Title:** Wood Extractives

**Citation:** Hillis, W. E. New York: Academic Press, 1962.

**Content:** Section A. Wood. Section B. Polyphenols in the tree. Section C. The biosynthesis of polyphenols. Section D. Tropolones, resins and fats. Section E. Influence on pulp and paper manufacture.

---

**Title:** Alcohol-Benzene Solubility of Wood and Pulp

**Citation:** Moore, Wayne E. and David B. Johnson. *Procedures for the Chemical Analysis of Wood and Wood Products* (As used at the U.S. Forest Products Laboratory.) Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Determination of Extractives in Wood

**Citation:** Moore, Wayne E. and David B. Johnson. *Procedures for the Chemical Analysis of Wood and Wood Products* (As used at the U.S. Forest Products Laboratory.) Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Preparation of Extractive Free Wood

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Standard Test Method for Methoxyl Groups in Wood and Related Materials<sup>1</sup>

**Citation:** ASTM D 1166-84

**Content:** This test method covers the determination of methoxyl groups in wood and related materials. The method is applicable to wood sawdust and, by suitable adjustment in size of the test specimen, to fractions isolated from wood and lignin.

**Availability:** ASTM

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.14 on Chemical Tests.

**Title:** Standard Test Methods for Carboxyl Content of Cellulose<sup>1</sup>

**Citation:** ASTM D 1926-63 (1985)

**Content:** These test methods cover the determination of the carboxyl content, or ion-exchange capacity, of cellulose from any source. Two methods are described, the sodium chloride-sodium bicarbonate method and the methylene blue method. The methods must be used within their limitations, and it must be recognized that there is no way of determining the accuracy of any method for the determination of carboxyl. The precision of the sodium chloride-sodium bicarbonate method is low in the lower range of carboxyl values. The methylene blue method can be used over the whole range of carboxyl values; it is especially useful in the low range. It is not applicable to the determination of carboxyl in soluble carbohydrate materials. Although these methods may be used to determine the ion-exchange capacity of unbleached pulps, the residual lignin will

cause an undetermined error, especially the sulfonic acid groups in unbleached sulfite pulps.

**Availability:** ASTM

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-223 on Cellulose and Cellulose Derivatives and are the direct responsibility of Subcommittee D23.20 on Cellulose.

**Title:** Testing Method for Methoxyl Groups in Pulpwood

**Citation:** JIS P 8013-1976

**Content:** This method is intended for determining methyl iodide, which is produced by decomposing methoxyl groups with hydroiodic acid, by making it absorbed in the acetic acid solution of potassium acetate containing bromine.

**Availability:** JIS

**Title:** Methoxyl Groups in Wood

**Citation:** TAPPI T 2 wd-72 (Withdrawn)

**Content:**

**Availability:** TAPPI

**Title:** Methoxyl Content of Pulp and Wood

**Citation:** TAPPI T 209 wd-79 (Withdrawn)

**Content:**

**Availability:** TAPPI

## FUNCTIONAL GROUPS AND COMPOUND CLASSES (STANDARDS)

**Title:** Carboxyl Content of Pulp

**Citation:** TAPPI T 237 om-88

**Content:** This method describes a procedure for the determination of the content of carboxyl groups in bleached and delignified pulps. Lignin and lignin degradation products, especially the sulfonic acid groups in sulfite pulps interfere with the determination of carboxyl, and the method is not applicable to unbleached and semi-bleached pulps.

Pulp is extracted (de-ashed) with dilute hydrochloric acid, washed, reacted with sodium bicarbonate-sodium chloride solution, and filtered. The filtrate is titrated with 0.01M hydrochloric acid to methyl red end point.

**Availability:** TAPPI

---

**Title:** Determination of Acetyl and Methoxyl Groups

**Citation:** Browning, B. L. Chapter 29 in *Methods of Wood Chemistry*. Vol. II. New York: Interscience Publishers, 1967.

**Content:**

---

**Title:** Uronic Acids

**Citation:** Browning, B. L. Chapter 28 in *Methods of Wood Chemistry*. Vol. II. New York: Interscience Publishers, 1967.

**Content:**

---

**Title:** New Method for Quantitative Determination of Uronic Acids

**Citation:** Blumenkrantz, Nelly and Gustav Asboe-Hansen. *Analytical Biochemistry* 54:481-489 (1973).

**Content:** A new method for determination of uronic acids with meta-hydroxy-diphenyl is introduced. It is simpler, quicker, more sensitive, and more specific than other methods, and it needs lesser amounts of fluid. It is recommended for determination of acid mucopolysaccharides in biological materials.

---

**Title:** Uronic Acids

**Citation:** Bylund and Donetzhuber. *Svensk Papperstidning*, 71(15):505 (1978).

**Content:** Uronic acid analysis

---

**Title:** Colorimetric Determination of Hexuronic Acids in Plant Materials

**Citation:** Scott, Ralph W. *Analytical Chemistry* 51(7):936 (1977).

**Content:** A colorimetric reagent, 3-5-dimethylphenol, is selective for 5-formyl-2-furancarboxylic acid, a chromogen formed

from uronic acids in concentrated H<sub>2</sub>SO<sub>4</sub> at 70°C. Addition of the reagent of 20°C produces within 10 min, a chromophore absorbing at 450 nm. Selectivity is critical because of interferences from neutral sugar products and lignin when uronic acids are at 1%-3% levels. D-galacturonic and 4-O-methyl-D-glucuronic acids could be measured separately from D-glucuronic acid, by adding H<sub>2</sub>BO<sub>3</sub>. About 12% more chromogen was produced from D-galacturonic and 4-O-methyl-D-glucuronic acids of polymers than from the monomers. Analyses of wood containing 3% uronic anhydride gave 0.5 standard deviation per measurement. The time for dissolution, reaction, and color formation is 30 min for fast reactors, 60 min for glucuronic acid.

---

**Title:** Acetyl

**Citation:** Mansson. *Svensk Papperstidning* 84(3):R15 (1981).

**Content:** Acetyl content measurement

---

**Title:** Comparison of a Gravimetric CO<sub>2</sub> Method for Uronic Anhydride with a Colorimetric Method

**Citation:** Scott, Ralph W., Kimball A. Libkie, and Edward L. Springer. *J. of Wood Chemistry* 4(4):497-504 (1984).

**Content:** Colorimetry gave consistently lower uronic anhydride values for four species of wood than did measurement by evolved CO<sub>2</sub>. These differences were partly related to CO<sub>2</sub> evolution from nonuronide wood extractives, and partly to CO<sub>2</sub> from nonuronide carbohydrates or lignin. After the usual benzene-ethanol extraction to remove interfering extractives, the uronic anhydride contents by gravimetric CO<sub>2</sub> analyses were still 30% to 40% higher than those by colorimetry. Based upon the greater selectivity of the colorimetric method, the authors conclude that colorimetry provides the more accurate uronic anhydride analyses of natural materials.

---

## FUNCTIONAL GROUPS AND COMPOUND CLASSES (LITERATURE)

**Title:** Determination of Sugar Alcohols,  
Glycerol and Glycols

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Determination of Furfural

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Determination of Lactic Acid

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Determination of Levulinic Acid

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Determination of Itaconic Acid

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Determination of Uronic Acids  
(Polyuronide Carboxyl)

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Determination of Acetyl and C-  
Methyl Groups

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Determination of Alkoxy Groups

**Citation:** Moore, Wayne E. and  
David B. Johnson. *Procedures for  
the Chemical Analysis of Wood and  
Wood Products* (As used at the U.S.  
Forest Products Laboratory.)  
Revised Dec. 1967. (Unpublished.)

**Content:**  

---

---

**Title:** Sugars in Plants (1) Preparation of Sample

**Citation:** AOAC 3.112

**Content:**

**Availability:** AOAC

---

**Title:** Glucose in Plants: Micro Method

**Citation:** AOAC 3.115

**Content:**

**Availability:** AOAC

---

**Title:** Fructose in Plants: Somogyi Micro or Munson-Walker Method

**Citation:** AOAC 3.116

**Content:**

**Availability:** AOAC

---

**Title:** Sugars (Reducing) in Plants: Munson-Walker General Method

**Citation:** AOAC 3.118

**Content:**

**Availability:** AOAC

---

**Title:** Sugars (Reducing) in Plants: Quisumbing-Thomas Method

**Citation:** AOAC 3.119

**Content:**

**Availability:** AOAC

---

**Title:** Sucrose in Plants

**Citation:** AOAC 3.120

**Content:**

**Availability:** AOAC

---

**Title:** Ether Extract of Plants: Gravimetric Method

**Citation:** AOAC 3.122

**Content:**

**Availability:** AOAC

---

**Title:** Starch in Plants: Titrimetric Method

**Citation:** AOAC 3.128

**Content:**

**Availability:** AOAC

---

**Title:** Sugars (Total) in Animal Feed: Modified Fehling Solution Method

**Citation:** AOAC 7.078

**Content:**

**Availability:** AOAC

---

**Title:** Sucrose in Animal Feed

**Citation:** AOAC 7.084

**Content:**

**Availability:** AOAC

---

**Title:** Starch in Animal Feed

**Citation:** AOAC 7.085

**Content:**

**Availability:** AOAC

---

## SUGARS AND OTHER CARBOHYDRATES (STANDARDS)

**Title:** Galactan in Animal Feed

**Citation:** AOAC 7.091

**Contents:**

**Availability:** AOAC

---

**Title:** Dry Matter Content - Starch

**Citation:** SCAN-P 52:84

**Contents:**

**Availability:** SCAN

---

**Title:** Carbohydrate Composition of  
Extractive-Free Wood and Wood Pulp  
by Gas-Liquid Chromatography

**Citation:** TAPPI T 249 cm-85

**Content:** This method is used to determine the five principal monosaccharides which define the carbohydrate composition of wood and wood pulp. The constituents determined quantitatively and on an absolute basis are glucan, mannan, arabinan, xylan, and galactan. Concentrations of the individual components as low as 0.1% can be determined. The method is applicable to extractive-free wood as well as to wood pulp.

**Availability:** TAPPI

---

**Title:** Chromatographic Analysis of Purified Pulp

**Citation:** TAPPI T 250 cm-85

**Content:** This method is designed for the rapid and routine analysis of the carbohydrate constituents of chemically refined pulps. It is based on a chemical determination of the chromatographically separated sugars derived from such materials.

Quantitative paper chromatographic analysis of polysaccharides involves the following sequence of procedures: Total Hydrolysis, Neutralization, Concentration, Chromatographic separation, Elution, Analysis of Separated Sugars, and Calibration and Calculation.

**Availability:** TAPPI

---

**Title:** Analysis of Starch and Starch Products

**Citation:** TAPPI T 638 cm-85

**Contents:**

**Availability:** TAPPI

---

**Title:** Determination of Carbohydrates Using Pulsed Amperometric Detection Combined with Anion Exchange Separations

**Citation:** Edwards, William T., Christopher A. Pohl, and Richard Rubin. *Tappi Journal* 70(6) (June 1987).

**Content:** Carbohydrates, including the monosaccharides commonly found in wood and wood pulp hydrolyzates, are separated by anion exchange chromatography using hydroxide and acetate eluants and are determined using pulsed amperometric detection. The detection method is based on oxidizing the sugars in a flow-through electrochemical cell equipped with a gold working electrode. A repeating cycle of three potentials is used: the first to oxidize the carbohydrates and measure the current generated, and two subsequent pulses to clean the electrode surface of oxidation products. The method is fast, sensitive, and requires no precolumn derivatation. It is applied to a sample of hydrolyzed wood pulp, which can be analyzed after minimal sample preparation. Detection limits are on the order of 1 mg/kg for monosaccharides in a 50  $\mu$ L injection.

---

**Title:** Carbohydrate Analysis: A Practical Approach

**Citation:** Edited by M. F. Chaplin and J. F. Kennedy. Oxford, Washington, DC: IRL Press, 1986.

**Content:**  
Chapter 1-Monosaccharides;  
Chapter 2-Oligosaccharides;  
Chapter 3-Neutral Polysaccharides;  
Chapter 4-Proteoglycans;  
Chapter 5-Glycoproteins;  
Chapter 6-Glycolipids.

---

**Title:** Simple Pentose Assay for Biomass Conversion Studies

**Citation:** Deschatelets, L. and E. K. C. Yu. *Applied Microbiology and Biotechnology* 24(5):379-385 (1986).

**Content:** A colorimetric method was modified for monitoring pentose release and utilization in the hydrolysis and fermentation of biomass substrates to fuels and chemicals. The proposed assay was specific for pentose monomers. Quantitation of pentoses by the assay method was not significantly interfered by other lignocellulosic components, common fermentation medium ingredients, and major volatile fermentation products encountered in biomass conversion processes. The assay procedure did not require sample pretreatment (e.g., deproteinization, desalting, or furfural extraction). Sugar estimation basing on the present assay correlated well with conventional sugar analysis by high performance liquid chromatography.

---

**Title:** Determination of Neutral Sugars in Plankton, Sediments, and Wood by Capillary Gas Chromatography of Equilibrated Isomeric Mixtures

**Citation:** Cowie, Gregory L. and John I. Hedges. *Anal. Chem.* 56:497-504 (1984).

**Content:** A reproducible technique is described for extraction and quantitative analysis of neutral monosaccharides from a variety of solid natural sample types, requiring as little as 10 mg of total organic matter. Acid hydrolysis yields monomeric sugars which may exist in up to five isomeric forms when in solution. Lithium perchlorate is used to catalytically equilibrate sugar isomer mixtures in pyridine prior to conversion to their trimethylsilyl ether derivatives. Analysis is carried out by use of gas-liquid chromatography on fused-silica capillary columns. Quantification on the basis of a single clearly resolved peak for each sugar is made possible by the equilibration step. Sugar losses and optimal conditions for maximum reproducible sugar recovery are determined for each extraction stage.

---

## SUGARS AND OTHER CARBOHYDRATES (LITERATURE)

**Title:** An Analysis of the Wood Sugar Assay Using HPLC: A Comparison with Paper Chromatography

**Citation:** Pettersen, Roger C., Virgil H. Schwandt, and Marilyn J. Effland. *J. of Chromatographic Science* 22:478 (1984).

**Content:** Fundamental chemical research concerning wood and wood-derived products depends on a knowledge of the materials' carbohydrate composition. Separation and quantitation of hydrolyzed carbohydrate components of woods and wood pulps by high performance liquid chromatography is fast and efficient. Sugars are separated with a lead(II)-loaded Aminex cation-exchange resin. In this study, six woods and four pulps were analyzed three times by liquid and paper chromatography (LC and PC). Statistical analysis at the 95% confidence level indicates the two methods are equally accurate for glucan, mannan, and galactan. There is a statistical difference for xylan and arabinan at 95% confidence. The LC precision is better than PC precision for glucan and xylan. The precision is equivalent for arabinan and mannan but not as good for galactan. The differential refractive index detector on the LC is linear up to a loading of 2 mg of glucose. The optimum column operating temperature is 45°-55°C.

---

**Title:** Determination of Soluble and Insoluble Pentoses in the Presence of Glucose

**Citation:** Holtzapple, Mark T. and Arthur E. Humphrey. *Tappi Journal* 66(8):90 (1983).

**Content:** Numerous reagents have been developed for colorimetric measurement of pentoses, including aniline, L-cysteine, phloroglucinol, and orcinol. The use of orcinol reagent is desirable because it is simple to prepare and the colorimetric reaction is easily employed. The orcinol reacts with furfural--which results from the acid degradation of both soluble and insoluble pentoses--to form a green chromogen. The orcinol also reacts with hydroxymethyl

furfural--which results from the acid degradation of hexoses--to form a brown-green chromogen. The difference in color between the pentose and hexose chromogens may be exploited to correct for the hexose interference.

---

**Title:** Determination of Soluble and Insoluble Glucose Oligomers with Chromotropic Acid

**Citation:** Holtzapple, Mark T. and Arthur E. Humphrey. *Analytical Chemistry* 55:584 (1983).

**Content:**

---

**Title:** Determination of Carbohydrates by Anion Exchange Chromatography with Pulsed Amperometric Detection

**Citation:** Rocklin, Roy D. and Christopher A. Pohl. *J. of Liquid Chromatography* 6(9):1577-1590 (1983).

**Content:** Carbohydrates such as sugar alcohols, monosaccharides, disaccharides, and other oligosaccharides are separated as anions by ion exchange chromatography with a sodium hydroxide eluent. Retention time and selectivity are controlled by varying eluent strength and column temperature. The carbohydrates are detected by oxidation at a gold electrode. A repeating sequence of three potentials electrochemically cleans the electrode surface of oxidation products and other interfering species. Detection limits are as low as 30 ppb for sugar alcohols and monosaccharides, and about 100 ppb for oligosaccharides. Other species containing CHOH groups can also be detected, such as alcohols and glycols.

---

**Title:** A Simple and Rapid Preparation of Alditol Acetates for Monosaccharide Analysis

**Citation:** Blakeney, Anthony B., Philip J. Harris, Robert J. Henry, and Bruce A. Stone. *Carbohydrate Research* 113:291-299 (1983).

**Content:** A simple and rapid method is described for the preparation of alditol acetates from monosaccharides. It can be performed in a single tube without transfers or evaporations. Monosaccharides are reduced with sodium borohydride in dimethyl sulphoxide and the resulting alditols acetylated using 1-methylimidazole as the catalyst. Removal of borate is unnecessary and acetylation is complete in 10 min at room temperature. Monosaccharides are quantitatively reduced and acetylated by this procedure. The alditol acetates are completely separated by glass-capillary, gas-liquid chromatography on Silar 10C. The method has been applied to the analysis of monosaccharides in acid hydrolysates of a plant cell-wall.

---

**Title:** Polysaccharides

**Citation:** Vol. 1. Edited by Gerald O. Aspinall. New York: Academic Press, 1982.

**Content:**

---

**Title:** Polysaccharides

**Citation:** Vol. 2. Edited by Gerald O. Aspinall. New York: Academic Press, 1983.

**Content:**

---

**Title:** Methods in Carbohydrate Chemistry

**Citation:** Edited by Roy L. Whistler and James N. BeMiller. New York: Academic Press, 1980.

**Content:** Volume I: Analysis and Preparation of Sugars, Volume II: Reactions of Carbohydrates, Volume III: Cellulose, Volume IV: Starch, Volume V: General Polysaccharides, Volume VI: General Carbohydrate Methods, Volume VII: General Methods, Glycosaminoglycans, and Glycoproteins, Volume VIII: General Methods.

---

**Title:** Analysis of Wood Sugars in Pulp and Paper Industry Samples by HPLC

**Citation:** Wentz, Frank E., A. Dale Marcy, and Michael J. Gray. *Journal of Chromatographic Science* 20:349 (1982).

**Content:** A high performance liquid chromatography (HPLC) method has been developed for analysis of wood sugars in samples from the pulp and paper industry. Using a Bio-Rad HPX-87P carbohydrate analysis column, it is possible to separate the sugars using isocratic elution with distilled water. Glucose, mannose, and xylose in 100:1:1 ratio, occurring in a pulp hydrolyzate, can be separated in 20 min. Using two columns in series, a separation of free glucose, mannose, galactose, arabinose, and xylose, present in very unequal proportions in spent sulfite liquor, can be done in 60 min.

---

**Title:** A Rapid Analysis for Total Carbohydrate in Wood or Pulp: Dehydrating to Furans in Concentrated Sulfuric Acid

**Citation:** Scott, Ralph W. and Jesse Green. *Tappi* 55(7):1061 (1972).

**Content:** A dehydration method of measuring total carbohydrate in wood or pulp, particularly adapted to glucose and xylose polymers, is described and compared to a reducing sugar method. Losses are usually smaller and less time is required than by the

## SUGARS AND OTHER CARBOHYDRATES (LITERATURE)

reducing sugar method. In the dehydration method, total carbohydrate of wood or pulp samples can be analyzed by dissolving samples in 72% sulfuric acid, reacting the diluted solution with about 95% sulfuric acid, and finally measuring the quantity of dehydration products spectrophotometrically.

---

**Title:** Determination of Pectic Substances in Plant Material

**Citation:** Dekker, R. F. H. and G. N. Richards. *J. Sci. Fd. Agric.* 23:475-483 (1972).

**Content:** Pectic substances have been extracted from plant material (a pasture legume, *Stylosanthes humilis*) by homogenisation with a solution of ammonium oxalate and oxalic acid and subsequently hydrolysed with polygalacturonase. The galacturonic acid produced was determined by a modified carbazole reaction. The enzymic hydrolysis step may be omitted by relying on the acid in the carbazole reaction partially to hydrolyse the pectic substances, but in doing so the sensitivity of the method is reduced sevenfold. Attempts to carry out the hydrolysis carbazole reaction partially to hydrolyse the pectic substances, but in doing so the sensitivity of the method is reduced sevenfold. Attempts to carry out the hydrolysis with sulphuric acid before the carbazole reaction gave incomplete hydrolysis and probably decarboxylation. Attempts to extract the pectic substances with alkali gave low values, probably because of incomplete extraction.

---

**Title:** Determination of Starch in Plant Material

**Citation:** Dekker, R. F. H. and G. N. Richards. *J. Sci. Fd. Agric.* Vol. 22 (1971).

**Content:** Starch has been determined in the pasture legume *Stylosanthes humilis* (Stylo) by hydrolysis and amyloglucosidase and subsequent analysis for glucose with glucose oxidase. Prior gelatinisation of starch granules within the plant sample by water at

130°C gave low values and it was concluded that the complete solubilisation of starch by alkali was necessary, with subsequent neutralisation of the extract with acetic acid. It was shown that the alkali also extracted material which inhibited one or more of the enzymes involved in the subsequent glucose analysis, but this inhibition was removed by treatment of the extract with charcoal. Under the above conditions the high acetate concentration decreased the efficiency of the final glucose analysis, but this effect was readily corrected by use of appropriate blank solutions. The proposed method of starch analysis is relatively economical in time compared with previous methods and is believed to give more meaningful values for plants with low starch content.

---

**Title:** Carbohydrates Chemistry: Monosaccharides and Their Oligomers

**Citation:** Hassan, S. and S. E. Khadem. San Diego, CA: Academic Press, 1988.

**Content:**

---

**Title:** Carbohydrate Chemistry

**Citation:** Williams, N.R., et al. Vol. 19. Part I: Monosaccharides, Disaccharides, and Specific Oligosaccharides. Letchworth, England: Royal Society of Chemistry, 1987.

**Content:**

---

**Title:** A Gas Chromatographic Method for Carbohydrates as Alditol-Acetates

**Citation:** Borchardt, Leroy G. and Carl V. Piper. *Tappi* 53(2):257 (1970).

**Content:** A gas chromatographic procedure is described which permits multiple analyses of monosaccharides in wood pulps to be carried out in a working time of 2-3 hr per sample. A single pulp analysis may be

completed in an 8-hr day. For the analysis, the monosaccharides present in a hydrolyzed sample are reduced to the alditols with sodium borohydride. Acetylation with acetic anhydride and sulfuric acid permits this step to be completed in a period of 1 hr. The acetylated mixture is precipitated in ice water and extracted with methylene chloride for injection into the chromatograph. Precision of the method is comparable to that obtained by paper chromatography and the sensitivity is increased significantly.

---

**Title:** The Reaction of Carbazole with Carbohydrates

**Citation:** Galambos, John T. *Analytical Biochemistry* 19:119-132 (1967).

**Content:** Experiments were performed to study the kinetics of the carbazole reaction with hexoses and with compounds containing hexuronic acid at various temperatures and to evaluate the effect of borate and sulfamate on the sensitivity and specificity of the carbazole reaction with hexuronic acids and glycosaminoglycans.

---

**Title:** Determination of Sugars

**Citation:** Chapter 27 in Browning, B. L. *Methods of Wood Chemistry*, Vol II. New York: Interscience Publishers, 1967.

**Content:**

---

**Title:** Use of Dinitrosalicylic Acid Reagent for Determination of Reducing Sugar

**Citation:** Miller, Gail Lorenz. *Analytical Chemistry* 31(3):26 (1959).

**Content:** Rochelle salt, normally present in the dinitrosalicylic acid reagent for reducing sugar, interferes with the protective action of the sulfite but is essential to color stability. The difficulty may be resolved either by eliminating Rochelle salt from the reagent and adding it to the mixture of reducing sugar and reagent after the color is

developed, or by adding known amounts of glucose to the samples of reducing sugar to compensate for the losses sustained in the presence of the Rochelle salt. The optimal composition of a modified dinitrosalicylic acid reagent is given.

---

**Title:** Colorimetric Method for Determination of Sugars and Related Substances

**Citation:** Dubois, Michel, K. A. Gilles, J. K. Hamilton, P. A. Rebers, and Fred Smith. *Analytical Chemistry* 28(3):350 (1956).

**Content:** Simple sugars, oligosaccharides, polysaccharides, and their derivatives, including the methyl ethers with free or potentially free reducing groups, give an orange-yellow color when treated with phenol and concentrated sulfuric acid. The reaction is sensitive and the color is stable. By use of this phenol-sulfuric acid reaction, a method has been developed to determine sub-micro amounts of sugars and related substances. In conjunction with paper partition chromatography the method is useful for the determination of the composition of polysaccharides and their methyl derivatives.

---

**Title:** A Photometric Adaptation of the Somogyi Method for the Determination of Glucose

**Citation:** Nelson, Norton. *J. Biological Chemistry* 153:375-380 (1944).

**Content:** A photometric method is described for the estimation of glucose (or reduction equivalent) with copper reagents and an arsenomolybdate reagent. The optical density of the color developed is proportional to the glucose taken and is stable over long periods of time.

---

## SUGARS AND OTHER CARBOHYDRATES (LITERATURE)

**Title:** Important Reference Books

**Citation:** Guthrie, R. D. and J. Honeyman. *An Introduction to the Chemistry of Carbohydrates*, 3rd edition, Oxford: Clarendon Press, 1968.

Pigman, W. and D. Horton. *The Carbohydrates*, New York: Academic Press, 1970.

**Content:**

---

**Title:** Determination of Wood Sugars

**Citation:** Moore, Wayne E. and David B. Johnson. *Procedures for the Chemical Analysis of Wood and Wood Products* (As used at the U.S. Forest Products Laboratory.) Revised Dec. 1967. (Unpublished.)

**Content:**

---

**Title:** Nitrogen (Total) (Crude Protein) in  
Plants: Kjeldahl Method for Nitrate-  
free Samples

**Citation:** AOAC 3.124

**Content:**

**Availability:** AOAC

---

**Title:** Nitrogen (Total) (Crude Protein) in  
Plants: Kjeldahl Method for Nitrate-  
containing Samples

**Citation:** AOAC 3.125

**Content:**

**Availability:** AOAC

---

**Title:** Nitrogen (Total) (Crude Protein) in  
Plants: Automated Method

**Citation:** AOAC 3.126

**Content:**

**Availability:** AOAC

---

**Title:** Nitrogen (Total) (Crude Protein) in  
Plants: Semiautomated Method

**Citation:** AOAC 3.127

**Content:**

**Availability:** AOAC

---

**Title:** Protein in Animal Feed: Qualitative  
Tests

**Citation:** AOAC 7.010

**Content:**

**Availability:** AOAC

---

**Title:** Protein (Crude) in Animal Feed:  
Kjeldahl Method

**Citation:** AOAC 7.015

**Content:**

**Availability:** AOAC

---

**Title:** Protein (Crude) in Animal Feed:  
Dumas Method

**Citation:** AOAC 7.016

**Content:**

**Availability:** AOAC

---

**Title:** Protein (Crude) in Animal Feed:  
Automated Kjeldahl Method

**Citation:** AOAC 7.021

**Content:**

**Availability:** AOAC

---

**Title:** Protein (Crude) in Animal Feed:  
Semiautomated Method

**Citation:** AOAC 7.025

**Content:**

**Availability:** AOAC

---

**Title:** Protein (Crude) in Animal Feed:  
Copper Catalyst Kjeldahl Method

**Citation:** AOAC 7.033

**Content:**

**Availability:** AOAC

---



**Title:** Accuracy in Kjeldahl Protein Analysis

**Citation:** Chen, Y.-S., S. V. Brayton, and C. C. Hach. *American Laboratory* 20(6):62 (1988).

**Content:**

---

**Title:** Fiftyfold Amplification of the Lowry Protein Assay

**Citation:** Sargent, Michael G. *Analytical Biochemistry* 163:476-481 (1987).

**Content:** The blue product of the Lowry *et al.* (1951, *J. Biol. Chem.* 193, 265-275) reaction interacts with malachite green (MG), inducing a change in the visible light spectrum. At  $A_{690\text{ nm}}$  the absorbance of malachite green solutions increases 10-fold in the presence of Lowry blue (LB). Under the optimum conditions, 0.01  $A_{700\text{ nm}}$  unit of Lowry blue produces a change in  $A_{690\text{ nm}}$  unit of malachite green of 0.5 and the  $\Delta A_{690\text{ nm}}$  is a linear function of Lowry blue concentration. Conditions under which this 50-fold amplification can be exploited to detect less than 100 ng of protein (or  $4\ \mu\text{g}\cdot\text{mF}^{-1}$ ) are described. A number of chemicals including sodium dodecyl sulfate can interfere with the assay but a strategy has been devised to overcome these problems. Amplification of the Lowry assay appears to involve a cooperative interaction between malachite green and the Lowry blue product such that about 23 molecules of malachite green undergo a spectral shift per molecule of a model reactant such as tyrosine. Malachite green can be used to amplify the molybdenum blue signal obtained in other assays. Less than 10 pmol of tyrosine can be detected using this procedure. Lowry blue also interacts with auramine O, giving a large increase in  $A_{500\text{ nm}}$  and a 40-fold amplification of the LB signal. As with malachite green, there is a cooperative interaction between auramine O and LB. About 72 molecules of auramine O undergo a

spectral shift per molecule of tyrosine. The product of this reaction is also fluorescent and could be exploited in a protein assay. However, both the spectrophotometric and fluorescent assays are of the same sensitivity as the MG assay.

---

**Title:** Determination of Protein: A Modification of the Lowry Method that Gives a Linear Photometric Response

**Citation:** Hartree, E. F. *Analytical Biochemistry* 48:422-427 (1972).

**Content:** The value of the method developed by Lowry, Rosebrough, Farr, and Randall for assay of protein concentration is apparent from its widespread adoption. In their critical assessment of the method these authors refer to its two disadvantages: (a) that the color yields of different proteins vary considerably, and (b) that the relationship between color yield and protein concentration is not linear. The former is inescapable, arising as it does from the complexity of the reactions of proteins in alkaline solution with cupric tartrate and the Folin-Ciocalteu reagent.

By the following adaptation of the Lowry procedure it is possible to establish a linear relationship between concentration of a soluble protein and color yield.

---

**Title:** Protein Measurement with the Folin Phenol Reagent

**Citation:** Lowry, Oliver H., Nira J. Rosebrough, A. Lewis Farr, and Rose J. Randall. *J. Biolog. Chem.* 193:265 (1951).

**Content:** Procedures are described for measuring protein in solution or after precipitation with acids or other agents, and for the determination of as little as 0.2  $\gamma$  of protein.

---

**PROTEINS  
(LITERATURE)**

**Title:** Protein Assays: A Review of Common Techniques

**Citation:** Davis, E. M. *American Biological Laboratory* (July 1988).

**Content:**  

---

---

**Title:** A Comparison of Spectroscopic Techniques for Protein Quantification in Aqueous Solutions

**Citation:** Hawkins, Barton K. and David E. Honigs. *American Biological Laboratory* (November/December 1987).

**Content:**  

---

---

**Title:** Primary Standards: The Basis for Accuracy in the Kjeldahl Protein Method

**Citation:** Hach, C. C. and S. V. Brayton. *Manual from the Technical Center for Applied Analytical Chemistry*. Loveland, CO: Hach Company.

**Content:**  

---

---



**Title:** Fiber (Crude) in Animal Feed:  
Ceramic Fiber Filter Method - AOCS-  
AOAC Method

**Citation:** AOAC 7.066 (Principle)  
AOAC 7.067 (Reagents)  
AOAC 7.068 (Apparatus)  
AOAC 7.069 (Preparation of  
Sample)  
AOAC 7.070 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Fiber (Crude) in Animal Feed: Fritted  
Glass Crucible Method

**Citation:** AOAC 7.071 (Principle)  
AOAC 7.072 (Apparatus and  
Reagents)  
AOAC 7.073 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Fiber (Acid Detergent) and Lignin in  
Animal Feed

**Citation:** AOAC 7.074 (Reagents)  
AOAC 7.075 (Apparatus)  
AOAC 7.076 (Determination of  
Acid-Detergent Fiber)  
AOAC 7.077 (Determination of  
Lignin)

**Content:**

**Availability:** AOAC

---



**Title:** Near Infrared Reflectance Spectroscopy (NIRS): Analysis of Forage Quality

**Citation:** Edited by G. C. Marten, J. S. Shenk, and F. E. Barton II. Agriculture Handbook No. 643. Washington, DC: United States Department of Agriculture, Agricultural Research Service, 1985.

**Content:**

---

**Title:** Analysis of Forages and Fibrous Foods

**Citation:** Van Soest, P. J. and J. B. Robertson. Ithaca, NY: Cornell University, 1985.

**Content:**

---

**Title:** Routine Forage Analysis Using Near Infrared Reflectance Analysis (NIRA): Calibrations and Performance Data

**Citation:** Workman, Jerome J. and Shirley A. Dieterman. Presented at Seventh International Symposium on Near Infrared Reflectance Analysis (NIRA), July 10-11, 1984.

**Content:**

---

**Title:** Determination of Lignin and Cellulose in Forages by Extraction with Triethylene Glycol

**Citation:** Edwards, Colin S. J. *Sci. Fd. Agric.* 24:381-388 (1973).

**Content:** A method of lignin determination which utilizes the solubility of lignin in HCl-activated triethylene glycol at 121°C is described. Experiments on a range of samples indicate that the method is simple, fast and reproducible, and relates well to in vitro organic matter digestibility.

---

**Title:** Determination of Lignin and Cellulose in Acid-Detergent Fiber with Permanganate

**Citation:** Van Soest, P. J. and R. H. Wine. *Journal of the A.O.A.C.* 51(4):780 (1968).

**Content:** A newly developed indirect method for lignin, utilizing permanganate, permits the determination of cellulose and insoluble ash in the same sample. The new permanganate lignin method is intended as an alternative procedure to the 72% sulfuric acid method over which it offers definite advantages as well as certain disadvantages. Choice of methods will depend upon the materials analyzed and the purpose for which the values are to be used.

---

**Title:** Use of Detergents in the Analysis of Fibrous Feeds. II. A Rapid Method for the Determination of Fiber and Lignin

**Citation:** Van Soest, P. J. *Journal of the A.O.A.C.* 46(5):828 (1963).

**Content:** The capacity of cetyl trimethylammonium bromide to dissolve proteins in acid solution has been utilized in development of a method, called acid-detergent fiber method (ADF), which is not only a fiber determination in itself but also the major preparatory step in the determination of lignin.

---

**Title:** Forage Fiber Analyses (Apparatus, Reagents, Procedures, and Some Applications)

**Citation:** Goering, H. K. and P. J. Van Soest. Agriculture Handbook No. 379. Washington, DC: United States Department of Agriculture, Agricultural Research Service, 1970.

**Content:**

---



**Title:** Algal Culture from Laboratory to Pilot Plant

**Citation:** Burlew, J. S. *Algal Culture from Laboratory to Pilot Plant*. Publication 600. Washington, DC: Carnegie Institution of Washington. 1953.

**Content:**

---

**Title:** Techniques of Lipidology: Isolation, Analysis and Identification of Lipids

**Citation:** Morris, Kates. 2nd Revised Edition. In *Laboratory Techniques in Biochemistry and Molecular Biology*, Vol. 3, Pt. 2. Edited by R. H. Burdon and P. H. van Knippenberg, New York: Elsevier, 1986.

**Content:** Ch. 1-Definition and Classification of Lipids; Ch. 2-Materials and Equipment; Ch. 3-Lipid Extraction Procedures; Ch. 4-General Analytical Procedures; Ch. 5-Separation of Lipid Mixtures; Ch. 6-Radioisotopic Techniques in Lipidology; Ch. 7-Identification of Individual Lipids and Lipid Moieties.

---

**Title:** Standard Methods for the Examination of Water and Wastewater

**Citation:** Fourteenth edition. Prepared and published jointly by American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Washington, DC: American Public Health Association, 1979.

**Content:** General Introduction, Physical Examination, Determination of Metals, Determination of Inorganic Nonmetallic Constituents, Determination of Organic Constituents, Automated Laboratory Analyses, Examination of Water and Wastewater Radioactivity, Bioassay Methods for Aquatic Organisms, Microbiological Examination of Water, Biological Examination of Water.

---

**Title:** Handbook of Phycological Methods: Culture Methods and Growth Measurements

**Citation:** Edited by Janet R. Stein. Cambridge: Cambridge University Press, 1973.

**Content:** I-Isolation and Purification; II-General Equipment and Methods; III-Special Culture Methods; IV-Growth Measurements; V-Bioassay.

---

**Title:** Handbook of Phycological Methods: Physiological and Biochemical Methods

**Citation:** Edited by Johan A. Hellebust and J. S. Craigie. Cambridge: Cambridge University Press, 1978.

**Content:** I-Isolation of Organelles and Membranes; II-Analysis of Chemical Constituents; III-Enzymes; IV-Physiological and Biochemical Processes; V-Nutrients; VI-Ion Content and Transport; VII-Inhibitors.

---

**Title:** Handbook of Phycological Methods: Developmental and Cytological Methods

**Citation:** Edited by Elisabeth Gantt. Cambridge: Cambridge University Press, 1980.

**Content:** I-Experimental Algal Systems and Techniques; II-Light and Electron Microscopy: Preparative Methods.

---

**Title:** CRC Handbook of Microalgal Mass Culture

**Citation:** Edited by Amos Richmond. Boca Raton, FL: CRC Press, Inc., 1986.

**Content:** The Production of Biomass: A Challenge to Our Society; A Historical Outline of Applied Algology; Photosynthesis and Ultrastructure in Microalgae; Cell

## MICROALGAE (LITERATURE)

Response to Environmental Factors; Productivity of Algae Under Natural Conditions; Laboratory Techniques for the Cultivation of Microalgae; Algal Nutrition; Microalgae of Economic Potential; Technological Aspects of Mass Cultivation--A General Outline; Elements of Pond Design and Construction; Outdoor Mass Cultures of Microalgae; Algae in Wastewater Oxidation Ponds; Nutritional Properties of Microalgae: Potentials and Constraints; Products from Microalgae; Blue-Green Algae as Biofertilizer; Economic Aspects of the Management of Algal Production; Future Prospects.

---

**Title:** Algal Biomass Technologies: An Interdisciplinary Perspective

**Citation:** Edited by W. R. Barclay and R. P. McIntosh. Berlin, Stuttgart: J. Cramer, 1986.

**Content:** Proceedings of a workshop on the present status and future directions for biotechnologies based on algal biomass production.

---

**Title:** Algae Biomass Production and Use

**Citation:** Edited by G. Shelef and C. J. Soeder. Amsterdam: Elsevier/North-Holland Biomedical Press, 1980.

**Content:**

---

**Title:** The *Chlamydomonas* Sourcebook: A Comprehensive Guide to Biology and Laboratory Use

**Citation:** Harris, E. H. New York: Academic Press, 1989.

**Content:** An overview of the Genus *Chlamydomonas*. Culture and Storage Methods. Cell Architecture and Division. The Sexual Cycle. Motility. Metabolism. Photosynthesis.

Organelle Heredity. Nucleic Acids and Protein Synthesis. Genetic Analysis. Mutant Strains. Procedures and Resources. Bibliography.

---

**Title:** UTEX--The Culture Collection of Algae at the University of Texas at Austin

**Citation:** Starr, R. C. and J. A. Zeikus. *Journal of Phycology*. Vol. 23, Supplement to September 1987.

**Content:**

---

**Title:** Microalgae Culture Collection 1986-1987

**Citation:** Barclay, W., J. Johansen, P. Chelf, N. Nagle, P. Roessler, and P. Lemke. SERI/SP-232-3079. Golden, CO: Solar Energy Research Institute, 1986.

**Content:**

---

**Title:** Addendum to Microalgae Culture Collection 1986-1987

**Citation:** Johansen, J., P. Lemke, N. Nagle, P. Chelf, P. Roessler, R. Galloway, and S. Toon. SERI/SP-232-3079a. Golden, CO: Solar Energy Research Institute, 1987.

**Content:**

---

**Title:** Standard Test Method for Preparation of Methyl Esters from Fatty Acid for Determination of Fatty Acid Composition by Gas-Liquid Chromatography<sup>1</sup>

**Citation:** ASTM D 3457-87

**Content:** This test method covers a procedure for conversion of animal and vegetable fatty acids into methyl esters of the fatty acids suitable for analysis by gas-liquid chromatography. This test method is applicable to animal and vegetable fatty acids having 8 to 24 carbon atoms.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.3 on Drying Oils.

---

**Title:** Methods for Sampling Animal and Vegetable Fats and Oils

**Citation:** BS 627:1982

**Content:** Methods for bulk (land tanks, ships' tanks, tank wagons and cars), packages (barrels, drums, cases, tins, bags), weigh tanks and pipe lines; descriptions and illustrations of equipment; temperature limits; sizes, packaging, and labelling of samples.

**Availability:** BSI

---

**Title:** Specification for Crude Rape Seed Oil

**Citation:** BS 631:1967

**Content:** Color, relative density, refractive index, iodine value, saponification value, acidity, unsaponifiable matter, viscosity, flash point, and size of sample. Viscosity method appended. For methods of sampling and testing and for flash point determination see BS 627, BS 684, and BS 2839 respectively.

**Availability:** BSI

---

**Title:** Specification for Crude Maize Oil

**Citation:** BS 651:1967

**Content:** Color, relative density, refractive index, iodine value, saponification value, acidity, unsaponifiable matter, size of sample. For sampling and testing see BS 627 and BS 684.

**Availability:** BSI

---

**Title:** Specification for Crude Soya Bean Oil

**Citation:** BS 653:1967

**Content:** Color, relative density, refractive index, iodine value, saponification value, acidity, unsaponifiable matter, size of sample. For sampling and testing see BS 627 and BS 684.

**Availability:** BSI

---

**Title:** Methods of Analysis of Fats and Fatty Oils

**Citation:** BS 684:Part 0:1982

**Content:** Covers sampling, preparation of the test sample, reagents, apparatus, test report, index to the entire standard. To be read in conjunction with the other parts. (BS 684 has many subsections.)

**Availability:** BSI

---

**Title:** Methods for the Analysis of Oilseeds

**Citation:** BS 4289

Part 2:1981 (Determination of impurities content)

**Content:** Samples are sieved and sorted into fines, non-oleaginous and oleaginous impurities, which are then weighed.

Part 4:1982 (Determination of hexane extract [or light petroleum extract], called "oil content")

## OILSEEDS AND CROPS (STANDARDS)

**Content:** Describes the extraction of a prepared test portion with light petroleum (hexane), removal of solvent and weighing of the residue.

Part 5:1968 (Determination of acidity of oil)

**Content:** Titration, with ethanolic potassium hydroxide solution, of solution of extracted oil in mixture of ethanol and diethyl ether. Reagents, apparatus, test procedure, expression of results, test report.

**Availability:** BSI

---

**Title:** Oilseeds--Sampling

**Citation:** ISO 542:1980

**Content:**

**Availability:** ISO

---

**Title:** Oilseeds--Determination of Hexane Extract (or Light Petroleum Extract) Called "Oil Content"

**Citation:** ISO 659:1979

**Content:**

**Availability:** ISO

---

**Title:** Oilseeds--Reduction of Contract Samples to Analysis Samples

**Citation:** ISO 664:1977

**Content:**

**Availability:** ISO

---

**Title:** Oilseeds--Determination of Moisture and Volatile Matter Content

**Citation:** ISO 665:1977

**Content:**

**Availability:** ISO

---

**Title:** Oilseeds Residues--Determination of Hexane Extract (or Light-Petroleum Extract), Called "Oil Content"

**Citation:** ISO 734:1979

**Content:**

**Availability:** ISO

---

**Title:** Oilseeds--Nomenclature; Trilingual Edition

**Citation:** ISO 5507:1982

**Content:**

**Availability:** ISO

---

**Title:** Oilseeds--Determination of Oil Content--Low Resolution Nuclear Magnetic Resonance Spectrometric Method

**Citation:** ISO 5511:1984

**Content:**

**Availability:** ISO

---

**Title:** 200-Hour Screening Test for Alternate Fuels

**Citation:** *Energy Notes*. Peoria, IL: U.S. Department of Agriculture Extension Service, Northern Agricultural Energy Center, September 1, 1982.

**Content:** The EMA 200-hour fuel screening test would be only preliminary to many more specific tests were an engine manufacturer to consider commercial applications of its equipment on non-specification fuels.

Specific further information is available from Northern Agricultural Energy Center, 1815 N. University Street, Peoria, IL 61604.

---

**Title:** Bailey's Industrial Fats and Oils

**Citation:** Swern, D. E. Volumes I and II. New York: John Wiley and Sons, 1979.

**Content:** An excellent reference on all aspects of vegetable oils including chemistry and methods of testing.

---

**Title:** Standard Methods for the Analysis of Oils, Fats and Derivatives

**Citation:** Paquot, C. and A. Hautfene. Oxford: Blackwell Scientific Publications Ltd., 1988).

**Content:** Revised and enlarged edition of *Standard Methods for the Analysis of Oils, Fats and Derivatives*. Contains methods for the analysis of oleaginous seeds and fruits (moisture, volatile matter, oil content, acidity of oil).

---



**Title:** Ash of Peat

**Citation:** AOAC 2.207 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Sand in Peat

**Citation:** AOAC 2.208 (Preparation of Sample)  
AOAC 2.209 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Organic Matter in Peat

**Citation:** AOAC 2.210 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Nitrogen (Total) in Peat

**Citation:** AOAC 2.211 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Water Capacity and Volumes for Peat

**Citation:** AOAC 2.212 (Apparatus)  
AOAC 2.213 (Preparation of Sample)  
AOAC 2.214 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Volume, Peat: Alternative Methods

**Citation:** AOAC 2.216 (Principle)  
AOAC 2.217 (Apparatus)  
AOAC 2.218 (Determination)

**Content:**

**Availability:** AOAC

---

**Title:** Volume Weight, Water-Holding Capacity, and Air Capacity of Water-Saturated Peat Materials

**Citation:** AOAC 2.219 (Apparatus)  
AOAC 2.220 (Preparation of Sample)  
AOAC 2.221 (Determination)  
AOAC 2.222 (Calculations)

**Content:**

**Availability:** AOAC

---

**Title:** Cation Exchange Capacity of Peat: Titrimetric Method

**Citation:** AOAC 2.223 (Principal)  
AOAC 2.224 (Reagents)  
AOAC 2.225 (Preparation of Sample)

**Content:**

**Availability:** AOAC

---

**Title:** Standard Test Methods for Moisture, Ash, and Organic Matter of Peat Materials<sup>1</sup>

**Citation:** ASTM D 2974-87

**Content:** These methods cover measurement of the weight percentage of moisture, ash, and organic matter in peat materials, including moss, humus, and reed-sedge types.

**Availability:** ASTM

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock.

---

## PEAT (STANDARDS)

**Title:** Horticultural Peat, Acidity

**Citation:** ASTM D 2976-71 (1981)

**Content:**

**Availability:** ASTM

---

**Title:** Peat, Moisture Content

**Citation:** DIN 51718-78

**Content:**

**Availability:** DIN

---

**Title:** Peat, Ash Content

**Citation:** DIN 51719-78

**Content:**

**Availability:** DIN

---

**Title:** Peat, Volatile Matter

**Citation:** DIN 51720-78

**Content:**

**Availability:** DIN

---

**Title:** Peat Decomposition

**Citation:** GOST 10650-72

**Content:**

**Availability:** GOST

---

**Title:** An Overview of Peat Research, Utilization, and Environmental Considerations

**Citation:** Boron, David J., Earl W. Evans, and Jeffrey M. Peterson. *International J. of Coal Geology* 8:1-31 (1987).

**Content:** The peat reserves in this country represent a vast resource for fuel and for chemical feedstock. As a fuel for combustion, peat generally has a low to moderate sulfur content (0.5%-3.0% on a dry basis), a low to high ash content (5.0%-20% on a dry basis), and an intermediate Btu content (6,000-10,000 per pound on a dry basis). As a chemical feedstock, peat can be extracted to provide various aliphatic, cyclic, and aromatic compounds, particularly oxygenated derivatives of these. Because of its chemical structure, peat provides a suitable feedstock for gasification not only for energy production but also for the synthesis of more complex compounds. In agriculture, peat and peat-derived chemicals are excellent soil additives and fertilizers. With such diversified application, peat is a valuable resource. The objective of this chapter is to provide some background information on peat and to overview select research, utilization, and environmental considerations involving peat.

---

**Title:** The Pyrolysis of Peat: A Comprehensive Review of the Literature

**Citation:** Roy, C., E. Chornet, and C. H. Fuchsman. *Journal of Analytical and Applied Pyrolysis* 5:261-332 (1983).

**Content:**

---

**Title:** An Overview of the Preparation and Analytical Methods of Peat at the University of North Dakota Energy Research Center

**Citation:** Schelkoph, Gwen M., Martha J. Mitchell, Dana P. Gallahan, and David J. Hassett. *Proceedings of Workshop on Mineral Matter in Peat: Its Occurrence, Form, and Distribution, September 26-30, 1983*. R. Raymond, Jr. and M. J. Andrejko, Eds., held at Los Alamos National Laboratory, Los Alamos, NM.

**Content:** In 1979, the U.S. Department of Energy funded a State Peat Resource Grant Program in which 14 states have participated. Grand Forks Energy Technology Center contributed to the program by providing program management and established a contract with the University of North Dakota Engineering Experiment Station to provide personnel to perform chemical analysis on 2401 peat samples provided by 13 of the participating states. This work provides a uniform chemical data base on the peat samples. These analyses, which are nearly complete, have been done in the laboratory facilities at GFETC (now the University of North Dakota Energy Research Center) and are the topic of this paper. The analytical data base consists of proximate, ultimate, and Btu values. The elemental analyses have been done on commercial C, H, N, and S analyzers. Details of the techniques are given in the paper as well as a discussion of the experimental difficulties encountered. Laboratory personnel are in the process of evaluating the methods used in the program. The original guidelines for the program were that the samples be treated as much like coal samples as possible.

---

## PEAT (LITERATURE)

**Title:** Comparison of Ashing Techniques for Determination of the Inorganic Content of Peats

**Citation:** Andrejko, M. J., F. Fiene, and A. D. Cohen. In *Testing of Peat and Organic Soils*, ASTM STP820, P.M. Jarrett, ed. Am. Soc. Test. and Materials, 5-20 (1983).

**Content:**

---

---

**Title:** Annual Book of ASTM Standards, Part 19, Soil and Rock; Building Stones

**Citation:** Philadelphia, PA: ASTM, 1981, 650 pp.

**Content:**

---

---

**Title:** A Comparative Study of Preparation and Analytical Methods for Peat

**Citation:** Schelkoph G. M., D. J. Hassett, and B. L. Weber. In *Testing of Peat and Organic Soils*. ASTM STP820, P.M. Jarrett, ed. Am. Soc. Test. and Materials, 99-110 (1983).

**Content:**

---

---

**Title:** Peat Testing Manual

**Citation:** Muskeg Subcommittee, Associate Committee on Geotechnical Research, NRC of Canada. Technical Memorandum. 1979. 193 pp.

**Content:**

---

---

**Title:** Pyrolysis of Peat Studied by Thermogravimetry and Fourier Transform Infrared Spectroscopy

**Citation:** Aho, Martti, Pekka Kortelainen, Jarmo Rantanen, and Veli Linna. *Journal of Analytical and Applied Pyrolysis* (in press).

**Content:** The usefulness of Fourier transform infrared spectroscopy for the study of peat pyrolysis was evaluated, both for char and for on-line gas analysis. In the first part of the work we compare different ways of obtaining the infrared spectrum of the charred peats. The peats were pyrolysed in a modified thermobalance and the structures of the chars were followed by recording spectra using KBr pellet, diffusion reflectance (DRIFT) and photoacoustic techniques (PAS). With black chars the DRIFT and PAS methods produced spectra of higher quality than the KBr technique. The decomposition of carbohydrates between 300° and 400°C and of long-chain hydrocarbons between 400° and 500°C was clearly observed in spectra recorded by all methods. Separate studies on the main compounds of peat revealed important details, such as the decomposition of aliphatic acids in the separated peat-wax fraction between 300° and 400°C, while the amount of aliphatic esters remained roughly constant.

In the second part of the work we studied the usefulness of the Fourier transform infrared spectrometer as an on-line gas analyzer. Eight gases (CO<sub>2</sub>, CO, NO, NO<sub>2</sub>, CH<sub>4</sub>, C<sub>2</sub>H<sub>2</sub>, C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub>) were measured with high sensitivity from the pyrolysis and combustion gases evolved from peat between 600° and 700°C. The detection limit of NO<sub>2</sub> was below 0.5 ppm/volume when the optical length of 6.75 m was used. The concentration of C<sub>2</sub>H<sub>2</sub> increased relative to the other hydrocarbons with the increasing vigor of the reaction conditions during pyrolysis and combustion.

---

---

**Title:** Standard Test Methods for Penetration of Preservatives in Wood and for Differentiating Between Heartwood and Sapwood<sup>1</sup>

**Citation:** ASTM D 3507-86

**Content:** These test methods cover procedures for determining penetration of preservatives in wood in cases where demarcation between the treated and untreated wood is not readily visible. Included are test methods for differentiating the heartwood and sapwood of wood samples for specific species, and a test method for differentiating the heartwoods between the red oaks and the white oaks.

The procedures appear in the following order: Penetration of Arsenic-Containing Preservatives, Penetration of Copper-Containing Preservatives, Penetration of Fluoride-Containing Preservatives, Penetration of Pentachlorophenol Using 4,4'-bis-Dimethylamino-Triphenylmethane (DMTM), Penetration of Pentachlorophenol Using a Silver-Copper Complex, Penetration of Solvent Used with Oil-Soluble Preservatives, Penetration of Zinc-Containing Preservatives, Differentiating between Sapwood and Heartwood in Pine Species (*Pinus sp.*), Differentiating between Sapwood and Heartwood in Douglas Fir (*Pseudotsuga menziesii*), Differentiating between Sapwood and Heartwood in White Fir (*Abies concolor*), Differentiating Between Woods of the Red Oak and the White Oak Species.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-7 on Wood and are the direct responsibility of Subcommittee D07.06 on Treatments of Wood Products.

---

**Title:** Methods for the Analysis and Testing of Coal and Coke

**Citation:** BS 1038

**Content:**

**Availability:** BSI

---

**Title:** Methods of Test for Pulp and Paper (Metric Units)

**Citation:** BS 1301

**Content:**

**Availability:** BSI

---

**Title:** Methods for Determination of Limiting Viscosity Number of Cellulose in Dilute Solutions

**Citation:** BS 6306:1982

**Content:**

**Availability:** BSI

---

**Title:** Quality of Pulpwood Chips

**Citation:** CPPA D. 18H

**Content:** This method will provide a uniform interpretation of chip quality attributes, which will assist pulp mill operators in assessing the quality of mill chips and serve as a guide to pulp mill and sawmill operators in extending the use of sawmill residue as a source of chips for chemical pulp mills. To this end, test procedures for determining chip quality are indicated along with a recommended reporting procedure and suggested quality standards. It should be emphasized that the reporting procedure and the suggested chip quality standards are offered here as a guide only.

**Availability:** CPPA

---

## MISCELLANEOUS ANALYSES OF BIOMASS MATERIALS (STANDARDS)

**Title:** Testing of Pulp; Determination of the Dry Content of Pulp Samples

**Citation:** DIN 54352

**Content:**

**Availability:** DIN

---

**Title:** Testing of Pulp; Determination of the Stability of Pulp against Sodium Hydroxide Solution (Alkali Resistance)

**Citation:** DIN 54355

**Content:**

**Availability:** DIN

---

**Title:** Prime Farmlands, Performance Standards

**Citation:** 30 CFR 823

**Content:**

**Availability:** EPA/CFR

---

**Title:** Pulps--Determination of Dry Matter Content

**Citation:** ISO 638:1978

**Content:**

**Availability:** ISO

---

**Title:** Coal and Coke--Calculation of Analyses to Different Bases

**Citation:** ISO 1170:1977

**Content:**

**Availability:** ISO

---

**Title:** Dry Matter Content--Pulp

**Citation:** SCAN-C 3:78

**Content:** This SCAN-test standard specifies a method for the determination of the dry matter content of pulp samples.

This method is applicable to moist or air-dry pulp which contains no appreciable quantity of matter, other than water, volatile at the temperature specified for the drying. It is used, for example, in the case of pulp samples taken for chemical and physical tests in the laboratory, when a concurrent determination of dry matter content is required.

This method is not applicable to the determination of the dry matter content of slush pulp nor to the determination of the saleable mass of pulp lots.

**Availability:** SCAN

---

**Title:** Dry Matter Content--Starch

**Citation:** SCAN-P 52:84

**Content:** This SCAN-test standard specifies a method for the determination of the dry matter content of samples of starch used in manufacture of papers or boards.

The standard is applicable to air-dry samples of native and modified starches that contain no appreciable quantity of matter, other than water, volatile at the temperature specified for the drying.

**Availability:** SCAN

---

**Title:** Compression Wood Identification in Pulpwood

**Citation:** TAPPI T 20 wd-85  
(Replaced by T 267 cm-85)

**Content:** This method is concerned with the detection of the compression wood that can be recognized by unaided vision or by means of a simple viewing device. Normally this is

sufficient for operating purposes. Microscopic and chemical tests may be required in special cases.

**Availability:** TAPPI

---

**Title:** Viscosity of Pulp (Capillary  
Viscometer Method)

**Citation:** TAPPI T 230 om-82

**Content:** This method describes a procedure for determining the viscosity of 0.5% cellulose solutions, using 0.5M cupri-ethylenediamine as a solvent and a Cannon-Fenske capillary viscometer. Measurements may be made on bleached cotton and wood pulps. Kraft pulps with up to 4% lignin, as defined by TAPPI T 222 "Acid-Insoluble Lignin in Wood and Pulp" can also be analyzed.

**Availability:** TAPPI

---



**Title:** Feedstock Analyses: The Proportion of Sapwood in Woody Samples

**Citation:** Hillis, W. E. Private Communication as member of Working Group, 1987.

**Content:** After a certain age or width, which can change with growing conditions, the sapwood in the interior of a stem or branch of a tree is transformed to heartwood. This transformation varies considerably between species, both in time and extent. Heartwood differs from sapwood with a lower ash content having usually a different composition, a lower moisture content in conifers (and usually in hardwoods), the absence of starch, a higher and different extractives content and hence different color, a lower rate of penetrability by fluids or gases, etc.

---

**Title:** The Chemistry of Solid Wood

**Citation:** Edited by Roger Rowell. *Advances in Chemistry Series 207*. Washington, DC: American Chemical Society, 1984.

**Content:** Structure and Chemistry; Properties and Reactivity; Surface Chemistry; Degradation Chemistry

---

**Title:** The Chemical Composition of Wood

**Citation:** Pettersen, Roger C. Chapter 2 in *The Chemistry of Solid Wood*. Roger Rowell, Editor. *Advances in Chemistry Series 207*. Washington, DC: American Chemical Society, 1984.

**Content:** This chapter includes overall chemical composition of wood, methods of analysis, structure of hemicellulose components and degree of polymerization of carbohydrates. Tables of data are compiled for woods of several countries. Components include: cellulose (Cross and Bevan, holo-, and alpha-), lignin, pentosans, and ash. Solubilities in 1% sodium hydroxide, hot water, ethanol benzene, and ether are reported. The data were collected at the

Forest Products Laboratory (Madison, Wisconsin) from 1927-68 and were previously unpublished. These data include both United States and foreign woods. Previously published data include compositions of woods from Borneo, Brazil, Cambodia, Chile, Colombia, Costa Rica, Ghana, Japan, Mexico, Mozambique, Papua New Guinea, the Philippines, Puerto Rico, Taiwan, and the USSR. Data from more detailed analyses are presented for common temperate-zone woods and include the individual sugar composition (as glucan, xylan, galactan, arabinan, and mannan), uronic anhydride, acetyl, lignin, and ash.

---

**Title:** Workshop on Standards in Biomass for Energy and Chemicals

**Citation:** *Proceedings*. Edited by Thomas A. Milne. SERI/CP-234-2506. Golden, CO: Solar Energy Research Institute, November 1984.

**Content:**

---

**Title:** Miscellaneous

**Citation:** Easty, D. Institute of Paper Chemistry. Private Communication, 1984.

**Content:** Specialized method collections include *Analytical Procedures for Tall Oil Products* (Pulp Chemicals Association, 1976) and those in Sarkanen and Ludwig's *Lignin* (Wiley, 1971). Review articles, such as E. Adler's "Lignin Chemistry--Past, Present, and Future" [*Wood Sci. Technol.* 11:169 (1977)], are also valuable resources.

---

**Title:** Heartwood and Tree Exudates

**Citation:** Hillis, W. E. Berlin: Springer-Verlag, 1987.

**Content:** Definitions and descriptions; influence of forestry aspects; chemical features; biological features; function, formation, and control.

---

# MISCELLANEOUS ANALYSES OF BIOMASS MATERIALS (LITERATURE)

**Title:** Analysis of Paper

**Citation:** Browning, B. L. Second Edition. New York: Marcel Dekker, Inc., 1977.

**Content:**

---

**Title:** Methods of Wood Chemistry

**Citation:** Browning, B. L. Vols. I and II. New York: Interscience Publishers, 1967.

**Content:**

---

**Title:** Procedures for the Chemical Analysis of Wood and Wood Products

**Citation:** Moore, Wayne E. and David B. Johnson. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Revised December 1967. (Unpublished)

**Content:** Analytical Methods: Acetyl and C-Methyl Groups; Alcohol-Benzene Solubility of Wood and Pulp; Alkoxy Groups; Ash in Pulp; Ash in Wood; Charcoal Analysis; Ether Solubility of Wood and Pulp; Ethyl Solubility of Wood and Pulp; Ethyl Alcohol; Extractives in Wood; Formaldehyde in Paper and Wood; Furfural; Halides in Wood; Holocellulose in Wood; Hydroxymethylfurfural; Ion-Exchange Capacity of Pulp; Itaconic Acid; Lactic Acid; Levulinic Acid; Lignin in Pulp (Standard Hydrolysis); Lignin in Pulp (Modified Hydrolysis); Lignin in Wood (Standard Hydrolysis); Lignin in Wood (Modified Hydrolysis); Lignin in Wood (Spectrophotometric); Moisture in Wood and Pulp; Nickel; Nitrogen by the Kjeldahl Method (Total, Ammoniacal, and Urea Nitrogen); Pentosans in Pulp; pH of Wood; Polyethylene Glycol in Wood; Propylene Glycol; Pyroligneous Acids; Sieve Analysis; Silica in Organics; Sodium in Fermentation Solutions; Solids in Water; Sugar Alcohols, Glycerol, and Glycols; Sulfate in Cellulose Nitrate; Total Organic Matter; Uronic Acids; Wood Sugars. Appendix: Definitions of Terms Related to Cellulose and Cellulose Derivatives; Definitions

of Terms Related to Precision and Accuracy; Extractive-Free Wood (Preparation of); Minimum Sample Sizes Required for Analyses; Spectrometry Nomenclature.

---

**Title:** Planning Report, NBS and Industrial Biotechnology: Technical Developments and Future Measurement Needs

**Citation:** O'Brien, Thomas C. NBSIR 82-2549. Gaithersburg, MD: National Bureau of Standards, July 1982.

**Content:**

---

**Title:** Quantification of Residual Polymeric Families Present in Thermomechanical and Chemically Pretreated Lignocellulosics via Thermal Analysis

**Citation:** Bouchard, J., S. Leger, E. Chornet, and R. P. Overend. *Biomass* 9: 161-171 (1986).

**Content:** Different species of wood and wood residues derived from thermomechanical and chemical treatments were studied by thermal analysis (TG/DTG) in order to establish a simple and rapid method for determining the major constituents. It is shown that TG/DTG with well-defined conditions is an appropriate method to distinguish between lignin and carbohydrate and, with less precision, between cellulose and hemicellulose for all the types of biomass studied, treated or untreated.

---

**Title:** Fractionation of Lignocellulosics

**Citation:** Chornet, E. and R. P. Overend. Sainte-Foy (Quebec), Canada: Centre Quebecois de Valorisation de la Biomasse, 1988.

**Content:** This overview, written for the scientific community, is aimed at all those (researchers, students, administrators) who are interested in the optimal utilization of lignocellulosics. Designed as a teaching manual, it makes an analysis of the state of the art of fractionation technologies, attach-

ing importance to the applications and constraints associated with the development of industrial sub-sectors (fine chemistry, energy, biotechnology).

---

**Title:** Methods of Analysis of Biomass for Fuels and Chemicals

**Citation:** Deglise, X. Working Group: Thermochemical Panel for November 18-20, 1987 Meeting.

**Content:** Among the laboratories working in the area of thermochemical conversion of biomass, it is rather difficult to separate feedstock analyses and thermochemical related analyses.

A collection of the different analyses which are used in France and Belgium in the different laboratories (public institutions, universities and industry) has been done.

We give here a summary of the analysis methods together with reports or publications for uncommon methods.

---

**Title:** Important Reference Books

**Citation:** Zimmerman, M. H. *The Formation of Wood in Forest Trees*, New York: Academic Press, 1965.

Loewus, F. A. and V. C. Runeckles. *The Structure, Biosynthesis and Degradation of Wood: Recent Advances in Phytochemistry*. Volume II. New York: Plenum Press, 1977.

Sarkanen, K. V. and D. A. Tilman. *Progress in Biomass Conversion*. Vols. I-II. New York: Academic Press, 1980.

Young, R. A. *Introduction to Forest Science*. New York: John Wiley and Sons, 1982.

*Energy from Biological Processes*. Washington, DC: Office of Technology Assessment, 1980.

Sjostrom, E. *Wood Chemistry*. New York: Interscience Publishers, 1963.

Rydholm, S. A. *Pulping Processes*. New York: Interscience Publishers, 1965.

**Content:**

---





**Title:** Standard for Densified Wood Pellet Fuel for Residential Use

**Citation:** APFI-PF-1-88

**Content:**

**Availability:** APFI

---

**Title:** Wafers, Pellets, and Crumbles-- Definitions and Methods for Determining Density, Durability, and Moisture Content

**Citation:** ASAE S269.3

**Content:** This standard defines wafers, pellets, and crumbles and establishes methods and procedures for measuring unit specific density, bulk density, durability, and moisture content.

**Availability:** ASAE

---

**Title:** Solid Fuels

**Citation:** ASME PTC 3.2-54

**Content:**

**Availability:** ASME

---

**Title:** Standard Definitions of Terms Relating to Coal and Coke<sup>1</sup>

**Citation:** ASTM D 121-85

**Content:**

**Availability:** ASTM

---

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee D-5 on Coal and Coke and are the direct responsibility of Subcommittee D05.02 on Nomenclature and Definition.

---

**Title:** Standard Test Method for Specific Gravity and Porosity of Lump Coke<sup>1</sup>

**Citation:** ASTM D 167-73 (1979)

**Content:** This test method covers the determination of apparent specific gravity and true specific gravity of lump coke larger than 1-in. (25-mm) size and calculating porosity from the specific gravity data.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.02 on Physical Tests of Coke.

---

**Title:** Standard Test Method for Grindability of Coal by the Hardgrove-Machine Method<sup>1</sup>

**Citation:** ASTM D 409-85

**Content:** This test method is used to determine the relative grindability or ease of pulverization of coals in comparison with coals chosen as standards. A prepared sample receives a definite amount of grinding energy in a miniature pulverizer, and the change in size is determined by sieving.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characterization and Beneficiation of Coal and Coal Slurries.

---

**Title:** Standard Method of Drop Shatter Test for Coal<sup>1</sup>

**Citation:** ASTM D 440-86

**Content:** This method of drop shatter test covers the determination of the relative size stability and its complement, the friability, of sized coal. It affords a means of indicating the ability of coal to withstand breakage

## SOLID FUELS (STANDARDS)

when subjected to handling at the mine and during transit to the consumer. The test is serviceable for ascertaining the similarity of coals in respect to size stability and friability rather than for determining values within narrow limits in order to emphasize their dissimilarity. This method is considered applicable for testing a selected single size of different coals, for testing different single sizes of the same coal, and for mixed sizes of the same of different coals.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characterization and Beneficiation of Coal and Coal Slurries.

---

**Title:** Standard Method of Tumbler Test for Coal<sup>1</sup>

**Citation:** ASTM D 441-86

**Content:** This method covers the determination of the relative friability of a particular size of sized coal. It affords a means of measuring the liability of coal to break into smaller pieces when subjected to repeated handling at the mine or subsequently, by the distributor or by the consumer. This method is serviceable for ascertaining the similarity of coals in respect to friability rather than for determining values within narrow limits in order to emphasize their dissimilarity. This method also may serve to indicate the relative extent to which sized coals will suffer size degradation in certain mechanical feed devices. This method may be employed for differentiating between certain ranks and grades of coals, and therefore the method is of service for coal classification purposes.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characterization and Beneficiation of Coal and Coal Slurries.

---

**Title:** Standard Test Method for Index of Dustiness of Coal and Coke

**Citation:** ASTM D 547-41 (1980)  
Intent to withdraw

**Content:** This method covers the determination of a relative index of the dust produced when handling coal or coke.

**Availability:** ASTM

---

**Title:** Standard Methods for Chemical Analysis of Wood Charcoal<sup>1</sup>

**Citation:** ASTM D 1762-84

**Content:** This method covers the determination of moisture, volatile matter, and ash in charcoal made from wood. The method is applicable to lumps and briquets and is designed for the evaluation of charcoal quality. The method employs apparatus that is found in most laboratories and is adapted to routine analyses of a large number of samples.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.14 on Chemical Tests.

---

**Title:** Standard Test Method for Fusibility of Coal and Coke Ash<sup>1</sup>

**Citation:** ASTM D 1857-68 (1987)

**Content:** This test method covers the observation of the temperatures at which triangular pyramids (cones) prepared from coal and coke ash attain and pass through certain

defined stages of fusing and flow when heated at a specified rate in controlled, mildly reducing, and where desired, oxidizing atmospheres.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Test Method for Plastic Properties of Coal by the Constant-Torque Gieseler Plastometer<sup>1</sup>

**Citation:** ASTM D 2639-74 (1985)

**Content:** This test method gives a relative measure of the plastic behavior of coal when heated under prescribed conditions. This test method may be used to obtain semiquantitative values of the plastic properties of coals and blends used in carbonization and in other situations where determination of plastic behavior of coals is of practical importance.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.15 on Plasticity and Swelling of Coal.

---

**Title:** Standard Method of Drop Shatter Test for Coke<sup>1</sup>

**Citation:** ASTM D 3038-72 (1983)

**Content:** This method covers two procedures for the determination of the property of coke of withstanding breakage when dropped under specified test conditions.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.22 on Physical Tests.

---

**Title:** Standard Method for Calculating Coal and Coke Analyses from As-Determined to Different Bases<sup>1</sup>

**Citation:** ASTM D 3180-84

**Content:** This method gives formulas to enable analytical data to be expressed on various different bases in common use. Such bases are: as received; dry; equilibrium moisture; dry ash free; and others.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

---

**Title:** Standard Method of Tumbler Test for Coke<sup>1</sup>

**Citation:** ASTM D 3402-81

**Content:** This method covers a procedure for obtaining a relative measure of the resistance of coke to degradation by impact and abrasion.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.22 on Physical Tests of Coke.

---

**Title:** Standard Method for Calculating Refuse-Derived Fuel Analysis Data from As-Determined to Different Bases<sup>1</sup>

**Citation:** ASTM E 791-87

**Content:** This method gives equations to enable analytical data from the application of RDF analyses procedures to be expressed on various different bases in common use. Such bases are: as-received; dry; dry, ash-free; and others.

## SOLID FUELS (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Standard Definitions of Terms and Abbreviations Relating to Physical and Chemical Characteristics of Refuse-Derived Fuel<sup>1</sup>

**Citation:** ASTM E 856-87

**Content:**

**Availability:** ASTM

---

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee E-38 on Resource Recovery and are the direct responsibility of Subcommittee E38.01 on Energy.

---

**Title:** Standard Test Methods for Analysis of Wood Fuels<sup>1</sup>

**Citation:** ASTM E 870-82 (1987)

**Content:** These test methods cover the proximate and ultimate analysis of wood fuels and the determination of the gross caloric value of wood fuels sampled and prepared by prescribed test methods and analyzed according to ASTM established procedures. Test methods as herein described may be used to establish the rank of fuels, to show the ratio of combustible to incombustible constituents, to provide the basis for buying and selling, and to evaluate for beneficiation or for other purposes.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee E-48 on Biotechnology and are the direct responsibility of Subcommittee E48.05 on Biomass Conversion Systems.

---

**Title:** Standard Test Method for Fusibility of Refuse-Derived Fuel 3 (RDF-3) Ash<sup>1</sup>

**Citation:** ASTM E 953-88

**Content:** This test method covers the observation of the temperatures at which triangular pyramids (cones) prepared from RDF-3 ash attain and pass through certain stages of fusing and flow when heated at a specific rate in controlled, mildly-reducing, and oxidizing atmospheres. The test method is empirical, and strict observance of the requirements and conditions is necessary to obtain reproducible temperatures and enable different laboratories to obtain concordant results.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E 38.01 on Energy.

---

**Title:** Standard Test Method for Characterizing the Performance of Refuse Size-Reduction Equipment<sup>1</sup>

**Citation:** ASTM E 959-83 (1988)

**Content:** This test method covers measuring the performance of solid-waste, size-reduction equipment.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.08 on Processing Equipment and Unit Operations.

---

**Title:** Standard Practice for Maintaining Health and Safety Records at Solid Waste Processing Facilities<sup>1</sup>

**Citation:** ASTM E 1076-85

**Content:** The purpose of this practice is to provide guidance to solid waste processing facility managers responsible for maintaining

records of the health and safety experience of their employees. This practice describes general principles for establishing a procedure to collect and document health and safety data within a solid waste processing facility and provides specific information on the forms and procedures to be used in recording illnesses among employees.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.07 on Health and Safety Aspects of Resource Recovery.

---

**Title:** Standard Method for Measuring the Throughput of Resource-Recovery Unit Operations<sup>1</sup>

**Citation:** ASTM E 1107-86

**Content:** This method is for measuring the throughput, or mass flowrate, of a resource-recovery unit operation, or series of unit operations.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.08 on Processing Equipment and Unit Operations.

---

**Title:** Standard Test Method for Determination of the Recovery of a Product in a Materials Separation Device<sup>1</sup>

**Citation:** ASTM E 1108-86

**Content:** This test method covers the determination of the recovery of a desired product in a device processing solid waste for the purpose of concentrating a component of interest. The recovery is determined with respect to the amount of the desired component in the output stream (accepts) as opposed to another output stream (rejects). The results of this calculation determine the effectiveness of component separation when

coupled with a measure of product purity as described in Test Method E 889.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-38 on Resource Recovery and is the direct responsibility of Subcommittee E38.08 on Processing Equipment and Unit Operations.

---

**Title:** Standard Terminology Relating to Biomass Fuels<sup>1</sup>

**Citation:** ASTM E 1126-86

**Content:**

**Availability:** ASTM

---

<sup>1</sup>This terminology is under the jurisdiction of ASTM Committee E-48 on Biotechnology and is the direct responsibility of Subcommittee E48.05 on Biomass Conversion Systems.

---

**Title:** Test Method for the Durability of Biomass Pellets

**Citation:** ASTM E 1288-89

**Content:**

**Availability:** ASTM

---

**Title:** Methods for Analysis and Testing of Coal and Coke

**Citation:** BS 1016 (Many Parts)

**Content:**

**Availability:** BSI

---

## SOLID FUELS (STANDARDS)

**Title:** Testing of Solid Fuels; General and Survey of Methods of Test

**Citation:** DIN 51700, Part 1

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Sampling and Sample Preparation: Sampling

**Citation:** DIN 51700, Parts 2-4

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Generalities and Index of Methods of Test

**Citation:** E DIN 51700

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Chemical Composition of Fuel Ash

**Citation:** DIN 51729, Parts 1-9

**Content:**

**Availability:** DIN

---

**Title:** Testing of Solid Fuels; Determination of Fusibility of Fuel Ash

**Citation:** DIN 51730

**Content:**

**Availability:** DIN

---

**Title:** Solid Fuel: Method for Determination of High Heat Value and Calculation of Low Heat Value

**Citation:** GOST 147-74

**Content:** The standard specifies a method for determination of the high heat value and calculating the low heat value of coal, brown coal, anthracite, oil shale, and lignites as well as the products of their beneficiation and heat treatment, coal breaks and peat breaks and peat.

**Availability:** GOST

---

**Title:** Solid Mineral Fuels--Determination of Fusibility of Ash--High Temperature Tube Method

**Citation:** ISO 540:1981

**Content:**

**Availability:** ISO

---

**Title:** Coke (greater than 20 mm in size)--Determination of Mechanical Strength

**Citation:** ISO 556:1980

**Content:**

**Availability:** ISO

---

**Title:** Outdoor Storage of Wood Chips

**Citation:** NFPA 46A-1973

**Content:**

**Availability:** NFPA

---

**Title:** Methods for the Analysis and Testing of Coal and Coke

**Citation:** AS 1038

**Content:**

- Part 1-1980: Total Moisture in Hard Coal
- Part 2-1979: Total Moisture in Coke
- Part 3-1979: Proximate Analysis of Hard Coal
- Part 4-1979: Proximate Analysis of Coke
- Part 5-1979: Gross Specific Energy of Coal and Coke
- Part 6.1-1986: Ultimate Analysis of Higher Rank Coal-Determination of Carbon and Hydrogen
- Part 6.2-1986: Ultimate Analysis of Higher Rank Coal-Determination of Nitrogen
- Part 6.3.1-1986: Ultimate Analysis of High Rank Coal-Determination of Total Sulphur (Eschka Method)
- Part 6.3.2-1986: Ultimate Analysis of High Rank Coal-Determination of Total Sulphur (High Temperature Combustion Method) Amdt 1, Sept. 1986
- Part 6.3.3-1986: Ultimate Analysis of Higher Rank Coal-Determination of Total Sulphur (Infrared Method)
- Part 7-1981: Ultimate Analysis of Coke
- Part 8-1980: Chlorine in Coal and Coke

- Part 9-1977: Phosphorus in Coal and Coke
- Part 10-1980: Arsenic in Coal and Cokes
- Part 10.1-1986: Determination of Trace Elements-Determination of Eleven Trace Elements in Coal, Coke and Fly-Ash--Flame Atomic Absorption Spectrometric Method
- Part 11-1982: Forms of Sulphur in Coal
- Part 12.1-1984: Determination of Crucible Swelling Number of Coal Part 12.2-1980: Assessment of Caking Power of Hard Coal Gray-King Coke Type Test
- Part 12.3-1984: Determination of the Dilatometer Characteristics of Higher Rank Coal
- Part 13-1976: Tests Special to Coke
- Part 14.1-1981: Analysis of Coal Ash, Coke Ash and Mineral Matter (Borate Fusion--Flame Atomic Absorption Spectrometric Method)
- Part 14.2-1985: Analysis of Higher Rank Coal Ash and Coke Ash (Acid Digestion--Flame Atomic Absorption Spectrometric Method)
- Part 15-1987: Fusibility of Higher Rank Coal Ash and Coke Ash
- Part 16-1986: Acceptance and Reporting of Results

**Availability:** SAA

---



**Title:** Determination of Combustible Volatile Matter in Fuels

**Citation:** Ecklund, G., J. R. Pedersen, and B. Stroemberg. *Fuel* 66 (1):13-16 (Jan. 1987).

**Content:** A method for determination of combustible volatile matter by flash-pyrolysis has been developed. The analysis is applicable to fuels with H/C values ranging from 0.2 to 2.05. This range includes hard coals, lignites, peats, biomass, and fuel oil. The precision is similar to traditional gas chromatography, i.e., 6%-8%. Combustible volatile matter should be better correlated to ignitibility of solid fuels than ASTM volatile matter.

---

**Title:** Ash Fusion Temperature: A Thermodynamically Based Model

**Citation:** Rhinehard, R. R. and A. A. Attar in *Proceedings of the Tenth Annual Energy-Sources Technology Conference and Exhibition, Dallas, Texas, February 15-18, 1987*; Vol. 8. New York: The American Society of Mechanical Engineers, 1987.

**Content:** This paper describes a thermodynamically-based correlation between coal ash fusion temperatures and ash composition. A wide range of data from the literature was used to obtain the values of model parameters. A seven-parameter correlation is proposed which permits predicting the ash fusion temperature with a standard error of  $\pm 65^{\circ}\text{C}$  or better.

---

**Title:** Laboratory Procedures for the Analysis of Biomass Fuels

**Citation:** Ebeling, J. M. and B. M. Jenkins. Paper No. 84-3074, presented at the 1984 Summer Meeting, American Society of Agricultural Engineers, University of Tennessee, Knoxville, June 24-27, 1984. St. Joseph, MI: American Society of Agricultural Engineers.

**Content:** Design and analysis of biomass energy systems requires a knowledge of the physical and chemical properties of the fuels. This paper describes a set of laboratory procedures for determining moisture content; proximate, ultimate, and ash analysis; and higher heating value of biomass materials. Also included is a discussion of interpreting results and data on some potential biomass fuels analyzed at UC Davis.

---

**Title:** Fuel Characteristics of Wood and Nonwood Biomass Fuels

**Citation:** Rossi, Amadeo. *Progress in Biomass Conversion*, Vol. 5. New York: Academic Press, Inc., 1984.

**Content:** Ch. I-Introduction; Ch. II-Methodology; Ch. IIA-Proximate Analysis; Ch. IIB-Ultimate Analysis; Ch. IIC-Higher Heating Values; Ch. IID-Bulk Density; Ch. IIE-Moisture Content; Ch. IIF-Screen Fractionation; Ch. IIG-Ash Fusion Temperature; Ch. III-Results; Ch. IIIA-Proximate Analysis; Ch. IIIB-Ultimate Analysis; Ch. IIIC-Higher Heating Values; Ch. IIID-Bulk Density; Ch. IIIE-Screen Fractionation; Ch. IIIF-Ash Fusion Temperature; Ch. IV-Discussion; Ch. IVA-Chemical Characterization of Biomass Fuels; Ch. IVB-Existing Combustion Facilities; Ch. V-Conclusions.

---

## SOLID FUELS (LITERATURE)

**Title:** Coal Processing Technology

**Citation:** A CEP technical manual published by AIChE. Prepared by editors of *Chemical Engineering Progress*.

**Content:** Individual articles treat a multitude of coal processes, in multiple volumes.

---

**Title:** Ash Chemical Composition, Deformation and Fusion Temperatures for Wood and Agricultural Residues

**Citation:** Osman, E. A. and J. R. Goss. Paper No. 83-3549, presented at the 1983 Winter Meeting, American Society of Agricultural Engineers, Chicago, Illinois, December 13-16, 1983. St. Joseph, MI: American Society of Agricultural Engineers.

**Content:** The elemental chemical and computed oxides for the ash from 26 biomass fuel samples are reported along with the ash deformation and fusion temperatures for each sample.  $\text{SiO}_2$  was found to be the main constituent of almost all ash samples.  $\text{CaO}$  and  $\text{K}_2\text{O}$  constituted most of the ash content. Twenty-one of the 25 samples had deformation temperatures above  $800^\circ\text{C}$ .

---

**Title:** Ash Deformation and Fusion Temperature Models for Wood and Agricultural Residues

**Citation:** Osman, E. A. and J. R. Goss. Paper No. 83-3550, presented at the 1983 Winter Meeting, American Society of Agricultural Engineers, Chicago, Illinois, December 13-16, 1983. St. Joseph, MI: American Society of Agricultural Engineers.

**Content:** Twenty-six determinations of biomass ash chemical constituents from which nine independent variables ( $\text{SiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{ZnO}$ ,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{SO}_3$ ,  $\text{P}_2\text{O}_5$ ) and one dependent variable (ash deformation or fusion temperature) were entered into the Minitab II multiple linear regression program to predict ash deformation and fusion temperatures.

---

**Title:** Physical and Chemical Properties of Biomass Fuel

**Citation:** Ebeling, J. M. and B. M. Jenkins. Paper No. 83-3546, Presented at the 1983 Winter Meeting, American Society of Agricultural Engineers, Chicago, Illinois, December 13-16, 1983. St. Joseph, MI: American Society of Agricultural Engineers.

**Content:** A preliminary set of physical and chemical properties of biomass fuels are presented. Included are ultimate and proximate chemical analysis, heating value (higher and lower), bulk density, and ash composition. Mathematical methods for relating various properties are described and the influence of moisture content discussed.

---

**Title:** Rapid Analysis of Important Fuel Properties by FT-IR Spectroscopy

**Citation:** Aho, M. and P. Kortelainen. To be published in Finnish Journal *Suo*, 1989.

**Content:**

---

**Title:** Optical and Chemical Characterization of Solid Residues Obtained from Vacuum Pyrolysis of Wood (Aspen Poplar)

**Citation:** Kalkreuth, W., D. Brouillard, and C. Roy. *Biomass* 10:27-45 (1986).

**Content:** Laboratory scale vacuum pyrolysis experiments on the thermal conversion of wood (aspen poplar) are reported. The conversion of wood into gaseous and liquid products was found to be almost complete at  $400^\circ\text{C}$  where the pyrolytic oil yield was 62% by weight, with 83% of wood being converted. The major pyrolytic reaction zone was between  $225^\circ$  and  $300^\circ\text{C}$ . Solid residues obtained from these experiments were characterized by methods of incident light microscopy and elemental analysis. The wood was transformed into vitrinite-like substances which resemble morphologically cell

tissues commonly encountered in the petrographic analysis of peats and coals. Fluorescence and reflectance measurements obtained from the residual materials indicate severe alterations within the organic material leading at elevated temperatures to reflectance values which correspond to the semi-anthracite rank level of coals. The increase of reflectance as reaction temperature increases correlates well with increasing carbon content and a decrease in the H/C-O/C-atomic ratios of the residual materials. There was a good correlation between calorific values determined on the residues and optimal parameters such as  $\lambda_{\max}$ , Q and random reflectance. Results suggest that vacuum pyrolysis has potential as a method for production of liquid products from biomass.

**Title:** ESCA Analysis of Partially Converted Lignocellulosic Materials

**Citation:** Ahmed, A., A. Adnot, and S. Kaliaguine. *Journal of Applied Polymer Science* 35:1909-1919 (1988).

**Content:** Further ESCA data of the solid residues obtained by supercritical extraction of *Populus tremuloides* are reported. The changes of the ESCA spectra with the severity of grinding are discussed. These data allow us to draw precise conclusions on the spatial distribution of carbonaceous recondensed material as thermal conversion proceeds. The  $C_{1s}$  peaks are of special interest as the distribution of the four components in these peaks bears information on the nature of the chemical compounds present on the surface of the sample.

**Title:** ESCA Study of the Solid Residues of Supercritical Extraction of *Populus tremuloides* in Methanol

**Citation:** Ahmed, A., A. Adnot, and S. Kaliaguine. *Journal of Applied Polymer Science* 34:359-375 (1987).

**Content:** A systematic ESCA study of the solid residues of supercritical extraction of *Populus tremuloides* prepared

in various conditions has been performed. Reference materials also examined by ESCA included the initial wood, Whatman no. 1 paper, and two lignins prepared by different procedures. Interest has been focused on the  $C_{1s}$  spectra and on the determination of surface O/C atomic ratio. A difference between bulk O/C values measured by chemical analysis and surface O/C ratios obtained from ESCA data is considered diagnostic of a difference in chemical composition of the bulk and the surface. In the  $C_{1s}$  peaks of wood and its constitutive polymers, the usual components peaks,  $C_1$ ,  $C_2$ , and  $C_3$  were observed. For the solid residues, however, a fourth peak designated as  $C_0$  appears, the importance of which increases steadily when the temperature of extraction is raised from 250° to 350°C. The component  $C_0$  was ascribed to polyaromatic constituents. Its proportion is correlated with the fraction of the carbon in the residue comprised in the recondensed material and determined independently. The  $O_{1s}$  peak shows also a complex structure with three components in the wood-derived reference materials and four in some of the solid residues. These structures have not been discussed previously in the literature and a tentative assignment for the component peaks is proposed.

**Title:** Characterization of the Solid Residues of Vacuum Pyrolysis of *Populus tremuloides*

**Citation:** Ahmed, A., H. Pakdel, C. Roy, and S. Kaliaguine. Accepted for publication in, *J. of Anal. Pyrolysis*, 1989.

**Content:** Bulk chemical analyses and surface composition ESCA results are reported for the solid residues of vacuum pyrolysis of *Populus tremuloides*.

The conversions of hemicellulose and lignin start as low as 207°C, but below 280°C the conversion products of lignin are mostly solids. Cellulose is converted to oil and gas above 280°C, but some of these products undergo secondary recondensation reactions which involve lignin degradation solid products. The char obtained above 315°C mostly consists of polyaromatic materials.

## SOLID FUELS (LITERATURE)

The ESCA analysis of chars produced from extracted and non-extracted wood indicate the presence of extractives with hydrocarbon chains on the surface of the fibers. These heavy components seem very resistant to thermal degradation and remain on the surface of the residues up to 400°C even under vacuum conditions. The effect of these extractives on the liquefaction of wood is discussed.

---

**Title:** Analysis of Wood Vacuum Pyrolysis Solid Residues by Diffuse Reflectance Infrared Fourier Transform Spectrometry

**Citation:** Pakdel, H., J. L. Grandmaison, and C. Roy. Accepted for publication in *Canadian Journal of Chemistry*, June 1988.

**Content:** Vacuum pyrolysis of wood enables the production of high yields of oils which are a source of liquid fuels and chemicals. Wood charcoal is a solid residue byproduct. Chemical analysis of chars produced at different pyrolysis temperatures in a Process Development Unit was performed. Solid residues produced at 200°, 263°, 327°, 363°, 401° and 448°C were analyzed using wet chemistry together with chromatographic and infrared spectrometric methods.

A Diffuse Reflectance Infrared Fourier Transform (DRIFT) study of the solid residues which contained various proportions of organic matters was performed. Unconverted lignin, polysaccharides and recondensed materials constituted the organic matters. The polysaccharide content was determined by hydrolysis in trifluoroacetic acid followed by derivatization and gas chromatography analysis. The IR study showed that the solid residue retained its wood nature below 263°C. Significant degradation, decomposition and recondensation reactions occurred with an increase in temperature and coal-like nature prevailed above 327°C. Occurrence of a new band at 1700 cm<sup>-1</sup> in samples produced at 363°C and above was found to be indicative of a new carbonyl group, presumably in recondensed material.

A series of equations was also developed to calculate Klason residue, glucose and xylose content of the solid residues. The usefulness of each equation is discussed in the article.

---

**Title:** Critical Analysis of the Dry Process Improvement of Ligneous Materials for Energy-Producing Purposes--Final Report. (Commission des Coramusanter Europeennes)

**Citation:** Carre, J., J. Hebert, and L. Lacrosse. Ministere Belge de L'Agriculture Centre de Recherches Agronomiques de L'Etat Gembloux (CRA)

**Content:**

- Ch 1 Fuel Application Qualification Test Methods of Ligneous-Cellulosic Materials
  - Ch 2 Usage Aptitude Tests on Compressed Ligno-Cellulosic Materials
  - Ch 3 Experimental Results
  - Ch 4 Technical Provisions (In English)
- 

**Title:** Pyrolysis-High Resolution Gas Chromatography and Pyrolysis Gas Chromatography-Mass Spectrometry of Kerogens and Kerogen Precursors

**Citation:** Van De Meent, Dik, Stephen C. Brown, R. Paul Philp, and Bernd R. T. Simoneit. *Geochemica et Cosmochemica Acta* 44:999-1013.

**Content:** A series of kerogens and kerogen precursors isolated from DSDP samples, oil shales and recent algal mats have been examined by Curie point pyrolysis-high resolution gas chromatography and gas chromatography-mass spectrometry. This study has shown that the three main types of kerogens (marine terrestrial and mixtures of both) can be characterized using these techniques. The marine (algal) kerogens yield principally aliphatic products and the terrestrial kerogens yield more aromatic and phenolic products with some *n*-alkanes and *n*-alkenes. The yields of *n*-alkanes and *n*-alkenes increase and phenols decrease with

increasing geologic age, however, pyrolysis-GC cannot be used to characterize the influence of short term diagenesis on the kerogen structure.

---

**Title:** Characterization of U.S. Lignites by Pyrolysis Mass Spectrometry and Multivariate Analysis

**Citation:** Metcalf, G. Stephen, Willem Windig, George R. Hill, and Henk L. C. Meuzelaar. *International Journal of Coal Geology* 7:245-268 (1987).

**Content:** Sixteen Texas (Gulf Province) lignite samples and six Montana and Wyoming (Northern Great Plains Province) lignitic coals were obtained from the Pennsylvania State University Coal Bank and analyzed in triplicate by pyrolysis mass spectrometry (Py-MS) using Curie-point pyrolysis (equilibrium temp. 610°C) in combination with low-voltage (12 eV) electron ionization. The spectra obtained were evaluated by means of factor analysis, followed by discriminant analysis using only factors with eigenvalue  $\geq 1$  and regarding each set of triplicate spectra as a separate category. The discriminant analysis results showed a definite separation between lignites from the two provinces as well as some clustering of samples from the same seam field or region. Six additional lignite samples obtained from an independent source and representing other regions of the Gulf Province were found to cluster with the Texas lignite samples when treated as "unknowns" in the discriminant analysis procedure.

---

**Title:** Remarks on the Terminology Used for the Chemical Transformations of Fuels

**Citation:** Roy, C. and E. Chornet. *Fuel Processing Technology* 2:209-213 (1979).

**Content:** The technical vocabulary used to describe the chemical transformations of fuels is critically revised with the objective of establishing a simple and coherent classification. The criterion used for such classification is based on the unique and specific chemical nature of each of the transformations. Thus three distinct categories are defined: thermal decomposition reactions, oxidation reactions and reduction reactions. The scope of application of these categories as well as their subdivisions is also discussed.

---

**Title:** Are Pellet Standards too Strict?

**Citation:** *Wood N Energy*, January 1989. pp. 6-7.

**Content:** Discusses and lists pellet fuel specifications.

---



**Title:** Manual of Petroleum Measurement Standards (Complete Set)

**Citation:**

**Content:** The Institute currently maintains a comprehensive *API Manual of Petroleum Measurement Standards*. This manual is an ongoing project, as new chapters and revisions of old chapters will be released periodically.

**Availability:** API

---

**Title:** Diesel and Burner Fuels

**Citation:** ASME PTC 3.1-58

**Content:**

**Availability:** ASME

---

**Title:** Determination of the Viscosity of Liquids Instruments and Apparatus

**Citation:** ASME PTC 19.17-65

**Content:**

**Availability:** ASME

---

**Title:** Test Method for Flash Point by Tag Closed Tester

**Citation:** ASTM D 56-87

**Content:**

**Availability:** ASTM

---

**Title:** Standard Method for Distillation of Petroleum Products<sup>1</sup>

**Citation:** ASTM D 86-82

**Content:** This method covers the distillation of motor gasolines, aviation gasolines, aviation turbine fuels, special boiling point spirits, naphthas, white spirit, kerosines, gas oils, distillate fuel oils, and similar petroleum products.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Saybolt Viscosity<sup>1</sup>

**Citation:** ASTM D 88-81 (1987)

**Content:** This test method covers the empirical procedures for determining the Saybolt Universal or Saybolt Furol viscosities of petroleum products at specified temperatures between 21° and 99°C (70° and 210°F). A special procedure for waxy products is indicated.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-8 on Roofing, Waterproofing, and Bituminous Materials and is the direct responsibility of Subcommittee D08.05 on Solvent-Bearing Bituminous Compounds for Roofing and Waterproofing.

---

**Title:** Standard Test Method for Flash and Fire Points by Cleveland Open Cup<sup>1</sup>

**Citation:** ASTM D 92-85

**Content:** This test method covers determination of the flash and fire points of all petroleum products except fuel oils and those having an open cup flash below 175°F (79°C).

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.08 on Volatility.

---

## PETROLEUM-DERIVED LIQUID FUELS (STANDARDS)

**Title:** Standard Test Methods for Flash Point by Pensky-Martens Closed Tester<sup>1</sup>

**Citation:** ASTM D 93-85

**Content:** These test methods cover the determination of the flash point by Pensky-Martens closed-cup tester of fuel oils, lube oils, suspensions of solids, liquids that tend to form a surface film under test conditions, and other liquids.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and are the direct responsibility of Subcommittee D02.08 on Volatility.

---

**Title:** Standard Test Method for Pour Point of Petroleum Oils<sup>1</sup>

**Citation:** ASTM D 97-87

**Content:** The test for pour point is intended for use on any petroleum oil. A procedure suitable for black oils, cylinder stock, and nondistillate fuel oil is described.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test<sup>1</sup>

**Citation:** ASTM D 130-83

**Content:** This method covers the detection of the corrosiveness to copper of aviation gasoline, aviation turbine fuel, automotive gasoline, natural gasoline or other hydrocarbons having a Reid vapor pressure no greater than 18 psi (124 kPa), cleaners (Stoddard) solvents, kerosine, diesel fuel, distillate fuel

oil, lubricating oil, and certain other petroleum products.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.05 on Physical Analysis of Fuels and Light Distillates.

---

**Title:** Standard Test Method for Conradson Carbon Residue of Petroleum Products<sup>1</sup>

**Citation:** ASTM D 189-88

**Content:** This test method covers the determination of the amount of carbon residue left after evaporation and pyrolysis of an oil, and is intended to provide some indication of relative coke-forming propensities. The method is generally applicable to relatively nonvolatile petroleum products which partially decompose on distillation at atmospheric pressure. Petroleum products containing ash-forming constituents as determined by ASTM Test Method D 482 or IP Method 4, Test for Ash from Petroleum Products, will have an erroneously high carbon residue, depending upon the amount of ash formed.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Method for Distillation of Natural Gasoline<sup>1</sup>

**Citation:** ASTM D 216-77 (1982)

**Content:** This method covers the distillation of natural gasoline. A sample of 100 ml is distilled at atmospheric pressure without fractionation, and readings are taken of the vapor temperatures corresponding to the amounts distilled.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Method for Distillation of Crude Petroleum<sup>1</sup>

**Citation:** ASTM D 285-62 (1978)  
Discontinued 1987

**Content:** This method covers the determination of the percentages and distillation range of the naphtha in any crude petroleum of the class known commercially as refinable crude oils. This method does not attempt to specify what quality of product shall be defined as naphtha, nor can it be expected to duplicate the results of commercial refining operations. It specifies apparatus and procedure, leaving selection of numerical limits and interpretation of results to be agreed upon by the interested parties.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)<sup>1</sup>

**Citation:** ASTM D 323-82

**Content:** This test method covers a determination of vapor pressure of gasoline. It is also applied to volatile crude oil and other volatile petroleum products, except liquefied petroleum gases.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Specification for Fuel Oils<sup>1</sup>

**Citation:** ASTM D 396-86

**Content:** This specification covers grades of fuel oil intended for use in various types of fuel-oil-burning equipment under various climatic and operating conditions. This specification is for the use of purchasing agencies in formulating specifications to be included in contracts for purchases of fuel oils and for the guidance of consumers of fuel oils in the selection of the grades most suitable for their needs.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.E on Burner, Diesel, and Gas Turbine Fuels Oils.

---

**Title:** Standard Specification for Automotive Gasoline<sup>1</sup>

**Citation:** ASTM D 439-86

**Content:** This specification guides in establishing the requirements of gasoline for ground vehicles equipped with spark-ignition engines. This specification describes various characteristics of gasolines for use over a wide range of operating conditions. It neither necessarily includes all types of gasolines that are satisfactory for automotive vehicles, nor necessarily excludes gasolines that may perform unsatisfactorily under certain operating conditions or in certain equipment.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.A on Gasoline.

---

## PETROLEUM-DERIVED LIQUID FUELS (STANDARDS)

**Title:** Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)<sup>1</sup>

**Citation:** ASTM D 445-86

**Content:** This test method covers the determination of the kinematic viscosity of liquid petroleum products, both transparent and opaque, by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer. The dynamic viscosity can be obtained by multiplying the measured kinematic viscosity by the density of the liquid.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties.

---

**Title:** Test Method for Sediment in Crude Oils and Fuel Oils by the Extraction Method

**Citation:** ASTM D 473-87

**Content:**

**Availability:** ASTM

---

**Title:** Standard Test Method for Oxidation Stability of Gasoline (Induction Period Method)<sup>1</sup>

**Citation:** ASTM D 525-86

**Content:** This test method covers the determination of the stability of gasoline under accelerated oxidation conditions.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.09 on Oxidation.

---

**Title:** Standard Test Method for Ignition Quality of Diesel Fuels by the Cetane Method<sup>1</sup>

**Citation:** ASTM D 613-86

**Content:** This test method describes the test for determining the ignition quality of diesel fuels in terms of ASTM cetane number.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration<sup>1</sup>

**Citation:** ASTM D 664-87

**Content:** This test method covers procedures for the determination of acidic constituents in petroleum products and lubricants. The test method resolves these constituents into groups having weak-acid and strong-acid, ionization properties, provided the dissociation constants of the more strongly acidic compounds are at least 1000 times that of the next weaker groups.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.06 on Analysis of Lubricants.

---

**Title:** Standard Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water<sup>1</sup>

**Citation:** ASTM D 665-82

**Content:** This method is used to evaluate the ability of inhibited mineral oils, particularly steam-turbine oils, to aid in preventing the rusting of ferrous parts should water become mixed with the oil. This method is also used for testing other oils, such as hydraulic oils and circulating oils. Provision is made in the procedure for testing heavier-than-water fluids.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Knock Characteristics of Aviation Gasolines by the Supercharge Method<sup>1</sup>

**Citation:** ASTM D 909-86

**Content:** This test method covers the determination of the knock-limited power, under supercharge rich-mixture conditions, of fuels for use in spark-ignition reciprocating aircraft engines, in terms of ASTM supercharge. By operational considerations, this method is restricted to testing fuels of 85 ASTM supercharge octane number and over.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Neutralization Number by Color-Indicator Titration<sup>1</sup>

**Citation:** ASTM D 974-87

**Content:** This method covers the determination of acidic or basic constituents in petroleum products and lubricants soluble or nearly soluble in mixtures of toluene. It is applicable for the determination of acids or bases whose dissociation constants in water are larger than  $10^{-9}$ ; extremely weak acids or bases whose dissociation constants are smaller than  $10^{-9}$  do not interfere. Salts react if their hydrolysis constants are larger than  $10^{-9}$ .

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Specification for Diesel Fuel Oils<sup>1</sup>

**Citation:** ASTM D 975-81

**Content:** This specification covers three grades of diesel fuel oils suitable for various types of diesel engines. This specification, unless otherwise provided by agreement between the purchaser and the supplier, prescribes the required properties of diesel fuels at the time and place of delivery.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

## PETROLEUM-DERIVED LIQUID FUELS (STANDARDS)

**Title:** Standard Test Method for Distillation Range of Volatile Organic Liquids<sup>1</sup>

**Citation:** ASTM D 1078-86

**Content:** This test method covers the determination of the distillation range of liquids boiling between 30° and 350°C, that are chemically stable during the distillation process. This test method is applicable to organic liquids such as hydrocarbons, oxygenated compounds, chemical intermediates, and blends thereof.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.35 on Solvents, Plasticizers, and Chemical Intermediates.

---

**Title:** Standard Test Method for Bromine Number of Petroleum Distillates and Commercial Aliphatic Olefins by Electrometric Titration<sup>1</sup>

**Citation:** ASTM D 1159-84

**Content:** This method covers the determination of the bromine number of the following materials: (1) Petroleum distillates that are substantially free of material lighter than isobutane and that have 90% distillation points under 327°C (620°F). The method is generally applicable to gasoline (including leaded fuels), kerosine, and distillates in the gas oil range that fall in the following limits, but not when blending agents such as alcohols, ketones, ethers, or amines are present. (2) Commercial olefins that are essentially mixtures of aliphatic mono-olefins and that fall within the range from 95 to 165 bromine number. The method has been found suitable for such materials as commercial propylene trimer and tetramer, butene dimer, and mixed nonenes, octenes, and heptenes. The method is not satisfactory for normal alpha-olefins.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Distillation of Petroleum Products at Reduced Pressures<sup>1</sup>

**Citation:** ASTM D 1160-87

**Content:** This test method covers the determination, at reduced pressures, of the boiling temperature ranges of petroleum products that can be partially or completely vaporized at a maximum liquid temperature of 750°F (400°C) at pressures of 50 to 1 mm Hg (6.55 to 0.133 kPa), absolute.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.08 on Volatility.

---

**Title:** Standard Test Method for Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus<sup>1</sup>

**Citation:** ASTM D 1310-86

**Content:** This test method covers the determination by Tag Open-Cup Apparatus of the flash point and fire point of liquids having flash points between 0° and 325° (-18° and 165°C) and fire points up to 325°F. This test method, when applied to paints and resin solutions that tend to skin over or that are very viscous, gives less reproducible results than when applied to solvents.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.22 on Health and Safety.

---

**Title:** Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption<sup>1</sup>

**Citation:** ASTM D 1319-84

**Content:** This test method covers the determination of hydrocarbon types over the concentration ranges from 5 to 99 volume % aromatics, 0.3 to 55 volume % olefins, and 1 to 95 volume % saturates in petroleum fractions that distill below 600°F (315°C). The method may apply to concentrations outside these ranges, but the precision has not been determined.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analyses.

---

**Title:** Standard Specification for Aviation Turbine Fuels<sup>1</sup>

**Citation:** ASTM D 1655-88

**Content:** This specification is for the use of purchasing agencies in formulating specifications for purchases of aviation turbine fuel under contract. This specification defines specific types of aviation turbine fuel for civil use. It does not include all fuels satisfactory for aviation turbine engines. Certain equipment or conditions of use may permit a wider, or require a narrower, range of characteristics than is shown by the specification.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.J on Aviation Fuels.

---

**Title:** Standard Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels<sup>1</sup>

**Citation:** ASTM D 2156-80

**Content:** This method covers the evaluation of smoke density in the flue gases from burning distillate fuels. It is intended primarily for use with home heating equipment burning kerosine or heating oils. It may be used in the laboratory or in the field to compare fuels for clean burning or to compare heating equipment.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Method for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity or to Saybolt Furol Viscosity<sup>1</sup>

**Citation:** ASTM D 2161-87

**Content:** This method covers the conversion tables and equations for converting kinematic viscosity in centistokes (cSt) at any temperature to Saybolt Universal viscosity in Saybolt Universal seconds (SUS) at the same temperature and for converting kinematic viscosity in centistokes at 122° and 210°F to Saybolt furol viscosity in Saybolt Furol seconds (SFS) at the same temperatures. Kinematic viscosity values are based on water being 1.0038 cSt at 68°F (20°C).

# PETROLEUM-DERIVED LIQUID FUELS (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Test Method for Viscosity Measurements and Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer

**Citation:** ASTM D 2196-81

**Content:**

**Availability:** ASTM

---

**Title:** Standard Method for Calculating Viscosity Index from Kinematic Viscosity at 40° and 100°C<sup>1</sup>

**Citation:** ASTM D 2270-86

**Content:** This method specifies the procedures for calculating the viscosity index of petroleum products, such as lubricating oils, and related materials from their kinematic viscosities at 40° and 100°C. Procedure A - For petroleum products of viscosity index up to and including 100. Procedure B - For petroleum products of which the viscosity index is 100 or greater.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry<sup>1</sup>

**Citation:** ASTM D 2425-83

**Content:** This test method covers an analytical scheme using the mass spectrometer to determine the hydrocarbon types present in virgin middle distillates 400° to 650°F (204° to 343°C) boiling range, 5 to 95 volume % as

determined by Method D 86. Samples with average carbon number value of paraffins C<sub>12</sub> and C<sub>16</sub> and containing paraffins from C<sub>10</sub> and C<sub>18</sub> can be analyzed. Eleven hydrocarbon types are determined. These include: paraffins, noncondensed cycloparaffins, condensed dicycloparaffins, condensed tricycloparaffins, alkylbenzenes, indans or tetralins, or both, C<sub>n</sub>H<sub>2n-10</sub> (indenes, etc.), naphthalenes, C<sub>n</sub>H<sub>2n-14</sub> (acenaphthenes, etc.), C<sub>n</sub>H<sub>2n-16</sub> (acenaphthylenes, etc.), and tricyclic aromatics.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analyses.

---

**Title:** Standard Test Method for Determination of C<sub>2</sub> Through C<sub>5</sub> Hydrocarbons in Gasolines by Gas Chromatography<sup>1</sup>

**Citation:** ASTM D 2427-87

**Content:** This test method covers the determination of the two- (C<sub>2</sub>) through five- (C<sub>5</sub>-) carbon paraffins and mono-olefins in gasolines. The concentrations by volume or weight (mass) of the following components are generally reported: Ethylene plus ethane, propane, propylene, isobutane, n-butane, butene-1 plus isobutylene, trans-butene-2, cis-butene-2, isopentane 3-methylbutene-1, n-pentane, pentene-1, 2-methylbutene-1, trans-pentene-2, cis-pentene-2, and 2-methylbutene-2.

This test method does not provide for the dT of cyclic olefins, diolefins, or acetylenes. These are usually minor components in finished gasolines. Samples to be analyzed should not contain significant amounts of material boiling lower than ethylene.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

**Title:** Standard Test Method for Cloud Point of Petroleum Oils<sup>1</sup>

**Citation:** ASTM D 2500-86

**Content:** This test method covers only petroleum oils which are transparent in layers 38 mm (1-1/2 in.) in thickness, and with a cloud point below 40°C (120°F). The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties.

---

**Title:** Standard Test Method for Estimation of Molecular Weight (Relative Molecular Mass) of Petroleum Oils from Viscosity Measurements<sup>1</sup>

**Citation:** ASTM D 2502-87

**Content:** This test method covers the estimation of the mean molecular weight (relative molecular mass) of petroleum oils from kinematic viscosity measurements at 100° and 210°F (37.78° and 98.89°C). It is applicable to samples with molecular weights in the range from 250 to 700 and is intended for use with average petroleum fractions. It should not be applied indiscriminately to oils that represent extremes of composition or possess an exceptionally narrow molecular weight (relative molecular mass) range.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

**Title:** Standard Test Method for Molecular Weight (Relative Molecular Mass) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure<sup>1</sup>

**Citation:** ASTM D 2503-82 (1987)

**Content:** This method covers the determination of the average molecular weight (relative molecular mass) of hydrocarbon oils. It can be applied to petroleum fractions with molecular weights (relative molecular mass) up to 3000; however, the precision of the method has not been established above 800 molecular weight (relative molecular mass). The method should not be applied to oils having initial boiling points lower than 220°C.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Separation of Representative Aromatics and Nonaromatics Fractions of High-Boiling Oils by Elution Chromatography<sup>1</sup>

**Citation:** ASTM D 2549-85

**Content:** This test method covers the separation and determination of representative aromatics and nonaromatics fractions from hydrocarbon mixtures that boil between 232° and 538°C (450° and 1000°F). Alternative procedures are provided for the separation of 2 g or 10 g of hydrocarbon mixture.

## PETROLEUM-DERIVED LIQUID FUELS (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

---

**Title:** Standard Test Method for Knock Characteristics of Motor Fuels by the Research Method<sup>1</sup>

**Citation:** ASTM D 2699-86

**Content:** This test method covers the determination of the knock characteristics of motor gasolines intended for use in spark-ignition engines, in terms of ASTM-IP research octane numbers.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

---

**Title:** Standard Test Method for Knock Characteristics of Motor and Aviation Fuels by the Motor Method<sup>1</sup>

**Citation:** ASTM D 2700-86

**Content:** This test method covers the determination of the knock characteristics of motor and aviation gasolines intended for use in spark-ignition engines.

The knock characteristics of motor gasolines are reported in terms of ASTM-IP motor octane numbers.

The knock characteristics of aviation gasolines are reported in terms of aviation method octane numbers below 100 and aviation method performance numbers above 100.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

---

**Title:** Standard Test Method for Hydrocarbon Types Analysis of Gas-Oil Saturates Fractions by High Ionizing Voltage Mass Spectrometry<sup>1</sup>

**Citation:** ASTM D 2786-86

**Content:** This test method covers the determination by high ionizing voltage mass spectrometry of seven saturated hydrocarbon types and one aromatic type in saturate petroleum fractions having average carbon numbers 16 through 32. The saturate types include alkanes (0-rings), single-ring naphthenes, and five fused naphthene types with 2, 3, 4, 5, and 6 rings. The nonsaturate type is monoaromatic. Noncondensed naphthenes are analyzed as single rings. Samples must be nonolefinic and must contain less than 5 volume % monoaromatic. Composition data are in volume percent.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

---

**Title:** Standard Test Method for Hydrocarbon Types in Low Olefinic Gasoline by Mass Spectrometry<sup>1</sup>

**Citation:** ASTM D 2789-86

**Content:** This test method covers the determination by mass spectrometry of the total paraffins, monocycloparaffins, dicycloparaffins, alkylbenzenes, indans or tetralins or both, and naphthalenes in gasoline having an olefin content of less than 3 volume % and a 95% distillation point of less than 210°C (411°F) as determined in accordance with Method D 86. Olefins are determined by Method D 1319, or by Method D 87.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

**Title:** Standard Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope<sup>1</sup>

**Citation:** ASTM D 2879-86

**Content:** This test method covers the determination of the vapor pressure of pure liquids, the pressure exerted by mixed liquids in a closed vessel at  $40 \pm 5\%$  ullage, and the initial thermal decomposition temperature of pure and mixed liquids. It is applicable to liquids that are compatible with borosilicate glass and that have a vapor pressure between 133 kPa (1.0 torr) and 101.3 kPa (760 torr) at the selected test temperatures. The method is suitable for use over the range from ambient to 748 K. The temperature range may be extended to include temperatures below ambient provided a suitable constant-temperature bath for such temperatures is used.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.11 on Engineering Science of High Performance Fluids and Solids.

---

**Title:** Standard Test Method for Research and Motor Method Octane Ratings Using On-Line Analyzers<sup>1</sup>

**Citation:** ASTM D 2885-86

**Content:** This test method covers the calibration and use of automatic analyzers for determining the antiknock quality of motor gasolines. Octane numbers from analyzers

operated in accordance with this method are equivalent to ASTM research or motor method octane numbers.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Knock Characteristics of Motor Fuels by the Distribution Octane Number (DON) Method<sup>1</sup>

**Citation:** ASTM D 2886-86

**Content:** This test method covers the determination of the knock characteristics of fuels for use in spark-ignition engines in terms of distribution octane numbers.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography<sup>1</sup>

**Citation:** ASTM D 2887-84

**Content:** This test method covers the determination of the boiling range distribution of petroleum products. The method is applicable to petroleum products and fractions with a final boiling point of 538°C (1000°F) or lower at atmospheric pressure as measured by this method. The method is not designed for use with gasoline samples or gasoline components. These samples must be analyzed by Test Method D 3710. The method is limited to samples having a boiling range greater than 55°C (100°F) and having a vapor pressure sufficiently low to permit sampling at ambient temperature.

# PETROLEUM-DERIVED LIQUID FUELS (STANDARDS)

## Availability: ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

---

**Title:** Standard Test Method for Calculation of True Vapor Pressures of Petroleum Distillate Fuels<sup>1</sup>

**Citation:** ASTM D 2889-86

**Content:** This test method describes the calculation of true vapor pressures of petroleum distillate fuels for which distillation data may be obtained in accordance with Method D 86 without reaching a decomposition point prior to obtaining 90 volume % distilled.

The test method may be used to calculate vapor pressures at temperatures between the 0% equilibrium flash temperature and the critical temperature of the fuel. Provision is included for obtaining a calculated critical temperature for fuels for which it is not known.

## Availability: ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

---

**Title:** Standard Method for Distillation of Crude Petroleum (15-Theoretical Plate Column)<sup>1</sup>

**Citation:** ASTM D 2892-84

**Content:** This method describes the procedure for the distillation of stabilized crude petroleum. It is based on a charge of 1 to 10 litres and employs a fractionating column having an efficiency of 14 to 18 theoretical plates and operated at a reflux ratio of 5:1. It specifies performance criteria for the necessary equipment and presents in schematic form some typical examples of acceptable

apparatus. The method offers a compromise between efficiency and time in order to facilitate the comparison of distillation data between laboratories.

## Availability: ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

---

**Title:** Standard Test Method for Total Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration<sup>1</sup>

**Citation:** ASTM D 2896-85

**Content:** This method covers the determination of basic constituents in petroleum products by titration with perchloric acid.

## Availability: ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

---

**Title:** Standard Test Method for Phosphorus in Gasoline<sup>1</sup>

**Citation:** ASTM D 3231-83

**Content:** This test method covers the determination of phosphorus generally present as pentavalent phosphate esters or salts, or both, in gasoline. This test method is applicable for the determination of phosphorus in the range from 0.0008 to 0.15 g P/U.S. gal, or 0.2 to 40 mg P/liter.

## Availability: ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.03 on Elemental Analysis.

---

---

**Title:** Standard Test Method for Lead in Gasoline by Atomic Absorption Spectrometry<sup>1</sup>

**Citation:** ASTM D 3237-79 (1984)

**Content:** This method covers the determination of the total lead content of gasoline within the concentration range of 0.010 to 0.10 g of lead/U.S. gal (2.5 to 25 mg/liter). The method compensates for variations in gasoline composition and is independent of lead alkyl type.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants.

---

**Title:** Standard Test Method for Aromatic Types Analysis of Gas-Oil Aromatic Fractions by High Ionizing Voltage Mass Spectrometry<sup>1</sup>

**Citation:** ASTM D 3239-86

**Content:** This test method covers the determination by high ionizing voltage, low resolution mass spectrometry of 18 aromatic hydrocarbon types and 3 aromatic thiophenotypes in straight run aromatic petroleum fractions boiling within the range from 205° to 540°C (400° to 1000°F) (corrected to atmospheric pressure). Samples must be nonolefinic, must contain not more than 1 mass % of total sulfur, and must contain not more than 5% nonaromatic hydrocarbons. Composition data are in volume percent.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

**Title:** Standard Test Method for Pumpability of Industrial Fuel Oils<sup>1</sup>

**Citation:** ASTM D 3245-85

**Content:** This test method is intended for use on petroleum fuel oils, such as those covered in Specification D 396 Grade No. 4 (Light), 4, 5 (Light), 5, and 6, or similar fuels.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties. It is based on IP 230 but contains a precision statement based on an ASTM/IP round robin using waxy and non-waxy fuel oils typical of those marketed in North America.

---

**Title:** Standard Test Method for Boiling Range Distribution of Gasoline and Gasoline Fractions by Gas Chromatography<sup>1</sup>

**Citation:** ASTM D 3710-83

**Content:** This test method covers determination of the boiling range distribution of gasoline and gasoline components. This test method is applicable to petroleum products and fractions with a final boiling point of 260°C (500°F) or lower as measured by this test method.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

## PETROLEUM-DERIVED LIQUID FUELS (STANDARDS)

**Title:** Method for Analysis of O-Xylene by Gas Chromatography

**Citation:** ASTM D 3797-88

**Content:**

**Availability:** ASTM

---

**Title:** Test Method for Flash Point by Setaflash Closed Tester

**Citation:** ASTM D 3828-87

**Content:**

**Availability:** ASTM

---

**Title:** Standard Test Method for Kinematic Viscosity of Volatile and Reactive Liquids<sup>1</sup>

**Citation:** ASTM D 4486-85

**Content:** This test method covers the measurement of kinematic viscosity of transparent, Newtonian liquids which because of their reactivity, instability, or volatility cannot be used in conventional capillary kinematic viscometers. This test method is applicable up to 2 atm ( $2 \times 10^{-5}$  N/m<sup>2</sup>) pressure and temperature range from -65° to +275°F (-53° to +135°C).

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.11 on Engineering Science of High Performance Fluids and Solids.

---

**Title:** Standard Test Method for Distillate Fuel Storage Stability at 43°C (110°F)<sup>1</sup>

**Citation:** ASTM D 4625-86

**Content:** This test method covers one method for an evaluation of the inherent storage stability of distillate fuels having flash points

above 38°C (100°F) and 90% recovered points below 340°C (644°F).

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.3 on Burner, Diesel, and Gas Turbine Fuel Oils.

---

**Title:** Test Method for Sediment in Crude Oil by Membrane Filtration

**Citation:** ASTM D 4807-88

**Content:** This test method covers the determination of sediment in crude oils by membrane filtration. This test method has been validated for crude oils with sediments up to about 0.15 mass %.

**Availability:** ASTM

---

**Title:** Test Method for Hydrogen Content of Light Distillates, Middle Distillates, Gas Oils, and Residues by Low Resolution Nuclear Magnetic Resonance Spectroscopy

**Citation:** ASTM D 4808-88

**Content:** These test methods cover the determination of the hydrogen content of petroleum products ranging from atmospheric distillates to vacuum residual using a continuous wave, low-resolution nuclear magnetic resonance spectrometer. (Test Method D 3701 is the preferred method for determining the hydrogen content of aviation turbine fuels using nuclear magnetic resonance spectroscopy.)

**Availability:** ASTM

---

**Title:** Standard Specification for Automotive Spark-Ignition Engine Fuel

**Citation:** ASTM D 4814-88

**Content:** This specification guides in establishing the requirements of automotive fuels for ground vehicles equipped with spark-ignition engines.

This specification describes various characteristics of automotive fuels for use over a wide range of operating conditions. It neither necessarily includes all types of fuels that are satisfactory for automotive vehicles, nor necessarily excludes fuels that may perform unsatisfactorily under certain operating conditions or in certain equipment.

The spark-ignition engine fuels covered in this specification are gasoline and its blends with oxygenates such as alcohols and ethers. The concentrations and types of oxygenates are not specifically limited in this specification. However, depending on oxygenate type, as oxygenate content increases above some threshold level, the likelihood for vehicle problems also increases. The composition of both unleaded and lead fuel is limited by economic, legal, and technical consideration, but their properties, including volatility, are defined by this specification. In addition, the composition of unleaded fuel is subject to the rules, regulations, and Clean Air Act waivers of the U.S. Environmental Protection Agency (EPA). With regard to fuel properties, including volatility, this specification may be more or less restrictive than the EPA rules, regulations, and waivers.

Tests applicable to gasoline are not necessarily applicable to its blends with oxygenates. Consequently, the type of fuel under consideration must first be identified, in order to select applicable tests. A method for identifying gasolines that contain alcohols is described. A method to identify gasolines that contain MTBE is under development.

**Availability:** ASTM

---

**Title:** Test Method for Analysis of C1 to C4 Alcohols and MTBE in Gasoline by Gas Chromatography

**Citation:** ASTM D 4815-88

**Content:** This test method covers a procedure for determination of methanol, ethanol, isopropanol, *n*-propanol, isobutanol, *sec*-butanol, *tert*-butanol, *n*-butanol, and methyl tertiary butyl ether (MTBE) in gasoline by gas chromatography.

Individual alcohols and MTBE are determined from 0.1 to 10 volume %.

**Availability:** ASTM

---

**Title:** Test Method for Estimation of Net and Gross Heat of Combustion of Petroleum Fuels

**Citation:** ASTM D 4868-88

**Content:**

**Availability:** ASTM

---

**Title:** Specification for Coal Tar Fuels

**Citation:** BS 1469:1962

**Content:** Specifications are given for two distillate fuels (C.T.F. 50, C.T.F. 100) and four heavier fuels (C.T.F. 200, C.T.F. 250, C.T.F. 300, C.T.F. 400) derived from tars obtained in coal-carbonizing and coal-gasification processes. Viscosity, flash point, gross calorific value, water content, matter insoluble in toluene, ash. For distillate fuels: liquidity, carbon residue, strong acid number. Methods of test appended.

**Availability:** BSI

---

**Title:** Methods of Test for Petroleum and Its Products

**Citation:** BS 2000 (Many Parts)

**Content:** Physical methods of analysis and test for petroleum and its products,

## PETROLEUM-DERIVED LIQUID FUELS (STANDARDS)

developed through the machinery of the Institute of Petroleum and accorded the status of British Standards. Each Part reproduces in facsimile an IP method with additional information in a foreword, marginal notes to the text and occasionally an appendix.

**Availability:** BSI

---

**Title:** Gasoline, Automotive

**Citation:** CAN 3.1-M78

**Content:** Applies to two types of gasoline suitable for use in automotive and spark ignition engines operating under all climatic conditions.

**Availability:** CSA

---

**Title:** Fuel Oil, Heating

**Citation:** CAN 2-3.2-M81

**Content:** Applies to four types of distillate fuel oils suitable for use in liquid-oil-burning equipment without preheating, and three types of fuel which may contain residual fuel components and may require preheating.

**Availability:** CSA

---

**Title:** Kerosine

**Citation:** CAN 2-3.3-M85

**Content:** Applies to two types of hydrocarbon oils, which differ only in the sulfur requirement.

**Availability:** CSA

---

**Title:** Gasoline, Automotive, Unleaded

**Citation:** CAN 3.5-M79

**Content:** This standard applies to two types of gasoline to which no lead or phosphorus has been added and are therefore suitable for use under all climatic conditions in spark

ignition engines equipped with emission control systems requiring the use of unleaded gasoline. In the interest of conservation of petroleum products it is essential that engine manufacturers continue to design engines to operate on Type 2 gasoline. Type 1 is then reserved for cases where octane requirement increase in use is such that a higher octane gasoline is required to prevent excessive knock.

**Availability:** CSA

---

**Title:** Diesel Fuel

**Citation:** CAN 2-3.6-M83

**Content:** Applies to three types of distillate fuels which are suitable for use in high and medium speed internal combustion engines of the compression-ignition type.

**Availability:** CSA

---

**Title:** Testing of Liquid Fuels;  
Determination of Oxidation Stability  
(Induction Period)

**Citation:** DIN 51780

**Content:**

**Availability:** DIN

---

**Title:** Testing of Mineral Oils and Fuels

**Citation:** DIN 51400 (Several Parts)

**Content:**

**Availability:** DIN

---

**Title:** Testing of Liquid Fuels;  
Determination of Smoke Point

**Citation:** DIN 51406

**Content:**

**Availability:** DIN

---

**Title:** Fuels and Fuel Additives Registration

**Citation:** EPA 40 CFR 79

**Content:**

**Availability:** EPA/CFR

---

**Title:** Fuels and Fuel Additives Regulation

**Citation:** EPA 40 CFR 80

**Content:**

**Availability:** EPA/CFR

---

**Title:** Motor and Aviation-Type Fuels--  
Determination of Knock  
Characteristics--Motor Method

**Citation:** ISO 5163:1977

**Content:**

**Availability:** ISO

---

**Title:** Motor Fuels--Determination of  
Knock Characteristics--Research  
Method

**Citation:** ISO 5164:1977

**Content:**

**Availability:** ISO

---

**Title:** Diesel Fuels--Determination of  
Ignition Quality--Cetane Method

**Citation:** ISO 5165:1977

**Content:**

**Availability:** ISO

---



**Title:** Industrial and Marine Fuels Reference Book

**Citation:** Clark, George H. Stoneham, MA: Butterworths, 1988, 784 pp.

**Content:** Major section includes laboratory test on fuels.

---

**Title:** Improving Refining Efficiency Using High-Temperature Simulated Distillation

**Citation:** Bashall, Anthony D. *American Laboratory*, May 1987.

**Content:**

---

**Title:** ASTM and Other Specifications for Petroleum Products and Lubricants

**Citation:** 4th Ed. New York: ASTM, 1985, 350 pp.

**Content:** Aimed particularly at individuals outside of laboratories or libraries, this book compiles specifications and classifications of interest to the petroleum industry. Includes ASTM standards on petroleum and lubricants, asphalt, roofing, insulating oils, and industrial chemicals. Also includes SAE, API, NLGI, federal, and military standards.

---

**Title:** Manual on Significance of Tests for Petroleum Products

**Citation:** 5th Ed. New York: ASTM, 169 pp.

**Content:** A handy reference to ASTM and Institute of Petroleum (IP) standards used in commercial transactions to definitively describe petroleum raw materials and petroleum products. All chapters have been updated since the 1977 edition to reflect new, revised standards by ASTM and IP.

Features complete descriptions of the raw material or product, as well as its known or prospective use applications; primary quality characteristics that define the material in use applications; and tests and analytical procedures that apply to the quality assessment of the material. Materials such as crude oils, gaseous products, and a wide range of liquid materials and greases and waxes are covered (Replaces STP 7C).

---



**Title:** Proposed Specification for Gasohol and Leaded Gasohol<sup>1</sup>

**Citation:** ASTM D-2 Proposal P 104

**Content:** This proposed specification for gasohol and leaded gasohol is to guide producers, marketers, and users of these products during the period that a standard specification for these products is being developed.

**Availability:** ASTM

---

<sup>1</sup>This proposed specification is under the jurisdiction of ASTM Committee D-2 on Petroleum and Lubricants.

---

**Title:** Proposed Information Document on Fuel Alcohol

**Citation:** ASTM 194RO

**Content:**

**Availability:** ASTM

---

**Title:** Standard Specification for Denatured Fuel Ethanol To Be Blended with Gasolines for Use as Automotive Spark-Ignition Engine Fuel<sup>1</sup>

**Citation:** ASTM D 4806-88

**Content:** This specification covers nominally anhydrous denatured fuel ethanol intended to be blended with unleaded or leaded gasolines at 5 to 10 volume % for use as a spark-ignition automotive engine fuel.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.A on specifications.

---



**Title:** Pyrolysis Oils from Biomass:  
Producing, Analyzing, and Upgrading

**Citation:** Edited by Ed J. Soltes and  
T. A. Milne. ACS Symposium  
Series 376. Washington, DC:  
American Chemical Society, 1988.

**Content:** Developed from a symposium  
sponsored by the Cellulose, Paper, and  
Textile Division and the Division of Fuel  
Chemistry at the 193rd Meeting of the  
American Chemical Society, Denver,  
Colorado, April 5-10, 1987.

---

**Title:** Some Aspects of Pyrolysis Oils  
Characterization by High-  
Performance Size Exclusion  
Chromatography

**Citation:** Johnson, David K. and Helena L.  
Chum. Chapter 15 in *Pyrolysis  
Oils from Biomass: Producing,  
Analyzing, and Upgrading*, edited  
by Ed J. Soltes and Thomas A.  
Milne. ACS Symposium Series  
376. Washington, DC: American  
Chemical Society, 1988.

**Content:** The utilization of biomass pyrolysis  
oils or isolated fractions of these feedstocks  
requires a fast overall characterization tech-  
nique. Gas chromatographic techniques typi-  
cally analyze only the volatile fraction (5%-  
50%) of underivatized oils. With proper  
choice of solvent and detector systems the  
HPSEC, on polystyrene-divinylbenzene co-  
polymer gels, of the whole oils can provide  
valuable information on their apparent mol-  
ecular weight distributions and changes that  
occur upon aging or chemical fractionation.  
Several pyrolysis oils have been analyzed as  
well as fractions isolated by solvent elution  
chromatography. In order to better under-  
stand the observed low-molecular-weight  
region, a number of model substances of the  
main classes of compounds found in pyrolysis  
oils have been investigated. While hydrogen  
bonding between the phenolic groups and  
tetrahydrofuran occurs, solute-solute inter-  
actions can be kept very small by operating  
at very low concentrations of solute; solute-  
gel interactions do occur with polycyclic

aromatic compounds. HPSEC provides very  
good information on the shelf life and reac-  
tivity of pyrolysis oils, and can be used to  
compare oils produced under different  
process conditions.

---

**Title:** Composition of Oils Obtained by Fast  
Pyrolysis of Different Woods

**Citation:** Piskorz, J., D. S. Scott, and  
D. Radlein. Chapter 16 in *Pyroly-  
sis Oils from Biomass: Producing,  
Analyzing, and Upgrading*, edited  
by Ed J. Soltes and Thomas A.  
Milne. ACS Symposium Series  
376. Washington, DC: American  
Chemical Society, 1988.

**Content:** Liquids obtained by fast pyrolysis  
of four different woods were analyzed. On  
addition of excess water they separated into  
water-soluble and water-insoluble fractions.  
The former, which is principally of carbohy-  
drate origin, was shown by HPLC analysis to  
consist of sugars, anhydrosugars, and low  
molecular weight carbonyl compounds. The  
latter was shown by  $^{13}\text{C}$  NMR to be a "pyro-  
lytic lignin." In this way 81% to 92% of the  
organic content of the liquids has been char-  
acterized.

---

**Title:** Product Analysis from Direct Lique-  
faction of Several High-Moisture  
Biomass Feedstocks

**Citation:** Elliott, Douglas C., L. John  
Sealock, Jr., and R. Scott Butner.  
Chapter 17 in *Pyrolysis Oils from  
Biomass: Producing, Analyzing,  
and Upgrading*, edited by Ed  
J. Soltes and Thomas A. Milne.  
ACS Symposium Series 376.  
Washington, DC: American Chem-  
ical Society, 1988.

**Content:** Experimental results are reported  
for high-pressure liquefaction of high-  
moisture biomass. The feedstocks included  
macrocystis kelp, water hyacinths, spent  
grain from a brewery, grain sorghum field  
residue, and napier grass. The biomass was  
processed in a batch autoclave as a ten  
weight percent slurry in water with sodium

## LIGNOCELLULOSIC AND OXYGENATED LIQUID FUELS (LITERATURE)

carbonate catalyst and carbon monoxide gas. Thirty-minute experiments were performed at 350°C with operating pressures ranging from 270 to 340 atmospheres. The oil products were collected by methylene chloride and acetone extractions. Oil yields ranged from 19 to 35 mass percent on a moisture and ash-free basis. The oil products contained from 9.9 to 16.7 percent oxygen with hydrogen to carbon atomic ratios from 1.36 to 1.61. Significant nitrogen content was noted in the oil product from those feedstocks containing nitrogen (kelp, hyacinth, spent grain). Chemical composition analysis by gas chromatography/mass spectrometry demonstrated many similarities between these products and wood-derived oils. The nitrogen components were found to be mainly saturated heterocyclics.

---

**Title:** An Integrated Spectroscopic Approach to the Chemical Characterization of Pyrolysis Oils

**Citation:** Hoesterey, Barbara L., William Windig, Henk L. C. Meuzelaar, Edward M. Eyring, David M. Grant, and Ronald J. Pugmire. Chapter 18 in *Pyrolysis Oils from Biomass: Producing, Analyzing, and Upgrading*, edited by Ed J. Soltes and Thomas A. Milne. ACS Symposium Series 376. Washington, DC: American Chemical Society, 1988.

**Content:** The hydrocarbon ("oil") fraction of a coal pyrolysis tar prepared by open column liquid chromatography (LC) was separated into 16 subfractions by a second LC procedure. Low voltage mass spectrometry (MS), infrared spectroscopy (IR), and proton (PMR) as well as carbon-13 nuclear magnetic resonance spectrometry (CMR) were performed on the first 13 subfractions. Computerized multivariate analysis procedures such as factor analysis followed by canonical correlation techniques were used to extract the overlapping information from the analytical data. Subsequent evaluation of the integrated analytical data revealed chemical information which could not have been obtained readily from the individual spectroscopic

techniques. The approach described is generally applicable to multisource analytical data on pyrolysis oils and other complex mixtures.

---

**Title:** Chemical Characterization of Wood Pyrolysis Oils Obtained in a Vacuum-Pyrolysis Multiple-Hearth Reactor

**Citation:** Pakdel, H. and Christian Roy. Chapter 19 in *Pyrolysis Oils from Biomass: Producing, Analyzing, and Upgrading*, edited by Ed J. Soltes and Thomas A. Milne. ACS Symposium Series 376. Washington, DC: American Chemical Society, 1988.

**Content:** A multiple hearth reactor has been used to produce high yield of pyrolysis oil from aspen poplar. The Process Development Unit (P.D.U.) has the capability of achieving a fair fractionation of wood oils by using six heat exchangers (Primary Condensing Unit, P.C.U.) and a series of cooling trap receivers (Secondary Condensing Unit, S.C.U.) at the outlets of the reactor. While the weight average molecular weights ( $M_w$ ) of the recovered compounds in the P.C.U. were 342, 528, 572, 393, 233 and 123 from top to bottom of the reactor, the low molecular weight compounds with  $M_w = 100$  or below were recovered in the S.C.U., which contained at least 90% of the total water. Silica-gel column chromatography enabled us to fractionate the oil from P.D.U. into fourteen fractions. Aromatic hydrocarbons were collected in Fraction 1 (F1) and F2 followed by elution of moderately polar compounds in F3 to F11 with about 23%-35% of P.C.U. oil which can be fully characterized. 8.1% sugar in P.C.U., mainly glucose, was found in F13. Usefulness of  $^1\text{H}$ -FTNMR and infrared spectroscopy was shown for preliminary characterization of the F12, F13 and F14. Overall 27.89% of the P.C.U. including water and low molecular weight carboxylic acids have been measured and identified so far.

---

**Title:** Fourier Transform Infrared Spectrometry and Thermogravimetry of Partially Converted Lignocellulosic Materials

**Citation:** Grandmaison, J. L., Jules Thibault, Serge Kaliaguine, and P. D. Chantal. *Anal. Chem.* 59: 2153-2157 (1987).

**Content:** The solid residues from a series of extraction of aspen poplar experiments conducted in supercritical methanol at temperatures ranging from 250° to 350°C have been further analyzed by using diffuse reflectance Fourier transform infrared spectrometry (DRIFT) and thermogravimetric analysis (TG/DTG) in flowing nitrogen. The results are compared with previous data obtained by wet chemistry analysis for the same samples. Equations relating the various sample characteristics obtained from this previous study (Klason residue, unconverted lignin, recondensed material, glucose and xylose) and DRIFT absorbance intensity ratios are reported.

**Title:** Production and Characterization of Carboxylic Acids from Wood. Part I: Low Molecular Weight Carboxylic Acids

**Citation:** Pakdel, Hooshang and Christian Roy. *Biomass* 13:155-171 (1987).

**Content:** Pyrolysis oil from wood has been fractionated directly at the outlets of a multiple hearth reactor using six heat exchangers in parallel. A large portion of the organic liquid phase was recovered in the heat exchangers, and the bulk of the aqueous phase was condensed in a series of cooling traps (secondary condensing unit). The C<sub>1</sub> to C<sub>7</sub> carboxylic acids in the wood pyrolysis oils were analyzed using gas chromatography following conversion into benzyl esters via tetrabutylammonium salts, purification by solvent extraction and silica-gel elution chromatography. The technique of benzylation and purification is an improved carboxylic acid determination method and is more accurate than the other techniques

particularly for the quantifications of C<sub>3</sub> to C<sub>7</sub> carboxylic acids. The method of C<sub>1</sub>-C<sub>7</sub> acid production of vacuum pyrolysis of wood and the reactor overall separation efficiency are also discussed.

**Title:** Degradation of Polysaccharides in Alkaline Solution to Organic Acids: Product Characterization and Identification

**Citation:** Krochta, John M., Sandra J. Tillin, and Joyce S. Hudson. *Journal of Applied Polymer Science* 33:1413-1425 (1987).

**Content:** Agricultural products have considerable potential for conversion to valuable oxychemicals. Analyses by ether extraction, titration, and anion-exchange classification of the alkaline degradation products of totally converted starch and celluloses showed that the product compounds are mainly organic acids. Almost all the organic acids are monocarboxylic in nature, with an average equivalent weight in the range 76-84. The organic acids identified thus far by HPLC and GC are formic, acetic, glycolic, lactic, 2-hydroxybutyric, 2-hydroxyisobutyric, and 2-hydroxyvaleric acids. Together, these compounds represent 41%-46% of the starting material weight.

**Title:** On the Presence of Anhydro-Oligosaccharides in the Sirups from the Fast Pyrolysis of Cellulose

**Citation:** Radlein, Desmond St. A. G., Anna Grinshpun, Jan Piskorz, and Donald S. Scott. *Journal of Analytical and Applied Pyrolysis* 12:39-49 (1987).

**Content:** Analysis by high-performance liquid chromatography of the carbohydrate fraction of sirups obtained from the fast pyrolysis of Avicel cellulose (82% yield of organic liquid) indicated the presence of a considerable amount of an unknown oligosaccharide, presumably a disaccharide. If this was formed from recombination of levoglucosan (the major product) it would be expected to be a mixture of disaccharides, with

## LIGNOCELLULOSIC AND OXYGENATED LIQUID FUELS (LITERATURE)

maltosan as a major component. If the unknown disaccharide was a primary product it should have a cellobiose structure. Maltosan and cellobiosan were synthesized and the unknown disaccharide was identified as almost entirely cellobiosan in yields varying from 6% to 15% of the sirup product. It is postulated that the production of cellobiosan as a primary pyrolysis product lends support to recent theories that cellulose is a polymer of cellobioside units rather than of glucoside units.

---

**Title:** Chromatographic Studies of Crude Oils from Wood

**Citation:** Meier, D., R. Doring, and O. Faix. *Energy from Biomass*, edited by W. Palz, J. Coombs, and D. O. Hall. London and New York: Elsevier Applied Science Publishers, 1985.

**Content:** Product oils derived from the direct thermochemical conversion of wood have been analyzed and characterized using one liquid and two gas chromatographic methods. High Performance Gel Permeation Chromatography (HPGPC) was applied to achieve a separation according to molecular size. Capillary gas chromatography was used for the separation and quantification of single components in the crude oil. A packed column was used to determine the boiling point distribution. All methods applied turned out to be suitable for the chemical comparison of oils from different feedstocks and processes.

---

**Title:** Separation of Functionalities in Pyrolytic Tar by Gel Permeation Chromatography-Gas Chromatography

**Citation:** Sheu, Y.-H.E., C. V. Phillip, R. G. Anthony, and Ed J. Soltes. *J. of Chromatic Science* 22:497 (1984).

**Content:** An analytical method combining gel permeation chromatography (GPC) and high resolution gas chromatography (GC) has been developed to analyze pine pyrolytic tars and their upgraded products. Pyrolytic tar,

obtained from pine barks and wastes by the Tech-Air pyrolysis process, and its hydrogenation products have been separated by GPC into aromatics, phenols, light nonvolatiles and alkanes, and heavy nonvolatile fractions. The GPC using 10-nm  $\mu$ Styragel columns and THF as a solvent results in reasonably clean separations. The GC with the use of an internal standard gives percentage of volatiles. High resolution gas chromatography-mass spectrometry (GC-MS) has been used to characterize the separated fractions. Changes in composition during hydrogenation have been determined by comparing the GPC and GC analyses of the charge stocks and products. This technique provides fast analyses and allows the determination of compositional changes during the upgrading process.

---

**Title:** High-Performance Liquid Chromatographic Analysis of Carboxylic Acids in Pyrolygneous Liquors

**Citation:** Menard, Hugues, Alain Gaboury, Denis Belanger, and Christian Roy. *Journal of Analytical and Applied Pyrolysis* 6:45-57 (1984).

**Content:** The qualitative and quantitative analysis of carboxylic acids present in pyrolygneous liquors was performed by high-performance liquid chromatography. The method was essentially based on the derivatization of the various acids with *p*-bromophenacyl bromide. Results are reported for analyses performed on pyrolygneous liquors obtained from aspen poplar (*Populus tremuloides*) and pure cellulose.

---

**Title:** High-Performance Liquid Chromatographic Elution Behaviour of Alcohols, Aldehydes, Ketones, Organic Acids and Carbohydrates on a Strong Cation-Exchange Stationary Phase

**Citation:** Pecina, R., G. Bonn, E. Burtscher, and O. Bobleter. *Journal of Chromatography* 287: 245-258 (1984).

**Content:** The high-performance liquid chromatographic separation of alcohols, aldehydes, ketones, carboxylic acids and carbohydrates on a polystyrene-based strong

cation-exchange resin is described. The column temperature was found to be a very important parameter for optimizing separations of these substances. The effect of different functional groups on the elution behaviour is discussed.

---

**Title:** Information Document on Gasohol (Motor Fuel Containing 10% Volume of Denatured Ethanol in Gasoline)

**Citation:** New York: ASTM, 1983.

**Content:** This document summarizes presently available information for motor fuels containing a nominal 10 volume % of denatured ethanol in leaded or unleaded gasoline. It must be recognized that experience with gasohol is presently inadequate to set limits on some properties, or to identify possible long-term effects.

---

**Title:** Coal Liquefaction: The Chemistry and Technology of Thermal Processes

**Citation:** Whitehurst, D. Duayne, Thomas O. Mitchell, and Malvina Farcasiu. New York: Academic Press, 1980.

**Content:** Contains principles of preparative fractionation and characterization that may be applicable to biomass oils.

---

**Title:** Alcohols, A Technical Assessment of Their Application as Fuels

**Citation:** Publ. 4261-76. American Petroleum Institute.

**Content:**

---

**Title:** Chemical Comparisons of Liquid Fuels Produced by Thermochemical Liquefaction of Various Biomass Materials

**Citation:** Russell, J. A., P. M. Molton, and S. D. Landsman. pp. 307-322 in *Alternative Energy Sources III*, Vol. 3. Solar Energy 3. Edited by T. N. Vizirolu. New York: Hemisphere Publishing Company, 1983.

**Content:**

---

**Title:** Analysis of Oil Fractions Derived from Hydrogenation of Aspen Wood.

**Citation:** Boocock, D. G. B., R. K. M. G. Kallury, and T. T. Tidwell. *Anal. Chem.* 55:1689 (1983).

**Content:**

---

**Title:** Biomass Liquefaction: Centralized Analysis

**Citation:** McKinley, J. W. Vancouver, B. C., Canada: B. C. Research, 1989.

**Content:**

---

**Title:** Preparative Separation of Chemicals from Wood Vacuum Pyrolysis Oil, Part I: Method Development

**Citation:** Pakdel, Hooshang, Zhang Hong-Gen, and Christian Roy. Fifth International Symposium on Wood and Pulping Chemistry. North Carolina State University, Raleigh, NC, May 22-25, 1989.

**Content:** The main objective of this investigation is to find a reliable technique for large scale separation of valuable compounds from wood pyrolysis oils. These oils mainly contain low molecular weight oxygenated

## LIGNOCELLULOSIC AND OXYGENATED LIQUID FUELS (LITERATURE)

compounds with  $M_w < 500$ . They are distributed in a wide range of compounds with different polarity ranging from non polar hydrocarbons to high polar carboxylic acids and carbohydrates. Sequential elution solvent chromatography was the basic separation method used in this investigation.

Following a method developed on a small column with 1 g capacity, a large column with 100 g capacity and  $80 \text{ ml} \cdot \text{min}^{-1}$  flow rate was designed. Satisfactory column reproducibility, yield and recycling of the solvent and stationary phase were achieved. The large column was designed to pre-fractionate the pyrolysis oil into various groups which eliminated the undesirable compounds. Further purification of the fractions obtained will be conducted in a high performance liquid chromatography column. Interestingly, a few compounds were separated which degree of purity was at least 70%. Their further purification and characterization are also discussed.

---

**Title:** Chemical Characterization of Hydrocarbons Produced by Vacuum Pyrolysis of Aspen Poplar Wood Chips

**Citation:** Pakdel, H., C. Roy, and K. Zeidan. Research in Thermochemical Biomass Conversion, May 2-6, 1988, Phoenix, Arizona. New York: Elsevier, 1989.

**Content:** Vacuum pyrolysis of aspen poplar wood chips was performed in a Process Development Unit multiple hearth furnace. Various pyrolysis oils were collected in a series of cooling traps installed in parallel at the reactor outlets (Primary Condensation Train, H-I to H-VI). Aqueous phase with about 45% water (96% of the total pyrolysis water) was collected separately in a Secondary Condensation Train (C-1 to C-4) and contained high volatile and partially soluble organic matter. Liquid-liquid and liquid-solid chromatographic techniques were developed to separate aliphatic and aromatic hydrocarbons. Preliminary characterization of the aliphatic and aromatic hydrocarbons was performed by gas chromatography. Aliphatic hydrocarbons comprised between 0.08% to

0.44% of the oil phase and 0.01% to 0.02% of the aqueous phase. The aliphatic hydrocarbon fraction of the H-VI was surprisingly dominated with n-alkanes in the range of n-C<sub>13</sub> to n-C<sub>28</sub> and n-alkenes in the range of n-C<sub>19</sub> to n-C<sub>26</sub>. Aromatic hydrocarbons contributed between 0.06% to 0.24% of the organic phase and were detected only in trace amounts in the aqueous phase. FTNMR and FTIR spectroscopic analyses of the aromatic fractions showed a complex mixture of highly branched aromatic hydrocarbons. Due to the highly branched nature of the aromatic fractions, both organic and aqueous phases were believed not to have any significant environmental and toxicological impact. Efficiency of the separation technique was also tested on tar sample from a 10 t h<sup>-1</sup> wood gasifier which contained over 50% polycyclic aromatic hydrocarbons.

---

**Title:** Study on the Corrosiveness of Wood Pyrolysis Oils

**Citation:** Aubin, H el ene and Christian Roy. Submitted to *Fuel Science and Technology Intern.* December 1988.

**Content:** A study has been conducted on the rate of corrosion of wood pyrolysis oils in the presence of carbon and stainless steel plates. Tests were performed to simulate the conditions existing in storage tanks. The effect of temperature, water content and acetic/formic acid concentration on the rate of corrosion of metals was studied, as well as their possible interaction effects. The method used involved a factorial design of experiments. All primary effects with their interactions were found statistically significant using the Fischer criterion at  $F_{0.1}$  % for the analysis of variance. Stainless steel resisted corrosion activity under all sets of conditions used. Wood oils were found not corrosive or slightly corrosive for cast iron at ambient temperature and low water content, whatever the acid concentration used. Increasing the temperature to 45°C, however, dramatically increased the oil corrosion activity.

---

**Title:** IEA Co-Operative Project D1 Biomass Liquefaction Test Facility Project

**Citation:** Elliott, D. C. Volume 4: *Analysis and Upgrading of Biomass Liquefaction Products*. NTIS DOE/NBM--1062 Vol. 4, July 1988.

**Content:**

---

**Title:** Analysis and Comparison of Biomass Pyrolysis/Gasification Condensates-Final Report

**Citation:** Elliott, D. C. PNL-5943. Richland, WA: Pacific Northwest Laboratory, June 1986.

**Content:**

---

**Title:** Description and Utilization of Product from Direct Liquefaction of Biomass

**Citation:** *Biotechnol. and Bioeng. Symp.* No. 11. pp. 187-198. New York: John Wiley & Sons, 1981.

**Content:**

---

**Title:** Chemistry and Stoichiometry of Wood Liquefaction

**Citation:** Davis, H. G., D. J. Kloden, and L. L. Schaleger. *Biotechnol. and Bioeng. Symp.* No. 11, pp. 151-169. New York: John Wiley and Sons, 1981.

**Content:**

---

**Title:** The Products of Direct Liquefaction of Biomass

**Citation:** Davis, H. G., M. A. Eames, C. Figueroa, R. R. Gansley, L. L. Schaleger, and D. W. Watt. *Fundamentals of Thermochemical Biomass Conversion*, pp. 1027-1038. Barking, England: Elsevier Applied Science Publishers, 1985.

**Content:**

---

**Title:** Characterization of Peat and Biomass Liquids

**Citation:** Karlsson, O. and P. Björnbom. *Fundamentals of Thermochemical Biomass Conversion*, pp. 1019-1026. Barking, England: Elsevier Applied Science Publishers, 1985.

**Content:**

---

**Title:** Research in Thermochemical Biomass Conversion

**Citation:** Edited by A. V. Bridgwater and J. L. Kuester. London and New York: Elsevier Applied Science Publishers, 1988.

**Content:** Edited and reviewed papers from the International Conference on Research in Thermochemical Biomass Conversion, April 1988, Phoenix, Arizona.

---

**Title:** Analytical Methodology Development for the Characterization of Products Obtained By Fractionation of Biomass, Final Report

**Citation:** Bouchard, J., E. Chornet, and R. P. Overend. Prepared for Bio-energy Development Program, Renewable Energy Division, Coal and Alternative Energy Branch, Energy, Mines and Resources Canada, Ottawa, Canada. DSS Contract File No: 24ST.23216-6-6168, 1988.

**Content:**

---

**Title:** Analysis and Comparison of Products from Wood Liquefaction

**Citation:** Elliott, D. C. In *Fundamentals of Thermochemical Biomass Conversion*. Edited by R. P. Overend, T. A. Milne, and L. K. Mudge. London and New York: Elsevier Applied Science Publishers, 1985.

**Content:**

---

# LIGNOCELLULOSIC AND OXYGENATED LIQUID FUELS (LITERATURE)

**Title:** Fundamentals of Thermochemical Biomass Conversion

**Citation:** Edited by R. P. Overend, T. A. Milne, and L. K. Mudge. London and New York: Elsevier Applied Science Publishers, 1985.

**Content:**

---

**Title:** Process Development for Direct Liquefaction of Biomass

**Citation:** Elliott, D. C. Chapter 24 in *Fuels From Biomass and Waste*. Edited by D. L. Klass and G. H. Emert. Ann Arbor, MI: Ann Arbor Science Publishers, Inc., 1981.

**Content:**

---

**Title:** Stabilization and Utilization of Pyrolytic Oils

**Citation:** Villeneuve, J., T. Huard, M. Essayegh, and P. L. Desbene. Biomass for Energy and Industry, 4th E.C. Conference, Orleans, France. London: Elsevier Applied Science, 1987.

**Content:**

---

**Title:** New Process of Suspension Pyrolysis and Use of Charcoal Slurry

**Citation:** Mezerette, C., M. Essayegh, F. Villeneuve, and P. L. Desbene. ECC Contractors Meeting (Energy from Biomass R&D Program), Paestum, 24-27 May 1988.

**Content:**

---

**Title:** Evolution Study and Stabilization of Pyrolytic Oils Influence of Pyrolytic Water pH

**Citation:** Essayegh, M., C. Mezerette, F. Villeneuve, and P. L. Desbene. Euroforum new Energies 88, Contractors Meeting (Energy from Biomass R&D Program), Sarbrucken, 24-28 October 1988.

**Content:**

---

**Title:** Implementation of a Technique for Particle and Gaseous Sampling in Effluents Issued from Pyrolysis in a Metallic Kiln

**Citation:** Lachenal, J. and C. Mezerette. International Conference on "Pyrolysis and Gasification" at Luxembourg, May 1989.

**Content:**

---

**Title:** Caractérisation des émissions de carbonisation en four à combustion partielle

**Citation:** Girard, P., C. Meyer, J. P. Fontelle, and M. Boillot. Mise au point de systèmes de traitement des funées de carbonisation. Biomass for Energy and Industry, 4th EC Conference, Orleans. Elsevier Applied Science ed. 1987.

**Content:**

---

**Title:** Analytical Techniques Suitable for Pyrolysis Liquid and Gas from Tropical Biomass

**Citation:** Vergnet, A.-M. and F. Villeneuve. In *Cahiers Scientifiques*. No. 9. Supplement de Bois et Forets des Tropiques. Edited by Centre Technique Forestier Tropical, France, 1988.

**Content:** Charcoal, with firewood, represents one of the basic energy sources in developing countries. In fact, the release of smoke in the processes of partial combustion represents 70% of the initial product mass or 50% of the initial energy.

To enable the development of the by-products of the pyrolysis of tropical biomass, through chemical or energy means, the constituents of the gas and liquid fractions should be known.

For that purpose, an analytical method was determined to make the study of these fractions possible. This analysis is based on separation by gas chromatography whose parameters are given in the herein article.

---

---

**Title:** A Methodology for Analysis of Wood Liquefaction Products

**Citation:** Burton, A., D. de Zutter, E. Churin, J. M. Liesse, P. Grange, and G. Poncelet. In *Biomass for Energy and Industry*, Proceedings of the 4th E.C. Conference. Edited by G. Grassi, B. Delmon, J.-F. Molle, and H. Zibetta. London and New York: Elsevier Applied Science, 1987.

**Content:** The analytical procedure used for the evaluation of products obtained by catalytic liquefaction of wood by mild hydrogenolysis in an organic solvent using hydro-treating catalyst is presented. Because two objectives were defined for the hydrotreatment, namely the depolymerization of the ligneous material into molecules of commercial value and the hydrocracking of the non-ligneous organic material into liquid fuels, the analytical method should give information concerning the catalytic selectivity to phenolic compounds and the yield in neutral fractions as well. The analysis starts with distillations at atmospheric and lower pressures in such a way that the light fraction and water are collected. A phenolic fraction is separated by alkaline extraction. The residue of distillation is extracted in a soxhlet for recovery of benzene soluble products. This methodology can be extended to the analysis of complex mixtures obtained by conversion of biomass.

---

---



**Title:** National Fuel Gas Code

**Citation:** AGA Z223.1-84

**Content:**

**Availability:** AGA

---

**Title:** Gaseous Fuels

**Citation:** ASME PTC 3.3-69

**Content:**

**Availability:** ASME

---

**Title:** Standard Methods for Volumetric Measurement of Gaseous Fuel Samples<sup>1</sup>

**Citation:** ASTM D 1071-83

**Content:** These methods cover the volumetric measuring of gaseous fuel samples, including liquefied petroleum gases, in the gaseous state at normal temperatures and pressures. The apparatus selected covers a sufficient variety of types so that one or more of the methods prescribed may be employed for laboratory control, reference, or in fact any purpose where it is desired to know the quantity of gaseous fuel or fuel samples under consideration.

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and are the direct responsibility of Subcommittee D03.01 on Collection and Measurement of Gaseous Samples.

---

**Title:** Standard Method of Sampling Manufactured Gas<sup>1</sup>

**Citation:** ASTM D 1247-80  
(Discontinued 1987)

**Content:** This method covers the procedures for securing representative samples of manufactured gas, and correlates the size or type

of sample with the analysis to be done subsequently on that sample.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and is the direct responsibility of D03.01 on Collection and Measurement of Gaseous Samples.

---

**Title:** Standard Method for Analysis of Reformed Gas by Gas Chromatography<sup>1</sup>

**Citation:** ASTM D 1946-82

**Content:** This method covers the determination of the chemical composition of reformed gases and similar gaseous mixtures containing the following components: hydrogen, oxygen, nitrogen, carbon monoxide, carbon dioxide, methane, ethane, and ethylene.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.07 on Analysis of Chemical Composition of Gaseous Fuels.

---

**Title:** Standard Test Method for Chemical Composition of Gases by Mass Spectrometry<sup>1</sup>

**Citation:** ASTM D 2650-83

**Content:** This test method covers the quantitative analysis of gases containing specific combinations of the following components: hydrogen; hydrocarbons with up to six carbon atoms per molecule; carbon monoxide; carbon dioxide; mercaptans with one or two carbon atoms per molecule; hydrogen sulfide; and air (nitrogen, oxygen, and argon).

## GASEOUS FUELS (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analyses.

---

**Title:** Standard Method of Calculating Calorific Value and Specific Gravity (Relative Density) of Gaseous Fuels<sup>1</sup>

**Citation:** ASTM D 3588-81

**Content:** This method describes the calculation of calorific value and specific gravity (relative density) of gaseous fuel from its composition. It is applicable to all common types of utility gaseous fuels (for example, dry natural gas, reformed gases, oil gas (both high- and low-Btu), propane-air, carbureted water gas, and coke oven and retort coal gas) for which suitable methods of analysis are available.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.03 on Determination of Calorific Value of Gaseous Fuels.

---

**Title:** Standard Method for Analysis of Hydrogen Sulfide in Gaseous Fuels (Lead Acetate Reaction Rate Method)<sup>1</sup>

**Citation:** ASTM D 4084-82

**Content:** This method covers the determination of hydrogen sulfide (H<sub>2</sub>S) in gaseous fuels. It is applicable to the measurement of H<sub>2</sub>S in natural gas, liquefied petroleum gas (LPG), substitute natural gas, and mixtures of fuel gases. Air does not interfere. The applicable range is 0.1 to 16 parts per million by volume (ppm/v) (approximately 0.1 to 22 mg/m<sup>3</sup>) and may be extended to 100% H<sub>2</sub>S by manual or automatic volumetric dilution.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.05 on Determination of Special Constituents of Gaseous Fuels.

---

**Title:** Standard Terminology Relating to Gaseous Fuels<sup>1</sup>

**Citation:** ASTM D 4150-84

**Content:**

**Availability:** ASTM

---

<sup>1</sup>This terminology is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.92 on Definitions and Nomenclature.

---

**Title:** Standard Practice for Calculation of Gas Chromatographic Response Factors<sup>1</sup>

**Citation:** ASTM D 4626-86

**Content:** This practice describes a procedure for calculating gas chromatographic response factors. It is applicable to chromatographic data obtained from a gaseous mixture or from any mixture of compounds that is normally liquid at room temperature and pressure or solids, or both, that will form a solution with liquids. It is not intended to be applied to those compounds that react in the chromatographic or are not quantitatively eluted. Normal C<sub>6</sub> through C<sub>11</sub> paraffins have been chosen as model compounds for demonstration purposes.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.04 on Hydrocarbon Analysis.

---

**Title:** Methods for the Analysis of Fuel Gases

**Citation:** BS 3156

**Content:** Consists of 11 parts.

**Availability:** BSI

---

**Title:** Specification for Apparatus for Physical Methods of Gas Analysis

**Citation:** BS 4314:Part 1:1968

**Content:**

**Availability:** BSI

---

**Title:** Gaseous Fuels and Other Gases; Types, Constituents, Application

**Citation:** DIN 1340

**Content:**

**Availability:** DIN

---

**Title:** Testing of Gaseous Fuels and Other Gases

**Citation:** DIN 51872 Parts 1-4

**Content:** 1. Determination of the main components, general statements. 2. Methods according to Orsat. 3. Methods according to Orsat and Janak. 4. Gas chromatographic procedure.

**Availability:** DIN

---

**Title:** Testing of Fuel Gases, Protective Gases and Exhaust Gases; Sampling

**Citation:** DIN 51853

**Content:**

**Availability:** DIN

---

**Title:** Gas Analysis--Vocabulary

**Citation:** ISO 7504:1984

**Content:** Bilingual Edition.

**Availability:** ISO

---



**Title:** Standard Method for Distillation of Creosote and Creosote-Coal Tar Solutions<sup>1</sup>

**Citation:** ASTM D 246-84

**Content:** This method covers a procedure for the distillation of creosote and creosote-coal tar solution.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-7 on Wood and is the direct responsibility of Subcommittee D07.06 on Wood Preservatives.

---

**Title:** Standard Test Method for Acidity in Volatile Solvents and Chemical Intermediates Used in Paint, Varnish, Lacquer, and Related Products<sup>1</sup>

**Citation:** ASTM D 1613-85

**Content:** This method covers the determination of total acidity as acetic acid, in concentrations below 0.05%, in organic compounds and hydrocarbon mixtures used in paint, varnish, and lacquer solvents and diluents. It is known to be applicable to such mixtures as low molecular weight saturated and unsaturated alcohols, ketones, ethers, esters, hydrocarbon diluents, naphtha, and other light distillate petroleum fractions.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.35 on Solvents, Plasticizers, and Chemical Intermediates.

---

**Title:** Standard Definitions of Terms Relating to Activated Carbon<sup>1</sup>

**Citation:** ASTM D 2652-76 (1987)

**Content:**

**Availability:** ASTM

---

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee D-28 on Activated Carbon and are the direct responsibility of Subcommittee D28.03 on Nomenclature and Editorial.

---

**Title:** Standard Test Method for pH of Activated Carbon<sup>1</sup>

**Citation:** ASTM D 3838-80 (1986)

**Content:** This test method covers determination of the pH of a water extract of activated carbon.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-28 on Activated Carbon and is the direct responsibility of Subcommittee D28.04 on Gas Phase Evaluation Tests.

---

**Title:** Practice for Estimating the Operating Performance of Granular Activated Carbon for Removal of Soluble Pollutants from Water

**Citation:** ASTM D 3922-80

**Content:**

**Availability:** ASTM

---

## NON-FUEL PRODUCTS (STANDARDS)

**Title:** Standard Test Method for Determination of Iodine Number of Activated Carbon<sup>1</sup>

**Citation:** ASTM D 4607-87

**Content:** This test method covers the determination of the relative activation level of unused or reactivated carbons by adsorption of iodine from aqueous solution. The amount of iodine absorbed (in milligrams) by 1 g of carbon using test conditions listed herein is called the iodine number.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-28 on Activated Carbon and is the direct responsibility of Subcommittee D28.02 on Liquid Phase Evaluation Tests.

---



**Title:** Method for Leaching Solid Waste in a Column Apparatus

**Citation:** ASTM D 4874

**Content:**

**Availability:** ASTM

---

**Title:** The Anaerobic Biodegradation Potential of Solid Wastes

**Citation:** ASTM Committee D-34, Subcommittee D34.09.03 on Biological Treatment and Land Applications

**Content:**

**Availability:** ASTM

---

**Title:** Criteria for Classification of Solid Waste Disposal Facilities and Practices

**Citation:** 40 CFR 257 (See also 40 CFR Parts 261, 264, and 265).

**Content:**

**Availability:** EPA/CFR

---



**Title:** Anaerobic Biodegradation Potential of Solid Wastes

**Citation:** *ASTM Standardization News*.  
October 1988, p. 11.

**Content:** The anaerobic biodegradation potential of solid wastes containing organic material will be studied by Subcommittee D34.09.03 on Biological Treatment and Land Application. The goal is to develop a standard laboratory procedure that will simulate naturally occurring anaerobic microbial processes that may alter or degrade complex solid waste materials in a disposal environment, and would be applicable to any organic waste material. Industries and municipalities who generate organic solid wastes that are currently disposed of on land or are land-treated will benefit.

---

**Title:** Chemical and Biological Characterization of Municipal Sludges, Sediments, Dredge Spoils, and Drilling Muds

**Citation:** STP 976. New York: ASTM, 1988.

**Content:** This volume is based on a symposium held to determine the state of the art in sampling and analytical methods for sludges and other solids. U.S. Environmental Protection Agency (EPA) program office and regional representatives at the program described the status of the regulations and the analytical needs related to characterization and regulation of sludge, sediment, and waste streams. Technical papers addressed quality assurance, sampling, organic and inorganic chemical methods, aquatic biological, microbiological, and virological methods and risk assessment.

---

**Title:** Test Methods for Evaluating Solid Waste, Physical/Chemical Methods

**Citation:** 3rd Ed., 2 Vols. SW-846.  
Washington, DC: U.S.  
Environmental Protection Agency,  
1986.

**Content:**  
Ch. 1--Quality Control;  
Ch. 2--Choosing the Correct Procedure;  
Ch. 3--Metallic Analytes;  
Ch. 4--Organic Analytes;  
Ch. 5--Miscellaneous Test Methods;  
Ch. 6--Properties;  
Ch. 7--Introduction and Regulator Definitions;  
Ch. 8--Methods for Determining Characteristics;  
Ch. 9--Sampling Plan;  
Ch. 10--Sampling Methods;  
Ch. 11--Ground Water Monitoring;  
Ch. 12--Land Treatment Monitoring;  
Ch. 13--Incineration

---



**Title:** Tests for Water: Determination of Biological Oxygen Demand (BOD)

**Citation:** NF T 90-103-75

**Content:**

**Availability:** AFNOR

---

**Title:** Standard Methods for the Examination of Water and Wastewater; Sixteenth Edition

**Citation:** APHA, AWWA, WPCF

**Content:** Part 100--General Introduction; Part 200--Physical Examination; Part 300--Determination of Metals; Part 400--Determination of Inorganic Nonmetallic Constituents; Part 500--Determination of Organic Constituents; Part 600--Automated Laboratory Analyses; Part 700--Examination of Water and Wastewater for Radioactivity; Part 800--Toxicity Test Methods; Part 900--Microbiological Examination of Water; Part 1000--Biological Examination of Water.

**Availability:** APHA

---

**Title:** Standard Test Methods for Chemical Oxygen Demand (Dichromate Oxygen Demand) of Water<sup>1</sup>

**Citation:** ASTM D 1252-88

**Content:** These test methods cover the determination of the quantity of oxygen that certain impurities in water will consume, based on the reduction of a dichromate solution under specified conditions. The following test methods are included: Test Method A--COD by Reflux Digestion; Test Method B--Micro COD by Spectrophotometric Procedure.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-19 on Water and are the direct responsibility of Subcommittee D19.06 on Methods for Analysis for Organic Substances in Water.

---

**Title:** Standard Test Methods for pH of Water<sup>1</sup>

**Citation:** ASTM D 1293-84

**Content:** These methods cover the determination of pH by electrometric measurement using the glass electrode as the sensor. Two procedures are included: Method A--Precise Laboratory Measurement; Method B--Routine or Continuous Measurement.

**Availability:** ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-19 on Water.

---

**Title:** Standard Test Methods for Particulate and Dissolved Matter, Solids, or Residue in Water<sup>1</sup>

**Citation:** ASTM D 1888-78

**Content:** These methods cover the determination of particulate, dissolved, and total matter, sometimes referred to as the suspended, dissolved, and total solids, in water. Two procedures, consistent with the total matter content, are provided as follows: Method A--Particulate and Dissolved Matter in Water with More Than 25 ppm of Total Matter; Method B--Particulate and Dissolved Matter in Water with 25 ppm or Less of Total Matter (Automatic Evaporation).

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee D-19 on Water.

---

**Title:** Standard Test Methods for Total and Organic Carbon in Water<sup>1</sup>

**Citation:** ASTM D 2579-85

**Content:** These test methods cover the determination of total and organic carbon in water and wastewater, including brackish waters, and brines. The following methods are included: Method A--Oxidation--Infrared Detection; Method B--Reduction--Flame Ionization Detection.

## LIQUID WASTE (STANDARDS)

### Availability: ASTM

---

<sup>1</sup>These test methods are under the jurisdiction of ASTM Committee D-19 on Water and are the direct responsibility of Subcommittee D19.06 on Methods for Analysis for Organic Substances in Water.

---

**Title:** Standard Practice for Measuring Volatile Organic Matter in Water by Aqueous-Injection Gas Chromatography<sup>1</sup>

**Citation:** ASTM D 2908-74 (1987)

**Content:** This practice covers general guidance applicable to certain test methods for the qualitative and quantitative determination of specific organic compounds, or classes of compounds, in water by direct aqueous injection gas chromatography.

Volatile organic compounds at aqueous concentrations greater than about 1 mg/L can generally be determined by direct aqueous injection gas chromatography.

### Availability: ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.06 on Methods for Analysis for Organic Substances in Water.

---

**Title:** Standard Practice for Concentration and Recovery of Organic Matter from Water by Activated Carbon<sup>1</sup>

**Citation:** ASTM D 2910-85

**Content:** This practice provides a technique for the concentration and recovery of organic matter from water for analytical purposes. The organic matter is adsorbed from the water onto activated carbon which is solvent-extracted to recover the organic constituents.

The practice is terminated without a prescribed analytical measurement of the organic matter. Analytical methods such as

infrared, mass spectroscopy, and gas chromatography will yield more qualitative and quantitative information than a gravimetric measurement of the residue from solvent evaporation. The choice is left to the user of the adsorption-extraction method subject to his particular needs and the availability of equipment.

### Availability: ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.06 on Methods for Analysis for Organic Substances in Water.

---

**Title:** Standard Test Method for Total Oxygen Demand in Water<sup>1</sup>

**Citation:** ASTM D 3250-77 (1982)

**Content:** This method covers the determination of total oxygen demand in the ranges from 10 to 200, 25 to 500, 50 to 1000 mg/L, in water including brackish waters and brines. Larger concentrations may be determined by suitable dilution of the sample.

The procedures are applicable to all oxygen-demanding substances in the sample that can be injected into the reaction zone. The injector opening limits the maximum size of particles which can be injected. If oxygen-demanding substances that are water-insoluble liquids or solids are present, a preliminary treatment may be desired.

This method is particularly useful for measuring oxygen demand in certain industrial effluents and process streams. Its application for monitoring secondary sewage effluents is not established. Its use for the monitoring of natural waters is greatly limited by the interferences defined in Section 5.

### Availability: ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.06 on Methods for Analysis for Organic Substances in Water.

---

**Title:** Standard Practices for Sampling Water<sup>1</sup>

**Citation:** ASTM D 3370-82

**Content:** These practices cover the sampling of water for chemical, physical, microbiological, and radiological analysis. The following are included: Practice A--Grab samples, Practice B--Composite samples, Practice C--Continual sampling.

**Availability:** ASTM

---

<sup>1</sup>These practices are under the jurisdiction of ASTM Committee D-19 on Water and are the direct responsibility of Subcommittee D19.03 on Hydraulics, Sampling, and Surveillance of Water and Water-Formed Deposits.

---

**Title:** Standard Practice for Identification of Organic Compounds in Water by Combined Gas Chromatography and Electron Impact Mass Spectrometry<sup>1</sup>

**Citation:** ASTM D 4128-82

**Content:** This practice covers the gas chromatography/mass spectrometry (electron impact) identification of organic compounds that are present in or extracted from water and are capable of passing through a gas chromatograph without alteration. The practice is intended primarily for, but not restricted to, solutions containing at least 50 ng of any component of interest. The practice has the advantage of providing tentative identifications of volatile organics, but is restricted to (a) compounds for which reference spectra can be obtained and (b) compounds that can be separated by gas chromatography (GC). These restrictions are imposed on the practice but are not a limitation of the technique. The practice is written for, but not restricted to, analyses using automated data acquisition and handling.

This practice is applicable to the identification of many organic constituents of natural and treated waters. It includes all modes of sample introduction.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of Committee D-19 on Water and is the direct responsibility of Subcommittee D119.06 on Methods for Analysis for Organic Substances in Water.

---

**Title:** Standard Test Method for Polynuclear Aromatic Hydrocarbons in Water<sup>1</sup>

**Citation:** ASTM D 4657-87

**Content:** This test method covers the determination of certain polynuclear aromatic hydrocarbons (PAHs) in water and wastewater. The following compounds may be determined by this method: Acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, dibenzo(ah)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. Additional PAHs may also be determined; however, the analyst should demonstrate that the test method is in fact applicable to the specific PAH(s) of interest before applying it to sample analysis. This test method has high sensitivity for the compounds of interest. It is limited to use by analysts familiar with high-performance liquid chromatography (HPLC) or working under close supervision of such persons.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.06 on Methods for Analysis for Organic Substances in Water.

---

**Title:** Determination of Biochemical Oxygen Demand

**Citation:** CPPA H.2

**Content:** This is a test for the determination of the oxygen depletion capacity of effluent or water. It is indirectly a measure of the organic concentration, but since only part of

## LIQUID WASTE (STANDARDS)

the organic material is oxidized biochemically, it does not measure the total organic concentration.

In its commonest form, the B.O.D. test is based on a five-day period of oxidation at 20°C and does not include the immediate oxygen demand.

**Availability:** CPPA

---

**Title:** Chemical Oxygen Demand

**Citation:** CPPA H.3P

**Content:** This method is used to determine Chemical Oxygen Demand (C.O.D.) of water and waste water, where C.O.D. is defined as the milligrams of oxygen consumed by 1 L of sample under the conditions of the test.

This test method should not be considered as a substitute for the Biochemical Oxygen Demand (B.O.D.) test, Tech. Sect., CPPA Standard H.2. The conditions of oxidation are much more severe in the C.O.D. test and it follows that C.O.D. results are usually higher than corresponding B.O.D. results for the same sample. However, in the case of wastes containing substances which are toxic toward the micro-organisms essential to the B.O.D. test, or which are resistant to biodegradation, the C.O.D. procedure may be the only method suitable for evaluating oxidizable matter in an effluent.

**Availability:** CPPA

---

**Title:** Water Resources Council, National Environmental Policy Act, Compliance

**Citation:** 18 CFR 707

**Content:**

**Availability:** CFR

---

**Title:** Water Pollution Effluent Guidelines and Standards for Point Source Categories: Pulp Paper, and Paperboard

**Citation:** 40 CFR 430

**Content:**

**Availability:** CFR

---

**Title:** Water Programs

**Citation:** 40 CFR 117 (Hazardous substances, reportable quantities determination)

40 CFR 116 (Hazardous substances designation)

40 CFR 129 (Toxic pollutants effluent standards, prohibitions)

40 CFR 131 (Water quality standards)

**Content:**

**Availability:** CFR

---

**Title:** Waste Waters Permanganate Number

**Citation:** SCAN-W 1:66

**Content:** The permanganate number of waste waters is defined as the number of milligrams of potassium permanganate consumed by one liter of waste water under standard conditions of test as specified in this method.

To the acidified sample is added a known amount of potassium permanganate at the temperature of a boiling water bath. The consumption of permanganate is taken as a measure of the content of organic matter in the sample. Unconsumed permanganate is determined iodometrically.

This method applies to waste waters and receiving waters, or dilutions thereof, containing less than 300 mg of chloride ions per litre.

**Availability:** SCAN

---

**Title:** Biochemical Oxygen Demand of  
Industrial Effluents

**Citation:** SCAN-W 5:71

**Content:** The biochemical oxygen demand of an industrial effluent is the amount of dissolved oxygen that is consumed in biochemical oxidation of organic matter under specified conditions.

This method is designed for application to normal industrial effluents containing no other toxic or interfering substances than active chlorine, sulfur dioxide, hydrogen sulfide, or other volatile sulfides.

The pretreated and suitably diluted sample is seeded with domestic sewage to initiate biochemical oxidation. Inorganic nutrient salts are added and the oxygen content is measured immediately and after an incubation period of 7 days at 20°C.

The oxygen dissolved in the sample is determined by adding  $Mn^{2+}$  ions, which are oxidized to manganese (III) hydroxide,  $MnO(OH)$ . On the addition of potassium iodide and acidification an equivalent amount of iodine is liberated and this is titrated with sodium thiosulfate.

**Availability:** SCAN

---



**Title:** Waste Testing and Quality Assurance

**Citation:** STP 999. New York: ASTM

**Content:** Focuses on methodology and quality assurance practices that are being developed for or applied to the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CER-CLA). The papers discuss leachability estimation, data quality assurance, and analytical method development and evaluation.

---

**Title:** Digestion and Analysis of Wastewater Liquids, Solids and Sludges

**Citation:** First Edition. Loveland, CO: Hach Company, 1987

**Content:** Selected methods for the determination of solid fractions and total elemental concentrations.

---

**Title:** Selection of a TOC Analyzer

**Citation:** Crane, Godfrey A. *American Laboratory*, July 1988, p. 51.

**Content:** Total organic carbon (TOC) measurement has come to the forefront as a fast and simple means of assessing water quality, as people the world over become increasingly concerned about environmental pollution, especially of water. This article summarizes applications for the measurement of TOC and related parameters, reviews the various methods available, and offers guidance on choosing a method.

---



**Title:** Particle Size Classifiers: A Guide to Performance Evaluation

**Citation:** AIChE E20-80

**Content:**

**Availability:** AIChE

---

**Title:** Determining the Properties of Fine Particulate Matter

**Citation:** ASME PTC 28-65

**Content:**

**Availability:** ASME

---

**Title:** Determining the Concentration of Particulate Matter in a Gas Stream

**Citation:** ASME PTC 38-80

**Content:**

**Availability:** ASME

---

**Title:** Flue and Exhaust Gas Analyses Instruments and Apparatus

**Citation:** ASME PTC 19.10-81

**Content:**

**Availability:** ASME

---

**Title:** Dust Separating Apparatus

**Citation:** ASME PTC 21-41

**Content:**

**Availability:** ASME

---

**Title:** Standard Definitions of Terms Relating to Atmospheric Sampling and Analysis<sup>1</sup>

**Citation:** ASTM D 1356-73a (1979)

**Content:**

**Availability:** ASTM

---

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres.

---

**Title:** Standard Recommended Practices for Sampling Atmospheres for Analysis of Gases and Vapors<sup>1</sup>

**Citation:** ASTM D 1605-60 (1979)

**Content:** These recommended practices cover the sampling of atmospheres for analysis of gases and vapors. Two types of sampling methods are covered: Sampling Atmospheres Without Concentration of Gases and Vapors; Sampling Atmospheres With Concentration of Gases and Vapors.

**Availability:** ASTM

---

<sup>1</sup>These recommended practices are under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres.

---

**Title:** Standard Test Method for Oxides of Nitrogen in Gaseous Combustion Products (Phenol-Disulfonic Acid Procedures)<sup>1</sup>

**Citation:** ASTM D 1608-77 (1985)

**Content:** This method describes the phenol-disulfonic acid colorimetric procedure for the determination of total oxides of nitrogen [nitrous oxide (N<sub>2</sub>O) excepted] in gaseous effluents from combustion and other nitrogen oxidation processes.

## ATMOSPHERIC ANALYSIS (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.06 on Source Sampling.

---

**Title:** Standard Test Method for Particulate Matter in the Atmosphere (Optical Density of Filtered Deposit)<sup>1</sup>

**Citation:** ASTM D 1704-78

**Content:** This method covers the measurement of the extent of soiling or darkening of clean filter paper or other white fibrous media by filtration of particulate matter in the atmosphere. Measurement is based on the light transmission or reflectance properties of the deposited solid or liquid particles that originally were dispersed in a gaseous medium.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.03 on Monitoring Instrumentation.

---

**Title:** Standard Practice for Conversion Units and Factors Relating to Atmospheric Analysis<sup>1</sup>

**Citation:** ASTM D 1914-68 (1983)

**Content:** ASTM requires the use of SI units in all of its publications and strongly recommends their use in reporting atmospheric measurement data. However, there is a wealth of historical data and even data reported at the present time that is based on a variety of units of measurement. This standard tabulates factors that are necessary to correct such data to other units of measurement.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.01 on Quality Control.

---

**Title:** Standard Recommended Practice for Collection by Filtration and Determination of Mass, Number, and Optical Sizing of Atmospheric Particulates<sup>1</sup>

**Citation:** ASTM D 2009-65 (1979)

**Content:** This recommended practice covers the sample collection of particulate matter from an atmosphere by filtration and for measurement of mass amount, particle size, and particle size distribution of the collected material. Variations in the recommended practice permit sampling to meet a number of widely different assay needs. Although especially applicable to collection of solid particles, the filter method may be used also to collect liquid particles if droplet size need not be determined.

**Availability:** ASTM

---

<sup>1</sup>This recommended practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres.

---

**Title:** Standard Test Method for Carbon Monoxide in the Atmosphere (Continuous Measurement by Nondispersive Infrared Spectrometry)<sup>1</sup>

**Citation:** ASTM D 3162-78

**Content:** This method covers the continuous analysis and automatic recording of the carbon monoxide (CO) content of the ambient atmosphere in range of 0.6 mg/m<sup>3</sup> (0.5 ppm) to 115 mg/m<sup>3</sup> (100 ppm). The measuring principle makes use of absorption of radiation by CO in the infrared region. The method has a limit of detection of about 0.6 mg/m<sup>3</sup> (0.5 ppm) carbon monoxide in air.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres, and is the direct responsibility of Subcommittee D22.03 on Monitoring Instrumentation.

---

**Title:** Standard Test Method for Relative Density of Black Smoke (Ringelmann Method)<sup>1</sup>

**Citation:** ASTM D 3211-79

**Content:** This method covers the determination of the relative density of black smoke.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.06 on Source Sampling.

---

**Title:** Standard Recommended Practice for General Ambient Air Analyzer Procedures<sup>1</sup>

**Citation:** ASTM D 3249-79

**Content:** This recommended practice is a general guide for ambient air analyzers used in determining air quality.

The actual method, or analyzer chosen, depends on the ultimate aim of the user: whether it is for regulatory compliance, process monitoring, or to alert the user of adverse trends. If the method or analyzer is to be used for federal or local compliance, it is recommended that the method published or referenced in the regulations be used in conjunction with this and other ASTM methods.

**Availability:** ASTM

---

<sup>1</sup>This recommended practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of D22.03 on Monitoring Instrumentation.

---

**Title:** Standard Test Method for Concentration and Particle Size Distribution of Airborne Particulates Collected in Liquid Media Using an Electronic Counter<sup>1</sup>

**Citation:** ASTM D 3365-77 (Discontinued)

**Content:** This method covers the determination of quantitative counts and size distribution of insoluble airborne particulate matter greater than 0.6- $\mu$ m diameter collected in a Greenburg-Smith or a midget liquid impinger, using an electronic particle size analyzer and counter. Both ambient and stack particulates can be analyzed by this method.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres.

---

**Title:** Standard Test Method for Total Hydrocarbons, Methane, and Carbon Monoxide in the Atmosphere (Gas Chromatographic Method)<sup>1</sup>

**Citation:** ASTM D 3416-78

**Content:** This method covers a collection of components which is designed for the semi-continuous measurement of total hydrocarbons, methane, and carbon monoxide in ambient air using the specificity of the hydrogen flame ionization detector for hydrocarbons, and a gas chromatographic technique for carbon monoxide and methane.

## ATMOSPHERIC ANALYSIS (STANDARDS)

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.03 on Monitoring Instrumentation.

---

**Title:** Standard Test Method for Particulates Independently or for Particulates and Collected Residue Simultaneously in Stack Gases<sup>1</sup>

**Citation:** ASTM D 3685-78

**Content:** This method covers the determination of the mass emission rate of particulate matter in effluent, in-stack (Method A--Dry) or out-of-stack (Method B--Wet) gas streams. The method also covers the simultaneous determination of particulate matter and collected residue in effluent gas streams.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.06 on Source Sampling.

---

**Title:** Standard Practice for Sampling Atmospheres to Collect Organic Compound Vapors (Activated Charcoal Tube Adsorption Method)<sup>1</sup>

**Citation:** ASTM D 3686-84

**Content:** This practice covers a method for the sampling of atmospheres for determining the presence of certain organic vapors by means of adsorption on activated charcoal using a charcoal tube and a small portable sampling pump worn by a worker. A list of some of the organic chemical vapors that can be sampled by this practice is provided in Annex A1. This list is presented as a guide and should not be considered as absolute or complete.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.04 on Analysis of Workplace Atmospheres.

---

**Title:** Standard Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption Method<sup>1</sup>

**Citation:** ASTM D 3687-84

**Content:** This practice covers the applications of methods for the desorption and gas chromatographic determination of organic vapors that have been adsorbed from air in sampling tubes packed with activated charcoal.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.04 on Analysis of Workplace Atmospheres.

---

**Title:** Standard Practice for Application of the Hi-Vol (High-Volume) Sampler Method for Collection and Mass Determination of Airborne Particulate Matter<sup>1</sup>

**Citation:** ASTM D 4096-82

**Content:** This practice provides for sampling a large volume of atmosphere, 1600 to 2400 m<sup>3</sup> (55,000 to 85,000 ft<sup>3</sup>), by means of a high flowrate blower at a rate of 1.13 to 1.70 m<sup>3</sup>/min (40 to 60 ft<sup>3</sup>/min).

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.03 on Ambient Atmospheres.

---

**Title:** Standard Test Method for High-Volume Sampling for Solid Particulate Matter and Determination of Particulate Emissions<sup>1</sup>

**Citation:** ASTM D 4536-86a

**Content:** This test method can be used to estimate the particulate matter concentration in stationary source stacks.

**Availability:** ASTM

---

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.02 on Source Sampling.

---

**Title:** Method for Measurement of Particulate Emission Including Grit and Dust (Simplified Method)

**Citation:** BS 3405:1983

**Content:** States the principles to adopt in carrying out a simplified method for the determination of particulate matter in effluent gases from industrial processes and describes the procedure. Sets out requirements to be met in designing apparatus required and indicates basic sampling procedures.

**Availability:** BSI

---

**Title:** Methods for the Determination of Particle Size Distribution

**Citation:** BS 3406

**Content:** Part 1:1986--Guide to Powder Sampling

Part 2:1984--Recommendations for Gravitational Liquid Sedimentation Methods for Powders and Suspensions

Part 3:1963--Air Elutriation Methods

Part 4:1963--Optical Microscope Method

Part 5:1983--Recommendations for Electrical Sensing Zone Method (the Coulter Principle)

Part 6:1985--Recommendations for Centrifugal Liquid Sedimentation Methods for Powders and Suspensions

**Availability:** BSI

---

**Title:** Testing of Fuel Gases of Oil Burning Systems; Visual and Photometric Determination of the Smoke Number

**Citation:** DIN 51402 Part 1

**Content:**

**Availability:** DIN

---

**Title:** Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air

**Citation:** EPA/600/S4-87/006

**Content:**

**Availability:** EPA

---

**Title:** Continuous Analyzers for Oxygen in Flue Gas

**Citation:** JIS B 7963-79

**Content:**

**Availability:** JIS

---

**Title:** Method for Sampling of Stack Gas

**Citation:** JIS K 0095-79

**Content:**

**Availability:** JIS

---

# ATMOSPHERIC ANALYSIS (STANDARDS)

**Title:** Use of the Ringlemann and Miniature  
Smoke Charts

**Citation:** NZS 5201:1973  
(Identical to BS 2742:1969)

**Content:**

**Availability:** SANZ

---

**Title:** Ringlemann Chart

**Citation:** NZS 5201C:1975 (Identical to  
BS 2742C:1957)

**Content:**

**Availability:** SANZ

---

**Title:** British Standard Miniature Smoke  
Chart

**Citation:** NZS 5201M:1975  
(Identical to BS 2742M:1960)

**Content:**

**Availability:** SANZ

---

**Title:** Ambient Air Quality Standards,  
National Primary and Secondary

**Citation:** 40 CFR 50

**Content:**

**Availability:** EPA/CFR

---

**Title:** Ambient Air Monitoring Reference  
and Equivalent Methods

**Citation:** 40 CFR 53

**Content:**

**Availability:** EPA/CFR

---

**Title:** New Stationary Sources Performance  
Standards

**Citation:** 40 CFR 60

**Content:**

Method 1--Sample and velocity traverses for  
stationary sources,  
Method 2--Determination of stack gas veloc-  
ity and volumetric flow rate (Type S pitot  
tube),  
Method 3--Gas analysis for carbon dioxide,  
oxygen, excess air, and dry molecular  
weight,  
Method 4--Determination of moisture con-  
tent in stack gases,  
Method 5--Determination of particulate  
emissions from stationary sources,  
Method 6--Determination of sulfur dioxide  
emissions from stationary sources,  
Method 6C--Determination of sulfur dioxide  
emissions from stationary sources,  
Method 7--Determination of nitrogen oxide  
emissions from stationary sources,  
Method 7A--Determination of nitrogen oxide  
emissions from stationary sources--Ion  
chromatographic method,  
Method 7B--Determination of nitrogen oxide  
emissions from stationary sources (Ultra-  
violet spectrophotometry),  
Method 7C--Determination of nitrogen oxide  
emissions from stationary sources--  
Alkaline-permanganate/colorimetric  
method,  
Method 7D--Determination of nitrogen oxide  
emissions from stationary sources--  
Alkaline-permanganate/ion  
chromatographic method,  
Method 7E--Determination of nitrogen oxides  
emissions from stationary sources (Instru-  
mental Analyzer Procedure),  
Method 9--Visual determination of the opa-  
city of emissions from stationary sources,  
Alternate Method 1--Determination of the  
opacity of emissions from stationary  
sources remotely by lidar,  
Method 10--Determination of carbon mono-  
oxide emissions from stationary sources,  
Method 17--Determination of particulate  
emissions from stationary sources (instack  
filtration method),

Method 18--Measurement of gaseous organic compound emissions by gas chromatography,  
Method 19--Determination of sulfur dioxide removal efficiency and particulate, sulfur dioxide and nitrogen oxides emission rates from electric utility steam generators,  
Method 20--Determination of nitrogen oxides, sulfur dioxide, and diluent emissions from stationary gas turbines,  
Method 21--Determination of volatile organic compound leaks,  
Method 22--Visual determination of fugitive emissions from material sources and smoke emissions from flares

**Availability:** EPA/CFR

---

**Title:** National Emission Standards for Hazardous Air Pollutants

**Citation:** 40 CFR 61

**Content:**

**Availability:** EPA/CFR

---

**Title:** Clean Air Act Requirements, Special Exemptions

**Citation:** 40 CFR 69

**Content:**

**Availability:** EPA/CFR

---



**Title:** Sampling and Calibration for Atmospheric Measurements

**Citation:** Edited by J. K. Taylor. ASTM STP 957. New York: ASTM, 1987, 228 pp.

**Content:** Papers explain how to design and carry out atmospheric sampling, how to reliably calibrate instruments, and thus how to obtain more reliable measurements in relation to understanding and controlling air pollution, work place atmospheres, and indoor air quality. This publication will be of interest to industrial hygienists, analytical chemists involved with atmospheres, building designers, and regulators.

---

**Title:** Air Sampling Instruments

**Citation:** Edited by P. J. Lioy and M. J. Y. Lioy. 6th Edition. Cincinnati: American Conference of Governmental Industrial Hygienists, 1983, 552 pp.

**Content:** Background Discussions--Air Sampling for Specific Purposes; Background Discussions--Instrument Operation and Performance; Discussions and Descriptions of Sampling Systems and Components; Discussions and Descriptions of Direct Reading Instruments.

---

**Title:** Climate Models and CO<sub>2</sub> Warming: A Selective Review and Summary

**Citation:** PUBL 4347-82. American Petroleum Institute, 48 pp.

**Content:**

---

**Title:** Economic Methods for Multipollutant Analysis and Evaluation

**Citation:** Baasel, William D. New York: Marcel Dekker, Inc., 1985.

**Content:**

---

**Title:** Modified Method 5 Train and Source Assessment Sampling System Operator's Manual

**Citation:** Schlickerieder, Lynn M., Jeffrey W. Adams, and Kathleen E. Thrun. EPA-600/8-85-003. Washington, DC: United States Environmental Protection Agency, 1985.

**Content:**

---





**Title:** Proposed Safety Test Standard for Automatic Feed Appliances

**Citation:** Prepared by APFI Store Safety Standards Committee

**Content:** This proposed standard covers all automated feed, solid fuel appliances for residential use which are intended to burn densified biomass or other suitable solid fuel.

**Availability:** APFI

---

**Title:** Steam Generating Units

**Citation:** ASME PTC 4.1-64

**Content:**

**Availability:** ASME

---

**Title:** Air Heaters

**Citation:** ASME PTC 4.3-68

**Content:**

**Availability:** ASME

---

**Title:** Routine Performance Tests of Steam Turbines, Simplified

**Citation:** ASME PTC 6S-70

**Content:**

**Availability:** ASME

---

**Title:** Reciprocating Internal-Combustion Engines

**Citation:** ASME PTC 17-73

**Content:**

**Availability:** ASME

---

**Title:** Measurement of Shaft Power Instruments and Apparatus

**Citation:** ASME PTC 19.7-80

**Content:**

**Availability:** ASME

---

**Title:** Gas Turbine Power Plants

**Citation:** ASME PTC 22-85

**Content:**

**Availability:** ASME

---

**Title:** Large Incinerators

**Citation:** ASME PTC 33-78  
(Appendix 33A-1980, 1987)

**Content:**

**Availability:** ASME

---

**Title:** Boiler and Pressure Vessel Codes - Non-Interfiled - (1986)

**Citation:** ASME

**Content:** Contains many subsections.

**Availability:** ASME

---

**Title:** Glossary of Terms Relating to Solid Fuel Burning Equipment

**Citation:** BS 1846:--  
Part 1:1968 (Domestic Appliances)  
Part 2:1969 (Industrial Water Heating and Steam Raising Installations)

**Content:**

**Availability:** BSI

---

## COMBUSTION (STANDARDS)

**Title:** Combination Gas and Solid-Fuel Fired Furnaces

**Citation:** CAN1-2.27-M84

**Content:** This standard applies to newly produced combination gas/solid-fuel furnaces having an input on gas not exceeding 120 kW (400,000 Btuh) that have provision for venting directly to the outdoors by means of flue pipes, chimneys, and are intended primarily for residential heating.

**Note:** Gas means natural gas or propane.

This standard applies to furnaces, factory or field-assembled, that have been, or could have been, completely assembled at the manufacturer's plant and transported in the assembled condition.

This standard also applies to outdoor-aired combination gas/solid-fuel fired furnaces. For the purposes of these requirements, "outdoor-aired" refers to furnaces wherein all combustion air is to be taken directly from the outdoors.

An appliance submitted for examination under this standard shall be constructed so that every part is secured against displacement and that a fixed relationship is maintained between essential parts under normal and reasonable conditions of handling and use.

This standard does not cover fireplaces or incinerators.

**Availability:** CGA

---

**Title:** General Requirements for Oil Burning Equipment

**Citation:** CAN/CSA-B140.0-M87

**Content:**

**Availability:** CSA

---

**Title:** Installation Code for Solid-Fuel-Burning Appliances and Equipment

**Citation:** CAN/CSA-B365-M87

**Content:** Covers minimum requirements for the installation of, alteration to, addition to and provision for maintenance for solid-fuel burning appliances and equipment intended to supply heat to air or water. It does not apply to the installation of incinerators, site-built fireplaces or process equipment. For the purpose of this standard, solid-fuel burning appliances shall include furnaces, boilers, stoves, ranges, space heaters, factory-built fireplaces, and service water heaters.

**Availability:** CSA

---

**Title:** Solid-Fuel-Fired Central Heating Appliances

**Citation:** CAN/CSA-B366.1-M87

**Content:** Applies to (a) hand-fueled or stoker-equipped solid-fuel fired appliances having an input rating not exceeding 300 kW (1 million Btu/h) that have provision for venting directly to the outdoors by means of flue pipes, chimneys, etc. and are intended primarily for residential heatings; (b) appliances, factory- or field-assembled, that have been, or could have been, completely assembled at the manufacturer's plant and transported in the assembled condition; (c) the hand-fueled or stoker-equipped solid-fuel features of a combination solid-fuel-/fuel-oil-fired appliance, intended primarily for residential heating, where the solid-fuel features may affect the safety or performance of the oil-fired appliance. In these cases, requirements in this standard are additional to the requirements for the specific oil-fired appliance; (d) outdoor-aired solid-fuel-fired appliances. For the purpose of these requirements, "outdoor-aired" refers to appliances wherein all combustion air is to be taken directly from the outdoors; and (e) solid-fuel-fired furnaces intended to be added on directly in series at a point after

the warm air leaves the existing forced-warm-air oil furnace (downstream series add-on). Contains suggested wood-chip and wood-pellet grades.

**Availability:** CSA

---

**Title:** List of Certified Fuel Burning Equipment and Fuels Handling Equipment

**Citation:** CSA DIR.006-1988

**Content:**

**Availability:** CSA

---

**Title:** Incinerator Performance

**Citation:** CSA Z103-1976

**Content:**

**Availability:** CSA

---

**Title:** Space Heaters for Use with Solid Fuels

**Citation:** CAN/CSA B366.2-M1984

**Content:**

**Availability:** CSA

---

**Title:** Acceptance Test Code for Steam Generators

**Citation:** DIN 1942, 1979

**Content:**

**Availability:** DIN

---

**Title:** Boilers for Central Heating

**Citation:** DIN 4702, 1987

**Content:** Terms, requirements, testing, marking.

**Availability:** DIN

---

**Title:** Efficiency of Combustors and Gasifiers

**Citation:** DIN 18800

**Content:**

**Availability:** DIN

---

**Title:** Slow-Combustion Stoves for Solid Fuel

**Citation:** DIN 18890

**Content:**

**Availability:** DIN

---

**Title:** Standard Glossary of Terms Relating to Chimneys, Vents, and Heat Producing Appliances

**Citation:** NFPA 97M-88

**Content:**

**Availability:** NFPA

---

**Title:** Chimneys, Fireplaces, Vents and Solid Fuel Burning Appliances

**Citation:** NFPA 211:88

**Content:** Presents requirements for the construction and installation of chimneys, fireplaces, vents, and solid fuel burning appliances in residential, commercial, and industrial applications.

**Availability:** NFPA

---

## COMBUSTION (STANDARDS)

**Title:** Specification for Incinerators

**Citation:** NZS 5202:1979

**Content:** The design, performance, construction, installation and operation of industrial, local authority, and commercial incinerators.

**Availability:** SANZ

---

**Title:** Specification of Solid Fuel Burning Domestic Appliances

**Citation:** NZS 7401:1985

**Content:** This standard applies to solid fuel fired heating appliances intended primarily for domestic use which have an input rating not exceeding 50 kW and provision for venting directly to the outdoors by means of flue pipes and chimneys.

This standard applies to appliances, factory or field-assembled, that have been, or could have been, completely assembled at the manufacturer's plant and transported in the assembled condition.

This standard does not cover open fireplaces.

A test for the pollution requirements for appliances is specifically excluded from this standard.

**Availability:** SANZ

---

**Title:** Specification for Installation of Solid Fuel Appliances

**Citation:** NZS 7421:1985

**Content:** This standard relates to the installation of solid fuel burning domestic appliances of the following classes: (a) Room heaters heating by direct radiation and/or convection. Open fires in conventional grates or fireplaces are excluded, but free standing open fires with hood and flue pipe over are included. Flueless portable appliances are excluded. (b) Ducted heaters heating spaces other than those in which they are installed by means of warm air passing through ducts. The air ducting is excluded. (c) Water heaters of non-pressure (vented to

atmosphere) type for supplying hot water. Radiators and their piping are excluded.

**Availability:** SANZ

---

**Title:** Chimneys, Factory-Built, Residential Type and Building Heating Appliance

**Citation:** UL 103

**Content:**

**Availability:** UL

---

**Title:** Solid-Fuel and Combination-Fuel Central and Supplementary Furnaces

**Citation:** UL 391

**Content:**

**Availability:** UL

---

**Title:** Chimneys, Medium Heat Appliance, Factory-Built

**Citation:** UL 959

**Content:**

**Availability:** UL

---

**Title:** Solid Fuel Type Room Heaters

**Citation:** UL 1482

**Content:**

**Availability:** UL

---

**Title:** Chimney Liners

**Citation:** UL 1777

**Content:**

**Availability:** UL

---

**Title:** Chimneys, Type A, Factory-Built

**Citation:** CAN/ULC-S604 (1982)

**Content:**

**Availability:** ULC

---

---

**Title:** Space Heaters for Use with Solid  
Fuels

**Citation:** CAN/ULC-S627 (1983)

**Content:**

**Availability:** ULC

---

---

**Title:** Chimneys, 650°C, Factory-Built

**Citation:** CAN/ULC-S629 (1987)

**Content:**

**Availability:** ULC

---

---

**Title:** Chimney Connectors, Factory-Built

**Citation:** CAN/ULC-S641 (1987)

**Content:**

**Availability:** ULC

---

---



**Title:** Correct Determination of Efficiency with Special Reference to Small Boilers

**Citation:** Asplund, Frank. Information No. 447. Swedish National Board for Technical Development, 1985.

**Content:** It should be possible, knowing the efficiency of a boiler installation and the useful power delivered by the installation, to determine the fuel demand. It should also be possible to compare the performances of different boilers with each other.

Neither of these things is possible with the methods generally used to determine efficiency today. Two boilers can have the same "efficiency" at the same useful power output, but the fuel consumption of one boiler may be 30% higher than that of the other. Obviously such an unsatisfactory method of determining efficiency can only be of interest to the supplier of the less efficient boiler!

In order to achieve correct determination of efficiency, a method that takes account of significant losses has been described. With the lowest possible input values, the procedure for calculating the efficiency and for calculating gas data after combustion has been stated. Provided that the input values are correct, it is estimated that the maximum deviation of the calculated efficiency from the correct efficiency is less than 0.1 percentage point in the area of definition.

Definitions of heating value that occur are clarified, as are the various efficiency terms.

For many processes, efficiency varies with time. This is the case with wood-fired or oil-fired domestic heating boilers, for example. To determine efficiency correctly in such cases, the average boiler efficiency over time has been defined, and a suitable method is described for indirect determination of efficiency.

The efficiency of the domestic heating boiler as a function of summer and winter operation has been studied. The study shows that efficiency is higher in summer than in winter and that the environmental losses during the "heating season," i.e. the season when the house requires heating, are not, in most cases, true losses, since they contribute to heating the house.

---

**Title:** Combustion and Emission Research on Wood-Refuse Boilers. Volume II. Description of Program and Common Methods

**Citation:** Prepared for Bioenergy Development Program, Renewable Energy Branch, Energy, Mines and Resources Canada, Ottawa, Canada. Coordinated by Canadian Boiler Society, Niagara Falls, Ontario, June, 1984.

**Content:**

---

**Title:** Sampling and Chemical Analyses of Air Pollution from Combustion of Biomass: A Draft

**Citation:** Benestad, Christel. Oslo, Norway: Center for Industrial Research, 1987.

**Content:**

---

**Title:** The National Incinerator Testing and Evaluation Program (NITEP)

**Citation:** Ottawa, Canada: NITEP, Environmental Protection Service, April 1985.

**Content:**

---



**Title:** Gas Producers and Continuous Gas  
Generators

**Citation:** ASME PTC 16-58

**Content:**

**Availability:** ASME

---

**Title:** Proposed Standard Test Methods for  
Performance Evaluation of Biomass  
Gasifiers

**Citation:** Proposal Document No. 108RD,  
Committee E48.05

**Content:**

**Availability:** ASTM (not yet released)

---



**Title:** Development of Sampling and Analytical Procedures for Biomass Gasifiers

**Citation:** Esplin, G. J., D. P. C. Fung, and C. C. Hsu. *The Canadian Journal of Chemical Engineering* 63:946 (1985).

**Content:** A design of a sampling train suitable for the analysis of raw producer gas from biomass gasifiers is presented. The sampler was designed to allow sampling of gas streams at a wide range of temperatures and tar concentrations and to facilitate the separation of gases, particulate, tar and aqueous fractions. The procedure for the collection, separation and analysis was evaluated on the results obtained from the biomass fluidized bed gasifier located at B.C. Research, Vancouver, B.C.

---

**Title:** Characterization of Wood-Derived Tars

**Citation:** Beall, K. and Douglas W. Duncan. B.C. Research Project No. 203-540, Vancouver, B.C.: B.C. Research, 1981.

**Content:** Tar and condensate samples have been collected from four different wood-waste gasifiers operating in Canada. Various solvent systems for the tars have been investigated and a mixture of ether: Tetrahydrofuran: ethanol (1:8:1) was found to give the best results. Dissolved tars are absorbed on neutral alumina and 5 fractions eluted: hydrocarbons, aromatic hydrocarbons and benzofurans, ethers, nitrogen compounds and hydroxyl compounds. An unrecovered fraction remains on the column. The composition of the various fractions is being determined using GC and HPLC analysis.

---

**Title:** UNDP/World Bank Guidelines for Field Monitoring of Small Scale Biomass Gasifiers

**Citation:** Draft, Prepared by Energy Department, The World Bank, Washington, D.C. and Chemical Engineering Department, Twente University of Technology, Enschede, The Netherlands, 1984.

**Content:**

---

**Title:** Determination of Polycyclic Aromatic Hydrocarbons in Biomass Gasifier Effluents with Liquid Chromatography/Diode Array Spectroscopy

**Citation:** Desilets, David J., Peter T. Kissinger, Fred E. Lytle, Mark A. Horne, Mark S. Ludwiczak, and Robert B. Jacko. *Environ. Sci. Technol.* 18:386-391 (1984).

**Content:** Liquid chromatography/diode array spectroscopy (LC/DAS) is used for the determination of polycyclic aromatic hydrocarbons (PAH) isolated from the emissions of biomass gasifiers. The spectrometer is capable of obtaining complete absorption spectra of components as they elute from the chromatograph, thus confirming the identities of pure peaks and mixed or poorly resolved peaks. This technique is especially well suited for the determination of polynuclear aromatics, where many isomers difficult to resolve chromatographically are easily distinguished by their electronic spectra. The instrument is also capable of differentiating between unsubstituted PAH and their methylated analogues, even though methylation does not greatly perturb the electronic nature of the parent hydrocarbon.

---

## GASIFICATION (LITERATURE)

**Title:** A Comparison of the Energy and Product Distribution from Biomass Gasifiers

**Citation:** Esplin, G. J., D. P. C. Fung, and C. C. Hsu. *Can. J. Chem. Eng.* 64, 651 1986.

**Content:** A detailed analyses of the raw producer gas streams generated by a downdraft gasifier and by a fluidized-bed gasifier are presented and are discussed in terms of raw gas clean-up considerations and of energy conversion efficiency.

The major gasifier operating parameters such as fuel/air ratio, carbon conversion efficiency, net energy conversion efficiency, and producer gas heating value are then compared between seven operational gasifiers and a computer simulation model of a fluidized-bed gasifier developed by Queen's University.

It is concluded that the Queen's University model correctly predicts that the fuel/air ratio is the single most important parameter for detemining gasifier performance. Downdraft gasifiers exhibit superior energy conversion efficiency and producer gas quality because they utilize a higher fuel/air ratio than do fluidized bed gasifiers.

---

**Title:** A Manual for Evaluating Biomass Gasifiers

**Citation:** Esplin, G. J., M. Aiken, and E. McDonald. B.C. Research for Techwest Enterprises Ltd. Energy, Mines and Resources. Canada, Ottawa. March 1984.

**Content:** Section B--Review of gasifier performance testing, including calculations of material and energy balances. Section C--Data needed for calculations. Section D--Collecting samples for analyses. Section E--Field and laboratory analyses. Section F--General calculation method, plus a sample calculation. Section G--Effects of omitting data.

---

**Title:** A Workbook for Biomass Gasifier Sampling and Analysis

**Citation:** Esplin, G. J., M. Aiken, and E. C. McDonald. ENFOR Project No. C-172 DSS File No. 41SS.KL229-1-4114. (Available through Energy, Mines and Resources). March 1983.

**Content:** This workbook provides a methodology for the following procedures:

- a. Obtaining an accurate sample of the raw producer gas. The components of this sample consist of coarse particles and/or aerosols as they exist at the sampling temperature, fine particles and those tars which condense at or above 200°C, tars and aqueous condensate which condense between 200°C and 0°C, and noncondensable, dry producer gas.
  - b. Measuring the total flow rate of the gas streams entering and leaving the gasifier system. Alternatively, these flows may be estimated using elemental mass balances.
  - c. Recovery and analyzing the components of the product stream for mass concentration, elemental composition and calorific value.
  - d. Using these data to calculate mass balances, energy balances, net conversion efficiency, and gross conversion efficiency.
  - e. Analyzing the aqueous condensate for phenolics, organic acids, alcohols and other components.
  - f. Modifying a commercial high volume stack sampler to enable it to sample the hot gases and tarry residues.
-

**Title:** Standard Method for Performance Evaluation of Fermentation Fuel Manufacturing Facilities<sup>1</sup>

**Citation:** ASTM E 869-82 (1987)

**Content:** This method covers the determination of relative performance characteristics of mass-produced alcohol manufacturing plants.

This method is applicable for all fermentable feedstocks.

This method is applicable to both batch and continuous alcohol manufacturing processes.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-44 on Solar Energy Conversion and is the direct responsibility of Subcommittee E44.12 on Biomass Conversion Systems.

---

**Title:** Standard Practice for Designs of Fuel-Alcohol Manufacturing Facilities

**Citation:** ASTM E 1117-86

**Content:**

**Availability:** ASTM

---

**Title:** Proposed Standard Test Methods for Performance Evaluation of Anaerobic Digesters

**Citation:** Proposal Document No. 109RD, Committee E48.05

**Content:**

**Availability:** ASTM (not yet released)

---

**Title:** Installation Code for Digester Gas Systems

**Citation:** CAN/CGA-B105-M87

**Content:** This code applies to the installation of systems for the production, handling, storage, and utilization of digester gas in newly constructed wastewater treatment plants, as well as additions to, and the upgrading of, existing systems.

This code applies to the safety aspects of the operation and maintenance for handling, storage, and utilization of digester gas in wastewater treatment plants.

This code applies to existing digester gas systems where, in the opinion of the authority having jurisdiction, a hazard or potential hazard exists.

**Availability:** CGA

---



**Title:** Standard Methods for the Examination of Water and Wastewater

**Citation:** 15th Edition, APHA-AWWA-WPCF, 1980.

**Content:**

---

**Title:** Manual of Methods for General Bacteriology

**Citation:** American Society for Microbiology, 1981.

**Content:**

---

**Title:** A Serum Bottle Modification of the Hungate Technique for Cultivating Obligate Anaerobes

**Citation:** Miller, T. L. and M. J. Wolin. *Applied Microbiology* 27(5):985-987 (1974).

**Content:**

---

**Title:** General Method for Determining Anaerobic Biodegradation Potential

**Citation:** Shelton, D. R. and J. M. Tiedje. *Applied and Environmental Microbiology* 47(4):850-857 (1984).

**Content:**

---

**Title:** Anaerobic Biogasification Potential Assay

**Citation:** Chynoweth, D. P. *et al.* In *Gasification of Land-Based Biomass*. IGT Project 30564 Final Report. Chicago: Institute of Gas Technology, June 1983.

**Content:**

---

**Title:** A Practical Method to Estimate the Acetoclastic Methanogenic Biomass in Anaerobic Sludges

**Citation:** Valcke, D. and W. Verstraete. *J. Water Pollution Control Federation* 55:1191-1194 (1983).

**Content:**

---

**Title:** Volatile Acids by Direct Titration

**Citation:** Dilallo, R. and O. E. Albertson. *J. Water Pollution Control Federation* 33(4):356 (1961).

**Content:**

---

**Title:** Bioassay for Monitoring Biochemical Methane Potential and Anaerobic Toxicity

**Citation:** Owens, W. F. *et al.* *Water Research* 13:485 (1979).

**Content:**

---

**Title:** Anaerobe Laboratory Manual

**Citation:** Holdeman, L. V. and W. E. C. Moore. Blacksburg, VA: Virginia Polytechnic Institute and State University, 1972.

**Content:**

---

**Title:** Proposal for the Definition of Parameters and Analytical Measurements Applicable to Carbohydrate Hydrolysis Processes

**Citation:** Belaich, J., G. L. Ferrero, M. P. L'Hermite, H. Naveau, Ph. Thonart, and T. M. Wood. *Process Biochemistry* 19:2 (February 1984).

**Content:** The term "carbohydrate hydrolysis process" is applied to a variety of processes that can be a microbiological fermentation process carried out by undefined or defined mixed or pure populations of microorganisms

## BIOCONVERSION (LITERATURE)

or hydrolysis catalyzed by pure or mixed enzymes or that can be a chemical process, each performed in a variety of types of reactors with feedstocks of different origins varying from wet solids to clear liquids. The feedstock may be synthetic and of exact analysis or it may be complex and only partially defined by analysis.

Describing hydrolysis in such a way that one set of results can be compared with another, or meaningful predictions of behavior of a full size plant can be made from pilot experiments, is thus difficult.

The amount of data that can be given about a fermentation of hydrolysis reaction must depend to some extent on the facilities available: for example, a full laboratory service may not be available for every plant. In addition, different data may be important in different circumstances. The power input to a laboratory fermentor may not be important in describing the biochemistry of the fermentation, but this input is obviously important in assessing the energy output from, or the cost of, a full-scale plant.

To try to overcome some of these difficulties in description and to give a guide to what information should be given if at all possible, we have drawn up these notes on the data needed to describe adequately a fermentation or hydrolysis experiment.

---

**Title:** Glossary of Terms Used in  
Biotechnology for Chemists

**Citation:** Nagel, B., H. Dellweg, and L. Gierasch. International Union of Pure and Applied Chemistry, Applied Chemistry Division, Commission VI.2 (Biotechnology) Project 4/87. Contributions from H. Dellweg, J. Engels, L. M. Gierasch, R. P. Gregson, B. Heinritz, H. G. Leuenberger, M. Moo-Young, A. Moser, B. Nagel, L. Nyeste, L. Penasse, G. B. Petersen, M. van Montagu.

**Content:**

---

**Title:** Living Resources for Biotechnology

**Citation:** An International Initiative by the World Federation for Culture Collections with Financial Support from UNESCO. Editorial Board, A. Doyle, D. Hawksworth, R. L. Hill, B. E. Kirsop, K. Komagata, and R. E. Stevenson. Cambridge University Press, 1989.

**Content:** This series of source books has been assembled to meet the needs of scientists using microbiological materials as tools in biotechnological investigations. When starting to handle bacteria, filamentous fungi, yeasts, algae, viruses, animal and plant cells, research workers are faced with a number of questions. Where can the material be obtained and who will supply basic information about its use and preservation? Are there identification services available? How is material deposited in gene banks? How are patents taken out? Are there centers that will carry out contract work? What safety regulations should be taken into account and what organizations exist to help?

This is the first time that such data have been drawn together in single volumes. The series will be valuable to workers all over the world in universities, research institutes, and industry.

---



**Title:** Production and Applications of Cellulase--Laboratory Procedures

**Citation:** Adapted from Mary Mandels, U.S. Army Materials Laboratories, December 1974 and T. W. Jeffries, USDA, Forest Products Laboratory, Madison, WI February 1987.

**Content:**

---

**Title:** Oxidation and Reduction of Lignin-Related Aromatic Compounds by *Aureobasidium pullulans*

**Citation:** Bourbonnais, Robert and Michael G. Paice. *Appl. Microbiol. Biotechnol.* 26:164-169 (1987).

**Content:** A yeast-like fungus, identified as *Aureobasidium pullulans*, was isolated from a kraft mill settling pond by enrichment culture on 1-(4-hydroxy-3-methoxyphenyl)-2-(2-methoxyphenoxy)-propane-1,3-diol (I). The fungus was also able to use the following aromatic acids as sole carbon source: Benzoic, p-hydroxybenzoic, vanillic, syringic, ferulic and protocatechuic acids. Various aromatic alcohols were oxidized to their corresponding aldehydes and acids during aerobic culture, while aromatic aldehydes were both oxidized and reduced. However, the aromatic acids were not reduced, but were slowly metabolized. Dimer I was cleaved at the alkyl-phenyl linkage to give glycerol-2-guaiacyl ether in high yield. The identity of the latter was determined by mass spectrometry and proton nmr. The dimers 1-(3,4-dimethoxyphenyl)-2-(2-methoxyphenoxy)-propane-1,3-diol (II), 3,4-dimethoxy- $\alpha$ -(2,6-dimethoxy-4-carboxyphenoxy)-acetophenone (III) and 5-carboxy-7-methoxy-2-(4-hydroxy-3-methoxyphenyl)-3-methyl-2,3-dihydrobenzo-[b]-furan (IV) were not metabolized. It is concluded that the fungus resembles *Fusarium* in many of its metabolic properties and could be considered as a potential lignin degrader.

---

**Title:** A Xylanase Gene from *Bacillus subtilis*: Nucleotide Sequence and Comparison with *B. pumilus* Gene

**Citation:** Paice, Michael G., Robert Bourbonnais, Michel Desrochers, Lubomir Jurasek, and Makoto Yaguchi. *Arch. Microbiol.* 144:201-206 (1986).

**Content:** A gene coding for xylanase (endo-1,4- $\beta$ -D-xylan xylanohydrolase, EC 3.2.1.8) from *Bacillus subtilis* PAP115 has been isolated and its complete nucleotide sequence determined. Starting from an ATG initiator codon, an open reading frame coding for 213 amino acids was found. The N terminus of the processed enzyme as expressed in *Escherichia coli* was located by amino acid sequence analysis. The amino acid analysis and apparent molecular weight (22,000) of the expressed enzyme were consistent with the translated nucleotide sequence. A proposed 28-residue signal sequence of the enzyme shows features comparable with other bacillus signal sequences, namely a negatively charged region close to methionine followed by a long hydrophobic string. The coding sequence is preceded by a possible ribosome binding site and, further upstream, by potential transcription initiation signals. When the xylanase amino acid sequence was compared to a xylanase from *B. pumilus*, strong evidence for homology was found, with over 50% identities in the processed enzymes.

---

**Title:** Xylanase

**Citation:** *Biotechnol. and Bioeng.* 25:1127-1146 (1983).

**Content:** This paper describes a method whereby xylanase was measured against sugarcane bagasse hemicellulose A as substrate. This resulted in a linear response between xylanase activity and time of hydrolysis for up to 20-30 min.

---

## ENZYMATIC ASSAYS (LITERATURE)

**Title:** Cellobiase/ $\beta$ -glucosidase

**Citation:** *J. Gen. Microbiol.* 127:177 (1981).

**Content:**

---

**Title:** Cellobiase/ $\beta$ -glucosidase

**Citation:** *Biotechnol. and Bioeng.* 28:1438 (1986).

**Content:**

---

**Title:** Assay Procedures for the Determination of Cellobiase Activity, and Measurement of Glucose in Enzymic Digests of Lignocellulose

**Citation:** Dekker, R. F. H. Program Report No. G-12 (GA), CSIRO, Division of Chemical and Wood Technology, 1982.

**Content:**

---

**Title:** Cellulase Activity

**Citation:** Mendels, M. *et al. Biotechnol. Bioeng. Symp.* 6:21-33 (1976).

**Content:**

---

**Title:** Xylanase Assays

**Citation:** Dekker, R. F. H. and G. N. Richards. *Adv. Carb. Chem. Biochem.* 32:277 (1976).

**Content:**

---

**Title:** Xylanase

**Citation:** *Biotechnol. and Bioeng.* 26:988 (1984).

**Content:** A report on the effect of enzyme dilution on enzyme activity.

---

**Title:** Lignin Modification by Enzymes

**Citation:** Kirk T. K. *et al. PNAS* 72:2515 (1975).

**Content:**

---

**Title:** Lignin Modification by Enzymes

**Citation:** Tien, M. and T. K. Kirk. *PNAS* 81:2280 (1984).

**Content:**

---

**Title:** Mikrobiologisch-fermentative Verwendungsmöglichkeiten von Lignocellulosen

**Citation:** Esterbauer, H. and M. Hayn. *Das Papier* 39(12):608-616 (1985).

**Content:**

---

**Title:** Methods in Enzymology

**Citation:** *Biomass. Cellulose and Hemicellulose*. Vol. 160, Part A. Edited by Willis A. Wood and Scott T. Kellogg. New York: Academic Press, Inc., 1988.

**Content:**

Section I: Cellulose

- A. Preparation of Cellulosic Substrates
- B. Assays for Cellulolytic Enzymes
- C. Chromatographic Methods for Carbohydrates
- D. Miscellaneous Methods for Cellulolytic Enzymes
- E. Purification of Cellulose-Degrading Enzymes

Section II. Hemicellulose

- A. Preparation of Substrates for Hemicellulases
  - B. Analysis of  $\beta$ -Glucan and Enzyme Assays
  - C. Purification of Hemicellulose-Degrading Enzymes
-

**Title:** Role of the Activity and Adsorption of Cellulases in the Efficiency of the Enzymatic Hydrolysis of Amorphous and Crystalline Cellulose

**Citation:** Klyosov, A. A., O. V. Mitkevich, and A. P. Sinitsyn. *Biochemistry* 25:540-542 (1986).

**Content:** With several different cellulase preparations from various microbial sources (fungi *Trichoderma*, *Geotrichum*, *Myrothecium*, *Sporotrichum*, and *Aspergillus* and actinomycete *Thermomonospora*), it was shown that the mechanisms of enzymatic hydrolysis of a crystalline and an amorphous cellulose are different. The major factor related to cellulases that control the difference in the reactivity of the crystalline and amorphous cellulose appears to be the adsorption capacity of endoglucanase on cellulose. Taking this factor into account as a partition coefficient of cellulases between the substrate surface and the bulk solution allows a quantitative prediction to be made of the enzymatic hydrolysis rate for both amorphous and crystalline celluloses.

---

**Title:** The Titration of the Active Centers of Cellobiohydrolase from *Trichoderma reesei*

**Citation:** Rabinowitch, M. L., A. A. Klyosov, and M. S. Melnick. *Analytical Biochemistry* 156:489-494 (1986).

**Content:** A novel approach has been developed for the titration of enzyme active centers and for the determination of the molecular activity of enzymes. It is based on the simultaneous use of a nonspecific chromogenic substrate and a specific ligand (a substrate or an inhibitor), the latter being tightly bound with the enzyme's active center. The approach is demonstrated using the titration (that is, the determination of the molar concentration of the enzyme active centers) of purified cellobiohydrolase I (CBHI) (EC 3.2.1.91) of the fungus *Trichoderma reesei*.  $\rho$ -Nitrophenyl- $\beta$ -D-lactoside was used as a reference substrate ( $K_m = 0.5$  mM), and cellobiose and CM-cellulose cellobiose was  $42,000 \pm 3,000$ .

The inhibition constant by cellobiose was  $(6 \pm 1) \cdot 10^{-6}$  M. The value of the catalytic constant for the hydrolysis of  $\rho$ -nitrophenyl- $\beta$ -D-lactoside calculated from the titration data was equal to  $0.063$  s $^{-1}$ . CM-cellulose turned out to be a more efficient titration agent for cellobiohydrolase than cellobiose, and might be used for the titration of the enzyme in concentrations of the latter of 0.008-0.02 mg/ml. The titration data showed that the inhibition constant of CM-cellulose toward CBHI was equal to  $(1.0 \pm 0.2) \cdot 10^{-7}$  M.

---

**Title:** Methods in Enzymology

**Citation:** *Biomass, Lignin, Pectin, and Chitin*. Vol. 161, Part B. Edited by Willis A. Wood and Scott T. Kellogg, New York: Academic Press, Inc., 1988.

**Content:**

Section I. Lignin

- A. Preparation of Substrates for Ligninases
- B. Assays for Ligninases
- C. Chemical Methods for Characterization of Lignin
- D. Chromatographic Methods for Lignin and Related Compounds
- E. Nucleic Acid Preparations Related to Lignin Degradation
- F. Purification of Lignin-Degrading Enzymes

Section II. Pectin

- A. Assays for Pectin-Degrading Enzymes
- B. Purification of Pectin-Degrading Enzymes

Section III. Chitin

- A. Preparation of Substrates for Chitin-Degrading Enzymes
  - B. Assay for Chitin-Degrading Enzymes
  - C. Analytical Methods for Chitin
  - D. Purification of Chitin-Degrading Enzymes
-

## ENZYMATIC ASSAYS (LITERATURE)

**Title:** Measurement of Cellulase Activities

**Citation:** Ghose, T. K. *Pure and Appl. Chem.*  
59:257-268 (1987).

**Content:**  

---

---

**Title:** Measurement of Hemicellulase  
Activities Part I: Xylanases

**Citation:** Ghose, T. K. and V. S. Bisaria.  
*Pure and Appl. Chem.* 59:1739-  
1752 (1987).

**Content:**  

---

---



**Title:** Test Method for Combustible Properties of Treated Wood by the Fire-Tube Apparatus

**Citation:** ASTM E 69-80

**Content:**

**Availability:** ASTM

---

**Title:** Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures<sup>1</sup>

**Citation:** ASTM E 582-88

**Content:** This method covers the determination of minimum energy for ignition (initiation of deflagration) and associated flat-plate ignition quenching distances. The complete description is specific to alkane or alkene fuels admixed with air at normal ambient temperature and pressure. This method is applicable to mixtures of the specified fuels with air, varying from the most easily ignitable mixture to mixtures near to the limit-of-flammability compressions.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-27 on Hazard Potential of Chemicals and is the direct responsibility of Subcommittee E27.04 on Flammability and Ignitability of Chemicals.

---

**Title:** Standard Test Method for Autoignition Temperature of Liquid Chemicals<sup>1</sup>

**Citation:** ASTM E 659-78 (1984)

**Content:** This method covers the determination of hot- and cool-flame autoignition temperature of a liquid chemical in air at atmospheric pressure in a uniformly heated vessel.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-27 on Hazard Potential of Chemicals and is the direct responsibility of Subcommittee E27.04 on Flammability and Ignitability of Chemicals.

---

**Title:** Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure<sup>1</sup>

**Citation:** ASTM E 918-83

**Content:** This practice covers the determination of the lower and upper concentration limits of flammability at temperatures up to 200°C and initial pressures up to as much as 1.38 MPa (200 psia). This practice is limited to mixtures which would have an explosion pressure less than 13.79 MPa (2000 psia).

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-27 on Hazard Potential of Chemicals and is the direct responsibility of Subcommittee E 27.04 on Flammability and Ignition of Chemicals.

---

**Title:** Determination of Limits of Flammability of Gases and Gas Mixtures in Air

**Citation:** DIN 51649 Part 1

**Content:**

**Availability:** DIN

---

**Title:** Method of Inflammability Test for Wood

**Citation:** JIS Z 2120-58

**Content:**

**Availability:** JIS

---

## FIRE AND FLAMMABILITY (STANDARDS)

**Title:** Chemistry and Physics of Fire<sup>1</sup>

**Citation:** NFPA SEC 4-1

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Combustion Products and Their Effects on Life Safety<sup>1</sup>

**Citation:** NFPA SEC 4-3

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Theory of Fire and Explosion Control<sup>1</sup>

**Citation:** NFPA SEC 4-4

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Wood and Wood Based Products<sup>1</sup>

**Citation:** NFPA SEC 5-2

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Dusts<sup>1</sup>

**Citation:** NFPA SEC 5-9

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Boiler Furnaces<sup>1</sup>

**Citation:** NFPA SEC 10-1

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Grinding Processes<sup>1</sup>

**Citation:** NFPA SEC 10-11

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Extrusion and Forming Processes<sup>1</sup>

**Citation:** NFPA SEC 10-12

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Solvent Extraction<sup>1</sup>

**Citation:** NFPA SEC 10-14

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Storage and Handling of Solid Fuels<sup>1</sup>

**Citation:** NFPA SEC 11-8

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Forest, Brush and Grass Fires<sup>1</sup>

**Citation:** NFPA SEC 12-9

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Gas and Vapor Testing<sup>1</sup>

**Citation:** NFPA SEC 16-5

**Contents:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Complete Titles of All Official NFPA Documents<sup>1</sup>

**Citation:** NFPA APP B

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Fire Protection Handbook*, 16th Edition, 1986.

---

**Title:** Vegetable and Animal Oil Processing<sup>1</sup>

**Citation:** NFPA Pt 2 Ch 7

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Industrial Fire Hazards Handbook*, 1984.

---

**Title:** Wood Products<sup>1</sup>

**Citation:** NFPA Pt 2 Ch 12

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Industrial Fire Hazards Handbook*, 1984.

---

**Title:** Pulp and Paper Processing<sup>1</sup>

**Citation:** NFPA Pt 2 Ch 14

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Industrial Fire Hazards Handbook*, 1984.

---

**Title:** Solvent Extraction<sup>1</sup>

**Citation:** NFPA Pt 3 Ch 32

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Industrial Fire Hazards Handbook, 1984.*

**Title:** Lumber Kilns and Agricultural Dehydrators and Dryers<sup>1</sup>

**Citation:** NFPA Pt 3 Ch 33

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Industrial Fire Hazards Handbook, 1984.*

**Title:** Grinding and Milling Operations<sup>1</sup>

**Citation:** NFPA Pt 3 Ch 34

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Industrial Fire Hazards Handbook, 1984.*

**Title:** Boiler-Furnaces<sup>1</sup>

**Citation:** NFPA Pt 4 Ch 42

**Content:**

**Availability:** NFPA

---

<sup>1</sup>*Industrial Fire Hazards Handbook, 1984.*

**Title:** *Flammable and Combustible Liquids Code Handbook, Third Edition, 1987*

**Citation:** NFPA

**Content:**

**Availability:** NFPA

---

**Title:** Stationary Combustion Engines and Gas Turbines

**Citation:** NFPA 37-84

**Content:** Covers location, protective devices, fuel supply, and exhaust piping.

**Availability:** NFPA

---

**Title:** Storage of Forest Products

**Citation:** NFPA 46-85

**Content:** Outlines recommendations to minimize hazards and control fires in storage areas that contain lumber, timber, wood chips, logs and similar products.

**Availability:** NFPA

---

**Title:** Standard for Bulk Oxygen Systems at Consumer Sites<sup>1</sup>

**Citation:** NFPA 50-85

**Content:** Provides recommendations for location, distance between bulk systems and exposures, containers and associated equipment.

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 2.

**Title:** National Fuel Gas Code

**Citation:** NFPA 54-88

**Content:** Provides requirements for the safe design, installation, operation, and maintenance of gas piping and for installation and venting of gas appliances in residential, commercial, and industrial applications.

**Availability:** NFPA

---

**Title:** Standard for the Prevention of Fires and Explosions in Grain Elevators and Facilities Handling Bulk Raw Agricultural Commodities

**Citation:** NFPA 61B-89

**Content:** Outlines updated practices to prevent dust explosions and to minimize damage if an explosion should occur.

**Availability:** NFPA

---

**Title:** Standard for the Prevention of Fire and Dust Explosions in Feed Mills

**Citation:** NFPA 61C-89

**Content:** Provides the updated standard for construction, ventilation, and equipment in feed mills. Supplemental precautions are also included.

**Availability:** NFPA

---

**Title:** Standard for the Prevention of Fire and Dust Explosions in the Milling of Agricultural Commodities for Human Consumption<sup>1</sup>

**Citation:** NFPA 61D-84

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 2

---

**Title:** Standard for Prevention of Furnace Explosions in Fuel Oil- and Natural Gas-Fired Single Burner Boiler-Furnaces<sup>1</sup>

**Citation:** NFPA 85A-87

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 3

---

**Title:** Standard for Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler-Furnaces<sup>1</sup>

**Citation:** NFPA 85B-84

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 3

---

**Title:** Standard for Prevention of Furnace Explosions in Fuel Oil-Fired Multiple Burner Boiler-Furnaces<sup>1</sup>

**Citation:** NFPA 85D-84

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 3

---

**Title:** Standard for Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces<sup>1</sup>

**Citation:** NFPA 85E-85

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 3

---

**Title:** Standard for the Installation and Operation of Pulverized Fuel Systems<sup>1</sup>

**Citation:** NFPA 85F-88

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 3

---

## FIRE AND FLAMMABILITY (STANDARDS)

**Title:** Standard for the Prevention of  
Furnace Implosions in Multiple Burner  
Boiler-Furnaces

**Citation:** NFPA 85G-87

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 3

---

**Title:** Standard for Chimneys, Fireplaces,  
Vents, and Solid Fuel Burning  
Appliances<sup>1</sup>

**Citation:** NFPA 211-88

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 6

---

**Title:** Standard Test Method for Potential  
Heat of Building Materials<sup>1</sup>

**Citation:** NFPA 259-87

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 6

---

**Title:** Standard Method of Test for Heat and  
Visible Smoke Release Rates for  
Materials and Products<sup>1</sup>

**Citation:** NFPA 263-86

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 6

---

**Title:** Basic Classification of Flammable and  
Combustible Liquids<sup>1</sup>

**Citation:** NFPA 321-87

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 6

---

**Title:** Standard for the Prevention of Fires  
and Explosions in Wood Processing and  
Woodworking Facilities

**Citation:** NFPA 664-87

**Content:**

**Availability:** NFPA

---

<sup>1</sup>National Fire Codes, Vol. 6

---

**Title:** Dust Explosions and Fires

**Citation:** Palmer, K. N. London: Chapman and Hall, 1973.

**Content:** Chapter 3. Tests for dust explosibility; Reasons for tests; Selection of dust sample; Toxicity of dust; Test methods in various countries (United Kingdom, United States, Federal German Republic, other countries); Special methods.

---

**Title:** Fundamentals of Fire and Explosion

**Citation:** Stull, D. R. AIChE Monograph Series. No. 10, Vol. 73, 1977.

**Content:** The growth of chemical production in recent years has been accompanied by a noticeable increase in the number of chemical fires and explosions. Information on the technology of such energy releases is scattered across many disciplines and varies from adequate in some places to inadequate in others. Moreover, while the basic fundamentals are well known for some chemical types, they are poorly understood for others. A review of the fundamentals of fire and explosion was undertaken for a better understanding of this complicated subject.

---





# MEASUREMENTS, UNITS, QUALITY ASSURANCE, AND ROUND-ROBIN TESTS (STANDARDS)

**Title:** Statistical Audit of Test Results

**Citation:** Appita P403 rp-73

**Content:**

**Availability:** Appita

---

**Title:** Use of SI (Metric) Units

**Citation:** ASAE EP285.7

**Content:** This engineering practice is intended as a guide for uniformly incorporating the International System of Units (SI). It is intended for use in implementing ASAE policy, "Use of SI Units in ASAE Standards, Engineering Practices, and Data." This engineering practice includes a list of preferred units and conversion factors.

**Availability:** ASAE

---

**Title:** Measurement Uncertainty -  
Instruments and Apparatus

**Citation:** ASME PTC 19.1-85

**Content:**

**Availability:** ASME

---

**Title:** Standard Practice for Conducting a  
Ruggedness or Screening Program for  
Test Methods for Construction  
Materials<sup>1</sup>

**Citation:** ASTM C 1067-87

**Content:** This practice covers a procedure for detecting and reducing sources of variation in a test method early in its development and prior to an interlaboratory study. One of the main purposes of the procedure, by means of a ruggedness or screening program, is the elimination of test methods that exhibit poor precision even after vigorous efforts to reduce their variability.

This practice covers, in very general terms, techniques for planning, conducting, and analyzing results from a few laboratories to

establish whether a well written test method is good enough to justify an interlaboratory study. Annex A1 provides the details of the procedure with an example and Annex A2 gives the theoretical background.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.02.01 on Evaluation of Data.

---

**Title:** Standard Practice for Determination  
of Precision and Bias of Applicable  
Methods of Committee D-19 on  
Water<sup>1</sup>

**Citation:** ASTM D 2777-86

**Content:** This practice establishes uniform standards for expressing the precision and bias of applicable test methods for Committee D-19 on Water.

Except as specified, this practice requires that the task group proposing a new test method must carry out a collaborative study from which statements for precision (multiple laboratory operational and single-operator standard deviation estimates) and observed bias can be developed. This practice provides general guidance to task groups in planning and conducting such determinations of precision and bias.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-19 on General Specifications and Technical Resources.

---

**Title:** Standard Practice for Determination  
of Precision and Accuracy of Methods  
of Committee D-22<sup>1</sup>

**Citation:** ASTM D 3670-81

**Content:** This standard practice establishes uniform standards and procedures for evaluation of the precision and accuracy of test

## MEASUREMENTS, UNITS, QUALITY ASSURANCE, AND ROUND-ROBIN TESTS (STANDARDS)

methods for Committee D-22 on Sampling and Analysis of Atmospheres.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.07 on Precision and Accuracy of Methods.

---

**Title:** Standard Practice for Evaluation of Laboratories Using ASTM Procedures in the Sampling and Analysis of Coal and Coke<sup>1</sup>

**Citation:** ASTM D 4182-87a

**Content:** This practice is limited to the evaluation of laboratories using ASTM procedures under the jurisdiction of Committee D-5 on Coal and Coke. They may be used to evaluate a laboratory's capability to perform the function for which it has been established. It is not the intention that this practice be used to evaluate capabilities beyond those specifically claimed by the laboratory.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D-05.30 on Accreditation.

---

**Title:** Standard Practice for Intralaboratory Quality Control Procedures and a Discussion on Reporting Low-Level Data<sup>1</sup>

**Citation:** ASTM D 4210-83

**Content:** This practice is applicable to all laboratories that provide chemical and physical measurements in water, and provides guidelines for intralaboratory control and suggested procedures for reporting low-level data.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-19 on Water and is the responsibility of Subcommittee D19.02 on General Specifications.

---

**Title:** Standard Guide for Accountability and Quality Control in the Coal Analysis Laboratory<sup>1</sup>

**Citation:** ASTM D 4621-86

**Content:** This guide describes the essential aspects of an accountability and quality control program for a coal analysis laboratory.

**Availability:** ASTM

---

<sup>1</sup>This guide is under the jurisdiction of ASTM Committee D-5 on Coal and Coke and is the direct responsibility of Subcommittee D05.30 on Accreditation.

---

**Title:** Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods<sup>1</sup>

**Citation:** ASTM E 177-86

**Content:** The purpose of this practice is to present concepts necessary to the understanding of the terms "precision" and "bias" as used in quantitative test methods. This practice also describes methods of expressing precision and bias and, in a final section, gives examples of how statements on precision and bias may be written for ASTM test methods.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-11 on Statistical Methods and is the direct responsibility of Subcommittee E11.04 on Development and Evaluation of Test Methods.

---

# MEASUREMENTS, UNITS, QUALITY ASSURANCE, AND ROUND-ROBIN TESTS (STANDARDS)

**Title:** Standard Practice for Dealing with Outlying Observations<sup>1</sup>

**Citation:** ASTM E 178-80

**Content:** This practice deals with the problem of outlying observations in samples and how to test the statistical significance of them. An outlying observation, or "outlier," is one that appears to deviate markedly from other members of the sample in which it occurs.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-11 on Statistical Methods.

---

**Title:** Standard for Metric Practice<sup>1</sup>

**Citation:** ASTM E 380-86

**Content:** This standard gives guidance for application of the modernized metric system in the United States. The International System of Units, developed and maintained by the General conference on Weights and Measures (abbreviated GPM from the official French name Conference Générale des Poids et Mesures) is intended as a basis for worldwide standardization of measurement units. The name International System of Units and the international abbreviation SI were adopted by the 11th GPM in 1960. SI is a complete, coherent system that is being universally adopted.

Information is included on SI, a limited list of non-SI units recognized for use with SI units, and a list of conversion factors from non-SI to SI units, together with general guidance on proper style and usage.

**Availability:** ASTM

---

<sup>1</sup>This standard is under the jurisdiction of ASTM Committee E-43 on Metric Practice and is the direct responsibility of Subcommittee E43.10 on Standards.

---

**Title:** Definitions of Terms Relating to Statistical Methods

**Citation:** ASTM E 456-88

**Content:**

**Availability:** ASTM

---

**Title:** Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method<sup>1</sup>

**Citation:** ASTM E 691-87

**Content:** This practice describes the techniques for planning, conducting, analyzing, and treating the results of an interlaboratory study (ILS) of a test method. The statistical techniques described in this practice provide adequate information for formulating the precision statement of a test method.

This practice does not concern itself with the development of test methods but rather with gathering the information needed for a test method precision statement after the development stage has been successfully completed. The data obtained in the interlaboratory study may indicate, however, that further effort is needed to improve the test method.

Since the primary purpose of this practice is the development of the information needed for a precision statement, the experimental design in this practice may not be optimum for evaluating materials, apparatus, or individual laboratories.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-11 on Statistical Methods and is the direct responsibility of Subcommittee E11.04 on Development and Evaluation of Test Methods.

---

## MEASUREMENTS, UNITS, QUALITY ASSURANCE, AND ROUND-ROBIN TESTS (STANDARDS)

**Title:** Standard Guide for Records Management in Mass Spectrometry Laboratories Performing Analysis in Support of Nonclinical Laboratory Studies<sup>1</sup>

**Citation:** ASTM E 899-82 (1987)

**Content:** This guide presents a summary of the records needed to demonstrate, in a retrospective audit, that scientifically sound mass spectral data have been generated.

This guide outlines a set of written laboratory procedures for the documentation of instrument operation, testing, and maintenance, as well as for the documentation of the analyses performed.

**Availability:** ASTM

---

<sup>1</sup>This guide is under the jurisdiction of ASTM Committee E-14 on Mass Spectrometry and is the direct responsibility of Subcommittee E14.14 on General Practices.

---

**Title:** Canadian Metric Practice Guide

**Citation:** CSA CAN3-Z234.1-79

**Content:** This standard has been prepared as a guide for the application of the International System of Units (SI). Information is included on SI units, recommended application of multiples and sub-multiples of the units, up-to-date terminology concerning the names of quantities, conversion factors that relate the SI and the yard/pound system, conversion and rounding of data, and dual dimensioning.

**Availability:** CSA

---

**Title:** The International System of Units (SI)

**Citation:** CSA CAN3-Z234.2-76

**Content:** The International System of Units (SI) is the source document for the SI in Canada. It is essentially a practical system of units and is both coherent and decimal. This standard provides definitions for the internationally agreed base units together with

their symbols; prefixes and their symbols; rules for their manipulation; and extracted historical decisions of the General Conference which relate to the SI. An appendix also provides some details regarding the practical realization of most of the base units for guidance to those who wish to generate their own primary standards.

**Availability:** CSA

---

**Title:** Glossary of Metric Units

**Citation:** CSA Z351-1980

**Content:**

**Availability:** CSA

---

**Title:** Metric Editorial Handbook

**Citation:** CSA Z372-1980

**Content:**

**Availability:** CSA

---

**Title:** General Rules for Chemical Analysis

**Citation:** JIS K 0050-83

**Content:**

**Availability:** JIS

---

**Title:** Statistical Treatment of Test Results

**Citation:** SCAN-G 2:63

**Content:** The advantage of statistical methods for the purpose of interpreting test results is the possibility of substituting subjective interpretation for strictly objective criteria. Statistical analysis of test data does not increase the experimental accuracy by transforming uncertain results to certainties, but it offers the possibility of expressing more effectively, in the form of definite probabilities, the conclusions drawn from the results.

## MEASUREMENTS, UNITS, QUALITY ASSURANCE, AND ROUND-ROBIN TESTS (STANDARDS)

Although statistical methods are based on mathematical theories of probability, a detailed knowledge of these theories is not necessarily required in the application of the methods.

The purpose of this guide is to give a brief description of some of the simple statistical methods commonly used in treating test data and to promote uniformity in the use of statistical terms and symbols, as well as in the mode of expressing test results.

Concerning more advanced statistical methods, reference is made to the special literature on the subject listed under Literature.

**Availability: SCAN**



# MEASUREMENTS, UNITS, QUALITY ASSURANCE, AND ROUND-ROBIN TESTS (LITERATURE)

**Title:** 1989 ASTM Directory of Testing Laboratories

**Citation:** New York: ASTM, 1988.

**Content:** This directory is a completely new book each year. All lab information is reverified or updated. The 1989 edition contains 400 labs not in the 1988 edition. Over 1100 laboratories are featured. The majority are located in the United States, 45 in Canada and several in 12 other countries.

---

**Title:** International Laboratory Accreditation

**Citation:** Locke, John W. *ASTM Standardization News*, September 1988, p. 24.

**Content:** A growing number of accreditation systems around the world facilitate acceptance of test data across international boundaries.

---

**Title:** Chemometrics as a Practical Research Tool

**Citation:** Windig, W. *Chemometrics and Intelligent Laboratory Systems* 3(3):159 (March 1988).

**Content:**

---

**Title:** Practical Statistics for the Physical Sciences

**Citation:** Havlicek, Larry L. and Ronald D. Crain. Washington, DC: American Chemical Society, 1988, 522 pp.

**Content:** Written in understandable, easy-to-follow steps, this book teaches the concepts underlying the use of statistics in research. Worked-out examples are provided to illustrate each procedure, and commonly-used formulas, tables, and reference information are also included. No prior knowledge of statistics is necessary to use this practical "how-to" book.

---

**Title:** Extending the LIMS (Laboratory Information Management Systems)

**Citation:** Scott, Frederick I. Jr. *American Laboratory*, May 1988, p. 8.

**Content:**

---

**Title:** Ruggedness Tests and Interlaboratory Studies

**Citation:** Paule, Robert C. *ASTM Standardization News*, May 1988, p. 56.

**Content:** What variables are important and how tightly do they need to be specified?

---

**Title:** Round Robins

**Citation:** Lashof, Theodore W. and John Mandel. *ASTM Standardization News*, July 1988, p. 42.

**Content:** Round robins are a way of life for ASTM committees and the newly revised ASTM Standard E 691, Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods, should help improve that way of life. Round robins, or more correctly interlaboratory studies, that are conducted in accordance with E 691, will generally be simpler and more informative than the usually prescribed interlaboratory studies

---

**Title:** Impediments to Analysis

**Citation:** Edited by J. Foster. STP 708. New York: ASTM, 1980, 100 pp.

**Content:**

---

**Title:** Quality Assurance of Chemical Measurements

**Citation:** Taylor, John Keenan. Chelsea, MI: Lewis Publishers, 1987, 328 pp.

**Content:**

---

# MEASUREMENTS, UNITS, QUALITY ASSURANCE, AND ROUND-ROBIN TESTS (LITERATURE)

**Title:** Quality Assurance Handbook

**Citation:** Gaithersburg, MD: Center for Analytical Chemistry, National Bureau of Standards, 1987.

**Content:** In an era of increased awareness and attention to quality in industrial production, there is a concomitant need for quality in measurement. As the National Reference Laboratory for chemical measurements, the Center for Analytical Chemistry has always viewed its mission at NBS as one of quality measurement and technology transfer of quality measurement. Although quality has been a major emphasis for the Center for Analytical Chemistry, as in all environments, improvement is always possible. As part of quality improvement activities in the Center for Analytical Chemistry and to provide information to our measurement constituency which was (and is still) requesting information, the Center for Analytical Chemistry established a Quality Assurance Task Force. The aim of this Task Force was to document and, in some instances, better formalize quality assurance practices in our laboratories.

The project of this effort has been the series of documents contained in this Quality Assurance Handbook. The Handbook is a living document, with all its contents subject to updating and revision. As additional documents to address new topics are prepared, they will be added to the Handbook.

The Handbook is intentionally contained in a loose leaf format to express that improvement and addition are possible and desirable. Comments are welcome on documents contained in this Handbook; also welcome are suggestions for additional documents. Harry S. Hertz, Director, Center for Analytical Chemistry.

---

**Title:** Thermocouples

**Citation:** *ASTM Standards on Thermocouples*, 2nd Edition. New York: ASTM, 1986, 257 pp.

**Content:** This edition has been expanded to include sixteen selected ASTM methods and

practices on thermocouples. It also contains a Temperature Electromotive Force (EMF) Table for the NICROSIL-NISIL Thermocouple System.

---

**Title:** Quality Assurance for Environmental Measurements

**Citation:** Editors: Taylor and Stanley. STP 867. New York: ASTM, 1985, 440 pp.

**Content:** Discusses data quality assurance, ambient air measurements, ambient water measurements, source measurements, discharge monitoring, and reference materials. Includes a general paper on quality assurance programs and a detailed paper on the U.S. E.P.A.'s quality assurance program.

---

**Title:** User-Friendly IBM PC Computer Programs for Solving Sampling and Statistical Problems

**Citation:** Lin, Philip C. L. EPA/600/S4-86/023. Cincinnati, OH: EPA Environmental Monitoring and Support Laboratory, July 1986.

**Content:** User-friendly IBM personal computer programs for solving sampling and related statistical problems have been prepared. The programs are designed so that persons without an in-depth understanding of statistics can easily use them. Specific, detailed, written instructions for application of the programs are provided in the full report.

---

**Title:** Trends in Analytical Instrumentation

**Citation:** McLafferty, Fred W. *Science* 226(4672):251 (October 19, 1984).

**Content:** Methods for deriving chemical information from a variety of systems and environments have changed dramatically in the last decade. Unique principles from physics, chemistry, and biology are the basis for sophisticated instruments that incorporate computers for data acquisition, reduction, and interpretation. Such analytical

systems have shown orders-of-magnitude improvements in sensitivity, specificity, and speed, yet with greater simplicity and lower price. The increasing importance of analytical instrumentation requires reexamination of its coverage in educational curricula and of the role of the analytical chemist in its further development and application.

---

**Title:** Compendium of Chemical Terminology: IUPAC Recommendations

**Citation:** Compiled by (the late) V. Gold, K. L. Loening, A. D. McNaught, and P. Schmis. Oxford, England: Blackwell Scientific Publications, 1987. 456 pp.

**Content:** Contains alphabetical entries, references and source documents.

---

**Title:** Compendium of Analytical Nomenclature: Definitive Rules

**Citation:** Prepared by H. Freiser and G. H. Nancollas. 2nd ed. Oxford, England: Blackwell Scientific Publications, 1987, 279 pp.

**Content:** Includes index.

---

**Title:** Quantities, Units and Symbols in Physical Chemistry

**Citation:** Prepared by I. Mills, T. Cvitas, K. Homann, N. Kallay and K. Ruchilsn. Oxford, England: Blackwell Scientific Publications, 1988, 134 pp.

**Content:**

---

**Title:** ASTM Standards on Precision and Bias for Various Applications

**Citation:** New York: ASTM, 1985, 570 pp.

**Content:** Contains 38 standards which describe procedures for obtaining data on the precision and bias of test methods, i.e., how well the method can be expected to measure the quantity being tested. Covers the measurements of different quantities in a wide variety of materials.

---





**Title:** Glossary of Terms Used in the  
Measurement of Fluid Flow in Pipes

**Citation:** ASME MFC-1M-1979

**Content:**

**Availability:** ASME

---

**Title:** Measurement Uncertainty for Fluid  
Flow in Closed Conduits

**Citation:** ASME MFC-2M-1983

**Content:**

**Availability:** ASME

---

**Title:** Measurement of Fluid Flow in Pipes  
Using Orifice, Nozzle and Venturi

**Citation:** ASME MFC-3M-1985

**Content:**

**Availability:** ASME

---

**Title:** Part 2: Pressure Measurement  
Instruments and Apparatus

**Citation:** ASME PTC 19.2-64

**Content:**

**Availability:** ASME

---

**Title:** Part 3: Temperature Measurement  
Instruments and Apparatus

**Citation:** ASME PTC 19.3-74

**Content:**

**Availability:** ASME

---

**Title:** Standard Practice for Rotameter  
Calibration<sup>1</sup>

**Citation:** ASTM D 3195-73 (1985)

**Content:** This practice covers the calibration of variable-area flowmeters (rotameters) used to determine air sample volumes at or close to ambient conditions of pressure and temperature, in the analysis of atmospheres for pollutant content.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.01 on Quality Control.

---

**Title:** Standard Specification for ASTM  
Thermometers<sup>1</sup>

**Citation:** ASTM E 1-88

**Content:** This specification covers liquid-in-glass thermometers graduated in Celsius (centigrade) or Fahrenheit degrees which are frequently specified in methods of the American Society for Testing and Materials.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee E-20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.05 on Liquid-in-Glass Thermometers and Hydrometers.

---

**Title:** Standard Method for Calibration of  
Thermocouples by Comparison  
Techniques<sup>1</sup>

**Citation:** ASTM E 220-86

**Content:** This method covers the techniques of thermocouple calibration based upon comparisons of thermocouple indications with those of a reference thermometer, different from methods involving the use of fixed points. The precise evaluation of the

## TEMPERATURE, PRESSURE, AND FLOW (STANDARDS)

electromotive forces (emf)-temperature relation of a thermocouple is accomplished by determining its emf output at each of a series of measured temperatures. Calibrations are covered over temperature ranges appropriate to the individual types of thermocouples within an over-all range from about  $-180^{\circ}$  to  $1700^{\circ}\text{C}$  ( $-290^{\circ}$  to  $260^{\circ}\text{F}$ ).

In general, the method is applicable to bare wire thermocouples or sheathed thermocouples. The latter may require special care to control thermal conduction losses.

**Availability:** ASTM

---

<sup>1</sup>This method is under the jurisdiction of ASTM Committee E-20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.04 on Thermocouples.

---

**Title:** Standard Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples<sup>1</sup>

**Citation:** ASTM E 230-87

**Content:** This standard consists of reference tables (Tables 3 to 16) that give temperature-electromotive force (emf) relationships for Types B, E, J, K, R, S, and T thermocouples. These are the thermocouple types most commonly used in industry.

Also included is a list (Table 1) of standard and special tolerances on initial values of emf versus temperature (tolerances), and recommendations (Table 2) covering upper temperature limits for the thermocouple types listed above.

**Availability:** ASTM

---

<sup>1</sup>These tables are under the jurisdiction of ASTM Committee E-20 on Temperature Measurement and are the direct responsibility of Subcommittee E20.04 on Thermocouples.

---

**Title:** Standard Specification for Thermocouples, Sheathed, Type K, for Nuclear or for Other High-Reliability Applications<sup>1</sup>

**Citation:** ASTM E 235-82

**Content:** This specification presents the requirements for sheathed, Type K thermocouples for nuclear service. Depending on size, these thermocouples are normally suitable for operating temperatures to  $1652^{\circ}\text{F}$  ( $900^{\circ}\text{C}$ ); special conditions of environment and life expectancy may permit their use at temperatures in excess of  $2012^{\circ}\text{F}$  ( $1100^{\circ}\text{C}$ ). This specification was prepared specifically to detail requirements for using this type of sheathed thermocouple in nuclear environments. This specification can be used for sheathed thermocouples which are required for laboratory or general commercial applications where the environmental conditions exceed normal service requirements.

**Availability:** ASTM

---

<sup>1</sup>This specification is under the jurisdiction of ASTM Committee E-20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.04 on Thermocouples.

---

**Title:** Method for Calibration of Refractory Metal Thermocouples Using an Optical Pyrometer

**Citation:** ASTM E 452-83

**Content:**

**Availability:** ASTM

---

**Title:** Specification for Sheathed Base-Metal Thermocouple Materials

**Citation:** ASTM E 585-88

**Content:**

**Availability:** ASTM

---

**Title:** Standard Methods for Testing  
Industrial Resistance Thermometers<sup>1</sup>

**Citation:** ASTM E 644-86

**Content:** These methods describe the principles, apparatus, and procedures for calibration and testing of resistance thermometers.

These methods cover definitions of terms and tests for insulation resistance, interchangeability, calibration, humidity, immersion error, pressure effects, thermal response time, vibration effect, self-heating effect, stability, and thermoelectric effect.

**Availability:** ASTM

---

<sup>1</sup>These methods are under the jurisdiction of ASTM Committee E-20 on Temperature Measurement, and are the direct responsibility of Subcommittee E20.03 on Resistance Thermometers.

---

**Title:** Standard Practice for Evaluating  
Temperature Scale for  
Thermogravimetry<sup>1</sup>

**Citation:** ASTM E 914-83 (1987)

**Content:** This practice for evaluating temperature scale is for general use in thermogravimetry. It provides means of relating temperatures of events observed in different laboratories and different instruments.

The practice is applicable to commercial and custom-built apparatus.

The purpose of this practice is to determine the agreement in temperature under the specific conditions of the principle experiment and not to determine the magnetic transition of Curie temperature of the certified reference materials.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.01 on Test Methods and Recommended Practices.

---

**Title:** Code for Temperature Measurement

**Citation:** BS 1041

**Content:**

Part 2:1985--Expansion thermometers  
Section 2.1:1985--Guide to selection and use  
of liquid-in-glass thermometers  
Part 3:1969--Industrial resistance  
thermometry  
Part 4:1966--Thermocouples  
Part 5:1972--Radiation pyrometers  
Part 7:1964--Temperature/time indicators

**Availability:** BSI

---

**Title:** Measurement of Fluid Flow in Closed  
Conduits

**Citation:** BS 1042

**Content:**

Part 1:--Pressure differential devices.  
Section 1.1:1981 Specification for square-edged orifice plates, nozzles and venturi tubes inserted in circular cross section conduits running full.  
Section 1.2:1984 Specification for square-edged orifice plates and nozzles (with drain holes, in pipes below 50 mm diameter, as inlet and outlet devices) and other orifice plates and Borda inlets.  
Section 1.4:1984 Guide to the use of devices specified in Sections 1.1 and 1.2.  
Part 2:--Velocity area methods.  
Section 2.1:1983 Method using Pitot static tubes.  
Section 2.2:1983 Method of measurement of velocity at one point of a conduit of circular cross section.

**Availability:** BSI

---

**Title:** International Thermocouple Reference  
Tables

**Citation:** BS 4937

**Content:**

Part 1:1973 Platinum-10 percent rhodium/  
platinum thermocouples. Type S.

## TEMPERATURE, PRESSURE, AND FLOW (STANDARDS)

Part 2:1973 Platinum-13 percent rhodium/  
platinum thermocouples. Type R.  
Part 3:1973 Iron/copper-nickel thermo-  
couples. Type J.  
Part 4:1973 Nickel-chromium/nickel-  
aluminum thermocouples. Type K.  
Part 5:1974 Copper/copper-nickel thermo-  
couples. Type T.  
Part 6:1974 Nickel-chromium/copper-nickel  
thermocouples. Type E.

**Availability:** BSI

---

**Title:** Measurement of Fluid Flow by Means  
of Orifice Plates, Nozzles and Venturi  
Tubes Inserted in Circular Cross-  
Section Conduits Running Full (VDJ-  
Rules for Measurement of Fluids)

**Citation:** DIN 1952

**Content:**

**Availability:** DIN

---

## TEMPERATURE, PRESSURE, AND FLOW (LITERATURE)

**Title:** Radiation Thermometry

**Citation:** Peacock, G. Raymond, *ASTM Standardization News*, May 1988, p. 33.

**Content:**

---

**Title:** International Temperature Scales

**Citation:** Mangum, B.W. *ASTM Standardization News*, May 1988, p. 36.

**Content:**

---

**Title:** Thermocouples

**Citation:** Biermann, Robert. *ASTM Standardization News*, May 1988, p. 40.

**Content:** What are thermocouples? When should they be used? Which thermocouple should be used?

---

**Title:** Industrial Temperature Sensors

**Citation:** Herskovitz, M.B. *ASTM Standardization News*, May 1988, p. 44.

**Content:**

---

**Title:** Liquid-in-Glass Thermometers

**Citation:** Wise, Jacquelyn A. *ASTM Standardization News*, May 1988, p. 48.

**Content:**

---

**Title:** Resistance Thermometry

**Citation:** Ortolano, Dominic J. *ASTM Standardization News*, May 1988, p. 52.

**Content:**

---

**Title:** An Overview of Flow Metering Devices

**Citation:** Okladek, Joseph. Part 1, *American Laboratory*, Jan. 1988, p. 84; Part 2, *American Laboratory*, May 1988, p. 92.

**Content:**

---

**Title:** International Comparisons of Pressure Standards: A Status Report

**Citation:** Tilford, Charles R. *Journal of Research of the National Bureau of Standards* 93(4):545 (July-Aug. 1988).

**Content:**

---

**Title:** Noncontact Temperature Measurement

**Citation:** Edited by M. C. Lee. Workshop on Noncontact-Temperature Measurement, NASA Headquarters, Washington, DC, April 30-May 1, 1987. NASA Conference Publication, Vol. 2503. Washington, DC: NASA, 1988, 430 pp.

**Content:**

---

**Title:** Fluid Flow Measurement Uncertainty

**Citation:** Draft Revision of ISO/DIS 5168 for International Organization for Standardization Committee, ISO TC30 SC9, May 1987.

**Content:**

---

## TEMPERATURE, PRESSURE, AND FLOW (LITERATURE)

**Title:** Thermocouples

**Citation:** *ASTM Standards on Thermocouples*, 2nd Edition, New York: ASTM, 1986, 257 pp.

**Content:** This edition has been expanded to include sixteen selected ASTM methods and practices on thermocouples. It also contains a Temperature Electromotive Force (EMF) Table for the NICROSIL-NISIL Thermocouple System.

---

**Title:** Gas Temperature Measurement

**Citation:** Moffat, Robert J. Chapter 52 in *Temperature: Its Measurement and Control in Science and Industry*, Vol. Three, Part 2. *Applied Methods and Instruments*, Edited by A. I. Dahl. New York: Reinhold Publishing Corporation.

**Content:**

---



**Title:** Standard Practice for Packed Column Gas Chromatography<sup>1</sup>

**Citation:** ASTM E 260-85

**Content:** This practice is intended to serve as a general guide to the application of gas chromatography (GC) with packed columns for the separation and analysis of vaporizable or gaseous organic and inorganic mixtures and as a reference for the writing and reporting of GC methods.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-19 on Chromatography and is the direct responsibility of Subcommittee E19.03 on Methods and Specifications, Gas Chromatography.

---

**Title:** Standard Recommended Practice for Testing Flame Ionization Detectors Used in Gas Chromatography<sup>1</sup>

**Citation:** ASTM E 594-77

**Content:** This recommended practice serves as a guide for the testing of the performance of a flame ionization detector (FID) used as the detection component of a gas chromatographic system.

**Availability:** ASTM

---

<sup>1</sup>This recommended practice is under the jurisdiction of ASTM Committee E-19 on Chromatography and is the direct responsibility of Subcommittee E19.03 on Methods and Specifications, Gas Chromatography.

---

**Title:** Test Method for Noncondensable Gases in C and Lighter Hydrocarbon Products by Gas Chromatography

**Citation:** ASTM D 2504-88

**Content:**

**Availability:** ASTM

---



**Title:** Supercritical Fluid Extraction and Chromatography: Techniques and Applications

**Citation:** Edited by B. A. Charpentier and M. R. Sevenants. ACS Symposium Series. Vol. 366. Symposium on Supercritical Fluid Extraction and Chromatography at the 193rd Meeting of the American Chemical Society, Denver, CO, April 5-10, 1987. Washington, DC: American Chemical Society, 1988, 253 pp.

**Content:**

---

**Title:** Field Flow Fractionation

**Citation:** Giddings, J. Calvin. *C&EN*, October 10, 1988, p. 34.

**Content:**

---

**Title:** Small-Molecule Gel Permeation Chromatography: A Technique for Everyone

**Citation:** Bidlingmeyer, Brian A. and F. Vincent Warren, Jr. *LC-GC*, 6(9):780.

**Content:**

---

**Title:** Absolute GPC Determinations of Molecular Weights and Sizes from Light Scattering

**Citation:** Wyatt, P. J., C. Jackson, and G. K. Wyatt. *American Laboratory*, May 1988, p. 86.

**Content:**

---

**Title:** Advances in Chromatography

**Citation:** Edited by J. C. Giddings, E. Grushka, and P. R. Brown. Vol. 27. New York: Marcel Dekker, 1987, 359 pp.

**Content:**

---

**Title:** Quantitative Thin Layer Chromatography and Its Industrial Applications,

**Citation:** Edited by L. Trieber. Chromatographic Science Series, Vol. 36. New York: Marcel Dekker, 1987, 353 pp.

**Content:**

---

**Title:** Analytical Affinity Chromatography

**Citation:** Edited by Irwin M. Chaikenm. Boca Raton, FL: CRC Press, 1987, 196 pp.

**Content:**

---

**Title:** Capillary Supercritical Fluid Chromatography, An Emerging Technology in Perspective

**Citation:** Later, Douglas W., Bruce E. Richter, and Marion R. Andersen. *LC-GC* 4(10):992.

**Content:**

---

**Title:** Chromatography with Supercritical Fluids

**Citation:** Lee, Milton L. and Karin E. Markides. *Science* 235:1342 (1987).

**Content:** In supercritical fluid chromatography (SFC) the mobile phase is neither a gas nor a liquid, but is a supercritical fluid. As a result of the unique properties of supercritical fluids, SFC is rapidly becoming a prominent separation technique for the

## CHROMATOGRAPHY (LITERATURE)

analysis of reactive, thermally labile, and nonvolatile compounds. This article reviews the history, instrumentation, and practice of the technique. Particular emphasis is placed on the different programming methods that allow elution to be selectively controlled in ways that are unique to SFC.

---

**Title:** Chromatography

**Citation:** *ASTM Standards on Chromatography*, New York: ASTM, 1981, 764 pp.

**Content:** Contains 103 ASTM chromatographic methods and practices. Provides an easy to use index that cross references ASTM chromatographic procedures by material analyzed and also by component/measured property.

---

**Title:** Chromatography

**Citation:** *Liquid Chromatographic Data Compilation-AMD 41*. New York: ASTM, 1975, 196 pp.

**Content:** Contains name, formula, and compound type indexes and listing of abstracts. Primary function is to provide information to separate one compound from another.

---

**Title:** Chromatography

**Citation:** *Bibliography on Size Exclusion Chromatography (Gel Permeation Chromatography), 1979-1982*. ADM 40-S3. New York: ASTM, 1985, 304 pp.

**Content:** Lists 1042 literature references on liquid size exclusion chromatography published during 1979 through 1982. This volume offers easy access to bibliographic references by separating all references by year of publication, dividing the subject index into eight major sections, and compiling an author-title index by year of publication.

---

**Title:** Process Supercritical Fluid Chromatography: An Introduction

**Citation:** Levy, G. B. *American Laboratory*, December 1986, p. 62.

**Content:**

---

**Title:** Response Factors for Gas Chromatographic Analyses

**Citation:** Dietz, W. A. *J. of Gas Chromatography* February 1967, p. 68.

**Content:** While there are many types of detectors employed in gas chromatographs, most units employ either flame ionization or thermal conductivity detectors. To obtain quantitative results from the GC trace, it is necessary to use correction factors; the amount of the correction is a function of the response of a given compound to the detecting device.

---

**Title:** Analytical Methods in Biomass Chemistry

**Citation:** Bonn, G. *Biomass for Energy and Industry*. Edited by G. Grassi, B. Delmon, J.-F. Molle, and H. Zibetta. New York: Elsevier Applied Science, 1987.

**Content:** For the description and optimization of technical lignocellulose conversion processes, and for calculating their economic feasibility, exact analytical methods applicable to routine operation are of major importance. Several chromatographic systems are described for the complete determination of the degradation and transformation products obtained during thermochemical and enzymatic hydrolyses and in fermentations. Particular emphasis has been laid on the analysis of carbohydrates, where a complete record extending to low concentrations is essential in studying the efficiency of biomass hydrolysis processes.

---

**Title:** Basic Tables for Chemical Analysis

**Citation:** Bruno, Thomas J. and Paris D. N. Svoronos. Gaithersburg, MD: National Bureau of Standards, April 1986.

**Content:** Tables of important data for use in the analytical chemistry laboratory are provided. These tables contain information for use in gas chromatography, liquid chromatography, infrared and ultraviolet spectrophotometry, mass spectrometry, and wet chemical techniques. Tables relating to safe practice in the analytical laboratory are also included.

---

**Title:** Sadtler Digital GC Retention Index Libraries

**Citation:** Bio-Rad, Sadtler Division, Philadelphia, PA.

**Content:** Sadtler Digital GC Retention Index Libraries are available for the following capillary GC columns:

OV-1- a cross-linked methyl silicone column from Hewlett-Packard Co. (25 m × 0.31 mm, 0.52 μm film thickness, phase ratio 150, HP part # 19091A-112)

SE-54- a cross-linked 5% phenylmethyl silicone column from Hewlett-Packard Co. (25 m × 0.31 mm, 0.52 μm film thickness, phase ratio 150, HP part # 19091B-112)

The libraries available include:

<u>Library</u>	<u>Number of Compounds</u>
Standards	1965
Flavors and Fragrances	300
Solvents	285
Pollutants	165
Hydrocarbons	100
Nitrogen Containing Compounds	575
Aromatic Compounds	735

These libraries are being expanded on an on-going basis.

---





**Title:** Standard Definitions of Terms and Symbols Relating to Molecular Spectroscopy<sup>1</sup>

**Citation:** ASTM E 131-88

**Content:**

**Availability:** ASTM

---

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee E-13 on Molecular Spectroscopy and are the direct responsibility of Subcommittee E13.04 on Nomenclature.

---

**Title:** Standard Practice for Evaluation of Mass Spectrometers for Quantitative Analysis from a Batch Inlet<sup>1</sup>

**Citation:** ASTM E 137-82 (1987)

**Content:** This practice provides general criteria and tests that are generally helpful for evaluating a mass spectrometer for use in ASTM mass spectrometric methods of chemical analysis. The number of types of mass spectrometers available, and the variety of materials that may be analyzed, preclude a discussion in this practice of the capabilities of each type of mass spectrometer for each specific method of analysis. Neither is it intended to include all the technical considerations involved in procuring a new mass spectrometer. Such considerations as mass range, sample introduction facilities, programming and data handling systems, scan rate, maintenance requirements, and price must all be evaluated relative to the needs and facilities available in a specific laboratory.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-14 on Mass Spectrometry and is the direct responsibility of Subcommittee E14.14 on General Practices.

---

**Title:** Standard Practices for General Techniques of Ultraviolet-Visible Quantitative Analysis<sup>1</sup>

**Citation:** ASTM E 169-87

**Content:** These practices are intended to provide general information on the techniques most often used in ultraviolet and visible quantitative analysis. The purpose is to render unnecessary the repetition of these description of techniques in individual methods for quantitative analysis.

**Availability:** ASTM

---

<sup>1</sup>These practices are under the jurisdiction of ASTM Committee E-13 on Molecular Spectroscopy and are the direct responsibility of Subcommittee E13.01 on Ultraviolet and Visible Spectroscopy.

---

**Title:** Standard Practices for Identification of Material by Infrared Absorption Spectroscopy, Using the ASTM Coded Band and Chemical Classification Index<sup>1</sup>

**Citation:** ASTM E 204-78 (1984)

**Content:** These practices describe a data system generated from 1955 through 1974. It is in worldwide use as the largest publicly available data base. It is recognized that it does not represent the optimum way to generate a new data base.

These practices describe procedures for identification of individual chemical substances using infrared absorption spectroscopy and band indexes of spectral data. Use of absorption spectroscopy for qualitative analysis has been described by many, but the rapid matching of the spectrogram of a sample with a spectral data in the literature by use of a band index system designed for machine sorting was contributed by Kuentzel. It is on Kuentzel's system that the ASTM indexes of absorption spectral data are based.

## SPECTROMETRY (STANDARDS)

Use of these practices requires, in addition to a recording spectrometer and access to published reference spectra, the encoded data and suitable data handling equipment.

**Availability:** ASTM

---

<sup>1</sup>These practices are under the jurisdiction of ASTM Committee E-13 on Molecular Spectroscopy and are the direct responsibility of Subcommittee E13.03 on Infrared Spectroscopy.

---

**Title:** Standard Practice for Use and Evaluation of Spark Source Mass Spectrometers for Analysis of Solids<sup>1</sup>

**Citation:** ASTM E 304-81 (1987)

**Content:** This practice provides guidelines for evaluation of suitability of solids mass spectrometers for use in ASTM methods for analysis of solids which specify the use of such apparatus. This practice is restricted to those instruments in which ions are produced in an electrical discharge directly from the solid.

This practice also includes discussion of the tests that are generally helpful in evaluating and improving the performance of a particular instrument as used in a particular ASTM method of analysis for solids. The variety of types of mass spectrometers which may prove suitable for a particular analysis precludes a discussion in this practice of the capabilities of each type of instrument or analysis.

**Availability:** ASTM

---

<sup>1</sup>This practice is under the jurisdiction of ASTM Committee E-14 on Mass Spectrometry and is the direct responsibility of Subcommittee E14.04 on Data and Information Problems.

---

**Title:** Standard Definitions of Terms, Symbols, Conventions, and References Relating to High-Resolution Nuclear Magnetic Resonance (NMR) Spectroscopy<sup>1</sup>

**Citation:** ASTM E 386-78 (1984)

**Content:** This standard contains definitions of basic terms, conventions, and recommended practices for data presentation in the area of high-resolution NMR spectroscopy. Some of the basic definitions apply to wide-line NMR or to NMR of metals, but in general it is not intended to cover these latter areas of NMR in this standard. This version does not include definitions pertaining to double resonance nor to rotating frame experiments.

**Availability:** ASTM

---

<sup>1</sup>These definitions are under the jurisdiction of ASTM Committee E-13 on Molecular Spectroscopy and are the direct responsibility of Subcommittee E13.07 on Nuclear Magnetic Resonance Spectroscopy.

---

**Title:** Practice for Flame Atomic Absorption Analysis

**Citation:** ASTM E 663-86

**Content:**

**Availability:** ASTM

---

**Title:** Molecular Absorption Spectrometry: Vocabulary--General--Apparatus

**Citation:** ISO 6286:1982

**Content:**

**Availability:** ISO

---

**Title:** Analytical Spectroscopic Methods--  
Flame Emission, Atomic Absorption,  
and Atomic Fluorescence--Vocabulary

**Citation:** ISO 6955:1982

**Content:**

**Availability:** ISO

---

**Title:** General Rules for Mass Spectrometric  
Analysis

**Citation:** JIS K 0118-79

**Content:**

**Availability:** JIS

---



**Title:** Problem Solving Using FTIR Spectroscopy

**Citation:** Pattacini, S. C. and T. J. Porro. *American Laboratory*, August 1988, p. 24.

**Content:**

---

**Title:** Spectroscopy

**Citation:** *Methods for Analytical Atomic Spectroscopy*. Eighth Edition. New York: ASTM, 1987, 1145 pp.

**Content:** This compilation presents 185 ASTM test methods and suggested methods covering atomic absorption, inductively coupled plasma, direct current plasma, flame, x-ray, optical emission spectrometric, as well as older, spectrographic methods. This edition replaces the 1982 version.

---

**Title:** Inductively Coupled Plasma-Mass Spectrometry: An Introduction

**Citation:** Taylor, H. E. *Spectroscopy* 1(11):20.

**Content:**

---

**Title:** A Move Toward Standardization in Nuclear Magnetic Resonance Spectrometry

**Citation:** Coates, John P. *Spectroscopy* 2(11):18.

**Content:** When considering the measurement of an NMR spectrum, it is readily apparent that the technique is one of the few methods of spectroscopy in which the results are not obtained on an absolute scale. Instead, spectra are presented relative to a standard resonance for a given nucleus. A problem arises when we move to multinuclear systems and there is the need to cross-reference the measured resonances within such systems. This subject is currently under review by the

International Union of Pure and Applied Chemists (IUPAC), which commissioned the paper presented here.

---

**Title:** Fourier Transform-Mass Spectrometry for Industrial Problem Solving

**Citation:** Asamoto, Bruce. *Spectroscopy* 3(6):38.

**Content:** Fourier transform-mass spectrometry (FT-MS) is a useful technique for analyzing "real-world" industrial samples. This article presents a brief overview of the theory of FT-MS and describes the instrumental setup required for calibration and increasing the dynamic range of this analytical technique. The combinations of FT-MS with gas chromatography (GC/FT-MS) and laser desorption (LD/FT-MS) methods are described in detail, and innovative methods such as plasma desorption and multiphoton ionization are referenced. Specific topics discussed include using a dual-cell arrangement to improve sensitivity of GC/FT-MS and the utility of preparative purification steps for improving analytical capabilities.

---

**Title:** Hybridized Techniques: Hyphenated and Slashed Instrumental Methods

**Citation:** de Haseth, James A. *Spectroscopy* 2(10):34.

**Content:**

---

**Title:** Hyphenated Techniques in Atomic Spectroscopy: A Review

**Citation:** Tatro, Mark E. *Spectroscopy* 2(10):18.

**Content:**

---

## SPECTROMETRY (LITERATURE)

**Title:** The Use of Off-Line Fourier Transform Infrared Spectroscopy for the Identification of High Performance Liquid Chromatography Peaks

**Citation:** Hurst, W. Jeffrey, R. A. Martin, Jr., and Richard M. Sheeley. *Spectroscopy* 2(10):30.

**Content:** Fourier transform infrared (FT-IR) spectroscopy has been used to identify peaks obtained from analytical and preparative high performance liquid chromatography (HPLC). This article outlines the methods used to collect, prepare, and identify these HPLC peaks. The studies in this article were performed with phospholipids obtained from soy lecithin, and the data were collected to confirm the identities of individual phospholipid peaks.

---

**Title:** Evaluation of a Near-Infrared Detector for High Performance Liquid Chromatography

**Citation:** Ciurczak, Emil W. and Frances M. B. Weis. *Spectroscopy* 2(10):33.

**Content:** This article examines the effectiveness of using a near-IR detector for high performance liquid chromatography applications. The near-IR detector's performance is judged for drift and noise levels, sensitivity, response time, linear dynamic range, dead volume, selectivity, and nondestructiveness of the sample.

---

**Title:** A Practical System for Hyphenated Thin-Layer Chromatography/Fourier Transform Infrared Spectroscopy

**Citation:** Bui, Hung. *Spectroscopy* 2(10):44.

**Content:** This technical note discusses a hyphenated system that combines thin-layer chromatography and Fourier transform infrared spectroscopy techniques. Separations performed with such a system use conventional TLC mobile phases and achieve positive identification through a spectral search routine performed with the spectrometer.

---

**Title:** Thermogravimetric Analysis with Fourier Transform Infrared Detection of Evolved Gases

**Citation:** Wieboldt, Dick and Greg Adams. *Spectroscopy* 2(10):46.

**Content:** The combined techniques of thermogravimetric analysis and Fourier transform infrared spectroscopy are capable of providing complete sample analysis. This technical note describes an interface that can be used to create a TGA-FT-IR system. In order to demonstrate this system's capabilities, an application is described in which the TGA-FT-IR system is used for the analysis of calcium oxalate.

---

**Title:** Fourier Transform-Mass Spectrometry, Part 2

**Citation:** Johnston, Mark. *Spectroscopy* 2(3):11.

**Content:**

---

**Title:** Inductively Coupled Plasma Emission Spectroscopy, Part II: Applications and Fundamentals

**Citation:** Edited by P. W. J. M. Boumans. New York: John Wiley & Sons, 1987, 486 pp.

**Content:** Wiley's "Chemical Analysis" monograph series, of which this book is the 90th volume, presents recent advances of current interest to practitioners and research experts in analytical chemistry. Boumans' volume on the applications of ICP atomic emission spectroscopy (ICP-AES) consists of 12 chapters, authoritatively written by active contributors in the field.

---

**Title:** PC Version of NBS/EPA/MSDC Mass Spectral Database

**Citation:** *NBS Update*, September 7, 1987.

**Content:** A major international resource of more than 44,000 analytical mass spectra is

now available for use on personal computers (PCs). The PC version was prepared from the NBS/EPA/MSDC Mass Spectral Database that is in use worldwide in a computer-magnetic tape format and as a six-volume, 7,000-page reference. The collection of evaluated electron ionization mass spectra of organic and inorganic substances was originally put together by the Environmental Protection Agency (EPA) and the National Institutes of Health. It is now maintained by NBS, EPA, and the Mass Spectrometry Data Centre (MSDC) in the United Kingdom. The PC database was prepared by Dr. Stephen E. Stein of NBS who compressed the 44,000 spectra in the magnetic-tape version and new search programs into 13 high-density floppy disks that can be stored on a hard disk of any AT-class or XT-class PC. Rapid searches can be made for the spectra of specific chemical names, formula, molecular weight, or Chemical Abstracts Registry Number, as well as for spectra with pre-selected characteristics such as peaks at certain masses.

**Title:** 1987 Registry of Mass Spectral Data: CD-ROM Version

**Citation:** McLafferty, Fred W. and Sixten Abrahamsson. Available from John Wiley and Sons, 305 Third Ave., New York, NY 10158

**Content:** The 1987 Registry of Mass Spectral Data is now available on CD-ROM. In addition to 123,000 spectra, the CD product supports search access of the database's extensive chemical name and synonym files, including nearly 90,000 CAS Registry Numbers.

The CD-ROM incorporates PBM/STIRS software, already in wide use for spectrometrists' computer-based laboratory instruments. The search retrieval software is Findit. The Registry of Mass Spectral Data is also available as a magnetic tape, a mass spectral library, and as a dial-up database.

**Title:** Investigations of Lignocellulosic Materials by the Carbon-13 n.m.r.c.p.-m.a.s. Method

**Citation:** Sterk, H., W. Sattler, and H. Esterbauer. *Carbohydrate Research* 164:85 (July 1, 1987).

**Content:**

**Title:** Carbon-13 NMR Spectral Data

**Citation:** Bremser, W., L. Ernst, W. Fachinger, R. Gerhards, A. Hardt, and P. M. E. Lewis. VCH Publishers, 1987.

**Content:** This fourth edition of a major reference work contains 58,108 spectra of 48,357 compounds on 235 microfiche. It is time-tested and designed for maximum ease of use.

**Title:** Carbon-13 NMR Spectroscopy: High-Resolution Methods and Applications in Organic Chemistry and Biochemistry

**Citation:** Breitmaier, Eberhard and Wolfgang Voelter. Third edition. VCH Publishers, 1987, 515 pp.

**Content:**

**Title:** Infrared Spectral Data

**Citation:** Passlack, M., W. Bremser, M. Beckmann, and H. Wagner. VCH Publishers, 1986

**Content:** In this collection of IR spectral data the problem of plotting spectrum and structure on the same microfiche has been solved. A versatile collection of indexes permits flexible searching for spectral and structural information in a way similar to an expert computer system. For the elucidation of structures and the evaluation of calculations, novel indexes of substructures and substructure combinations allow the fast correlation of structural with spectral features.

## SPECTROMETRY (LITERATURE)

This microfiche collection is compatible with the microfiche collection of Carbon-13 NMR Spectral Data by Bremser et al. (VCH Publishers, 1987).

---

**Title:** Merck IR Atlas, A Collection of FT-IR Spectra, Part I

**Citation:** Editors: E. Merck, Darmstadt, in collaboration with Bruker Analytische Messtechnik, Karlsruhe. VCH Publishers, 1987, 1146 pp.

**Content:** The 3,000 quite frequently used standard spectra contained in this book were generated in collaboration between the E. Merck and Bruker companies. The collection is distinguished from other sources of similar data by a number of special features. All spectra represent FT-IR data of a high quality as measured on a Bruker IFS 85 spectrometer.

---

**Title:** Focal Points in Mass Spectrometry

**Citation:** Delgass, W. N. and R. G. Cooks. *Science* 235:545 (Jan. 30, 1987).

**Content:** Mass spectrometry has advanced with the renaissance of time-of-flight mass analysis, the use of ion traps as analyzers and reactors, the application of tandem mass spectrometers to problems in ionic reaction mechanisms and chemical analysis, and the development of new desorption ionization techniques. These developments have allowed determination of the molecular weight distributions for polymers through the 10,000-dalton range, as well as the molecular weight and partial sequence of biopolymers of similar size. Surfaces can be characterized by use of the mass, energy, and angle distributions of particles ejected by sputtering or by laser-induced desorption. Mass spectrometry has yielded new information on the kinetics of catalytic surface reactions and on the reactivity of metal clusters.

---

**Title:** Analysis of Volatile Organic Solvents by Inductively Coupled Plasma Emission Spectrometry

**Citation:** Nygaard, Danton D. and John J. Sotera. *Applied Spectroscopy* 41(4):703.

**Content:**

---

**Title:** Fourier Transform Infrared Spectrometry Chemical Analysis

**Citation:** Griffiths, P. R. and J. A. Dehaseth. New York: John Wiley and Sons, 1986.

**Content:**

---

**Title:** Expanded MS/MS Applications through Improved Instrumentation

**Citation:** Busch, Kenneth L. and Gerald C. DiDonato. *American Laboratory*, August 1986, p. 17.

**Content:**

---

**Title:** Rapid Analysis of Important Fuel Properties by FT-IR Spectroscopy

**Citation:** Aho, M. and P. Kortelainen. The Finnish Journal, *SUO*, in press.

**Content:**

---

**Title:** Sadtler UV/Visible Library

**Citation:** Philadelphia, PA: Bio-Rad, Sadtler Division.

**Content:** The Sadtler UV/Visible Library features fully quantitative Sadtler and user generated library information. Samples have been prepared in methanol (at acidic, neutral, and basic pH) and cyclohexane solvents. Cyclohexane and methanol were selected so that spectral characteristics can best be determined when comparing polar and non-polar solvents. Sadtler presently has a digital library of 2000 compounds. This will

be expanded on an annual basis. In addition, Sadtler will be preparing library subsets in order to meet the needs of many different application areas.

Bio-Rad Laboratories, Sadtler Division offers a broad range of digital FT-IR search libraries. These libraries include fixed size collections, incorporating selected compounds for specific applications, and continually expanding libraries to which new compounds are regularly added as they become available. Sadtler digital libraries provide users with a wide selection of collection sizes, prices and applications to meet the specific and growing needs within any laboratory. Sadtler offers five different categories of digital FT-IR libraries: the Sadtler Package Libraries; the Sadtler Infrared Commercial Libraries; the Sadtler Condensed Phase Library; the Hummel/Sadtler Polymer Library and the Sadtler Standard Vapor Phase Library.

Sadtler Research Laboratories now offers its  $^{13}\text{C}$  NMR Search Libraries on the IBM PC Series computers. These search libraries include over 26,000 compounds of pure materials (98% purity or better) and also a separate library of  $^{13}\text{C}$  NMR of monomers and polymers spectra. The standard library contains data of simple aliphatic, aromatic, alicyclic and heterocyclic compounds as well as numerous complex materials. The  $^{13}\text{C}$  NMR of monomers and polymers library contains data for 800 monomers, polymers and resins.

Sadtler's infrared search libraries, already the largest and highest quality available, are currently being expanded at an accelerated rate. These fully digital libraries now contain over 120,000 spectra. Included are 9,200 vapor phase spectra, 61,000 standard condensed phase IR spectra of pure compounds, and 53,000 spectra from Sadtler's many commercial spectra libraries including monomers and polymers, surfactants, adhesives and sealants, inorganics, coating chemicals, controlled pyrolyzates of polymers, plasticizers, abused drugs, pharmaceuticals, solvents, and others.

---

**Title:** Handbook of Atomic Absorption Analysis

**Citation:** Varma, A. *Handbook of Atomic Absorption Analysis*, Volume I and II, CRC Press, Boca Raton, Florida. 1984.

**Content:** This two volume set is a very complete and useful bibliography of literature on atomic absorption analysis. It is an excellent source for anyone wishing to survey the literature for specific methods.

---





## APPENDIX I

### Working Group Members for the IEA Voluntary Standards Activity

#### Feedstocks Panel

Helena L. Chum  
Solar Energy Research Institute  
Golden, CO, USA

Roger C. Pettersen  
Forest Products Laboratory  
Madison, WI, USA

Maurice Douek  
Pulp and Paper Research Institute of  
Canada  
Pointe Claire, Quebec, Canada

Roger Sutcliffe  
Forintek Canada  
Ottawa, Ontario, Canada

Wolfgang C. Glasser  
Virginia Polytechnic Institute and  
State University  
Blacksburg, VA, USA

Olof Theander  
University of Agricultural  
Science  
Uppsala, Sweden

W. E. Hillis  
CSIRO  
Clayton, Victoria, Australia

Jack Ranney  
Oak Ridge National Laboratory  
Oak Ridge, TN, USA

#### Biochemical Panel

Tom Clark  
Forest Research Institute  
New Zealand

M. Moo-Young  
University of Waterloo  
Waterloo, Ontario, Canada

R. F. H. Dekker  
CSIRO  
Victoria, Australia

Michael Paice  
Pulp and Paper Research  
Institute  
Pointe Claire, Quebec, Canada

Hermann M. Esterbauer  
University of Graz  
Graz, Austria

Jacques Pourquie  
Institut Francais du Petrole  
Fueil-Malmaison, France

Douglas Eveleigh  
Rutgers University  
New Brunswick, NJ, USA

Juergen Puls  
BFJ Inst. Wood Chemistry  
Hamburg  
Federal Republic Germany

Karel Grohmann  
Solar Energy Research Institute  
Golden, CO, USA

Jack Saddler  
Forintek Canada  
Ottawa, Ontario, Canada

Barbel Hahn-Hagerdahl  
University of Lund  
Sweden

M. Wayman  
Morris Wayman Ltd. Consultants  
Toronto, Ontario, Canada

### Thermochemical Panel

Xavier Deglise  
Universite de Nancy  
Nancy, France

Eugene Domalski  
National Institute of Standards  
and Technology  
Gaithersburg, MD, USA

Doug Elliott  
Battelle Pacific Northwest Laboratories  
Richland, WA, USA

Ralph Overend  
National Research Council of Canada  
Division of Biosciences  
Ottawa, Ontario, Canada

Hooshang Pakdel  
Laval University  
Ste-Foy, Quebec, Canada

Herbert L. Retcofsky  
Pittsburgh Energy Technology Center  
Pittsburgh, PA, USA

Geoffrey Richards  
University of Montana  
Missoula, MT, USA

Donald S. Scott  
University of Waterloo  
Waterloo, Ontario, Canada

Kai Sipila  
Tech. Research Centre of Finland  
Espoo, Finland

## APPENDIX II

### Standards Organizations

Quite a number of societies and organizations maintain a standard-setting function or provide information on standards. Many of these have been cited in the methods section and the key to the methods section. Here we list organizations, with full addresses, to whom readers may want to refer--or better yet, become actively involved with. In some cases details on relevant subcommittees, working groups, and the like are described. We encourage users of this source book to help fill in the many gaps for the second edition, particularly for entities outside North America. Please communicate additional information to Thomas A. Milne or Ann Brennan at SERI.

#### AFNOR

Association Francaise de Normalisation  
Tour Europe, Cedex 7  
92080 Paris La Defense  
FRANCE

#### AGA

American Gas Association  
1515 Wilson Boulevard  
Arlington, VA 22209  
USA

#### AIChE

American Institute of Chemical Engineers  
345 East 47th Street  
New York, NY 10017  
USA

#### ANMC

American National Metric Council  
1010 Vermont Ave. NW  
Suite 320  
Washington, DC 20005  
USA

#### ANSI

American National Standards Institute  
1430 Broadway  
New York, NY 10018  
USA

#### AOAC

Association of Official Analytical Chemists  
Box 540 Benjamin Franklin Station  
Washington, DC 20044  
USA

All method numbers refer to the 14th Edition of *Official Methods of Analysis of the Association of Analytical Chemists*. Edited by S. Williams. 1984.

**APCA**

Air Pollution Control Association  
4400 Fifth Avenue  
Pittsburgh, PA 15213  
USA

The Air Pollution Control Association contributes to the development of standards through representation in the following committees of standards-setting organizations: American National Standards Committee Z-21; Subcommittee on Standards for Domestic Gas-Fired Incinerators; American National Standards Z-105; Air Cleaning Equipment Committee of Installation Standards for Oil Burners and Oil Burning Equipment; American National Standards Z-228; Incinerator Committee; International Organization for Standardization; Technical Committee ISO/TC 146; Air Purity and Intersociety Committee (Manual of Methods of Ambient Air Sampling Analysis).

**APFI**

Association of Pellet Fuel Industries  
905 Greg Street  
Sparks, NV 89431  
USA

**APHA-AWWA-WPCF**

**APHA**

American Public Health Association  
1015 15th Street NW  
Washington, DC 20005  
USA

**AWWA**

American Water Works Association  
6666 West Quincy Avenue  
Denver, CO 80235  
USA

**WPCF**

Water Pollution Control Federation  
2626 Pennsylvania Ave. NW  
Washington, DC 20037  
USA

These three groups have a standards committee on sludge gas and methane.

**API**

American Paper Institute  
260 Madison Ave.  
New York, NY 10016  
USA

This institute, formed January 1966, is the successor organization of the American Paper and Pulp Association and its divisions, and the National Paperboard Association. Because of the numerous grades of paper and paperboard and their various uses, there have been no quality standardization programs engaged in by the American Paper Institute or its predecessor organizations. However, standards for testing

certain physical characteristics such as bursting strength, tear, brightness, and opacity have been developed for many grades of paper. These specifications are officially published by the Technical Association of the Pulp and Paper Industry, One Dunwoody Park, Atlanta, GA 30341. Standard gauge lists for combination paperboard were revised effective January 1969 and adopted by members of the Combination Paperboard Division of the Paperboard Group, API.

Although not directly related to standardization itself, the *Dictionary of Paper* contains more than 500 pages of concise descriptions of pulp and other raw paper-making materials, papers, paperboards, paper and properties, and papermaking terms.

**API**

American Petroleum Institute  
1220 L Street NW  
Washington, DC 20005  
USA

**Appita**

Australian and New Zealand Pulp and Paper Industry Technical Association  
Clunis Ross House  
191 Royal Pde.  
Parkville, Victoria 3052  
AUSTRALIA

**ASAE**

American Society of Agricultural Engineers  
2950 Niles Road  
St. Joseph, MI  
USA

See *ASAE Standards*, 34th Edition. Edited by R. H. Hahn and E. E. Rosentreter. 1987

**ASCE**

American Society of Civil Engineers  
345 East 47th Street  
New York, NY 10017  
USA

The American Society of Civil Engineers has a Task Committee on Design of Anaerobic Digestors.

**ASHRAE**

American Society of Heating, Refrigerating and Air-Conditioning Engineers  
1719 Tullie Circle NE  
Atlanta, GA 30329  
USA

**ASME**

American Society of Mechanical Engineers  
United Engineering Center  
345 East 47th Street  
New York, NY 10017  
USA

## ASTM

American Society for Testing and Materials  
1916 Race Street  
Philadelphia, PA 19103  
USA

See *1988 Annual Book of Standards*, Vol. 00.01 for subject and alphanumeric list.

ASTM has many active committees and subcommittees that would welcome participation from the biomass-related community. Among these are:

ASTM Committee D-1 (Paint and Related Coatings and Materials) now contains the former Committee D-23 on Cellulose and Cellulose Derivatives.

ASTM Committee D-2 on Petroleum has a subcommittee IV, Section M, looking at mass spectrometry for fuel analysis of petroleum fractions and derivatives. It is considering round-robin tests, and D-2 is also working on two documents on specification for fuel methanol.

ASTM Committee D-3 on Gaseous Fuels has as its scope the promotion of knowledge and the development of definitions; specifications; classifications; recommended practices; and methods of sampling, analysis, and testing relating to gases used as commercial fuels. Several subcommittees address subjects of relevance to biomass gasification.

ASTM Committee D-5 on Coal has written many standards used by the biofuels community or used as a point of departure for specifically biofuels standards.

ASTM Committee D-6 on Paper and Paper Products has as its scope the development of specifications, methods of sampling and testing, and definitions of terms pertaining to paper and paper products.

ASTM Committee D-7 on Wood is responsible for several very relevant methods used by the biofuels community. Its scope is the promotion of knowledge, stimulation of research, and development of standardized nomenclature, quality classifications, specifications, methods of test, methods of and materials for modifying properties; study of the effect of various factors on the properties, questions of utility, and related subjects pertaining to wood, veneer, plywood, laminated wood, and wood-based laminates.

ASTM Committee D-17 on Naval Stores has the following scope: the formulation of specifications, methods of test, and definitions relating to the products generally included in the term "naval stores," which includes turpentine, rosin, pine oleoresins, pine oils, rosin oils, tall oils, wood tars, wood pitches, and other closely related natural resinous materials. Naval stores could have increasing relevance to the production of chemicals from biomass.

ASTM Committee D-22 on Sampling and Analysis of Atmospheres seeks the promotion of knowledge and the formulation of methods of sampling and analysis of atmospheres, the selection of acceptable nomenclature and definitions, and the stimulation of research to accomplish the foregoing purposes. As an example, in 1984 Subcommittee D22.02 on Source Sampling began developing documents on sampling hydrochloric and sulfuric acid.

Committee D-23 on Cellulose and Cellulose Derivatives, developer of a number of standards in this sourcebook, has now become a part of Committee D-1 on Paint and Related Coatings and Materials.

Committee D-34 on Waste Disposal now includes the former Committee E-38 on Resource Recovery. The proposed scope of the new merged D-34 and E-38 Committee is the promotion and knowledge, stimulation of research, and development of test methods, specifications, practices, nomenclature, classifications, and definitions relating to the management of wastes. Wastes are here defined as those materials that are generated by industrial, commercial or household sources and that are either destined for disposal or already disposed. Management of such wastes is defined here to include generation, storage, transportation, treatment, disposal, and resource recovery. The activities of D-34 will be coordinated in cooperation with other relevant committees within ASTM and outside organizations.

Committee E-06 on Performance of Building Constructions has a subcommittee on Solid Fuel Burning Appliances, E06.54, which addresses wood stove efficiency, safety, and related matters.

Committee E-48 on Biotechnology has absorbed the former E44.12 subcommittee of E-44 (Solar Energy Conversion), which is now the E48.05 subcommittee on Biomass Conversion. Other relevant committees of E-48 are E48.01 on Materials for Biotechnology, E48.02 on Characterization and Identification of Biological Systems, E48.03 on Unit Processes and Their Controls, E48.04 on Environmental Issues, and E48.91 on Terminology. The scope of E-48 is the promotion of knowledge and the development of standards (classifications, guides, practices, specifications, terminology, and test methods) for biotechnology. Committee E48.05 is currently working on a Test Method for Durability of Biomass Pellets and is considering test methods for ash (D-7's method is currently used) and a microwave moisture content analysis.

Information on joining ASTM and on committee structures and goals can be obtained from ASTM, 1617 Race Street, Philadelphia, PA 19103, Phone (215) 299-5400.

ASTM offers an online index, through Pergamon. The Standards Search File has moved to a new database provider, Pergamon ORBIT Infoline. This file provides bibliographic information on all the standard documents developed by ASTM as well as those developed by SAE. It's a search tool to help you find the standards you need. When you use Standards Search, the file displays the document number and title, date of issue, equivalent standards, DoD approval, cross references, index terms for additional searching, and information on how to obtain the full test. You have electronic access to more than 11,000 documents. To order Standards Search, or to obtain technical details, contact ORBIT SEARCH, Division of Pergamon ORBIT Infoline, 8000 Westpark Drive, McLean, VA 22102, 703-442-0900 (Va) or 800-421-7229 (Continental U.S. except Va).

### **ATIBT**

International Technical Tropical Timber Association  
45 bis  
Avenue de la Belle-Gabrielle  
94130  
FRANCE

Standardization Activities: Develops grading rules for the tropical timber trade (logs and lumber) and standardized nomenclature for tropical timbers.

**AWWA**

American Water Works Association  
6666 West Quincy Avenue  
Denver, CO 80235  
USA

**BSI**

British Standards Institution  
2 Park Street  
London, W1A 2 BS  
UNITED KINGDOM

Standards information provided by BSI, through their STANDARDLINE data base, is greatly acknowledged.

**CBS**

Canadian Boiler Society  
4786 Queen Street  
Niagara Falls, Ontario  
CANADA L2E 2M3

**CFR**

Code of Federal Regulations, United States

**CGA**

Canadian Gas Association  
55 Scarsdale Rd.  
Don Mills, Ontario  
CANADA M3B 2R3

**CIMAC**

International Council on Combustion Engines  
10 Avenue Hoche  
75382 08  
FRANCE

Standardization Activities: Involved in the development of ISO standards related to combustion engines (reciprocating engine and gas turbine types) and test methods. Is not involved with combustion engines used to propel construction and earth moving vehicles, tractors, automobiles, trucks, and aircraft.

**CPPA**

Canadian Pulp and Paper Association  
Sun Life Building, 23rd Floor  
1155 Metcalfe Street  
Montreal, Quebec  
CANADA H3B 2X9

**CSA**

Canadian Standards Association  
178 Rexdale Boulevard  
Rexdale, Ontario  
CANADA M9W 1R3

(See also Standards Council of Canada, 350 Sparks Street, Ottawa, Ontario, CANADA K1R 7S8, which publishes a catalog of standards of the Canadian Gas Association and the Canadian General Standards Board as well as CSA standards.)

#### CSIRO

Division of Chemical and Wood Technology  
Private Bag No. 10,  
Clayton, Victoria, 3168  
AUSTRALIA

#### DIN

Deutsches Institut für Normung  
Burggrafenstrasse 4-10  
Postfach 1107, D-1000  
Berlin 30  
FEDERAL REPUBLIC OF GERMANY

#### EN

European Committee for Standardization  
rue Brederode 2 Bte 5  
1000 Brussels  
BELGIUM

(Member countries are Austria, Belgium, Denmark, Finland, France, Germany (F.R.), Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, U.K.). (See P.W. Cooke. *A Summary of the New European Community Approach to Standards Development*. NBSIR 88-3793-1, August 1988).

#### EPA

U.S. Environmental Protection Agency  
Office of Solid Waste and Emergency Response  
Washington, DC 20460  
USA

#### FAO

Food and Agriculture Organization of the United Nations  
(International Development)  
Via delle Terme di Caracalla  
I-00100 Rome  
ITALY

Organizes special subject conferences and meetings; hosts expert consultations. Maintains library of 1 million volumes, in addition to films, videotapes, and computer tapes. **Computerized Services:** Data bases; AGRIS (International Information System for the Agricultural Sciences and Technology), which encompasses 1 million references reported by national centers; CARIS (Current Agricultural Research Information System), which functions as an information exchange for 70 countries; ICS (Interlinked Computer Storage and Data Processing System of Food and Agricultural Commodity Data); ASFIS (Aquatic Sciences and Fisheries Information System); FISHDAB (Fisheries Data Base); FORIS (Forest Resources Information System).

#### FPL

Forest Products Laboratory  
U.S. Department of Agriculture  
One Gifford Pinchot Dr.  
Madison, WI 53705  
USA

*Procedures for the Chemical Analysis of Wood and Wood Products* (as used at the U.S. Forest Products Laboratory). W.E. Moore and D.B. Johnson. Revised, Dec. 1967. (Unpublished) (Although FPL is not a standards-setting body, the FPL Procedures Manual served as an ad-hoc standard for many early researchers.)

#### FRI

Forest Research Institute  
Private Bag  
Rotorua  
NEW ZEALAND

#### GOST

USSR State Committee for Standards  
Research and Production Association  
4, ul. Schuseva  
Moscow, 103001  
USSR

#### ICSU-CODATA

International Council of Scientific Unions  
Committee on Data for Science and Technology  
CODATA Secretariat  
51 bd. de Montmorency  
75016  
FRANCE

Publishes a newsletter.

#### ICUMSA

International Commission for Uniform Methods for Sugar Analysis  
c/o Institut für landwirtschaftliche  
Technologie und Zuckerindustrie  
Langer Kamp 5  
P.O. Box 5224  
D-3300 BRAUNSCHWEIG  
F.R. GERMANY

Standardization Activities: Develops uniform analytical methods for sugar analysis.

#### IPC

Institute of Paper Chemistry  
P.O. Box 1039  
Appleton, WI 54912  
USA

### ISO

International Standards Organization  
1, rue de Varembe  
Case postale 56  
CH-1211 Genève 20  
SWITZERLAND

### IUFRO

International Union of Forestry Research Organizations (IUFRO)  
(Internationaler Verband Forstlicher Forschungsanstalten)  
Schonbrunn  
Tirolergarten  
A-1131 Vienna  
AUSTRIA

### IUPAC

International Union of Pure and Applied Chemistry  
Bank Court Chambers  
2-3 Pound Way  
Cowley Centre  
Oxford OX4 3YF  
UNITED KINGDOM

Two divisions of IUPAC are especially relevant to biomass for fuels and chemicals, particularly at the basic research level. The Analytical Chemistry Division (V) has subcommittees and commissions in Environmental Analytical Chemistry; Analytical Reactions, Reagents, and Separations; Microchemical Techniques and Trace Analysis; Analytical Nomenclature; Spectrochemical and Other Optical Procedures for Analysis; Electroanalytical Chemistry; Equilibrium Data; Radiochemistry and Nuclear Techniques; and Solubility Data.

The Applied Chemistry Division (VI) has commissions on Food Chemistry; Biotechnology; Oils, Fats and Derivatives; Atmospheric Chemistry; Agrochemicals; and Water Chemistry.

(Source: *IUPAC Handbook, 1987-1989*. Blackwell Scientific Publications, London, England.)

### JIS

Japanese Industrial Standards  
1-24, Akaska 4, Minato - ku  
Tokyo 107  
JAPAN

(See G. Mori, *ASTM Standardization News*, Oct. 1987, p. 56 for a description of the Japanese Standards Association and the scope and development of JIS Standards (e.g., a committee exists on natural resources and energy).

**NCSL**

National Conference of Standards Laboratories  
325 Broadway  
Radio Bldg., M.C. 104  
Boulder, CO 80303  
USA

**NCWM**

National Conference on Weights and Measures  
National Institute of Standards and Technology  
U.S. Department of Commerce  
Gaithersburg, MD 20899  
USA

**NCSCI**

National Center for Standards and Certification Information  
Administration Building  
Room A-629  
Gaithersburg, MD 20899  
USA  
Phone (301) 975-4040  
FAX 301-975-2128  
TELEX TRT 197674 NISTUT

Housed at NIST, this center maintains an extensive catalog of standards from many countries as well as many standards in hard copy or microform. NCSCI offers an inquiry and referral service.

**NFPA**

National Fire Protection Association  
Batterymarch Park  
Quincy, MA 02269  
USA

**NIST (Formerly NBS)**

National Institute of Standards and Technology  
Gaithersburg, MD 20899  
USA

The National Institute of Standards and Technology (NIST) is the new name of the Commerce Department's National Bureau of Standards (NBS). NIST was created by the Omnibus Trade and Competitiveness Act signed by President Reagan on August 23, 1988.

NBS was originally established in 1901 as the government's science and engineering laboratory for measurement technology and research on standards. Over the years it evolved to become the sole federal laboratory directly concerned with aiding industry and commerce.

The name National Institute of Standards and Technology reflects the broadened role and new responsibilities assigned to the agency, which will include the traditional functions of providing the measurements, calibrations, data, and quality assurance support that are vital to U.S. commerce and industry, together with several new programs to support the aggressive use of new technologies in American industry.

NIST has a new purpose, "to assist industry in the development of technology and procedures needed to improve quality, to modernize manufacturing processes, to ensure product reliability, manufacturability, functionality, and cost-effectiveness, and to facilitate the more rapid commercialization...of products based on new scientific discoveries."

NIST will maintain the traditional functions of NBS and will continue to offer the full array of measurement and quality assurance services that were provided by NBS, including calibration services, standard reference materials, standard reference data, and measurement assurance programs.

NSF

Norges Standardiseringsforbund  
Postboks 7020 Homansbyen  
N-0306 Oslo 3  
NORWAY

PPRIC

Pulp and Paper Research Institute of Canada  
570 St. John's Boulevard  
Pointe Claire, Quebec  
CANADA H9R 3J9

SAA

Standards Association of Australia  
Head Office, Standards House  
80 Arthur Street  
P.O. Box 458  
North Sydney, NSW 2059  
AUSTRALIA

SANZ

Standards Association of New Zealand  
Sixth Floor, Wellington Trade Centre  
181-187 Victoria Street, Private Bag  
Wellington  
NEW ZEALAND

SCAN

Scandinavian Pulp, Paper and Board  
Testing Committee (Denmark, Finland, Norway, Sweden)  
Secretariat, Box 5604  
S-11486 Stockholm  
SWEDEN

SCC

Standards Council of Canada  
International Standardization Branch  
2000 Argentinia Road  
Suite 2-401  
Mississauga, Ontario L5N1V8  
CANADA

**SES**

Standards Engineering Society  
1709 N. West Ave.  
Suite 122  
Jackson, MI 49202  
USA

SES was established in 1947 to promote the use of standards; advance the techniques of standardization; represent the views of standards users; and provide a network of standards professionals from industry, academia, government, and standards-developing organizations to address questions on standards and standardization.

**SFS**

Suomen Standardisoimisliitto SFS  
(Finnish Standards Association)  
PL 205  
SF-00121  
Helsinki 12  
FINLAND

**SMS**

Sveriges Mekanstandardisering  
Box 5395  
S-102 46 Stockholm  
SWEDEN

**TAPPI**

Technical Association of the Pulp and Paper Industry  
Technology Park, P.O. Box 105113  
Atlanta, GA 30348  
USA

(Abstracts quoted for TAPPI methods are copywrited and are printed with permission of TAPPI.)

**UL**

Underwriters' Laboratories, Inc.  
333 Pfingsten Road  
Northbrook, IL 60062  
USA

**ULC**

Underwriters' Laboratories of Canada  
7 Crouse Rd.  
Scarborough, Ontario  
CANADA MIR 3A9

**USDA**

U.S. Department of Agriculture  
Independence Ave. and 14th St. SW  
Washington, DC 20250  
USA

## VTT

Technical Research Centre of Finland

Maintains a register of Methods for Testing and Inspection at VTT. Distributed by:  
Government Printing Centre  
P.O. Box 516  
SF-00101, Helsinki 10  
FINLAND

## WPCF

Water Pollution Control Federation  
2626 Pennsylvania Ave., NW  
Washington, DC 20037

(Issued by American National Standards Institute, 1430 Broadway, New York NY 10018)

## Agents for Standards Throughout the World

National standardizing bodies, especially the Member Bodies of the International Organization for Standardization (ISO), serve as national representatives for one another. Each acts within its own country as sole sales agent and information center for the standards of the other national standardizing bodies. Hence standards issued by the American National Standards Institute, the United States Member Body of ISO, may be purchased abroad from the respective national standardizing body in each of the following countries. Overseas prices may differ from those listed in the current *Catalog of American National Standards*.

### ALGERIA

Institut Algerien de Normalisation et  
de Propriete Industrielle  
5 Rue Abou Hamou Moussa  
B.P. 1021  
Centre de Tri, Alger

### ARGENTINA

Instituto Argentino de  
Racionalizacion de Materiales  
Chile 1192  
Buenos Aires

### AUSTRALIA

Standards Association of Australia  
Standards House  
80-86 Arthur Street  
North Sydney, N.S.W. 2060

### AUSTRIA

Osterreichisches Normungsinstitut  
Leopoldsgasse 4  
Postfach 130  
A-1021 Wien 2

### BANGLADESH

Bangladesh Standards Institution  
3-DIT (Extension) Avenue  
Motijheel Commercial Area  
Dhaka 2

### BARBADOS

Barbados National Standards  
Institution  
"Flodden" Culloden Road  
St. Michael

### BELGIUM

Institut Belge de Normalisation  
Av. de la Brabanconne 29  
B-1040 Bruxelles

### BRAZIL

Associacao Brasileira de Normas  
Tecnicas  
Av. 13 de Maio, n° 13-28° andar  
Caixa Postal 1680  
CEP: 20.003  
Rio de Janeiro

**BULGARIA**

State Committee for Science and  
Technical Progress  
Standards Office  
21, 6th September Street  
1000 Sofia

**CANADA**

Standards Council of Canada  
International Standardization Branch  
2000 Argentia Road, Suite 2-401  
Mississauga, Ontario L5N 1V8

**CHILE**

Instituto Nacional de Normalizacion  
Matias Cousino 64-6° piso  
Casilla 995-Correo 1  
Santiago

**CHINA—(Peking, Peoples Republic of  
China)**

China Association for Standardization  
P.O. Box 820  
Beijing

**CHINA—(Republic of China)**

National Bureau of Standards  
Ministry of Economic Affairs  
102 Kwang-Fu S. Rd.  
Taipei, Taiwan, 105

**COLOMBIA**

Instituto Colombiano de Normas  
Tecnicas  
Carrera 37 No. 52-95  
P.O. Box 14237  
Bogota

**COSTA RICA**

Instituto Centramericano de  
Investigaciones y Tecnologia  
Industrial  
4a Calle y Avenida la Reforma,  
Zona 10  
Guatemala City, Guatemala

**CYPRUS**

Cyprus Organization for Standards  
and Control of Quality  
Ministry of Commerce and Industry  
Nicosia

**CZECHOSLOVAKIA**

Urad pro Normalizaci a Mereni  
Vaclavske Namesti 19  
113 47 Praha 1

**DENMARK**

Dansk Standardiseringraad  
Aurehojvej 12  
Postbox 77  
DK-2900 Hellerup

**DOMINICAN REPUBLIC**

Direccion General de Normas y  
Sistemas de Calidad  
Secretaria de Industria y Comercio  
Av. Mexico No. 30  
Santo Domingo

**EGYPT**

Egyptian Organization for  
Standardization  
2 Latin America Street  
Garden City, Cairo

**EL SALVADOR**

Instituto Centroamericano de  
Investigaciones y Tecnologia  
Industrial  
4a Calle y Avenida la Reforma,  
Zona 10  
Guatemala City, Guatemala

**ETHIOPIA**

Ethiopian Standards Institution  
P.O. Box 2310  
Addis Ababa

**FINLAND**

Suomen Standardisoimisliitto r.y.  
P.O. Box 205  
SF-00121 Helsinki 12

**FRANCE**

Association Francaise de  
Normalisation  
Tour Europe  
Cedex 7  
92080 Paris La Defense

**GERMANY, F.R.**

Deutsches Institut fur Normung  
Burggrafenstrasse 4-10  
Postfach 1107  
D-1000 Berlin 30

**GHANA**

Ghana Standards Board  
P.O. Box M.245  
Accra

**GREECE**

Hellenic Organization for  
Standardization  
Didotou 15  
106 80 Athens

**GUATEMALA**

Instituto Centroamericano de  
Investigaciones y Tecnologia  
Industrial  
4a Calle y Avenida la Reforma  
Zona 10  
Apartado Postal 1552  
Guatemala City

**HONDURAS**

Instituto Centroamericano de  
Investigaciones y Tecnologia  
Industrial  
4a Calle y Avenida la Reforma  
Zona 10  
Guatemala City, Guatemala

**HONG KONG**

Hong Kong Standards and Testing  
Centre  
Dai Wang Street  
Taipo Industrial Estate  
Taipo N.T., Hong Kong

**HUNGARY**

Magyar Szabvanyugyi Hivatal  
Postafioek 24  
1450 Budapest

**ICELAND**

Technological Institute of Iceland  
Division of Standards  
Skiopholt 37  
IS-110 Reykjavik

**INDIA**

Indian Standards Institution  
Manak Bhavan  
9 Bahadur Shah Zafar Marg  
New Delhi 110002

**INDONESIA**

Badan Kerjasama Standardisasi LIPI-  
YDNI  
(LIPI-YDNI Joint Standardization  
Committee), Jln  
Teuku Chik Ditiro 43  
P.O. Box 250  
Jakarta

**IRAN**

Institute of Standards and Industrial  
Research of Iran  
Ministry of Industries  
P.O. Box 2937  
Tehran

**IRAQ**

Central Organization for  
Standardization and Quality  
Control Planning Board  
P.O. Box 13032  
Aljadiria, Baghdad

**IRELAND**

Institute for Industrial Research and  
Standards  
Ballymun Road  
Dublin-9

**ISRAEL**

Standards Institution of Israel  
42 University Street  
Tel Aviv 69977

**ITALY**

Ente Nazionale Italiano di  
Unificazione  
Piazza Armando Diaz 2  
I-20123 Milano

**JAMAICA**

Jamaica Bureau of Standards  
6 Winchester Rd.  
P.O. Box 113  
Kingston 10

**JAPAN**

Japanese Standards Association  
1-24 Akasaka 4  
Minato-ku 107  
Tokyo

**JORDAN**

Directory of Standards  
Ministry of Industry and Trade  
P.O. Box 2019  
Amman

**KENYA**

Kenya Bureau of Standards  
Off Mombasa Road Behind Belle Vue  
Cinema  
P.O. Box 54974  
Nairobi

**KOREA**

Bureau of Standards  
Industrial Advancement  
Administration  
Yongdeungpo-Dong  
Seoul

**KOREA**

Korea Standards Association  
105-153 Kongduck-dong  
Mapo-ku  
Seoul

**KUWAIT**

Standards and Metrology Department  
Ministry of Commerce and Industry  
Post Box No. 2944  
Kuwait

**LIBYAN ARAB JAMAHIRIYA**

Libyan Standards and Patent Section  
Department of Industrial  
Organization and Services  
Secretariat of Light Industries  
Tripoli

**MALAYSIA**

Standards and Industrial Research  
Institute of Malaysia  
Lot 10810, Phase 3, Federal Highway  
P.O. Box 35  
Shah Alam, Selangor

**MEXICO**

Direccion General de Normas  
Calle Puente de Tecamachalco No. 6  
Lomas de Tecamachalco  
Seccion Fuentes  
Naulcalpan de Juarez 53 950

**MONGOLIA**

State Committee for Prices and  
Standards of the Mongolian  
People's Republic  
Marshal Zhukov Avenue, 51  
Ulan Bator

**MOROCCO**

Service de Normalisation Industrielle  
Marocain  
Direction de l'Industrie  
Ministere du Commerce, de  
l'Industrie  
5 rue Arrich  
Rabat

**NETHERLANDS**

Nederlands Normalisatie-Instituut  
Kalfjeslaan 2  
P.O. Box 5059  
2600 GB Delft

**NEW ZEALAND**

Standards Association of New  
Zealand  
Private Bag  
Wellington

**NICARAGUA**

Instituto Centroamericano de  
Investigaciones y Tecnologia  
Industrial  
4a Calle y Avenida la Reforma  
Zona 10  
Guatemala City, Guatemala

**NIGERIA**

Nigerian Standards Organization  
Federal Ministry of Industries  
No. 4 Club Road  
P.M.B. 1323  
Enugu

**NORWAY**

Norges Standardiseringsforbund  
Postboks 7020 Homansbyen  
N-Oslo 3

**OMAN**

Directorate General for  
Specifications and Measurements  
Ministry of Commerce and Industry  
P.O. Box 550  
Muscat

**PAKISTAN**

Pakistan Standards Institution  
39 Garden Road  
Saddar, Karachi-3

**PANAMA**

Instituto Centroamericano de  
Investigaciones y Tecnologia  
Industrial  
4a Calle y Avenida la Reforma  
Zona 10  
Guatemala City, Guatemala

**PERU**

Instituto de Investigacion Tecnologia  
Industrial y de Normas Tecnicas  
Jr. Morelli--2da  
Cuadra, Urbanizacion San Borja--  
Surquillo  
Lima 34

**PHILIPPINES**

Product Standards Agency  
Ministry of Trade and Industry  
361 Buendia Avenue Extension,  
Makati  
Metro Manila 3117, Manila

**POLAND**

Polish Committee for Standardization  
Measures and Quality Control, UI  
Elektoralna 2  
00-139 Warszawa

**PORTUGAL**

Direccao-Geral de Qualidade  
Rua Jose Estevao 83-A  
1199 Lisboa Codex

**REPUBLIC OF SOUTH AFRICA**

South African Bureau of Standards  
Private Bag X191  
Pretoria 0001

**ROMANIA**

Institutul Roman de Standardizare  
Casuta Postala 6214  
Bucarest 1

**SAUDI ARABIA**

Saudi Arabian Standards Organization  
P.O. Box 3437  
Riyadh

**SINGAPORE**

Singapore Institute of Standards and  
Industrial Research  
Maxwell Road  
P.O. Box 2611  
Singapore 9046

**SPAIN**

Instituto Nacional de Racionalizacion  
y Normalizacion  
Calle Fernandez de la Hoz 52  
Madrid 10

**SRI LANKA**

Bureau of Ceylon Standards  
53 Dharmapala Mawatha  
P.O. Box 17  
Colombo 3

**SUDAN**

Standards and Quality Control  
Department  
Ministry of Industry  
P.O. Box 2184  
Khartoum

**SWEDEN**

Standardiseringskommissionen i  
Sverige  
Tegnergatan 11  
Box 3 295  
S-103 66 Stockholm

**SWITZERLAND**

Association Suisse de Normalisation  
Kirchenweg 4  
Postfach  
8032 Zurich

**SYRIA**

Syrian Arab Organization for  
Standardization and Metrology  
P.O. Box 11836  
Damascus

**TANZANIA**

Tanzania Bureau of Standards  
P.O. Box 9524  
Dar es Salaam

**THAILAND**

Thai Industrial Standards Institute  
Ministry of Industry  
Rama VI Street  
Bangkok 10400

**TRINIDAD and TOBAGO**

Trinidad and Tobago Bureau of  
Standards  
Trincity Industrial Estate  
Tunapuna  
P.O. Box 467  
Trinidad and Tobago

**TUNISIA**

Institut National de la Normalisation  
et de la Propriete Industrielle  
B.P. 23  
1012 Tunis-Belvedere

**TURKEY**

Turk Standardlari Enstitusu  
Necatibey Cad. 112  
Bakanliklar  
Ankara

**UNITED ARAB EMIRATES**

Directorate of Standardization and  
Metrology  
P.O. Box 433  
Abu Dhabi

**UNITED KINGDOM**

British Standards Institution  
2 Park Street  
London W1A 2BS

**USSR**

USSR State Committee for Standards  
Leninsky Prospekt 9  
Moskva 117049

**VENEZUELA**

Comision Venezolana de Normas  
Industriales  
Arda  
Andres Bello-Efd  
Torre Fondo Comun  
Piso 11  
Caracas 1050

**YUGOSLAVIA**

Savezni zavod za Standardizaciju  
Slobodana Penezica-Kruna br. 35  
Post. Pregr. 933  
11000 Belgrad

**Title:** Standards Activities of Organizations in the United States

**Citation:** NTIS, PB85-106151, Prepared by Toth (R.B.) Associates, McLean, VA

**Content:** This directory is a guide to mandatory and voluntary standards activities in the United States at federal and state levels and by nongovernment (trade associations, technical and other professional societies). It supersedes the 1975 edition (NBS SP 417), *Directory of United States Standardization Activities* and, for the first time, includes standards distributors, libraries, and information centers, and union lists of standards repositories by regional areas. It also lists organizations that no longer develop standards or have become defunct since the previous directory was issued.

More than 750 current descriptive commentaries are formatted, with subject headings to facilitate access to specific information. The main sections cover nongovernment; federal government; state procurement offices; sources of standards documents and information; a subject index and related listings covering acronyms and initials, defunct bodies, and those organizations with name changes. Organizations have been included if they develop standards or contribute to the standardization process, whether voluntary or mandatory, or are sources of standards documents or information. An introductory section provides general information on federal (including military) standards activities, a list of 20 major nongovernment standards developers, some historical notes, and an overview of U.S. (national) standardization activities.

**Title:** Directory of International and Regional Organizations Conducting Standards-Related Activities

**Citation:** Maureen A. Breitenberg, Editor. Office of Product Standards Policy, National Bureau of Standards, Washington, DC 20234. April 1983.

**Content:** This directory contains information on 282 international and regional organizations that conduct standardization, certification, laboratory accreditation, or other standards-related activities. This volume describes their work in these areas, as well as the scope of each organization, national affiliations of members, U.S. participants, restrictions on membership. The availability of any standards in English is also noted.

This volume summarizes an effort by the National Bureau of Standards to obtain information relevant to monitoring U.S. participation in the many international organizations active in standardization. It is designed to serve the needs of federal agencies and standards writers for information on international and regional organizations involved in standardization and related activities. It may also be useful to manufacturers, engineers, purchasing agents, and others.

---

---

## APPENDIX III

### Methods For Testing Combustion Equipment Energy Efficiency

M.Sc. (Tech) Martti Flyktman  
M. Sc. (Tech) Heikki Oravainen

Domestic Fuel Laboratory

Jyvaskyla, Finland  
October 14, 1988

Project KPA7013/KPA3/02

#### ABSTRACT

In this report, efficiency testing methods for small size combustion equipment are discussed. This work is part of the IEA (International Energy Agency) activity, Voluntary Standards, under the Bioenergy Agreement. The aim of the activity is to collect, select, test, and disseminate key analytical methods for the thermochemical and biological conversion of biomass to fuels and chemicals.

The material used in this report has been collected from the literature and with the help of fellow researchers. In spite of that the material is limited and will be augmented in the future.

At first the theoretical background of efficiency determination and terms is discussed. After that the methods used in a few countries are dealt with. Finally some conclusions based on the work are presented.

It turned out that the need for standardized methods also for efficiency determination for biomass combustion equipment is essential. Available standards are basically developed for big lignite and coal fired boilers. Biomass boilers differ from those boilers and that is why problems occur in determination of radiant and convective heat losses and ash losses. The essential part of an efficiency determination is to obtain representative fuel samples. Very important is to develop sampling methods for biomass fuels. Terms used should also be standardized.

## CONTENTS

	<u>Page</u>
Foreword .....	III-3
1.0 Introduction .....	III-3
2.0 Theoretical Background for Measuring and Calculating Efficiencies of Heating Equipment .....	III-3
2.1 Determination of efficiency .....	III-3
2.2 Terms Used .....	III-5
2.2.1 Balance boundaries .....	III-5
2.2.2 Reference temperature .....	III-5
2.2.3 Definition of heating value .....	III-5
2.2.4 Definitions for efficiency .....	III-5
3.0 Determination Methods and Calculation of Efficiency in Different Countries .....	III-7
3.1 General .....	III-7
3.2 Fuel analysis .....	III-7
3.2.1 Sampling of fuel and ash .....	III-7
3.2.2 Laboratory analysis .....	III-8
3.3 Comparison of efficiency determination methods .....	III-8
3.3.1 Heating value .....	III-8
3.3.2 Small boilers and fireplaces .....	III-8
3.3.3 Bigger boilers .....	III-15
3.4 Accuracy demands in measurements .....	III-16
3.4.1 General .....	III-16
3.4.2 Measurements from water circulation .....	III-18
3.4.3 Measurements from flue gas .....	III-18
4.0 Conclusions .....	III-19
References .....	III-20
Other Literature .....	III-21
Appendix 1: List of standards .....	III-24
Appendix 2: List of persons, to whom the inquiry was sent .....	III-27

## FOREWORD

This work is a part of the International Energy Agency (IEA) Bioenergy Agreement, Biomass Conversion (Annex IV), Voluntary Standards Activity: Methods of Analysis of Biomass for Fuels and Chemicals. The aim of the activity is to assemble and develop methods for analysis of biomass and biomass products.

Countries carrying out the activity are Canada, Finland, New Zealand, USA, and in 1988, Italy. This special project of Finland is called: "Methods for testing efficiency of biomass combustion systems." The work is carried out in the Technical Research Centre of Finland, in the Domestic Fuel Laboratory. M.Sc (Tech) Veli Seppanen has worked as a project leader in the Domestic Fuel Laboratory. The work is carried out by M.Sc (Tech) Martti Flyktman and M.Sc (Tech) Heikki Oravainen.

In this report the methods of determination and calculation of heating efficiencies of fireplaces and boilers using biomass (including peat) as a fuel, are dealt with. The material of this report comes from literature and standards used in different countries.

### 1.0 INTRODUCTION

In this report, the methods of determination and testing of heating efficiencies of fireplaces and boilers, using biomass as a fuel, are dealt with. Peat is also taken as biomass. Combustion equipment has been separated into two categories: fireplaces and small boilers (under 120 kW) under small equipment; and district heating size boilers (1-30 MW) under bigger boilers.

Emissions of fireplaces and boilers are dealt with only if they have some effect on the efficiency (CO and fly ash emissions).

In different countries there has been found to be a problem with lack of methods good enough for testing and determination of heating efficiencies of combustion equipment using biomass fuel. This is caused by the fact that properties of biomass differ greatly from those of coal.

The methods of determination of efficiencies have been originally developed for big coal and lignite boilers. When using these methods, typical problems arise in determination of heat losses by radiation and convection and in determination of bottom ash and fly ash losses.

Because of unsteady-state burning in fireplaces, the determination of produced energy, and also the amount of flue gas losses, is difficult, which makes it difficult to measure the behavior of such combustion equipment and thus the calculation of thermal efficiency.

### 2.0 THEORETICAL BACKGROUND FOR DETERMINATION AND CALCULATION OF COMBUSTION EQUIPMENT EFFICIENCY

#### 2.1 The determination of efficiency

The efficiency of combustion equipment can be determined either by direct or by indirect methods. When using direct methods, the efficiency is determined as the ratio of produced energy to total energy fed to a process.

By using indirect methods, the efficiency is calculated using measured heat losses and produced energy. Heat losses can be separated into the following main parts:

- sensible enthalpy of flue gas
- reaction enthalpy of flue gas
- unburned fuel in grate ash and fly ash
- losses by radiation and convection
- other losses

The calculation of efficiency is based on material and energy balances made over certain balance limits. Balance limits must be the same for material and for energy balances. Table I shows the measurements that are needed to determine different energy losses.

**Table I. Measurements Needed in the Determination of the Efficiency of Combustion Equipment (1)**

---

Energy losses through sensible enthalpy and reaction enthalpy of flue gases

- flue gas temperature at the balance limit
- flue gas composition ( $O_2$ ,  $CO_2$ ,  $CO$ ,  $C_xH_y$ )
- temperature and moisture of combustion air
- fuel properties
- moisture content
- heating value
- ash content
- elemental analysis (C, H, N, O, S)
- temperature
- thermal output of the combustion equipment at the balance limit
- temperatures in the water circuit and water mass flow
- electric power of pumps, fans etc. inside the balance limit

Heat losses through unburnt fuel in grate ash and fly ash

- mass flow of grate ash or fly ash (usually fly ash)
- unburnt fuel in grate ash and in fly ash and its heating value
- temperatures of grate ash and fly ash

Heat losses through radiation and convection

- by estimating according to the standard or
  - by calculating according to surface areas and surface temperatures
-

## 2.2 Terms used

### 2.2.1 Balance limit

Balance limit is the closed surface through which material and energy flows are determined. In figure 1, the balance limit of a big pulverized coal fired boiler, according to the standard DIN 1942, is shown (2).

### 2.2.2 Reference temperature

Reference temperature is the temperature on the basis of which all input and output energy streams are calculated. Reference temperature affects the enthalpies of combustion air, flue gas and fuel and the heating value of fuel. Reference temperature is, in most standards and methods, 25°C. This temperature is equivalent to normal room temperature.

### 2.2.3 The definition of heating value

Higher heating value of a fuel refers to the amount of energy that is released by complete combustion of a fuel unit, when the water formed from the hydrogen in the fuel is condensed after combustion at the reference temperature.

Lower heating value of a fuel refers to the amount of energy that is released by complete combustion of a fuel unit when the water formed from the hydrogen in the fuel remains as vapor after combustion.

The effective heating value of a wet fuel refers to the heating value that has been calculated from the heating value of dry fuel (usually from lower heating value,  $H'_{\text{eff}}$ ) according to fuel moisture as follows:

$$H_{\text{eff}} = H'_{\text{eff}} (100-w)/100 - 0.0244 w, \text{ where} \quad (1)$$

$H'_{\text{eff}}$  is the lower heating value of dry fuel (MJ/kg), 2.44 MJ/kg is the heat of vaporization of water at 25°C and w is the moisture content of fuel on a wet basis (%).

### 2.2.4 Definitions of efficiency

#### Combustion efficiency

Combustion efficiency refers to the ratio of reacted fuel to the total possible reactive fuel. Combustion efficiency is not dependent on the flue gas temperature.

#### Boiler efficiency

Boiler efficiency refers to the ratio of energy supplied to the energy utilized. Energy utilized includes both fuel energy and sensible enthalpy of fuel, combustion air and ash and also electricity used inside the balance limit.

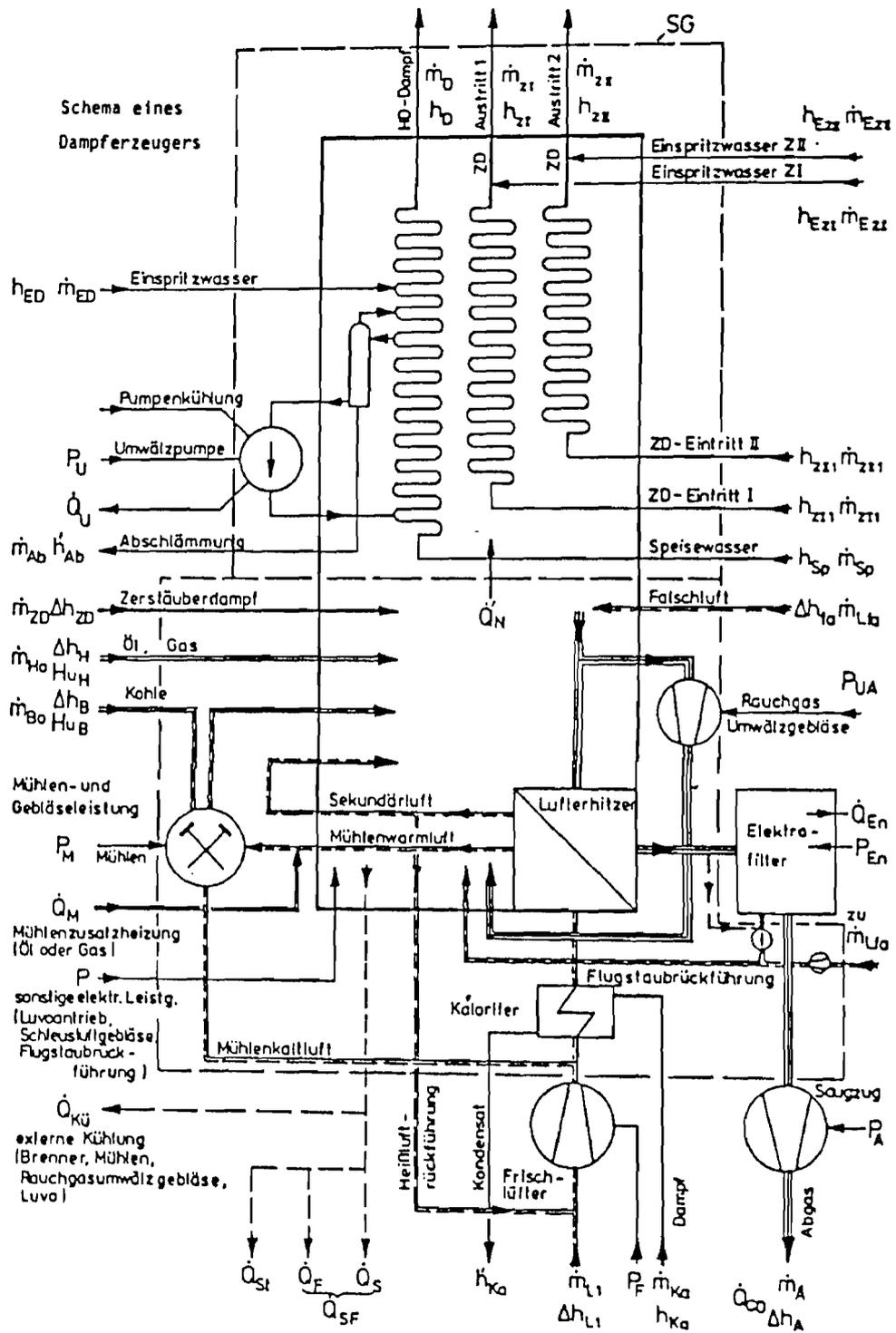


Fig 1. Balance limits of a big pulverized coal boiler according to German standard DIN 1942 (2).

## Annual efficiency

Annual efficiency refers to the ratio of energy transferred to boiler water or steam, to the energy fed to a boiler, calculated during a period of one year.

### **3.0 EFFICIENCY DETERMINATION METHODS USED IN DIFFERENT COUNTRIES AND THE CALCULATION OF EFFICIENCY**

#### **3.1 General**

The efficiency determination methods are either direct or indirect. The method used has been chosen mainly according to the heating rate of the combustion equipment and to the combustion process. The efficiency of big boilers is determined usually by indirect methods, because the accurate determination of fuel energy is difficult. The efficiency of fireplaces or small boilers is usually determined by direct methods.

These methods are used, because fuel consumption of small equipment is easy to determine by weight and because the heat losses are difficult to measure because of unsteady-state burning. The state of the fuel batch, heating rate, foud gas flow and combustion temperature are never in steady-state.

#### **3.2 Fuel analysis**

##### **3.2.1 Sampling of fuel and ash**

Because fuel properties vary widely, the method of fuel sampling has a great effect on the accuracy of efficiency determination. When the direct method is used, representative fuel sampling is even more important.

Standards used for fireplaces and small boilers often determine the properties of fuel used in the tests. When testing bigger biomass boilers, there are seldom standards available for fuel sampling. Separate methods are used, or coal sampling standards are adapted.

For example in Finland there are directions for fuel sampling for determination of fuel energy, but there are none suitable for use in efficiency testing. In the Finnish recommendation for biomass boiler guarantee tests, the following directions are given for fuel sampling:

- fuel samples must be taken at 15 minute intervals, as near as possible to the boiler, for example from the feeding hopper or from the conveyor feeding the boiler. Samples must be taken without making any selections and they must contain all material, for example fines, sticks and snow. Each sample of milled peat or wood chips must be at least 2 dm<sup>3</sup> and sod peat and bark samples must be at least 4 dm<sup>3</sup>. If the particle size distribution will be analyzed, a separate sample for sieving must be at at least 50 dm<sup>3</sup>.
- samples of grate ash and fly ash must be taken at at least 30 minute intervals. Samples must be combined in a collection sample from<sub>3</sub> which analysis will be made. The volume of a collection sample must be at least 2 dm<sup>3</sup>.

In efficiency tests, the particulates matter content in flue gases is measured to determine the heat loss by fly ash. When using biomass fuels, particle size distribution in flue gas is not uniform, which makes measurements more complicated than, for example, in big pulverized coal fired boilers. Flue gas can contain also quite large particles.

### 3.2.2 Laboratory analysis

There is a lack of uniform standards to determine biomass properties. In most countries, standards made for coal and lignite analysis are applied also for biomass analysis. To determine the efficiency of biomass combustion equipment, the following analyses must be carried out:

- heating value
- moisture content
- ash content
- elementary analysis (C, H, N, O, S)

To determine heat losses by grate ash and fly ash, unburn fuel in ash and/or the heating value of the ash must be analyzed.

As an example it can be mentioned that in efficiency calculations a term is used: volatile matter of ash. It is quite difficult to determine for biomass fuels, because combustion temperature affects quite a lot the analysis result.

In some countries moisture content is calculated on a wet basis, while some countries use the dry basis expression (5).

In elemental analysis of a fuel, the oxygen content is normally calculated by a difference:  $O_2 = 100 - C - H - N - S$ , because there is not an accurate method for direct analysis of fuel oxygen content. There is a list of fuel analysis standards in Appendix 1 (6).

## 3.3 Comparison of efficiency determination methods

### 3.3.1 Heating value

To determine the efficiency of combustion equipment, the heating value of a fuel must be known. As a heating value lower or higher heating value can be used. In Europe, lower heating value is normally used. In North-America, higher heating value is commonly used. The efficiency result depends on which heating value is used. The combustion product of fuel hydrogen can be taken as liquid water or as water vapor.

If the flue gas is cooled so much that water vapor condenses, the efficiency can be over 100% on a lower heating value basis. For example in Europe, the widely used standard DIN 1942 (3) uses lower heating value. The theoretically correct way would be to use the higher heating value. Then the efficiency is always lower than 100%.

### 3.3.2 Small boilers and fireplaces

In Finland a lot of work was done to develop small boilers and fireplaces using biomass fuels in the late 1970's and early 1980's. Then almost all small boilers were tested and also a Finnish standard testing method was developed (7 - 9). The testing method is explained in reference 7. A schematic diagram of the testing facility is shown in figure 2.

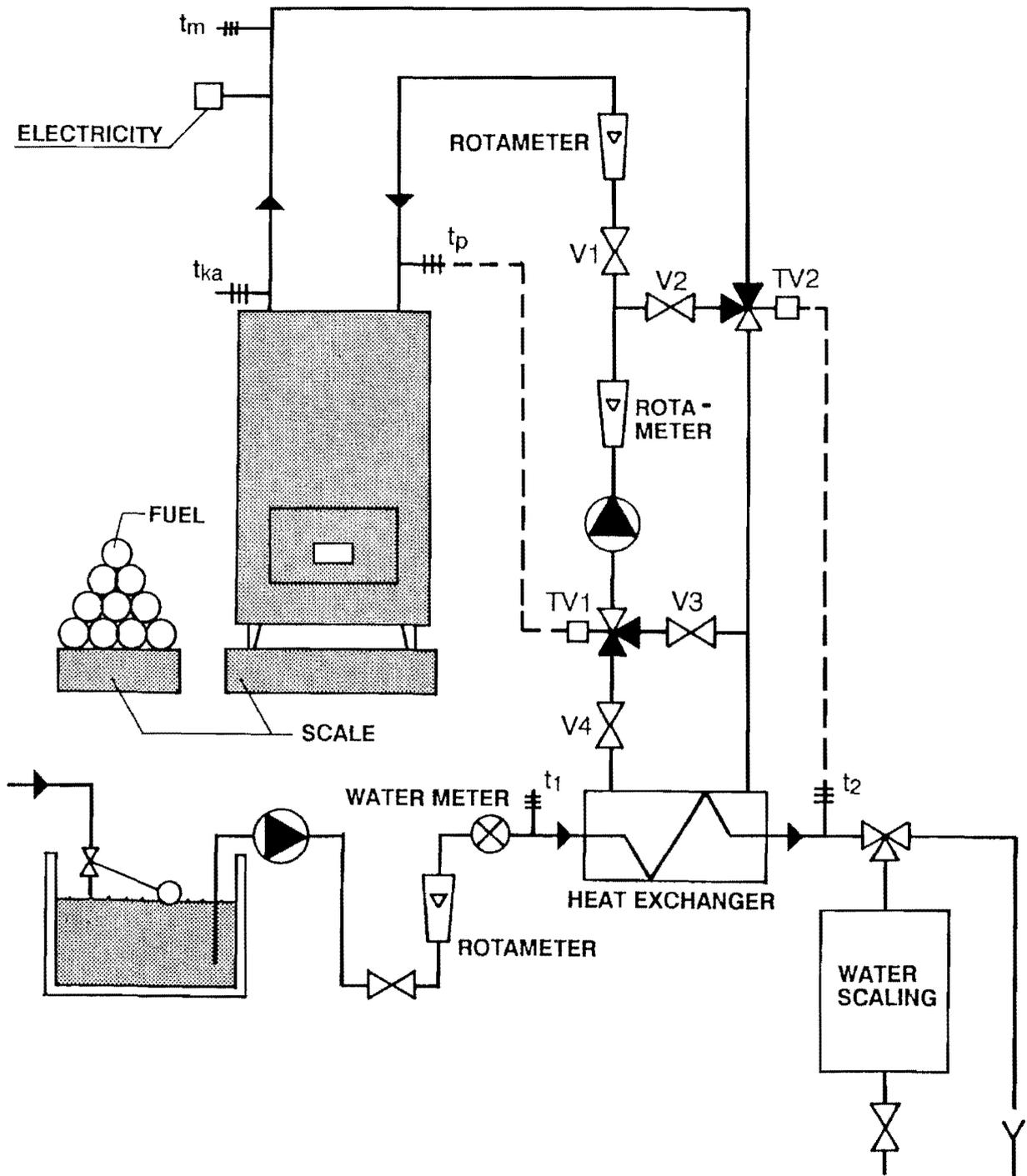


Fig 2. Efficiency testing facility for small biomass boilers (7).

The testing method is designed for small biomass boilers that have a maximum heating rate of 120 kW. The efficiency is determined by the direct method. The boiler is located on a scale by which the fuel consumption is followed. Also the properties of fuels are presented in the standard.

In Sweden and in Austria testing of small boilers has been carried out according to the German standard DIN 4702 (10 - 14).

The testing methods for fireplaces differ greatly in different countries. In efficiency determination, direct or indirect methods or a combination of those has been used. At the Technical University of Tampere (Finland), a calorimeter room for fireplace testing has been built (15). The schematic of the calorimeter room is shown in figure 3. The efficiency of fireplaces could be calculated when combustion efficiency and heat losses and cooling of the calorimeter room were measured.

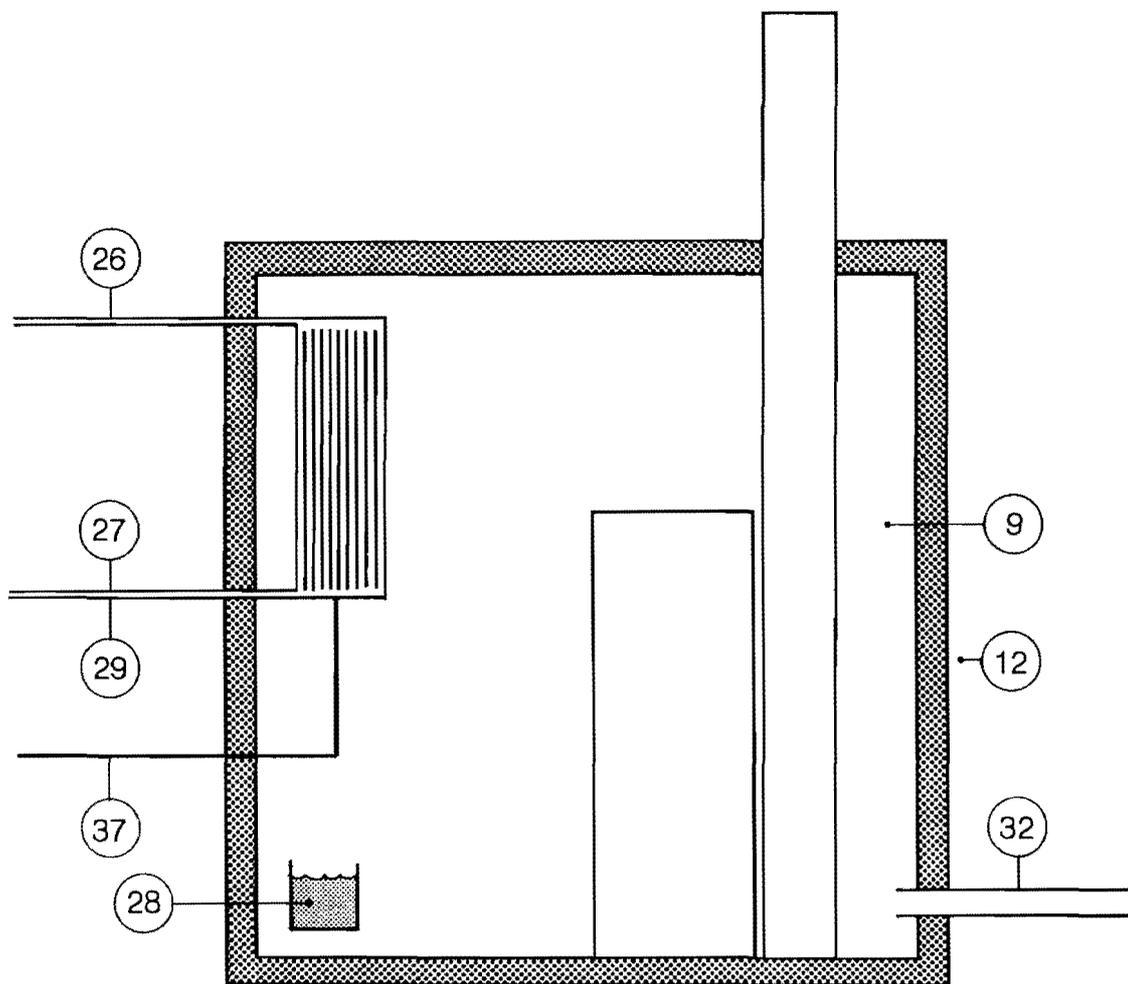
In the Technical Research Centre of Finland, Domestic Fuel Laboratory, small biomass boiler efficiency testing has been carried out usually by the so-called direct method. Fuel has been weighed, enthalpy of flue gas has been determined by measuring flue gas temperature and flue gas composition by continuous IR-analyses and grate ash has been analyzed in the laboratory. Boiler heat output has been measured. Heat losses by radiation and convection, and possible other heat losses, have been calculated by difference: total heat losses - (flue gas enthalpy + ash losses) (15).

At the University of Tasmania (Australia) a calorimeter room has been built where efficiency is determined by measuring flue gas losses and measuring direct heating of the calorimetric room. The cooling rate of the calorimetric room can be determined by measuring air mass flow and air temperature of the cooling system. The enthalpy of the combustion air is determined by temperature measurements. Also electricity consumption of the testing facility is measured (16).

The small boiler and fireplace testing standard of the Wood Heating Alliance (previously known as the Fireplace Institute) (USA) includes descriptions for open combustion chamber appliances and closed combustion chamber appliances. To test open chamber heating appliances, measurements are carried out in the calorimetric room, a schematic diagram of which is shown in figure 4(17). This test standard has been developed at Auburn University.

Air is recirculated between the inner and outer shell, which is cooled in the cooling coil. Air flowing to the calorimeter room for combustion is measured. To calculate results, at least the following measurements are needed:

1. mass flow of cooling water and input and output temperatures
2. temperature inside the calorimeter room
3. pressure difference between inlet to appliance and flue exit



**Measuring points:**

- 9      INSIDE TEMPERATURE
- 12     OUTSIDE TEMPERATURE
- 26, 27 TEMPERATURE OF THE COOLING WATER
- 28     REFERENCE TEMPERATURE (ICE-BATH)
- 29     WATER METER
- 32     COMBUSTION AIR FLOW
- 37     ELECTRICITY

Fig 3. Calorimeter room at the Technical University of Tampere Finland) (15).

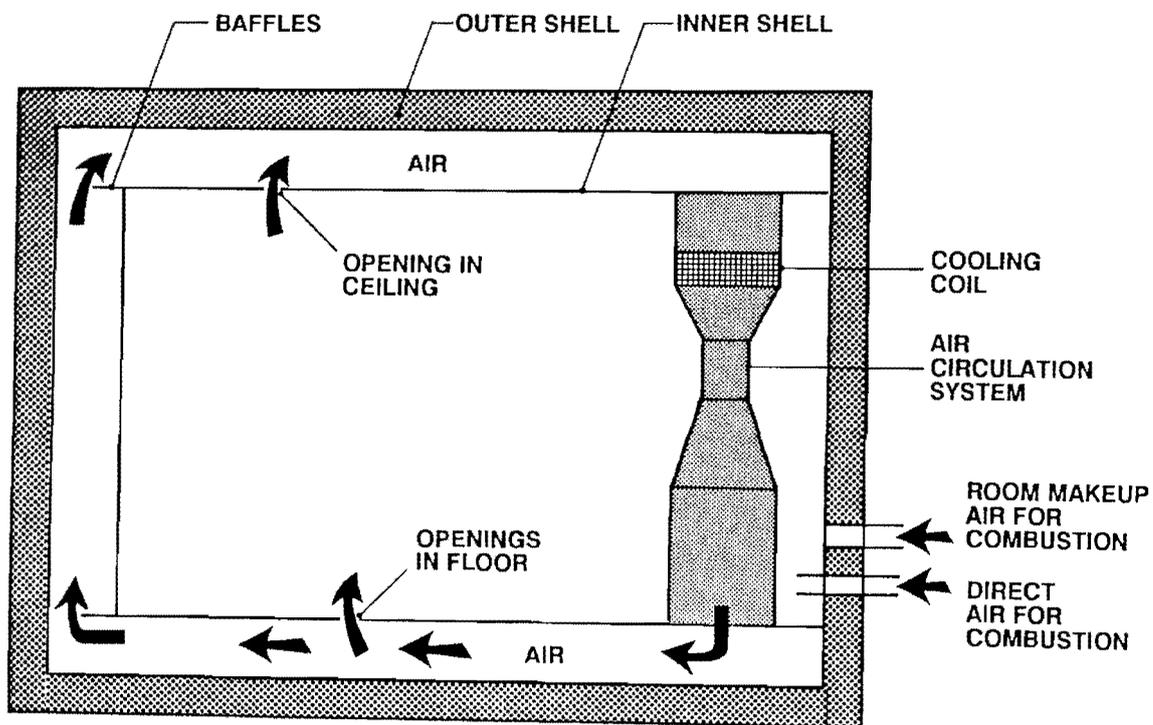


Fig 4. Schematic diagram of the calorimeter room used by Wood Heating Alliance (17).

4. the flow of air to the calorimeter room
5. power input to fans, lights, and other power consuming devices placed in the calorimeter room
6. weight of fuel

Heat loss of the calorimeter room is measured by an electric heater. Average heating capacity, energy efficiency, fuel burning rate and air flow rate for heating appliance are calculated from the measurement results.

Testing of closed chamber heating appliance is based on the indirect method. A schematic diagram of the testing facility is shown in figure 5 (18). Flue gas losses and ash loss are determined and on the basis of these values average power output and efficiency can be calculated. A more exact description of the testing method is in reference (5).

In Norway fireplaces and stoves have been tested by, among others, Forsvarets Forskningsinstitut (FFI) and Selskapet for industriell og teknisk forskning ved Norges Tekniske Hogskole (SINTEF). FFI has developed a unique continuous method for determining flue gas loss, that is based on continuous measurement of flue gas flow.

In the FFI laboratory a trace method has been adapted. A certain amount of some inert gas is mixed with the flue gas leaving a heating appliance. The concentration of this inert gas is then analyzed with a continuously working analyser. The flue gas flow can be calculated on the basis of trace concentration. In addition, the components of flue gas are analyzed continuously, so flue gas enthalpy can also be determined continuously.

Especially in batch combustion processes, like fireplaces and stoves, this method gives better accuracy for efficiency determination (15).

The German standard for small combustion equipment is presented in reference (19). Due to the standard, efficiency should be at least 70% and the flue gas temperature may not exceed 400°C.

Great Britain has a long tradition of burning different kind of coal product in small combustion equipment. Combustion equipment has exact standards for construction details. Efficiency tests cannot be started unless the equipment meets those standards. For every type of combustion equipment, standard fuels have been determined that must be used in tests. Tests have been selected on the basis of the following principles:

- the method must be repeatable and it has to be suitable to be carried out in every laboratory that has been instrumented for that purpose
- the method must describe the normal behavior of the combustion equipment

The efficiency of a boiler is determined normally using the indirect method in which flue gas losses are measured. The BCURA radiometer cage is used to measure direct radiative heat transfer.

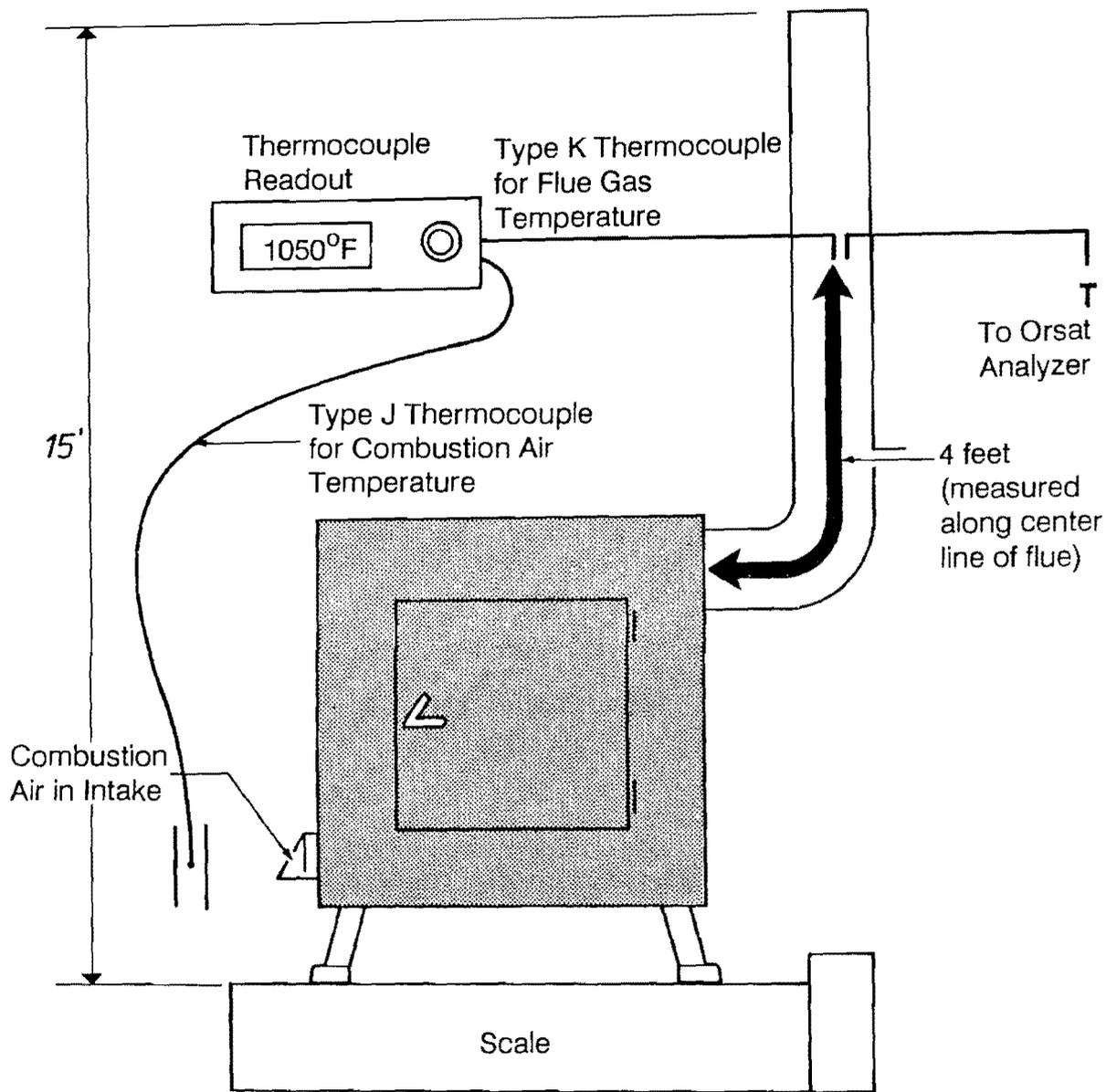


Fig 5. A schematic diagram of the closed combustion chamber testing facility (18).

The use of test standards developed for coal combustion caused problems with wood burning equipment, because the maximum heat output was much bigger than is needed in Great Britain. The burning of wood is much more batch-wise compared with steady burning, "smokeless" coals. That is why the determination of flue gas losses is difficult. For that reason, testing of wood burning heating equipment is made by the indirect method (20).

### 3.3.3 Large boilers

There is not a standard for determining efficiency of biomass boilers in many countries. Normally the standards developed for coal or lignite fired boilers are used.

In Finland the Finnish District Heating Association has drawn up the recommendation of approval tests for biomass boilers that have a heat output of 0,2 -10 MW. According to the recommendation, determination of efficiency should be carried out by applying the German standard DIN 4702. For bigger boilers DIN 1942 should be applied (4).

The above mentioned German standards are developed for determination of coal and lignite boiler efficiencies. In Austria, the German standard DIN 4702 is used for testing biomass boilers (21). Also standards used in Sweden and Norway are based on the DIN 4702, but there is a small difference in applying them (11,22).

The differences in applying DIN 4702 are in how certain heat losses and substance properties are calculated. The main differences are in determination of ash losses and heat losses by radiation and convection.

Heat loss by radiation and convection, in the Swedish recommendation, is calculated according to DIN 4702 as a function of boiler surface temperature and the temperature of the environment (11). In the Norwegian standard, heat loss by radiation and convection is assumed to be one percent of the nominal boiler output (22).

In the Finnish recommendation, heat loss by radiation and convection is calculated according to DIN 1942 using equations developed for brown coal/lignite boilers (4).

Unburnt fuel in fly ash and grate ash are determined in a laboratory from ash samples. Calculation methods differ in how the heating value of ash is taken into account.

In the Norwegian standard the heating value of unburnt fuel in the ash is assumed to be 33 MJ/kg, which corresponds nearly to the heating value of carbon (22). In the Swedish recommendation the value is 30 MJ/kg if the ash does not contain flying unburnt particles. If it contains so much unburnt fuel that heat losses are over 0,3%, the heating value of the ash must be determined (11).

According to the Finnish recommendation, the heating value of ash must be determined if the unburnt fuel in the ash is over 30% and power output of a boiler is over 2 MW. If the power output is less than 2 MW, the heating value of unburnt fuel in the ash is assumed to be 30 MJ/kg. In boilers, where sample taking of fly ash is impossible, the unburnt fuel in fly ash is assumed to be 30% and the heating value of the ash to be 9 MJ/kg (4).

In the Domestic Fuel Laboratory of the Technical Research Centre of Finland, the usual procedure is to determine both the unburnt fuel and the heating value of the ash. In figure 6 the correlation between heating value of ash and unburnt fuel in ash is shown for

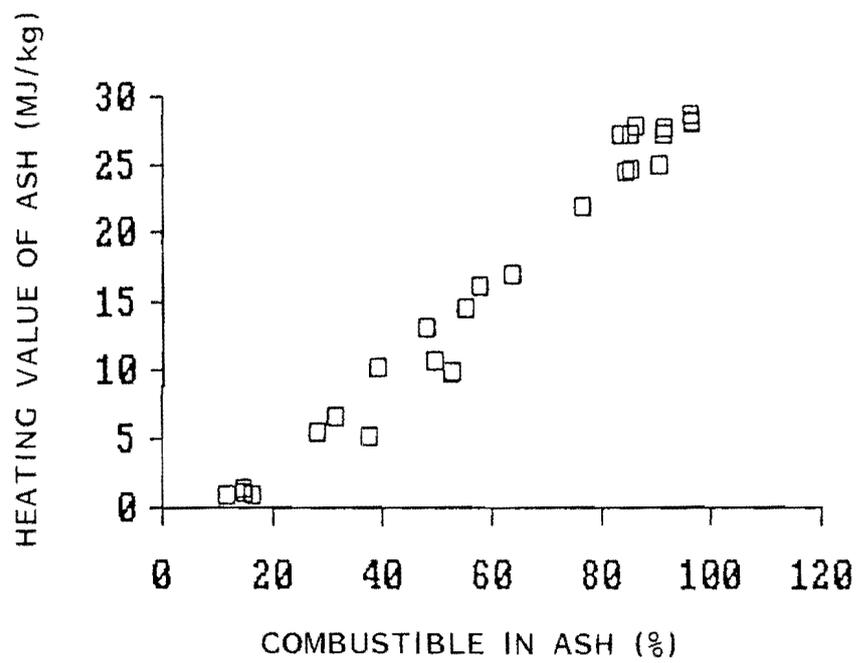


Fig 6. Correlation of heating value and unburnt fuel in ash for Finnish wood and peat fuels.

wood and peat fuel. In many standards, flue gas substance properties are read directly from nomograms.

A computer model for efficiency calculation based on the DIN 1942 standard has been developed in the Domestic Fuel Laboratory of VTT. The original standard is developed for large coal, lignite and oil-fired boilers. The standard must be modified when used for biomass boilers, because fuels and combustion methods cause significant process heat losses, which in big power plant boilers are usually small. The main activity in the VTT standard development was the determination of grate ash and fly ash losses. When grate ash and fly ash contain unburnt material (C, H, N and S), the theoretical amount of combustion air and the composition of the air do not correspond each other. If flue gas contains unburnt gases, the situation is the same.

Besides the normal mass- and energy balances, carbon balance was also included in the method. With this inclusion, grate ash and fly ash mass flows, and the energy losses through grate ash and fly ash, could be determined more accurately. For example the efficiency of a sod-peat fired grate boiler was 0.38 percent higher when calculated with this modified method. When wood chips were used in the same boiler, the efficiency was only 0.02 percent higher than when calculated according to the standard DIN 4702.

When mass balances were determined more accurately, it had very little effect on the boiler efficiency. More significant was the effect of volatiles in ash, both for the mass balances and for the efficiency. A new term was adopted, the "ash content of ash." When using this new method, the grate ash mass flow became 38% higher in the sod peat test and 17% higher in the wood chip test. Also the calculation of flue gas and combustion air enthalpy, and the reaction enthalpy of unburnt gases in the flue, were described more precisely.

### **3.4 Accuracy Requirements in Measurements**

#### **3.4.1 General**

In the recommendations for district heating plant measurements the following introductory remarks are given (4):

- during the tests, boiler output and boiler water temperature must be as standard as possible. If the temperatures differ at the beginning and at the end of the test, the heat capacity of the boiler must be taken into account when calculating the boiler output.
- The test period must be at least four hours. Before the test begins, the boiler must be operated at least one hour at standard conditions. Especially for boilers having pre-ovens or construction that has a lot of hot brickwork, the steady-state period before the test must be long enough.

- Measuring points must be located according to standards. This assures that measuring equipment measures the desired values. Pipe angles, mixing valves etc. cause disturbances to flow.

### 3.4.2 Measurements in the water circuit

#### Temperatures

According to the Finnish recommendation for district heating boilers (4), water- and fuel gas temperatures are measured with resistance temperature probes. Probes must be in accordance with DIN 43760 A-type Pt100 probes. Probes must be calibrated so that the temperature difference in the whole measuring range is, at the maximum, 0.2°C. In the water circuit, the distance before the mixing point in the flow must be at least 20 times the pipe diameter, according to the Finnish standard SFS 5059.

#### Water flow measurement

According to the Swedish recommendation (11) water flow in small boilers can be measured with the aid of pressure difference in the measuring pipe. Water meters must be calibrated to the right flow range and the measurement must be accurate to 0.5%. Water flow of big boilers shall be measured with a throttle probe, according to DIN 1952 or ISO R541.

### 3.4.3 Measurements in the flue

#### Flue gas temperature

In the Swedish recommendation (11) the measurement shall be accurate to 1 degree Kelvin. Temperature shall be measured at several places in the flue to get a precise measurement. In standards there is often the demand that flue gas temperature of small boilers shall not exceed 350°C or 400°C.

#### Flue gas analysis

Flue gas composition is measured from the flue, after the boiler, according to directions that are the same in many countries. Measurements shall be made before flue gas cleaner and blower to avoid air leakage (4).

The following flue gas components are continuously analyzed

- oxygen (O<sub>2</sub> %)
- carbon dioxide (CO<sub>2</sub> %)
- carbon monoxide (CO %)

Continuously analyzed emissions are:

- nitrogen oxides (NO<sub>x</sub> ppm)
- sulphur dioxide (SO<sub>2</sub> ppm)
- total hydrocarbons (C<sub>x</sub>H<sub>y</sub> ppm)

Flue gas analysers shall be calibrated with gases that are accurate to at least 1 %. Concentrations of calibration gases shall be in the measurement range. Particulate concentration in the flue gas stream is often measured when efficiency of the boiler is

determined. Methods are quite similar in many countries and are based on isokinetic sampling from the flue gas stream, with a probe.

#### 4.0 CONCLUSIONS

Efficiency testing methods were originally developed for large lignite and coal boilers. Biomass properties differ greatly from that of lignite and coal and boilers are often of different type. Typically biomass is used in smaller boilers and combustion equipment. Problems occur mostly in the determination of heat losses through radiation and convection. With small boilers, the significance of these losses is greater.

Biomass can be very inhomogeneous. The moisture content and ash content of fuel can vary greatly. The determination of boiler efficiency is based on knowledge of fuel properties. That is why the sampling for laboratory analysis is very important. The development of fuel sampling protocols and the development of standards is very important also for the development of efficiency determination standards. Also the fuel analysis methods are based on the standards developed for coal analysis. Methods should be developed taking into account the specific properties of biomass fuels.

Special attention should be paid to precise measurements and accuracy. Standards should be developed for measuring methods and accuracy. Methods should be simpler for small boilers so that test prices would not become too high.

The efficiency calculation methods are facilitated today through the use of personal computers. Very complicated calculations can be carried out quickly. The standardization of efficiency determination methods is technically quite easy.

In Europe, the determination of boiler efficiency is commonly based on the lower heating value. Efficiencies over 100% are possible if water in the flue gas is condensed. Of course the efficiency of over 100% is not theoretically correct. In many countries, for example, in the USA, the calculation is based on the higher heating value of the fuel. The efficiency is the lower, but never over 100%. The standardization of methods is necessary. The use of SI-units would also clarify the situation.

## REFERENCES

1. Huotari, J. Laitosmittaukset ja hyötysuhteen parantaminen. Jyväskylä 1984. Kunnallisliitto, "Kotimaista polttoainetta käyttävien aluelämpölaitosten teknistaloudellinen kehittäminen". 24 s.
2. Din 1942 Abnahmeversuche an Dampferzeugern. (VDI-Dampferzeugerregeln). Düsseldorf 1979. VDI-Verlag, 36 s.
3. Brandt, F. Erläuterungen zu den "Abnahme versuchen an Dampferzeugern" DIN 1942 (Ausgabe 1975), Fortschritt-Berichte der VDI Zeitschriften, Düsseldorf 1976. Reihe 6, Nr 46, VDI Verlag.
4. Lämpölaitosyhdistys ry. Kotimaista polttoainetta käyttävien 0.2 - 10 MW:n kattiloiden vastaanottokokeet. Helsinki 1987. Suositus H6/1987. 22 s. + liitt.
5. ANSI/ASHRAE Standard 106-1984. Method of testing for performance rating of woodburning appliances. Atlanta 1984. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. 14 p.
6. Impola, R. Kallio, M., Pirkonen, P. Peat classification and standards. Helsinki 1986. International energy agency. Programme of research, development and demonstration on peat production and utilization. Report No. 5. 94 p + liitt.
7. Ketola, T., Siltanen, T. Tuominen, T. Kiinteillä polttoaineilla käytettävien pienkattiloiden testausmenetelmä. Helsinki 1981. Valtion teknillinen tutkimuskeskus. Tutkimuksia 42/1981. 20 s + liitt. 10 s.
8. Ketola, T. Kotimaisten polttoaineiden pienkattiloiden testausmenetelmä. LVI (1981) 9, s. 54-56.
9. Siltanen, T. Kiinteiden polttoaineiden käyttö pientaloissa. LVI (1981) 9, s. 57 - 61.
10. Din 4702 Heizkessel. Prüfregelein (1967). Berlin and Köln 1967. Beuth-Vertrieb BmbH. 12 s.
11. Schuster, R., Wester, L. Förslag till provisoriska provningsregler för fastbränsleeldade pannanläggningar mindre än 10 MW från miljövårdssynpunkter. Stockholm 1983. Statens Naturvårdsverket Rapport snv pm 1668. 52 s. + liitt.
12. Prüfbericht. Akt ZI. : 190/84, Prot.Nr.:133/84. Gruppe:14e. Bundesanstalt für Landtechnik Wieselburg/Erlauf, Österreich.
13. Manfred Wörgetter. Test methods of wood combustion systems up to 120 kW-Experiences of Bli-Wieselburg. Finnish-Austrian Workshop on Energy from Wood 14-16 November 1983 at Vienna.
14. Sundström, L, Sönsteröd, G. Effektivitetsprovning av vedeldade kaminer, spisar och öppna spisar med resultat från 10 provningar. Borås 1981. Statens Provningsanstalt. Teknisk rapport SP-RAPP 1981:19. s. 75.
15. Oravainen, H., Takkojen ja tulisijojen tutkimusmenetelmät. Loppuraportti. Esitutkimus. Jyväskylä 1986. Julkaisematon raportti. 25 s.

16. Fittas, A. C. & Sikorski, W. B. Design of a testing laboratory for wood stoves. Proc. of the Conference Bio-Energy '84. Gothenburg 1984. Vol. IV. p. 40-45.
17. Test standards for rating wood-fired, open combustion- chamber, heating appliances. Chicago 1979. Fireplace Institute. 20 p.
18. Test standards for rating wood-fired, closed combustion-chamber, heating appliances. Chicago 1979. Fireplace Institute. 20 p.
19. Din 18890. Dauerbrandöfen für feste brennstoffe. Berlin and Köln 1971. Beuth-Vertrieb GmbH. 10 p.
20. Kaye, W. G. UK standards for testing and approval of solid fuel burning appliances. Novotel, Hammersmith, London 1985. Real Fire Heating International 1985, manufacturers seminar. 9 p. + liitt. 12 p.
21. Manfred Wörgetter. Test results of biomass fired boilers for central heating. FAO/CNRE. First technical consultation of the CNRE on biomass conversion for energy. Freising (Germany), 14-17 October 1985.
22. Beregning av virkningsgrad. Kjelforening Norsk Energi.

#### OTHER LITERATURE

23. Norsk Standard NS 4861, NS 4862, NS 4863. Norges Standardiseringsforbund (NSF). 1985.
24. Asplund, F. Correct determination of efficiency with special reference to small boilers. Stockholm 1985. Styrelsen för teknisk utveckling. Energy informaion NO. 447 - 1985. 44 p.
25. Vuorelainen, O. Savukaasuh äviöiden laskenta täydellissa ja epätäydellisessä palamisessa. Helsinki 1961. Valtion teknillinen tutkimuslaitos, Tiedotus. Sarja III-Rakennus. 53. Pienpuualan toimikunnan julkaisu 133. 41 p.
26. Svedberg, G. Rökgaskondensering. Kungliga Tekniska Högslan. Institut for värmeteknik. p. 84-96.
27. Lämpölaitosyhdistys ry. Kotimaista polttoainetta käyttävien 1-10 MW:n kattilalaitosten tekniset ratkaisut. Helsinki 1985. Suositus HI/1985. 37 s. + liitt.
28. ANSI Z21.13-1982. American National Standard for Gas-fired low-pressure steam and hot water boilers. 83 p.
29. Cooke, W. M., Piispanen, W. H., Wensty, A. R., Levy, A. Barnes, R. H., Cormaby, B. W., Degner, K. B. Candidate sampling and analysis methods for 21 suspect carcinogens in combustion emissions. Columbus 1984. EPA project summary, Research and development EPA-600/S7-84-078 Sept. 1984.
30. Dikke, R. D. DOE/NBS Forum on testing and rating procedures for consumer products.

31. Esplin, G. J., Fung, D. P. C., Hue, C. C. Development of sampling and analytical procedures for biomass gasifiers. *The Canadian journal of chemical engineering* 63 (1985) 12. p. 946-953.
32. McDonald, E. C., Aiken, M., Development of analytical methodology for biomass gasification products. Vancouver 1983. Enfor Project C-172. Final Report. 29 p.
33. Milne, T. A. Proceedings workshop on standards in biomass for energy and chemicals. National Bureau of Standards Gaithersburg, Maryland 1-3 August 1984. 78 p.
34. Dyer, D. F., Maxwell, T. T., Maples, G. Improving the efficiency, safety and utility of wood burning units. DOE technology for consumer reports branch. Contract No. DE-As05-77ET11288. October 1980.
35. Maxwell, T. T., Maples, G., Pruitt, T. M., Dyer, D. F., Wood burning handbook. Design handbook for residential woodburning equipment. Prepared for Department of Energy, Washington, D.C., DE-AS-5-77ET11288. Auburn University, Auburn, Alabama, June 1981.
36. Harris, J. S., Larsen, D. J., Rechsteiner, C. E., Thrun, C. E. Combustion of hazardous wastes, sampling and analysis methods. Cambridge, Massachusetts 1983. Noyes Data Corp.
37. Valtion teknillinen tutkimuskeskus, Valtion maatalouskoneiden tutkimuslaitos. Kotimaista polttoainetta käyttävien pienkattoloiden testaustuloksia. Helsinki 1982. Kauppa- ja teollisuusministeriö Energiaosasto. 11 s. + liitt.
38. Polcyn, A. J., Hesketh, H. E. A review of current sampling and analytical methods for assessing toxic and hazardous organic emissions from stationary sources. *Journal of the Air Pollution Control Association* 35 (1985) 1 p. 54-60.
39. Stack emission standards for industrial wood fired boilers. Northeast regional biomass program. West Chester, PA: Roy F. Weston Co.
40. Particulate emissions from residential wood combustion. Northeast regional biomass program. West Chester, PA: Roy F. Weston Co.
41. Burnett, P. G. The northeast cooperative woodstove study. Volume I. Springfield 1987. United States Environmental Protection Agency. EPA Research and Development Publication No. EPA-600/7-87-026a.
42. Burnett, P. G. Northeast cooperative woodstove study. Volume II. Technical Appendix. Oregon 1987. United States Environmental Protection Agency. EPA Research and Development. EPA-600/7-87-026b.
43. Combustion and emission research on wood-refuse boilers. Volume II. Description of program and common methods. Ottawa 1984. Bioenergy Development Program, Renewable Energy Branch, Energy, Mines and Resources Canada. 50 p. + liitt.
44. Ofenwirkungsgrad. *Klima und Raum*. 54 (1986) 3 s. 15-16.
45. Mitchell, W. J., Bruffey, C. L. Effect of sampling temperature, filter material and sample treatment on combustion source emission test results. *Environ. Sci. Technol.* (1984) 18 p. 803-808.

46. Stanzel, W., Hack, R., et al. Begleitendes messprogramm fuer die holzheizungsanlage der waldbauerschule pichl. Institut für Umweltforschung. Projekt Nr.: 318/U84128. Graz. October 1986. p. 217.
47. Pitkäkangas, J., Rätty, M. Pyrolyysitekniiikan käyttö kotimaisten polttoaineiden lämpökeskuksissa: Kokemuksia poltto-tekniikan muutoksen vaikutuksista. Esitutkimus. Kiuruvesi 1987. Projekt; Rno 25/881/86 KTM 13.3.1986. 32 p.

.

## Appendix I

Representative standard methods for the determination of fuel properties of biomass

### 1. DEFINITIONS AND INTRODUCTION

ASTM D 121-78

Standard definitions of terms relating to coal and coke.

DIN 51700 (1967)

Prüfung fester Brennstoffe - Allgemeines und übersicht über Untersuchungsverfahren.

SS 18 71 06 (1984)

Biobränslen - Terminologi for vissa biobränslen.

SS 18 71 73 (1984)

Biobränslen - Omräkning av analys resultat till olika provtillstånd.

ISO 1170-1977

Coal and coke - Calculation of analyses to different bases

GOST 13674-68

Peat products - Rules for quality inspection

### 2. DETERMINATION OF MOISTURE CONTENT

#### 2.1 Peat

ASTM D2974-71 (1980). Standard test methods for moisture, ash, and organic matter of peat materials.

B.S 4156:1967

British standard specification for peat. Method for the determination of moisture content.

GOST 11305-65

Method of determination of moisture content.

GOST 7302-73

Method of rapid determination of moisture content and ash content.

SS 18 71 70 (1984)

Biobränslen - Bestämning av torr halt och fukthalt.

#### 2.2 Other solid fuels

ASTM D3302-74 (1980)

Standard test method for total moisture in coal.

ASTM D3173-73 (1979)

Standard test method for moisture, in the analysis sample of coal and coke.

- ASTM D2961-79  
Standard test method for total moisture in coal reduced to no. 8 top sieve size.
- DIN 51718 (1978)  
Feste Brennstoffe-Bestimmung des Wassergehaltiges.
- ISO 589-1981 (E)  
Hard coal - Determination of total moisture.
- ISO 331-1975 (E)  
Coal - Determination of moisture in analysis sample - Direct gravimetric method.
- ISO 348-1974 (E)  
Coal - Determination of moisture in analysis sample - Distillation method.
- ISO 687  
Coke - Determination of moisture in analysis sample.
- ISO 1015-1975 (E)  
Brown coal - Determination of moisture content.

### **3. ASH CONTENT**

#### **3.1 Peat**

- ASTM D 2974-71 (1980).  
Standard test methods for moisture, ash, and organic matter of peat materials.
- B.s 4156:1967  
British standard specification for peat. Method for the determination of ash content.
- GOST 11306-65  
Peat - Method of determination of ash content.
- SS 18 71 70 (1984)  
Biobränslen - Bestämning av ask halt.

#### **3.2 Other solid fuels**

- DIN 51719 (1978)  
Prüfung fester Brennstoffe - Bestimmung des Aschegehaltes.
- ASTM D 2974-71 (1980)  
Standard test method for ash in the analysis sample of coal and coke.
- ISO 1171-1981 (E)  
Solid mineral fuels - Determination of ash

## 4. HEATING VALUE

### 4.1 Peat

SS 18 71 72 (1984)

Biobränslen - Bestämning av kalorimetriskt värme-värde och beräkning av effektivt värmevärde.

GOST 147-64

Brown coals, anthracite, oil shales, peat and briquettes - Method for the determination of calorific value.

### 4.2 Other solid fuels

DIN 51900 (1977)

Prüfung fester und Flüssiger Brennstoffe, Bestimmung des Brennwertes mit dem Bombenkalorimeter und Berechnung des Heizwertes.

ISO 1928-1976 (E)

Solid mineral fuels - Determination of gross calorific value by the calorimetric bomb method, and calculation of net calorific value.

ASTM D 2015-77 (1978)

Standard test method for gross calorific value of solid fuel by adiabatic bomb calorimeter.

ASTM D 3286-77

Standard test method for gross calorific value of solid fuel by the isothermal jacket bomb calorimeter.

## Appendix 2

An inquiry about standard methods available was sent to the following persons:

Prof. N. N. Bakhshi  
Dept. of Chem. Engineering  
University of Saskatchewan  
Saskatoon S7N 0W0, CANADA

Dr. Christel Benestad  
Center for Industrial Research  
P.O. Box 124, Blindern  
0314 Oslo 3, Norway

Dr. Peter Benson  
Renewable Energy Systems, Inc.  
12115 So. 87th Avenue  
Palos Park, IL 60464, USA

Dr. Paul Blankenhorn  
School of Forest Resources  
Penn. State University  
University Park, Pa 16802, USA

Orif, Davud Boocock  
University of Toronto  
200 College St. Toronto  
Ontario M5S 1A4, Canada

Dr. Tony Bridgwater  
The University of Aston  
Gosta Green  
Birmingham B4 7ET, ENGLAND

Dr. Tom Clark  
Forest Research Institute  
Private Bag Rotorua  
New Zealand

Dr. Janet H. Cushman  
Oak Ridge National Lab  
MS 352, P.O. Box X  
Oak Ridge, TN 37830, USA

Dr. Bruce E. Dale  
Dept. of Agric. and Chem. Eng.  
Colorado State University  
Fort Collins, CO 80523 USA

Dr. Robert F. H. Dekker  
CSIRO, Div. of Chem. and Wood  
Private Bag 10, Clayton  
3168 Victoria, AUSTRALIA

Dr. T. Funazukuri  
Dept. of Chemical Eng.  
Yokohama National University  
Tokiwadai, Yokohama 240, JAPAN

Dr. M. H. Rei  
Department of Chemical Eng.  
National Taiwan University  
Taipei 10764, TAIWAN

Statens provningsanstalt  
Eddie Åkesson  
P.O. Box 857  
50115 BORAS, SVERIGE

KTH  
Dept. of Heat and Furnace Tech  
S - 100 44 Stockholm  
SVERIGE

Studvik Energiteknik Ab  
Niklas Berge  
S - 611 82  
Nykoping, SVERIGE

Statens Naturvardsverk  
Leif Bernergard  
P.O. Box 1302  
S - 171 25 Solna, SVERIGE

Ugnsgruppen AB  
Lars-Erik Eriksson  
Bygelvagen 20  
722 33 Vasteras, SVERIGE

Dr. Xavier Deglise  
E SSTIB-Universite de Nancy I  
BP 239, 54506 Vandoeuvre  
les Nancy Cedex, FRANCE

Dr. Eugene Domalski  
National Bureau of Standards  
Gaithersburg, MD 20899  
USA

Dr. Hooshang Pakdel  
Dept. of Chemical Eng.  
Laval University, Ste-Foy,  
Quebec G1K 7P4, CANADA

Dr. Herbert L. Retcofsky  
Division of Coal Science  
Pittsburgh Energy Tech. Center  
P.O. Box 10940, Pittsburgh PA 15236  
USA

Professor Geoffrey Richards  
Wood Chemistry Laboratory  
University of Montana  
Missoula, MT 59816, USA

Professor Donald S. Scott  
Dept. of Chemical Engineering  
University of Waterloo  
Waterloo, Ontario N2L 3G1, CANADA

Alexis C. Pittas  
University of Tasmania  
P.O. Box 252C, G.P.O.  
Hobart, 7005, AUSTRALIA

Fireplace Institute  
111 East Wacker Drive  
Chicago, Illinois 80801  
USA

Wood Heating Alliance  
1101 Connecticut Avenue  
Suite 700  
Washington, D.C. 20036, USA

Electric Power Research Institute  
Don augenstein  
3412 Hillview Avenue  
Palo Alto, CA 94303, USA

George T. Tsao  
Lab. of Ren. Resource Eng.  
Purdue University  
West Lafayette, IN 47907, USA

Lawrence Hudson  
New York State ERDA  
Two Rockefeller Plaza  
Albany, NY 12223 USA

Jim Fisher  
Fiber Fuel Institute  
310 Cedar Street, Suite 400  
St. Paul, MN 55101 USA

Douglas C. Elliot  
Battelle-Pacific Northwest Lab  
P.O. Box 999  
Richland, WA 99352 USA

Dave Keenan  
National Wood Energy Association  
P.O. Box 4548  
Portsmouth, NH 03801 USA

William Newby  
Canadian Boiler Society  
4786 Queen Street, Niagara Falls  
Ontario L2E 2N3 CANADA

Jim Walsh  
Eng. Experiment Station  
Georgia Inst. of Technology  
Atlanta, GA 30332 USA

Ralph Overend Division of Energy R&D  
National Research Council of Canada  
Building M-55 Montreal Road Ottawa,  
Ontario K1A 0R6  
CANADA

Sam Ghosh  
Institute of Gas Technology  
3424 South State Street  
ITT Center  
Chicago, IL 60616 USA

William Bryan  
USDA  
Southern Agric. Energy Center  
Tifton, GA 31794 USA

B. H. Levelton and Associates, Ltd.  
8805 Osler Street  
Vancouver, B.C.  
V6P 4G1 CANADA

## APPENDIX IV

### Round-Robin Tests

An integral part of the IEA Voluntary Standards activity has been the planning and execution of round-robin tests of particularly critical methods. At the Working Group meeting in Denver in 1987, each of three subpanels made recommendations for initiation, or continuation, of round-robin testing.

#### Biochemical Panel of the Standards Working Group

This group laid plans to complete a round-robin assay of enzymatic hydrolysis of a pure cellulose, using common enzymes and cellulose and an assay procedure developed by Hermann Esterbauer (1). In addition, a common protein (bovine serum albumin - BSA) was distributed by Karel Grohmann (2) so that each laboratory could analyze the enzymes and BSA by the methods they normally use. The general plan and progress have been described by Barbel Hahn-Hagerdahl (3).

This round-robin is an augmentation of efforts begun several years ago by another IEA activity (CPD), and is continuing largely under the new IEA activity in bioconversion led by Jack Saddler (4). The enzymatic hydrolysis results from some ten laboratories are being submitted to the journal *Biomass* (5).

#### Thermochemical Panel of the Standards Working Group

This panel recommended a round-robin test of pyrolysis/liquefaction oils for moisture and ultimate analysis (with direct oxygen determination when possible), using the methods ordinarily used in each laboratory. This round-robin is being coordinated by Jim McKinley (6), Ralph Overend, and Doug Elliott.

Two samples of pyrolysis/liquefaction oils from wood were distributed to participating laboratories in October 1988.

Sample 1 was a Waterloo Fast Pyrolysis process oil.

Sample 2 was a PERC process oil from the U.S. Department of Energy's Biomass Liquefaction Experimental Facility.

The samples have been analyzed by the procedures normally used in the participant's laboratory. The results are compiled, and a report will be published after all the information is received.

Fifteen laboratories from five countries participated. The results were presented in a poster session at the Seventh Canadian Bioenergy R&D Seminar in Ottawa, Ontario in April 1989.

#### Feedstocks Panel of the Standards Working Group

This panel elected to test a new protocol for analyzing both woody and herbaceous species (7).

The feedstocks analysis comparison is being coordinated by Olof Theander (Swedish Agricultural University) and Helena Chum (SERI). Theander is finalizing his protocol, and samples will be available from the Office of Standard Reference Materials of NIST

(*Pinus radiata*, *Populus deltoides*, bagasse, and wheat straw). A fifth sample, sweet sorghum, was recommended for testing. However, frozen and forced-air dried samples of freshly harvested samples supplied by Jerry Cherney of Purdue University (as part of Janet Cushman's herbaceous species program at ORNL), were analyzed by Lundgren and Theander at Uppsala. The results showed such great losses of some carbohydrates on drying that the utility of maintaining a dried reference sorghum is questionable. As soon as materials and protocols for these round-robins are finalized, a solicitation of cooperating laboratories will be made.

Please contact T. A. Milne if you wish to participate in any of the round-robin tests.

#### Notes to Appendix IV

- (1) Esterbauer, H., University of Graz, Graz, Austria.
- (2) Grohmann, K. Bioconversion Research Branch, Solar Energy Research Institute, 1617 Cole Boulevard, Golden, CO 80401.
- (3) Hahn-Hagerdahl, B. University of Lund, Sweden.
- (4) Saddler, J. Forintek Canada, Ottawa, Ontario, Canada
- (5) Esterbauer, H., W. Steiner, and W. Sattler. (1989). "The Results of a Round Robin Test for the Evaluation of the Enzymatic Digestibility." Submitted to *Biomass*.
- (6) McKinley, J. BC Research, 3650 Wesbrook Mall, Vancouver, BC V6J 2L2, Canada.
- (7) Theander, O. University of Agricultural Science, Uppsala, Sweden.
- (8) Milne, T. A. (1989). "Voluntary Standards for Biomass for Fuels and Chemicals." Final Report to the IEA for 1986-1988. To be published in *Biomass*, together with other IEA Task activity reports.

## APPENDIX V

### Reference Biomass Materials

There exist few, if any, publically available standard reference materials (SRMs) representing major biomass feedstocks (1). The National Institute of Standards and Technology's (NIST) Office of Standard Reference Materials (OSRM) maintains a few SRMs of plant materials, but these are inorganic trace materials (2). TAPPI formerly had some standard pulps, but these are no longer available. Individual government programs and laboratories have maintained supplies of wood chips or powdered wood for their own analytical use and for use by their subcontractors (e.g., National Research Council of Canada; Energy, Mines and Resources Canada; Forest Products Research Laboratory of the U.S. Department of Agriculture). However, these are not generally available.

It has been a goal of the IEA activity, and was a major recommendation of the voluntary standards working group (3), that a bare minimum of typical biomass materials be obtained and made available for round-robin tests and analytical quality control. The materials recommended were *Pinus radiata* (without bark), *Populus deltoides* (with bark), wheat straw, sugarcane bagasse, and sweet sorghum. (Subsequent tests of sweet sorghum showed such alteration on drying that it has been dropped from the list as impractical to maintain in a representative form for several years).

Negotiations have been completed with NIST-OSRM to prepare, package, maintain, list, and sell 50-gm lots of these materials (sealed in 10-gm mylar-sealed packets). It is planned that these will be available for the round-robin testing discussed in Appendix IV and for use by many laboratories in both analytical method testing and small-scale conversion tests. As studies are made on these materials, a data base on their varied properties will emerge and can be reported in the future.

### References

- 1) Milne, T. A., editor. *Proceedings: Workshop on Standards in Biomass for Energy and Chemicals*. SERI/CP-234-2506. Golden, CO: Solar Energy Research Institute. November, 1984.
- 2) Seward, R. W., editor. *NBS Standard Reference Materials Catalog 1988-89*. NBS Special Publication 260. Gaithersburg, MD: National Institute of Standards and Technology. January, 1988. (Samples of citrus leaves, tomato leaves, pine needles, corn stalks and corn kernels, certified for a large number of organic elements, are available.)
- 3) Milne, T. A. *Methods of Analysis of Biomass for Fuels and Chemicals*, Annual Progress Report for Energy, Mines and Resources of Canada. SERI-RR-3330. Golden, CO: Solar Energy Research Institute. April, 1988.

## APPENDIX VI

### Other Sources of Information

Considering the nascent state of much of the new industry using biomass for fuels and chemicals, and considering the explosive growth in new analysis methods and techniques, many of the methods of analysis are emerging from the literature or meetings and are not yet codified. This short appendix lists some of the meetings, journals, and miscellaneous sources of analytical information at the frontiers.

#### MEETINGS

Among the largest gatherings on analytical methods and instrumentation is the so-called "Pittsburgh Conference and Exposition on Analytical Chemistry and Applied Spectrometry." This conference is now held in various U.S. cities, the 40th being in Atlanta in 1989. Contact: Pittsburgh Conference, 12 Federal Drive, Suite 322, Pittsburgh, PA 15235.

The Association of Official Analytical Chemists also holds annual meetings covering areas of interest to biofuels and chemicals. The 103rd Annual International Meeting and Exposition was held in 1989. Contact: Meeting Department, AOAC, 1111 North 19th Street, Suite 210, Arlington, VA 22209.

The Federation of Analytical Chemistry and Spectroscopy Societies held its 16th annual meeting in 1989. Contact: FACSS, c/o Dr. Edward G. Brame, Jr., 13 N. Cliffe Dr., Wilmington, DE 19809.

Two regional meeting series of international scope are the Eastern Analytical Symposium and the Rocky Mountain Conference on Analytical Chemistry. The former holds its 28th annual meeting in 1989 (Contact: Eastern Analytical Symposium, P.O. Box 633, Montchanin, DE 19710) and the latter its 31st in Denver in 1989 (Contact: Rocky Mountain Conference on Analytical Chemistry, c/o Carol Gies, 2155 W. 144th Avenue, Broomfield, CO 80020).

The American Chemical Society holds national meetings every year plus regional and specialized meetings. The Analytical Chemistry Division offers major sessions. Contact: American Chemical Society, 1155 16th St. N.W., Washington, DC 20036.

#### JOURNALS AND SERIAL BOOKS

##### *American Laboratory*

Institute of Scientific Communication, Inc., 30 Contrtol Dr, Shelton, CT 06484.

##### *Analysis*

Societe Francaise Chemie, 250 Rue St., Jacques, 75005 Paris, France

##### *Analytical Chemistry*

American Chemical Society, 1155 16th St., N.W., Washington, DC 20036.

##### *Analytical Instrumentation*

Marcel Dekker Journals, 270 Madison Ave., New York, NY 10016.

##### *Analytical Letters*

Marcel Dekker, Journals, 270 Madison Ave., New York, NY 10016.

***Analytical Sciences***

Japan Society of Analytical Chemistry, 26-2 Nishigotanda 1-choue, Shinagawa-Ku, Tokyo 141, Japan.

***Appita Journal***

Technical Association of the Australian and New Zealand Pulp and Paper Industry, Inc., Clunies Ross House, 191 Royal Pde., Parkeville, Victoria, 3052, Australia.

***Applied Spectroscopy***

Society of Applied Spectroscopy, Box 64008, Baltimore, MD 21264.

***Biomass***

Elsevier Applied Science Publishers, Ltd., Crown House, Linton Road, Barking, Essex IG11 8JU, England.

***Biomedical and Environmental Mass Spectrometry***

Wiley and Sons Ltd., Baffin's Lane, Chichester, Sussex PO19 1UD, England.

***CRC Critical Reviews in Analytical Chemistry***

CRC Press, Inc., 2000 Corporate Blvd., Boca Raton, FL.

***Environmental Science and Technology***

American Chemical Society, 1155 16th St. N.W., Washington, DC 20036.

***Journal of the Association of Official Analytical Chemists***

AOAC, 1111 N. 19th Street, Suite 210-P, Arlington, VA 22209.

***Journal of Chromatographic Science***

Preston Publications, Inc., 7800 Merrimac Ave., P.O. Box 48312, Niles, IL 60648.

***Journal of Chromatography***

Elsevier Science Publishers B. V., Box 211, 1000 AE Amsterdam, The Netherlands.

***Journal of High Resolution Chromatography***

Journal of High Resolution Chromatography and Chromatography Communications, Dr. Allred Huethig, Verlag CmbH, Im Weher 10, Postlach 102869, 6900 Heidelberg 1, W. Germany.

***Journal of the Air Pollution Control Association***

Three Gateway Center, Four West, Pittsburgh, PA 15222.

***Journal of Testing and Evaluation***

American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103

***LC-GC, Magazine of Liquid and Gas Chromatography***

Aster Publishing Corp., 859 Willamette St., Box 10460, Eugene, OR 97440.

***Organic Mass Spectrometry***

Wiley and Sons, Ltd., Baffins Lane, Chichester, Sussex PO19 1UD, England.

***Spectroscopy***

Aster Publishing Corp., 859 Willamette St., Box 10460, Eugene, OR 97440.

**Standardization News**

American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

**The Analyst**

Royal Society of Chemistry, Burlington House, London W1V 0BN, England.

**TAPPI Journal**

The Technical Association of the Pulp and Paper Industry, Inc., Technology Park-Atlanta, Box 105113, Atlanta, GA 30348.

Many other journals and other sources of methods information are cited in the literature section of the methods section. Future editions of this source book will provide more complete coverage of non-U.S. sources.

**GENERAL STANDARDS INFORMATION**

Hahn, R.H. "Standards--A Vital Tool in Engineered Agriculture." *Agricultural Engineers Yearbook*. 1988.

Cooke, P.W. and D.R. Mackay. "The New European Community Approach--Harmonization of Standards and Certification Systems." *ASTM Standardization News*, December 1988, p. 31.

Breitenberg, M.A. *The ABC's of Standards-Related Activities in the United States*. NBSIR 87-3576. Gaithersburg, MD: National Bureau of Standards.

*A Review of U.S. Participation in International Standards Activities*. NBSIR 88-3698. Gaithersburg, MD: National Bureau of Standards.

Bruno, T.J. and P.D.N. Svoronos. *Basic Tables for Chemical Analysis*. Gaithersburg, MD: National Bureau of Standards, 1986.

*Chemical Analysis--A Series of Monographs on Analytical Chemistry and Its Applications*. Edited by P.J. Elving and J.D. Winefordner. New York: John Wiley and Sons.

Volume 83 is on Fourier Transform Infrared Spectrometry (Griffiths and deHaseth) and Volume 82 on Chemometrics (M.A. Sharof, B.L. Illman, and B. Kowalski) for example.

"Information on Biomass: A Resource List." *Appropriate Technology* 12(2):16 (1985).

Contains information on data bases, networks, organizations, useful reference material, and directories and bibliographies.

Bhagoroalia, B.S., J.L. Donaldson, R.B. Toth, and S.M. Spivak. "Standards Education: Part III-Special Needs of the Developing Nations." *ASTM Standardization News*, March 1988, p. 54.

*Biofuels and Municipal Waste Technical Information Guide*. SERI/SP-220-3366. Golden, CO: Solar Energy Research Institute, 1989.

"Summit calls for research integration--Western political leaders endorsed demands to harmonize technical norms and scientific procedures in different nations." *Science* 228:825 (1985).

L.M. Prigge, Managing Editor. Information Handling Services, Inverness Business Park,  
15 Inverness Way East, Englewood, CO 80150.

Provides instant on-site access to standards information.

## APPENDIX VII

### Glossary of Useful Terms

#### Introduction

This glossary is a compendium of terms frequently encountered by those interested or involved in the use of biomass for energy purposes. As this is a newly developing technology crossing many disciplines, there is a special need for definitions, including the definition of biomass itself. This need was cited in a survey on standard needs in biomass for energy and chemicals and has been recognized by the U.S. Department of Energy and U.S. Department of Agriculture's biofuels conversion and production programs. The Biomass Energy Research Association in a survey of information needs for research and development identified a ". . . need for concise and consistent definitions of biomass terms. Glossaries should be used more often."

The initial basis of the present glossary was a collection of terms prepared by George Barton for the Bioenergy Program of the National Research Council of Canada. To this list were added many terms from existing published glossaries and lists of definitions in published government reports. This preliminary collection of terms was submitted to a number of reviewers for initial screening and assessment. The reviewers', and SERI's, consensus was that many extant definitions are in need of reformulating or are actually technically incorrect. Furthermore, it became apparent that many different opinions exist as to the proper thrust of definitions. This preliminary review experience leads us to the following conclusions:

- There is need for a comprehensive, and comprehensively reviewed, glossary of biofuels terms.
- A glossary is a living document, constantly in need of revision and tuning to reflect the consensus of people actively involved in the relevant research and technology.
- Ultimately, the biofuels glossary would benefit from review and adoption by recognized standards bodies such as ASTM and ASME.

This glossary is submitted as part of a continuing review and enhancement process, both to improve the accuracy and appropriateness of the definitions and to enlarge the scope of the coverage.

**absorbance** - a spectrophotometric term related to the ratio of the amount of photons (light) transmitted through a sample to the amount of photons transmitted through a reference substance.  $A = -\log(T_s/T_r)$ . Absorbance is linear with respect to the concentration of the absorbing species. Absorbances are also additive when different absorbing species are present in the same sample.

**accuracy** - a measure of agreement between an observed value and the accepted or "true" value.

**acetyl** - a chemical group related to acetic acid. It is bound through an ester linkage to polyose chains (especially xylans) in wood and other plants. The natural moisture present in plants hydrolyzes the acetyl groups to acetic acid, particularly at elevated temperatures. Most woods are naturally slightly acidic (ph = 4.0-5.5).

**acid detergent fiber (ADF)** - organic matter that is not solubilized after one hour of refluxing in an acid detergent of cetyltrimethylammonium bromide in 1 N sulfuric acid. ADF includes cellulose and lignin.

**acid gas** - raw gaseous mixture of carbon dioxide (CO<sub>2</sub>), hydrogen sulfide (H<sub>2</sub>S), and carbon oxysulfide (COS) present in natural and synthetic fuel gases. Also, sulfur and nitrogen oxides and chlorides in flue gases from combustion processes.

**acid hydrolysis** - the treatment of cellulosic, starch or hemicellulosic materials using acid solutions (usually mineral acids) to break down the polysaccharides to simple sugars.

**activated sludge** - a product of processes used to biologically degrade organic matter in water suspension. Generally, diffusion of air through a dilute slurry promotes the growth of aerobic bacteria and other organisms that generate a sludge upon acting on the organic material. Their respiration reduces the amount of biomass that accumulates and thus reduces the disposal problem.

**adsorption** - the adhesion, in an extremely thin layer, of molecules (as of gases, solutions, or liquids) to the surface of solid bodies or liquids with which they are in contact. Used also to describe a form of solar cooling employing this principle.

**aerobic** - able to live, grow, or take place only where free oxygen is present.

**aerobic fermentation** - fermentation processes that require the presence of air.

**air gasification; oxygen gasification** - processes in which biomass is converted to a low- or medium-energy content gas through reaction with air or oxygen, respectively. The processes are exothermic and operate typically at temperatures of 572°-2012°F (300°-1100°C). The gases are composed primarily of CO, H<sub>2</sub>, CO<sub>2</sub>, and H<sub>2</sub>O with lesser amounts of hydrocarbon gases, primarily methane. They have an energy content of 250-400 Btu/scf when oxygen is used, or 100-200 Btu/scf when air is used because of nitrogen dilution of the gas. The gas produced with air is called producer gas. The gas produced with oxygen, after reforming and acid-gas removal, is called synthesis gas and can be used to make other fuels such as methane, methanol, or gasoline.

**alcohols** - the family name of a group of organic compounds that vary in chain length and consist of a hydrocarbon plus one or more hydroxyl groups; for example, the straight chain series CH<sub>3</sub>-(CH<sub>2</sub>)<sub>n</sub>-OH. Includes methanol, ethanol, isopropyl alcohol, etc. If the hydrocarbon is aromatic, the compounds are called phenols.

**aldehydes** - any of a class of highly reactive organic chemical compounds characterized by the common group CHO and used in the manufacture of resins, dyes, and organic acids. Also the end group of reducing sugars.

**algae** - simple photosynthetic plants containing chlorophyll, often fast growing, and able to live in fresh water, seawater, or damp soils. May be unicellular and microscopic or very large, as in the giant kelps.

**alkali** - soluble mineral salt of alkali metals having characteristically "basic" properties.

**alkaline hydrolysis** - the use of solutions of sodium hydroxide (or other alkali) in the treatment of cellulosic material (wood). Called the soda pulping process.

**amylase** - a family of enzymes that act together to hydrolyze starch to individual glucose, maltose, and dextrin units.

**anaerobic** - living or active in an airless environment.

**anaerobic bacteria** - microbes whose metabolisms require the absence of free oxygen.

**anaerobic digester** - a chemical reactor in which anaerobic bacteria are used to decompose biomass or organic wastes to produce methane and carbon dioxide.

**anaerobic digestion** - degradation of organic matter by microbes in the absence of air (oxygen) to produce methane and carbon dioxide (biogas).

**anaerobic fermentation** - fermentation processes conducted in the absence of air. The following anaerobic fermentation processes are significant in obtaining useful forms of energy from biomass: (1) alcoholic fermentation: fermentation processes whereby certain microorganisms convert glucose and other substrates, with alcohol as an end product; (2) methane fermentation: generally termed anaerobic digestion (see above).

**angiosperms** - various orders of plants that have true flowers and seeds enclosed in a fruit. Includes all the hardwoods.

**anhydrous** - a material that does not contain water either absorbed on its surface or as water of crystallization; a water-free product.

**apparent digestible organic matter (ADOM)** - the observed or net digestibility achieved regardless of whether refractory matter has substrate or bacterial origins. Synonymous with volatile solids destroyed.

**ash** - inorganic residue remaining after combustion, determined by definite prescribed methods.

**ash fusion temperature** - melting point of ash; usually expressed in degrees Fahrenheit. Variations include oxidizing atmosphere or reducing atmosphere, initial softening, or final fluid temperature. Some specifications include two intermediate points between initial softening and final fluid.

**autohydrolysis** - literally "self" hydrolysis; in the case of biomass, the term refers to the conversion of lignocellulosic matter to sugars under elevated temperatures and pressure and in the absence of an external source of acid.

**azeotrope** - the chemical term for a mixture of two liquids that, at a certain concentration, boil at the same temperature; alcohol and water cannot be separated further than 194.4 proof because at this concentration, alcohol and water form an azeotrope and vaporize together at lower temperature.

**azeotropic distillation** - distillation in which a substance is added to the mixture to be separated in order to form an azeotropic mixture with one or more of the components of the original mixture; the new azeotrope formed will have a boiling point lower than the boiling point of the original mixture, thus allowing separation to occur.

**bacteria** - any of numerous unicellular or multicellular prokaryotic microorganisms lacking chlorophyll, existing either as free-living organisms or as parasites, and having a wide variety of biochemical properties.

**bacteriophage** - a type of virus that attacks bacteria rather than ordinary cells. A particle of bacteriophage consists of a nucleic acid (usually DNA) molecule enclosed in a protein shell. The nucleic acid can enter a bacterium and either multiply in it to form progeny particles, or variously interact with the chromosome of the bacterium.

**bagasse** - residue remaining after extraction of a sugar containing juice from plants like sugar cane.

**ball mill** - a device used to prepare uniform samples for testing. Usually a porcelain crock charged with sample and small (9-13 mm diameter) stainless steel balls. The chamber is sealed and mechanically rotated. The grinding action of the balls yields a fine, well-mixed powder.

**bar** - metric unit of pressure equivalent to about one atmosphere at sea level (14.5 psi or 29.53 in. of Hg).

**bark** - the outer protective layer of a tree outside the cambium comprising the inner bark and the outer bark.

**bark, inner** - the layer of living bark (phloem) that separates the outer bark from the cambium and that in the living tree generally is moist and soft.

**bark, outer** - the layer of dead bark outside the inner bark, forming the exterior surface of the tree stem. The outer bark frequently is corky and dry.

**batch distillation** - a process in which the liquid feed is placed in a single container and the entire volume is heated, in contrast to continuous distillation in which the liquid is fed continuously to the still.

**batch fermentation** - fermentation conducted from start to finish in a single vessel without addition to or removal of major substrate or product stream, respectively, until the process is complete.

**batch process** - unit operation where one cycle of feedstock preparation, reaction, and product separation is completed before the next cycle is started.

**bioassay** - an assay method that uses a change in biological activity as a means of analyzing a material's response to biological treatment; method of assessing toxic effects of industrial wastes by using viable organisms as test species.

**bioconversion** - a general term describing the use of biological systems to transform one compound into another. Examples are digestion of organic wastes or sewage by microorganisms to produce methane.

**biodegradable volatile solids (BVS)** - those volatile solids that have been stabilized by microorganisms after an infinite amount of time.

**bioenergy** - the production, conversion, and use of material directly or indirectly produced by photosynthesis (including organic waste) to manufacture fuels and substitutes for petrochemical and other energy-intensive products.

**biofuel** - biomass-derived fuel.

**biogas** - a gaseous mixture of mainly carbon dioxide and methane produced by the anaerobic digestion of organic matter.

**biogasification** - the process of gasifying biomass by biological treatment.

**biological oxygen demand (BOD)** - quantity of oxygen used in the biological oxidation of organic matter within a specified time and temperature.

**biomass** - The total weight of living matter in a given volume. When considered as an energy source, biomass is further subdivided into: (1) **primary biomass** - rapidly growing plant material that may be used directly or after a conversion process for the production of energy, and (2) **secondary biomass** - biomass residues remaining after the production of fiber, food, or other products of agriculture, or biomass by-products from animal husbandry or food preparation that are modified physically rather than chemically. Examples include waste materials from agricultural and forestry industries (manure, sewage, etc.) from which energy may be produced. The above distinction noted between primary and secondary biomass is based on economic factors; these terms are defined differently in ecological science.

Also, material, excluding fossil fuels, which is or was a living organism that can be used as a fuel directly or after a conversion process. Wood, peanut hulls, agricultural waste, corn and other grains, sugar, and bagasse are all examples of biomass. Matter formed from living cells.

Also the living materials in the biosphere and their refuse and waste products. Defined in the Energy Security Act (P.L. 96-294) as any organic matter that is available on a renewable basis, including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants.

**biomethanation** - the formation of methane by microorganisms from hydrogen, carbon monoxide, and carbon dioxide.

**biophotolysis** - the sunlight-driven production of hydrogen and oxygen from water using photosynthetic organisms or isolated components as biological catalysts.

**biosynthesis** - production and transformation of substances from other compounds by living organisms.

**black liquor** - the dark, alkaline waste liquor from the manufacture of pulp by the kraft (sulfate) process or the soda process. Usually concentrated and burned in a furnace to recover heat and chemicals.

**bole** - the stem or trunk of a tree large enough to yield lumber, veneer, or poles.

**bone dry unit (BDU)** - 2400 lb of moisture-free wood, unless otherwise stated.

**bottom ash** - noncombustible refuse collected in the bottom of the fuel bed combustors or gasifiers.

**bound water** - water contained within the cell walls of organisms and held by hydroscopic forces.

**briquette** - a densified particle with all surfaces die-formed. Uniform in size with no broken surfaces. Large diameter densified fuel, sometimes referred to as "hockey pucks," sometimes called briquettes, which are technically large pellets.

**British thermal unit (Btu)** - the amount of heat required to raise the temperature of 1 pound of water 1°F under one stated condition of pressure (1 atm) and temperature (from 60° to 61°F).

**bulk density** - mass per unit volume of material as packed in a container.

**calorie (gram)** - originally the energy required to heat one gram of water 1°C. Gram calories are normally used in science and energy technology. Redefined as equal to 4.184 joules.

**calorie (kilogram)** - energy required to heat one kilogram of water 1°C. Kilogram calories are normally used in food technology. (1 kcal = 3.968 Btu).

**calorific value** - the potential heat-production value of a fuel source. For biomass depends on the cellulose-lignin ratio, the percentage of extractives, the moisture content, and ash, among other parameters.

**cambium** - the layer of reproducing cells between the inner bark (phloem) and the wood (xylem) of a tree that repeatedly subdivides to form new wood and bark cells.

**carbohydrate** - organic compounds made up of carbon, hydrogen, and oxygen having approximately the formula  $(CH_2O)_n$ ; includes cellulose, starches, and sugars.

**carbonization** - a process of decomposition of a solid such as wood or biomass into solid, liquid, and gaseous products by heating.

**catalyst** - any substance that facilitates the occurrence of a chemical reaction but does not itself undergo permanent change. In the presence of the appropriate catalyst, reactions that are slow to reach equilibrium are facilitated.

**cell** - a general term for the minute units of plant or animal structure. In plants, cells have distinct walls and cavities, and include wood fibers, vessel segments, and other elements of diverse structure and function.

**cell recycle** - the process of separating live cells such as yeast from fermentation products and returning them to the fermentation process for further conversion, in either batch or continuous operations.

**cell soluble matter** - organic matter that is solubilized after one hour of refluxing in a neutral detergent of sodium lauryl sulfate and EDTA at pH 7. This includes cell contents and pectin.

**cellulases** - enzymes capable of degrading cellulose to its component sugars.

**cellulose** - the carbohydrate that is the principal constituent of wood and forms the structural framework of the wood cells.

**cetane rating (cetane number)** - a measure of a fuel's ease of self ignition. Diesel fuel, with a high cetane rating, is suitable for compression ignition engines, while alcohol and gasoline with low cetane ratings are not.

**char** - a porous, solid carbonaceous residue resulting from the pyrolysis or incomplete combustion of organic material. If produced from coal, it is called coke; if produced from wood or bone, it is called charcoal. It is closer to pure carbon than the coal, wood, or bone from which it is produced.

**charcoal** - a dark-colored or black porous carbonaceous material made from vegetable or animal substances (i.e., by charring wood in a kiln) often used for fuel. Wood residue after most volatile substances have been heated and driven off. Consists mainly of carbon.

**chemical oxygen demand (COD)** - a measure of the amount of oxidizable components present in water, as measured in specified test.

**chips** - small fragments of wood chopped or broken by cuts such as by a planer, chipper, mechanical hog, or hammermill. Typically 1/4 in. × 1 in. × 2 in. (6.35 mm × 25.4 mm × 50.8 mm). Total tree chips include wood, bark, and foliage. Pulp chips or clean chips are bark-free.

**chromatography** - a technique used to separate the chemical components of a mixture. Gas chromatography and liquid chromatography are two common methods used by analytical chemists. See **column**.

**coke** - a carbonaceous solid produced from coal, petroleum, or other materials by thermal decomposition.

**coke breeze** - the fine screenings from crushed coke or from coke as taken from the ovens, of a size varied in local practice, but usually passing a 1/2-in. (12.7-mm) or 3/4-in. (19.0-mm) screen opening.

**coke, by-product** - coke manufactured with attendant recovery of by-products in ovens that are heated externally.

**column** - in chromatography a tube packed with fine resin or coated on the inside with a chemical. Sample mixtures are injected at one end of the tube and carried through with a liquid or gaseous solvent. The different components of the mixture interact with the resin or chemical coating and are carried through the column at different rates. As the components elute from the opposite end of the tube, they can be detected, identified, and measured quantitatively.

**combustion** - an exothermic chemical reaction of a fuel with oxygen, often intended for the direct production of heat.

**combustion efficiency** - the efficiency computed by dividing the actual heat produced in the firebox by the total heat potential of the fuel consumed.

**comminution** - mechanical shredding or pulverizing of waste; a process that converts waste into a homogeneous and more manageable material. Used in solid waste management and in the primary stage of wastewater treatment.

**compression wood** - abnormal wood formed typically on the lower side of branches and inclined trunks of softwood trees. Compression wood is identified by its relatively wide annual ring, usually eccentric; relatively large amount of latewood, sometimes more than 50% of the width of the annual ring in which it occurs; and its lack of demarcation between earlywood and latewood in the same annual rings. Compression wood shrinks

excessively lengthwise, as compared with normal wood. Contains higher proportions of lignin and galactans than normal wood.

**conifer** - a tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves, and producing wood known commercially as "soft-wood."

**continuous fermentation** - a steady-state fermentation system in which substrate and is continuously added to a fermenter while products and residues are removed at a steady rate.

**cooker** - a tank or vessel designed to cook a liquid or extract or digest solids in suspension; the cooker usually contains a source of heat and is fitted with an agitator.

**cord of wood** - a stack of wood 4 ft × 4 ft × 8 ft (1.2 m × 1.2 m × 2.4 m) occupying a gross space of 128 ft<sup>3</sup> (3.7 m<sup>3</sup>). Burned, it produces approximately 5 × 10<sup>6</sup> kcal of energy, equal to about 20 × 10<sup>6</sup> Btu.

**corn stover** - the stalks of the maize plant.

**cross section** - a section of a stem, board, or other piece of wood taken at right angles to its longitudinal axis. Often the surface exposed by crosscutting.

**cutin** - a nonphenolic complex lipid fraction found in the cuticle, measured as matter resistant to hydrolysis in 72% sulfuric acid and oxidation by potassium permanganate.

**cytoplasm** - the main body of a cell, exclusive of the nucleus (in a bacterium, exclusive of the chromosome) and of the cell membrane and wall.

**dbh** - diameter of a tree at breast height, usually taken as 4.5 ft (1.37 m) above ground.

**decay** - decomposition of organic material caused by action of bacteria, yeasts, and molds.

**decay, advanced (or typical)** - the older stage of decay in wood in which the destruction is readily recognized because the wood has become punky, soft and spongy, stringy, ring-shaked, pitted, or crumbly. Decided discoloration or bleaching of the rotted wood is often apparent.

**decay, incipient** - the early stage of decay in wood that has not proceeded far enough to soften or otherwise perceptibly impair the hardness of the wood. It may be accompanied by a slight discoloration or bleaching of the wood.

**dehydration** - the removal of a substantial portion of the water from any substance.

**dehydrogenation** - removal of hydrogen from a chemical compound.

**densified biomass fuels** - fuel made by compressing biomass to increase the density and to form the fuel into a specific shape such as cubes, pressed logs, pellets, or briquettes.

**depolymerization** - a breakdown of long-chain molecules, such as cellulose, into smaller molecules.

**destructive distillation** - the process (pyrolysis) of breaking down biomass or coal into charcoal, gases, and liquids. Widely practiced in the last century for production of chemicals.

**detector** - a broad term denoting the device on an analytical instrument that is able to respond to the presence of one or more chemical species. The device usually responds in such a way to produce an electrical signal, which is then output in graphical or digital form.

**dewatering** - the separation of free water from the solids portion of spent mash, sludge, or whole stillage by screening, centrifuging, filter pressing, or other means. The remaining solids portion is a wet cake that still contains 50% to 80% moisture.

**dextran** - a polymer of glucose units. Also glucan or anhydroglucose.

**dextrins** - polymers of D-glucose that are intermediate in complexity between starch (10,000 structural units) and maltose (2 structural units); formed by hydrolysis of starches.

**digester** - a bioreactor in which anaerobic bacteria are used to decompose biomass or organic wastes into methane and carbon dioxide.

**disaccharides** - the class of compound sugars that yields two monosaccharide units upon hydrolysis; examples are sucrose, maltose, and lactose.

**distillate** - the portion of a liquid that is removed as vapor and condensed during a distillation process.

**distillation** - the process by which the components of a liquid mixture are separated by boiling and recondensing the resultant vapors. The main components in the case of alcohol production are water and ethyl alcohol.

**dry fuel** - biomass materials with low moisture content, generally 8% to 10%. The allowable moisture content for dry fuel varies with requirements of the combustion or gasification system.

**drying (seasoning)** - moisture removal from biomass to improve its serviceability and utility.

**dry ton** - 2000 lb of biomass on a moisture-free basis.

**dry-weight-basis moisture content** - moisture content expressed as a percentage of the dry fuel (weight of water/weight of oven-dry wood).

**early wood** - the less dense, large-celled part of the growth layer of a tree formed first during the annual growth cycle. A synonym is springwood.

**efficiency, thermal** - fraction or percentage of available energy input that is converted to useful purposes; i.e., Btu output/Btu input.

**effluent** - the liquid or gas discharged after processing activities, usually containing residues from such use. Also discharge from a chemical reactor.

**emulsification** - the mixing of two fluids that do not dissolve in each other (e.g., oil and water). The result is an emulsion where one fluid is dispersed in very fine droplets in the other fluid.

**ensilage** - green forage crops and grains that are by-products of an anaerobic fermentation process.

**enzymatic hydrolysis** - use of an enzyme to promote the conversion, by reaction with water, of a complex substance into two or more smaller molecules.

**enzymes** - a class of proteins that catalyze specific biochemical reactions.

**equilibrium moisture content** - a moisture content at which biomass neither gains nor loses moisture to the surrounding air.

**essential oils** - pleasant smelling oils prepared by passing steam through foliage and finely divided twigs of several wood species (mainly cedars, Douglas fir, and western hemlock in the United States).

**ethanol (ethyl alcohol, grain alcohol)** -  $\text{CH}_3\text{CH}_2\text{OH}$ ; can be produced chemically from ethylene or biologically from the fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood.

**extractives** - substances in biomass, not an integral part of the cellular structure, that can be removed by solution in hot or cold water, ether, benzene, methanol, or other solvents that do not substantially degrade the biomass structure.

**fast pyrolysis** - pyrolysis in which reaction times are short, resulting in higher yields of certain fuel products, which may range from primary oils to olefins and aromatics depending on the severity of conditions. Rapid heating suppresses the formation of charcoal.

**fatty acids** - any of a number of organic acids such as the acetic, propionic, butyric, and valeric acids formed (among other means) as intermediates in the anaerobic digestion process.

**fermentation** - decomposition of organic compounds, by microorganisms, to fuels and chemicals such as alcohols, acids, and energy-rich gases.

**fiber saturation point** - the moisture content at which the cell walls are saturated with water (bound water) and no water is held in the cell cavities by capillary forces. It usually is taken as 25% to 30% moisture content, based on oven dry weight.

**fiber, wood** - a comparatively long (1/25 in. [1.02 mm] or less to 1/3 in. [8.47 mm]), narrow, tapering wood cell closed at both ends.

**fixed carbon** - carbon remaining after heating in a prescribed manner to decompose thermally unstable components and to distill volatiles.

**flash point** - the temperature at which a combustible liquid will ignite when a flame is held over the liquid; anhydrous ethanol will flash at 51°F (10.6°C) and 90-proof ethanol will flash at 78°F (25.6°C).

**fly ash** - small ash particles carried in suspension in combustion products.

**forest residues** - unused wood in the forest including logging residue; rough, rotten, and dead trees; and annual mortality.

**fossil fuel** - organic fuels formed from the remains of plants or animals within or beneath the earth's crust, e.g., coal, petroleum, and natural gas.

**free water** - moisture that is contained in cell cavities and intercellular spaces and is held by capillary forces only.

**friability index** - a fuel quality measurement, also called durability index. Expressed in percent of the total weight degraded to fines in a standard test procedure.

**furfural** - an aldehyde; derivative of certain biomass conversion processes; used as a solvent.

**fusel oil** - a clear, colorless, poisonous, liquid mixture of alcohols obtained as a by-product of grain fermentation; generally amyl, isoamyl, propyl, isopropyl, butyl, and isobutyl alcohols and acetic and lactic acids.

**gasification** - any chemical or heat process used to convert a feedstock to a gaseous fuel. (See also air gasification).

**gasifier** - a device that converts solid fuel to gas. Generally refers to thermochemical processes. Major types are moving bed (fixed bed), entrained bed, and fluidized bed.

**gasohol** - a blend of 10% anhydrous ethanol and 90% unleaded gasoline.

**gigajoule (GJ)** - one billion joules. One million Btu (MBtu) equals 0.9486 GJ.

**glucose** - a simple sugar containing six carbon atoms ( $C_6H_{12}O_6$ ). A sweet, colorless sugar that is the most common sugar in nature and the primary component of starch and cellulose. The sugar most commonly fermented by yeast to produce ethyl alcohol.

**grain** - the fruit of members of the grass (Poaceae) family; e.g., corn, wheat.

**green wood** - freshly sawed wood, or wood that has received no drying; unseasoned wood. Lumber that may have become wet to above the fiber saturation point may be referred to as being in the "green condition."

**green fuel** - freshly harvested biomass not substantially dried.

**green ton** - 2000 lb of undried material, (e.g., wood residue including moisture content).

**gross calorific value** - (gross heat of combustion at constant volume).  $Q_v(\text{gross})$  - the heat produced by combustion of a unit quantity of a solid or liquid fuel when burned at a constant volume in an oxygen bomb calorimeter under specified conditions with the resulting water condensed to a liquid. Also higher heating value, HHV.

**guaiacyl** - a chemical component of lignin. It has a six-carbon aromatic ring with one methoxyl group attached. It is the predominant aromatic structure in softwood lignins. See **syringyl**.

**gum** - a light colored carbohydrate exudate from specific woody genera, insoluble in organic solvents, slowly soluble in hot water.

**gymnosperms** - plants producing seeds that are not enclosed in a fruit; includes the conifers.

**hammermill** - a device consisting of a rotating head with free-swinging hammers that reduce in suspension, chips, hogged fuels, pellets, etc. to a predetermined particle size through a perforated screen. Moisture content of hammer-milled material should not exceed 20%.

**hardwood** - generally one of the botanical groups of dicotyledonous trees that have broad leaves in contrast to the conifers or softwoods. The term has no reference to the actual hardness of the wood.

**heartwood** - the inner portion of a wood stem wholly composed of nonliving cells and usually differentiated from the outer enveloping layer (sapwood) by its darker color. It is usually more decay resistant than sapwood.

**heating value** - (1) higher heating value (HHV) is the potential combustion energy when water vapor from combustion is condensed to recover the latent heat of vaporization, commonly used in the United States; (2) lower heating value (LHV) is the potential combustion energy when water vapor from combustion is not condensed, commonly used in Europe.

**hemicellulose** - noncellulosic polysaccharides of the cell wall that are easily decomposed by dilute acid, yielding several different simple sugars such as xylose, arabinose, mannose, and galactose. Also called polyose.

**herbaceous plants** - non-woody species of vegetation, usually of low lignin content such as grasses.

**hexose** - any of various simple sugars that have six carbon atoms per molecule (e.g., glucose).

**high-Btu gas (HBG)** - a gas containing mostly methane with a heating value of 800-1100 Btu per standard cubic foot (heating value of natural gas = 1000 Btu/scf).

**holocellulose** - the total carbohydrate fraction of wood; - i.e., cellulose plus hemicellulose.

**hydrocarbon** - a chemical compound containing only hydrogen and carbon.

**hydrolysis** - the conversion, by reaction with water, of a complex substance into two or more smaller units, such as the conversion of cellulose into smaller sugar units.

**immobilized cells** - microbial cells that have been fixed onto solid supports such that the cells will remain in the system during product removal.

**immobilized enzymes** - stable, enzymes entrained on solid supports by various chemical techniques such that the enzymes remain in the reaction system during product removal.

**indirect liquefaction** - conversion of biomass to a liquid fuel through a synthesis-gas intermediate step.

**inoculum** - microorganisms produced from a pure culture that are used to start a new culture in a larger vessel than that in which they were grown.

**in vitro** - isolated from a living organism and maintained in an artificial environment. Literally, in glass.

**in vivo** - in the living body of a plant or animal.

**joule (J)** - the amount of energy produced by one watt in one second. One newton of force over a distance of one meter. One joule = 0.239 calories.

**juvenile wood** - the wood formed adjacent to the pith, characterized by progressive change in cell dimension and chemical composition, different microstructure than mature wood, and greater shrinkage parallel to the grain.

**kiln** - a chamber used for drying and conditioning lumber, veneer, and other wood products in which the temperature and relative humidity of the circulated air can be varied and controlled, often steam heated and vented.

**knot** - that portion of a branch or limb that has been surrounded by subsequent growth of the wood of the tree. As a knot appears on the cut surface, it is merely a section of the entire knot, its shape depending upon the direction of the cut.

**kraft (sulfate) process** - a chemical pulping process in which lignin is dissolved by a solution of sodium hydroxide and sodium sulfide.

**landfill gas** - biogas produced from the natural degradation of the organic material in landfills.

**latewood** - the denser, smaller celled, later formed part of a growth layer. A synonym is summerwood.

**lignin** - the noncarbohydrate, polyphenolic structural constituent of wood and some other plant tissues, which encrusts the cell walls and cements the cells together.

**lignin, alkali** - lignin obtained by acidification of an alkaline extract of wood.

**lignin, klason** - lignin obtained from wood after the nonlignin components of the wood have been removed with a prescribed sulfuric acid treatment.

**lignin, native** - the lignin as it exists in the lignocellulosic complex before separation.

**lignin, willstatter** - lignin obtained from the lignocellulosic complex after it has been extracted with fuming hydrochloric acid.

**lignin, acid soluble** - lignin from hardwoods soluble in sulfuric acid.

**lignocellulose** - refers to plant materials made up primarily of lignin, cellulose, and hemicelluloses.

**lipases** - enzymes that break down fats.

**lipids** - water-insoluble biomolecules, such as fats and oils.

**low-Btu gas (LBG)** - a gas composed of H<sub>2</sub>O, CO<sub>2</sub>, CO, H<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub> with a heating value of about 90 to 200 Btu per standard cubic foot (Btu/scf).

**mash** - a mixture of grain and other ingredients with water to prepare wort for brewing operations.

**mean** - a statistical term denoting the average of several repeated measurements. Mathematically it is the sum of all the repeated measurement values divided by the number of measurements.

**medium-Btu gas (MBG)** - a gas composed of CO<sub>2</sub>, CO, H<sub>2</sub>, CH<sub>4</sub>, and higher hydrocarbons but little or no N<sub>2</sub>, having a heating value of 250 to 500 Btu/scf.

**megagram (Mg)** - A unit of mass equal to 1000 kilograms (kg). A form for expressing a metric tonne.

**membrane** - a sheet polymer capable of separating liquid solutions; for example, membrane separation of alcohol and water.

**mesophilic** - organisms that thrive in a temperature range of 68° to 95°F (20°-35°C).

**metabolism** - the sum of the physical and chemical processes involved in the maintenance of life and by which energy is made available to the organism.

**metabolite** - a general term for a biological compound that is produced or used in metabolism.

**methanation** - a process for producing methane by passing carbon oxides and hydrogen mixtures over nickel catalysts. Medium-Btu gas can be upgraded to high-Btu gas by methanation. The reactions are  $\text{CO} + 3\text{H}_2 = \text{CH}_4 + \text{H}_2\text{O}$ ;  $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$ .

**methane** - CH<sub>4</sub>, the major component of natural gas. It can be formed by anaerobic digestion of biomass or gasification of coal or biomass.

**methane fermentation** - a bacteria-mediated process whereby organic matter is metabolized in an oxygen-free environment with a net release of energy, resulting in end-products of carbon dioxide and methane gas.

**methanogenic bacteria** - microorganisms capable of producing methane.

**methanol (methyl alcohol, wood alcohol)** - an alcohol, CH<sub>3</sub>OH, formed by catalytically combining carbon monoxide (CO) with hydrogen (H<sub>2</sub>) in a 1:2 ratio, under high temperature and pressure. Commercially, it is often manufactured by steam reforming natural gas. Also formed in the destructive distillation of wood.

**methoxyl** - a chemical group bonded to the aromatic rings in lignin. A quantitative determination of methoxyls in lignin is used to characterize the lignin.

**microalgae** - unicellular, photosynthetic aquatic plants.

**microorganism** - refers to any microscopic organism such as yeast, bacteria, fungi, or actinomycete.

**middle lamella** - the lignin-rich layer that cements adjoining wood cells together. This layer is dissolved in the chemical pulping processes that separate wood into pulp fibers.

**million (10<sup>6</sup>) Btu (MBtu)** - the predominant unit of energy in the United States. Frequently written MMBtu in non-metric, historical usage.

**moisture content** - the amount of water contained in the biomass, expressed as either a percentage of the mass of the oven-dry biomass or of the wet biomass.

$$\text{moisture content, dry basis} = \frac{(\text{weight wet sample} - \text{weight dry sample})}{\text{weight dry sample}} \times 100.$$

$$\text{moisture content, wet basis} = \frac{(\text{weight wet sample} - \text{weight dry sample})}{\text{weight wet sample}} \times 100.$$

**monosaccharide** - a simple sugar such as a five-carbon sugar (ribose, xylose) or six-carbon sugar (glucose, fructose). Sucrose on the other hand is a disaccharide, composed of a combination of two simple sugar units, glucose and fructose.

**morphology** - the structure of the vegetative and reproductive features of an organism.

**municipal solid wastes (MSW)** - the refuse materials collected from urban areas in the form of organic matter, glass, plastics, waste paper, etc., not including human wastes.

**naval stores** - oils, resins, tars, and pitch extracted from pine and fir trees. Historically, the term was derived to describe those products when they were used in the construction of wooden sailing vessels.

**net calorific value** (net heat of combustion at constant pressure).  $Q_p(\text{net})$  - the heat produced by combustion of a unit quantity of a solid or liquid fuel when burned at a constant pressure of 1 atm (0.1 MPa) under conditions such that all the water in the products remains in the form of vapor. Also the lower heating value, LHV.

**neutral detergent fiber (NDF)** - organic matter that is not solubilized after one hour of refluxing in a neutral detergent consisting of sodium lauryl sulfate and EDTA at pH 7. NDF includes hemicellulose, cellulose, and lignin.

**NO<sub>x</sub>** - nitrogen oxides; regulated air pollutants, primarily nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>), but including other nitrogen oxides in minute concentrations.

**octane rating (octane number)** - a measure of a fuel's resistance to self ignition, hence a measure as well of the antiknock properties of the fuel. Whereas diesel fuel has a low octane rating, gasoline and alcohol have high octane ratings and are suitable for spark ignition engines.

**oleoresin** - essentially a solution of resin acids in turpentine, which exudes when the resin canals in the wood of conifers are ruptured; and on evaporation leaves a brittle solid (rosin). Their function is to protect the plant.

**other forest land** - forest land incapable of producing 20 ft<sup>3</sup> per acre of industrial wood under natural conditions because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness.

**outplanting** - the establishment of a forest stand by planting tree seedlings or tree cuttings.

**oven dry megagram or metric tonne (ODMg)** - an amount of wood that weighs 1000 kg or 2204.6 lb at 0% moisture content.

**oven dry ton (ODT)** - an amount of wood that weighs 2000 lb at 0% moisture content.

**oven dry wood** - wood that has been dried to constant weight at about 215°F (100°C) and low humidity. By definition, oven dry wood has zero moisture content.

**PAH** - polycyclic aromatic hydrocarbons.

**particulate emissions** - solid particles discharged with exhaust gas. Usually expressed in terms of grains per cubic foot or pounds per million Btu input.

**particulates** - minute solid or liquid particles in the air or in an emission. Particulates include dust, smoke, fumes, mist, spray, and fog.

**particulate size** - size of small particles expressed in many ways including ASTM mesh, microns, equivalent diameter, chip size range, etc. Specification may include maximum and minimum or percent of various sizes.

**pasteurization** - the destruction of bacteria in media by maintaining a temperature over a sufficient period of time to obtain a desired bacteria kill.

**peat** - carbonaceous material formed in swamps from accumulated plant organic matter as a result of varying degrees of decomposition of plant components.

**pellet** - a densified fuel form, usually cylindrical, die-formed, usually by extrusion, with random lengths and open broken ends. Generally of high density.

**pelletizing** - the densification of finely sized wood and bark into a uniform, usually cylindrical, shape by high pressure and intermediate temperature.

**pH** - a measure of acidity, the negative log of the hydrogen ion concentration, pH 1 is very acid, pH 7 is neutral, and pH 14 is very alkaline (basic).

**phase separation** - separation of a mixture into two or more phases under an external influence. An example is when water is added to gasohol or diesohol. The alcohol/water mix may separate from the gasoline or diesel fuel and settle to the bottom of the tank.

**phloem** - in plants, the inner bark; the principal tissue in a tree concerned with the transport of sugars and other nutrients from the leaves. A synonym is bast.

**photosynthesis** - the process generally by which chlorophyll-containing cells in green plants convert incident light to chemical energy and synthesize organic compounds from inorganic compounds, especially carbohydrates from carbon dioxide and water, with the simultaneous release of oxygen.

**pitch** - a term applied to the resin occurring in the wood of certain conifers.

**pith** - the small soft tissue occurring in the structural center of a tree trunk, branch, twig, or log.

**PNA** - polynuclear aromatic compounds.

**polyose** - a polysaccharide composed of more than one simple sugar as a repeating unit. Galacto-glucomannan is an example, commonly found in softwoods. Most polyoses contain branching units on a linear backbone. See **hemicelluloses**.

**polysaccharide** - a long-chain carbohydrate containing at least three molecules of simple anhydro-sugars linked together; examples would include cellulose and starch.

**POM** - in chemistry, polycyclic organic matter including polynuclear aromatic compounds. In aquatic ecology, particulate organic matter.

**pores** - in wood anatomy, a term applied to the cross section of a vessel or of a vascular tracheid.

**preservative** - a chemical mixture which, when absorbed by wood, makes the wood resistant to attack by fungi, insects, marine borers, or weather conditions.

**pressure-treated wood** - wood treated by applying pressure to force a preservative into it.

**protein** - a protein molecule is a chain of up to several hundred amino acids and is folded into a more or less compact structure. Because some 20 different amino acids are used by living matter in making proteins, the variety of protein types is enormous. In their biologically active states, proteins function as catalysts in metabolism and to some extent as structural elements of cells and tissues.

**provenance** - the original geographic source of seed, seedlings, or cuttings.

**proximate analysis** - the determination, by prescribed methods, of moisture, volatile matter, fixed carbon (by difference), and ash. The term proximate analysis does not include determinations of chemical elements or determinations other than those named.

**pulp, kraft** - a chemical wood pulp obtained by cooking wood chips at high temperature in a solution of sodium hydroxide and sodium sulfide (kraft process).

**pulp, semichemical** - pulp obtained by mild treatment of wood chips by any of the chemical pulping processes, which remove only part of the lignin from the wood chips, followed by mechanical treatment to complete the separation of individual wood fibers.

**pulpwood** - any wood cut or prepared primarily for the production of wood pulp.

**pyroligneous acid** - the acidic brown aqueous liquid obtained by condensing the gaseous products of pyrolysis of wood. Pyroligneous acid, when distilled, yields wood creosote as a fraction.

**pyrolysis** - the breaking apart of complex molecules by heating (over the range from 392° to 932°F (200°-500°C) in the absence of oxygen, producing solid, liquid, and gaseous fuels.

**quad** - one quadrillion ( $10^{15}$ ) Btu.

**reaction wood** - wood with abnormal structure and chemical composition formed in parts of leaning or crooked stems and in branches. In hardwoods it is called "tension wood"; in softwoods, "compression wood."

**oven dry megagram or metric tonne (ODMg)** - an amount of wood that weighs 1000 kg or 2204.6 lb at 0% moisture content.

**oven dry ton (ODT)** - an amount of wood that weighs 2000 lb at 0% moisture content.

**oven dry wood** - wood that has been dried to constant weight at about 215°F (100°C) and low humidity. By definition, oven dry wood has zero moisture content.

**PAH** - polycyclic aromatic hydrocarbons.

**particulate emissions** - solid particles discharged with exhaust gas. Usually expressed in terms of grains per cubic foot or pounds per million Btu input.

**particulates** - minute solid or liquid particles in the air or in an emission. Particulates include dust, smoke, fumes, mist, spray, and fog.

**particulate size** - size of small particles expressed in many ways including ASTM mesh, microns, equivalent diameter, chip size range, etc. Specification may include maximum and minimum or percent of various sizes.

**pasteurization** - the destruction of bacteria in media by maintaining a temperature over a sufficient period of time to obtain a desired bacteria kill.

**peat** - carbonaceous material formed in swamps from accumulated plant organic matter as a result of varying degrees of decomposition of plant components.

**pellet** - a densified fuel form, usually cylindrical, die-formed, usually by extrusion, with random lengths and open broken ends. Generally of high density.

**pelletizing** - the densification of finely sized wood and bark into a uniform, usually cylindrical, shape by high pressure and intermediate temperature.

**pH** - a measure of acidity, the negative log of the hydrogen ion concentration, pH 1 is very acid, pH 7 is neutral, and pH 14 is very alkaline (basic).

**phase separation** - separation of a mixture into two or more phases under an external influence. An example is when water is added to gasohol or diesohol. The alcohol/water mix may separate from the gasoline or diesel fuel and settle to the bottom of the tank.

**phloem** - in plants, the inner bark; the principal tissue in a tree concerned with the transport of sugars and other nutrients from the leaves. A synonym is bast.

**photosynthesis** - the process generally by which chlorophyll-containing cells in green plants convert incident light to chemical energy and synthesize organic compounds from inorganic compounds, especially carbohydrates from carbon dioxide and water, with the simultaneous release of oxygen.

**pitch** - a term applied to the resin occurring in the wood of certain conifers.

**pith** - the small soft tissue occurring in the structural center of a tree trunk, branch, twig, or log.

**PNA** - polynuclear aromatic compounds.

**polyose** - a polysaccharide composed of more than one simple sugar as a repeating unit. Galacto-glucomannan is an example, commonly found in softwoods. Most polyoses contain branching units on a linear backbone. See **hemicelluloses**.

**polysaccharide** - a long-chain carbohydrate containing at least three molecules of simple anhydro-sugars linked together; examples would include cellulose and starch.

**POM** - in chemistry, polycyclic organic matter including polynuclear aromatic compounds. In aquatic ecology, particulate organic matter.

**pores** - in wood anatomy, a term applied to the cross section of a vessel or of a vascular tracheid.

**preservative** - a chemical mixture which, when absorbed by wood, makes the wood resistant to attack by fungi, insects, marine borers, or weather conditions.

**pressure-treated wood** - wood treated by applying pressure to force a preservative into it.

**protein** - a protein molecule is a chain of up to several hundred amino acids and is folded into a more or less compact structure. Because some 20 different amino acids are used by living matter in making proteins, the variety of protein types is enormous. In their biologically active states, proteins function as catalysts in metabolism and to some extent as structural elements of cells and tissues.

**provenance** - the original geographic source of seed, seedlings, or cuttings.

**proximate analysis** - the determination, by prescribed methods, of moisture, volatile matter, fixed carbon (by difference), and ash. The term proximate analysis does not include determinations of chemical elements or determinations other than those named.

**pulp, kraft** - a chemical wood pulp obtained by cooking wood chips at high temperature in a solution of sodium hydroxide and sodium sulfide (kraft process).

**pulp, semichemical** - pulp obtained by mild treatment of wood chips by any of the chemical pulping processes, which remove only part of the lignin from the wood chips, followed by mechanical treatment to complete the separation of individual wood fibers.

**pulpwood** - any wood cut or prepared primarily for the production of wood pulp.

**pyroligneous acid** - the acidic brown aqueous liquid obtained by condensing the gaseous products of pyrolysis of wood. Pyroligneous acid, when distilled, yields wood creosote as a fraction.

**pyrolysis** - the breaking apart of complex molecules by heating (over the range from 392° to 932°F (200°-500°C) in the absence of oxygen, producing solid, liquid, and gaseous fuels.

**quad** - one quadrillion ( $10^{15}$ ) Btu.

**reaction wood** - wood with abnormal structure and chemical composition formed in parts of leaning or crooked stems and in branches. In hardwoods it is called "tension wood"; in softwoods, "compression wood."

**refuse-derived fuel (RDF)** - fuel processed from industrial waste, municipal waste, garbage, or sewage sludge.

**renewable energy resources** - sources of energy that are regenerative or virtually inexhaustible, such as solar, wind, ocean, biomass, municipal wastes, and hydropower energy. Geothermal energy is sometimes also included in the term.

**residues; wood:**

- **coarse residues** - plant residues suitable for chipping, such as slabs, edgings, and ends.
- **fine residues** - plant residues not suitable for chipping, such as sawdust, shavings, and veneer clippings.
- **logging residues** - the unused portions of sawtimber and poletimber trees cut or killed by logging.
- **plant residues** - wood materials from primary manufacturing plants that are not used for any product.
- **urban residues** - wood materials from urban areas, such as newspapers, lumber and plywood from building demolition, and used packaging and shipping wood materials.

**retention time** - in anaerobic digestion, the average time that the slurry remains in the digester.

**RVP (Reid vapor pressure)** - a measure in a test bomb of the vapor pressure of a sample of gasoline (fuel) at 100°F (37.8°C).

**saccharide** - a simple sugar or a more complex compound that can be hydrolyzed to simple sugar units.

**saccharification** - a conversion process using acids, bases, or enzymes in which long-chain carbohydrates are broken down into their component fermentable sugars.

**saccharify** - to hydrolyze a complex carbohydrate into simpler soluble fermentable sugars, such as glucose.

**sap** - the circulating fluid in living plants, containing nutrients and other chemicals in solution.

**sapwood** - the initial wood layer beneath the bark of the tree containing some living cells. The thickness of the sapwood layer varies by species and may be lighter in color than heartwood. Under most conditions the sapwood is more susceptible to decay than heartwood.

**screen analysis** - method for measuring proportion of variously sized particles in solid fuels. The sample is passed through a series of screens of known size openings. Biomass fuel screen sizes usually range from 5 to 100 openings per inch (square mesh).

**short-rotation intensive culture (SRIC)** - intensive management and harvesting at 2- to 10-year intervals or cycles of specially selected fast-growing species (generally hardwoods) for the purpose of producing wood as an energy feedstock.

**slash** - the residue left on the ground after harvesting or thinning, or resulting from storms, fire, etc.; it includes unused logs, uprooted stumps, broken or uprooted stems, tops, and branch wood.

**sludge** - a nonpumpable mixture of solids and liquids. Often refers to the residue of sewage treatment.

**softwoods** - generally, one of the botanical groups of trees that in most cases have needlelike or scalelike leaves; the conifers; also the wood produced by such trees. The term has no reference to the actual hardness of the wood.

**solvolysis** - decomposition (thermal) in a solvent.

**sound wood** - wood free of any form of decay, incipient or advanced, and from insect holes.

**specific gravity** - as applied to wood, the ratio of the oven dry weight of a sample to the weight of a volume of water equal to the volume of the sample at some specific moisture content, as green, air-dry, or oven dry.

**specific heat** - the heat in joules (Btu) required to raise the temperature of one gram of substance 1°C.

**spectrophotometer** - an analytical instrument used to measure the interaction of photons with different chemical species. The term is broad and includes different instruments which measure photons in the ultraviolet, visible and infrared regions of the electromagnetic spectrum. The instrument is able to generate spectra that relate the amount of photon absorption to the frequency or wavelength of the photons.

**spent grains** - the nonfermentable solids remaining after fermentation of a grain mash.

**spent mash** - the residual "slop" of unfermented matter plus the microbial cell mass that has accumulated after fermentation. When the feedstock to the fermenter is corn or cereal grain and the residual spent mash is dried, it is given the term "distillers dried grain" (DDG).

**standard deviation** - a statistical term. It is a measure of the precision or scatter of a set of data.

**starch** - a molecule composed of long chains of  $\alpha$ -glucose molecules linked together. Starch is a major component of potatoes and grains and can be readily broken down into glucose and other simple sugars.

**stem** - the bole or trunk of a tree.

**stillage** - a mixture of nonfermentable solids and water that remains after removal of the alcohol by distillation; also called spent beer.

**stover** - the dried stalks and leaves of a crop remaining after the grain has been harvested.

**substrate** - the base on which an organism lives or a substance acts upon (as by an enzyme).

**syngas** - The synthetic gas resulting from incomplete combustion or pyrolysis of organic material to primarily carbon monoxide and hydrogen. See **synthesis gas**.

**synthesis gas** - mixtures of gas in suitable proportions for the production of synthetic products without adding further reactants, such as carbon monoxide and hydrogen for synthesis of methanol.

**syringyl** - a component of lignin, normally found only in hardwood lignins. It has a six-carbon aromatic ring with two methoxyl groups attached. See **guaiacyl**.

**tannins** - complex, water-soluble phenolic extractives of plants that precipitate gelatin and are used to tan animal skins. Some classes are suitable as bases for wood adhesives.

**tar** - a liquid product of thermal processing of carbonaceous materials.

**tension wood** - an abnormal form of wood found in the upper side of the bole and branches of leaning trees of some hardwood species and characterized by the presence of gelatinous fibers and excessive longitudinal shrinkage. Tension wood fibers hold together tenaciously so that sawed surfaces usually have projecting fibers, and planed surfaces often are torn or have raised grain. Tension wood may cause warping. Contains greater amounts of cellulose and lesser amounts of lignin than normal wood.

**thermal efficiency** - the ratio of energy output of a process to the energy input.

**thermochemical conversion** - the use of heat to change substances chemically to produce energy products.

**TOC** - total organic carbon.

**TOD** - total oxygen demand, i.e., BOD plus COD.

**ton** - a short ton or 2000 lb.

**tonne** - a metric ton or 2205 lb.

**tree** - a woody plant having one well-defined stem and a more or less definitely formed crown, usually attaining a height of at least 8 ft (2.4 m).

**ultimate analysis** - the determination of the elemental composition of the organic portion of carbonaceous materials as well as the total ash and moisture. Determined by prescribed methods.

**uronic acid** - a simple sugar whose terminal  $-CH_2OH$  group has been oxidized to an acid,  $COOH$  group. The uronic acids occur as branching groups bonded to polyoses such as xylans.

**vacuum distillation** - the separation of two or more liquids under reduced vapor pressure; reduces the boiling points of the liquids being separated.

**variance** - a statistical term equal to the sum of the squares of the deviations from the mean for a given set of repeated measurements. Variances are additive. It is a measure of the precision of a set of data.

**vessels** - wood cells of comparatively large diameter that have open ends and are set one above the other so as to form continuous tubes. The openings of the vessels on the surface of a piece of wood are usually referred to as pores.

**volatile matter** - those products, exclusive of moisture, given off by a material as gas or vapor, determined by definite prescribed methods that may vary according to the nature of the material.

**wet air oxidation** - a process that operates on the principle that the rate of oxidation of organic compounds is increased at high pressures. By pressurizing an aqueous organic waste, heating it to an appropriate temperature, and then introducing air or oxygen, liquid-phase oxidation reaction is produced, destroying most of the organics.

**wet basis moisture** - the moisture content expressed as the ratio of the weight of water in the fuel to the total weight of the fuel.

**whole tree chips (WTC)** - wood chips produced by chipping whole trees, usually in the forest. Thus the chips contain both bark and wood. They are frequently produced from low quality or from tops, limbs, and other logging residues.

**whole tree harvesting** - a harvesting method in which the whole tree is removed for use, except for the stump and root system.

**wood** - a solid lignocellulosic material naturally produced in trees and some shrubs, made up of 40% to 50% cellulose, 20% to 30% hemicellulose, and 20% to 30% lignin. An empirical formula for wood is  $C_6H_9O_4$ .

**wood-oil** - the fluid products of wood pyrolysis at temperatures below about 500°C, composed of the monomers, oligomers, derivatives and fragments of the cellulose, hemicellulose, lignin, and extractives that make up biomass.

**wood-tar** - the highly viscous products of pyrolysis of wood vapors above about 600°C, often containing, among other things, polynuclear aromatics (PNAs) not originally found in biomass.

**wort** - the liquid remaining from a brewing mash preparation following the filtration of fermentable beer.

**xylem** - the portion of the tree trunk, branches, and roots that lies between the pith and the cambium.

**xylose** - a five-carbon sugar, a product of hydrolysis of some hemicelluloses; naturally occurs in many plants and trees, especially hardwood.

## References

The following sources were used in compiling the terms and definitions included in this glossary. Many of the borrowed terms have been altered based on reviewers' comments.

Agriculture Canada, n.d., *Farm-Scale Production and Use of Fuel Alcohol—Opportunities and Problems*, Ottawa, Ontario, Canada: Agriculture Canada.

American Society for Testing and Materials, 1981, *Standard Definitions of Terms Relating to Wood*, ASTM-D 9-81, Philadelphia, PA: ASTM.

American Society for Testing and Materials, 1983, *Standard Definitions of Terms and Abbreviations Relating to Physical and Chemical Characteristics of Refuse-Derived Fuel*, ASTM-E 856-83, Philadelphia, PA: ASTM.

American Society for Testing and Materials, 1983, *Standard Definitions of Terms Relating to Coal and Coke*, ASTM-D 121-78, Philadelphia, PA: ASTM.

Barton, G., 1984, Original collection of terms submitted to R. Overend of the National Research Council of Canada, unpublished.

Bonner, T., B. Desai, J. Fullenkamp, T. Hughes, E. Kennedy, R. McCormick, J. Peters, and D. Zanders, 1981, *Hazardous Waste Incineration Engineering*, Park Ridge, NJ: Noyes Data Corporation.

Bonneville Power Administration, 1985, *Pacific Northwest and Alaska Bioenergy Program Glossary*, DOE/BP-395, Washington, DC: U.S. Department of Energy.

Chandler, J., and W. Jewell, 1980, *Predicting Methane Fermentation Biodegradability*, Final report prepared by the Department of Agricultural Engineering, Cornell University, Ithaca, NY, SERI/TR-09038-1, Golden, CO: Solar Energy Research Institute.

Cheremisinoff, N., 1979, *Gasohol for Energy Production*, Ann Arbor, MI: Ann Arbor Science Publishers, Inc.

Davy McKee Corporation, 1980, *Fuel Alcohol - Report and Analysis of Plant Conversion Potential to Fuel Alcohol Production*, Prepared for the U.S. National Alcohol Fuels Commission under Contract No. T16076552, Chicago, IL: Davy McKee Corp.

Fisher, J., 1984, *Fiber Fuels - Standard Specifications Development*, Final report - Phase I, St. Paul, MN: Fiber Fuels Institute.

Gibbs, D., and M. Greenhalgh, 1983, *Biotechnology, Chemical Feedstocks and Energy Utilization*, Dover, NH: Francis Pinter for the Commission of the European Communities.

Hall, C., 1981, *Biomass as an Alternative Fuel*, Rockville, MD: Government Institutes, Inc.

Hayes, R., and G. Timbers, 1980, *Alcohol Fuels from Agriculture - A Discussion Paper*, Report I-165, Engineering and Statistical Research Institute, Ottawa, Ontario, Canada: Agriculture Canada.

International Solar Energy Society Ad-Hoc Committee Members on Standardization and Education, 1984, "Glossary of Terms Used in Solar Energy," *Solar Energy*, Vol. 33, No. 1, pp. 97-114.

Kresovich, S., C. Wagner, D. Scantland, S. Groet, and W. Lawhon, 1982, *The Utilization of Emergent Aquatic Plants for Biomass Energy Systems Development*, Prepared by Battelle Columbus, SERI/TR-98281-03, Golden, CO: Solar Energy Research Institute.

Levi, M., and M. O'Grady, 1980, *Decision Maker's Guide to Wood Fuel for Small Industrial Energy Users*, Prepared by School of Forest Resources, North Carolina State University, Raleigh, NC, SERI/TR-8234-1, Golden, CO: Solar Energy Research Institute.

National Academy of Sciences, 1980, *Firewood Crops—Shrub and Tree Species for Energy Production*, Washington, DC: National Academy of Sciences.

Palmer, L., R. McKusick, and M. Bailey, 1980, *Wood and Energy in New England - A Review and Bibliography*, Bibliographies and Literature of Agriculture No. 7, Washington, DC: USDA, Biomass, Statistics and Cooperative Services.

Sarkanen, K., and D. Tillman, editors, 1980, *Progress in Biomass Conversion Vol. 2*, New York: Academic Press.

Snyder, E., editor, 1972, *Glossary for Forest Tree Improvement Workers*, New Orleans: USDA Southern Forest Experiment Station, Forest Service.

Solar Energy Research Institute, *Fuels from Farms - A Guide to Small-Scale Ethanol Production*, 1980, SERI/SP-451-519R, Golden, CO: Solar Energy Research Institute.

Solar Energy Research Institute, 1982, *Biomass Research Highlights*, SERI/SP-281-1742, Golden, CO: Solar Energy Research Institute.

Solar Energy Research Institute, 1982, *Ethanol Fuels - Reference Guide*, SERI/SP-451-442, Golden, CO; Solar Energy Research Institute.

Timbers, G., and D. Marshall, 1981, *Biogas as a Farm Energy Source*, Report I-297, Engineering and Statistical Research Institute, Ottawa, Ontario, Canada: Agriculture Canada.

U.S. Department of Agriculture, Forest Service, n.d., *An Analysis of the Timber Situation in the United States 1952-2030*, Forest Resource Report No. 23, Washington, DC: U.S. Department of Agriculture.

U.S. Department of Energy, 1982, *Biomass Energy Technology Program Summary*, DOE/ET/20647-1, Prepared by Meridian Corporation/PRC Systems Services, Falls Church, VA, Washington, DC: U.S. Department of Energy.

U.S. Department of Energy, Biomass Energy Technology Division, 1983, *Biomass Energy Technology Annual Technical Progress Report, FY 1982*, Vol. I. Executive Summary, SERI/SP-281-2154, Golden, CO: Solar Energy Research Institute.

U.S. Department of Energy, Office of Scientific and Technical Information, 1985, *Renewable Energy - A Glossary*, DOE/TIC-11617, Oak Ridge, TN: U.S. DOE Office of Scientific and Technical Information.

U.S. National Alcohol Fuels Commission, 1980, *Fuel Alcohol on the Farm - A Primer on Production and Use*, Washington, DC: U.S. National Alcohol Fuels Commission.

Wilcox, R., compiler, 1983, *Energy Conversion and Utilization Technologies Program, Chemical Processes Project Report FY 1982*, JPL-PUB-83-58, Pasadena, CA: Jet Propulsion Laboratory. (Also DOE/CS/66001-1, Washington, DC: U.S. Department of Energy.)

World Energy Conference, 1983, *Energy Terminology, A Multi-Lingual Glossary: A Glossary for Engineers, Research Workers, Industrialists, and Economists*, NY: Pergamon Press.

## Selected Readings

Although the publications on the following list were not used in compiling this glossary, they may be of interest to the audience addressed here and may be consulted for special interests.

American Society for Testing and Materials, 1982, *Compilation of ASTM Standard Definitions*, Philadelphia, PA: ASTM.

American Society for Testing and Materials, n.d., *Excerpts from Standard for Metric Practice*, ASTM-380, Philadelphia, PA: ASTM.

American Society for Testing and Materials, 1980, *Standard Nomenclature of Domestic Hardwoods and Softwoods*, ASTM-D 1165-80, Philadelphia, PA: ASTM.

American Society for Testing and Materials, n.d., *Standard Terminology Relating to Biomass Fuels*, ASTM E1126-86, Philadelphia, PA: ASTM.

American Society for Testing and Materials, n.d., *Thesaurus on Resource Recovery Terminology*, ASTM STP-832, Philadelphia, PA: ASTM.

Association Francaise de Normalisation, n.d., *Wood: Timber Glossary*, AFNOR NF B50-002-61, Paris: AFNOR.

Association Francaise de Normalisation, n.d., *Wood: Vocabulary*, AFNOR NF B50-003-85, Paris: AFNOR.

Canadian Standards Association, n.d., *Manual of Terms and Definitions Recommended for Use in CSA Wood Standards*, CSA 0414-M1986, Rexdale, Ontario, Canada; CSA.

Dravo Corporation, 1980, *Synfuels Glossary*, Pittsburgh, PA: Dravo Corporation.

Drew, A.P., L. Zsuffs, and C. P. Mitchell, 1987, "Terminology Relating to Woody Plant Biomass and Its Production," *Biomass* 128:79-82.

Fowler, J. M., and K. C. Kryger, 1977, *Alternative Energy Sources - A Glossary of Terms*, Factsheet No. 18, Washington, DC: National Science Teachers Association.

Gold, V., K. L. Loening, A.D. McNaught, and P. Sehmi, compilers, 1987, *Compendium of Chemical Terminology: International Union of Pure and Applied Chemistry Recommendations*, London: Blackwell Scientific Publications.

Harmathy, T. Z., 1984, "Burning, Pyrolysis, Combustion and Char-oxidation: Need for Clarifying Terminology," *Fire and Materials* 8(4):224-226.

International Association of Wood Anatomists, Committee on Nomenclature, 1964, *Multilingual Glossary of Terms Used in Wood Anatomy*, Winterthur: Verlaganstadt Buchdruckerei Konkordia.

"IUPAC Recommendations on Nomenclature and Symbols and Technical Reports from Commissions," September 1988, *Pure and Applied Chemistry* 60(9):1385-1461.

Japanese Industrial Standards, n.d., *Glossary of Terms Used in the Pulp and Paper Industry*, JIS P 0001-79, Tokyo: JIS.

"List of Symbols with Units Recommended for Use in Biotechnology," 1982, *Pure and Appl. Chem.* 54(5):1743-1749.

Nentwig, K., compiler, 1985, *Elsevier's Dictionary of Solar Technology* (in English, German, French, Spanish, and Italian), NY: Elsevier Science Publishing Co., Inc.

Secretariat of the European Parliament, 1982, *Terminology of New and Renewable Sources of Energy* (English, French, Italian, German, Dutch, and Danish indexes), Luxemburg.

Sicard-Lussier, T., 1984, *Harvesting of Forest Biomass for Energy - A Terminology Study*, ENFOR P-280, Ottawa, Ontario, Canada: Forest Engineering Research Institute of Canada.

Stanek, W., 1974, *Peatland Terminology: A List of Terms and Definitions*. Final Report of the I.U.F.R.P. Working Group. SI.05.1.

*Terminology on the Characteristics of Fuel Peat and Coal*, 1983, SARJA D:42, Helsinki, Finland: Valtion Teknillinen Tutkimuskeskus, Poltto-Ja Voiteluainelaboratorio.

*Thesaurus of Scientific, Technical, and Engineering Terms*, 1988, New York: Hemisphere Publishing Corp.

Worley, I. A., 1983, "A Terminology of Virgin Peat and Peatlands," In *Symposium on Peat Utilization*, edited by C. H. Fuchsman and S. A. Spigarelli, pp. 75-102.

## INDEX OF STANDARDS BY ORGANIZATION

<b>Association Francaise de Normalisation</b>		<b>Association of Official Analytical Chemists (con't)</b>	
NF B 51-003-85	9	AOAC 3.040	77
NF B 51-004-85	93	AOAC 3.041	78
NF B 51-005-85	21	AOAC 3.044	78
NF T 12-007-87	127	AOAC 3.045	78
NF T 12-008-87	123	AOAC 3.049	78
NF T 12-010-87	127	AOAC 3.052	78
NF T 12-014-61	127	AOAC 3.054	78
NF T 12-019-87	127	AOAC 3.061	78
NF T 12-028-87	105	AOAC 3.066	78
NF T 90-103-75	251	AOAC 3.067	78
NF X 11-500-85	27	AOAC 3.068	78
NF X 11-507-70	27	AOAC 3.069	71
NF X 11-666-84	27	AOAC 3.070	71
NF X 11-671-81	27	AOAC 3.071	71
		AOAC 3.072	71
<b>American Gas Association</b>		AOAC 3.073	71
AGA Z223.1-84	239	AOAC 3.074	71
		AOAC 3.075	71
<b>American Institute of Chemical Engineers</b>		AOAC 3.081	71
AIChE E20-80	259	AOAC 3.082	71
		AOAC 3.095	78
<b>Association of Official Analytical Chemists</b>		AOAC 3.097	79
AOAC 112	79	AOAC 3.098	79
AOAC 113	79	AOAC 3.101	79
AOAC 2.198	9	AOAC 3.102	79
AOAC 2.199	9	AOAC 3.108	67
AOAC 2.200	93	AOAC 3.109	67
AOAC 2.201	93	AOAC 3.110	67
AOAC 2.202	27	AOAC 3.111	67
AOAC 2.207	105, 179	AOAC 3.112	155
AOAC 2.208	105, 179	AOAC 3.115	155
AOAC 2.209	105, 179	AOAC 3.116	155
AOAC 2.210	179	AOAC 3.118	155
AOAC 2.211	61, 179	AOAC 3.119	155
AOAC 2.212	93, 179	AOAC 3.120	155
AOAC 2.213	93, 179	AOAC 3.122	155
AOAC 2.214	93, 179	AOAC 3.124	163
AOAC 2.216	179	AOAC 3.125	163
AOAC 2.217	179	AOAC 3.126	163
AOAC 2.218	179	AOAC 3.127	163
AOAC 2.219	179	AOAC 3.128	155
AOAC 2.220	179	AOAC 3.130	127
AOAC 2.221	179	AOAC 3.131	127
AOAC 2.222	179	AOAC 3.132	127
AOAC 2.223	179	AOAC 3.133	127
AOAC 2.224	179	AOAC 3.134	127
AOAC 2.225	179	AOAC 7.001	9
AOAC 3.001	9	AOAC 7.003	93
AOAC 3.002	9	AOAC 7.004	93
AOAC 3.003	93	AOAC 7.005	93
AOAC 3.004	105	AOAC 7.006	93
AOAC 3.005	105	AOAC 7.007	93
AOAC 3.006	77	AOAC 7.009	105
AOAC 3.013	77	AOAC 7.010	163
AOAC 3.017	77	AOAC 7.015	163
AOAC 3.018	77	AOAC 7.016	163
AOAC 3.019	77	AOAC 7.021	163
AOAC 3.029	77	AOAC 7.025	163
AOAC 3.033	77	AOAC 7.033	163
AOAC 3.035	77	AOAC 7.066	169
AOAC 3.038	77	AOAC 7.067	169
AOAC 3.039	77	AOAC 7.068	169

**Association of Official Analytical Chemists (con't)**

AOAC 7.069	169
AOAC 7.070	169
AOAC 7.071	169
AOAC 7.072	169
AOAC 7.073	169
AOAC 7.074	127, 169
AOAC 7.075	127, 169
AOAC 7.076	127, 169
AOAC 7.077	127, 169
AOAC 7.078	155
AOAC 7.084	155
AOAC 7.085	155
AOAC 7.090	123
AOAC 7.091	156
AOAC 7.093	105
AOAC 7.094	105
AOAC 7.095	105
AOAC 7.096	105
AOAC 7.097	105
AOAC 7.098	105
AOAC 7.099	105
AOAC 7.100	105
AOAC 7.101	79
AOAC 7.102	106
AOAC 7.104	71
AOAC 7.106	71
AOAC 7.109	79
AOAC 7.110	79
AOAC 7.111	79
AOAC 7.114	71
AOAC 7.119	71
AOAC 7.121	79
AOAC 7.123	79
AOAC 7.125	79

**Association of Pellet Fuel Industries  
APFI PF-1-88**

193

**American Public Health Association  
16th Edition**

251

**American Petroleum Institute  
Petroleum Measurements Standards  
Manual**

207

**Australian and New Zealand Pulp and Paper  
Industry Technical Association**

Appita P1s:79	21
Appita P2m-73	9
Appita P3s:78	106
Appita P4m-61 (1981)	139
Appita P5m-68 (1981)	139
Appita P6rp-78	127
Appita P7m-70	139
Appita P8m-59	139
Appita P9m-68	119
Appita P10rp-86	93
Appita P11s:1978	128
Appita P12s-79	139
Appita P200m-77	94
Appita P201m-86	128
Appita P204m-56	105
Appita P210m-69	139
Appita P401s-78	94
Appita P403 rp-73	305

**Australian and New Zealand Pulp and Paper  
Industry Technical Association (con't)**

Appita P408m-70	61
Appita P410m-56	105
Appita P417m-73	9
Appita P418s:78	106

**American Society of Agricultural Engineers**

ASAE D241.3	21, 94
ASAE D243.3	45
ASAE D245.4	94
ASAE EP285.7	305
ASAE S269.3	94, 193
ASAE S319.1	27
ASAE S352.2	94
ASAE S358.2	94
ASAE S424	27

**American Society of Mechanical Engineers**

ASME MFC-1M-1979	317
ASME MFC-2M-1983	317
ASME MFC-3M-1985	317
ASME PTC 3.1-58	207
ASME PTC 3.2-54	193
ASME PTC 3.3-69	239
ASME PTC 4.1-64	271
ASME PTC 4.3-68	271
ASME PTC 6S-70	271
ASME PTC 16-58	279
ASME PTC 17-73	271
ASME PTC 19.1-85	305
ASME PTC 19.2-64	317
ASME PTC 19.3-74	317
ASME PTC 19.7-80	271
ASME PTC 19.10-81	259
ASME PTC 19.16-65	21
ASME PTC 19.17-65	207
ASME PTC 21-41	259
ASME PTC 22-85	271
ASME PTC 28-65	259
ASME PTC 33-78	271
ASME PTC 38-80	259

**American Society for Testing and Materials**

ASTM C 177-85	45
ASTM C 518-85	45
ASTM C 1067-87	305
ASTM D-2 Proposal P 104	227
ASTM D 56-87	207
ASTM D 70-82 (1986)	21
ASTM D 86-82	207
ASTM D 88-81 (1987)	207
ASTM D 92-85	207
ASTM D 93-85	208
ASTM D 95-83	94
ASTM D 96-73 (1984)	95
ASTM D 97-87	208
ASTM D 121-85	193
ASTM D 129-64 (1978)	67
ASTM D 130-83	208
ASTM D 167-73 (1979)	193
ASTM D 189-88	208
ASTM 194RO	227
ASTM D 197-82 (1987)	28
ASTM D 216-77 (1982)	208
ASTM D 240-87	39

American Society for Testing and Materials Con't

ASTM D 246-84	243
ASTM D 285-62 (1978)	209
ASTM D 287-82 (Reapproved 1987)	21
ASTM D 293-69 (1980)	28
ASTM D 311-84	28
ASTM D 323-82	209
ASTM D 346-78	9
ASTM D 396-86	209
ASTM D 409-85	193
ASTM D 410-84	28
ASTM D 431-84	28
ASTM D 439-86	209
ASTM D 440-86	193
ASTM D 441-86	194
ASTM D 445-86	210
ASTM D 473-87	210
ASTM D 482-87	106
ASTM D 525-86	210
ASTM D 547-41 (1980)	194
ASTM D 583-63 Discontinued	106
ASTM D 588-42 (1971) Discontinued	117
ASTM D 613-86	210
ASTM D 644-88	95
ASTM D 664-87	210
ASTM D 665-82	211
ASTM D 803-82 (1987)	139
ASTM D 804-79 (1987)	140
ASTM D 856-49 (1987)	140
ASTM D 909-86	211
ASTM D 974-87	211
ASTM D 975-81	211
ASTM D 982-65 (1971)	61
ASTM D 1018-87	53
ASTM D 1033-76	80
ASTM D 1035-76 (1987)	80
ASTM D 1070-85	22
ASTM D 1071-83	239
ASTM D 1072-80	67
ASTM D 1078-86	212
ASTM D 1102-84	106
ASTM D 1103-60 (1977) Discontinued	117
ASTM D 1104-56 (1978) Discontinued	117
ASTM D 1105-84	10, 140
ASTM D 1107-84	140
ASTM D 1108-84	140
ASTM D 1109-84	141
ASTM D 1110-84	141
ASTM D 1142-86	95
ASTM D 1159-84	212
ASTM D 1160-87	212
ASTM D 1161-70 (1974)	72
ASTM D 1166-84	151
ASTM D 1247-80 (Discontinued 1987)	239
ASTM D 1252-88	251
ASTM D 1293-84	251
ASTM D 1298-85	22
ASTM D 1310-86	212
ASTM D 1319-84	213
ASTM D 1326-76 (1987)	80
ASTM D 1348-61 (1985)	95
ASTM D 1356-73a (1979)	259
ASTM D 1481-81	22
ASTM D 1506-85	107
ASTM D 1605-60 (1979)	259
ASTM D 1608-77 (1985)	259

American Society for Testing and Materials Con't

ASTM D 1613-85	243
ASTM D 1619-86	67
ASTM D 1627-71 (1987)	80
ASTM D 1628-83	80
ASTM D 1655-88	213
ASTM D 1695-77 (1983)	117
ASTM D 1696-61 (1985)	117
ASTM D 1704-78	260
ASTM D 1716-82 (1987)	118
ASTM D 1744-83	95
ASTM D 1757-86	68
ASTM D 1762-84	194
ASTM D 1787-62 (1985)	123
ASTM D 1794-62 (1985)	141
ASTM D 1795-62 (1985)	118
ASTM D 1796-83	96
ASTM D 1826-88	39
ASTM D 1857-68 (1987)	194
ASTM D 1888-78	251
ASTM D 1914-68 (1983)	260
ASTM D 1915-63 (1985)	118
ASTM D 1926-63 (1985)	151
ASTM D 1946-82	239
ASTM D 2009-65 (1979)	260
ASTM D 2013-72 (1986)	10
ASTM D 2014-85	45
ASTM D 2015-85	39
ASTM D 2016-74 (1983) (Withdrawn 1988)	96
ASTM D 2019-65 (1970) Discontinued	107
ASTM D 2044-68 (1974) (Discontinued)	96
ASTM D 2156-80	213
ASTM D 2161-87	213
ASTM D 2196-81	214
ASTM D 2234-82 (1986)	10
ASTM D 2270-86	214
ASTM D 2361-85	72
ASTM D 2382-83	39
ASTM D 2395-83	22
ASTM D 2425-83	214
ASTM D 2427-87	214
ASTM D 2438-68 (1985)	107
ASTM D 2492-84	68
ASTM D 2500-86	215
ASTM D 2502-87	215
ASTM D 2503-82 (1987)	215
ASTM D 2504-88	325
ASTM D 2549-85	215
ASTM D 2579-85	251
ASTM D 2639-74 (1985)	195
ASTM D 2641-70 (1985)	72
ASTM D 2650-83	239
ASTM D 2652-76 (1987)	243
ASTM D 2699-86	216
ASTM D 2700-86	216
ASTM D 2717-86	45
ASTM D 2766-86	46
ASTM D 2777-86	305
ASTM D 2786-86	216
ASTM D 2789-86	216
ASTM D 2795-86	107
ASTM D 2854-83	23
ASTM D 2862-82 (1987)	29
ASTM D 2866-83	107
ASTM D 2867-83	96
ASTM D 2879-86	217

American Society for Testing and Materials Cont'd

ASTM D 2885-86	217
ASTM D 2886-86	217
ASTM D 2887-84	217
ASTM D 2889-86	218
ASTM D 2890-87	46
ASTM D 2892-84	218
ASTM D 2896-85	218
ASTM D 2908-74 (1987)	252
ASTM D 2910-85	252
ASTM D 2929-70 (1985)	68
ASTM D 2961-87	97
ASTM D 2973-71 (1981)	61
ASTM D 2974-87	179
ASTM D 2976-71 (1981)	180
ASTM D 2988-86	72
ASTM D 3038-72 (1983)	195
ASTM D 3162-78	260
ASTM D 3173-87	97
ASTM D 3172-73 (1984)	89
ASTM D 3174-88	108
ASTM D 3175-82	89
ASTM D 3176-84	53
ASTM D 3177-84	68
ASTM D 3178-84	53
ASTM D 3179-84	61
ASTM D 3180-84	195
ASTM D 3195-73 (1985)	317
ASTM D 3211-79	261
ASTM D 3231-83	218
ASTM D 3237-79 (1984)	219
ASTM D 3239-86	219
ASTM D 3245-85	219
ASTM D 3249-79	261
ASTM D 3250-77 (1982)	252
ASTM D 3286-85	40
ASTM D 3302-82	97
ASTM D 3365-77 (Discontinued)	261
ASTM D 3370-82	253
ASTM D 3402-81	195
ASTM D 3416-78	261
ASTM D 3457-87	175
ASTM D 3507-86	183
ASTM D 3516-76 (1985)	108
ASTM D 3588-81	240
ASTM D 3590-84	61
ASTM D 3670-81	305
ASTM D 3682-87	81
ASTM D 3683-78 (1983)	81
ASTM D 3685-78	262
ASTM D 3686-84	262
ASTM D 3687-84	262
ASTM D 3701-87	53
ASTM D 3710-83	219
ASTM D 3797-88	220
ASTM D 3828-87	220
ASTM D 3838-80 (1986)	243
ASTM D 3922-80	243
ASTM D 3971-80 (1985)	141
ASTM D 4006-81 (1987)	97
ASTM D 4007-81 (1987)	98
ASTM D 4052-86	23
ASTM D 4084-82	240
ASTM D 4085-81 (1987)	81
ASTM D 4096-82	262
ASTM D 4128-82	253

American Society for Testing and Materials Con't

ASTM D 4150-84	240
ASTM D 4182-87a	306
ASTM D 4208-88	72
ASTM D 4210-83	306
ASTM D 4239-85	69
ASTM D 4278-83	81
ASTM D 4278-88	108
ASTM D 4326-84	81
ASTM D 4377-86	98
ASTM D 4442-84	98
ASTM D 4486-85	220
ASTM D 4536-86a	263
ASTM D 4607-87	244
ASTM D 4621-86	306
ASTM D 4625-86	220
ASTM D 4626-86	240
ASTM D 4629-86	62
ASTM D 4657-87	253
ASTM D 4749-87	29
ASTM D 4806-88	227
ASTM D 4807-88	220
ASTM D 4808-88	53, 220
ASTM D 4809-88	40
ASTM D 4814-88	221
ASTM D 4815-88	221
ASTM D 4868-88	221
ASTM D 4874	247
ASTM E 1-88	317
ASTM E 11-87	29
ASTM E 69-80	295
ASTM E 105-58 (1975)	11
ASTM E 122-72 (1979)	11
ASTM E 131-88	333
ASTM E 137-82 (1987)	333
ASTM E 141-69 (1975)	11
ASTM E 144-64 (1987)	40
ASTM E 161-87	29
ASTM E 169-87	333
ASTM E 177-86	306
ASTM E 178-80	307
ASTM E 203-86	98
ASTM E 204-78 (1984)	333
ASTM E 220-86	317
ASTM E 230-87	318
ASTM E 235-82	318
ASTM E 258-67 (1987)	62
ASTM E 260-85	325
ASTM E 304-81 (1987)	334
ASTM E 323-80 (1985)	30
ASTM E 380-86	307
ASTM E 386-78 (1984)	334
ASTM E 437-85	30
ASTM E 452-83	318
ASTM E 454-80 (1985)	30
ASTM E 456-88	307
ASTM E 472-86	46
ASTM E 473-85	46
ASTM E 537-86	47
ASTM E 582-88	295
ASTM E 585-88	318
ASTM E 594-77	325
ASTM E 644-86	319
ASTM E 659-78 (1984)	295
ASTM E 663-86	334
ASTM E 691-87	307

<b>American Society for Testing and Materials Con't</b>		<b>British Standards Institution Con't</b>	
ASTM E 711-81	40	BS 1846:--Part 1:1968	271
ASTM E 775-87	69	BS 1846:--Part 2:1969	271
ASTM E 776-87	73	BS 2000 (Many Parts)	221
ASTM E 777-87	54	BS 2074:1967	31
ASTM E 778-87	62	BS 2511:1970	99
ASTM E 790-81 (1987)	98	BS 3156	241
ASTM E 791-87	195	BS 3405:1983	263
ASTM E 793-81 (1985)	47	BS 3406	263
ASTM E 828-81	30	BS 3406--Part 1:1986	32
ASTM E 829-81	11	BS 3631:1984	109
ASTM E 830-87	108	BS 4289	175
ASTM E 856-87	196	BS 4314:Part 1:1968	241
ASTM E 869-82 (1987)	283	BS 4496:1984	109
ASTM E 870-82 (1987)	196	BS 4498:1982	128
ASTM E 871-82 (1987)	99	BS 4499:1984	141
ASTM E 872-82 (1987)	89	BS 4896:1973	109
ASTM E 873-87	23	BS 4937	319
ASTM E 885-88	82	BS 6306:1982	183
ASTM E 886-88	82		
ASTM E 887-88	108	<b>Code of Federal Regulations Versus</b>	
ASTM E 889-82 (1988)	12	18 CFR 707	254
ASTM E 897-88	89	30 CFR 823	184
ASTM E 899-82 (1987)	308	40 CFR 50	264
ASTM E 914-83 (1987)	319	40 CFR 53	264
ASTM E 918-83	295	40 CFR 60	264
ASTM E 926-88	82	40 CFR 61	265
ASTM E 949-88	99	40 CFR 69	265
ASTM E 953-88	196	40 CFR 79	223
ASTM E 954-83 (1988)	12	40 CFR 80	223
ASTM E 955-83 (1988)	47	40 CFR 116	254
ASTM E 959-83 (1988)	196	40 CFR 117	254
ASTM E 1037-84	31	40 CFR 129	254
ASTM E 1076-85	196	40 CFR 131	254
ASTM E 1107-86	197	40 CFR 257	247
ASTM E 1108-86	197	40 CFR 430	254
ASTM E 1109-86	23		
ASTM E 1117-86	283	<b>Canadian Gas Association</b>	
ASTM E 1126-86	197	CAN1-2.27-M84	272
ASTM E 1131-86	47	CAN/CGA-B105-M87	283
ASTM E 1183 (1987)	99		
ASTM E 1183-87	12	<b>Canadian Pulp and Paper Association</b>	
ASTM E 1225-87	48	CPPA A.1H	23
ASTM E 1260-88	31	CPPA A.2	99
ASTM E 1269	48	CPPA A.8P	24
ASTM E 1288-89	197	CPPA D.18H	183
ASTM STP 832	12	CPPA G.1	100
		CPPA G.3	100
<b>American Water Works Association</b>		CPPA G.4 AND G.5	141
16th Edition	251	CPPA G.6 AND G.7	142
		CPPA G.8	128
<b>British Standards Institution</b>		CPPA G.9	128
BS 410:1986	31	CPPA G.10	109
BS 627:1982	12, 175	CPPA G.11	109
BS 631:1967	175	CPPA G.12	123
BS 651:1967	175	CPPA G.13	142
BS 653:1967	175	CPPA G.14	142
BS 684:Part 0:1982	175	CPPA G.15	142
BS 1016 (Many Parts)	197	CPPA G.16	129
BS 1017:1977 (Parts 1 and 2)	13	CPPA G.17H	129
BS 1038	183	CPPA G.18	129
BS 1041	319	CPPA G.20	142
BS 1042	319	CPPA G.24P	118
BS 1293	31	CPPA G.26	119, 142
BS 1301	183	CPPA G.27P	119
BS 1469:1962	221	CPPA G.28	69

**Canadian Pulp and Paper Association Con't**

CPPA G.29P	119
CPPA G.31P	13
CPPA G.33P	109
CPPA H.2	253
CPPA H.3P	254
CPPA Useful Method D.3U-77	109
CPPA Useful Method D.12U-77	32
CPPA Useful Method D.25U	32
CPPA Useful Method D.26U	32
CPPA Useful Method D.27H	32
CPPA Useful Method G.9U-77	118

**Canadian Standards Association**

CSA Z90-1975	13
CAN 3.1-M78	222
CAN 2-3.2-M81	222
CAN 2-3.3-M85	222
CAN 3.5-M79	222
CAN 2-3.6-M83	222
CAN/CSA-B140.0-M87	272
CAN/CSA-B365-M87	272
CAN/CSA-B366.1-M87	272
CSA DIR.006-1988	273
CSA Z103-1976	273
CAN/CSA B366.2-M1984	273
CSA CAN3-Z234.1-79	308
CSA CAN3-Z234.2-76	308
CSA Z351-1980	308
CSA Z372-1980	308

**Deutsches Institut fur Normung**

<del>DIN 1340</del>	241
DIN 1942; 1979	273
DIN 1952	320
DIN 4702; 1987	273
DIN 5499	40
DIN 18800	273
DIN 18890	273
DIN 51400 (Many Parts)	222
see EN 41	69
DIN 51402 Part 1	263
DIN 51406	222
DIN 51649 (Part 1)	295
E DIN 51700	198
DIN 51700, Part 1	198
DIN 51700, Parts 2-4	198
DIN 51701 Part 2	13
DIN 51718	100
DIN 51718-78	180
DIN 51719	110
DIN 51719-78	180
DIN 51720	89
DIN 51720-78	180
DIN 51724 Parts 1-2	69
DIN 51729 Part 1	110
DIN 51729 Part 2	110
DIN 51729 Part 3	110
DIN 51729 Part 4	110
DIN 51729 Part 5	110
DIN 51729 Part 6	110
DIN 51729 Part 7	110
DIN 51729 Part 8	111
DIN 51729 Part 9	111
DIN 51729, Parts 1-9	198
DIN 51730	198

**Deutsches Institut fur Normung Con't**

DIN 51780	222
DIN 51872 Parts 1-4	241
DIN 51853	241
DIN 51900 Parts 1-3	40
DIN 54352	184
DIN 54355	184
DIN 54356	142
DIN 54357	129
DIN 54361	123

**European Committee for Standardization**

EN 41	69
see DIN 51400	222

**U.S. Environmental Protection Agency**

EPA 40 CFR 79	223
EPA 40 CFR 80	223
EPA 40 CFR 257	247
EPA/600/54-87/006	263
30 CFR 823	184
40 CFR 50	264
40 CFR 53	264
40 CFR 60	264
40 CFR 61	265
40 CFR 69	265

**USSR State Committee for Standards**

GOST 147-74	198
GOST 10650-72	180
GOST 11305-83	100
GOST 11306-83	111

**International Standards Organization**

ISO 186:1985	13
ISO 302:1981	129
ISO 331:1983	100
ISO 332:1981	62
ISO 333:1983	62
ISO 334:1975	69
ISO 351:1984	69
ISO 352:1981	73
ISO 540:1981	198
ISO 542:1980	176
ISO 556:1980	198
ISO 565-83	33
ISO 602:1983	111
ISO 609:1975	54
ISO 625:1975	54
ISO 638:1978	184
ISO 659:1979	176
ISO 664:1972	176
ISO 665:1977	176
ISO 692:1982	142
ISO 734:1979	176
ISO 760:1978	100
ISO 776:1982	111
ISO 1170:1977	184
ISO 1171:1981	111
ISO 1762:1974	111
ISO 1928:1976	41
ISO 1953:1972	33
ISO 1988:1975	13
ISO 1994:1976	57
ISO 2395:72	33
ISO 3129-75	13

<b>International Standards Organization Con't</b>			
ISO 4471-82	13		
ISO 5069-1:1983	14		
ISO 5069-2:1983	14		
ISO 5163:1972	223		
ISO 5164:1977	223		
ISO 5165:1977	223		
ISO 5507:1982	176		
ISO 5511:1984	176		
ISO 6286:1982	334		
ISO 6955:1982	335		
ISO 7213:1981	14		
ISO 7504:1984	241		
<b>Japanese Industrial Standards</b>			
JIS B 7963-79	263		
JIS K 0050-83	308		
JIS K 0095-79	263		
JIS K 0118-79	335		
JIS P 8001-1976 (1985)	14		
JIS P 8003-1976	111		
JIS P 8004-1976	143		
JIS P 8005-1976 (1985)	143		
JIS P 8007-1976 (1984)	119		
JIS P 8008-1976 (1984)	129		
JIS P 8009-1976 (1984)	143		
JIS P 8010-1976 (1984)	143		
JIS P 8011-1976	123		
JIS P 8012-1976 (1984)	119		
JIS P 8013-1976	151		
JIS P 8015-1976	100		
JIS Z 2120-58	295		
<b>National Fire Protection Association</b>			
NFPA SEC APPB	297		
NFPA SEC 4-1	296		
NFPA SEC 4-3	296		
NFPA SEC 4-4	296		
NFPA SEC 5-2	296		
NFPA SEC 5-9	296		
NFPA SEC 10-1	296		
NFPA SEC 10-11	296		
NFPA SEC 10-12	296		
NFPA SEC 10-14	297		
NFPA SEC 11-8	297		
NFPA SEC 12-9	297		
NFPA SEC 16-5	297		
NFPA Pt2 Ch7	297		
NFPA Pt2 Ch12	297		
NFPA Pt2 Ch14	297		
NFPA Pt3 Ch32	298		
NFPA Pt3 Ch33	298		
NFPA Pt3 Ch34	298		
NFPA Pt4 Ch42	298		
NFPA 37-84	298		
NFPA 46-85	298		
NFPA 46A-1973	198		
NFPA 50-85	298		
NFPA 54-88	298		
NFPA 61B-89	299		
NFPA 61C-89	299		
NFPA 61D-84	299		
NFPA 85A-87	299		
NFPA 85B-84	299		
NFPA 85D-84	299		
NFPA 85E-85	299		
<b>National Fire Protection Association Con't</b>			
NFPA 85F-88	299		
NFPA 85G-87	300		
NFPA 97M-88	273		
NFPA 211-88	273, 300		
NFPA 259-87	300		
NFPA 263-86	300		
NFPA 321-87	300		
NFPA 664-87	300		
<b>Standards Association of Australia</b>			
AS P4m-61	143		
AS 1038	198		
AS 1301	139		
AS 1301, P3s:1978	106		
AS 1301, p6rp:1978	127, 129		
AS 1301, P9m:1968	119		
AS 1301, P10rp:1986	93		
AS 1301, P11s:1978	130		
AS 1301, P12s-79	143		
AS 1301, P200m:1977	94		
AS 1301, P201m:1986	128		
AS 1301, P418s:1978	106		
AS 1301, 005s-1967	139		
<b>Standards Association of New Zealand</b>			
NZS 535	33		
NZS 2175:1967	33		
NZS 5201:1973	264		
NZS 5201C:1975	264		
NZS 5201M:1975	264		
NZS 5202:1979	274		
NZS 7401:1985	274		
NZS 7421:1985	274		
<b>Scandinavian Pulp, Paper and Board</b>			
SCAN-C 1:77R	130		
SCAN-C 2:61	143		
SCAN-C 3:78	184		
SCAN-C 4:61	123		
SCAN-C 6:62	111		
SCAN-C 7:62	143		
SCAN-C 8:62	144		
SCAN-C 9:62	112		
SCAN-C 10:62	83		
SCAN-C 29:72	130		
SCAN-C 30:73	83		
SCAN-G 2:63	308		
SCAN-G 3:71	119		
SCAN-G 4:72	119		
SCAN-P 1:61	14		
SCAN-P 4:63	101		
SCAN-P 5:63	111		
SCAN-P 52:84	156, 184		
SCAN-P 54:84	73		
SCAN-P 56:86	63		
SCAN-T 1:65	144		
SCAN-T 2:65	144		
SCAN-T 3:66	144		
SCAN-T 4:66	144		
SCAN-T 5:67	144		
SCAN-T 6:67	145		
SCAN-T 7:67	145		
SCAN-T 8:68	145		
SCAN-T 9:68	145		
SCAN-T 10:69	145		

**Scandinavian Pulp, Paper and Board Con't**

SCAN-T 11:72	145
SCAN-T 12:72	146
SCAN-T 13:74	146
SCAN-T 14:78	146
SCAN-T 15:78	146
SCAN-T 16:82	146
SCAN-W 1:66	254
SCAN-W 5:71	255

**Technical Association of the Pulp and Paper Industry**

TAPPI T 1 wd-75	146
TAPPI T 2 wd-72	151
TAPPI T 17 wd-70	120
TAPPI T 20 wd-85	184
TAPPI T 21 wd-82	24
TAPPI T 201 wd-76	120
TAPPI T 203 om-88	120
TAPPI T 204 om-88	146
TAPPI T 207 om-88	146
TAPPI T 208 om-84	101
TAPPI T 209 wd-79	151
TAPPI T 211 om-85	112
TAPPI T 213 om-85	112
TAPPI T 222 om-88	131
TAPPI T 223 cm-84	123
TAPPI T 229 wd-76	70, 73
TAPPI T 230 om-82	185
TAPPI T 236 cm-85	131
TAPPI T 237 om-88	152
TAPPI T 238 wd-75	120
TAPPI T 244 om-88	112
TAPPI T 245 om-88	112
TAPPI T 249 cm-85	156
TAPPI T 250 cm-85	156
TAPPI T 255 om-84	70
TAPPI T 256 cm-85	73
TAPPI T 257 cm-85	14
TAPPI T 258 om-85	101
TAPPI T 264 om-88	14
TAPPI T 265 om-87	112
TAPPI T 266 om-88	83
TAPPI T 267 cm-85	184
TAPPI T 412 om-88	102
TAPPI T 413 cm-85	113

**Technical Association of the Pulp and Paper Industry Con't**

TAPPI T 418 om-85	63
TAPPI T 429 cm-84	120
TAPPI T 635 om-82	147
TAPPI T 638 cm-85	156
TAPPI T 689 om-88	147
TAPPI Useful Method 2	24
TAPPI Useful Method 4	14
TAPPI Useful Method 5	33
TAPPI Useful Method 6	33
TAPPI Useful Method 7	101
TAPPI Useful Method 8	101
TAPPI Useful Method 9	24
TAPPI Useful Method 10	101
TAPPI Useful Method 11	113
TAPPI Useful Method 12	24
TAPPI Useful Method 13	33
TAPPI Useful Method 16	24
TAPPI Useful Method 21	33
TAPPI Useful Method 23	24
TAPPI Useful Method 201	130
TAPPI Useful Method 228	130
TAPPI Useful Method 229	130
TAPPI Useful Method 236	124
TAPPI Useful Method 245	130
TAPPI Useful Method 246	130
TAPPI Useful Method 250	130
TAPPI Useful Method 251	131
TAPPI Useful Method 254	70, 73
TAPPI Useful Method 257	147
TAPPI Useful Method 496	113

**Underwriters' Laboratories, Inc.**

UL 103	274
UL 391	274
UL 959	274
UL 1482	274
UL 1777	274

**Underwriters' Laboratories of Canada**

CAN/ULC-S604 (1982)	275
CAN/ULC-S627 (1983)	275
CAN/ULC-S629 (1987)	275
CAN/ULC-S641 (1987)	275

## SUBJECT INDEX

acetyl	153, 154	coke	9, 13, 28, 31, 33, 39, 40, 53, 54, 61, 68, 69, 81, 89, 97, 107, 108, 183, 184, 193-195, 197-199, 306
acid copper chromate	80	combustion	271-277, III-1
acid number	145	combustors	273
activated carbon	23, 29, 96, 107, 243, 244, 252, 262	compound classes	151-154
air heaters	271	copper	77, 79, 83, 108
alcohol fuels	221, 227, 232, 233	creosote	243
aldehydes	103, 232	crude oil	95, 97, 98, 210, 220
algae see: microalgae		density	21-25, 94, 101, 145
alkoxyl	154	diesel fuel	39, 40, 207, 210, 211, 222, 223
aluminum	77	dirt	105-115
ammoniacal copper arsenate	80	distillates	46, 53, 212-214, 218, 220, 222
anaerobic digestion	247, 249, 283, 285	dry matter	184
animal fat	12, 175, 297	dust	296, 299, 301
animal feed	9, 27, 71, 79, 93, 105, 123, 127, 155, 156, 163, 169, 299	enzymatic assays	289-292
aqueous waste see: wastewater		enzymology	290, 291
arsenic	78, 85, 108, 199	ethanol	227, 233
ash	68, 81, 82, 105-115, 145, 179, 180, 194, 198, 199, 201, 202, III-1	extractives	139-150
atmospheric analysis	259-267	fats	13, 177
aviation fuels	53, 211, 213, 216, 223	fatty acid	175
beta-glucosidase	390	feedstock preparation see: preparation	
bioconversion	283-286	feedstock sampling see: sampling	
biological oxygen demand (BOD)	251, 253, 255	fermentation	283
biomass	1, 23, 43, 91, III-1	fiber	17, 119, 127, 169
biotechnology	286	fire	295-301
bituminous materials	21, 28, 94	flammability	295-301
boilers	272, 273, 277, III-1	flash point	145, 207, 212, 220
boron	78, 85	flow	317-322
calcium	77, 79, 83, 105	fluor-chrome-arsenate-phenol	80
carbohydrates	9, 135, 155-162, 232	fluoride	71
carbon	53, 54, 55, 251	fluorine	71, 85
carbon black	67, 107	forage	27, 94, 169-171
carbon dioxide	264	fossil fuels	91
carbon monoxide	260, 261, 267	Fourier-Transfer Infrared Spectrometry see: spectrometry	
carboxyl	151, 152	fructose	155
carboxylic acids	231, 232	functional groups	151-154
cellobiase	290	furfural	123, 154
cellobiohydrolase	291	furnaces	272, 296, 298-300
cellulase	289, 290, 292	galactan	156
cellulose	37, 68, 72, 81, 95, 107, 108, 117-121, 123, 127, 141, 151, 171, 183, 231, 290, 291	gas turbines	39, 40, 271, 298
charcoal	194	gaseous fuels	22, 95, 239-241
chemical oxygen demand (COD)	251, 254	gases	39, 67, 259, 297, 322
chimneys	272, 273, 274, 275, 300	gasification	235, 236, 273, 279-282
chitin	291	gasohol	227, 233
chloride	71, 72, 73	gasoline	39, 40, 208-210, 214, 216, 218, 219, 221, 222, 227
chlorine	71-73, 75, 85, 199	glucose	155, 158, 161
chromated copper arsenate	80	glycerol	154
chromated zinc chloride	80	grain	21, 45, 94
chromatography	118, 134, 135, 156-160, 175, 204, 214, 215, 217, 219-221, 229, 232, 239, 240, 252, 253, 261, 264, 281, 325-329, 338	halide	72, 75
chromium	85, 108	halogen analysis	71-75
coal	10, 13, 14, 28, 29, 31, 33, 39, 40, 45, 53, 54, 61, 62, 68, 69, 72, 81, 89, 91, 97, 100, 107, 108, 111, 183, 184, 193-195, 197-199, 201, 202, 221, 233, 243, 306, III-1	Halse lignin	127, 129
cobalt	77, 79	heating values	201
		heats of combustion	39-43, 221
		hemicellulose	123-125, 290
		hexuronic acid	153
		holocellulose	117-121

hydrocarbons	39, 62, 213-216, 234, 253, 261, 325
hydrogen	53-55
hydrolysis	138
hydroxyl	137
incinerators	271-274, 277
inorganics	77-85, 182
internal combustion engines	271
International System of Units (SI)	305, 307, 308
iodine	71
iron	77, 83
itaconic acid	154
Kappa number	128-131, 133
kerosine	39, 40, 222
ketones	103, 232
Klason lignin	127, 133
knock	211, 216, 217, 223
lactic acid	154
lead	219
levulinic acid	154
lignins	127-138, 169, 171, 290, 291
lignite	14, 91, 198, 201, 205, III-1
lipids	173
liquefaction	229, 233, 235-237
liquid fuels	103, 222, 227-237
liquid waste	251-257
liquids	21, 23, 31, 45, 46, 210, 220
magnesium	77
manganese	77, 79, 83
mass spectrometry	135, 137, 204, 205, 214, 216, 219, 239, 253, 308, 333-335, 338
measurements	305-313
mercury	85
metals	77-85
methane	261, 285
methoxyl	151, 153
methyl	154
microalgae	173, 174
mineral matter	105-115, 199
minerals	9, 105
moisture	14, 21, 24, 61, 91, 93-104, 145, 176, 179, 180, 199, 201, 264
molybdenum	78
monosaccharides	159, 160
motor fuels	216, 217, 223
municipal solid waste (MSW)	43
nitrogen	163, 179
nitrogen analysis	61-65
nitrogen oxides	259, 264
nuclear magnetic resonance (NMR) spectrometry	see: spectrometry
octane	217
oils	22, 53, 69, 96, 177, 201
oilseeds	175-177
organic acids	232
organic matter	179
organic solvents	72, 139, 149
oxygen	57, 263, 264
oxygen analysis	57-59
oxygenated liquid fuels	221, 227-237
paper	9, 14, 61, 70, 72, 73, 75, 83, 94-96, 100-102, 105-107, 109, 113, 117, 119, 120, 127, 142, 143, 159, 183, 188, 254, 297
paperboard	9, 13, 14, 61, 63, 95, 96, 101, 102, 106, 107, 109, 112, 142, 254
paraffin	142
particle size	27-35, 259, 261, 263
particulates	251, 260-264
peat	9, 15, 27, 61, 91, 93, 105, 111, 179-182, 201, 235
pectic substances	291
pentose	123, 124, 157, 158
permanganate number	127, 130, 131, 254
petroleum	21, 22, 53, 62, 67, 94, 95, 106, 207-225
phenol	137
phosphate	108
phosphorus	78, 79, 82, 199, 218
pitch	142, 145
plankton	157
plants	9, 16, 67, 71, 77, 93, 105, 127, 153, 155, 160, 163
polysaccharides	159, 231
pore size	37, 193
potassium	78
powders	27, 32
preparation	7, 9-17, 155, 181, 182
pressure	218, 317-322
pressure vessels	271
proteins	163-166
proximate analysis	89-91, 199, 201
pulp	9, 14, 70, 73, 75, 82, 83, 85, 94, 99-101, 104-106, 109, 111, 112, 115, 119, 120, 123, 127-130, 133, 136, 138-139, 141-143, 146, 149, 151, 159, 183-185, 254, 297
pulpwood	14-16, 24, 32, 33
pyrolysis	135, 137, 181, 182, 202-204, 229-237
quality assurance	257, 305-313
rape seed oil	175
reference materials	1, 103
refuse-derived fuel (RDF)	11, 12, 30, 31, 40, 47, 54, 62, 69, 73, 82, 89, 98, 99, 108, 195, 196
resins	13, 149
Ringlemann chart	261, 264
round-robin tests	305-313
salts	105
sampling	7, 9-17, 145, 175, 239, 241, 253, 259, 262, 263, 267, 277, 281, 282, 306
sand	105, 179
saponification	146
sawdust	100, 151
seeds	94
selenium	79
sieving	27-35
silica	105, 107, 108, 111
sludge	16, 249, 257, 285
sodium	78, 83
sodium hydroxide	117
soil	16, 137, 182
solid fuels	13, 41, 69, 73, 82, 89, 100, 110, 193-205, 271, 297, 300
solid waste	12, 23, 43, 247-249

solids	21, 37, 46	thermocouples	312, 317-319, 321, 322
solubility	119, 139, 141-143, 146, 149	ultimate analysis	53-55, 199, 201
space heaters	273, 275	units	305-313
specific gravity	21-25, 94, 193, 240	uronic acid	153, 154
spectrometry	53, 83, 133, 134, 137, 176, 182, 202, 204, 219, 230, 231, 260, 281, 333-341	vapor pressure	208
spectroscopy see: spectrometry		vegetable oil	12, 175, 177, 297
spectrophotometry	77, 81, 82, 85, 136, 264	viscosity	118, 145, 183, 185, 207, 210, 213-215, 220
standards organizations	II-1	volatile matter	89, 91, 176, 180, 201, 252, 265
starch	63, 155, 156, 160, 184	wastewater	173, 251, 257, 285
statistics	308, 311	water see: moisture	
steam generators	271, 273	wood	9, 10, 13-15, 17, 21-25, 35, 37, 75, 81, 85, 89, 93, 94, 96, 99, 103, 104, 106, 108, 109, 112, 115, 117, 119-121, 125, 127-130, 133, 136-139, 141, 146, 149-151, 153, 161, 183, 187, 188, 229, 232, 295, 296, 300
steam turbines	271	wood chips	14, 15, 21, 24, 33, 35, 37, 93, 100, 101, 109, 112, 113, 183, 198, 234, 273
stoves	272, 273	xylanase	289, 290, 292
straw	13	zinc	78, 85, 108
sucrose	155		
sugars	155-162		
sulfates	73		
sulfur analysis	67-70, 75, 199		
sulfur dioxide	264		
tall oil	139, 144-147, 149		
tars	140, 281		
temperature	317-322		
thermal properties	19, 45-49		

**PRODUCED BY THE**

**Solar Technical Information Program,  
U.S. Department of Energy,  
with joint funding from the  
International Energy Agency,  
Energy, Mines and Resources Canada,  
and the Solar Energy Research Institute**

A Product of the  
Development and Communications  
Office



**Solar Energy Research Institute**  
A Division of Midwest Research Institute  
1617 Cole Boulevard  
Golden, Colorado 80401

Operated for the  
**U.S. Department of Energy**

SERI/SP-220-3548  
DE89009494  
February 1990