PROCEEDINGS

Pellet Fuels Conference
November 16-17, 1995

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Carlton Wiles
Conference Chairman

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PROCEEDINGS: PELLET FUELS CONFERENCE

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EXECUTIVE SUMMARY

The 1995 Pellet Fuels Conference brought together professionals from the process-engineered-fuels (PEF) industry, utility industry, and related fields to increase understanding of PEF derived from non-recyclable paper and plastics. They determined that, while the last two decades have produced impressive technical breakthroughs, efforts to advance PEF must now focus on increasing commercial breakthroughs. Professionals from every corner of the industry agreed that successful commercialization will depend on increasing supplier, consumer and regulator confidence and support by demonstrating and communicating the performance and value of PEF products. Related efforts to enhance PEF's credibility and competitiveness will involve research (test burns and economic analysis), inter-industry partnerships, and a commitment to present PEF products in terms that are meaningful to regulators and fuel consumers (such as performance standards and fuel grades).

The Pellet Fuel Conference was sponsored by the U.S. Department of Energy, the National Renewable Energy Laboratory, the American Plastics Council, and the American Forest and Paper Association. The conference gathered more than 60 experts from around the world to share knowledge and experiences about using PEF as an alternative or complement to fossil fuels. Conference participants met November 16-17, 1995 in Washington, D.C., to increase general understanding of key issues affecting the use of PEF in utility, industrial, and institutional boilers, and exchange ideas on ways to advance commercialization of the technology.

Throughout the first day of the conference, speakers provided updates on how PEF technology is evolving with regard to technical, economic, and regulatory challenges. During the second day, participants were asked to direct their focus to the future, sharing their insights on which actions will be most critical to make the next advances into full commercialization of PEF. Representative stakeholders from different industry stakeholders started by presenting analyses of critical issues and needed actions. These presentations included speakers from the paper industry, the plastics industry, the boiler industry, and the utility industry. Speaker notes for these presentations are included in a later section of these proceedings.

Conference participants were then asked to engage in one of four discussion groups. Each group focused on a different aspect of the PEF industry: materials sourcing, fuel processing and transportation, combustion, and ash handling. The following is a summary of key ideas identified by the groups as critical next steps toward commercialization of PEF.

SUMMARY: MATERIAL SOURCING

The material sourcing group identified a full range of potential actions including efforts to: change the perception of PEF, promote access to clean source streams, increase the consistency of related regulations, and accommodate feedstock variability.

The group prioritized two actions for immediate attention:

1) Develop grades of fuel by source of supply (allow for traceability from final product to source);
2) Motivate generators of industrial, commercial, and institutional fuel feedstock supplies to divert their clean, concentrated streams for fuel.

SUMMARY: FUEL PROCESSING AND TRANSPORTATION

The fuel processing and transportation group focused on addressing market and economic barriers, emphasizing the challenge of competing against coal as a low cost and familiar option for fuel consumers. Other concerns centered on gaps in the industry's credibility caused by some history of product failure and ongoing problems with uncertain feedstock supplies.

The group identified actions in several categories:

1) Refine related economic analyses, focusing on life cycle analyses
2) Develop and gain industry support for product definitions and standards
3) Combine efforts in an organization to help market PEF

SUMMARY: COMBUSTION

The combustion group emphasized actions that would increase the data available to regulators and others regarding performance characteristics of different PEFs and their compatibility with different combustion technologies. As such, the group prioritized actions that could produce, consolidate, and distribute related data. On an ascending scale of investment, the group prioritized the following actions:

1) An information and research center
2) Test burns for regulators
3) A commercial scale performance testing center

SUMMARY: ASH HANDLING

The ash handling group differentiated between "real" technical issues and concerns which are a matter of debatable legal constraints, based on the definition of "waste" and regulatory inconsistencies. In particular, the group focused on how current regulatory trends and perceptions regarding ash and related topics are affecting PEF-related issues, including the definition of potential feedstock materials as "waste", ash use, co-combustion of waste with coal, and recycling credits for combustion.

The ash handling group identified potential actions to address both technical and regulatory barriers, prioritizing three efforts:

1) A state-by-state effort to assess how state regulators are approaching key issues and provide data and education on related matters, emphasizing positive opportunities as well as concerns.

2) An effort to change adverse public perceptions by clarifying nomenclatures and terms either by working with the American Society for Testing and Materials (ASTM) to develop a consensus on definitions and terminology, or by pursuing an education campaign.

3) Determining whether the American Plastics Council (APC) program and other industry organizations will include ash testing.

SECTION 1: OVERVIEW AND OUTCOMES

Section One offers the reader an overview of the conference and the outcomes of related participant discussions in the following sub-sections.

CONFERENCE AGENDA

An outline of conference activities and speakers.

SUMMARY OF PRESENTATIONS

Brief summaries of the key points from each speaker's presentation. Related materials, submitted by each speaker, are included in subsequent sections of these proceedings.

DISCUSSION GROUP REPORTS

A record of the key points presented by participant discussion groups at the close of the conference. each group identified drivers of barriers that still face the PEF industry and prioritized actions that will be most critical for promoting full commercial success of PEF. Each group focused on a different aspect of the industry:

- materials sourcing;
- fuel processing and transportation;
- combustion; and
- ash handling.

PARTICIPANT COMMENTS

CONFERENCE AGENDA

Conference Objective:

The conference has been designed to define issues, facilitate exchange of information and increase understanding of the use of pellet fuels in utility, industrial, and institutional boilers for the purposes of advancing commercialization of the technology.

Wednesday, November 15, 1995

The conference will begin with a 6:30 p.m. reception in the Rappahannock Room on the lobby level of the Stouffer hotel.

Thursday, November, 16, 1995

Objective: Develop shared understanding of the issues and challenges.

Opening Session Chair, Carlton Wiles, Municipal Solid Waste Program Manager, National Renewable Energy Laboratory

8:00 Opening Remarks

- Mike Fisher, Director of Technology, American Plastics Council
- Jeremy Metz, Director, Energy & Technology, American Forest and Paper Association
- Simon Friedrich, Program Manager, US Department of Energy
- Susan Lawson Gonzales, Conference Facilitator, R. W. Beck

8:30 The Challenge: Definitions, Drivers and Barriers

Results from Previous Pellet Fuels Forum - Greg Sutherland, National Director Client Services - Solid Waste, R.W. Beck

9:00 An Historic Perspective of the Pellet Fuel Industry: Lessons Learned

Harvey Alter, Ph.D., Manager, Resources Policy
US Chamber of Commerce

10:00 Break

Session 1 Market Challenges and Technical Issues

Chair, Greg Sutherland,
National Director Client Services-Solid Waste, R. W. Beck

10:30 Market Challenges (Economics)

Roger Davis, Executive Director, Pellet Fuel Institute

- What is the value of this fuel in the open market?
- What are the factors influencing this value (production costs, plant modifications, costs for compliance, competitive advantages, etc.)?

11:00 Technical Issues - Fuel Production

Robert Massengill, President, Pellet Fuels Institute

11:30 Technical Issues - Combustion

Olé Ohlsson, Program Manager, Argonne National Laboratory

Noon Luncheon Speaker on European Experiences and Trends - Niranjan Patel, Section Manager, Resource Recovery & Combustion Section, ETSU, UK

Session 2 Panel on Regulatory Issues

Chair, Simon Friedrich, Municipal Solid Waste Program Manager, US DOE

1:15 Panel

- Air Emissions - Walter Stevenson, US EPA
- Ash and Associated Issues - Carlton C. Wiles
- State Requirements (MSW, air ash, permitting, etc.) -

  Charles Williams, Commissioner, Minnesota Pollution Control Agency
- William Demarest, Holland and Hart

2:45 Break

Session 3 Case Studies (technical, regulatory, economic issues)

Chair, Olé Ohlsson, Program Manager, Argonne National Laboratory

3:15 Otter Tail Power Company - Dean Pawlowski, Plant Engineer

3:45 Idaho Chemical Processing Plant - Jim Hopla, Manager of Utilities,

Lockheed-Martin Idaho Technologies

4:15 Timber Energy Resources - Blake McBurney, Executive Vice-President, McBurney Corporation

4:45 Pellet Fuel Programs at the Central Mining Institute in Poland

5:10 Positioning Fuel Recovery - Martin Frankenhaeuser, Corporate Coordinator, Borealis Polymers, Porvoo, Finland

5:30 Adjournment

Dinner 6:30

Friday, November 17, 1995

8:15 Recap of Case Studies and Issues - All

Sue Lawson Gonzales, Conference Facilitator will lead discussions.

9:30 Break

10:00 Group Discussion: How do we work together to promote this technology? - All

Facilitator's Overview; Discussion Format

Opening Comments; Industry Stakeholder Representatives

- Paper Industry - Gary Griffith, Georgia Pacific
- Plastics Industry - Don Goodman, Occidental Chemical Corporation
- Boiler Industry - Bob Bessette, President,
  Council for Industrial Boiler Owners (CIBO)

11:00 Facilitated Discussion: Conference Participant Comments - All

After reviewing the distributed materials that list potential next steps, please help us determine which steps are most critical? Which technical advances and regulatory initiatives will be most effective in moving toward our ultimate goal of integrating this technology into the open market?

- Materials Sourcing
- Fuel Processing and Transportation
- Combustion
- Ash Handling

Additional Comments or Clarification: Please complete the participant comment sheet that has been distributed.

12:30 Working Luncheon

Breakout sessions for participants to lunch with members of their industry sector to discuss how that sector can support the next steps.

2:00 Adjournment

SUMMARY OF PRESENTATIONS

While highlighting the advances PEF technologies have made in the last two decades, conference speakers also characterized significant roadblocks to commercial viability of PEF. In general, speakers and participants agreed that successful commercialization will depend on increasing supplier, consumer and regulator confidence and support by demonstrating and communicating the performance and value of PEF products. Related efforts to enhance PEF credibility and competitiveness will involve research (test burns and economic analysis), inter-industry partnerships, and a commitment to present PEF products in terms that are meaningful to regulators and fuel consumers (e.g., performance standards, fuel grades, etc.).

The opening presentations provided some historical background on PEF issues. Subsequent presentations centered on three success factors: market conditions, technical performance, and regulatory trends. Several case studies from the U. S. and Europe provided detailed examples of efforts to address these factors. In addition, representatives from the paper, plastics, boiler, and power utility industries outlined related concerns and priorities for the future.

Following is a brief summary of key points from each presentation. Related materials, submitted by each speaker, are included in subsequent sections of these proceedings. Please note that the following summaries were not submitted by the speakers and are only provided to offer the reader an overview of the discussion.

OPENING SESSION

To put this conference into perspective, the first two presenters provided historical background and updates on the technical, economic, regulatory and political challenges that have influenced development of the PEF industry to date. Harvey Alter, Manager, Resource Policy, US Chamber of Commerce, provided a broad historical perspective on the evolution of PEF. Acknowledging many of the early industry pioneers, Alter characterized the last two and one-half decades as a period of enormous technical advancement. He summarized how the industry has steadily addressed many of the most serious challenges in PEF preparation, handling, and co-combustion. In the 1990s, Alter asserted, the challenges will be commercial, not technical. To thrive, the PEF industry must learn how to understand and improve its basic economics while developing the proof needed to correct the misperceptions of boiler makers, regulators, and the public.

Gregg Sutherland, National Director of Client Services for Solid Waste at R. W. Beck, Inc., summarized related recommendations and findings from the 1994 Pellet Fuels Forum. The Forum engaged 18 PEF industry professionals in a detailed discussion of the industry's current challenges. Consistently, the Forum group's concerns centered on five interrelated areas: misperceptions by regulators and the public, regulatory constraints and risks, a significant lack of test data; and market barriers based on skewed energy economics and the costs of processing and handling PEF. Though the Forum was not designed to produce a consensus, the group did analyze and recommend objectives for each area of concern. Highlights include recommendations that the PEF industry support test burns, coordinate and synthesize available technical and economic data; work to change misperceptions of PEF, lobby for reasonable, consistent regulations, and promote technology and quality control initiatives.

In addition, participants in the 1994 Forum identified the interests and concerns of key industry stakeholders, including: materials suppliers, local and federal governments, regulators, fuel processors, and boiler operators. They recommended that the discourse be expanded to include a broader group of stakeholder representatives. This 1995 Pellet Fuels Conference is, in part, an outgrowth of that recommendation. Full description of the opening session, including speaker materials can be found in Section Two of these proceedings.

MARKET CHALLENGES AND TECHNICAL ISSUES

The opening session identified the 1990s as the decade for PEF commercialization. The next four speakers focused on the business and science of making PEF competitive and compatible with other fuels, coal, in particular. Each speaker identified a similar set of success factors, including consistent quality, competitive pricing, compatibility and reliability. Most emphasized a need to talk about PEF in the "language" of the primary customers—boiler operators who are currently using coal. Each of the speakers expressed optimism that PEF will have a substantive niche in future fuel markets. Speaker materials are included in Section Three of these proceedings.

Roger Davis, Executive Director of the Pellet Fuel Institute, opened the discussions with an emphasis on factors that affect the value of PEF and the impact of these factors in the dialogue between boiler operators and PEF suppliers. To get boiler operator's attention, Davis asserts that PEF suppliers must offer a quality product in terms of handling, consistency (energy mix), compatibility with handling and combustion systems, and integrity during storage. To make the sale, the PEF supplier will need to move past the product's basic features and into a discussion about how the fuel can benefit the boiler operator without compounding plant maintenance and other stresses. In particular, Davis stressed that PEF suppliers will need to make the operator comfortable with how the fuel will affect the handling systems and long term maintenance. PEF suppliers must be able to demonstrate that related emission profiles can help, not complicate an operator's regulatory situation.

Finally, fuel prices should be framed as cost per MM BTU's, laid in at the plant. In this context, Davis points out that projecting the market price for PEF is, at best, challenging. While the price will be subject to all the factors affecting both buyer and seller, Davis projected a range of $15 to $22 per ton in the commercial and industrial boiler market. Optimal market conditions involve coal plants with sulfur dioxide and oxides of nitrogen concerns that could be addressed through co-firing. Davis also spent some of his presentation discouraging those who would seek to compete for the $100 to $120 per ton paid by the wholesale residential market for sawdust or wood pellets.

Given these market conditions, Davis urged PEF suppliers to scrutinize their opportunities carefully. He stressed that suppliers should be very confident that they can profit from a deal that requires them to provide a reliable and consistent energy mix supply that will withstand transport, storage and plant handling. Factors include "off-setting" revenues such as recycling credits or tip fees. Davis closed his discussion with a pitch for using legislated markets to ensure that high energy waste streams are not landfilled. He suggested that related legislation could involve flow control as well as requirements for utilities to purchase a specified amount of fuels produced by post consumer or post manufacturing waste streams.

Bob Massengill, President of the Pellet Fuels Institute, focused on the technical challenges associated with preparing a competitive fuel product. He reinforced Davis' overview of factors affecting fuel quality: uniform density, consistent heating value, and ease of handling. In particular, Massengill emphasized that many quality issues can be overcome through refined densification processes. In each case, the PEF supplier must weigh the cost of additional processing or new technologies with the benefits of a more versatile, marketable product. Massengill illustrated some of the tradeoffs and possibilities, stressing three densification factors: the size (grind) of raw stock, moisture levels, and die design. Larger stock with higher moisture will be less expensive to process, but this must be traded off for back end challenges in handling and combusting the resulting fuel particles. In the end, Massengill stressed, decisions will be most affected by the specifications and requirements of the market. As combustion sites get farther away or involve more sensitive handling systems, there will be increased demand for more refined pellets (high density, low moisture, and less fines).

Ole Ohlsson, Program Manager of the Energy Systems Division at Argonne National Laboratory, expanded the discussion to focus on the remaining technical challenges associated with co-firing. Ohlsson began by outlining some of the market drivers for PEF. Specifically, he noted that operators of coal-fired boilers are willing to consider more expensive fuels, such as PEF, when these fuels can help the plant comply with more stringent air quality standards (1990 Clean Air Act Amendments) and when boilers can be modified at relatively low cost. Ohlsson also pointed out that PEF continues to be a sound means of increasing energy security and reducing the impact of solid waste disposal. He noted that the majority of coal-fired generators (75%) are located in the same regions where 70-80% of the nation's solid waste is generated. Additional information in Ohlsson's presentation illustrated that industrial boilers remain a prime market target in part because the majority use stoker-fired or fluidized-bed technologies that are relatively compatible with co-firing PEF.

Ohlsson then outlined technical and economic challenges that currently constrain the commercialization of PEF in the utility boiler market. In the face of deregulation, electric utilities have been forced to prioritize cost reduction and increase their threshold for risk. At the same time coal-fired utility plants are facing increased cost and risk from more stringent air quality standards. Utility boiler operators are naturally reluctant to consider co-firing alternatives that might involve increased fuels costs (coal is @ $1.00/MM BTU) even minimal capital investments or regulatory risks associated with air emissions or ash management. This reluctance is amplified by the fact that the majority of utility boilers are designed for suspension firing using pulverized coal. Ohlsson emphasized that, at this point, pulverized coal boilers are the most challenging and may require a separate pulverizer for PEF.

Ohlsson observed that some PEF may compete in the electric utility market by offering some regulatory relief on air emissions. However, Ohlsson cautions, these fuels must still meet the technical challenge of narrowing the gap with coal's higher heating value, energy density, and bulk density; as well as lower ash rates. Clearly, test burn data and other hard evidence of performance will be critical to dealing with reluctant market sectors. In related comments, Ohlsson described an on-going study in Poland, involving co-firing of municipal solid wastes (MSW) with coal wastes. The study is designed to determine the viability of developing a composite fuel pellet using coal fines and a combustible fraction of MSW. Initiated in late 1994, the study is scheduled to end in August, 1996.

In the closing session, Dr. Niranjan Patel, Section Manager of the Resource Recovery and Combustion Section of the Energy Technology Support Unit (ETSU) in the United Kingdom (UK), outlined how the RDF industry in the UK and Europe has coped with similar trends and issues. The ETSU functions like NREL, managing governmental funded energy and environmental programs. Providing a brief history of solid waste fuels in the UK, Dr. Patel, emphasized that RDF evolved during the 1980s in the face of a declining reliance on mass burn incinerators for waste disposal. RDF was viewed as a constructive intermediate solution, diverting a reasonable percentage of the combustible solid waste stream at a fraction of the cost for mass burn. Over the course of the decade, fuel quality was substantially improved and market development programs took hold in small scale boilers.

However, as in the United States, RDF technologies have run into technical, regulatory, and economic difficulties in the 1990s. In particular though, market conditions shifted in 1989 as a result of interrelated legislative and regulatory changes. New emission limits on waste combustors, including RDF, added capital and operating costs. These new air quality constraints combined with the privatization of the coal and electric industries to create a profound change in the solid fuels market. As a result, there has been a marked increase in gas-firing technologies and a decline in solid-fuel generating capacity.

At the same time, the deregulation of the electric industry in the UK was coupled with the Non-Fossil-Fuel Obligation (NFFO), a mechanism to support market enablement for renewable energy sources. Under the

NFFO, the government will guarantee 15-year power-sales contracts, with no obligation placed on the power purchaser. The government will also pay a premium price for power, as determined by competitive bidding process. The NFFO includes solid-waste fuels and the speaker materials include examples of the economic effect on RDF. All of these changes have combined to stabilize RDF use and focus it into a niche market emphasizing industrial applications. Dr. Patel concludes that this trend will continue, augmented by a growing interest in RDF.

REGULATORY ISSUES

In the Regulatory Issues section of the program four speakers cataloged regulatory trends that continue to impede the commercialization of PEF. Despite evidence of PEF's environmental benefits, the current approach to regulating air emissions and ash management produces intolerable uncertainty and additional costs for both fuel processors and boiler operators. In turn, even supportive regulators struggle in the face of federal rulings that curtail flow control and some state policies that help skew economics toward traditional fuels.

AIR EMISSIONS

Reflecting these regulatory trends, the revised federal air quality standards of performance for both new and existing municipal waste combustors (MWC) are broader and more stringent. James Kilgroe, National Risk Management Research Laboratory, USEPA, submitted detailed fact sheets summarizing the 1990 Clean Air Act Amendments (CAAA) guidelines. The new guidelines apply to a greater number of MWC's, including plants with capacities as low as 35 Mg/day. The guidelines specify emission levels for additional pollutants, including cadium, lead, mercury and oxides of nitrogen. Visible emissions from ash handling must be limited to no more than 5 percent of the time. New levels of operator certification are now required, as are more stringent monitoring and compliance testing.

The most stringent standards apply to plants constructed after September 20, 1994. A section on siting requirements for the new plants specifies that plant developers must now submit a cost/benefits analysis for a proposed site, develop a materials separation plan, and hold a series of public hearings.

All of the air emission guidelines are based on maximum available control technology (MACT) and Kilgroe submitted a third technical paper (National Waste Processing Conference, ASME 1996) which reviews related MWC technologies and explains the basis for the revised emission limits. In addition, the paper summarizes current knowledge concerning formation and control of mercury MWC flue gases, polychlorinated dibenzo-p-dioxins, and polychlorinated dibenzofurans.

The CAA does offer PEF several windows of opportunity. One is that while air emissions from MWC's are tightly controlled, the rules exempt institutional, industrial, and utility boilers co-firing up to 30 percent (by heating value) of municipal solid waste (MSW) with coal. Another is that co-firing some PEF with coal has been demonstrated to help boiler operators reduce regulated levels of sulfur dioxide emissions from the coal.

ASH MANAGEMENT

According to Carlton Wiles, Technology Manager, Municipal Solid Waste Program, National Renewable Energy Laboratory, the regulatory challenges for PEF facilities begin at the other end. The US Environmental Protection Agency has determined that the management of ash generated by facilities combusting any MSW is covered under the Resource Conservation and Recovery Act (RCRA). Based on this ruling, co-mingled ash must be disposed in accordance with municipal solid waste landfill criteria.

Coal burning facilities are reluctant to adopt such regulatory complications. On the other hand, though European experience has demonstrated that energy recovery can provide substantial relief as a landfill alternative, state regulators and the US EPA have been slow to give recycling or waste diversion credit for waste combustion. Wiles called on the USEPA to relieve some of this regulatory tangle by clarifying its conflicting definitions of "waste".

STATE REQUIREMENTS

Even when state regulators support PEF and MSW diversion through combustion they can be stymied by federal level regulations and court rulings. Addressing the topic of state requirements, Charles Williams, Commissioner, Minnesota Pollution Control Agency, outlined how Minnesota's notable success in MSW diversion has been threatened by recent Supreme Court rulings and related federal rules. In particular, Williams expressed alarm at the May, 1994 Supreme Court ruling that declared it unconstitutional for any jurisdiction to institute flow control for MSW. According to Williams, the ruling has destabilized Minnesota's hard-won integrated solid waste management system and toxic waste reduction programs. More than 30 percent of the MSW is currently incinerated or composted at facilities around the state and none of the incinerators has failed the hazardous waste test now required under federal rules. Many of these public and private MWC's were financed based on the assumption that counties could designate where waste would flow. Without flow control, such facilities are at risk, forced to set tip fees below cost in order to compete directly with the region's landfills. Williams called for strong lobbying of Congress to restore flow control through legislation.

Outside the regulatory context, Williams stressed a number of technical challenges that continue to impede PEF commercialization. He stressed the need for PEF suppliers to provide boiler operators with consistent, long-term supplies that are available and reliable during the appropriate operating "window". In light of the dismal economics of incinerators without flow control, Williams emphasized the need for PEF suppliers to minimize other types of challenges. In particular, he expressed concern regarding technical challenges associated with pellet contamination, slagging, toxicity, and air emissions.

On a positive note, Williams noted that several years of analytical information from leachate collection systems at MSW-ash monofills around the state appears to demonstrate that heavy metals are not a problem in incinerator ash. He attributes this outcome, in part, to effective toxic waste diversion and, in part, to regional efforts to lower the levels of heavy metals in packaging. He also attributes some of this success to constructive partnership between state regulators and incinerator operators.

Direct and Indirect Impacts

In some cases, the beneficial development of PEF may be inadvertently impeded by conflicting rules and policies. The lack of accurate test burn data for PEF is at the root of much of the regulatory confusion. William Demerest, Jr., Holland and Hart, noted two such examples. Under the CAA, co-firing of PEF with coal is recognized as a potentially more cost-effective means for coal-fired utilities to achieve compliance with the Acid Rain Program's limits on sulfur dioxide emissions. However, permitting rules under the same act fetter the industry with the burden of proving that co-firing will not increase other specific emissions or pollutants. Boiler operators will resist PEF alternatives, until they have accurate, convincing test burn data to present to permit regulators.

In another case, co-firing of PEF is hindered by a lack of data and uncertainty in how the US EPA applies rules governing Title V operating permits and MSW ash disposal under RCRA. In the case of Title V, Demerest recommends that the US EPA facilitate PEF data collection by exempting short-duration "test burns". He also recommends that the USEPA reduce uncertainty about "fuel-switching" by being more

definitive on how it will apply related permit rules. In the case of RCRA, he recommends that the US EPA discern between ash generated by an MWC and ash generated by co-firing coal with PEF manufactured from materials that have been separated from MSW. Again, he cites a need for data on co-mingled ash characteristics. He also cites the need for the PEF industry to take a hold of the issue by setting industry standards for diverting hazardous materials from PEF feedstock.

Finally, Demerest identified a more indirect regulatory impediment. Some state policies governing utilities are eroding the economic incentives intended in the CAA's sulfur dioxide emission allowance trading system. Specifically, the policy of some state public utility commissions (PUCs) is to allow utilities to recover the capital costs for environmental compliance technology (such as scrubbers) as part of its rate base, under "cost of service". These policies encourage utility managers to favor capital-intensive alternatives for achieving environmental compliance. They skew the analysis against less capital-intensive alternatives, such as co-firing. Demerest encouraged the PEF industry to become more active in educating PUCs about this inadvertent effect and supporting incentive ratemaking principles that promote the most cost-effective compliance options.

CASE STUDIES

Given all the emphasis on the need for data and analysis, the three case studies provided optimistic reports on a growing body of knowledge and refined technologies and an emerging research "infrastructure" as test burn centers develop PEF experience. In addition, analytic advances and test burn results in Europe support optimism that data combined with life-cycle analysis can help to demonstrate concrete value for PEF technology. Detailed speaker materials and handouts are included in Section Five.

OTTER TAIL POWER COMPANY

Persistence paid off in demonstrating that technical difficulties associated with a refuse-derived-fuel (RDF) /lignite co-fire test could be managed through operational modifications, instead of more expensive system retrofits. The 15-month co-fire test was an extension of the Otter Tail Power Company's active commitment to burning alternative fuels.

The test was conducted at the Big Stone Plan, a 440 MW single unit with a cyclone furnace.

Dean Pawlowski, Plant Engineer, reported that, Otter Tail was satisfied by the test that the Big Stone Plant can burn RDF. No definitive conclusions could be made regarding reduction in air emissions because of coal variability from test to test and the short duration of the co-fire test. The test did show, however, that the RDF did not increase PCBs and that the ash generated satisified toxic characteristic leaching procedure (TCLP) requirements. They also showed that coal quality probably has a larger effect on air emissions than the RDF.

The co-fire did decrease boiler efficiency and the operating group identified coal quality as a critical variable for emissions. Further, the test team identified a series of operating challenges associated with long-term RDF/lignite co-firing, including: plugged equipment and increased litter. Airborne plastic particles complicated combustion and plant air handling systems.

IDAHO TEST BURN CENTER

In the pursuit of on-site waste management solutions, the Idaho National Engineering Laboratory is developing a test burn track record that lays promising groundwork for a test burn center. Based on suggestion that INEL start using "cold" waste from its chemical processing plant to supplement its on-site coal combustion power plant. The plant is based on a fluidized bed boiler. The assigned INEL team

identified partners to provide technical support and pellet manufacturing. INEL received a permit modification from the State of Idaho EPA to co-fire up to 30% RDF. The trial runs evaluated combustion performance in a fluidized bed boiler; monitored emissions signatures and analyzed ash.

Test burn results showed the plant to be suitable for burning RDF. All emission signatures were lowered and ash appears to have potential for beneficial use on the INEL reservation. Moving to the future, INEL will continue to explore how to increase co-firing efficiencies; install permanent RDF feed systems; line up sources for additional RDF and explore the potential to sell or use the ash. Further, INEL is seeking to establish a test facility for DOE, NREL, and private sector RDF testing.

EUROPEAN DATA AND ANALYSIS

Martin Frankenhaeuser, Borealis Polymers, Finland, reported on "positioning" of RDF in the European combustion markets by the development of hard data and detailed economic analysis (life-cycle analysis). Armed with this information, RDF proponents are meeting with a more open hearing from the combustion industry, regulators and the public about the roles that RDF can play.

Frankenhaeuser summarized how life-cycle analyses had been combined with test burn results to illustrate net benefits from diverting solid wastes into combustion streams. He shared results of long-term test burns with RDF and coal or peat that are generally encouraging including specific outcomes for a long-term co-combustion test of coal and course, fluff RDF conducted at a 65-MW cyclone-furnace-boiler power plant in Finland.

The test burns of up to 25 percent RDF proved technical and economical feasibility. Emissions of carbon monoxide and sulfur dioxide were lowered; though HCL emissions did increase based on the chlorine content of particular RDF. Heavy metals were primarily traced to inks or pigments in package-derived fuels and the metals concentrated in the fly ash in unleachable form. Dioxin emissions remained at normal levels for coal combustion. Operational measures during the test proved effective in avoiding fouling. Long-term combustion of 10 percent RDF did not cause any high temperature chlorine corrosion of the boiler's superheater.

Frankenhaeuser also reported on a project that demonstrates strong potential for plastics to provide high value and environmental benefit as co-combustion partners with traditional carbon fuels. The project also developed performance data on different plastics using pyrolysis technologies. Polyethylene, polypropylene, and polystyrene were found to perform like oil. Polyvinyl chloride performed more like wood, though the resultant char contained less than 1 percent chlorine. In general, the only major environmental challenge was presented by heavy metals in the inks and pigments of packaging.

INDUSTRY STAKEHOLDER ISSUES AND CONCERNS

The last series of speakers summarized the PEF industry's challenges and priorities from different points of view. Representatives from the paper and plastics industry highlighted the views of those who generate feedstock for PEF. Representatives from the power utilities industry and the boiler industry addressed the conference from the point of view of those who purchase and use PEF. Section Six includes related speaker materials.

Gary Griffith of Georgia Pacific spoke on behalf of the American Forest Products Association. He challenged the PEF industry to prove its value through accurate, convincing performance data. In particular, he urged the industry to develop comprehensive data on how PEF perform with a full range of boiler technologies. In view of the regulatory complications plaguing the industry, Griffith recommended

that the research emphasize emissions data as well as the general performance data that boiler operators will need to compare PEF with their traditional fuels.

Don Goodman of Oxychem spoke on behalf of the American Plastics Council. He challenged the PEF industry to establish credibility as a responsible option, improve industry economics, and demonstrate the value of PEF to fuel consumers. In particular, Goodman promoted responsible analyses to determine the most appropriate role for plastics. He supported the need to develop and communicate combustion performance data, including environmental impacts and benefits. He also stressed the importance of deepening our understanding of the industry's economics through life-cycle analysis. Finally, Goodman challenged the PEF industry to improve its odds for success by making its case in "easy English".

Bob Bessette, President of the Council of Industrial Boiler Operators (CIBO), challenged the PEF industry to approach the problem from a boiler operator's point of view. The field of boiler operation is currently highly uncertain. Operators are under pressure from global competition to be more efficient and cost effective. At the same time, the cost and complexity of environmental compliance is on the rise. In the absence of Navy training programs, new operators are less formally prepared for this pressure. In this atmosphere, boiler operators are resistant to exploring new fuel opportunities, especially when the data on PEF is limited and the regulatory risks are still high. Bessette urged PEF vendors to give themselves a head start by talking the operator's "language", providing data and specs that can be compared to the traditional fuel: COAL. Organize your spec sheets to match the parameters on a coal spec. He also recommended that the PEF industry openly address the technical challenges, providing data and other proof about how a fuel will handle and store; how it will perform; and how the fuel will affect the operating system. Be prepared to help operators up the learning curve and through the compliance hoops for ash and emissions. And then be prepared to deliver!

Charles McGowain, Manager of Biomass Conversion for the Generation Group of the Electric Power Research Institute, submitted discussion notes on behalf of the power utility industry. He challenged the PEF industry to focus on ways that PEF can help utility managers succeed in a changing competitive environment. In the face of increasing competitive pressures, utilities have an urgent need to operate at optimum efficiency and they are very adverse to risk. They need combustion solutions that do not require a lot of capital investment or maintenance expense. Utilities also need to control the net cost of fuel and environmental compliance. McGowain urged PEF vendors to focus on helping utilities reduce costs and liabilities and provided industry details on these cost thresholds. In particular, he reinforced Bessette's point that the discussion will be most productive if the proposed fuel is presented in comparison with the fuel they already know: coal.

DISCUSSION GROUP REPORTS

During the course of the conference, participants were asked to share their insights by electing to contribute to one of four discussion groups. Each group focused on a different aspect of the industry and discussed how to achieve the ultimate goal of successful commercialization for PEF. The groups were organized as follows:

- materials sourcing
- fuel processing and transportation
- combustion
- ash handling.

Participants specified significant drivers and barriers facing each part of the industry, discussed potential actions, and determined the most critical steps for integrating this technology into the open market.

At the close of the conference, each group presented their findings. A summary and transcription of easel pad notes for each of the discussion group follows.

GROUP 1: MATERIALS SOURCING

DISCUSSION SUMMARY

Development of a viable pellet fuel industry depends first upon the ability to collect appropriate feedstocks in an economical way. The materials sourcing discussion group emphasized that sourcing feedstocks for PEF competes primarily with disposal options. To the degree that diverting pellet fuel feedstocks is less costly than disposal, sourcing for PEF will be successful. Since disposal is such a low-cost option in many areas, diverting feedstocks for PEF will require targeting high-quality sources such as concentrated commercial load and developing low-cost collection and processing infrastructures. Material recovery facilities and transfer stations designed to recover source separated materials and materials from co-mingled municipal solid waste (MSW) were suggested as the kind of infrastructure need.

The group also emphasized that public and customer resistance to materials sourcing is associated with misconceptions of waste-derived fuels. Current regulatory actions that treat PEF as MSW contribute to this problem. In particular, the group prioritized a need to develop standard grades of fuel, based, in part, on the source of supply. This would facilitate collection and processing, as well as customer acceptance.

In addition, the group identified a need to refine our understanding of the related economics and support regulatory reform to enhance public acceptance, reduce barriers, and introduce related market incentives such as recycling credits.

EASEL PAD NOTES

POTENTIAL ACTIONS: WHAT ARE SOME OF THE THINGS WE COULD DO?

Market/Economics	Regulation / Institutional	Technical
Minimize incremental collection costs	Try to achieve federal-law consistency pertaining to definition of MSW and exemptions from MSW regulation (air, ash, etc.) for supplemental combustion of PEF.	Promote access to clean, concentrated streams of high-Btu PEF feedstocks (commercial and industrial sources)
Collect targeted loads: • rich in high-Btu paper and plastic • derived from industrial and commercial loads	Focus on achieving similar regulatory reform and consistency among key states (e.g., WI,MI,NY,MA)	Develop ability to deal with feedstock variability
Deliver MSW to sorting facilities (e.g., commingled-MSW material recovery facilities) - lower incremental costs than facility for PEF-sourcing only	Lobby for reasonableness and consistency regarding the definition of MSW	
Understand competition for recycling and communicate to public (i.e., PEF sourcing is supplemental to recycling, targeting materials that are good for fuel, but less cost-effective for recycle)	Work to stay clear of "refuse stigma" – differentiate PEF from waste-linked terminology, such as refuse-derived fuels (RDF), muni. solid waste (MSW)	
Oppose new flow control authority Form partnerships between large fuel material producers and PEF mfg to optimize costs of collection/processing	Develop grades of fuel by source of supply. Allow for tractability from final product to source (H)(H)(H)(H)(H)(H)	

(H) This symbol indicates group member votes for "hottest", most critical action

CRITICAL NEXT STEPS: HOW DO WE GET IT DONE?	
Task	**Who**
separate PEF from MSW in regulations and rules	Could include leadership from a stronger Pellet Fuels Institute (PFI)
Get generators of industrial, commercial and institutional (ICI) feedstock material supplies to divert for fuel (H) (H) (H) (H) (H)	Potential role for merchant fuel manufactures; pellet mill manufactures, APC(?), and other organizations (?) Potential to use Internet (e.g., PFI Home Page)
Promote Commingled MSW MRF and Transfer Station Recovery	Potential role for MRF and Transfer Station Vendors
Investigate unit-based disposal fees as incentives to segregate fuel materials for recovery	Potential role for APC?, SWANA?
Include PEF material in waste exchanges	Must include PEF Manufacturers
Get recycling/recovery credit for PEF (such as in Maine, Florida) or tax credit	Potential roles for AFPA?, APC?, and waste vendors (e.g., BFI?) Could include leadership through a stronger PFI
PEF recovery pilot programs to investigate and prove out economical ways to cost-effectively source PEF feedstocks.	Potential roles for SWANA?, APC?, AFPA?

(H) This symbol indicates number of group votes for "hottest", most critical step

GROUP 2: FUEL PROCESSING AND TRANSPORTATION

DISCUSSION SUMMARY

The fuel processing and transportation group focused on economic and consumer issues, acknowledging that PEF manufacturers have been slow to move their focus from technical to marketing issues. Currently, the economics of PEF production and handling are driven by three key factors: economics, consumer confidence, and supply. PEF is competing head-on with coal, which is relatively low cost, has high consumer confidence, and is available in large supply. The economics of the PEF industry are still largely driven by tipping fees which can be charged for accepting the feedstocks, rather than the value of the PEF to end-users. Consumer confidence in PEF is uneven. Misconceptions about PEF as well as some past failures in the PEF industry need to be overcome. Compounding the consumer skepticism is the recent drop in available supply of paper feedstock caused by record high values for recyclable paper.

In order to promote the PEF industry, the group recommended that the industry focus on earning credibility by getting a handle on the "real" economics and by PEF industry acceptance and enforcement of product standards. Life cycle analyses should be performed to better compare the management of solid waste through PEF production and use compared to other solid waste management approaches on an environmental and economic basis. Other key actions will include getting past conflicting agendas to reach agreement on a definition of PEF and a set of minimum standards. These tasks could be accomplished through a PEF marketing association. The group also recommended supporting economically viable projects. To minimize transportation and handling costs they suggested targeting opportunities with optimal locations of feedstock sources, processing facilities, and combustion facilities—preferably all operating at the same site.

EASEL PAD NOTES

MARKET AND ECONOMIC BARRIERS

General

- Past efforts have been geared to address manufacturing problems. The manufacturers have not focused on marketing

Economics

- Revenues = avoided landfill costs plus $/MMBtu PEF revenue plus political factor
- Lower landfill fees = lower avoidance costs
- Future deregulation of utilities will demand cheap Btus
- Coal is cheap & plentiful ($1.50/MMBtu) Max PEF Price $1 /MMBtu

- Economics demand tip fee for feedstock

- Corporate financial strength of PEF suppliers

Problems with Consumer Confidence

- Lack of confidence by buyers in the longevity & consistency of supply (e.g., high fiber value in recycling market = lower available fiber)

- Misconception about PEF

Quality Control Issues

- Previous failures & poor pellet quality

- Lack of standards

TECHNICAL BARRIERS

- Lack of information on value of PEF
- Friable paper + plastics, blowing debris

OPTIONS FOR ACTION

- Develop life cycle analyses (determine the upper range of value)
- Develop association for PEF marketing
    - Educate boiler operators about PEF
    - Disseminate list of suppliers to users
- Optimize locations of source, processing & combustion facilities to minimize handling
    - Help manufacturers build PEF plants close to end-user
- Develop product standards
    - Write definition of PEF
    - Get industry acceptance of definition
    - Develop minimum preliminary standards

GROUP 3: COMBUSTION

EASEL PAD NOTES

BARRIERS AND CHALLENGES

Paper + Plastic + EPRI

1. No data base on operating history
2. No database on PEF supply
3. Linking fuel suppliers and users
4. Change perceptions - user, public, environmentalists, regulators
5. Data on plastics combustion / co-combustion
6. Fuel sources are small (individually) > Need for fuel blending
7. Emissions reductions
8. Matching fuel to boiler - need to look at all the technologies
9. PC (suspension) as target? (too large - no match with local fuel availability)

INDUSTRY SECTORS INVOLVED IN COMBUSTION

1. Utility
2. Industrial
3. Institutional

POTENTIAL ACTIONS

1) Supplier-Customer Communication
2) Utility & Industrial

   - Low Cost Fuel Competition

   - Need to Qualify fuels at each facility

   - Limited supply & logical constraints

1) Test Burns - Commercial Scale - regulators

2) Center on PEF

3) Technology - e.g. boiler types

MOST CRITICAL ACTIONS (BASED ON DIFFERENT BUDGETS)

1. Test burns for regulators
2. Commercial scale test burns for utility industry
3. Permitting support

(A)	(B)	(C)
$300,000	**$10,000,000**	**$50,000,000**
1. Organize existing data	1. Conduct tests for regulators	2.Commercial-scale performance testing center
2. Create a center for reference/ A PEF CENTER		(Build on F-W, ABB, etc.)
Data Collection		
Strategic Plan		
Newsletter		
Economic Studies		
Some small scale R&D?		
re: Data Collection		
• Available Feedstocks		
• Available Processors		

GROUP 4: ASH HANDLING

DISCUSSION SUMMARY

The ash handling group identified several issues associated with municipal solid waste (MSW) and management of MSW-combustion ash that affect the markets for pellet fuels derived from waste materials. These issues can be differentiated as "real" concerns based on technical considerations such as lack of credible data to base decisions on and concerns based on legal interpretations of language in the Resource Conservation and Recovery Act (RCRA). These include the fact that ash from a municipal solid waste-to-energy facility is not exempted from hazardous waste regulations), US Environmental Protection Agency's stated position that co-mingled ash from facilities that burn coal with a material derived from the household must dispose of the ash in RCRA Subtitle D landfills, USEPA and state policies on ash use and recycling credits and other regulatory considerations. Various definitions and perception of waste also contribute to marketing problems.

The group identified several potential actions to address these technical, regulatory, and perception barriers to increase use of pellet fuels.

1. Conduct a state-by-state assessment of state rules, policies and guidelines regarding issues such as definitions of waste, recycling credits for combustion, ash recycling, co-combustion of waste- derived fuels with coal and how each state interprets and applies federal policies and rules regarding these issues.
2. Seek to change adverse perceptions of waste-derived fuels by clarifying their benefits and the terminology and nomenclature used to describe them in order to promote a positive image rather than a negative one. One approach is to work with the American Society for Testing and Materials (ASTM) to develop new consensus definitions for fuels derived from MSW and similar sources.
3. Compile available data on co-mingled ash (ash from burning coal and waste derived fuels) and on MSW ash characteristics, leaching, management, etc.. Conduct studies to fill data gaps so as to provide the technical basis for demonstrating that the co-mingled ash is safe for use. This requires a road map of who would conduct the studies, how and at what cost.
4. With complete data on co-mingled ash characteristics, the pellet fuel industry will be in a better position to educate USEPA, states, and others on the benefits on using pellet fuels as a source of energy. This would provide the basis to approach USEPA for a favorable ruling on how this ash should be managed.

EASEL PAD NOTES

DEFINITION OF "ASH"

The term ash refers to co-mingled ash (i.e., ash generated from co-combusting coal with other fuel sources and as MSW).

THE CHALLENGE OF DEFINING THE NEED

Must determine which needs are real and which are a matter of legal constraints

RE: REGULATORY BARRIERS

Current laws cascade down to ash issues:

The USEPA applies the "derived from" concept in determining if co-mingled ash (i.e., ash from co-

combustion of household waste and coal) is subject to Subtitle D landfill criteria. A strict interpretation of the "derived from " rule results in the determination that the co-mingled ash (even containing small quantities of MSW ash) must be managed according to Subtitle D landfill criteria.

Key Questions

- Is USEPA correct?
- When is a waste a waste? When does it become useful material?

Potential Actions

- Could force USEPA to make determination (Problem - we could get negative response)
  - Try to get states & USEPA to give recycling credit for WTE technologies
  - Recovery of energy from materials recovered from MSW & other sources

How/Next Steps

Go state by state to assess situation re: policies on ash, recycling credits, definitions for waste (etc.) and how they interpret and apply USEPA actions.

RE: TECHNICAL BARRIERS

We need more specific data on co-mingled ash (i.e., ash from burning coal with other fuels):

- Information on characteristics and fate when managed (including TCLP and others) ; not just total concentrations
- Before going to the USEPA, we need to get data re: mixtures of PEF and coal (others)

Potential Actions

- Determine what data is available from:
  - existing plants burning "Alternative Fuels"
  - other sources - American Coal Ash, CIBO, EPRI, etc.
- If needed, DO TESTING!
- Get verification data re: ash properties & fate when managed (including treatments & economics)
- re: CAA 30% exemptions - determine what background data/info is available re: USEPA decision

How/Next Steps

- Determine if APC program will include ash testing
- Clarify nomenclatures/terms to help change adverse perceptions through:
  - communications?
  - education?
  - ASTM?
- Develop a more specific road map on how/who can/will do this with what $.

PARTICIPANT COMMENTS

In addition to the group discussions described above, individual participants were encouraged to contribute additional ideas, details and observations by commenting on plenary session summations or using a participant comment form. Summaries of verbal and written responses grouped by subject are followed by the actual comments that were submitted on participant comment forms.

SUMMARY OF GENERAL COMMENTS FROM PLENARY SESSIONS

Challenges/Opportunities	Options/Next Steps
GENERAL	
• general public bias against "garbage" related technologies • overall lack of inter-industry coordination and communication • overall lack of accurate data on the technologies, fuel performance, economics (life-cycle costs) • general industry stagnation	• reduce bias by educating lawmakers, regulators, and the general public • identify and pursue opportunities that involve partnerships between utilities and PEF industries (source material industries and PEF manufacturers) • develop and distribute data • refocus/reframe the way we see our mission -- focus on PEF (v RDF) • form alliance between paper and plastics as complimentary fuel feedstocks • lobby for regulatory reform: Clean Air Act (CAA), Resource Conservation Recovery Act (RCRA), Title V (site operating rules), state utility rules • provide capital to help private sector get past the initial infrastructure barriers
MATERIALS SOURCING	
• inconsistent regulations, state to state • ($) low cost of disposal in some areas (competes w/ diversion/recovery effort) • ($) competition with recycling • contamination of MSW feedstocks	• lobby for consistent regulations • target clean, concentrated industrial and commercial waste streams • target specific streams for use in pyrolysis applications

FUEL PROCESSING • managing conflicting stakeholder agendas re: fuel specs • ($) difficulties controlling the cost of transportation • ($) expense of producing high-density pellets, balanced against benefits of more marketable product (re: stability, transportability, etc.)	• renew efforts to develop appropriate specs /standards and fuel grades • support R&D on using blending techniques to reduce densification costs
COMBUSTION • lack of test burn data • negative bias or resistance from boiler operators • negative public perception • ($) competing directly w/ low cost of coal • fuel customers' concern w/ unpredictable regulatory trends • OPPORTUNITY: increased availability of cyclone/fluidized-bed boilers	• seek opportunities to use PEF-friendly boilers that are already in use • educate boiler operators using context they are used to using (compare w/coal) • educate PEF manufacturers about what boiler operators are looking for and how they evaluate new fuel options (v coal) • lobby states for consistency and "stability" in air and ash regs • provide capital for enhanced, more PEF-friendly technologies
ASH HANDLING • also see combustion (above) • USEPA agenda to regulate co-mingled ash under Subtitle D • lack of regulatory clarity re: status of industrial ash • public bias against "garbage"-related technologies	• see comments under combustion (above)

PARTICIPANT COMMENT FORMS

SUBMITTED BY: A. A. ADAMS, (713) 754-2701

Because it has been proven that PEF works and is potentially viable under certain conditions, a major need to advance this concept in the eyes of the public is to open up the discussion to a larger audience. Heretofore, the attendance for this forum/workshop has been restricted to the "experts", but we can talk among ourselves and not get very far. Therefore, next year, our meeting should be a "conference" and attendance should be opened up to anyone who has an interest in the success of this business. This will greatly help to clarify and communicate the benefits and advantages of PEF to society.

SUBMITTED BY: LOUIS PEREZ, NORTON ENVIRONMENTAL (216) 447-0070

There is a problem in the Pellet Fuel Industry - the perception of d-RDF as plain old garbage being burned. Mass burn facilities are the only real recognition given to this young industry. How can the boiler industry change their perception is a good topic for discussion. Maybe a topic for a group discussion.

One of the answers we have to consider is to change the perception to an engineered fuel and develop a specification for the industry. A specification can be developed for engineered fuels and traded on the Chicago Board of Trade. What can we do as an industry to make this happen?

SUBMITTED BY: HUGH ETTINGER, BEDMINSTER BIOCONVERSION CORP. (609) 662-2662

(1) I could use more data on where the stoker-fired boilers are. Are most of them at manufacturing plants? In paper mills? What percentage of coal-fired utility boilers are P-C (pulverized coal)? One of the speakers yesterday had these numbers, but the slide went off the screen too quick.

If you had an all-plastic pellet and if you fired it into a P-C boiler, wouldn't it instantly gassify? If it did, the gas would burn. Why shouldn't this be attractive to the utilities which are using P-C boilers? The ash from an all-plastic pellet should be a low percentage of the pellet's weight. This, in turn would minimize the ash problem -- where the utilities don't want to risk of having their ash declared not from Bevel Waste or would it?

Therefore, why aren't people (except for the man from Finland) talking about all-plastic pellets or cubes? What's the problem with all-plastic pellets?

(2) Why is no one talking about dedicated on-site power generation units to provide steam and/or electricity to local markets? Is there small power generation technology (25-200 ton-per-day) available which would burn the pellets?

Why wouldn't a dirty MRF use its pellets to generate power on-site for its own use and to sell to the local utility?

SUBMITTED BY: C. J. ZYGARLOCKE, EERC (701) 777-5123

PROBLEM: There is a great need for fundamental and applied research that is very broad-based to address issues that can not be argued due to lack of information. For example, it is difficult to argue with USEPA or a state agency for getting a permit for trial burns, etc., when you have little data to back up any claims, or to deal with wrong perceptions.

SOLUTION: Form a consortia to fund major research programs for characterizing different pellet fuel types. Key issues are:

1) Specific types of pellet fuels and impacts on boiler efficiency, including potential for fouling, gassing, adverse reactivity and handling
2) Air toxic metal emissions from various pellet fuel types
3) Market assessments that show potential pellet fuel types and qualities across the U.S., as in what is the breakdown of pellet fuel types across the country (i.e., 30% wood waste, 25% paper waste; 10 % sewage sludge, 5% food byproduct residues, etc.)

The consortia should be a conglomeration of pellet material suppliers, pellet fuel makers, possibly state agencies, and DOE cost share.

SUBMITTED BY: JOSEPH MARTARANA, WCT INC. (914) 949-2639

Regulatory agencies on a federal and state level appear to be slow in accepting "fuel pellets" (PEF/RDF) as an alternative source of energy. This attitude can be caused either by a lack of full understanding of the benefits of the fuel pellet industry or by a cautious resistance to "something new" or "change". In either case, our industry's efforts should be directed towards changing the regulatory agencies' attitude by familiarizing or "educating" them on the benefits of our PEF. This, perhaps, could be achieved by inviting more "regulatory heads" to future meetings of our group.

SUBMITTED BY: GEORGE NASSOS (708) 947-2789

Regarding Material Sourcing

The consensus appears to be in favor of industrial process waste (pre-consumer) over MSW (post-consumer) when building and operating a pellet fuel facility. The big question is whether the supply of industrial process waste will be there.

It seems that an issue to be addressed is the impact of recycling demand and prices of this waste stream. We have seen OCC go from $25/Ton to $175/Ton in less than one year. Experts say that price will come down, but it will never see $25/Ton again. It will probably settle in the $50-75/Ton range. Although the feedstock for a pellet plant is, in general, non-recyclable, the paper recycling prices do have an impact on the availability.

How does one account for variability in feedstock supply? Or do we focus on MSW?

SUBMITTED BY: KEN DAUGHERTY (360) 679-2866

MOST SIGNIFICANT DRIVERS AND BARRIERS

- public perception (barrier)
- government non-support - in particular, the USEPA (barrier)
- plastics additions (driver)

POTENTIAL ACTION

- better ways to introduce binders into the system

MOST CRITICAL ACTION

- get USEPA on board! re: ash, emissions, etc.

  This industry cannot advance until uncertainties are minimized!

NEXT STEPS

- with increased use of plastics, appropriate binders will be more important to mitigate dioxin and furan formation.

SUBMITTED BY: ANONYMOUS

- Pellet Fuels Institute newsletter needs to significantly increase its coverage of the PEF/RDF segment of the alternative fuel industry and thereby become a key communication tool for advancing the industry.
- IDEA: Pellet producers utilize material suppliers in marketing/selling PEF product to producer's customer, i.e., jointly develop data, make joint visits to customers.

SUBMITTED BY: ANONYMOUS

MOST SIGNIFICANT DRIVERS AND BARRIERS

- funding for "more " materials testing
- user facilities - test burns
- ash uses

POTENTIAL ACTION

- challenge regulatory actions or non-actions
- get facts through sound science

MOST CRITICAL ACTION

- educate the public - "Reuse or landfill"!?!

NEXT STEPS

- partnering industry with government

SECTION 2: OPENING SESSION

This section includes notes and publications submitted by conference speakers . Brief summaries of each presentation can be found in Section 1: Overview and Outcomes.

THE CHALLENGE: DEFINITIONS, DRIVERS AND BARRIERS

Presented by Gregg Sutherland, National Director of Client Services - Solid Waste, R. W. Beck

AN HISTORIC PERSPECTIVE: LESSONS LEARNED

Presented by Harvey Alter, PhD, Manager - Resources Policy, US Chamber of Commerce

R·W·BECK

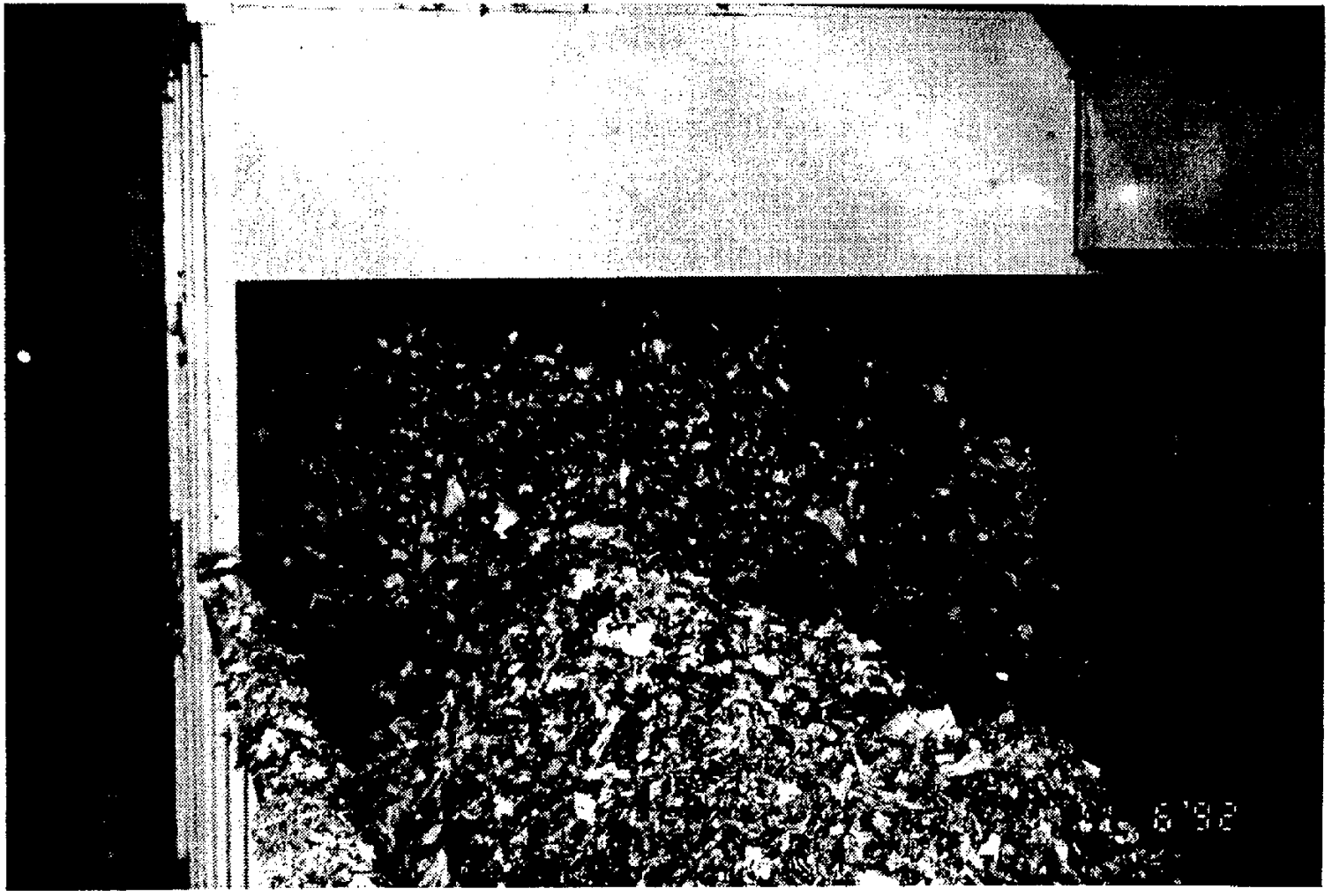
Pellet Fuel Utilization in the United States

Gregg D. Sutherland
National Director
Solid Waste Management
R. W. Beck
Denver, Colorado

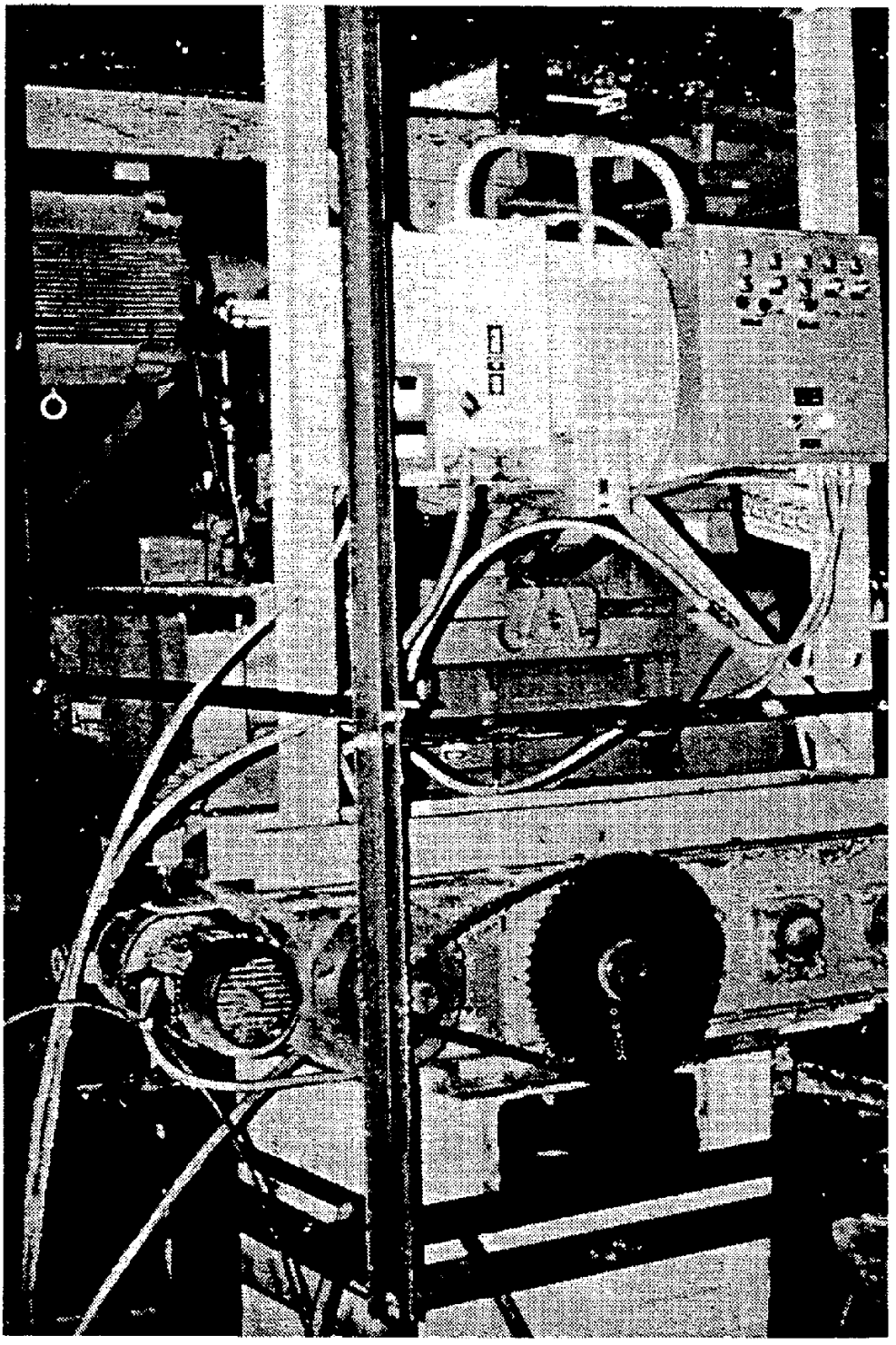
Pellet Fuel: Definition

- Processed solid fuel
- Made from segregated paper and plastic
- Derived from industrial, commercial, or residential sources
- For use by utilities and industry

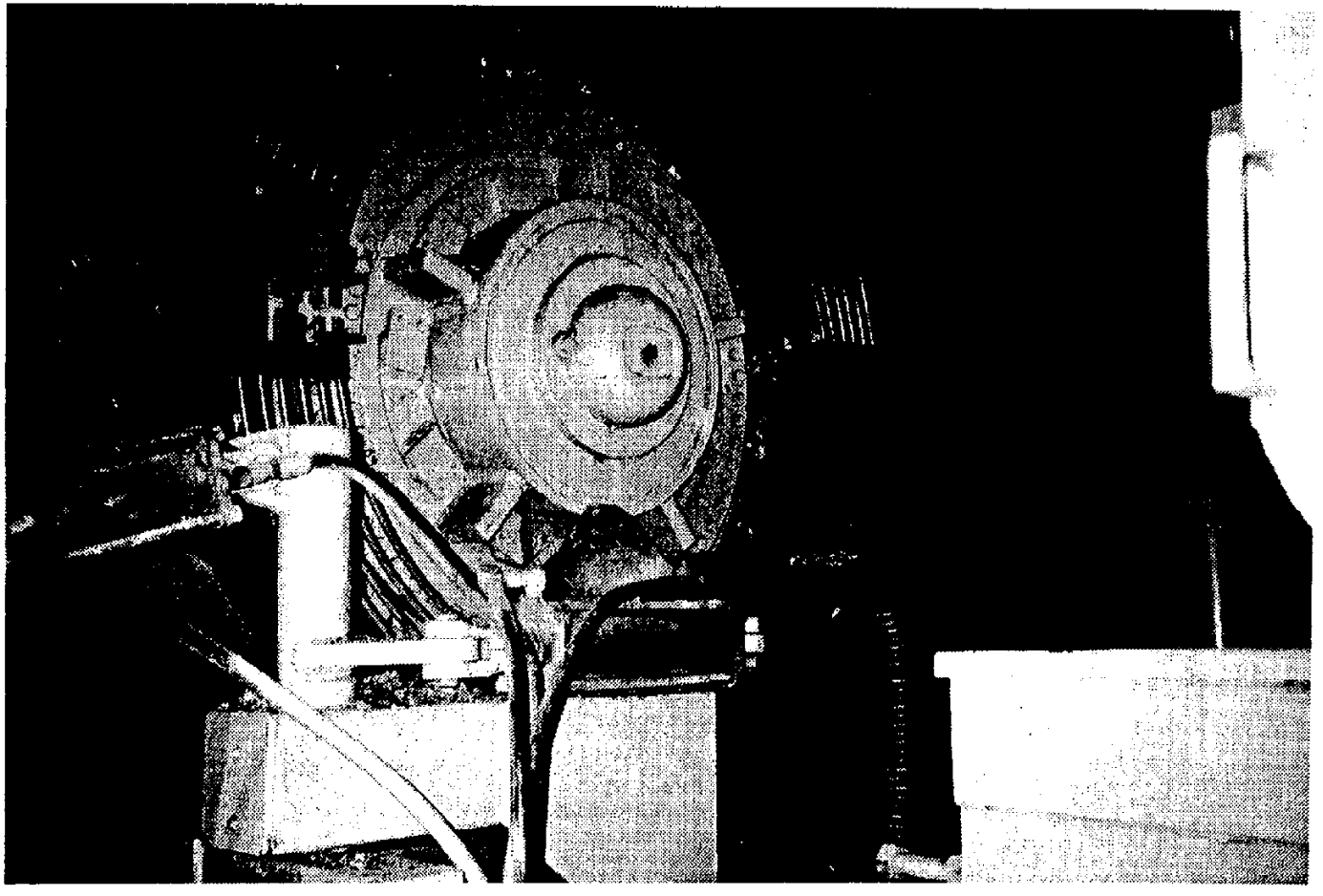
Pelletized Fuel Processing and Handling



Pelletizer



Pelletized Fuel Cuber



Pellet Fuel Forum

- December 7 and 8, 1994
- Eighteen industry professionals
- Full range of stakeholders
- NOT a policy consensus

Pellet Fuel Forum: Sponsors

- American Plastics Council
- Argonne National Laboratory
- Cemtech
- Council of Industrial Boiler Owners
- National Renewable Energy Laboratory
- Pellet Fuels Institute
- U.S. Department of Energy
- Washington State Energy Office
- Waste Management of North America, Inc.
- Organized and facilitated by R.W. Beck

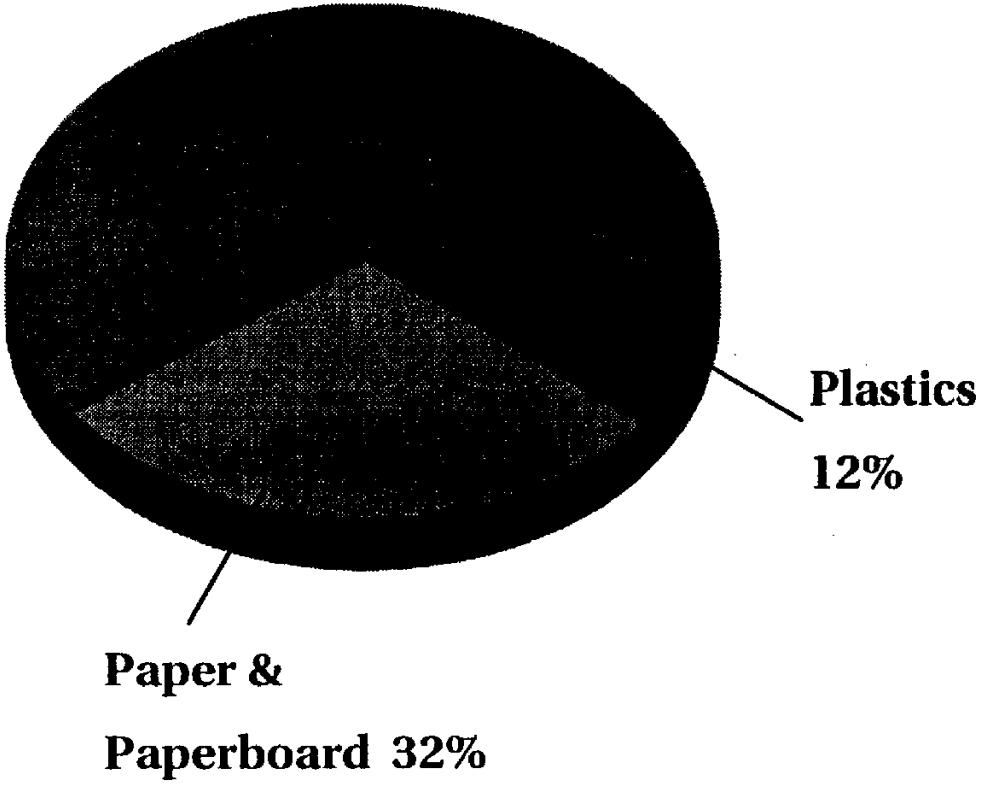
Forum: Value to Participants

- Discovery of similar views among diverse stakeholders
- Discovery of high level of interest across stakeholders
- Insight into emerging regulatory trends and threats
- New sources for information
- Identified plastics as a realistic option for pellet fuels

Common Themes

- Public regulatory perception
- Regulatory structure and risk
- Environmental benefits
- Economic questions
- Test data: development, availability and synthesis

Materials discarded in MSW, 1993



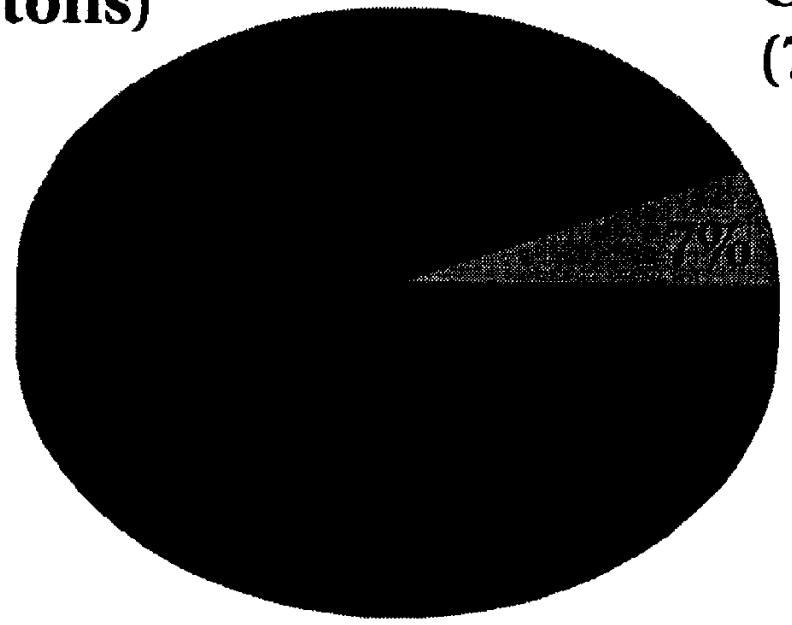
- Potential Pellet Feedstock 44% (70 million tpy)

Source: U.S. EPA, 1994

Potential Pellet Fuel as a Percentage of US Coal Comsumed

U.S. Coal Consumption
(1,034 million tons)

Potential Pellet Fuel
Consumption
(70 million tons)



Comparative Heating Values

Paper & Paperboard	Coal	Plastics
6,000 to 9,000	8,000 to 16,000	13,000 to 20,000

in BTU/pound

Stakeholder Interests

- Material industries: supplement to recycling for recovery
- Local government: additional option for material recovery
- Federal government: renewable fuel, pollution abatement
- Collectors, processors: additional value-added service
- End users: lower costs and emissions
- Regulators: allow beneficial recovery, restrict pollution

Public Perception

- Key issue: NOT combustion of MSW
- "Alternative fuel" more preferable than "mass burn"
- Public combustors: more concern than industrial boilers
- Key: Perceive material as a resource, not as waste
- Public perception drives regulation

Regulatory and Environmental Considerations

- High environmental costs and risks drive material to landfill.
- Clean Air Act: exempt from waste combustor regulation if waste is less than 30% by weight with coal.
- Bevill Amendment: exempts ash co-combusted with coal from hazardous waste regulation.
- Caution: court rulings and emerging rules could mitigate these exemptions.

State Regulations

- States can supersede federal rules
- Ton-per-day limits
- Interpretation of "waste"
- Interpretation of limits that apply to ash
- States range from accommodating to very restrictive
- Uncertainty and variation creates risk

Potential Environmental Benefits

- Resource conservation
- Reduced air emissions
- Avoided landfill gas emissions
- Reduced landfill volume
- Best material use for these feedstocks

Regulatory and Environmental Objectives

- Minimize testing costs
- Consider overall system emission reductions
- Certify fuels by specification to minimize regulation and testing
- Treat pellet fuels differently than MSW
- Base regulations on sound analysis
- Establish consistent regulatory framework

Sources of Feedstock

- Current sources emphasize non-recyclable industrial process scrap
  - Paper
  - Paper mill sludge
  - Plastic scrap
- "Dirty MRFs" could supply fuel product
- "Clean MRFs" could supply residue

Integration with Recycling

- Some paper recyclers see pellet fuel as a potential competitor for supply
- "Fiber as fuel" cannot compete economically with "fiber as fiber" (recycling)
- Pellet fuel as a backup to recycling markets
- Pellet fuel as outlet for recycling residues
- Pellet fuel could reduce collection costs by commingling materials on truck

Process and Combustion Technology

- Binders can reduce emissions, improve material handling
- Target utilization is co-combustion with coal
- Limit to utilization is often material handling
- Pulverized coal boilers are biggest challenge, biggest opportunity

Economics

- Minimum tip fee plus fuel value is $40/ton for pellet fuel.
- Pellets must compete with low-price coal (10% discount is typical).
- Capital improvements at end user must be minimal.
- Collection and transportation costs must be minimized.

Economics (cont'd)

- "Pass through" fuel cost clause: May limit incentive to use pellet fuel.
- Economies of scale are not yet realized.
- Could sell sulfur allowances.

Pelletized Fuel Economics

- Pick-up and hauling costs
- MRF and MWPF economics
- Formulation/Pelletization costs
- Energy economics
- Competing fuel prices

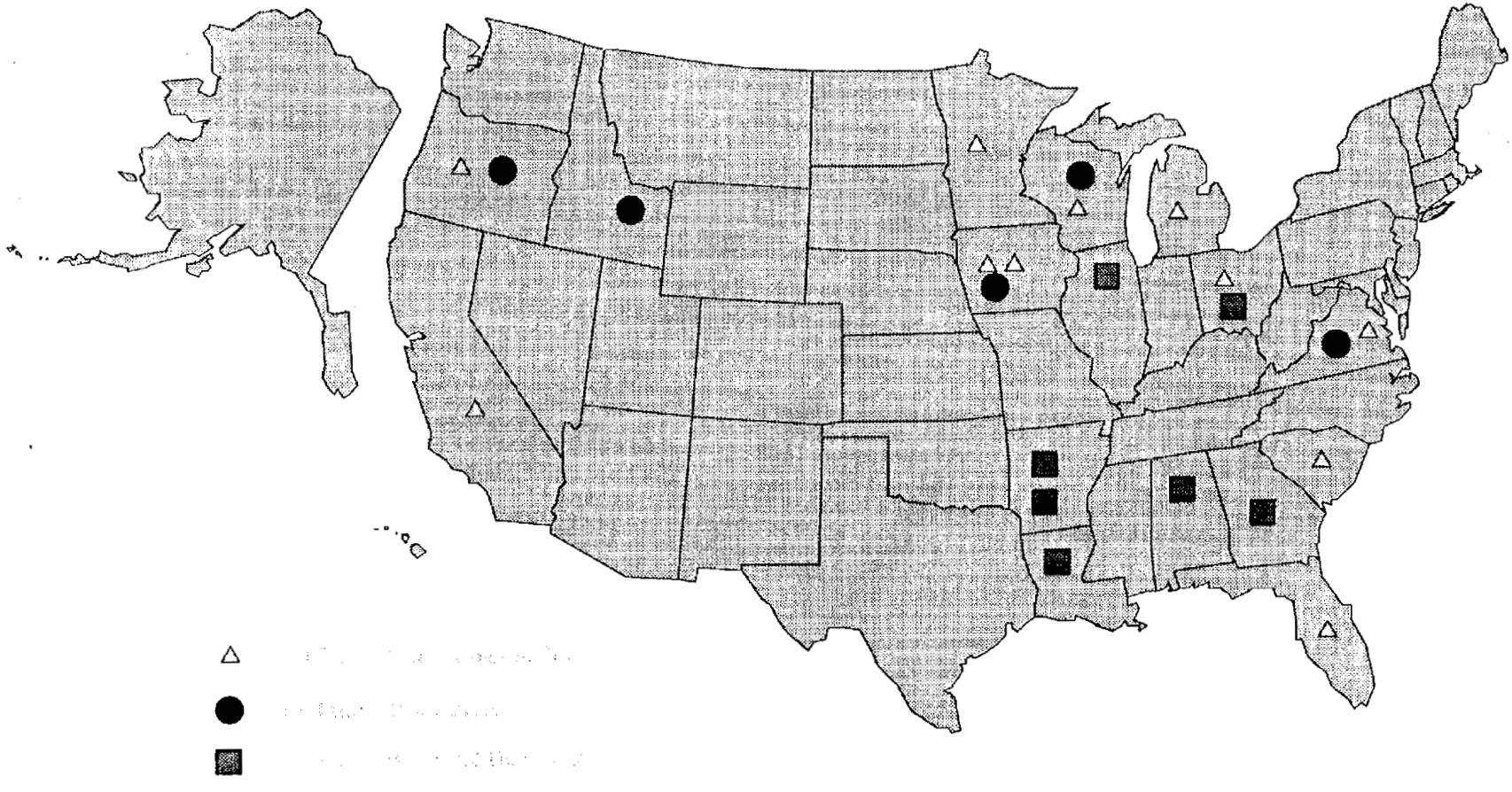
Pelletized Fuel Economics

- Incremental
- Low capital
- Existing combustion equipment
- Cost avoidance
  - Clean fuel allowances
  - Landfill diversion credits

Pellet Fuels: Operating Facilities

• Richmond, VA	Cemtech	200 TPD
• Georgetown, SC	International Paper	450 TPD
• Souix Center, IA	Van Beek	5 TPD
• Maryville, OH	NMSU	NA
• Neenah, WI	General Fuels	NA
• 10 Paper mills	NCASI Study	NA
• California	Norcal	NA
• Florida	Timber Energy	NA
• Oregon	BFI	NA
• Iowa	City Container	NA
• Michigan	Montcalm	NA
• Eden Prairie, MN	BFI	NA

Pellet Fuels in the United States



Source: RW Beck

Pellet Fuels: Test Burns

• Jarratt, VA	Georgia Pacific
• Oshkosh, WI	University of Wisconsin
• Souix City, IA	Dordt College
• Newberg, OR	Smurfit
• Manistique, MI	Akzo Salt
• Idaho Falls, ID	Idaho National Engineering Laboratory

Pellet Fuels Testing Conclusions

- SO_x reduction
- NO_x Reduction
- HCl evaluation and control
- Metals variability
- Pellets: spreader stroker and fixed grate boilers
- Cleaner than RDF
- Much data is unavailable

Pellet Fuels: Testing Objectives

- Pulverized coal boilers
- Metals from specific fuels
- Long term boiler impacts
- Plastics
- Source of furnish
- Processing (pellets vs. cubes vs. shred)
- Collect and analyze existing data

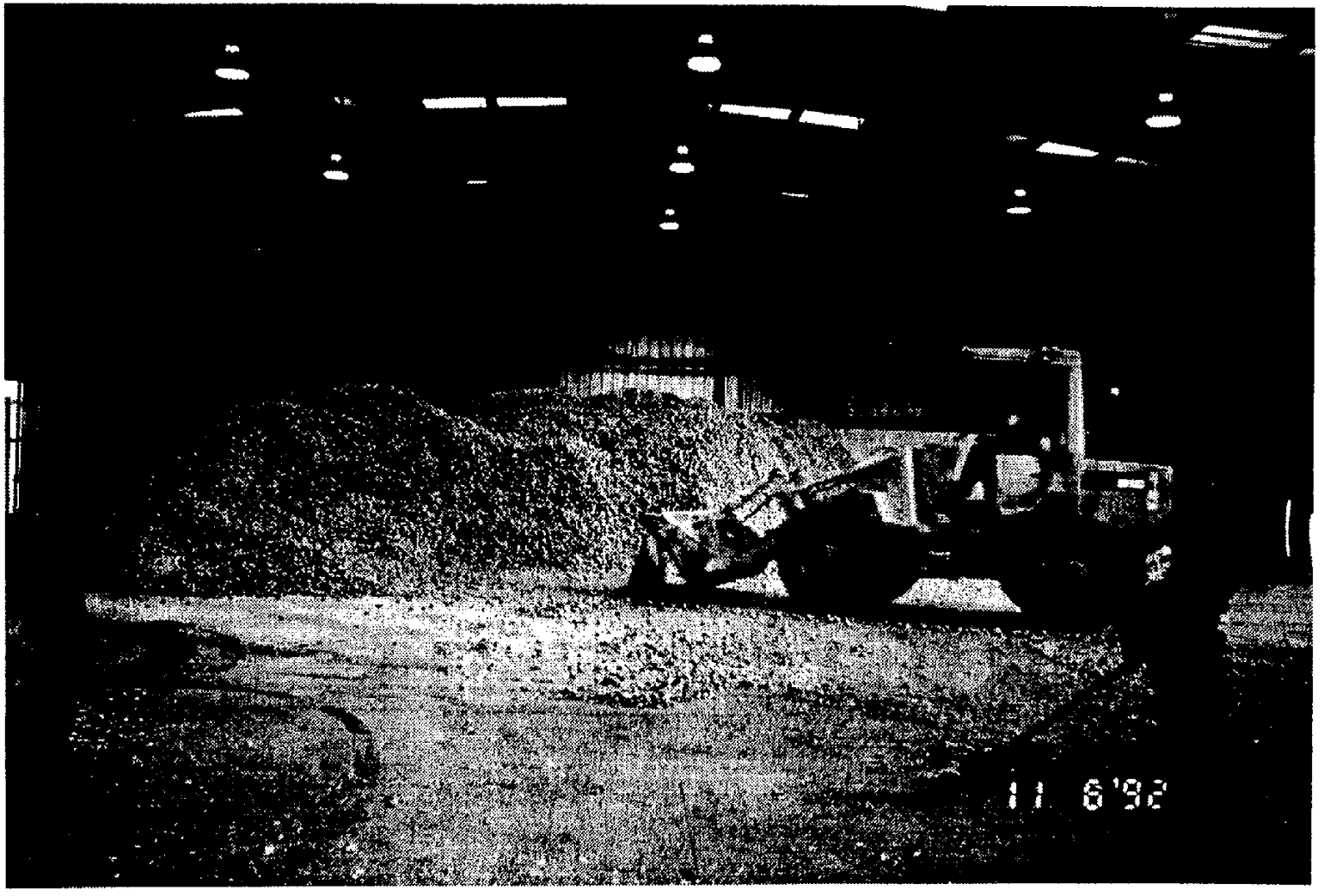
Agenda for the Development of a Pellet Fuel Industry

- Increase communication among stakeholders
- Coordinate and synthesize available information
  - Industry survey
  - Technical data base
- Business feasibility analysis
- Support test burns

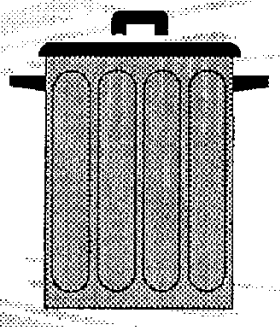
Agenda for the Development of a Pellet Fuel Industry (cont'd)

- Facilitate projects
- Change perception of pellet fuels
- Develop reasonable, consistent regulations
- Promote technology and quality control initiatives

Pelletized Fuel Processing and Handling



HARVEY ALTER



HISTORY OF d-RDF

pellets, briquettes, logs, cubettes, etc.

WHY d-RDF?

- **"RDF" coined by J. Collins *ca.*.** 1973
- "d-RDF" coined by H. Alter *ca.* 1975
  - *'d'* used to call attention in an EPA proposal
- Waste-Derived Fuels include:
  - RDF
  - tire-derived fuel
  - etc.
- RDF in several forms (ASTM)
  - d-RDF is RDF-5

THE EARLY YEARS and ON

- **1880: US Patent for compressing sawdust at elevated temperatures**
- **1917: refuse to bricks - "oakcoal"**
- 1917 (?): UK pulverised refuse densified to "coalesine"
- 1960: Stirrup (UK)
- 1972: Hollander & Cunningham
- 1976: Nelson

STIRRUP'S CONTRIBUTIONS (1960)

- Extruded processed MSW
  - magnetic separation
  - shredding
  - drying (suspension dryer)
  - extrusion ~ 6 t/h
- Briquettes large, cylindrical, ~ 1 kg
- Commercial plant described
  - apparently never built
  - some burning tests (1965)

HOLLANDER & CUNNINGHAM (1972)

- Cubettes
  - shredder
  - air classifier
  - screens
  - John Deere alfalfa cubetter
- Cubettes ~ 38x38x64 mm
- ~ 35 tons burned with coal

NELSON (1976)

- John Deere cubetter
  - developed for newspaper exports
  - flame-sprayed dies and press wheel
  - tungsten carbide coatings
- Used in the "BRINI" plants for household and commercial waste
- High thru-puts, large shred size

NCRR - (1976-79)

- Processed household waste
  - shred
  - magnetic separation
  - screen
  - air classify
  - shred
  - California pellet mill
- Similar work at Warren Spring
- Large burns

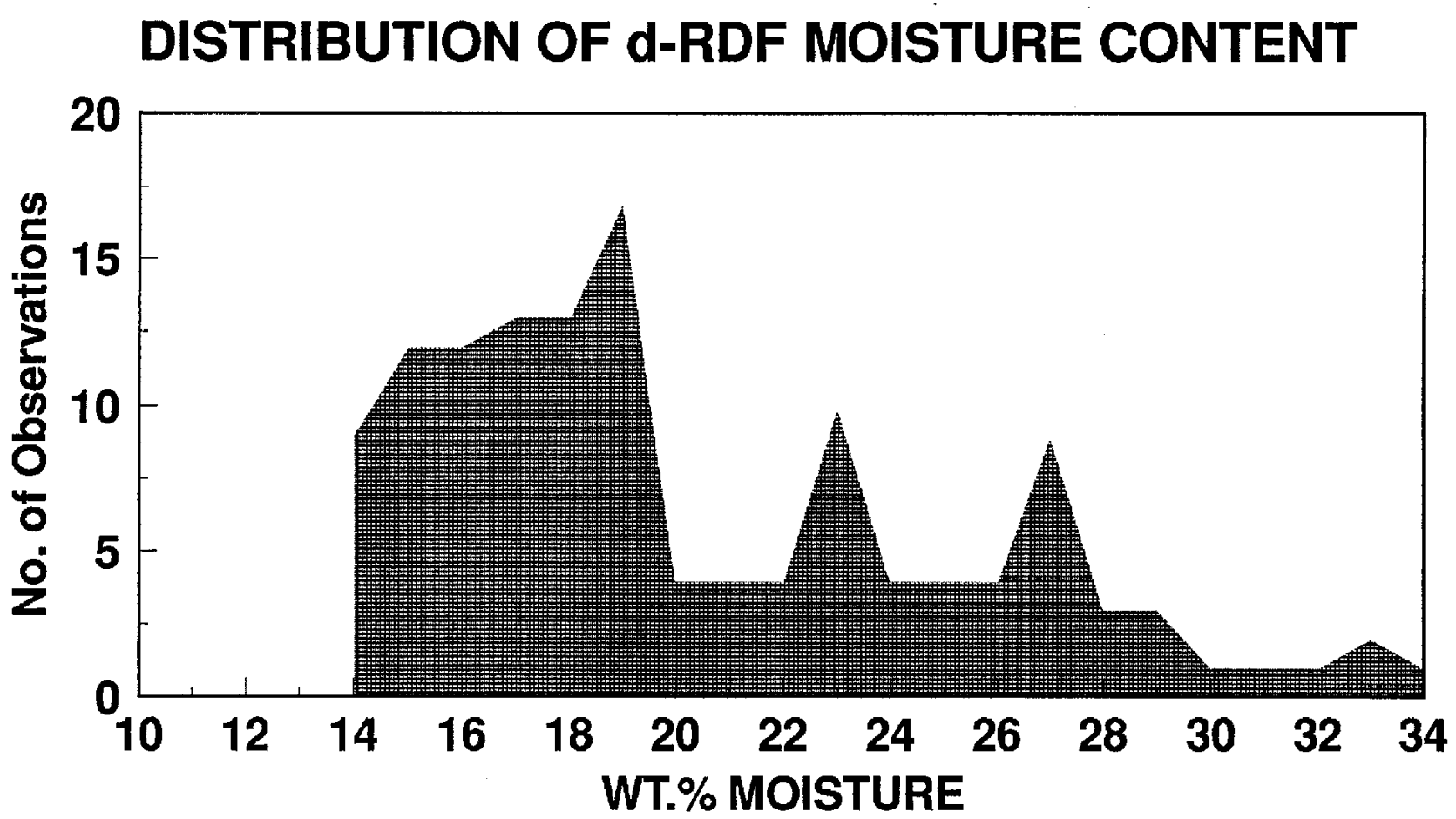
SOME LESSONS LEARNED

- Low through-puts (7-9 Mg/h not realized)
- Don't shred A/C light fraction
- "Stringy" materials are death
- High wear on dies and press wheels
  - more screening necessary
- Moisture content not important over a wide range
  - some needed to bind the pellets (~15%)
  - too much weakens (>30%)

MORE LESSONS LEARNED

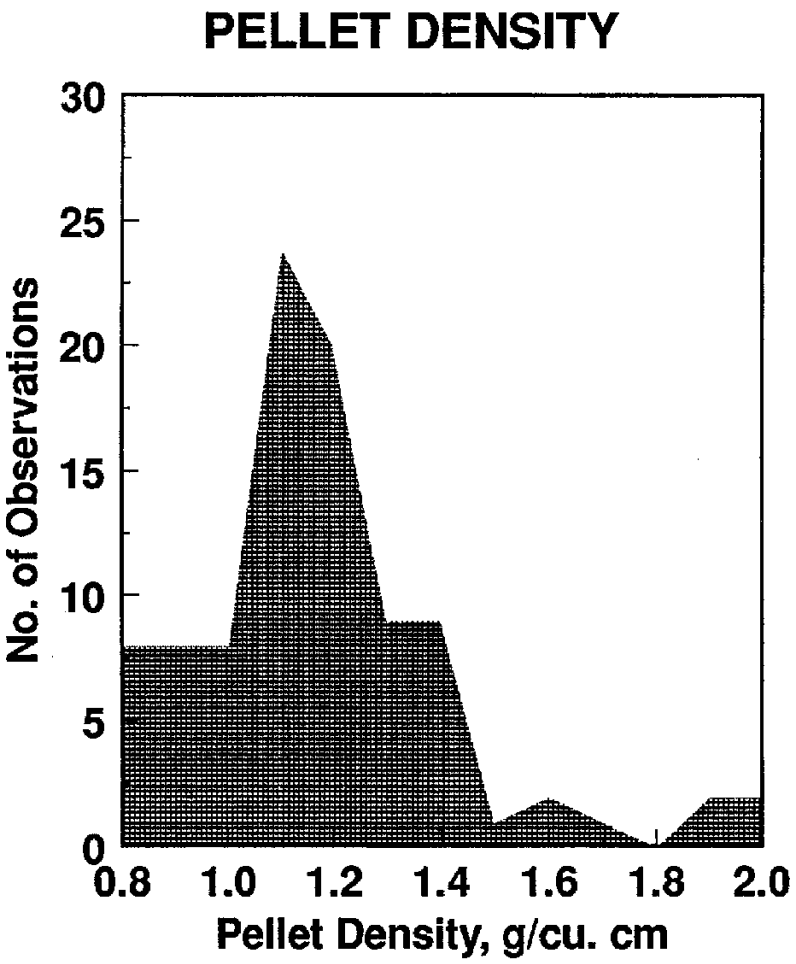
- Don't include waste oil - mush
- Can include waste plastics - somewhat
  - pellets get scaly and break
- Large piles caused fires - Why?
- Pellets can have ~130% moisture
- Pellets have great integrity
  - withstand rough handling

DISTRIBUTION OF MOISTURE CONTENT

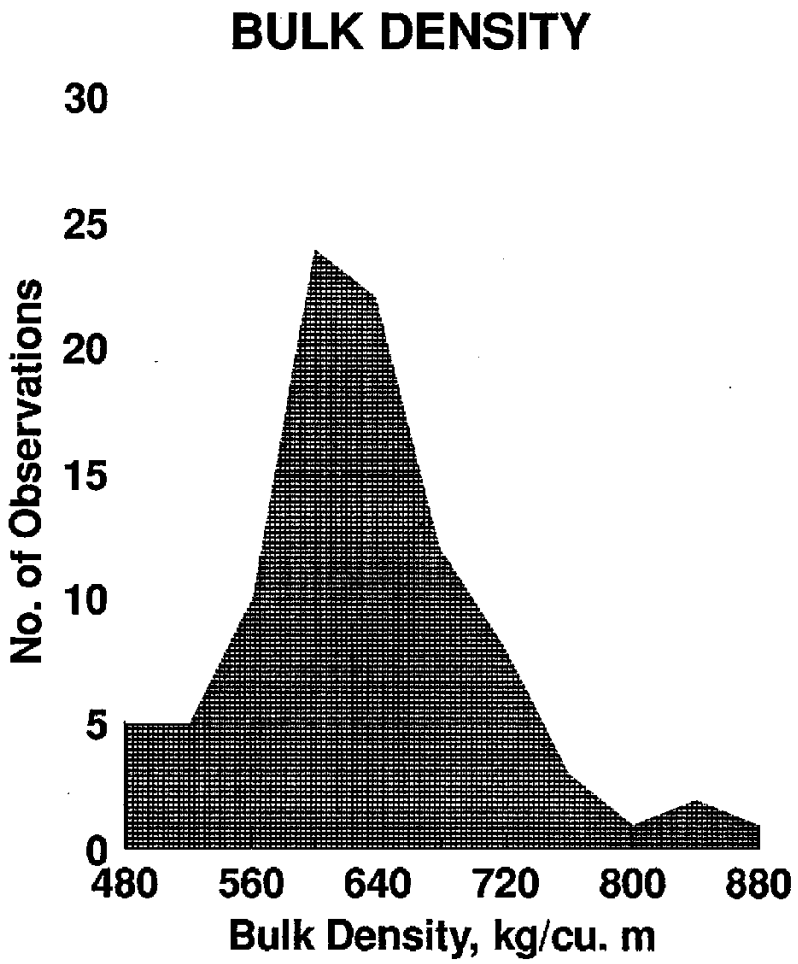


Each observation mean of 5 to 7 measurements
mean value 19.1 wt.%; s=5.41 wt. %

DISTRIBUTION OF d-RDF DENSITY



83 observations, each avg. of 5-7
mean=1.17 g/cu. cm; s=0.214



89 observations, each avg. of 5-7 measurements
mean=619 kg/cu. m, s=71.6

DROP-SHATTER

adopted from ASTM D 3038, dropped on a slanted steel plate from a height of 1.8 m

No. Drops	F	t	chi sq.	length	wt% fines
0	-	-	-	10.28	17.9
2	*	*	|*|	9.32	22.1
4	*	*	*	9.38	24.2
10	*	*	*	9.59	25.6

* no change (p=0.95)
|*| change (p=0.95)
fines < 10 mm

d-RDF with COAL TEST BURNS

- 1972-1980
  - 20 test burns
  - each > 10 Mg
  - >7000 Mg total
- Results:
  - paper burns
  - air pollution control equipment works
- Other test burns in England & France

1978 BUSINESS PROPOSAL

- 50,000 tpy of commercial and institutional wastes per plant
- RoI of 58% pre-tax per plant
- Seven year plan
  - 5 plants @ 50,000 tpy; 2 @ 12,000 tpy
  - $~7million (1978)
  - break-even after 5-1/2 years
  - 9.2% return cumulative capital year 6
  - 39.5% return cumulative capital year 7
- 100% debt leveraged

1978 BUSINESS PROPOSAL

- 200 tpd commercial and institutional waste
- Simple flow sheet
  - trommel
  - shred
  - Papakube densifier
- Selected waste results in high yields
- Proprietary technology for assuring meeting high fuel specifications
- Fuel sold at $1/MM Btu
  - RoI has low sensitivity to fuel sales

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- 200 tpd commercial and institutional waste
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- Fuel sold at $1/MM Btu
  - RoI has low sensitivity to fuel sales

Some of the Pioneers

- Stirrup
- Hollander & Cunningham
- Heikki Elo
- Gerry Nelson
- National Recycling Corp.
- Vista
- Grumman
- Black Clawson Co.
- Teledyne National Co.
- National Center for Resource Recovery

SPECIAL RECOGNITION OF A PIONEER

Carlton Wiles
Project Officer
1974-1979

SECTION 3: MARKET CHALLENGES AND TECHNICAL ISSUES

This section includes notes and publications submitted by conference speakers . Brief summaries of each presentation can be found in Section 1: Overview and Outcomes.

MARKET CHALLENGES: ECONOMICS

Presented by Roger Davis, Executive Director, Pellet Fuels Institute

TECHNICAL ISSUES: FUEL PREPARATION

Presented by Robert Massengill, California Pellet Mill Companies

TECHNICAL ISSUES: COMBUSTION

Presented by Ole Ohlsson, Program Manager, Argonne National Laboratory

EUROPEAN TRENDS

Presented by Niranjan Patel, Section Manager, Resource Recovery & Combustion Section, ETSU, UK

Roger Davis, Pellet Fuels Institute

Market Challenges – The Economics of Selling the Fuel

I. Introduction

Today, more than any time since the early to mid 80's, the interest level in Processed Engineered Fuels has again started to rise. Historically, the early 70's, represented by peaks surrounding an oil crisis, was a period of problem recognition and a scrambling to replicate whatever the Europeans had discovered about energy recovery from waste sources. In 1972, while still a college professor, I managed a four–person research team that completed a five–state study entitled "Feasibility Analysis of Recovery and Recycling of Multi Grades of Residential, Commercial and Industrial Plastic Waste". I reread that study recently and am amazed that what we discovered and what we predicted then was accurate and is still applicable in today's setting. If the 80's represented interest, the 90's to this point have represented lost opportunities and litigation.

II. Factors Influencing the Value of the Fuel.

So, what is today's setting? I am going to reverse the order of the issues I am to speak on as listed in the program. I will address <u>What are the factors influencing the value of the fuel</u> before addressing what is the fuel value in the current open market.

So, what <u>are</u> the factors that influence fuel value. Let me start by stating that these factors are influenced first by the existence, within a reasonable distance of the production point, of at least one boiler system that can handle your type of fuel in a form that you and they can agree to. Handling and combusting, as others have already alluded to, are two very separate issues and often enough it is the handling system issue more than the combustion issues, coupled with the PUC fuel savings policy, that dictate whether a facility has **any** interest in even talking to you. Ask Dean Pawlowski from Ottertail about the PUC factor. Ottertail is a "white hat", dedicated company; there is no other reason they were the industry leader on the issue of purchasing PEF.

The key factors are:

1) Will the product handle within the existing power plant hauling system configuration.

2) What existing fuel is the primary and does it have any short comings, such as:
    a) high moisture levels
    b) BTU level low
    c) emission level concerns – acid rain, etc.

3) What are the fuel buyers used to paying per million BTU's for their primary fuel and for any other alternative they might be using or are contemplating using.

4) What part of the total energy mix is your product (are you 2% or 20%)?

5) What does **your** fuel bring to **their** table. In other words, what specifically might cause your fuel to be more (or less) valuable to the buyer?

6) How reliable can you be in supplying the buyer's needs? Keep in mind that:

   a) They are typically a base load plant, on line seven days a week, 24 hours a day and, except for prescheduled maintenance or emergencies, they are going to want your fuel on site in the same percentage mix on their schedule.

   b) **They** are going to want your fuel to be internally pretty consistent, particularly if there is a significant BTU difference between their base line fuel and your fuel and/or **as your** percentage grows as part of their overall mix (i.e. 20% instead of 2%).

7) How your delivery system and their receiving system interface, including outside storability, surge capacity and yard cleanliness issues.

While these above seven points may be the keys, they are really only the points you and the buyer need to know the answers to before either one of you know whether or not it is even worth talking to each other about the other issues. From the buyer's point of view, **if he is comfortable** with the above, he then will move on to:

1) What's in the fuel that might harm my plant handling system? (Tripping out and going off line or even getting an upset boiler is not just an inconvenience of the moment.) Do we – John – Dean, Oli want to talk about **the EXEL** fuel problem at 5:30 a.m. in our Big Stone test burn? Not a good scene.

2) Are there any regulatory related problems, either direct (such as particulate, trace metals in the ash or air) or indirect, such as a need for repermitting or a need for a new ash disposal permit.

3) Are there things in the fuel that might impact long-time maintenance issues – aluminum, as an example.

4) Long term regulatory indirect issues.

5) And, finally – what's this stuff going to cost me, laid in, in the form, **and quantity** that I want it in, per million BTU's.

From the seller's point of reference, he wants to max his net profit, which means he must, in addition to the common issues, consider the following:

1) How does the fuel sale value relate to other revenue streams within my plant? As an example, if I am getting $50 per ton for tipping, and another $10 per ton in recycling revenues **but I can't sell off the fuel,** I really can't get at those other revenues unless I get the fuel stream out of my back door. If I bury it or store it (Hi, John), there is a cost of doing that. Is that cost more or less than the cost I might get from selling the fuel, even at a loss? Think about that.

2) Since fuel is purchased by the plant laid in at the plant (traditional), what form do I need to put it in to max out my shipping, tonnage wise rather than volume wise.

   a) density – plant capability vs power buyer need and the cost of production to match that need.

   b) back hauling – how dependable

   c) dependability of the hauler

   d) the distance factor

   e) truck cycling time

   f) cost/vs the "value" of the fuel; keep in mind that the **value of the fuel is not necessarily the value paid by the buyer**, but the value you place on it to "get it out of the door" in order to get at the other revenue streams.

III. The Value of Fuel in the Open Market

What is the value of the fuel in the open market? My God, what a dumb question this has now become. After figuring in all the previous factors and issues, both the seller

and their buyer know that each has a range they need to be in to make the sell/buy deal work. For the buyer, he will place a value on the fuel and, realistically, it should have very little to do with the cost he is actually paying for his primary fuel because it is a lesser quantity – let's say the coal he is "buying" from a coal mine he already owns a piece of plus the local super railroad rate he gets on a cost per million BTU basis. Unfortunately, ego, etc, tells the buyer he can always burn only coal (unless he has a sulfur or NOX issue/problem) so obviously the price he will pitch to the PEF supplier will be less than the coal alternative, usually 50%–80% of his existing coal contract price delivered.

From the seller's stand point, knowing what the buyer is paying for the coal laid in is really not difficult to find out. It's public – PUC can and will tell you. Unfortunately, so what, right? Since the fuel buyer has probably also done his homework and usually knows he is "the only act in town", he is going to act and negotiate accordingly. I was in one meeting recently where the power company wanted, as an opening shot, to be paid to take the fuel – at a cost they figured out, was just a little bit cheaper than the cost the fuel supplier would pay to bury the stuff in a local landfill – **$30 per ton, you pay me!** Let's hope that is the bottom of the range we are trying to establish as to what the fuel is worth "in the open market". The top of the market is, in all likelihood, the cost to the buyer of his alternative, i.e. more coal, wood or whatever his dominate, under contract, long term, base fuel. Best case, your fuel value gets a little more if an SO^2, NOX issue exists.

So, where does that put us in today's pricing of PEF, delivered. Probably in the $15–$20 per ton range in most cases, and around $20–$22 if something else gets solved and they own their own landfill for ash disposal and the rules don't change, and, and, and. That is a very far cry from the fuel value in terms of my other role for the Pellet Fuels Institute – which Bob Massengill over here is our President. Our wood waste pellet industry gets $100 – $120 per ton wholesale, $175–240 per ton retail for their residential fuel in the open market. Is there any wonder that I probably average 2–3 calls per day with people that want to figure out if they can turn their particular waste stream into a fuel for the residential stove market? Thank God we have standards that I can fall back on and an association leadership and staff that understands both the PEF commercial fuel characteristic, combustion, ash, clinkering potential, etc. and also the residential fuel specifications and standards. And we are willing/able to defend, discourage and even occasionally threaten people that are wanting to make a quick buck by selling a fuel that would damage our present industry. It is a lot easier and smarter to prevent a problem than trying to find a way to explain all the various whys to a person that bought a $4,000 residential heating appliance that is now a fouled up mess or that has just wrecked havoc on the inside walls of their home. There is a need for an ability to prevent marginal fuels from ever reaching the residential fuel markets. That need is being filled by our Institute because we understand both products. Unfortunately, some people in my "other" industry – the wood waste fuel folks – do not understand that this attraction/impact relationship exists and probably

never will until a bad situation slams them in the face. I do not want, and will always work hard to prevent those of you in this room that admire the fiscal rewards side of selling into the residential market from ever selling a single ton of fuel to a residential customer. Sawdust to wood pellets works and if it ain't broke, we don't want you to try to fix it.

IV. What If It Isn't An Open Market Issue.

One last thought. What I have talked about up to this point is "the current open market". There is an alternative and that is a non open market. I was recently assured by a certain legislative body that they could pass legislation that would require utilities to purchase a specified percent of their fuel needs from post consumer/post manufacturing waste streams. **That is an alternative** and my bet is that we will see a movement in that direction if more utilities like Ottertail and NSP don't step forward on their own to take responsible steps toward using a portion of our currently landfilled high energy waste streams. I would say bet on it, and take that thought to the bank. I believe that if you don't see more power companies step forward on their own by the time some form of flow control comes back into being, look for several states to look at this alternative seriously.

COMMON POINTS

1) WILL THE PRODUCT HANDLE WITHIN THE EXISTING POWER PLANT HAULING SYSTEM CONFIGURATION.

2) WHAT EXISTING FUEL IS THE PRIMARY AND DOES IT HAVE ANY SHORT COMINGS, SUCH AS:

   A) MOISTURE LEVELS

   B) BTU LEVEL LOW

   C) EMISSION LEVEL CONCERNS – ACID RAIN, ETC.

3) WHAT ARE THE FUEL BUYERS USED TO PAYING PER MILLION BTU'S FOR THEIR PRIMARY FUEL AND FOR ANY OTHER ALTERNATIVE THEY MIGHT BE USING OR ARE CONTEMPLATING USING.

4) WHAT PART OF THE TOTAL ENERGY MIX IS YOUR PRODUCT (ARE YOU 2% OR 20%)?

5) WHAT DOES YOUR FUEL BRING TO THEIR TABLE. IN OTHER WORDS, WHAT SPECIFICALLY MIGHT CAUSE YOUR FUEL TO BE MORE (OR LESS) VALUABLE TO THE BUYER?

6) HOW RELIABLE CAN YOU BE IN SUPPLYING THE BUYER'S NEEDS? KEEP IN MIND THAT:

   A) THEY ARE TYPICALLY A BASE LOAD PLANT, ON LINE SEVEN DAYS A WEEK, 24 HOURS A DAY AND, EXCEPT FOR PRESCHEDULED MAINTENANCE OR EMERGENCIES, THEY ARE GOING TO WANT YOUR FUEL ON SITE <u>IN THE SAME PERCENTAGE MIX</u> ON THEIR SCHEDULE.

   B) THEY ARE GOING TO WANT YOUR FUEL TO BE INTERNALLY PRETTY CONSISTENT, PARTICULARLY IF THERE IS A SIGNIFICANT BTU DIFFERENCE BETWEEN THEIR BASE LINE FUEL AND YOUR FUEL AND/OR AS YOUR PERCENTAGE GROWS AS PART OF THEIR OVERALL MIX (I.E. 20% INSTEAD OF 2%).

7) HOW YOUR DELIVERY SYSTEM AND THEIR RECEIVING SYSTEM INTERFACE, INCLUDING OUTSIDE STORABILITY, SURGE CAPACITY AND YARD CLEANLINESS ISSUES.

BUYER'S POINT

1) WHAT'S IN THE FUEL THAT MIGHT HARM MY PLANT HANDLING SYSTEM? (TRIPPING OUT AND GOING OFF LINE OR EVEN GETTING AN UPSET BOILER IS NOT JUST AN INCONVENIENCE OF THE MOMENT.)

2) ARE THERE ANY REGULATORY RELATED PROBLEMS, EITHER DIRECT (SUCH AS PARTICULATE, TRACE METALS IN THE ASH OR AIR) OR INDIRECT, SUCH AS A NEED FOR REPERMITTING OR A NEW ASH DISPOSAL PERMIT.

3) ARE THERE THINGS IN THE FUEL THAT MIGHT IMPACT LONG-TIME MAINTENANCE ISSUES - ALUMINUM, AS AN EXAMPLE.

4) LONG TERM REGULATORY INDIRECT ISSUES.

5) AND, FINALLY - WHAT'S THIS STUFF GOING TO COST ME, LAID IN, IN THE FORM, AND QUANTITY THAT I WANT IT IN, PER MILLION BTU'S.

SELLER'S POINT

1) HOW DOES THE FUEL SALE VALUE RELATE TO OTHER REVENUE STREAMS RELATED TO MY PLANT? AS AN EXAMPLE, IF I AM GETTING $50 PER TON FOR TIPPING, AND ANOTHER $10 PER TON IN RECYCLING REVENUES BUT I CAN'T SELL OFF THE FUEL, I REALLY CAN'T GET AT THOSE OTHER REVENUES UNLESS I GET THE FUEL STREAM OUT OF MY BACK DOOR. IF I BURY IT OR STORE IT THERE IS A COST OF DOING THAT. IS THAT COST MORE OR LESS THAN THE COST I MIGHT GET FROM SELLING THE FUEL, EVEN AT A LOSS? THINK ABOUT THAT.

2) SINCE FUEL IS PURCHASED BY THE PLANT LAID IN AT THE PLANT (TRADITIONAL), WHAT FORM DO I NEED TO PUT IT IN TO MAX OUT MY SHIPPING TONNAGE WISE RATHER THAN VOLUME WISE.
   - A) DENSITY – PLANT CAPABILITY VS POWER BUYER NEED AND THE COST OF PRODUCTION TO MATCH THAT NEED.
   - B) BACK HAULING – HOW DEPENDABLE
   - C) DEPENDABILITY OF THE HAULER
   - D) THE DISTANCE FACTOR
   - E) TRUCK CYCLING TIME
   - F) COST/VS THE "VALUE" OF THE FUEL; THE VALUE OF THE FUEL NOT NECESSARILY BEING THE VALUE PAID BY THE BUYER, BUT THE VALUE YOU PLACE ON IT TO "GET IT OUT OF THE DOOR" IN ORDER TO GET AT THE OTHER REVENUE STREAMS.

Technical Issues: Fuel Preparation

Presented by:

Robert Massengill
California Pellet Mill Companies

WASHINGTON DC PRESENTATION
NOVEMBER 16, 1995

I wear several hats in my line of work and I am appearing here today wearing all of them. I want to talk about the technical aspects of producing process engineered fuels. This is commonly known as pelleted or cubed fuel. I have spent my adult life in the use of densification equipment. Currently, I represent both California Pellet Mill Co. and Warren & Baerg. They are respecttively the largest producers of pellet mills and cubing equipment. I also helped found the only trade association that works almost exclusively with people in the densified fuel industry. This association is the Pellet Fuels Institute. So you can see I am vitally interested in today's meeting.

Some years ago, a combustion engineer some of you may have known , named Richard Wright and worked for Aqua Chem Engineering, told me something that I have never forget and that changed my life around. It was during those fuel shortage days of the mid-seventies and many of us were looking at alternative fuels for the first time. He said, and I quote< " If I could invent a perfect solid fuel, I don't know how I could improve on the wood pellet.

He was refering to those characteristics that we take for granted in pelleted fuel today. Uniformity of size

and density, low moisture, good flow and bulk handling ability, and good heating value. THis is a fuel that can flow like sand or shelled corn and is handled with the same equipment. This is a fuel with built in areation if relatively free of fines in the fire box. It will store and keep indefinitely if dry. It can be made from an almost limitless array of waste products that when in their original form are so different, yet become so similar when pelleted or cubed. Just a few of the products I am personally acquainted with that are used as densified fuel include wood, garbage, waste paper, sun flower hulls, peanut hulls, almond hulls, oat hulls, sugar beet seed, switch grass, corn stover, textile scrap, rice hulls and on and on.

Many of you are aware of most of these fuels and that they are frequently densified before being used as fuel. What you may not be so aware of is that the varying degrees of quality that limits their use in some cases, can be over come by understanding the densification process a bit better. I'm sure you're familiar with the fact that some fuels have been discontinued in specific areas due to low quality. Again, this could usually be over come by being aware of what can be done to improve this percieved low quality. Just about anything can be made into a processed Engineered fuel if we follow a few guide lines. I'd like to start by showing a short video that takes a look at a fairly typical process

in Alaska. It is a PEF operation at Eielson Airforce Base in Anchorage, Alaska.

Show video with sound down - Narrate

What you just saw is a fairly simple and economical installation that does a good job in areas where raw material is as clean and accessable as this one. Raw material in this case is packaged and/or clean which simplifies the preperation of the material for cubing. In most areas of the Country, due to the high price of paper, only low quality and contaminated paper is available for fuel processing.

Understand that the processing of waste stock into cubes or pellets does not change the heating value . The exception is where moisture removal is part of the process. What densification does is allow for a lot more fuel to be placed in a given sized fire box. So many BOILERS can be up graded by this method, supplying more fuel due to the increased densification. This can be dramatic where the contrast is great as where pellets are substituted for RDF "fluff" or wood pellets instead of green wood chips. This leads to the question of how much up grading can be done. This will depend upon the increase in density that is accomplished in the cubing or pelleting process. This in turn, depends in part on whether you make pellets or cubes. Let's look at some of the usual differences between the two.

Transparency #1 Pellet-Cube comparison-Discuss

Transparency #2 Photo of pellets and cubes-show

Preperation of raw material for densification is very similar whether it be for pelleting or cubing. The biggest difference in preperation is the particle size. Let me explain. if you want tyo make a 1/4" pellet, expect to reduce the raw stock down to near the 1/4" size the pellet will be. Any material that is going to pass through a 1/4" die has to be 1/4" or less in size and there are more efficient ways to reduce the stock to this size than to let the pellet mill grind away on it. A pellet mill is for densification, not grinding. The other side of this is that the smaller size allows the pelet mill to make a more dense product. The cuber on the other hand, is making a larger pellet or cube and can accept larger size particles. This is so up to several times the cube size, Since the cuber is normally making the product as dense, there is not as much resistence in the Die so more "face" grinding can be accomplished. The product is still being reduced to cube size before entering the cube orfice. Typically, a cuber producing 1 1/4" cubes can work nicely on raw stock of 3-5" single dimension. The down side if there is one,is a product of lower density and one that doesn't withstand handling as well.

So let's look at a flow diagram that is very sililar to what you saw in the video.

Transparency #3

Take through the system, naming each step.

For a more refined cube and / or pellet the flow may be extended to include a couple more steps.

Transparency #4

point out the same flow with the addition of cooler. To stabilize the moisture. Prevent spontaneous combustion, prevent condensation et. The shaker willl remove the smaller particles or fines, return them to the system for re-pelleting and deliver a clean product to storage or transport. This step is particularly necessary where the end user cannot tolerate fines as they will cause premature combustion.

The two biggest variables that contribute to pellet quality that we havn't discussed are moisture and density. These , more than anything else determine the value and market for the product as a fuel. The higher moisture value will obviously lower the heating value of the fuel. Also, since moisture cannot be compressed and stay moisture, higher moisture raw material will not make as dense a product. For these reasons, it may be

desirable to add a dryer to the densification process. This answers both problems of allowing a higher BTU cube as well as amore dense one.

So, with moisture a given. let's say 20%, what determines the density of the pellet or cube beside the grind which we have already covered. Die design. This is the most mis-understood and most complex of the entire process. Let me put this in a simple way by showing how densification occurs .

Transparency #5 How pellets are made

Go through the process.

Now let me take this Die I have just described and blow it up to show what causes the densification. And how we can vary it.

Slide # 6 Die design. Explain compression ratio.

Variations can also ocur to change the co-officient of friction of the raw material. TRhis is accomplished by the addition of slip agents or binders, depending whether you want to lower or raise density with out the task of changing Dies. Doing this does not change the need to change Dies,We have instead changed the co-efficient of friction of the raw material to where it requires a different compression ratio.

The equipment you select to densify your chosen product then depends on your market for the finished fuel more than anything else. If you are processing the material for combustion on site or a short distance away, cubes would make more sense. Is your market far away, will it need to be handled with conventional grain handling equipment, does it need to be stored in bins. is a dense product desired, than pellets are you choic. Is quality more important than capacity, pellets are the answer. Is capacity and cost more important than density , go cubing.

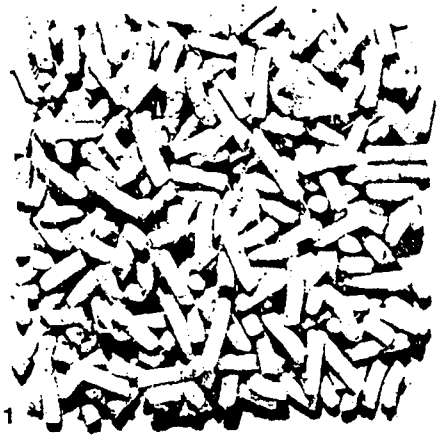
Time permitting, go through cuber layout and cuber.

Transparency # 7 Cuber lay out explain all componets

Transparency # 8 Cuber-explain briefly.

#1

	PELLETS	CUBES
SIZE	1/16" - 1"	1" - 2"
DENSITY LB CU FT	35-45	25-32
MOISTURE	0-40%	0-40%
FLOWABILITY	EXCELLANT	FAIR
PRODUCTION COST-TON	$15.00	$10.00



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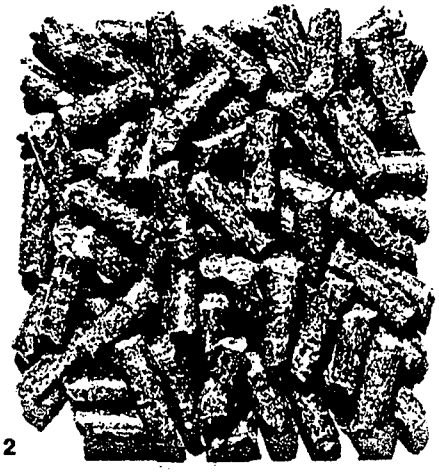

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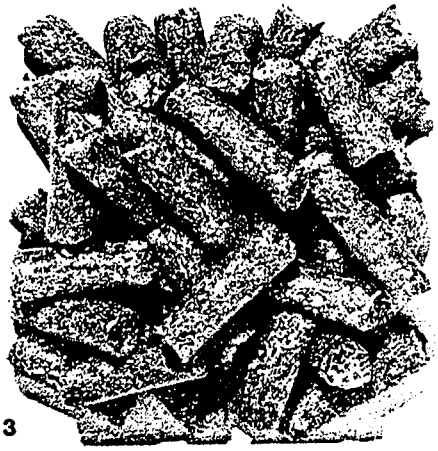

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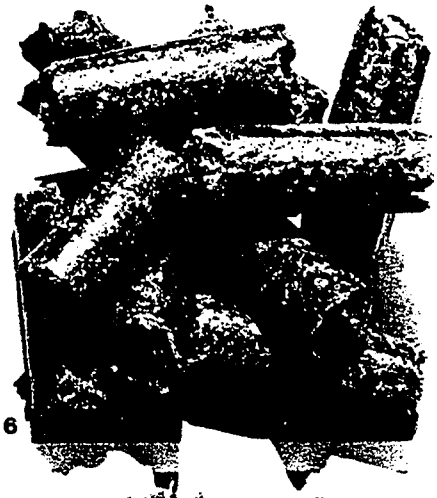


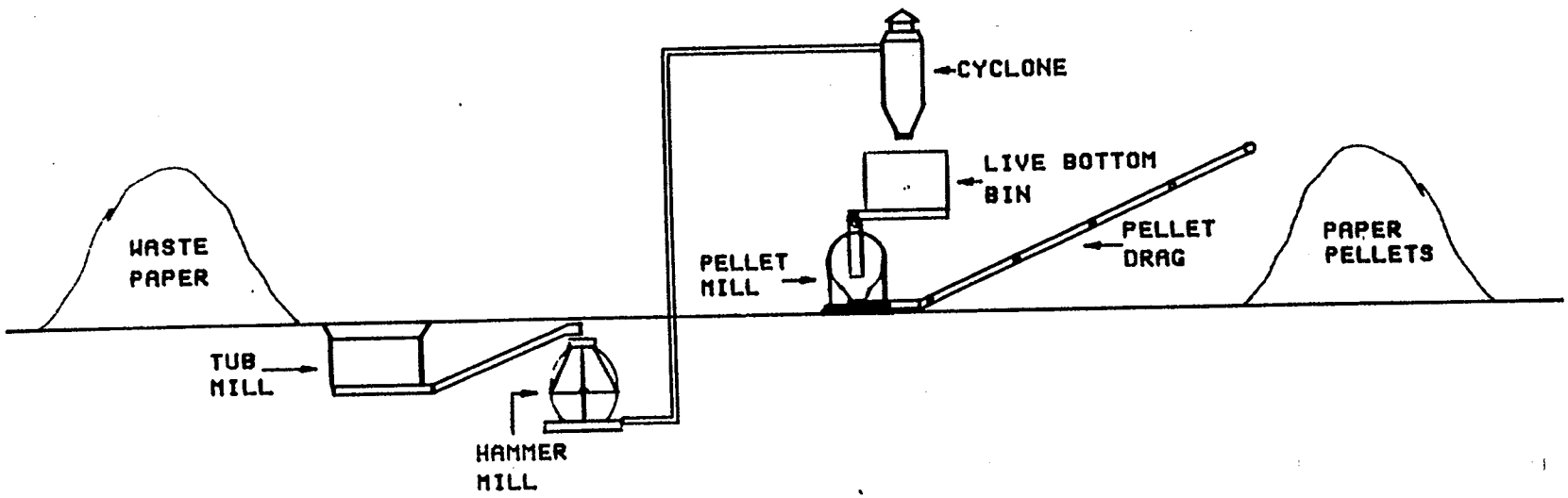
6

7

1 Mineral feed
2 Rabbit feed
3 Hop
4 Cattle feed
5 Dried forage
6 Dried beet pulp
7 Complete straw feed

#2

THIRTY TON PER DAY PAPER PELLET PLANT



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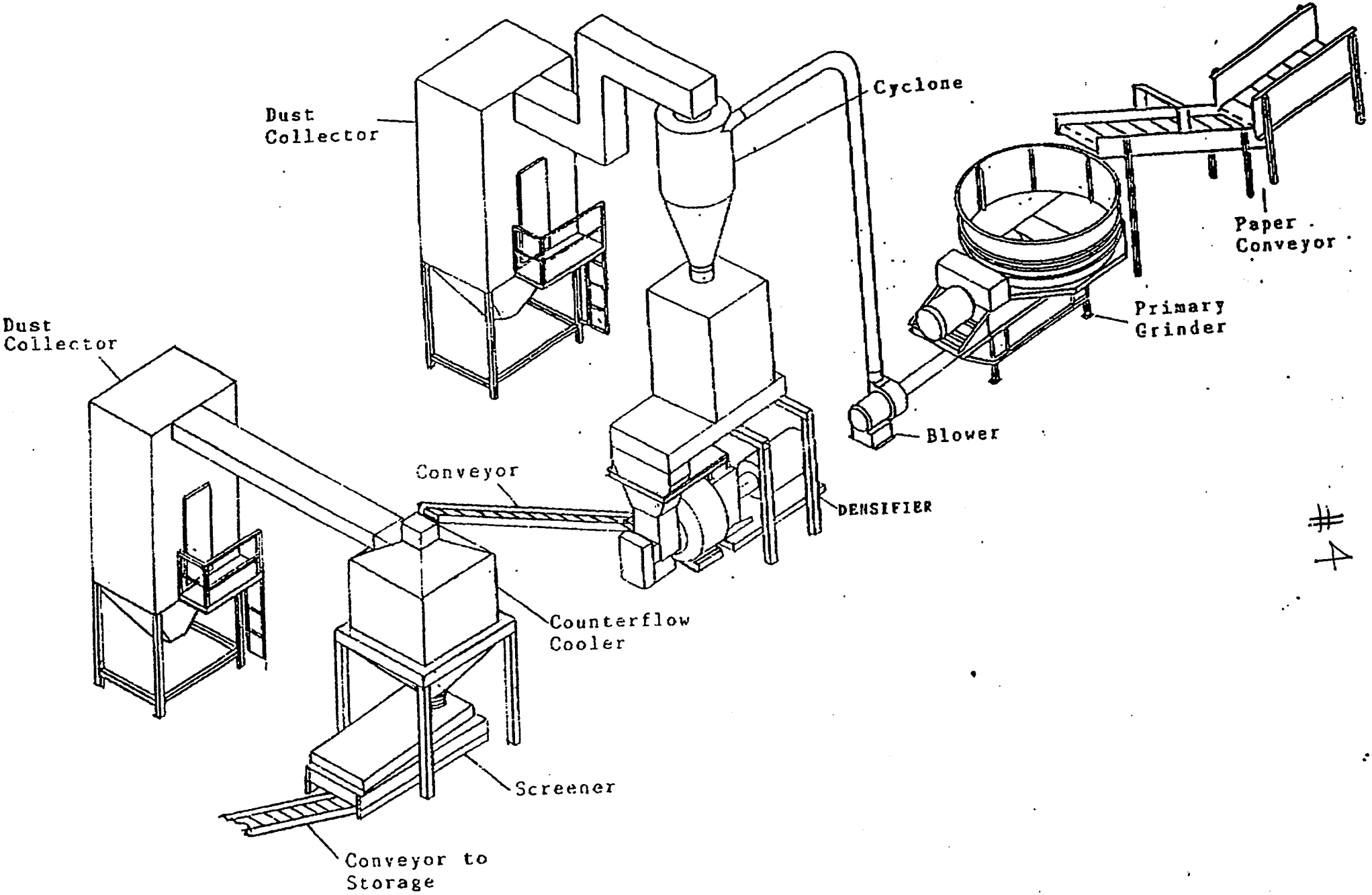
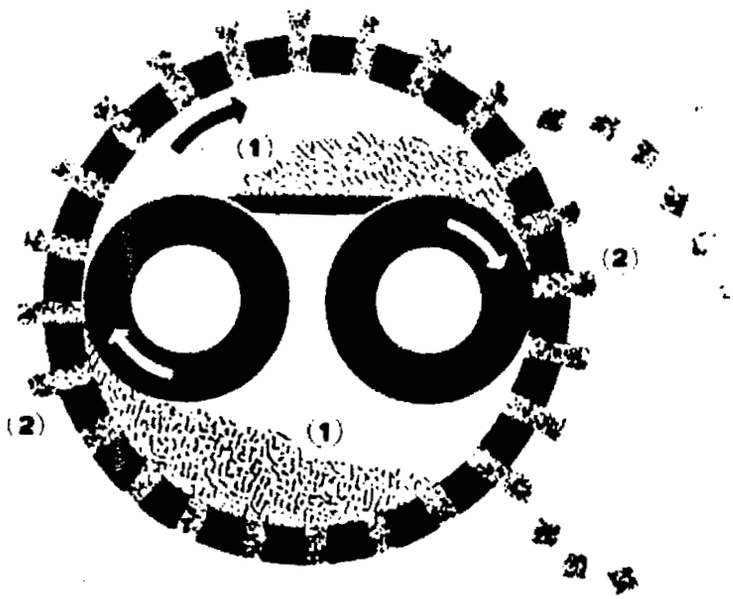

Dust
Collector
Cyclone
Paper
Conveyor
Primary
Grinder
Blower
Dust
Collector
Conveyor
DENSIFIER
Counterflow
Cooler
Screener
Conveyor to
Storage

#4

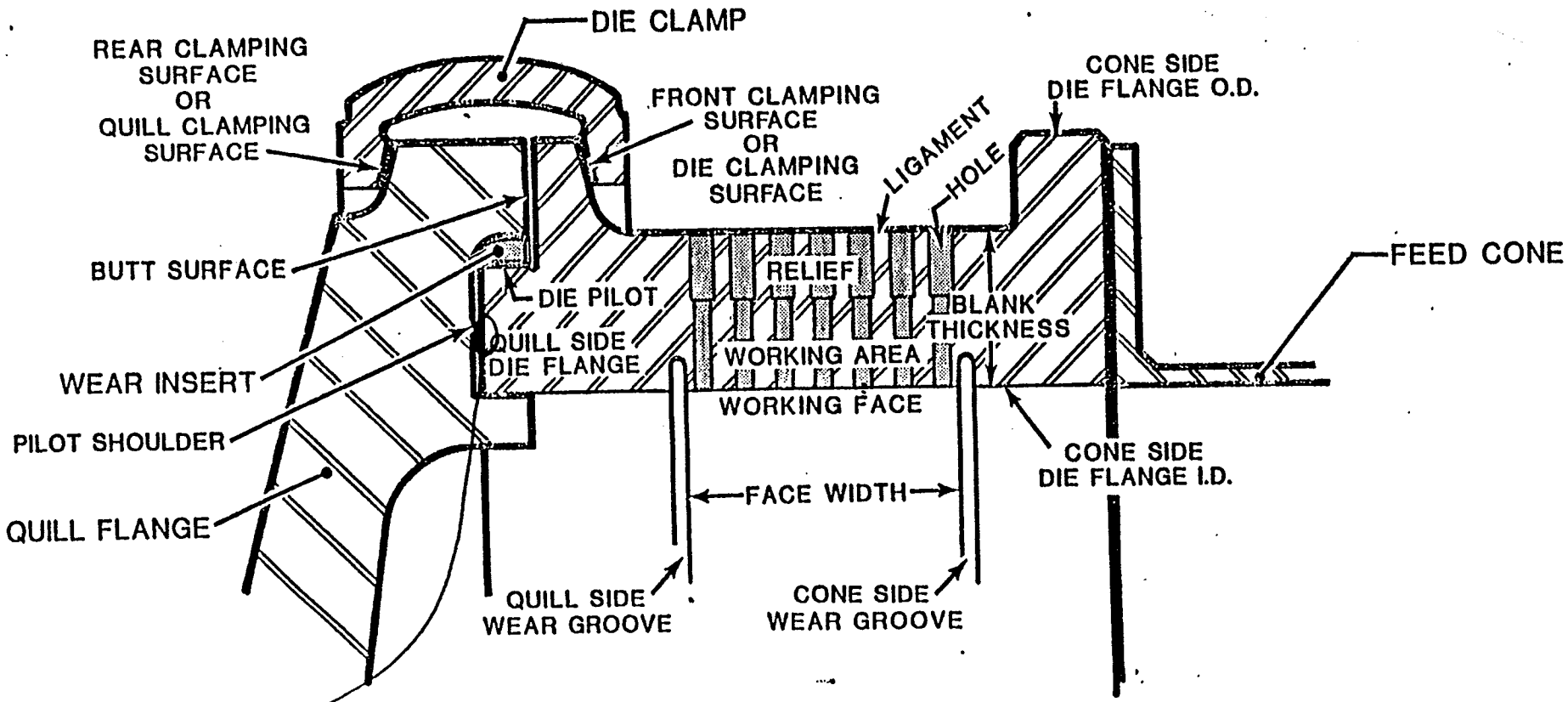
5



HOW PELLETS ARE MADE

In operation, the material to be pelleted is fed continuously to the pelleting chamber. Here it is directed equally into the two areas formd by the steel rollers and the inside face of the die. Rotation of the die in contact with the rollers causes rollers to turn. The material is thus compressed and, under extreme pressure, forced through the die holes.

1. Loose material is fed into pelleting chamber.
2. Rotation of die and roller pressure forces material through die, compressing it into pellets.

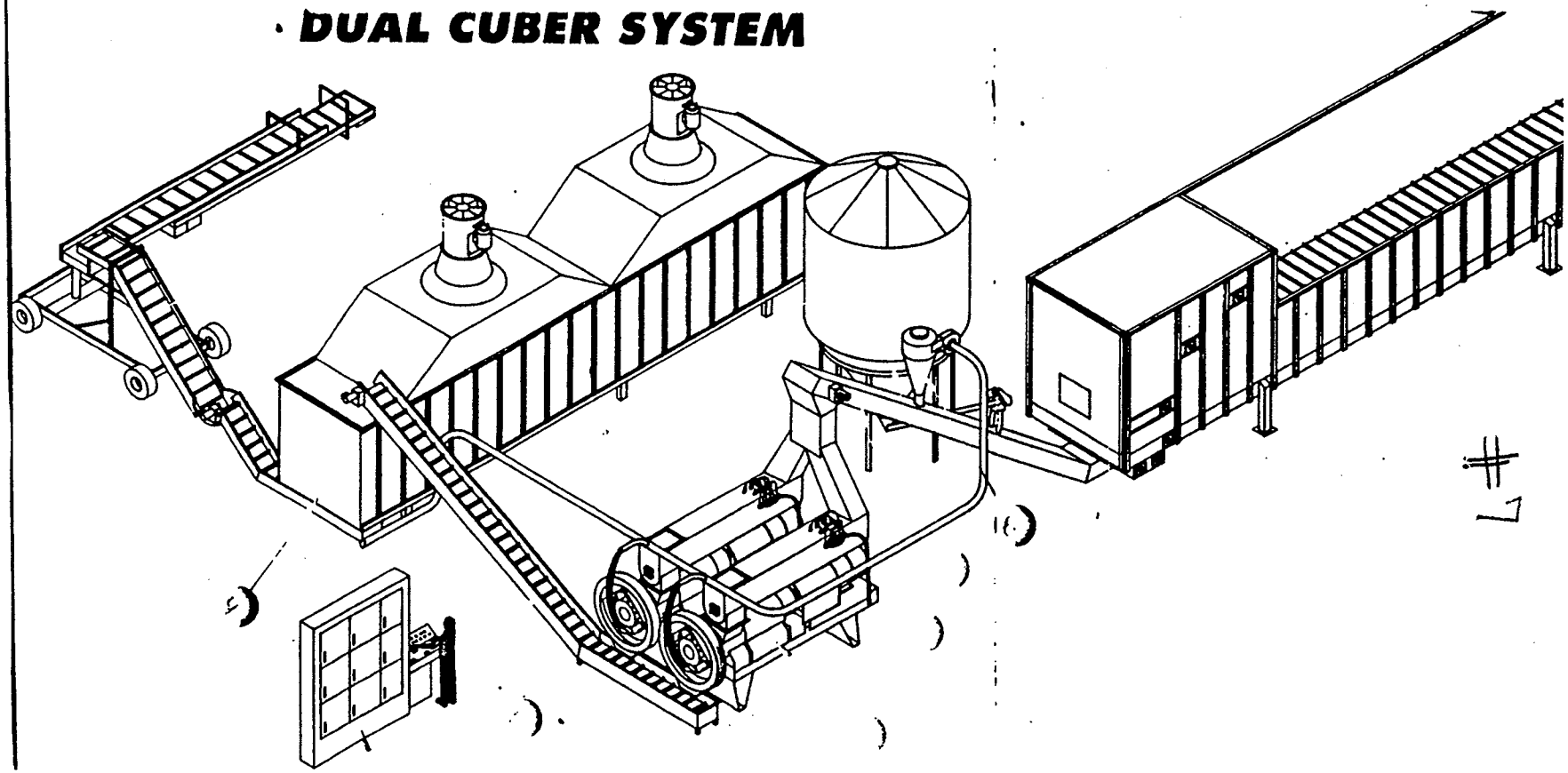


#6

WORN AREA - ALMOST LIKE A DEEP HAMMER MARK

DIE CROSS SECTION VIEW

DUAL CUBER SYSTEM

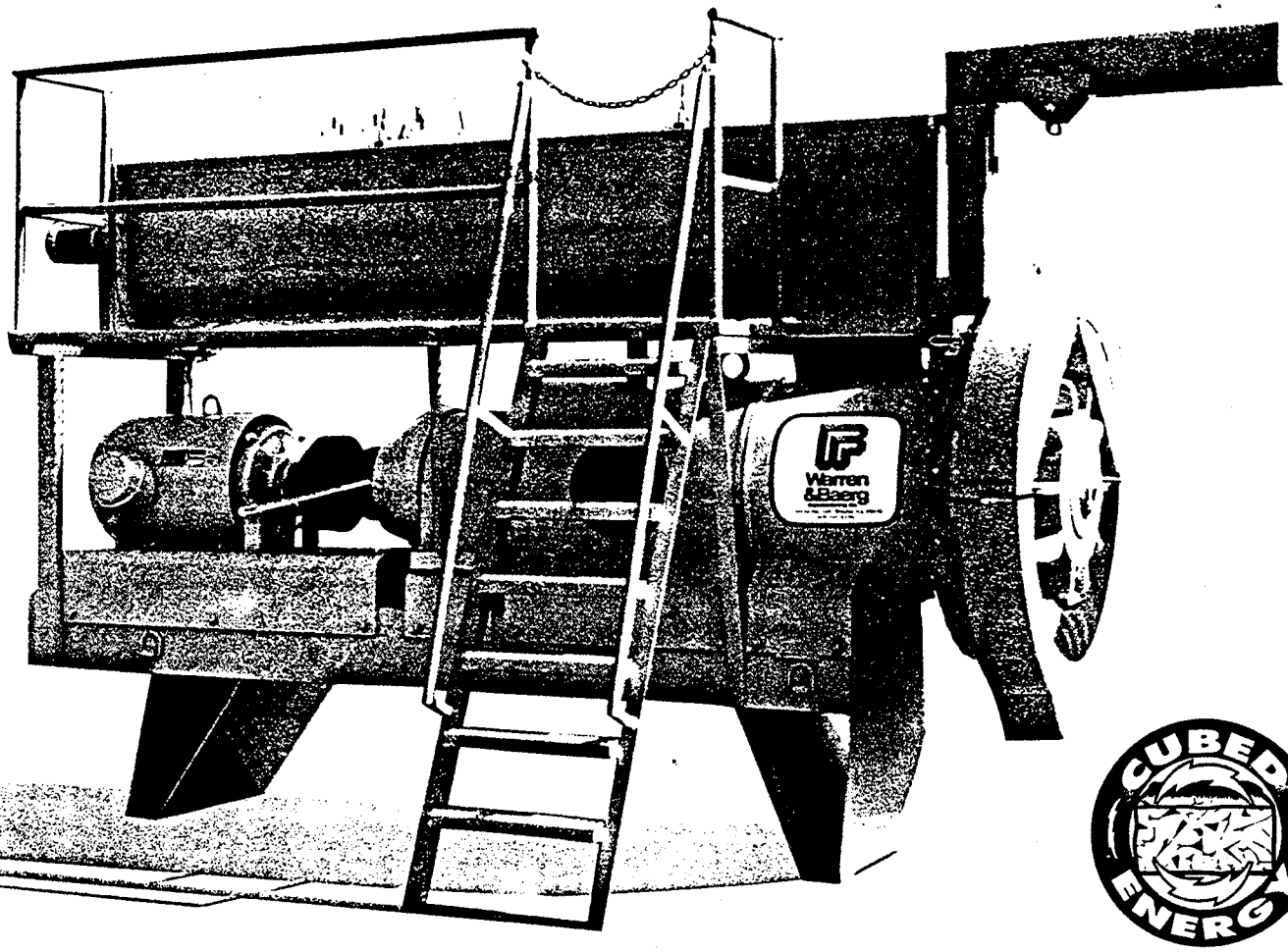


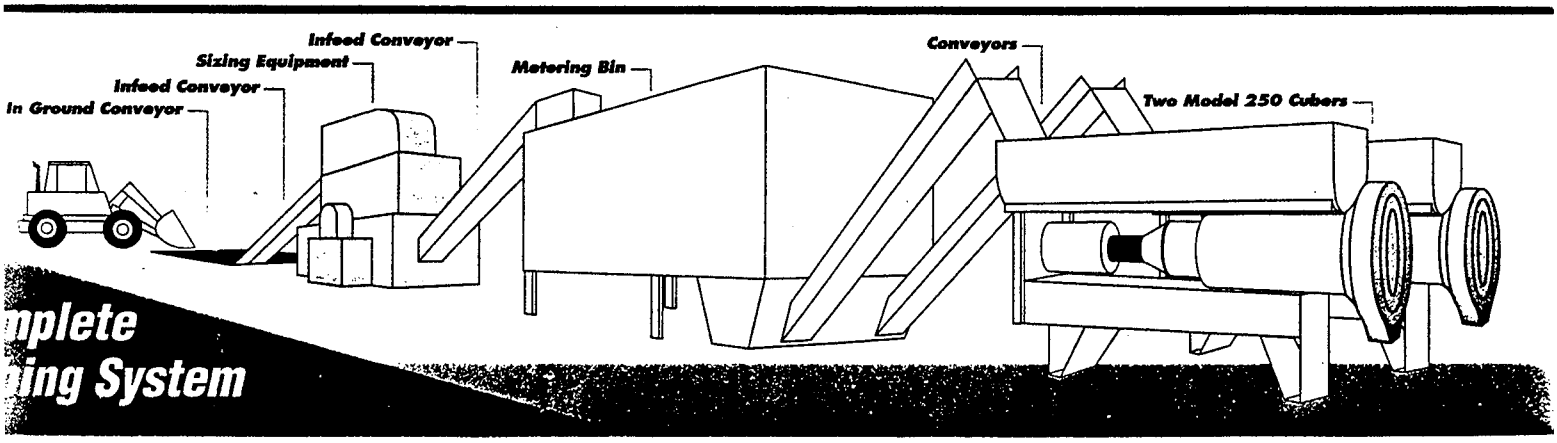
#7

8

ber

Of The System





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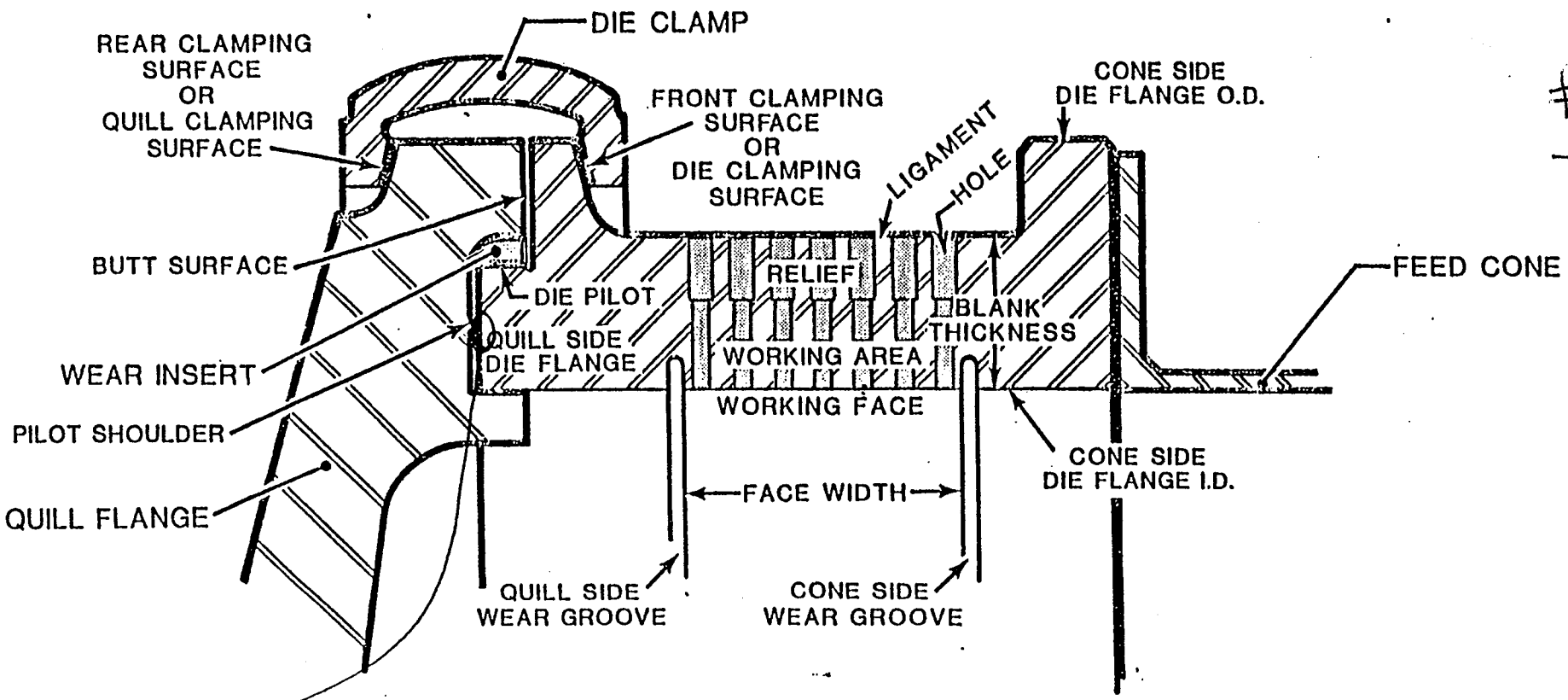


#9

WORN AREA - ALMOST LIKE A DEEP HAMMER MARK

DIE CROSS SECTION VIEW

Combustion of Pellet Fuels

Presented at the

Pellet Fuels Conference
Washington, D.C.
November 16-17, 1995

Argonne National Laboratory
University of Chicago

Ole Ohlsson, Argonne National Laboratory

Reasons for Interest in Co-Firing

- Siting problems can be minimized; existing facility with operating permit and experienced plant operators can be used
- Boilers can be modified at little or relatively low cost to accommodate co-combustion with existing fossil fuel
- Users can meet 1990 CAAA regulations without additional pollution control equipment or switching to more expensive fuels

Reasons for Interest in Co-Firing (cont.)

- Recover energy value from combusting pellet fuels
- Fuel base can be broadened to increase energy security
- Landfill life can be extended by reducing waste volume
- Disposal costs can be reduced

Energy Recovery Methods from RDF

- Combustion in a spreader stoker-fired boiler
- Combustion in a fluidized bed boiler
- Combustion in a cyclone-fired boiler
- Combustion in a suspension-fired boiler

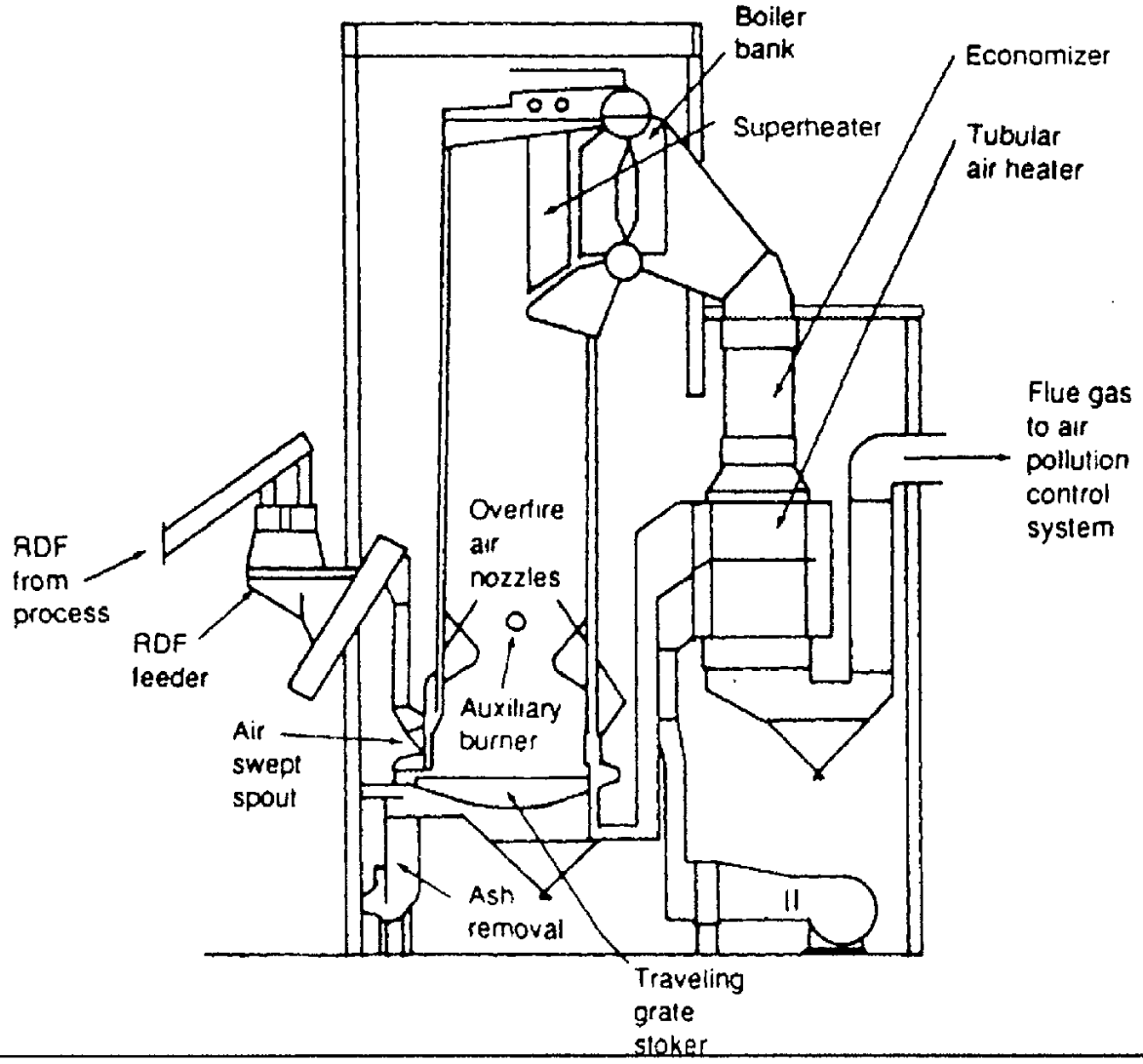
Energy Recovery Methods from RDF (cont.)

- Combustion in a cement kiln
- Pyrolysis of RDF with the combustion of gases, oils and/or char
- Bioconversion of RDF with the combustion of methane gas

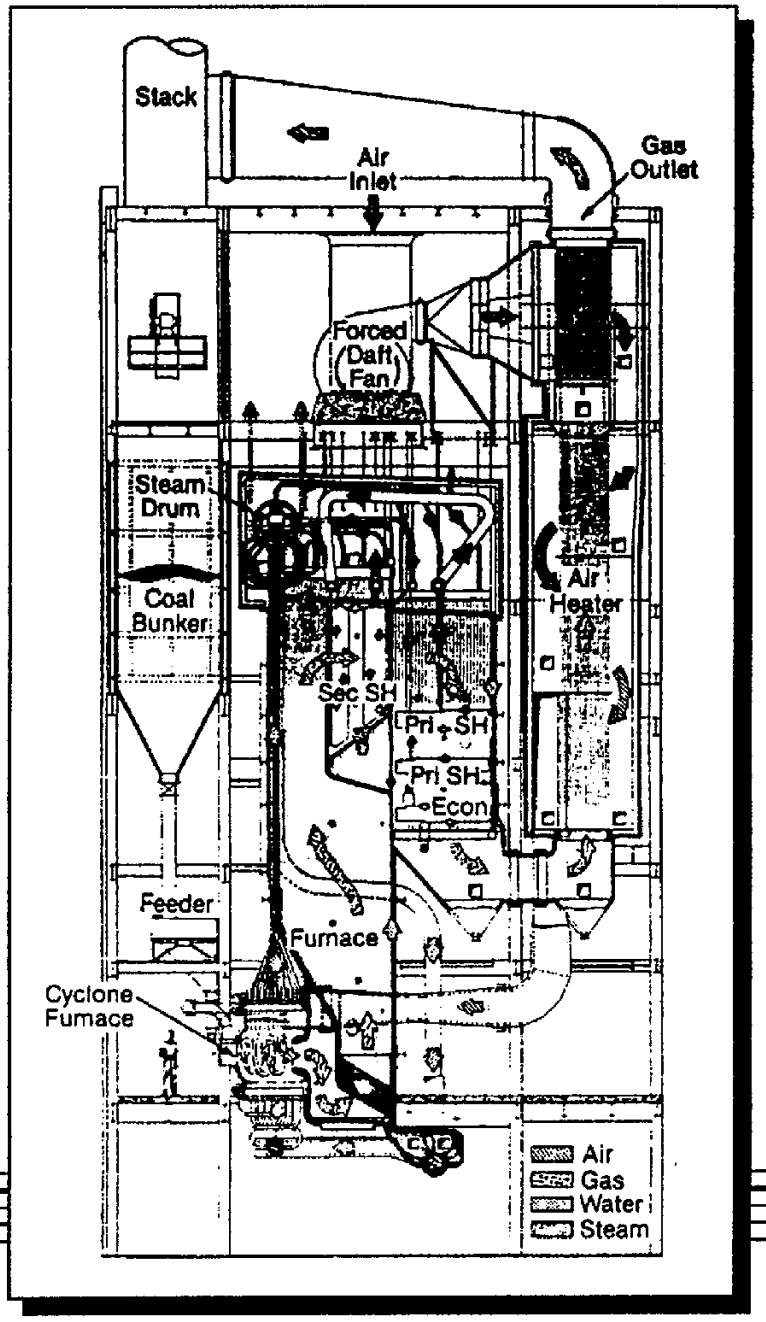
Combustion Systems Most Suited for Co-Fired Applications

- Spreader stoker, traveling grate
- Cyclone-fired
- Fluidized bed combustors

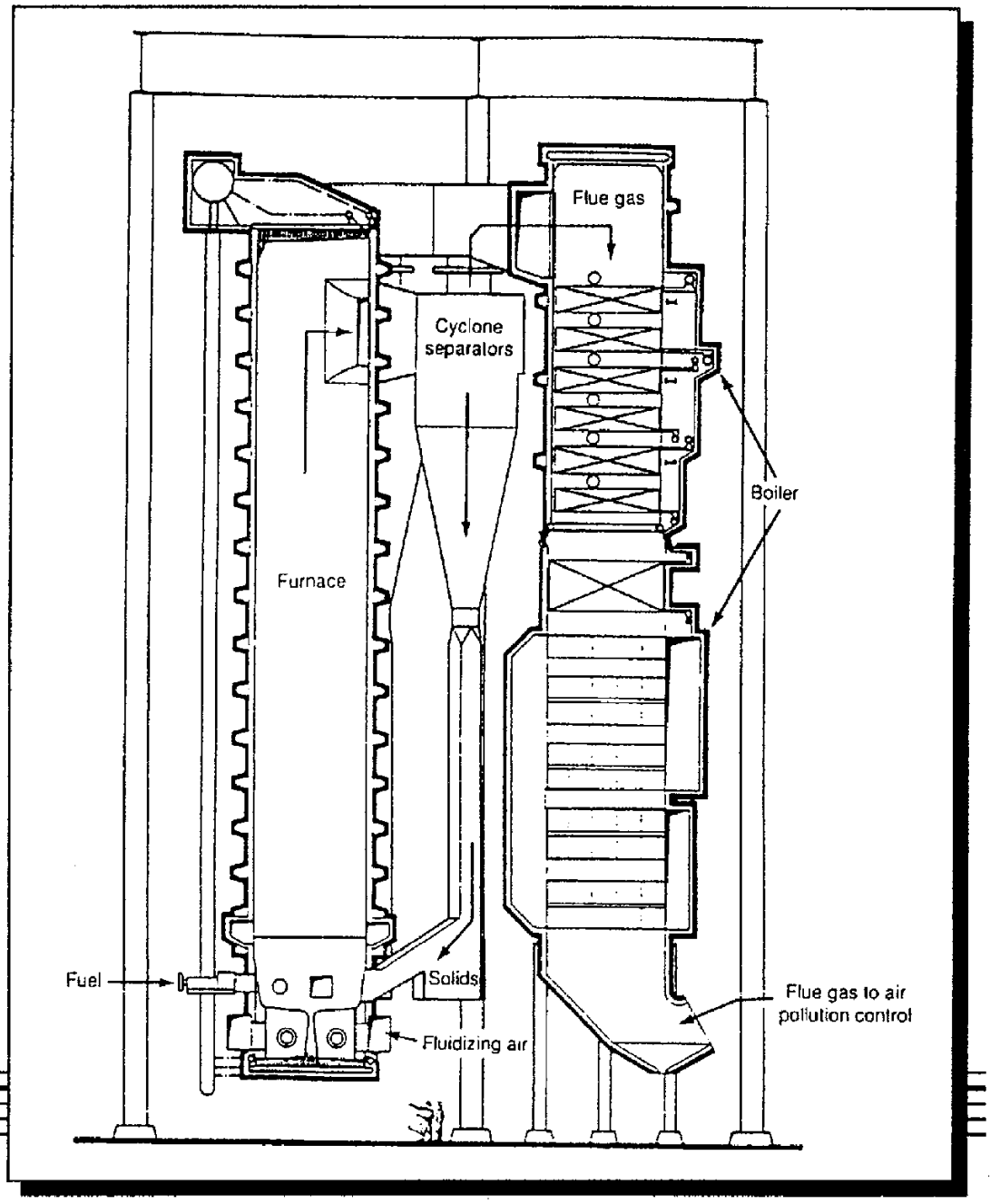
Spreader Stoker Fired Boiler



Cyclone-Fired Boiler



Fluidized Bed Boiler



Percentage of Coal-Fired Utility and Industrial Boilers by Combustion Types

Combustion System	Utility	Industrial
Suspension Fired (PC)	75	20
Stoker-Fired	7	60
Fluidized Bed	3	19
Cyclone	15	1

Market Considerations

- In 1990 the electric utility industry consumed 86% of coal produced in the U.S. In 1995 it is estimated to consume 88%. Industrial users consumed approximately 13% in 1990 and is estimated to consume 11% in 1995.

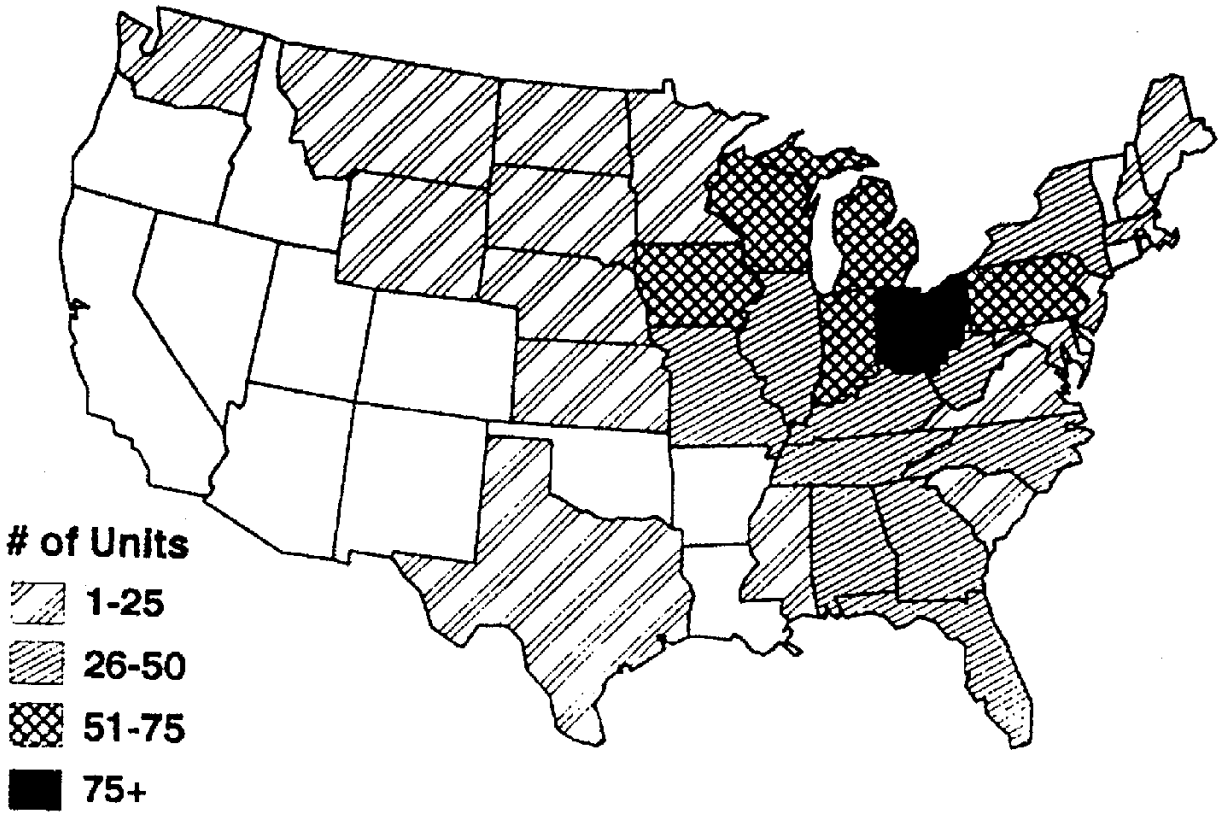
- Coal supplies 57% of all electrical power produced

- Approximately 75% of all coal-fired boilers are located in three federal regions, Middle Atlantic, Great Lakes and Southeast

- 70-80% of the nations solid waste is generated in these same federal regions

- Impact of CAAA

Utility Boilers Exceeding SO_2 Levels Under CAAA (# units per state)



Fuel Characteristics That Influence Suitability of Co-Firing

- Ultimate analyses
- Proximate analyses
- Heating value
- Fuel density
- Energy density
- Fuel combustion rate

Comparison of Fuel Characteristics

Fuel Parameters (as-fired)	dRDF Pellets (ANL tests)	dRDF Pellets (Otter Tail tests)	Coal (ANL tests)	Coal (Otter Tail tests)
• HHV (Btu/Lb)	7,648	5,940	11,861	6,185
• Moisture (% by wt.)	6.4	18.80	10.68	40.73
• Sulfur (% by wt.)	0.14	0.22	2.97	0.79
• Chlorine (% by wt.)	0.36	0.123	0.06	0.008
• Ash (% by wt.)	12.40	12.44	8.12	9.57
• Fuel bulk density (lbs/ft^3)	26.50	19.86	41.96	44.65
• Energy density (Btu/ft^3)	202,670	117,970	497,690	276,160
• Fuel feed rates (ft^3/MMBtu)	4.9	8.5	2.0	3.6
• Ash input rate (lbs/MMBtu)	16.2	20.9	6.8	15.4

Selected Performance for Various Electric Power Technologies*

Technology	Net Heat Rate (Btu/kWh)	Thermal Efficiency (%)
• MSW-fired mass burn	16,373	20.8
• Natural gas comb. cycle	7,900	43.2
• New coal/FGD	10,020	34.1
• Older coal fired plant	10,114	33.7
• Co-fired RDF/coal plant**	10,271	33.2

*Source EPRI Project RP3295-2

**Assumes 15% RDF/85% coal

Combustion of Municipal Wastes Along with Coal Wastes (MP/DOE-94-205)

- Objective
  - determine viability of developing a composite fuel pellet consisting of coal fines combined with combustible fraction of MSW to use as an alternative fuel
- Study sponsors
  - U.S. Dept. of State
  - DOE, Office of International Affairs
- Participating country and organizations
  - Poland Ministry of Industry and Trade
  - Central Mining Institute, Katawice, Poland

Combustion of Municipal Wastes Along with Coal Wastes (cont.)

- Study schedule
  - September 1994 - August 31, 1996
- Principal investigators
  - Dr. Janusz Girczys, Central Mining Institute
  - O. Ohlsson, ANL, Energy Systems Division

Combustion of Municipal Wastes Along with Coal Wastes (cont.)

- Study tasks
  - develop an inventory of waste materials in the Upper Silesian area
  - conduct laboratory tests of waste products
  - prepare fuel pellets of various percentages of coal/MSW vary coal and MSW particle sizes
  - conduct trial burns at laboratory scale

Cofiring Pellet Fuels and Coal in Utility Boilers

Utility Issues and Fuel Requirements

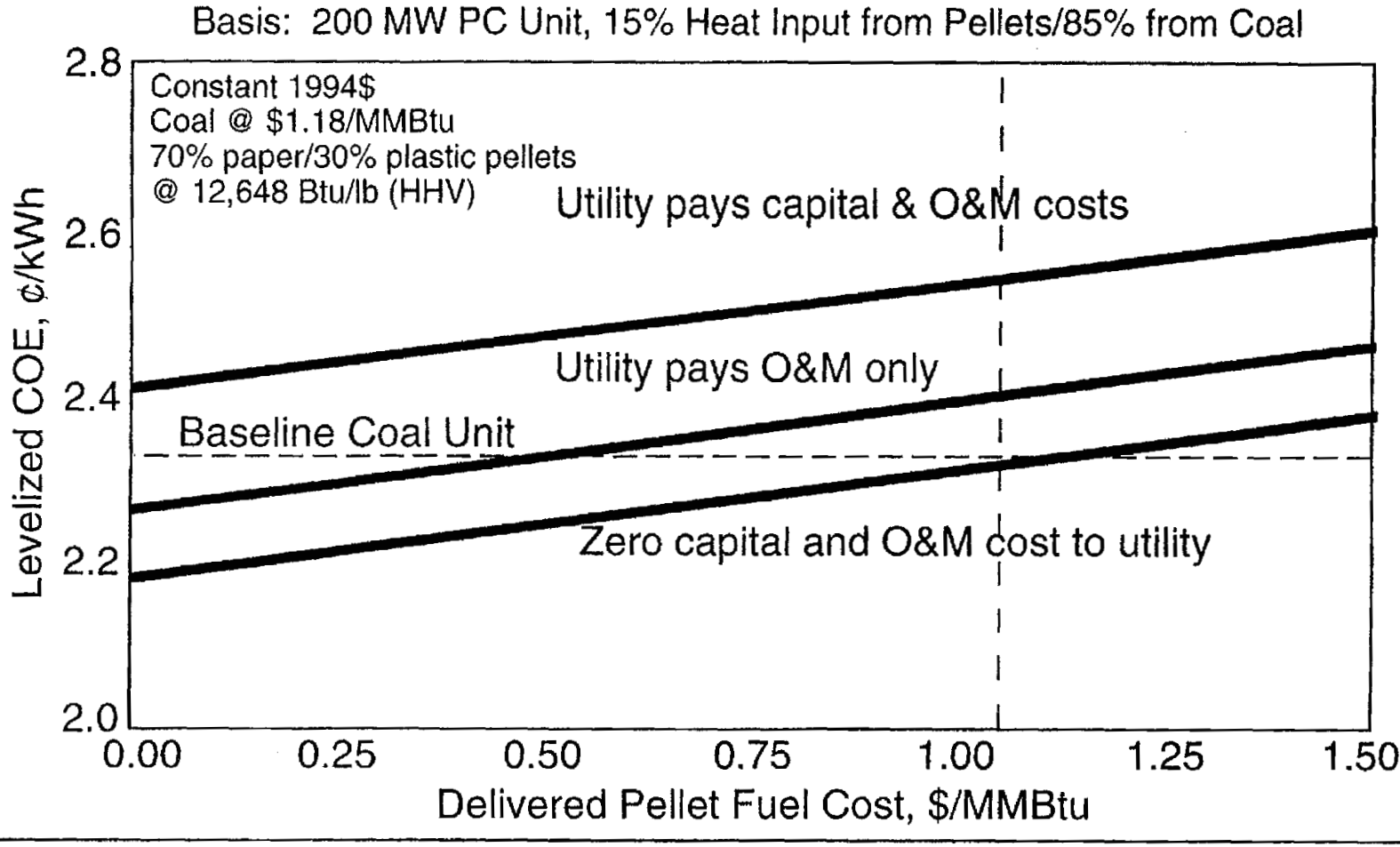
- Competition in power markets forcing cost reductions
- Delivered fuel cost << coal cost (coal @ $1.00/MM Btu)
- Low or zero capital investment by utility
- Pellet fuel specs: low moisture & ash; high HHV; low S, Cl, & Na/K; zero toxic metals and organics

Cofiring Pellet Fuels and Coal in Utility Boilers (cont.)

- Pellet fuel compatibility depends on boiler type:
  - OK for most stoker, fluid bed, and cyclone boilers
  - OK for some pulverized coal boilers, may need separate pulverizer for pellets

- Other concerns: Impacts on SO_2 & NO_x emissions, ash disposal and unit derating

Cofiring Pellet Fuels and Coal in Utility Boilers



Notes for the Pellet Fuel Conference
Washington, November 1995

EUROPEAN TRENDS IN RDF

Dr Niranjan Patel
ETSU
Harwell
OXON
UK

Slide 1 Introduction

- Thank APFC and NREL for invite.
- This is a broad subject, so I shall relay UK experience in developing RDF; including Government support; and finally bring you up to date with current situation. Briefly mention development in other parts of Europe.

Slide 2 ETSU

- Currently part of AEAT; it is national laboratory c.f. Argonne; undergoing privatisation; ETSU has a professional staff pf ~ 250 and its function is similar to that of NREL; Manages Government funded programmes in Energy/Environment sector. Most of UK Government funding of RDF channelled through ETSU.

Slide 3 UK Disposal 1995

- Understanding of the disposal infrastructure - is starting point of presentation.
- MBI with energy recovery widely deployed in early part of century.
- Currently about 12% treated by incineration, remainder consigned to landfill; situation static for ~20 yr.

Slide 4 Tyseley

- Current stock of 34 incinerators built in 60/70's by then Borough Councils.
- BC's had powers to raise capital to fund MBI. Priority was waste disposal (volume reduction) and given the low coat of fuel, not considered worthwhile to install power generation.
- Consequently, of 34 only 4 recovered energy. The last built in 1978.
- Slide shows the 150kt/y incinerator at B'ham; New plant in foreground.

Slide 5 Decline of MBI

- Two reasons for decline in fortune of MBI.
- 1. Local Government Boundary changes introduced in '70's abolished smaller BC's and transferred their waste management responsibilities to larger County Councils.

CC's had access to and control of large areas of rural land on which they could develop landfill operations.

- 2. Capital spending restrictions were placed by central Government on CC. This meant that CC were no longer able to raise capital to invest in construction of incineration plant.
- These two changes effectively halted the progress of MBI. Between the period 1978 - 1993 on new facilities were built and the lead that UK equipment suppliers and manufacturers in incineration was lost to overseas competitors.

Slide 6 RDF Development

- Decline of MBI and dominance of low cost landfill provided the opportunity for RDF development - believed to be an intermediate cost option.
- Capital costs for RDF processing plant are significantly lower than for MBI and CC's could invest in such facilities.
- Following pilot scale work on processing, and against a background of anticipated increases in fuel and waste disposal costs, the UK DoE cost shared with a CC the construction of the first full-scale demonstration facility - initially based on an American developed flowline.

Slide 7 Heat Value/Yield Graph

- This graph, based on some of that pilot scale work, shows quite well the relationship between the degree of waste processing (x-axis) and the heat yield of the residual product (y-axis).
- The far right represents the case for MBI - all of the waste is treated and all of the heat content is recovered.
- By processing the waste to remove putrescible and non-combustible material varying quality of RDF can be produced. Thus between 20-40% of the waste can be removed and still leave a residue which retains over 80% of the heat value.
- The most intensive processing, to produce the densified product, retains over 60% of the heat value from a residue which is only some 35% of the original waste.
- Studies of this type backed up the rationale for RDF development. Capital costs of plant were low, residues could be disposed of at low cost, and a fuel product of potentially high value could be produced for the solid fuel market.

Slide 8 Byker

- The first commercial scale dRDF facility was built in the NE of the country and commenced operation in 1979. Processing 100kt/y MSW it would produce 35kt/y of RDF.
- The fuel product was destined for sale at a nearby steel works - thus a ready market was envisaged at the outset.
- Unfortunately, shortly after the RDF plant came into operation the steel works closed! Another market had to be found.

Slide 9 dRDF Product

- This is what the dRDF product looked like. A hard compact pellet about 2-3 in long and 3/4 in width. The intention was that it should resemble as closely as possible the small coals used in the solid fuel market. At one time anthracite coal dust was also added to the pellet making process to enhance the CV and produce a black pellet.

Slide 10 Small scale boiler market

- The search for a new market quickly focused on the small scale industrial/commercial boiler market. Many industries in the UK relied on these boilers to provide steam and/or hot water to drive their manufacturing processes or provide space heating.
- In the early '80 there were over 60,000 units in operation using primarily coal as the solid fuel. A 5MW boiler would be a typical size and they would employ a moving chain grate mechanism to transport the fuel through the furnace.

Slide 11 RDF Development

- The early '80's saw a parallel development process taking place. A continual refinement of the processing technology to produce a consistent good quality RDF product of known specification. And a market development programme to demonstrate the use of RDF on small scale solid fuel boiler plant.

Slide 12 IoW RDF Plant

- The development of the processing technology culminated in the late '80's with the construction of the latest generation facilities - this shows the processing plant at the IoW, an island community. The facility processes about 70,000 t/y of MSW producing about 25,000 t/y of dRDF.

Slide 13 RDF Flowsheet

- The basic components of the modern plant are shown in this flowsheet. MSW is tipped onto the floor and a manual screening process removes any immediately obvious non-processible items.
- The first and probably most important stage of the process is the trommell screen. The apertures on this screen are set to sort out three size fractions:
    - <50mm - putrescible for compost/AD or disposal
    - 50-500mm - for further processing
    - >500mm - bulky reject fraction
- Metals are recovered from the heavy reject stream of the air classifier. Initially only Fe was recovered but nFe recovery in now practised as well.
- The light fraction from the air classifier is the fuel product which is dried, shredded and pelletised.

Slide 14 Mass Balance

- The typical mass balance for MSW processed by such facilities is given in this table. Of the 100 kt/y input the reject fraction amounts to about 61 kt, of which the largest

contribution comes from the <50 mm fines and air classifier heavies. The fuel product represents about 33% of the input material.

Slide 15 Map of Facilities

- At the height of RDF development (1989) there were 8 facilities operating including one cRDF plant serving a cement kiln. These processed nearly 0.5 Mt/y MSW. The MBI (energy recovery) facilities are also shown.
- Presently only 3 of the dRDF facilities are operating; Byker, IoW & Hastings. The others have all closed.
- Why did the RDF plants run into difficulty?

Slide 16 Cf RDF Vs Coal

- We can start to answer this question by comparing the fuel properties of RDF with that of a typical British Coal:
    - The CV and energy density of RDF is much lower than for coal
    - Rdf contains 4 times as much ash as coal
    - Rdf has a much higher volatile content than coal and also a higher level of Cl

Slide 17 RDF Combustion Problems

- These differences led to various combustion problems when RDF was simply substituted for coal on moving grate shell boilers.
    - Boiler outputs were reduced due to the lower CV and energy density of Rdf
    - There was a need to introduce secondary air to cope with the higher volatile fuel content of Rdf
    - Ash handling requirements were greatly increased
    - and there were a variety of boiler fouling particulate emission problems.
- The notion that Rdf could easily substitute for coal was quickly displaced following the very first combustion trials.

Slide 18 RDF Production Vs Time

- It is useful to pause here and see where we are on the development timescale.
    - '79 -'84 Process plant development (Byker, pilot plant & cRDF)
    - '83 - '87 Intensive combustion trials
    - '84 - '89 New commercial scale facilities
    - I'll come back to what happened in '89

Slide 19 Combustion Trials (Byker Shell Boilers)

- The combustion trials work between '83 & '87 was sponsored by the Government through ETSU. The most intensive work was carried out on 5MW chain grate shell boilers located adjacent to the Byker RDF plant. These trials determined the modifications necessary, to coal fired plant, to enable successful utilisation when firing 100% RDF.

Slide 20 Boiler Modifications

- As it turned out the modifications needed were relatively simple, but absolutely necessary.
    - A suitable chain grated drive mechanism is needed to cope with the increased throughput of RDF required to maintain boiler output.
    - Adequate underfire air, preferably delivered via compartments in the grate is recommended.
    - A secondary air supply and soot blowers are also a prerequisite.

Slide 21 Payback

- The modifications needed are simple to make and their cost is low.
- At the time ('88) we estimated a total cost of about £50k which, assuming an RDF price a 1/3 that of coal, gave a very attractive payback period of under 2 yr.

Slide 22 Legislative Changes 1989

- Major impact on RDF industry.
- New Emissions limits to be met by waste burners - come back to this.
- Coal industry privatised:
    - Increased competition in solid fuel market
    - Recession - small/medium size industries closing
    - Conversion to gas firing
    - Decline in solid fuel boiler market.
- Privatisation of Electricity Industry (Generation/Distribution)
    - Closure of old coal fired generating capacity - switch to gas firing
    - Introduction of NFFO - support mechanism for renewable energy sources (come back to this)

Slide 23 New Emission Limits

- Prior to '89 control on emissions from waste burners, including RDF, was restricted to grit & dust arrestment and the suppression of dark smoke. In '89 new more stringent requirements were introduced. These sought to minimise air pollution through the establishment of:
    - minimum combustion requirements
    - emission limits for specified pollutants
    - and stringent monitoring requirements.
- What this meant in practice was that a semi-dry gas scrubbing plant had to be fitted adding substantially to the capital and operating costs of RDF combustion.

Slide 24 Gas Scrubber

- This is what a gas scrubber on the back end of a 5MW shell boiler plant looks like - a substantial piece of hardware now needed to meet the new limits.

Slide 25 Payback

- Of course this had a major impact on the payback period. No longer was it the case that £50k for some minor modification was all that was needed. With the gas cleaning plant the investment now required was three times as much. This increased the payback period from under 2yrs to nearly five.
- There was little experience of these small scale scrubbing systems and if the operating costs were 10% higher than anticipated the payback would increase to about 9yrs.
- Little surprise than that these new emission limits, set against the background of the other changes taking place, meant the end of the small scale solid fuel market that the dRDF industry had cultivated for nearly a decade.

Slide 26 Bold Power Station

- In the lead in to the privatisation of the power generation industry, the older, more costly and vulnerable stations, looked for new ways to survive. And the dRDF industry looked for new markets to replace the small scale market lost to them. One of dRDF processing plants was located close to one of these older coal fired plants.
- They agreed, with support from the ETSU programme, to undertake a 3 week dRDF cofiring trial.

Slide 27 Bold 2

- This slide shows the temporary equipment installed to produce an 8% thermal mix of dRDF and pulverised coal - this was basically taking the entire plant output for that period.

Slide 28 Bold 3

- The dRDF was introduced into the coal feed and this transferred to a mixing table

Slide 29 Bold 4

- before being fed into the ball mills and from there into the PF furnaces.
- What these limited trials demonstrated was that there were no insurmountable operational problems when cofiring with these low levels of dRDF.
- The next stage should have been more extensive trials, longer duration with high dRDF loadings. However the whole experiment was once more caught up in the restructuring going on in the industry and the power station was given notice of closure within the year.
- No more trials were carried out, and even before the closure of the power station, the dRDF plant was closed and its waste diverted to landfill.

Slide 30 NFFO

- For a long time the policy of the Government has been to support those RE technologies which have the best prospects to show economic and environmental acceptability.
- Privatisation of the electricity industry in '89 allowed the Government to introduce a support mechanism for RE known as the Non Fossil Fuel Obligation - NFFO.
- NFFO is a market enablement mechanism which supports RE technologies by:
    - providing 15y guaranteed power sales contracts, an obligation placed by the Government on the purchaser of the power
    - and by paying a premium price for power determined by a competitive bidding process.
- NFFO is a limited support mechanism. It was introduced in 1990 and is due to end in 1998.

Slide 31 Gate Fee Vs Power Value

- The best way I can illustrate what NFFO does is by considering the case for MBI
- This graph shows the relationship between the gate fee, or disposal cost, for MSW and the value of power generated by a mass burn facility.
- Explain Graph
    - Two scales considered
    - Low power value & Gate Fee - no MBI
    - Premium price under NFFO enables technology
    - Increasing Gate fee and/or power price makes technology viable

Slide 32 RDF Vs Time

- If we look at our time curve again we see the full impact of the legislative changes of '89. dRDF processing capacity drops from a peak of ~ 0.5 Mt/y to just over 300 kt/y. All but 3 of the facilities are now closed.

Slide 33 IoW

- NFFO has made an impact across all of the technologies for waste treatment.
- It has allowed the three remaining dRDF processing plants to find a secure outlet for their fuel product - In this case allowing on-site utilisation for power generation at two of the facilities, supported by premium payments from the NFFO.

Slide 34 Slough

- the remaining plant supplies all of its fuel to a fluidised bed facility which co-fires it with coal - also supported by premium power payments under NFFO.

Slide 41 UK Waste Disposal

- This brings me back to where we are in the UK. By the year 2000 I expect that about 15% of the MSW stream will be treated in energy recovery plant - still dominated by MBI but with RDF established at about the 3-4% mark. But Landfill, certainly in the short term will continue to dominate.

Slide 42 RDF Trends

- Finally, in conclusion, I believe these are the trends for Europe
    - Waste processing technology to produce RDF is firmly established and available from a number of suppliers.
    - The potential for dRDF will depend on the health of the solid fuel market but neiche opportunities will always exist and the commercial waste sector will provide the feedstock.
    - There is greater interest in the demonstration of cRDF systems

This section includes notes and publications submitted by conference speakers . Brief summaries of each presentation can be found in Section 1: Overview and Outcomes.

CONTROL OF AIR POLLUTION EMISSIONS FROM MUNICIPAL WASTE COMBUSTORS

Submitted by James D. Kilgroe, USEPA, National Risk Management Research Laboratory

ASH AND ASSOCIATED ISSUES

Presented by Carlton Wiles, Program Manager, Municipal Solid Waste Program, National Renewable Energy Laboratory

STATE REQUIREMENTS

Presented by Charles Williams, Commissioner, Minnesota Pollution Control Agency

REGULATORY ISSUES AFFECTING GROWTH OF PEF

Presented by William Demarest, Attorney, Holland & Hart

CONTROL OF AIR POLLUTION EMISSIONS FROM MUNICIPAL WASTE COMBUSTORS

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ABSTRACT

The November 1990 Clear Air Act Amendments (CAAAs) directed EPA to establish municipal waste combustor (MWC) emission limits for particulate matter, opacity, hydrogen chloride, sulfur dioxide, nitrogen oxides, carbon monoxide, dioxins, dibenzofurans, cadmium, lead, and mercury. Revised MWC air pollution regulations were subsequently proposed by EPA on September 20, 1994, and promulgated on December 19, 1995. The MWC emission limits were based on the application of maximum achievable control technology (MACT). This paper provides a brief overview of MWC technologies, a summary of EPA's revised air pollution rules for MWCs, a review of current knowledge concerning formation and control of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans, and a discussion of the behavior and control of mercury in MWC flue gases.*

INTRODUCTION

In June 1987, EPA announced its intention to develop new air pollution rules for MWCs.[1] This decision was based, in part, on a study of the potential environmental risk associated with MWCs.[2] Pollutants posing the highest risks included polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and hazardous trace metals. On December 20, 1989, EPA proposed New Source Performance Standards (NSPS) for new MWCs and Emission Guidelines (EGs) for existing MWCs.[3] NSPS and EGs for MWCs larger than 225 Mg/day in capacity were promulgated in February 1991.[4]

The November 1990 CAAAs directed EPA to establish MWC emission limits for particulate matter (PM), opacity, hydrogen chloride (HCl), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), PCDDs/PCDFs, cadmium (Cd), lead (Pb), and mercury (Hg).[5] Revised MWC air pollution regulations were subsequently proposed by EPA on September 20, 1994, and promulgated on December 19, 1995.[6-9] These emission limits were based on the application of MACT. For existing units, MACT is defined as the best emission limit achieved by 12 percent of the operating units in a category such as large or small units. For new units, MACT is defined as the best emission limit achieved by the best single unit in a category of units.[5]

This paper provides a brief overview of MWC technologies, a summary of EPA's revised air pollution rules for MWCs, a review of current knowledge concerning formation and control of PCDDs/PCDFs, and a discussion of the behavior and control of Hg in MWC flue gases. The focus of the paper is on the performance of combustion and flue gas cleaning technologies used at MWC facilities in controlling emissions of PCDDs/PCDFs and Hg.

MWC TECHNOLOGIES

Three major types of MWCs are commonly used in the U.S.: field-erected mass burn incinerators, refuse-derived fuel (RDF) combustors, and factory-constructed modular mass burn incinerators.[10] The best combustion technologies ensure adequate waste burnout and produce minimal products of incomplete combustion (PICs) in the flue gas.

In the U.S., dry flue gas cleaning technologies are generally used to control air pollution emissions.[11] Wet scrubbing systems are seldom used. PM is typically collected in

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* This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative policies and has been approved for publication.

TABLE 1. BASIS FOR MACT PERFORMANCE REQUIREMENTS[a] (DECEMBER 19, 1995)[8,9]

Proposed Requirements	Basis for Emission Limits[b]
Emissions Guidelines (EG) - Existing Plants	
Small (>35 to 225 Mg/day)	GCP + DSI + ESP (or FF) + CI
Large (>225 Mg/day)	GCP + SD/ESP (or SD/FF) + CI + SNCR[c]
New Source Performance Standards (NSPS) - New Plants	
Small (>35 to 225 Mg/day)	GCP + SD/FF + CI
Large (>225 Mg/day)	GCP + SD/FF + CI + SNCR

[a] Technologies which provide equivalent or better performance may also be used.

[b] GCP = Good Combustion Practice
DSI = Dry Sorbent Injection into the Combustor Furnace or Flue Gas Duct
ESP = Electrostatic Precipitator
FF = Fabric Filter Baghouse
CI = Carbon Injection
SD/ESP = Lime Spray Dryer Absorber and ESP
SD/FF = Lime Spray Dryer Absorber and Fabric Filter Baghouse
SNCR = Selective Non-catalytic Reduction

[c] No NO_x control requirements for small MWC plants or large existing mass burn refactory combustors

electrostatic precipitators (ESPs) or fabric filters (FFs). Most trace metals such as Cd and Pb are solids at flue gas cleaning temperatures and are efficiently collected in ESPs or FFs. Hg is normally a vapor at flue gas cleaning temperatures, and special methods must be used for its control.[12,13]

Acid gases are controlled in dry or semi-dry scrubbers by injecting either a calcium- or sodium-based reagent into the flue gas to convert HCl and SO_2 into solid compounds that can be collected in a PM control device.[13,14] The most commonly used reagents are quicklime (CaO), hydrated lime [$Ca(OH)_2$], limestone ($CaCO_3$), and sodium bicarbonate [$Na(CO_3)_2$]. Several methods may be used to inject and mix the sorbent with the flue gas: lime spray dryers (SDs), dry sorbent injection (DSI) of limestone or lime into the combustor furnace or the flue gas duct. Selective non-catalytic reduction (SNCR), the most advanced NO_x control technology being applied in the U.S. on MWCs, uses either ammonia (NH_3) or urea [$CO(NH_2)_2$] as a reagent to reduce NO_x to nitrogen.[15]

The chemistry involved in acid gas and NO_x control and the mechanisms involved in PM control are generally well understood. The major problem associated with control of these pollutants (PM, acid gases, and NO_x) is the engineering optimization of flue gas cleaning processes that are also effective in the control of trace metals and trace organics.

The most difficult to control MWC pollutants of concern are PCDDs/PCDFs and Hg. PCDDs/PCDFs can be formed in MWCs as high temperature PICs, or they can be formed downstream of the combustor by low temperature synthesis reactions involving fly ash.[10,16] Hg, typically a vapor at flue gas cleaning temperatures, is difficult to collect in flue gas cleaning equipment.

FEDERAL EMISSION CONTROL REQUIREMENTS

On December 19, 1995, EPA promulgated revised NSPS for new MWCs and EGs for existing MWCs.[7-8] These revised rules require the use of good combustion practice (GCP) and MACT flue gas cleaning techniques to continuously limit emissions of PCDDs/PCDFs, CO, PM, Cd, Hg, Pb, HCl, SO_2, and NO_x. The control technologies on which the performance requirements are based are summarized in Table 1. Alternatively, technologies which can provide equivalent or better performance than those on which the standards are based may also be used.

The control of PCDDs/PCDFs is based on the use of GCP in combination with appropriate flue gas cleaning techniques. The objectives of GCP are to maximize furnace destruction of organics and minimize low temperature PCDD/PCDF formation reactions.[16-18] Furnace destruction of organics is controlled by establishing technology-based emission limits for CO (see Table 2). Downstream formation and stack emissions are controlled by a limit on steam load for waste-to-energy plants and a limit on PM control device operating temperature. The load is a surrogate parameter used to limit

TABLE 2. GOOD COMBUSTION PRACTICE FOR MWCs (DECEMBER 19, 1995)[8,9]

.. CO Requirements

Type of Combustor	CO Emission Limits: EG Limit, ppm (Ave. Time, h)	CO Emission Limits: NSPS Limit, ppm (Ave. Time, h)
Mass Burn Water Wall (MBWW)	100 (4)	100 (4)
Mass Burn Refractory Wall (MBRW)	100 (4)	100 (4)
Mass Burn Rotary Water Wall (RWW)	250 (24)	100 (24)
Mass Burn Rotary Wall Refractory (RWR)	100 (24)	100 (4)
Refuse-Derived Fuel Stokers (RDF)	200 (24)	150 (24)
Fluidized Bed Combustors (FBC)	100 (4)	100 (4)
Modular Combustion Units (MCU)	50 (4)	50 (4)
Coal/RDF Mixed Fuel-Fired		
- Spreader Stokers (Coal-RDF/SS)	250 (24)	150 (24)
- Pulverized Coal (Coal-RDF/PC)	150 (4)	150 (4)

2. Load not to exceed maximum load demonstrated during most recent PCDD/PCDF compliance tests.

3. PM control device inlet temperature not to exceed a temperature 17 °C above the maximum temperature demonstrated during most recent PCDD/PCDF compliance tests.

4. Chief facility operator, shift supervisors, and control room operators must meet training and certification requirements.

the relative amount of PM carried out of the combustor with flue gas (PM carryover). The purpose of the inlet temperature limit is to control PCDD/PCDF synthesis reaction rates, and solid- and vapor-phase partitioning of PCDDs/PCDFs in the PM control device. Solid-phase PCDD/PCDF emissions are limited by the use of efficient PM control equipment such as high performance ESPs or FFs.

All MWC plants must comply with an Hg emission limit of 80 ug/dscm or an 85 percent reduction in Hg emissions.[6] The Hg emission limit is based on the use of powdered activated carbon in conjunction with dry scrubbing. The activated carbon adsorbs gas-phase Hg and is collected in the PM control device. Acid gases (HCl and SO_2) and metal (Cd, Hg, and Pb) emission limits require equipment and operating conditions that are also needed for PCDD/PCDF control.

Acid gas sorbents may reduce PCDD/PCDF formation rates and allow for reductions in the PM control device operating temperature. The use of activated carbon for Hg control improves PCDD/PCDF control.

The 1995 EPA emission requirements for new and existing sources are summarized in Table 3. The rules have different requirements for new and existing plants, and for small (> 35 to 225 Mg/day) and large (> 225 Mg/day) plants. Emission limits are expressed either in mass concentration per dry standard cubic meter (dscm) or parts per million on a dry volumetric basis (ppmv), corrected to 7 percent O_2 and standard conditions at 20 °C (68 °F) and 101.3 kPa (14.7 psi)

The PCDD/PCDF limits are: 125 ng/dscm for small existing plants, 60 ng/dscm for large existing plants with ESP-based air pollution control systems, 30 ng/dscm for existing non-ESP-based systems, and 13 ng/dscm for large and small new plants.[6,7] Each MWC will be subject to annual PCDD/PCDF compliance tests unless they qualify for less frequent testing. MWC plants are allowed to conduct PCDD/PCDF performance tests on only one unit per year if all units achieve emission levels for 2 consecutive years of 30 ng/dscm for small existing plants, 15 ng/dscm for large existing plants, and 7 ng/dscm for all new plants.[6,7]

Although PCDD/PCDF emissions cannot be continuously monitored, operating and emission parameters which correlate with PCDD/PCDF emissions will be continuously monitored and controlled. These continuous compliance parameters include CO emission limits, boiler steam load, PM control device inlet temperature, and activated carbon hourly feed rates. Opacity and SO_2 are to be continuously monitored to guarantee proper operation of the flue gas cleaning equipment. The use of these continuous monitoring and compliance parameters will ensure that each MWC operates at

TABLE 3. EMISSION LIMITS FOR MWCs[a] (DECEMBER 1995)[8,9]

Pollutant/ Measurement	Guideline Limits - Existing Plants (or % Reduction)		NSPS Limits - New Plants (or % Reduction)
	Small >35 to 225 Mg/Day	Large >225 Mg/Day	Large and Small ≥35 Mg/day
ng/dscm [ ][b]	125 [30]	60[c][15]	13 [7]
PM,mg/dscm	69	27	15
Opacity[d], %	10	10	10
Cd, mg/dscm	0.10	0.04	0.01
Pb, mg/dscm	1.6	0.50	0.10
Hg, mg/dscm	0.08 (85)	0.08 (85)	0.08 (85)
HCl, ppmv	250 (50)	35 (95)	25 (95)
SO_2, ppmv[e]	80 (50)	35 (75)	30 (80)
NO_x, ppmv[e]	None	200 -250[d,f]	150[d,g]

a All emissions corrected to 7 percent O_2.

b Average of three stack tests using EPA Method 23. Values are weight of total tetra- through octa- congeners. Values in brackets for [emission limits to qualify for less frequent testing].

c Emission limit for ESP-based air pollution control systems. Non ESP-based systems must comply with a 30 ng/dscm limit or the "less frequent testing" requirement.

d EPA Method 9. Limit for 6-minute averages.

e 24-hour averaging time.

f 200 ppmv for MBWW, 250 ppmv for RWW, 250 ppmv for RDF, 240 ppmv for FBC, no NO_x control requirement for MBRW, and 200 ppmv for others.

g Applies to large plants only. 150 ppmv, except 180 ppmv is allowed for the first year of operation.

conditions necessary to control emission of PCDDs/PCDFs, Hg, and other regulated pollutants.

DIOXIN AND MERCURY CONTROL METHODS

Control technologies in the U.S. for PM and acid gas control also provide a degree of control for PCDDs/PCDFs and Hg. Both PCDDs/PCDFs and Hg may be in a vapor phase at flue gas temperatures, and collection of these pollutants is primarily dependent on sorption on fly ash particles or flue gas cleaning sorbent particles with subsequent collection in a PM control device. The capture efficiency of PCDDs/PCDFs and Hg in MWC air pollution control equipment typically used in the U. S. depends primarily on the amount and properties of carbon in the fly ash, the amounts and properties of sorbents injected into the flue gas, and the operating temperature of the PM control device.

Field tests have shown that in semi-dry scrubbing systems, PCDDs/PCDFs and Hg emissions decrease with increasing fly ash carbon content. Variations in combustion conditions affect the amounts of carbon in fly ash and its capacity for adsorbing semi-volatile trace organics and Hg. Increased combustion efficiencies needed to maximize destruction of organics reduce the absorption capacity of fly ash and its ability to capture semi-volatile pollutants in PM control devices. The formation and emission of PCDDs/PCDFs and emission of Hg are affected by the PM control device operating temperature as the sorption of semi-volatile pollutants is reduced with increasing operating temperatures.

Methods which can be used to enhance control of PCDDs/PCDFs and Hg in MWCs equipped with conventional dry and semi-dry flue gas cleaning systems include:

Enhanced PCDDs/PCDFs control
- Good combustion practices,
- Injection of activated carbon, and
- Injection of specialized multipollutant sorbents.

Enhanced control of Hg
- Injection of sodium sulfide,
- Injection of activated carbon, and
- Injection of specialized multipollutant sorbents.

PCDD/PCDF FORMATION MECHANISMS

There are three primary routes for PCDD/PCDF formation: (1) gas-phase reactions involving chlorinated precursors such as chlorobenzenes (CBs), chlorophenols (CPs), or polychlorinated biphenyls (PCBs); (2) surface reactions involving gas-phase precursors and fly ash; and (3) solid-phase reactions on the surface of fly ash involving metal

chlorides and fly ash carbon.[19-24] Formation route (3), which involves the reaction of unburned carbon in fly ash in the presence of oxygen and water vapor to form PCDDs/PCDFs, is called *de novo* synthesis.[20,21] The reactions associated with formation routes (2) and (3), which involve both gas- and solid-phase reactions, are called heterogeneous reactions

Gas-phase precursors can originate as waste thermal decomposition products or as high temperature PICs. Low temperature oxidation reactions involving fly ash carbon can also produce CPs or other precursor compounds that in turn react to form PCDDs/PCDFs by surface mediated reactions (condensation, absorption-desorption, etc.).[25]

De novo synthesis consists of low temperature carbon oxidation reactions which provide the biaryl ring structures for PCDD/PCDF formation and metal ion catalyzed reactions which provide the necessary chlorine (Cl) for PCDD/PCDF formation. Low temperature carbon oxidation reactions may be catalyzed by metal ions or carbon structures similar to activated carbon.[26,27] The Cl for (oxy)-chlorination reactions can be provided from either metal chlorides in the fly ash or Cl in the flue gas.[27,28]

De novo synthesis reactions generate a variety of chloro-organic compounds including CPs, chloro-benzonitriles, -thiophenes, -benzofurans, -benzothiophenes, PCDDs, -naphthalenes, PCDFs, and -benzenes (see Figure 1).[23] Laboratory experiments (see Figure 2) show that *de novo* reactions occur at temperatures ranging from approximately 250 to 600°C with maximum tetra- to octa-PCDD formation rates near 300°C. Maximum tetra- to octa-PCDF formation rates also occur at 300°C with a lower peak near 450°C.[23] Maximum PCDD/PCDF formation rates are typically reported to occur near 300°C.[20-23] At temperatures above 600°C, chloro-organics are rapidly destroyed, and at temperatures below 250°C, reaction rates result in minimal formation.

PCDD/PCDF CONTROL AT MWCs

Stack emissions of PCDDs/PCDFs from MWCs have been found to range from < 1.0 to > 20,000 ng/dscm depending on combustion and flue gas cleaning conditions (see Figure 3).[29-32] Although the stack emissions are dependent on combustion conditions, the highest emissions are generally obtained with MWCs equipped with only ESPs followed in order of decreasing emissions by DSI/ESP, SD/ESP, DSI/FF, and SD/FF.

Factors affecting the formation and subsequent emission of PCDDs/PCDFs from MWCs include the:

- Composition and properties of waste,
- Combustion Conditions,
- Composition of flue gas,
- Amount of entrained PM,
- Flue gas time/temperature profile,
- PM control device operating temperature, and
- Methods of acid gas and PM control.

Composition and Properties of Waste

Rapid changes in waste composition or properties may cause combustion upsets and lead to PCDD/PCDF formation. Although PCDDs/PCDFs are formed during steady state combustion conditions, the amounts formed are believed to increase substantially during combustion upsets associated with improper feed conditions. It is important to blend or mix waste prior to combustion to reduce variations in heating content, volatility, and moisture content.[16-18]

While waste composition probably affects the amounts of specific organics formed during combustion, there is no conclusive scientific evidence that specific solid waste components, such as polyvinyl chloride (PVC), are primarily responsible for the formation and emission of PCDDs/PCDFs.[32,33] Sufficiant Cl is available from other waste components to account for observed levels of PCDDs/PCDFs in MWCs.

Combustion Conditions

PCDDs/PCDFs contained in the waste are believed to be destroyed in active flame zones or the high temperature

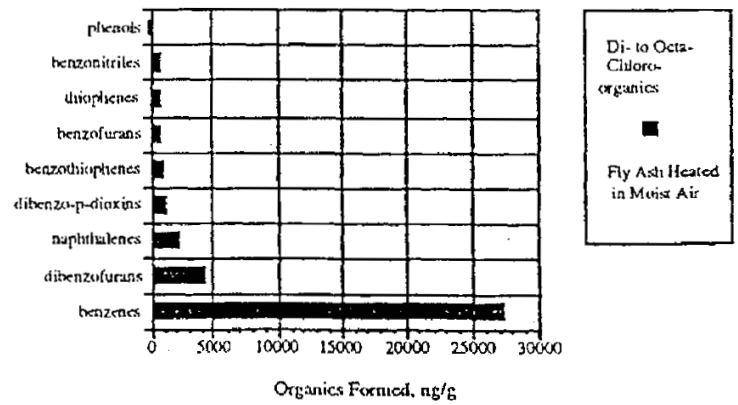

FIGURE 1. CHLORO-ORGANICS FORMED DURING *DE NOVO* SYNTHESIS

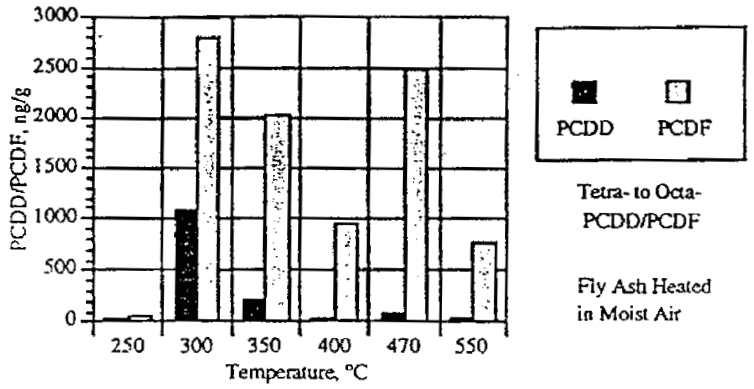

FIGURE 2. EFFECT OF TEMPERATURE ON *DE NOVO* FORMATION RATES OF TETRA - TO OCTA- PCDD/PCDF

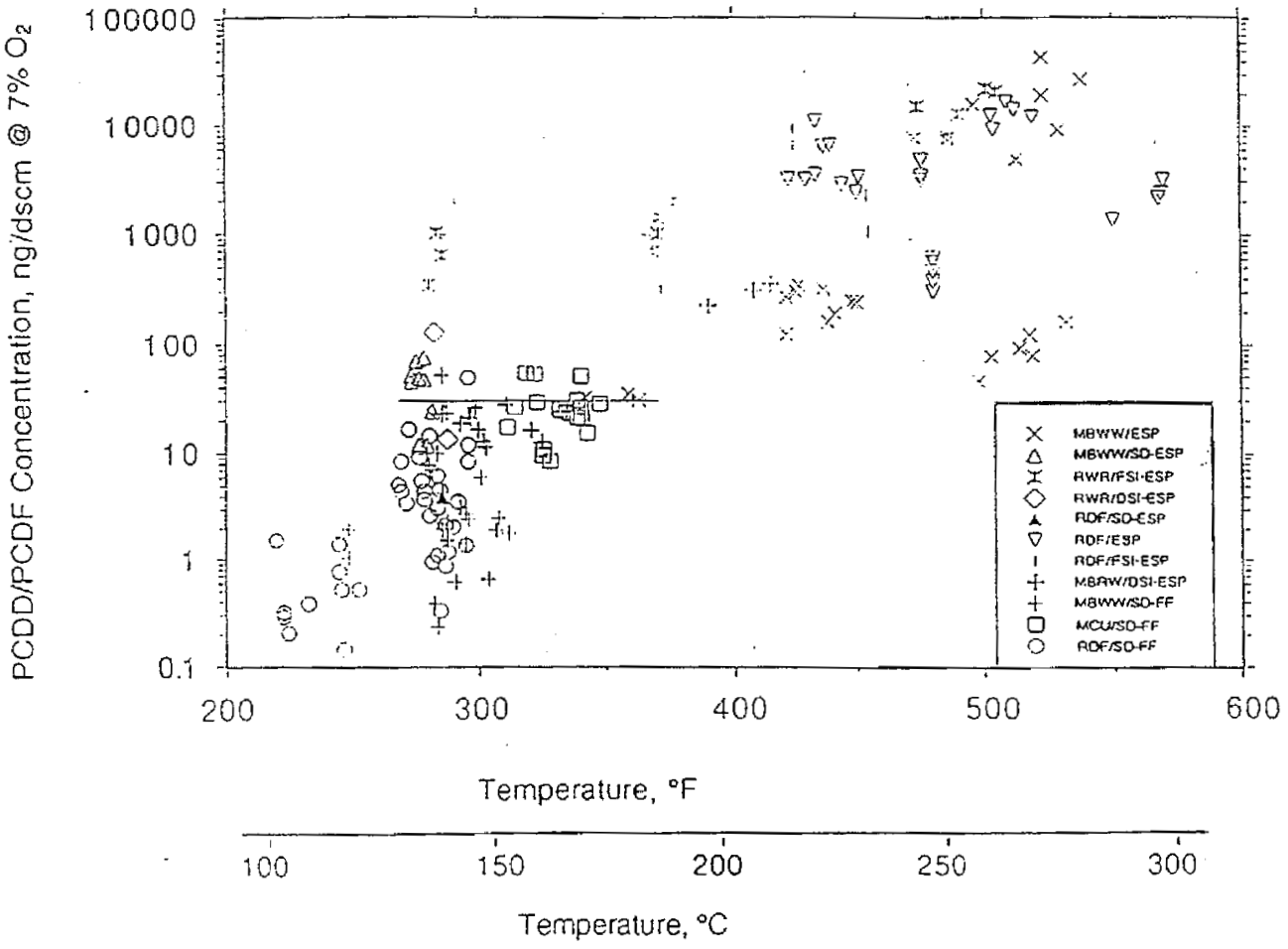

FIGURE 3. DEPENDENCY OF PCDD/PCDF EMISSIONS ON TECHNOLOGY AND PM CONTROL DEVICE OPERATING TEMPERATURE

regions of MWCs.[10,16] However, the waste composition and combustion conditions determine the availability of specific precursors needed for PCDD/PCDF formation. These precursor compounds are formed by the thermal destruction, oxidation, and synthesis reactions which occur in the burning waste bed, the active flame region above the bed, and the high temperature regions of the furnace. Combustion conditions and the time/temperature profile in the cooling zones downstream of the combustor determine the amounts of PCDDs/PCDFs precursor material entering flue gas cleaning devices and the potential for formation within the devices. Organics that have been implcated in PCDD/PCDF formation include: CBs, CPs, PCBs, and the carbon in fly ash.[25-28]

GCP can be used to maximize the furnace destruction of organics and minimize the downstream formation of PCDDs/PCDFs by controlling the amounts of PM carried out of the furnace with flue gas. Furnace destruction of organics must include destruction of both gas- and condensed-phase organics. Field test experiments have shown that formation of PCDD/PCDF and other trace organics correlates with the CO and the amounts of PM carried out of the combustor with flue gases (see Figures 4 and 5).[16,17,34-36] In extensive tests at a RDF combustor, CO and total hydrocarbons (THCs) were found to be the two best parameters for predicting PCDDs, PCDFs, CBs, CPs, and PAHs at the SD inlet.[36]

Waste and its associated thermal decomposition products must be exposed to elevated temperatures for a sufficient time to completely destroy their organic components. Time scales required for destruction are typically measured in milliseconds for gaseous compounds in active flame zones. Combustion reaction times in the order of seconds to minutes may be required for the complete destruction of small solid particles. Combustion temperatures and residence times of 980°C (1800°F) and 1 to 2 seconds, respectively, are generally believed sufficient to thermally destroy gas-phase compounds.[10] However, even at temperatures of 980°C or higher, residence times needed for the complete combustion of entrained solid particles may be insufficient, and residual unburned carbon in fly ash may lead to reactions which form PCDDs/PCDFs.[16]

The amount of air used for combustion must be high enough to minimize the existence of fuel-rich pockets and low enough to avoid quenching of combustion reactions.[10,16] The distribution of combustion air is also important. Burning refuse beds contain drying, devolatization, combustion, and burnout zones. Each zone requires a different amount of combustion air. State-of-the-art MWCs often use zoned underfire air supplies to provide proper air distribution to the refuse bed and overfire air to complete combustion of unburned material leaving the bed.[10]

Poor mixing increases the amount of organic material available for the formation of PCDDs/PCDFs. It may result in local stoichiometries that are insufficient for the complete oxidization of gas- and solid-phase organics. Poor mixing may also lead to the formation of difficult-to-destroy soot particles. Methods of achieving good mixing include the use of furnace configuration and overfire air jets.[10,16]

Composition of Flue Gas

The effects of flue gas composition on PCDDs/PCDFs are complex.[24,25] Oxygen is required for the low temperature carbon oxidation reactions that are associated with *de novo* synthesis. Oxygen and H_2O are also required for the Deacon process reaction which provides Cl for the chlorination of

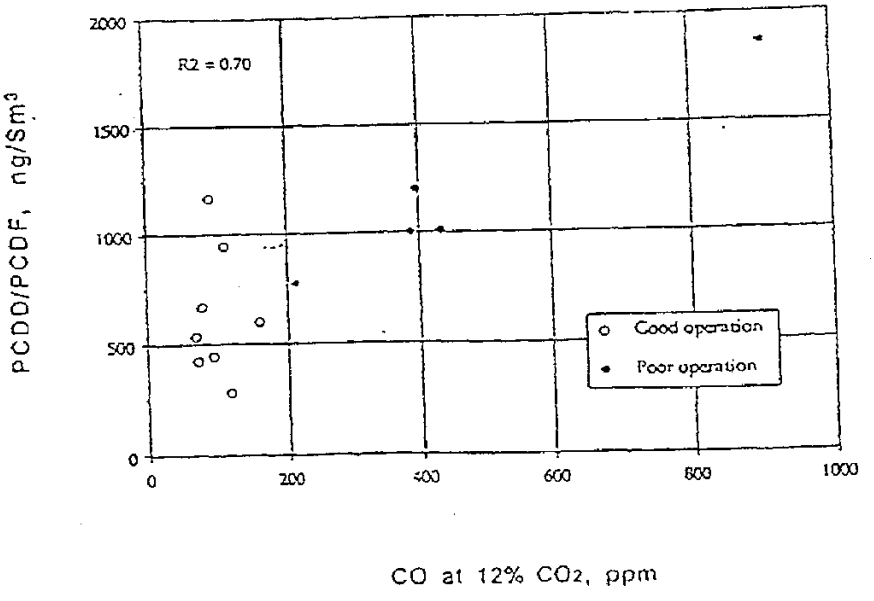

FIGURE 4. RELATIONSHIP BETWEEN CO AND PCDD/PCDF CONCENTRATIONS AT SD INLET, MID-CONNECTICUT MWC

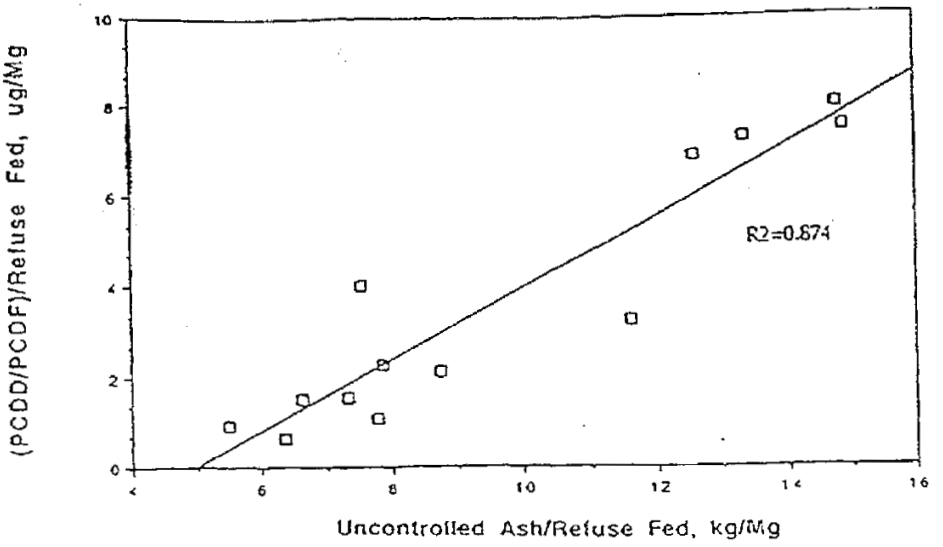

FIGURE 5. RELATIONSHIP OF PM CARRYOVER TO PCDD/PCDF EMISSIONS, QUEBEC CITY MWC

PCDDs/PCDFs or their precursor compounds. The Cl for the Deacon process reaction may come from either the inorganic chlorides in fly ash or the HCl in flue gas. Some bench and pilot scale experiments show that PCDD/PCDF formation increases with increasing levels of HCl or Cl_2 in combustion gases.[28,37] Although the flue gas concentrations of O_2 and H_2O may affect the rate of PCDD/PCDF formation, the waste moisture content and excess air levels determine the concentrations of these two constituents. The amount of excess air must be fixed at levels needed to obtain good combustion, and it is generally not practical to control the moisture content of wastes to the extent needed to control formation of PCDDs/PCDFs.

Entrained Particulate Matter

The entrainment and carryover of fly ash into the cooler regions of MWCs may lead to the formation of PCDDs/PCDFs and other trace organics. Metal ions or fly ash carbon can catalyze condensation formation reactions, and fly ash carbon can serve as the source of organics for the *de novo* synthesis of PCDDs/PCDFs. PM carryover is determined by the aerodynamic properties of particles, the method of waste combustion, and combustor gas flow characteristics. Methods of limiting PM carryover include proper furnace design, control of the underfire-to-overfire air ratio, the amount of excess air, and load (refuse burn rate).[16,18]

The correlation between PM carryover and PCDD/PCDF emission rates from tests at the Quebec City, Canada, mass burn combustor is shown in Figure 5.[34] These data, which are measured in the stack downstream of an ESP, show the effects of changing combustion conditions on emission of PCDDs/PCDFs. Changes in the PM carryover rate can be attributed primarily to changes in the flue gas flow rate and the ratio of underfire-to-overfire air. At higher loads, increased gas flow rates increase entrainment and carryover of PM. Higher underfire air flow rates also increase PM entrainment. During the low combustion temperature tests at Quebec City, Canada, excess air rates were increased to lower the combustion temperature. This had the effect of increasing volumetric flow rates and particle entrainment. During the poor combustion air distribution tests, the underfire-to-overfire air ratio was increased, thereby increasing PM carryover. Increasing emission rates of PCDDs/PCDFs with increasing amounts of fly ash is consistent with heterogeneous formation theories.

Time/Temperature Profile

Pilot scale experiments have shown that the concentration of PCDDs/PCDFs in flue gas downstream of the furnace depends on the time/temperature profile in the cooling sections of combustion systems.[37-39] The time/temperature profile is determined by the time required by flue gas and suspended PM to pass through the heat extraction regions of boilers, superheaters, and economizers. High flue gas temperature quench rates reduce the time that gas-phase organics and entrained particles spend in the temperature range associated with high PCDD/PCDF formation rates.

PM Control Device Operating Temperature

ESPs and FFs can function as chemical reactors that generate and emit PCDDs/PCDFs.[40] A large fraction of the PCDDs/PCDFs entering PM control devices is commonly associated with collectible fly ash. However, the large mass of particles within the device can serve as a source for the synthesis of PCDDs/PCDFs. Limiting the temperature at which PM control devices are operated is important in controlling the formation and emission of PCDDs/PCDFs.[16-18,40,41]

The ESP operating temperature is perhaps the most important variable affecting the formation and emission of chloro-organics in ESP systems. At PM control device operating temperatures above 250°C, *de novo* synthesis reaction rates become significant and the partitioning of

PCDDs/PCDFs into a vapor phase increases with increasing temperature.

The results of tests to evaluate the effects of ESP operating temperature on the formation and emission of PCDDs/PCDFs are depicted in Figure 6. These tests were conducted on a mass burn refractory MWC with a water spray flue gas quench chamber and an ESP located in Montgomery County, Ohio.[40] Quench water flow rates were adjusted to obtain nominal ESP inlet temperatures of 300 , 200 , and 150 °C. The test conditions included: normal and poor combustion (low temperature) tests at 300 °C inlet temperature; normal combustion with and without furnace injection of $CaCO_3$ at 200°C inlet temperature; and normal combustion with furnace injection of $CaCO_3$ and duct injection of $Ca(OH)_2$ at 150°C ESP inlet temperature.

The flue gas concentrations of PCDDs/PCDFs were higher at the ESP outlet than at the inlet for all tests, indicating PCDD/PCDF formation within the ESP. Under normal combustion conditions at the high ESP inlet temperature (300 °C), ESP inlet concentrations of PCDDs/PCDFs averaged 200 ng/dscm, while stack concentrations averaged 17,000 ng/dscm. Reducing the ESP inlet temperature to 200°C without sorbent injection reduced average stack emissions to 870 ng/dscm. For tests with furnace injection of $CaCO_3$, stack emissions of PCDDs/PCDFs averaged 1480 ng/dscm at an ESP inlet temperature of 200°C and 670 ng/dscm at 150°C inlet temperature. The lowest emissions (57 ng/dscm) were obtained using duct injection of $Ca(OH)_2$. Operating at the lowest practical ESP operating temperature is critically important in minimizing PCDD/PCDF emissions.

Methods of Acid Gas and PM Control

The methods of acid gas and PM control are major determinants of PCDD/PCDF emissions. Acid gas controls modify the chemistry of the PCDD/PCDF formation environment, affect flue gas quench rates, and allow operation of PM control devices at low temperatures. Low operating temperatures are necessary to minimize *de novo* synthesis rates and partitioning of trace organics between solid and vapor phases. Efficient collection of PM is necessary to collect solid-phase organics. Vapor-phase organics can be absorbed onto the surface of PM as it passes through the fly ash filter cake in FFs. DSI and SD can be used to reduce acid gases, modify PCDD/PCDF formation chemistry, and allow for lower PM control device operating temperatures.

Experiments in a 14.7 kW (63,000 Btu/hr) pilot scale combustor have shown that injection of $Ca(OH)_2$ into the flue gas at temperatures greater than 800°C significantly reduces the formation of PCDDs/PCDFs.[37] The reduction in PCDD/PCDF yield appears to result from both a reduction in the HCl content of flue gas and an inhibitory effect on fly ash surface reactions. DSI can also be used to remove HCl and reduce heterogeneous formation rates in the PM control device, but substantial amounts of PCDDs/PCDFs may be

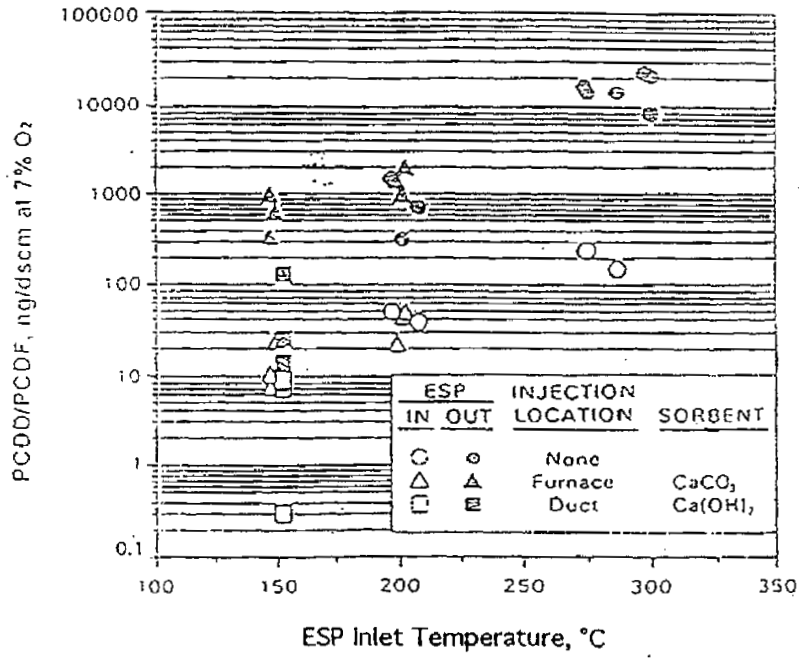

FIGURE 6. EFFECT OF ESP INLET TEMPERATURE ON PCDD/PCDF FORMATION, MONTGOMERY COUNTY MWC

formed upstream of the sorbent injection locations near the inlet to the PM control device. Most of the PCDDs/PCDFs formed upstream will be retained in the PM control device if the PM control device operating temperatures are low enough. SD systems combine the advantages inherent in high flue gas quench rates, sorbents which probably modify PCDD/PCDF synthesis reactions, and low PM control device operating temperatures.

Flue gas concentrations of PCDDs/PCDFs can either decrease or increase across an ESP.[30] Increases are associated with high rates of PCDD/PCDF synthesis within a PM control device. PM control devices containing collected fly ash can function as reactors for formation of PCDDs/PCDFs.[40] The amount formed will depend on the temperature, the mass of PM within the control device, the composition of the fly ash, the composition of the flue gas, and the residence time of PM within the device. Maximum *de novo* synthesis reaction rates occur at temperatures near 300°C.[23] Lowering PM control device operating temperatures to less than 250°C results in low PCDD/PCDF formation rates and alters the partitioning of vapor- and solid-phase PCDDs/PCDFs. In ESPs, operating temperature is critical, and it may be necessary to scrub acid gases from the flue gas to permit lowering of the PM control device operating temperature to a level where acid gas corrosion of the device is not a problem.

PM control device collection efficiencies >99 percent are probably necessary to adequately control PCDD/PCDF emissions. At the lower PM control inlet device temperatures typically employed by dry scrubbing systems, formation rates are greatly reduced and PCDDs/PCDFs are predominantly retained on captured fly ash. Although substantial quantities of trace organics may be formed during the combustion process, most of the semi-volatile organics are effectively collected in dry scrubbing systems. This is especially true of SD/FF systems.

MWCs equipped with SD/ESP systems are less effective in controlling PCDD/PCDF emissions than similar MWCs equipped with SD/FF.[30,42] The latter devices often have better PM control efficiencies, and the flue gas is passed through a filter cake where PCDDs/PCDFs can be absorbed on fly ash and sorbent particles. A review of data from eight different combustion units equipped with SD/ESPs indicated PCDD/PCDF emissions ranging from 9 to 173 ng/dscm (mass). All but one of these units had emissions of less than 75 ng/dscm, and the average for the range of typical emissions was 38.1 ng/dscm.[42]

The performance of SD/ESP systems for controlling PCDDs/PCDFs in mass burn MWCs can also be improved by the injection of activated carbon into the flue gas at the entrance to the SD system or by use of a carbon-enhanced lime-based sorbent in place of lime.[43-45] During three EPA-sponsored tests at the Camden County, New Jersey, MWC, stack concentrations of PCDDs/PCDFs without activated carbon averaged 46.8 ng/dscm. During three tests in which 360 mg/dscm of dry activated carbon was injected into the flue gas upstream of the SD/ESP, stack concentration of PCDD/PCDF averaged 5.6 ng/dscm.[44,45] Tests in Europe on MWCs equipped with SD/FF and SD/ESP systems have also shown the effectiveness of carbon injection for reducing PCDD/PCDF emissions.[43]

An EPA review of data from 20 different combustion units equipped with SD/FF systems indicated PCDD/PCDF emissions ranging from 1 to 22 ng/dscm. Nineteen units had emissions <12 ng/dscm, and the average for these units was 6.6 ng/dscm. Two large MWCs with DSI/FF systems had PCDD/PCDF emissions of 5 and 18 ng/dscm.[42]

CONTINUOUS CONTROL OF PCDDs/PCDFs

There is currently no feasible method for continuously measuring PCDD/PCDF emissions. Continuous control of PCDDs/PCDFs is of concern from regulatory and risk assessment perspectives. EPA's strategy to ensure continuous compliance with PCDD/PCDF emission limits is to place limits on CO concentrations, steam load, PM control device operating temperature, carbon feed rate, and opacity. The first four parameters are used to limit formation and partitioning of PCDDs/PCDFs, and the final parameter (opacity) will ensure proper operation of the PM control device which is needed for effective collection of solid-phase PCDDs/PCDFs. The effectiveness of these parameters for continuously controlling PCDD/PCDF emissions is verified by periodic compliance tests on each MWC that is subject to regulation.

CONTROL OF OTHER ORGANICS

Field test measurements show that a wide variety of trace organics are formed during combustion of municipal solid waste. Trace organics formed include semi- volatile organics such as PCDDs/PCDFs, CBs, CPs, PCBs, PAHs, and a variety of volatile organics. Analysis of data from the Quebec City MWC mass burn tests and the Mid-Connecticut RDF combustor tests show that flue gas concentrations of PCDDs/PCDFs, CBs, CPs, and PAHs all correlate with each other and with flue gas concentrations of CO and THC.[30,36] Measures taken to control emission of PCDDs/PCDFs are also effective in controlling CBs, CPs, and PAHs. (It is expected that these measures will also control PCBs, but the concentrations of PCBs in MWC flue gases are generally so low that strong statistical correlations with other pollutants are not found.)

Combustion controls are effective in controlling all trace organics. Dry and semi-dry scrubbers with FFs and temperature control are effective in controlling semi-volatile organics, but the degree of control is probably related to the amounts of carbon in the fly ash. Activated carbon or multipollutant sorbent containing calcium and carbon (lime enhanced sorbents) should also enhance capture of all semi-volatile organics in MWCs equipped with dry and semi-dry scrubbing systems. Dry and semi-dry scrubbing systems are probably not effective for controlling volatile organics, and the best method for controlling these pollutants is the use of GCP as a preventive measure.

MERCURY CONTROL AT MWCs

The capture of Hg in flue gas cleaning devices depends on the

- Waste composition,
- Flue gas properties (temperature, gas composition, moisture, etc.),
- Hg form [speciation and phase (vapor or solid)],
- Fly ash and sorbent properties, and
- Type of control device.

The waste composition and the relative amounts of Hg in each component determine the concentration of Hg in MWC flue gas. Hg mass balances from Environment Canada's Quebec City mass burn test project indicated that more than 96 percent of Hg in the MWC output streams was in either the collected ESP ash or the flue gas, indicating the volatile nature of Hg in MSW.[34]

MERCURY SPECIATION AND CONTROL MECHANISMS

The form of Hg in flue gas depends on the flue gas composition and temperature. Thermal-chemical calculations indicate that Hg is converted to elemental mercury (Hg°) in the high temperature regions of the combustor. As the flue gas cools, some or all of the Hg° is converted to other Hg species.[46,47] For combustion systems containing substantial amounts of Cl in the waste (or fuel), the two predominant forms of Hg at flue gas cleaning temperatures (< 300°C) are believed to be ionic mercury (Hg^{2+}) and Hg°.[46-49] Thermochemical equilibrium calculations indicate that the Hg^{2+} will be predominantly mercuric chloride ($HgCl_2$).[49]

Most metals condense to form solid particles as flue gas is cooled so that they can be collected as PM. However, both Hg° and $HgCl_2$ are vapors [Hg(v)] at typical flue gas cleaning control device operating temperatures (300 to 140°C), and special methods must be devised for their capture.[12,13]

Hg in MWC flue gases can be captured if it is in the solid phase [Hg(s)] or is adsorbed on fly ash or special sorbents such as activated carbon or enhanced lime-based sorbents containing activated carbon. Hg(v) capture without the use of special sorbents depends on the amount and properties of carbon in the fly ash. Well-designed and well-operated mass burn combustors have little carbon in their fly ash and, even when equipped with SD/FFs or SD/ESPs, they often exhibit Hg control levels below 50 percent. Conversely, RDF combustors contain relatively high amounts of carbon in the fly ash (> 2 percent). And, they can exhibit control efficiencies above 80 and 90 percent when equipped with SD/ESPs and SD/FFs, respectively. Figure 7 shows the distribution of Hg stack concentrations for RDF and non-RDF MWCs equipped with SD/FF and SD/ESP systems.[42]

Two techniques employed for Hg capture in dry flue gas cleaning systems are the use of activated carbon and sodium sulfide (Na_2S).[12,13] Na_2S, a crystalline solid, is dissolved in water and injected upstream of the flue gas cleaning equipment. $Hg^{\circ}(v)$ and $Hg^{2+}(v)$ are converted to a solid form of Hg [mercury sulfide (HgS)] that can be collected in a PM control device. Na_2S has been used at MWC facilities in Europe and Canada for Hg control. Na_2S test results from European facilities show Hg emissions ranging from 40 to 70 µg/dscm and removal efficiencies from 65 to 90 percent.[10] Na_2S is not currently being used in the U.S. Activated carbon can be used in three ways to control Hg(v) emissions: (1) it can be injected as a powder in dry or semi-dry scrubbers to

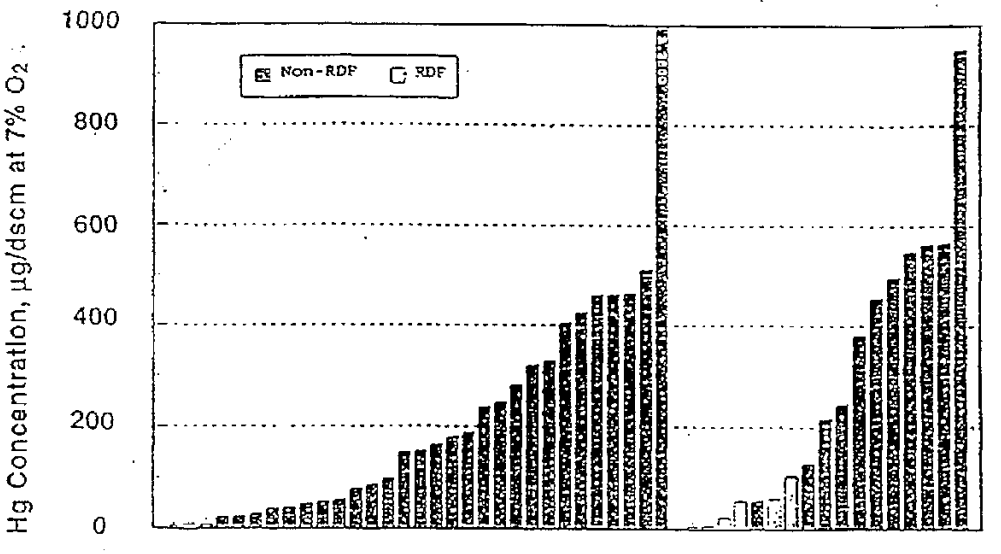

FIGURE 7. HG CAPTURE IN MWCS WITH SD/FF AND SD/ESP, LARGE PLANTS (>225Mg/d)

absorb Hg(v) for subsequent collection in an ESP or FF,[12,13] (2) it can be used in a sorbent system combining both lime and carbon in a single multipollutant sorbent,[50] and (3) flue gas can be filtered through a carbon bed polishing filter downstream of other air pollution control devices to enhance removal of Hg(v) and other pollutants.[51] Carbon bed filters are currently being applied to European MWCs where they are primarily used to improve emission control of PCDDs/PCDFs, Hg, and other trace metals.[51]

CARBON CAPTURE MECHANISMS

The adsorption of Hg and organics by activated carbon is controlled by the properties of both the carbon and the adsorbate, and by the conditions under which they are contacted. This phenomenon is generally believed to result from the diffusion of vapor-phase molecules into the pore structure of carbon particles. These molecules are retained at the surface because of intermolecular Van der Waals forces.

As the temperature falls, or as the partial pressure of the vapor above the carbon rises, the average time that a molecule resides on the surface increases. So does the fraction of the available surface covered by the adsorbate. However, the carbon surface is not uniform and consists of sites whose activities vary. More active sites will become occupied first and, as the activity of the remaining available sites decreases, the adsorption energy will change.

The physical structure of activated carbon is not known in detail, but it is believed to contain randomly distributed pores in the carbon, between which lies a complex network of irregularly, interconnected passages. Pores range in diameter down to a few angstroms, and provide an internal surface area from 300 to 1,000 m^2/g of carbon. The volume of pores at each diameter is an important variable that directly affects carbon performance.

Since adsorption takes place at the carbon/gas interface, the surface area of the carbon is one of the most important factors to consider. Another important factor is the pore radius. Bench scale tests have shown that increasing the surface area and adding sulfur compounds to the sorbent result in higher adsorption rates of some Hg species. Until recently, most of the laboratory work on carbon adsorption has been done on Hg°, not with the Hg compounds normally found in MWC flue gas.

The actual adsorption capacity of carbon is affected by:

- Gas temperature,
- Inlet concentrations of Hg,
- Species of Hg,
- Type of carbon and surface area,
- Contact time,
- Flue gas moisture,
- Acid content of flue gas, and
- Concentration of compounds which compete with Hg for sorption sites .

PERFORMANCE OF ACTIVATED CARBON SYSTEMS

The performance of activated carbon systems depends primarily on the carbon injection rate, carbon injection method, carbon properties, flue gas temperature, and PM control method. Performance tests in the U.S. and Europe have been limited primarily to the application of carbon injection to mass burn MWCs equipped with SD/FF or SD/ESP systems.[13,42,43,52]

EPA has sponsored two major field tests on the injection of powdered activated carbon for Hg control and has selected this technology as the basis for Hg emission control requirements on MWCs.[44,45,52-54] Both tests were conducted at facilities with conventional mass-burn waterwall combustors. The first was conducted on an MWC in Stanislaus County, California, equipped with a SD/FF system. The second was conducted on two MWCs in Camden County, New Jersey, equipped with SD/ESP systems. These tests show that stack concentrations of Hg depend on the Hg concentration in the flue gas (SD inlet concentration), the carbon content of fly ash, and the operating conditions of the carbon injection system.

Mercury concentrations in MWC flue gas are highly variable with time. In MWCs, the total solid-phase flue gas carbon (carbon in fly ash plus the carbon injection rate) appears to be the key determinant of Hg capture. In the absence of carbon injection, the amount of Hg captured depends on the amount and properties of carbon in the fly ash. When the fly ash carbon content is low or when Hg concentrations are high, poor removal efficiencies are obtained. When the fly ash carbon content is high and the Hg concentrations are low, stack emissions of Hg are low.

Powdered activated carbon can be injected into the flue gas to increase solid-phase carbon concentrations and improve Hg capture. Increasing the carbon injection rate reduces both the average and variability of emissions. At high carbon injection rates, there is generally sufficient carbon to capture low or high levels of Hg. The amount of excess carbon needed for continuously high levels of capture will depend on the variation of Hg concentration in the flue gas. Highly variable Hg inlet concentrations will require high excess carbon injection rates to ensure continuous Hg capture.

In SD/FF tests at the Stanislaus County MWC, Hg capture without carbon injection ranged from 16 to 46 percent. Outlet Hg concentrations for these tests ranged from 311 to 538 µg/dscm. Hg capture increased with increasing carbon injection rates and, at the highest injection rates of approximately 70 to 100 mg/dscm, Hg outlet concentrations ranged from 17 to 77 µg/dscm (see Figure 8).[52-54] SD outlet temperatures at Stanislaus County normally ranged between 136 and 145 °C.

During the Camden County SD/ESP carbon injection test project, Hg capture without carbon injection ranged from 18 to 92 percent.[44,45] When dry carbon injection rates exceeded 150 mg/dscm and the ESP inlet temperature was 132 °C, stack emissions of Hg were generally less than 80 µg/dscm (see Figure 9). The dependency of Hg reduction efficiency on the total solid carbon concentration in the flue gas during the Camden County tests is shown in Figure 10.

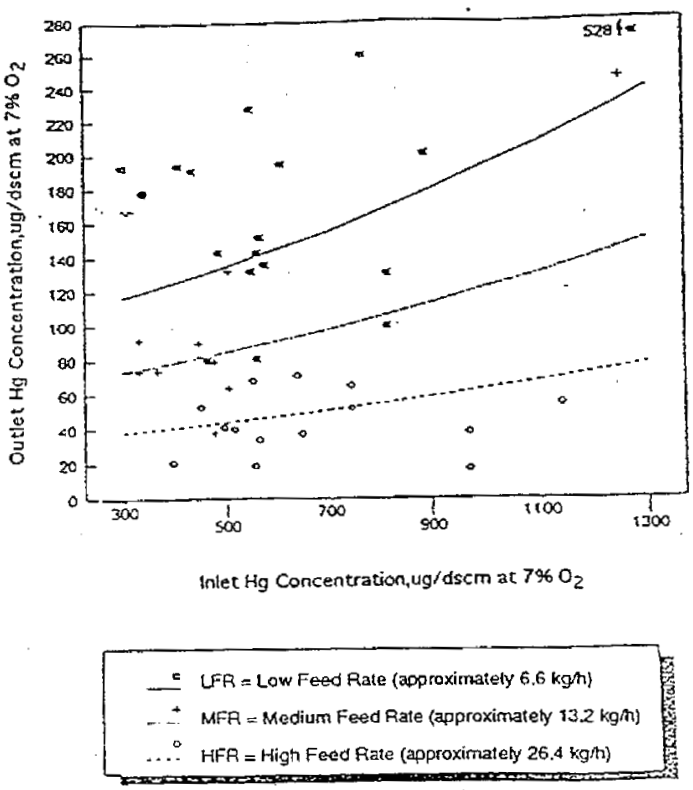

FIGURE 8. PERFORMANCE OF ACTIVATED CARBON IN SD/FF SYSTEM, STANISLAUS COUNTY MWC

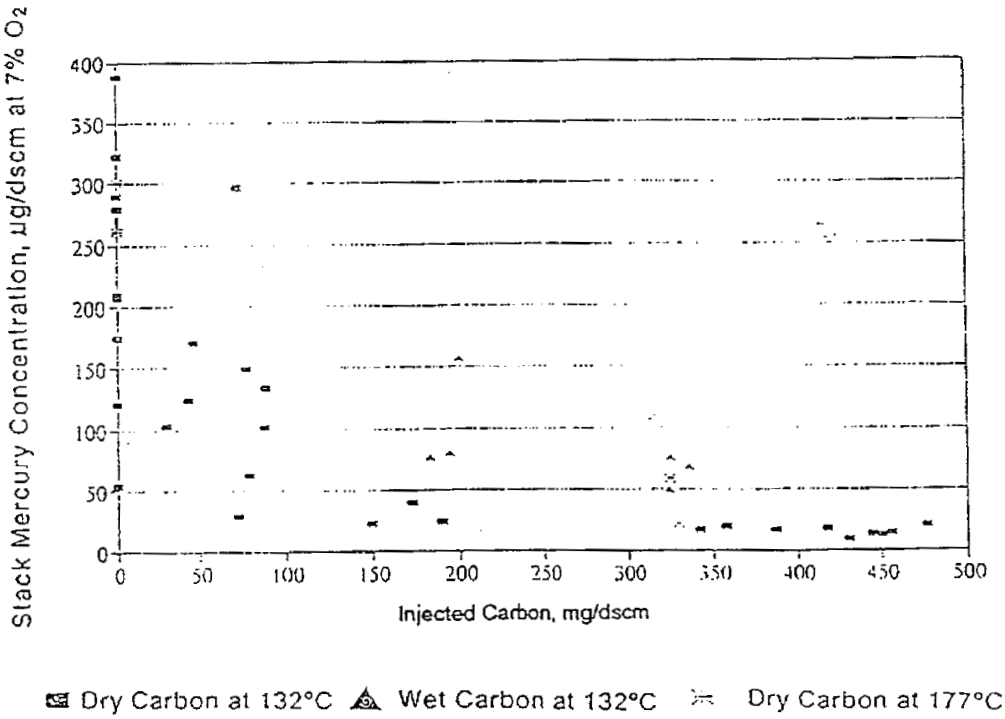

FIGURE 9. EFFECT OF INJECTED CARBON ON MERCURY CONTROL IN SD/ESP, CAMDEN COUNTY MWC

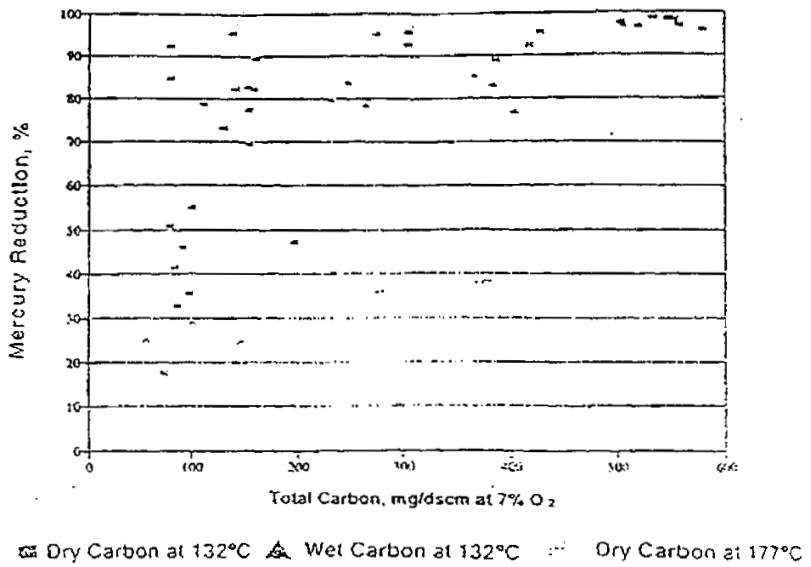

FIGURE 10. EFFECT OF TOTAL CARBON ON MERCURY CONTROL IN SD/ESP, CAMDEN COUNTY MWC

The performance of activated carbon in adsorbing Hg is dependent on temperature. The temperature at the inlet to the PM control device is normally used as a parameter in evaluating the performance of the device in collecting condensed or adsorbed pollutants. The PM control device inlet temperature for SD/FF and SD/ESP systems on MWCs is normally between 135 and 145 °C. Tests on the Camden County SD/ESP system at 177 °C indicated only moderate reduction in Hg capture relative to similar tests at 132 °C (see Figure 10).[44,45] Temperature variations over the normal operating range of SD/FFs and SD/ESPs can be expected to have only minor effects on Hg capture. Similar tests on European MWCs have shown that carbon injection can be used to reduce Hg emissions in SD/FF and SD/ESP systems to less than 80 µg/dscm.[43]

ESPs and wet scrubbers are commonly used to control emissions from European MWCs. Some European plants have installed activated carbon beds downstream of the primary air pollution control devices to act as polishing filters for the control of metals, dioxins, and acid gases. The use of activated carbon filter beds in combination with conventional control equipment has demonstrated Hg reductions exceeding 99 percent and Hg outlet concentrations of less than 1 µg/dscm.[51]

PERFORMANCE OF ENHANCED LIME-BASED SORBENTS

Several enhanced lime-based sorbents are commercially available for use in MWCs. One enhanced sorbent (Scansorb) is designed for improved HCl and SO_2 control in dry injection systems.[55] Another sorbent (Sorbalit) is a multipollutant sorbent designed for control of acid gases, Hg, and trace organics.[50] Sorbalit is produced by mixing lime, surface-activated carbon, a sulfur-based compound, and other additives. The Sorbalit carbon content can range from 4 to 65 percent depending on the technical and economic requirements of each project.

Comparative performance tests between Sorbalit and a typical activated carbon on a mass-burn MWC equipped with an SD/FF system have indicated equivalent or slightly higher capture of Hg by the enhanced lime-based sorbent.[50] The lime-based sorbent captured 87.7 percent of the total Hg, while the conventional activated carbon captured 84.2 percent. Analysis of the sampling train data indicated that it captured 83.2 percent of the vapor-phase Hg, while the conventional carbon captured 77.6 percent. Additional performance testing is being planned to evaluate the effectiveness of Sorbalit in controlling emissions from MWCs with other flue gas cleaning equipment configurations.

FORM OF MERCURY EMISSIONS

In conducting risk assessments, it is important to estimate the form and speciation of Hg stack emissions. The transport, deposition, and environmental uptake of Hg are dependent on the form and speciation of Hg. Several studies estimate the speciation of Hg in MWC flue gases. Metzger and Braun estimate that nearly all Hg in MWCs at flue gas cleaning temperatures is in the form of mercury chlorides.[49] Lindqvist and Schager estimate that the speciation of Hg in raw flue gases is approximately 20 percent Hg°, 60 percent Hg^{2+}, and 20 percent Hg(s).[48] Pacyna estimates that Hg

emissions from European waste incinerators consist of 10 percent Hg°, 85 percent Hg^{2+}, and 5 percent Hg(s).[56]

There is currently no validated U.S. method for determining the speciation of Hg in stack gas. However, information on the chemical behavior of Hg and the distribution of Hg in EPA's multimetal sampling train (Method 29) can be used to estimate the form and speciation of Hg in the MWC stack gas These estimations are valid only for measurements downstream of the air pollution control devices. The phase and speciation of Hg at inlet sample locations can be significantly affected by PM collected in the Method 29 probe and filter. For outlet samples, Hg found in the probe and filter can be assumed to have been either vapor-phase Hg adsorbed onto PM or a solid-phase Hg compound. Both are associated with PM as designated by Hg(PM). $HgCl_2$ is soluble in water and should be removed in the nitric acid/peroxide (HNO_3/H_2O_2) impingers. Hg found in the downstream permangenate/sulfuric acid ($KMnO_4/H_2SO_4$) impingers was probably Hg°(v). The distribution of multimetal train samples collected during the activated carbon injection tests at the Camden County MWC and Stanislaus County tests is shown in Figure 11.[44,45]

For the Camden and Stanislaus County tests, the fraction of Hg(PM) was generally below 5 percent and exceeded 10 percent for only one test. Tests with stack concentrations of Hg >100 µg/dscm represent tests without carbon injection or low carbon injection feed rates. For these tests, Hg° ranges from 2 to 26 percent of total Hg. As carbon injection rates and Hg capture increase, the percentage of Hg° as a fraction of total Hg increases. This implies that Hg^{2+} is more easily captured by activated carbon than Hg°. For stack concentrations of Hg <50 µg/dscm, the fraction of Hg° ranges from approximately 14 to 72 percent.

From the results of these tests it can generally be concluded that, for MWCs equipped with SD/ESPs and SD/FFs, the stack emission of Hg(PM) is negligible unless further Hg is absorbed on the surface of PM between the stack sampling location and the stack exit.

At low levels of control, the stack concentration of Hg is probably 15 to 30 percent Hg°(v) and the rest is Hg^{2+}(v) and Hg(PM). In MWCs with SD/FF or SD/ESP systems, stack concentrations of Hg(PM) are probably less than 5 percent. At high levels of control, Hg^{2+}(v) is selectively removed, increasing the relative concentration of Hg° (v). The relative concentration of Hg (v) may be 50 percent or higher.

CONCLUSIONS

Dioxin formation is predominantly associated with heterogeneous reactions involving fly ash. These low-temperature synthesis reactions can occur downstream of the combustor at temperatures ranging from approximately 250 to 600°C.

Spray dryers and FFs can be used to continuously reduce PCDD/PCDF emissions to less than 20 ng/dscm. Activated carbon, which is needed for Hg control in many MWCs, will provide additional PCDD/PCDF control.

Spray dryers and ESPs can be used to reduce typical PCDD/PCDF emissions from mass burn combustors to less than 75 ng/dscm. Injection of activated carbon, to control Hg emissions, can be used to further reduce PCDD/PCDF emissions to 60 ng/dscm or less.

The Hg in MSW is volatilized during combustion and converted to elemental and ionic Hg. Hg in MWC flue gas is believed to be predominantly $HgCl_2$ and Hg°. Both are predicted to be in a vapor phase at stack gas temperatures.

In dry flue gas cleaning systems, Hg(v) can be absorbed onto the surface of particles for collection in PM control devices. Hg(v) can be adsorbed either on the residual carbon in fly ash, on activated carbon, or on enhanced lime-based sorbents which have been injected into the flue gas.

RDF combustors have relatively high amounts of carbon in their fly ash (>2 percent), and those equipped with SD/FFs

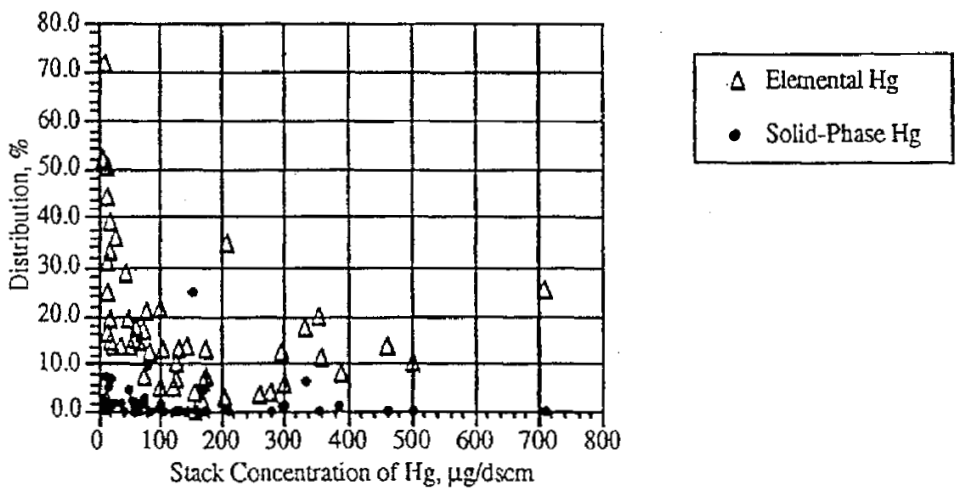

FIGURE 11. DISTRIBUTION OF Hg IN EPA METHOD 29 SAMPLING TRAIN, CAMDEN COUNTY AND STANISLAUS COUNTY CARBON INJECTION PROJECTS

may attain Hg removal efficiencies of >90 percent due to adsorption of Hg(v) onto the fly ash carbon. Other types of MWCs, such as mass-burn water-wall combustors, may require the injection of activated carbon or enhanced lime-based sorbents to obtain efficient Hg(v) control.

Nearly all of the uncontrolled Hg in MWC stack gas is in a vapor form. Method 29 sampling train data suggest that carbon absorption methods collect Hg^{2+}(v) more efficiently than Hg°(v). As Hg removal efficiencies increase, $HgCl_2$ (v) is preferentially removed and the proportion of Hg that is Hg°(v) increases. In MWCs equipped with SD/FFs and SD/ESPs, the relative amount of Hg(PM) in stack gas will generally be less than 5 percent.

ACKNOWLEDGMENTS

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ASH AND ASSOCIATED ISSUES

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Several issues must be addressed in order to increase the use of pellet fuels in industrial, institutional, and utility boilers, and thereby the markets for these products. Federal Clean Air Act (CAA) regulations strictly control emissions from municipal solid waste combustors (MWC). In cases where institutional, industrial and utility boilers are burning waste derived fuels with coal, these facilities are exempt from the CAA air emission requirements when burning up to 30% (based on heating value) of municipal solid waste (MSW). Rules governing the management of the ash generated from these facilities are covered under the Resource Conservation and Recovery Act (RCRA). These acts are administered by two different organizations in the U.S. Environmental Protection Agency (US EPA).

Strictly interpreted, current RCRA rules require that the ash generated from co-combustion of MSW and coal (co-mingled ash) be subjected to the same requirements governing the ash generated from units burning only MSW. On October 8, 1993 the US EPA stated that due to the presence of household waste in refuse derived fuel, the Agency believes that the co-mingled ash would be subject to the municipal solid waste landfill criteria (40 CFR Part 258). These criteria specify the minimum requirements for designing, construction, and operating municipal solid waste landfills. Because of this situation, many facilities burning coal are reluctant to supplement their coal with refuse derived fuel, especially those that have disposal options for their ash other than disposal into municipal solid waste landfills. There is no exemption for the ash such as the 30% exemption for the air emissions. This position is dictated more by RCRA language than by technical considerations. Scrap waste from an industrial process (i.e., scrap plastic and paper) that does not enter the MSW stream may not come under the same interpretations by US EPA's Office of Solid Waste. It is interesting to note that the paper, glass, plastic, etc. that the home owner sets out for recycling and/or processing at the materials recovery facility seem to have no such restrictions as those placed on the same materials going to a waste-to-energy facility. This raises questions such as "when is a waste not a waste" and "when does a material become a waste?"

Also of interest is the trend in some other countries to restrict the organic content of waste going to landfilling. These restrictions are resulting in increased dependance on waste-to-energy and biological degradation technologies to treat the waste prior to landfilling. Many of these countries also have high recycling rates. The US EPA does not give recycling credit for waste-to-energy, even when the facility reclaims ferrous and other metals from the ash. Waste-to-energy facilities recover significant quantities (600,000 tons in 1994) of high quality ferrous materials. Some states, however, are beginning to allow some recycling credit for waste-to-energy.

These issues need to be clarified in order for pellet fuels derived from MSW and similar materials to be better accepted in industrial, institutional and utility boilers.

Ash Handling

The group identified several issues associated with municipal solid waste (MSW) and MSW combustion ash management that are affecting the markets for pellet fuels derived from waste materials. These issues can be differentiated between "real" concerns based on technical considerations (e.g., lack of credible data to base decisions on) and concerns based on legal interpretations of language in RCRA (e.g., that ash from a municipal solid waste-to-energy facility is not exempted from hazardous waste regulations), U.S. EPA's stated position that co-mingled ash from facilities that burn coal with a material derived from the household must dispose of the ash in RCRA Sub-Title D landfills, other regulatory considerations, U.S. EPA and state policies on ash use and recycling credits, etc. and one's definition/perception of waste.

The group identified potential actions to address these technical, regulatory and perception barriers to increase use of pellet fuels. These include:

1. A state by state assessment of state rules, policies, guidelines, etc. regarding issues such as definitions of waste, recycling credits for combustion, ash recycling, co-combustion of waste derived fuels with coal, etc. and how each state interprets and applies Federal policies and rules regarding these issues.

2. An effort to change adverse perceptions of waste derived fuels by clarifying their benefits and the terminology/nomenclature used to describe them in order to promote a positive image rather than a negative one. One approach is to work with the American Society for Testing and Materials (ASTM) to develop new consensus definitions for fuels derived from MSW and similar sources.

3. Compile available data on co-mingled ash (ash from burning coal and waste derived fuels) and on MWC ash characteristic, leaching, management, etc. Conduct studies to fill data gaps. This will provide the technical basis for demonstrating that the co-mingled ash is safe for use. This will require a roadmap of how, who, and cost to conduct the studies.

4. With complete data on co-mingled ash characteristics, the pellet fuel industry will be in a better position to educate U.S. EPA, states and others of the benefits of using pellet fuels as a source of energy. This would provide the basis to approach EPA for a favorable ruling on how this ash should be managed.

Pellet Fuels Conference

Thursday, November 16, 1995
Stouffer Concourse Washington DC Hotel — National Airport

1:15 p.m.
Panel Discussion on Regulatory Issues

Regulating Solid Waste as a Fuel Source in Minnesota

Speech for
Chuck Williams, Commissioner
Minnesota Pollution Control Agency

I. Introduction and Overview

- Thanks for inviting me here this afternoon. I'm flattered to be speaking to a group of such highly talented and experienced individuals in the pellet and alternative fuels industry.
- Minnesota has quite a bit of experience working with alternative fuels, including pellet fuels. Our experience in Minnesota goes back about 15 years.
- I'd like to spend a little time talking about where the MSW processing and incineration industry has come in Minnesota and how my agency has been a part of that evolution.
- Then I'll give you a glimpse of where I think the industry is headed and what challenges I think it needs to overcome.

II. Evolution of the Waste-Processing and Incineration Industry in Minnesota

- About 15 years ago, Minnesota took a bold step forward in the management of residential and commercial wastes. Our Legislature passed the Waste Management Act, which set the direction and goals our 87 counties were to strive to meet in their management of solid and household hazardous wastes.
- Minnesota made a commitment to support an integrated waste management system that focused on resource recovery and protection of the environment.
- Before the early 1980s, we relied entirely upon landfilling for waste disposal in Minnesota.
- Today, we recycle more than 40 % of our waste, incinerate and compost a little over 30% and landfill about 30%.
- When we first began looking at alternatives to landfilling for disposing of waste, waste-to-energy incineration was one of the first technologies embraced by our counties.

- The current federal definition of a waste combustor — facilities burning more than 30%-by-weight of all fuel — was adopted by Minnesota last June.
- For facilities that co-fire less than 30% by weight of MSW-derived fuel, a facility's permitted emission and ash-disposal standards essentially keep them in compliance with state and federal regulations.
- Minnesota has led the pack for burning alternative fuels. We've got some facilities that have become very good at burning "odd-ball" fuels. One of those is the Western Lake Superior Sanitary District. They operate a very good burner in Duluth that co-fires waste-water sludge and MSW.
- In 1988, our state Legislature created a temporary program for MSW ash, creating a special classification for it. This exempted the ash from hazardous waste rules, directed the Minnesota Pollution Control Agency to write rules for ash and set up a temporary program to manage the ash until rules were finalized.

- In April 1992, our state's new MSW-ash disposal rules became effective. These rules replaced the temporary program established in 1988.
- The new rules set up a quarterly testing regiment, establish 5 different liner designs for ash monofills, the most stringent of which is equivalent to federal hazardous waste landfill regulations, and required operators of incinerators to take steps to reduce the amount and toxicity of the ash they generate.
- These rules also prohibit co-mingling MSW-ash with raw MSW in landfills, but they do allow the mixing of fly and bottom ash before landfilling.
- The 1988 law also required incinerator operators to find ways to reduce the amount and toxicity of the ash they were generating.
- None of our waste combustors has failed the hazardous waste test under the new federal requirements as a result of the Supreme Court's 1994 ruling on MSW incinerators.

- Counties have reduced the toxicity of their ash was by removing toxic materials from the waste stream before processing or incineration. Increased recycling has helped to reduce the toxicity of the ash and lower air emissions.
- Also, our counties have instituted household hazardous waste collection programs, and our state has some pretty aggressive waste disposal bans on items like fluorescent lamps, mercury-containing products, certain kinds of batteries and many other materials that might affect the emissions or ash at a waste combustor.
- Hennepin County has a model recycling program that has allowed them to keep a lot of toxic material out of their waste stream before it is incinerated — things like button batteries.
- Two other state laws are helping to reduce the toxicity of the waste that we burn and compost, as well as landfill.
- These toxics in packaging and products laws target four heavy metals, cadmium, hexavalent chromium, lead and mercury.

- Studies have shown that all of these metals have an effect on the human and other animal's endocrine systems.
- We've joined governments from nine northeastern states in establishing standards lowering the levels of these four metals in packaging that is sold or distributed in our state.
- These two state laws illustrate Minnesota's intention to move the regulation to the front-end of the pipe instead of pulling it out of the garbage at the back end.
- In Minnesota, we've taken a real pollution-prevention philosophy to how we are going to clean up the post-consumer waste stream, no matter what the disposal option.

III. Where is the Pellet Fuels Industry Headed in Minnesota?

- What I really want to talk about is the reality of the flow of solid waste in the U.S. and the impacts the Supreme Court's decision in May of 1994 has on the future of pelletized MSW.

- I don't need to remind everyone in this room that the pelletizing of waste, by necessity, has to be competitive with other disposal methods, such as landfilling.
- Our experience in Minnesota points to the pelletizing industry being at a severe competitive disadvantage to landfilling, especially at landfills in neighboring states.
- Before the Supreme Court's decision, our communities and counties were able to sign contracts and pass ordinances that gave them the ability to designate where waste would go. In almost all cases, these powers were exercised to support resource-recovery facilities, like waste-to-energy facilities, MSW composting plants and refuse-derived fuel processing plants.
- Now, all of our public and private resource-recover facilities are having to compete with in-state and out-of-state landfills. To remain competitive, most of these resource recovery facilities have had to lower their garbage tip fees. This has meant that for private facilities, they are probably losing money to stay afloat.

- And for public facilities and public-private partnerships, our taxpayers have to pick up the slack through increased service fees and higher taxes.
- Minnesota is being penalized for protecting the environment ... penalized for its forward-looking policies.
- And private industries like the ones that you represent are also being penalized.
- If you are truly interested in the future of waste as a resource for fuel, then you need to let your voice be heard at Congress.
- All of us need to tell our congressional representatives that Congress needs to approve legislation to restore flow control authority to communities that entered into legally binding contracts for delivery of MSW to a designated waste management facility.
- Even though flow control is a short-term solution to maintaining Minnesota's model waste management system, we need flow-control to stabilize what is happening in the industry right now.

- If you are not interested in pelletizing MSW, and are going for other pre-consumer waste types, such as industrial rejects and industrial recyclables, then agencies like mine don't have much to say about it. We don't regulate pre-consumer material.
- And if any new pelletizing technology can produce a high-Btu pellet from industrial pre-consumer rejects, I would advise boiler operators to beware of what they are purchasing.
- If I were to give a boiler operator advice on whether to burn MSW- or some other type of pellet fuels, I would tell them to overcome the market challenges of obtaining a consistent, long-term source for pellets. My agency's role is to help boilers handle the pellet fuel properly, ensure they store the material properly, have the right air-emission control equipment, and that they handle the ash properly.

- Beyond that, I would tell them to call my agency early and often for technical assistance and be confident about your operating window — when are you going to accept pellet fuels and when are you not.
- If you are considering a new technology that will allow you to pelletize just about anything and still provide you with high BTU value, consider a few things:
    1. First, you will still need to meet the emission requirements in your air permit in Minnesota.
    2. Second, you will still need to meet the requirements of the ash disposal part of your permit, which are based on the state's industrial waste disposal rules.
- If industrial facilities are considering using pelletized fuel as a fuel source, I'd like to encourage them to take a good look at the fuel pellet and what's in it. What is it going to do to your boilers? What kind of plastics are used in the pelletizing process? What are those plastics going to do the metal parts of your boiler.

- And what will the inferior substances in the pellet do to increase the slag you need to deal with, not to mention the increased maintenance issues.
- I applaud facilities for attempting to find ways to save money by using alternative fuel sources. But you need to consider all of the costs of burning a new fuel source. Will you need to add more controls to keep air emissions within your permit? Will you need to spend more time maintaining your boiler? Will you need to spend more to dispose of the ash? Will you need to spend more to reduce the toxicity of the ash you're producing?
- Our state values the reuse of resources. We value preventing pollution. And we value protecting our environment.
- Minnesota's regulatory system is based on the philosophy of protecting human health and the environment from pollution.

- Those goals can work in partnership with the pellet fuels industry and we have shown that they can. We want this industry to succeed.
- Thank you.

Background on the Pellet Fuels Speech, Nov. 16, 1995

- We have 12 MSW combustors, 27 operating MSW landfills, 7 MSW composting facilities and almost 900 recycling facilities statewide; about 40 HHW facilities; and two dRDF processing facilities (Future Fuels in Thief River Falls and BFI in Eden Prairie, which is at about 25% capacity right now). In Minnesota, there are two facilities burning dRDF — a municipal hospital in Thief River Falls and the Future Fuels processing facility in Thief River Falls.
- When we began large-scale incineration of municipal solid waste in the early to mid-1980s, the ash:
  - was tested to determine if it was hazardous;
  - was disposed of separate from regular MSW and other wastes;
  - could be a possible mixture of bottom and fly ash.

- Our state now has several years of analytical information about leachate coming from MSW-ash monofills. From what we're seeing come from the leachate-collection systems, there does not seem to be a problem with high levels of metals in the leachate. It appears to be very clean.
- It doesn't really matter what we do with the MSW, reducing the toxicity of the waste will help no matter where it goes. With incinerators, we get fewer toxics in the emissions. At composting plants, the final product is cleaner. At ash landfills, the leachate coming out is cleaner and therefore easier for waste-water treatment plants to handle -- and that helps to reduce the toxicity of the sludge that that facility will need to land spread or burn. The bottom line is that if we can reduce the toxicity of products and packaging, everyone down the line will benefit -- the manufacturer, the consumer, the disposal facilities and last, but certainly not least, the environment.
- The MPCA has a good relationship with the industrial and broad business sector in Minnesota.

- I pride myself on making my agency as helpful as possible to industry, because they are our partners in protecting the environment. We enforce the regulations and give technical assistance, but it's the job of industry to protect the environment.
- The 1994 Green and Gold Report, which reports on the economic and environmental status of states, last year ranked Minnesota in the top nine states with the best environmental records and that also offer the best job opportunities and climate for long-term economic development.
- Another way Minnesota is fostering economic and environmental benefits simultaneously is through an innovative 1995 law that allows companies to conduct environmental audits of facilities, discover violations of environmental regulations and correct them without the fear of fines or penalties.
- In response to the issue of using plastics as an encapsulating ethnology for pelletizing, I want to let you know about Minnesota's legislative mandate to recycle.

- In 1989, our state passed a very aggressive recycling law that mandated that counties achieve progressively higher recycling rates over the course of several years, with the goals of 35 percent in our rural areas and 50 percent in our twin cities metro area by 1996.
- Now this law is supported by the legislature's hierarchy of waste management in Minnesota, which places greatest importance on waste reduction, recycling and reuse of resources first. Incineration and landfilling are obviously further down on the list.
- There are several incentives for counties to reach their recycling goals:
  1. First, they get funding for their solid waste and recycling and public education programs when they meet their legally-mandated targets.
  2. Second, they will have less garbage to dispose of, and fewer toxic materials in the garbage that they do need to dispose of.
  3. Third, they get revenue from the recyclables they sell.

- Now, given that scenario and the fact that counties have to meet their targets based on percentages of garbage produced by weight, there is great incentive for them to recycle plastics.
- We recently had to deal with a small incinerator operator from a meat processing facility who lobbied his legislators for an exemption from the new air-quality regulations my agency was charged with enforcing. He received his exemption based upon the fact that he did not have a market for a wax-impregnated cardboard waste he had to deal with. At the last moment, by working with staff from the state, this person found a market for this waste cardboard. So, he found a new revenue source, someone else found a resource they could re-use and we were pleased because he was not incinerating the cardboard.

REGULATORY ISSUES AFFECTING GROWTH OF PEF

WILLIAM F. DEMAREST, JR.
HOLLAND & HART

1995 PELLET FUELS CONFERENCE
NOVEMBER 16, 1995

Co-firing of Process Engineered Fuels ("PEF") with coal offers a potentially more cost-effective means for coal-fired utilities to achieve compliance with the federal Acid Rain Program of the 1990 Clean Air Act Amendments than through installation of scrubbers or other capital-intensive alternative compliance strategies. This result may be realized either directly, through co-firing of PEF with coal in utility boilers, or indirectly through purchase by utilities of SO_2 emission allowances generated by co-firing of PEF in industrial boilers which opt-in to the Acid Rain Program. An additional environmental and resource conservation benefit from co-firing of PEF is conservation of nonrenewable resources and reduction in the amount of solid waste requiring landfill disposal.

However, regulatory impediments, at both the federal and state levels, need to be resolved if the full SO_2-emission-reduction-potential and other environmental benefits of PEF are to be realized. In some cases, more data is needed to permit an accurate assessment of regulatory consequences. This alone could reduce current regulatory uncertainty that acts as a brake on expansion of PEF in utility and non-utility sectors. In other cases, action by regulators is needed to clarify application of environmental regulatory requirements to PEF. Finally, state utility commission regulatory policies may need to be modified if the nation and utility customers are to realize the economic benefits of trading SO_2 emission allowances.

The primary regulatory issues involve:

(1) Clean Air Act ("CAA") requirements, including permitting consequences of co-firing PEF with coal (or other conventional fuels);

(2) Resource Conservation and Recovery Act ("RCRA") regulation of disposal of ash from co-firing of PEF with coal; and

(3) State Public Utility Commission ("PUC") policies respecting recovery of environmental compliance costs by regulated utilities.

CLEAN AIR ACT ISSUES

Under the Clean Air Act, up to 30% Municipal Solid Waste ("MSW") or MSW-derived fuel may be co-combusted with non-MSW fuels without triggering Municipal Waste Combustor ("MWC") regulation. Nevertheless, significant potential CAA regulatory consequences may flow from co-firing of PEF depending on the emissions consequences. Thus, the threshold Clean Air Act issue is whether co-firing of PEF will result in an increase in emissions of CO, NO_x, VOCs, particulates or Hazardous Air Pollutants ("HAPs"). The answer to this question is essential to assure utility and non-utility managers that adverse regulatory consequences (generally in the form of permitting requirements) will not follow from a decision to co-fire PEF. In brief overview, utility and non-utility managers need to know whether any of the following potential regulatory consequences will flow from co-firing of PEF with coal or other fuels:

(1) If the source is not already a "major source" of CO, NO_x or VOCs, CAA permitting requirements as a major source will be triggered if

the increase pushes ***total*** emissions above the major source threshold (generally 100 tons/year).

(2) If the source is already a major source of CO, NO_x or VOCs, permitting as a "major modification" will be triggered if the ***increase*** in CO emissions is greater than 100 tons/year, or the ***increase*** in NO_x or VOCs is greater than 40 tons/year.

(3) If the increase in total particulates exceeds 25 tons/year or in PM_{10} exceeds 15 tons/year, the change in fuels would also trigger permitting requirements under the Prevention of Significant Deterioration ("PSD") program.

(4) If the source is not already a major source of HAPs, permitting as a major HAP source will be required if total HAP emissions exceed 25 tons/year or if emissions of any single HAP exceed 10 tons/year. This would trigger Title V Operating Permit requirements as well as potential application of Maximum Achievable Control Technology ("MACT") in the future.

(5) If the source is a major HAP source within any HAP source category listed by EPA, any change in operations which results in more than a "*de minimis*" increase in any HAP emission will trigger HAP permitting requirements.

A COMPREHENSIVE DATA BASE IS NEEDED

Obviously utility and non-utility managers alike need accurate data on which to base predictions of the emissions consequences of a change in fuels ***before*** they will be willing to experiment with an alternative fuel such as PEF. Even if the SO_2-emission-reduction-potential of PEF is manifest, if there is a risk of triggering New Source Review ("NSR") in nonattainment areas, PSD permitting or HAP permit requirements, managers of both major and non-major sources will be reluctant to consider co-firing of PEF with coal. Accordingly a comprehensive data base is needed to enable managers to accurately predict the regulatory consequences of a decision to co-fire PEF.

EPA CAN ELIMINATE UNCERTAINTY

EPA can be helpful in eliminating some of uncertainty regarding the potential consequences of co-firing PEF by clarifying both the application of its Title V Operating Permit rules to changes in fuels and by giving more guidance on what constitutes a "*de minimis*" increase in HAP emissions for purposes of HAP permitting requirements. In particular:

(1) EPA should exempt short-duration "test-burns" of PEF from its permitting requirements to enable the industry to gather the data needed to evaluate whether a broad exemption from permitting requirements is appropriate for switching to co-firing of PEF.

(2) EPA should expressly provide that a change in fuels to co-fire up to 30% PEF (made from non-hazardous materials separated or diverted

from MSW and/or from nonhazardous industrial waste or scrap materials) does not constitute a "modification" of a source requiring revisions to a source's Title V Operating Permit if the emissions levels remain within the source's "plantwide applicability limit" ("PAL").

(3) EPA should adopt the provisions of its August 31, 1995 Proposed Rule authorizing non-major sources of HAP emissions to be permitted as "synthetic minor sources" for purposes of the Operating Permit program. This would facilitate fuel-switching by non-major sources of HAPs by reducing the need for revisions to Operating Permits if small quantities of new HAPs are emitted as a consequence of the change in fuels.

(4) EPA should provide additional guidance concerning the "*de minimis*" rule for major HAP sources, especially as applied to changes in fuels.

SOLID WASTE DISPOSAL -- RCRA ISSUES

The RCRA/solid waste disposal issues associated with PEF are principally ash-related. Unless resolved, these issues threaten to limit the source of materials for production of PEF to ***industrial*** scrap and to foreclose utilization of materials separated or diverted from municipal solid waste ("MSW").

Currently, ash from combustion of coal is treated as a "Bevill waste." As such, coal-ash need not be tested for hazardousness and may be disposed in a landfill facility that does not meet RCRA Subtitle D MSW landfill specifications. Notwithstanding the

exemption of up to 30% co-fired PEF from MWC regulation under the CAA, the CAA exemption does not assure that the resulting ash will also be exempt from RCRA regulation as MWC-ash.

RCRA establishes criteria for "municipal solid waste landfills" ("MSW landfills"). These requirements make disposal of ash in a MSW landfill far more expensive. MSW landfills are those which receive "household waste." Household waste is, in turn, defined as "any solid waste . . . ***derived*** from households . . .." (Emphasis added.) The preambles to both EPA's proposed Subtitle D rules and to the final Subtitle D rules indicated that landfills which receive "MWC ash" (undefined) are regulated under Subtitle D as MSW landfills. If PEF is "derived" from MSW, *i.e.*, from household waste, an argument can be made ash from co-firing of PEF with coal would likewise be "derived" from MSW and, therefore, subject to EPA's requirement that such ash be disposed in a Subtitle D MSW landfill. Ironically, however, combustor ash from co-firing with coal of PEF *produced from industrial waste or scrap materials* is not subject to this same rule!

Whatever the merit for such a disposal requirement may be in the context of MWCs which mass-burn largely unprocessed MSW (including household waste that may contain batteries and small quantities of other hazardous household wastes), the same cannot be said for applying stringent Subtitle D regulation to ash generated by co-firing of PEF with coal ***where the PEF is manufactured from materials separated or diverted from MSW, in the course of which batteries and other hazardous materials have been removed from the PEF feedstock.*** This is especially true in light of the fact that ash from co-firing

with coal of PEF manufactured from industrial-sourced feedstock materials is exempt from the Subtitle D landfill requirement.

EPA NEEDS TO ADDRESS THIS INCONGRUOUS RESULT

EPA's RCRA rules have the potential for frustrating both the CAA's exemption from the MWC rules for combustors which co-fire up to 30% MSW, and the efficiency gains hoped to be achieved through trading of SO_2 emission allowances under the Acid Rain Program. Two alternative regulatory approaches could resolve this problem:

(1) EPA could recognize that PEF is a new product "manufactured" from MSW and, as such, is no longer "solid waste" even though "derived" from MSW. Broader policy-related concerns may foreclose this approach as a solution to the narrow issues presented by PEF-ash.

(2) Under the Boiler and Industrial Furnace Rule, EPA determined that hazardous wastes may be processed with Bevill raw materials in a smelter or other high temperature metal recovery device without disturbing the Bevill-exempt status of the resulting wastes as long as the hazardous waste content is less than 50% and the waste characteristics are similar to those exhibited by other typical Bevill wastes. 40 C.F.R. § 266.112. Using the Boiler and Industrial Furnace Rule as its precedent, EPA could rule that mixed PEF/coal-ash does not lose its Bevill-exempt status as long as the MSW component of the PEF co-fired

with coal is less than 30% of the total fuel combusted and the PEF itself is not more than 50% of the total fuel.

Clarification of the waste-treatment rules applicable to ash from co-firing of PEF with coal would greatly expand the available source materials for production of PEF, increasing potential output and potentially reducing costs.

INDUSTRY DATA AND SUPPORT IS NEEDED IF EPA IS TO ACT

The PEF industry could enhance the likelihood for favorable regulatory action by establishing standards for processing of household waste materials to produce PEF feedstock, e.g., by establishing criteria for removal of batteries and household hazardous wastes. The PEF industry could also promote favorable regulatory action by developing comprehensive data on the characteristics of ash from co-firing of PEF with coal. Without detailed data on the characteristics of the ash from co-firing of PEF with coal, and absent standards for removal of potential contaminants such as batteries and other hazardous wastes sometimes found in MSW, favorable regulatory action will remain problematic.

PUBLIC UTILITY REGULATORY POLICIES

Discussion of regulatory impediments to expansion of PEF too often tends to focus exclusively on ***environmental*** regulatory impediments. However, public utility regulatory policies play a critical role in whether the economic incentives sought to be created in the SO_2 emission allowance trading system will in fact encourage utilities to achieve compliance with the SO_2 emission reduction requirements of the Acid Rain

Program through co-firing of PEF or through reliance on purchase of SO_2 emission allowances.

The first several auctions of SO_2 emission allowances yielded prices far below those predicted by economists at the time the 1990 CAA Amendments were debated ($700 vs. $132-$159). These price levels reduce the likelihood of industrial sources "opting in" to the Acid Rain Program (if that was ever a realistic, if optimistic, possibility) for the purpose of achieving cost-effective SO_2 emission reductions, *e.g.*, through co-firing of PEF, that would generate potentially valuable, tradable SO_2 emission allowances. These price levels for SO_2 emission allowances also undermine the hope that revenue from trading of SO_2 emission allowances would help offset some of the cost of producing PEF.

The low level of demand for SO_2 emission allowances reflects utility bias toward capital-intensive solutions to environmental compliance that are encouraged, or perhaps even driven, by cost-recovery policies of state utility commissions.

State PUC cost recovery mechanisms generally permit utilities to include in their "cost of service," capital investments in environmental compliance technology such as scrubbers. Inclusion of such costs in the utility's "rate base" enables the utility to earn its authorized rate of return on these investments, just as if the investments were made in additional generation capacity. In an era of slow growth in demand for utility generation capacity, investments in capital-intensive "solutions" to environmental mandates become particularly attractive to utility managers. Moreover, utilities are generally allowed a passthrough of "prudently incurred" fuel costs. Accordingly, environmental compliance

strategies that might achieve fuel cost-savings (assuming that PEF can compete favorably with coal through cost-abatement associated with receipt of a tipping fee by the manufacturer of the PEF from the supplier of the MSW used as feedstock) are not favored by utility managers since any cost-saving will ultimately inure to the benefit of rate payers rather than shareholders. By contrast, a capital intensive solution that burdens rate payers with higher rates may nevertheless be favored because these higher rates benefit utility shareholders. While theoretically State PUCs may be capable of establishing safeguards against these types of perverse regulatory incentives, the reality is that such perverse incentives are endemic to the current U.S. regulatory model -- embedded cost-of-service ratemaking. Moreover, those who would challenge utility management decisions as imprudent typically face heavy procedural burdens and such challenges rarely succeed.

With respect to reliance upon SO_2 emission allowances as an acceptable Acid Rain compliance strategy, the interplay of the character of the allowances under federal law with state cost-recovery policies argues against reliance on emission allowances and in favor of capital-intensive solutions. Thus, under the CAA, SO_2 emission allowances are ***not*** "property." Congress chose to deny property-right status to these allowances in order to avoid Constitutional "takings" problems if EPA chose to discontinue the allowance trading program in the future. As Jan Johnston recently observed in *Regulation*, utility managers can either install costly pollution abatement equipment or gamble on the availability of SO_2 emission allowances to meet the utility's SO_2 emission target. While the first choice is "routinely approved" by state PUCs, the second choice

poses substantial economic risks to shareholders. If the allowance trading system is terminated or modified in a way that causes the price of SO_2 emission allowances to rise, utility commissions are likely to second guess the prudence of utility management decisions to rely on an untested and uncertain allowance trading system. On the other hand, if reliance of SO_2 emissions allowances ultimately save the utility money, there are currently few mechanisms to flow through such savings to shareholders. In a "heads -- the ratepayers win; tails -- the shareholders lose" regulatory environment, utility managers can be expected to pursue the conservative, capital-intensive alternative.

Additionally, State PUC review of the cost of SO_2 emission allowances contributes another potential regulatory uncertainty to discourage risk-averse utility management from considering the SO_2 emission allowance option. If public utility regulators second-guess the cost of SO_2 emission allowances or judge purchase costs against spot-market transactions, utility managers would be ill-advised to rely on SO_2 emission allowances as a long-term environmental compliance strategy option. As Professors Jaffe and Kalt stated in their 1993 study,

> If . . . PUCs do not permit the full scope of risk-shedding and risk-reducing transactions, or insist on always evaluating allowance trades for revenue purposes at then-current spot prices, the ability to mitigate allowance price risk will be destroyed, and the cost of achieving the policy objectives of the Clean Air Act will be increased.
>
> * * * * * * * *
>
> . . . The challenge of good public policy vis-a-vis the SO_2 allowance market is to lay in place incentives for utilities to aggressively participate in the buying and selling of allowances so as to minimize [the utilities'] costs of compliance with the Clean Air Act Amendments of 1990.

THE PEF INDUSTRY NEEDS TO BECOME ACTIVELY INVOLVED IN THE UTILITY-COST-RECOVERY POLICY DEBATE AT THE STATE LEVEL

The PEF industry needs to carry its message aggressively to State utility commissions if the industry desires for PEF to be preserved as an SO_2-emission-compliance option. The PEF industry needs a coordinated two-part program:

(1) to educate PUCs (and State legislators) of the cost-saving potential of co-firing of PEF and/or reliance on SO_2 emission allowances to achieve utility compliance with the SO_2 emission reduction targets of the Acid Rain Program; and

(2) working in conjunction with regulated utilities, to develop incentive ratemaking principles that will encourage utility managers to seek the most cost-effective environmental compliance option by permitting shareholders to participate in the savings achieved thereby, and by not exposing shareholders to unreasonable risks of second-guessing concerning the prudence of the costs of future compliance if the PUC has pre-approved the utility's compliance strategy.

The PEF industry can work with other stakeholders to implement these programs, including the National Association of Regulatory Utility Commissioners and electric utility industry trade associations. Other stakeholders with a similar interest include the natural gas industry which, although a competitor to PEF as a fuel for generation of electricity by utilities, is also interested in assuring that switching to cleaner burning fuels remains a viable option for utilities to achieve compliance with the SO_2 emission reduction targets of the Acid Rain Program.

This section includes notes and publications submitted by conference speakers . Brief summaries of each presentation can be found in Section 1: Overview and Outcomes.

OTTER TAIL COMANY

Presented by Dean Pawlowski, Plant Engineer, Otter Tail Power Company

IDAHO TEST BURN CENTER

Presented by Jim Hopla, Manager of Utilities, Lockheed-Martin Idaho Technologies

POSITIONING FUEL RECOVERY

Presented by Martin Frankhaeuser, Corporation Coordinator, Borealis Polymers, Poroo, Finland

RDF PELLET COFIRING EXPERIENCE AT OTTER TAIL POWER'S BIG STONE PLANT

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PO Box 218
Big Stone City, SD 57216

Abstract

The Big Stone Plant is a 440 MW single unit located in northeastern South Dakota. It is jointly owned by Otter Tail Power Co. of Fergus Falls, MN; Northwestern Public Service of Huron, SD; and Montana-Dakota Utilities of Bismarck, ND. The Plant is staffed and operated for the co-owners by Otter Tail Power Company. It has been burning RDF, Refused Derived Fuel, pellets for approximately 15 months with over 32,000 tons burned as of January 1, 1993. This paper addresses the results of a RDF/lignite cofire test conducted at the Big Stone Plant.

Plant Overview

Otter Tail Power Company has become active in burning alternative fuels. The company's alternative fuels policy states it "encourages the use of alternative fuels when the burning of such alternative fuels can be done as a way to both lower fuel costs and provide an environmentally acceptable disposal mechanism of the fuel in question."

The existing lignite handling, feeding and burning equipment at the Big Stone Plant has made it possible to cofire RDF and lignite on a small scale without plant modifications. The unloading system features a 3000 ton per hour rotary car dumper with associated conveyors that feed lignite to a 28,000 ton live storage building. The conveying system from live storage to the lignite silos was designed for a feed rate of 550 tons per hour.

RDF was handled in much the same manner as lignite except in the way it was delivered to the Plant. RDF arrived only by truck (approximately 20 tons/load). During the test the RDF was fed onto an auxiliary conveyor and mixed with lignite (being simultaneously fed from live storage) at the transfer house. The transfer house contains the yard hammermill crusher which reduced the coal down to three-quarter inch diameter. The RDF/lignite mixture then entered the boiler building on a single conveyor. Once in the boiler building the fuel mixture was dumped into twelve silos.

The coal feeding system at Big Stone is more complex than most coal-fired plants. This system employs a predry circuit designed to remove water in the 40 to 43 percent moisture laden lignite and is shown in Figure 1.

Big Stone's boiler is a B & W cyclone boiler. It has 12 cyclones and is rated at 3,250,000 lbs/hr at 2400/1000/1000 while burning 6200 btu/lb lignite. An electrostatic precipitator cleans the flue gas.

Coal Test Burn

The first day, October 26, strictly coal was burned. This data was used as a baseline. The test ran from 10:00 to 18:00 without any problems. One coal sample was taken for analysis between 10:00 and 13:00, Table 1.

Cofire Test Burn

The second day, October 27, was the cofire test. This test ran from 09:30 to 18:00. From 09:30 until 15:00 the fuel mixture was approximately 3% RDF/97% lignite. This was not the desired fuel mixture for the test. However, the fuel mixture averaged an estimated 12% RDF/ 88% lignite, by weight, from 15:00 to 18:00. The coal and RDF fuel analysis is shown in Table 1.

The main problem encountered during the test was contamination consisting of large unprocessed material in the RDF. This contaminated material plugged the yard crusher twice, causing an inconsistent fuel feed to the Plant. To get the yard crusher working, it was cleaned out by hand.

During the test several cyclones tripped off, attributed to an inconsistent feed rate of the RDF. This was caused by RDF building up on the sides of the silo. With the yard crusher plugged, the silos could not be kept full. As the silos emptied, large quantities of RDF released from the sides and became lodged in the discharge chute. Vibrators were used to get the silos flowing again. One slug of RDF made it to a rotary seal, causing it to trip. Operations reversed the direction to restart the rotary seal. Also, several feeders tripped on underweight because the fuel entering was mostly RDF and the lighter density caused problems. The problems with slugs of RDF cleared up after adding straight coal.

The fuel mixture 12% RDF/88% lignite would not have been a problem to burn. The problem was with the contamination causing an inconsistent fuel feed to the Plant. This is what caused the slugs of RDF to plug the equipment.

Problems Associated With Burning RDF For An Extend Period Of Time

The largest problem the Big Stone Plant has encountered burning RDF is with the housekeeping nuisance created by loose plastic. RDF contains some plastic which is freed when the RDF is dumped. This plastic becomes airborne and litters the Plant site.

During the initial stages, RDF was dumped on the ground and pushed in with a front end loader. The loader started to overheat after about two months due to RDF plugging the air side of the radiator.

Numerous problems have occurred as a result of this airborne plastic becoming entrained with the combustion air. The Unit's two forced draft fans pull in debris and distribute it to auxiliary equipment seal air lines which eventually become plugged. Also, some RDF is starting to collect on the air preheater coils in the forced draft fan ductwork.

Before the RDF makes it to the coal silo it has gone through the yard crusher and is broken up considerably. The dust collectors (which are big vacuums that remove airborne coal particles) collect loose plastic. Inside the collector is a catwalk for maintenance where the plastic collects and then bridges across to the wall. This problem was solved by removing the catwalks.

The material collected by the dust collector is dumped into two silos. These silos are more prone to having the discharge plug up. To prevent this from happening under controlled circumstances, operation's lowers the silos once a week.

Emissions and Boiler Performance

The boiler efficiency decreased from 80%, test 1, to 78.2%, test 2, attributed to the boiler upsets caused mainly by the fuel. Some of these upsets included: loss of cyclones, slugs of RDF, and different fuel mixtures. As can be seen in Figure 2, the fuel feed rate was not constant. Some possible reasons are slugs of RDF, inaccurate fuel analysis, and operational problems discussed above. These items also had a direct affect on boiler efficiency, see Figure 3.

The amount of SO_2 decreased 17% from test 1 to test 2 when measured in ppm on the dry base at 7% O_2. However, the sulfur in the coal changed from 0.96% to 0.76% by weight, a 21% change. This was not expected. The RDF had 4% lime added by weight to bind the pellet together and to reduce the amount of SO_2 and NOx emitted. Because the coal quality varied dramatically, no conclusions are possible about SO_2 or NOx reduction with the burning of the RDF pellets.

The opacity and carbon monoxide remained about the same from test 1 to test 2. The test to determine the amount of particulate emissions during test 2 was performed before the proper fuel mixture was burned. Therefore, no conclusion is possible on the amount of particulate emitted.

Bottom ash, economizer ash, and fly ash samples were collected and analyzed for trace metals. All the samples were found to be below TCLP Regulatory limits, Table 2.

Conclusion

The RDF pellet cofire test conducted at Big Stone Plant showed it is possible to burn RDF in a cyclone furnace. Some minor operational problems did occur as stated above.

One of the main reasons for conducting the test was to prove that burning RDF reduces the amount of stack emissions. However, no conclusion can be made on stack emissions. One of the reasons was the variability of the coal from test to test as shown in Table 1. Another problem was the correct fuel mixture being burned for only three hours during the cofire test. Therefore, only one set of data was used and some data was not taken. Also, during this test there were boiler upsets which could have affected the data.

The only items which can be concluded from this test is that RDF does not increase PCB's to a detectable amount and the ash is within TCLP leach test limits. It also showed that coal quality has a large effect on stack emissions, possibly a larger effect than does burning RDF pellets.

Acknowledgements

The RDF was supplied by EPR, Inc. of Eden Prairie, Minnesota and Waste Systems Inc. of Crestwood , Illinois. The coordination of the test was conducted by Oscar Ohlsson of Argonne National Laboratory. Stuart Schreurs coordinated the test for the Big Stone Plant. Dan Despen coordinated the testing for Interpol Laboratories.

Table 1

FUEL ANALYSIS

Ult. AR	100% Coal 10/26/92	100% Coal 10/27/92	100% RDF 10/27/92	12% RDF/88% Coal 10/27/92
MOISTURE %	40.73	40.73	18.8	38.10
SULFUR %	0.96	0.76	0.23	0.70
HEAT VALUE BTU/LB	6185	6228	5940	6193.44
METALS (ug/g)				
ANTIMONY	5.9	12	19	12.84
ARSENIC	3.63	4.3	0.19	3.81
BARIUM	1090	273	81.2	249.98
BERYLLIUM	0.98	0.66	0.19	0.60
CADMIUM	0.8	1.5	1.1	1.45
CHROMIUM	18	12	26	13.68
COPPER	29	15	132	29.04
LEAD	29	206	16	183.20
MERCURY	0.087	0.005	0.19	0.03
NICKEL	11	6	10.7	6.56
SELENIUM	0.4	0.23	0.095	0.21
SILVER	0.99	0.3	1.3	0.42
ZINC	23	107	190	116.96
TOTAL CHLORINE	0.008	0.005	2.16	0.26

Table 2

TCLP Leach Test

METALS	REGLA-TORY LIMITS mg/L	BOTTOM ASH 10/26 mg/L	BOTTOM ASH 10/27 mg/L	ECONOMIZER ASH 10/26 mg/L	ECONOMIZER ASH 10/27 mg/L	FLY ASH 10/26 mg/L	FLY ASH 10/27 mg/L
ARSENIC	5			0.19	0.22	0.14	0.104
BARIUM	100	4.73	2.88	0.508	0.364	0.96	1.14
CADMIUM	1						
CHROMIUM	5			0.022	0.02	0.18	0.349
LEAD	6	0.064	0.03	0.06	0.06		
MERCURY	0.2					0.00007	0.00007
SELENIUM	1					0.45	0.59
SILVER	5	0.02	0.02				

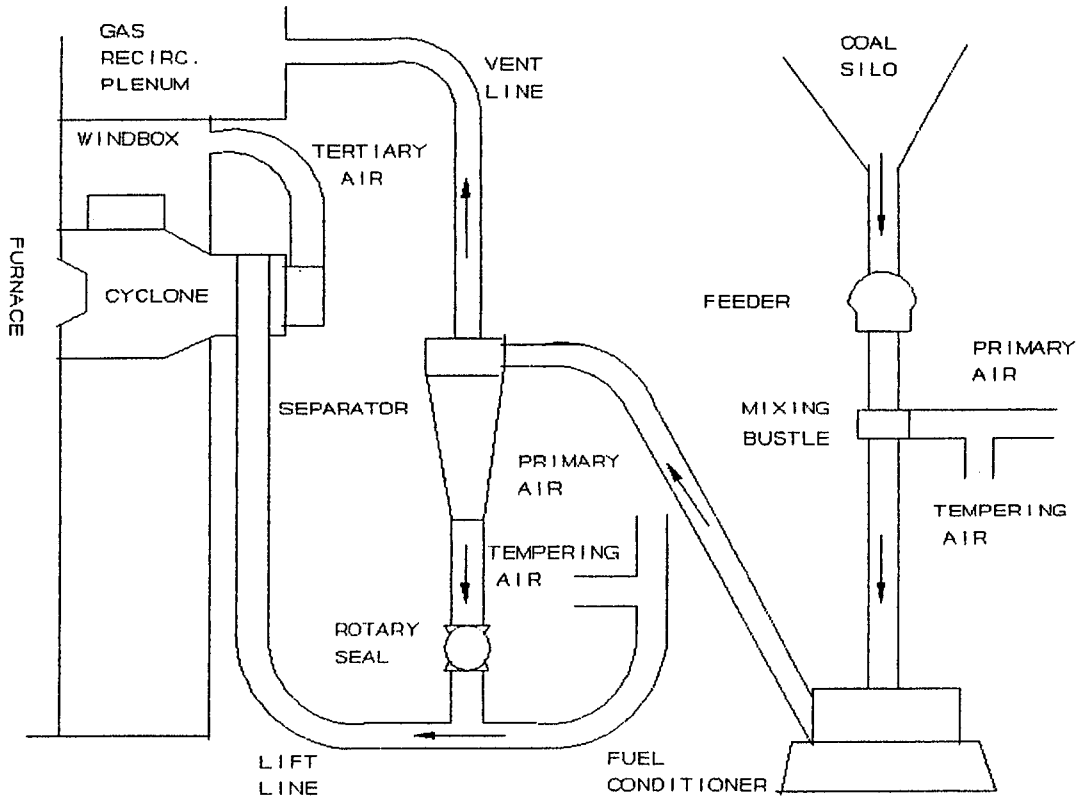

Figure 1

Coal Handling System

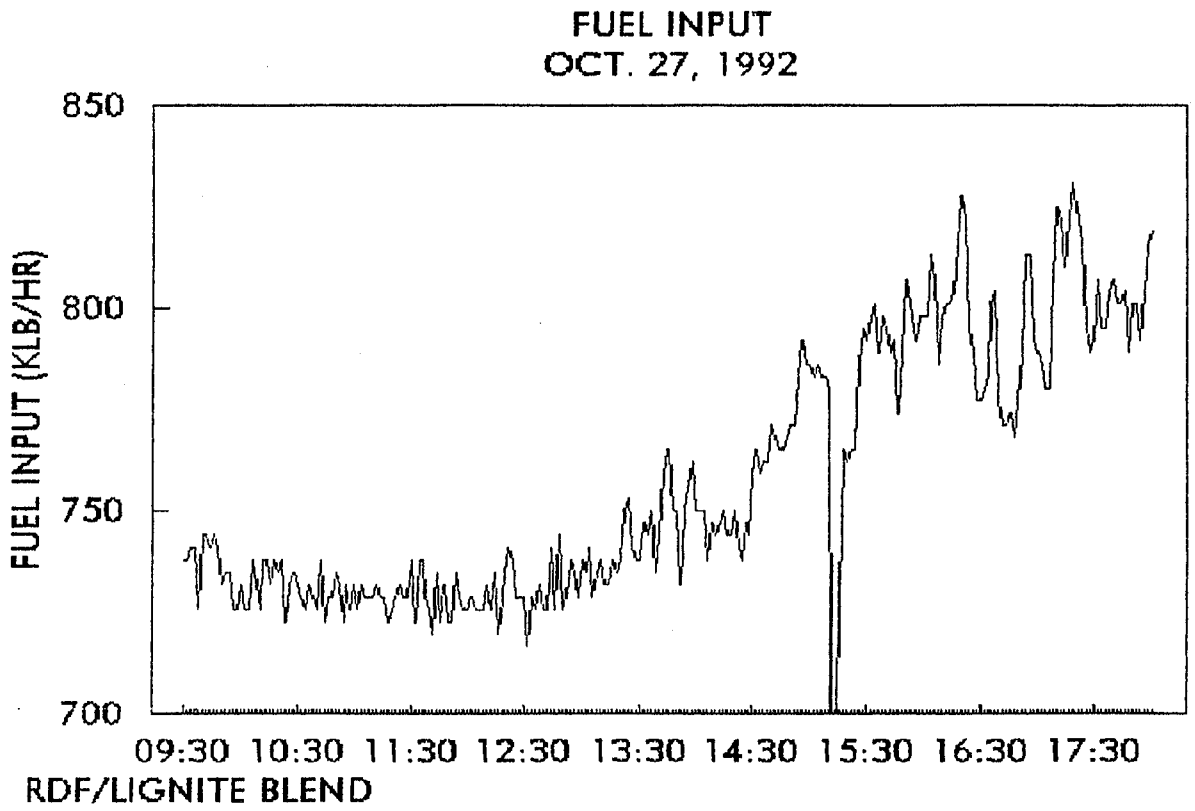
FUEL INPUT
OCT. 27, 1992
850
800
750
700
FUEL INPUT (KLB/HR)
09:30 10:30 11:30 12:30 13:30 14:30 15:30 16:30 17:30
RDF/LIGNITE BLEND

Figure 2

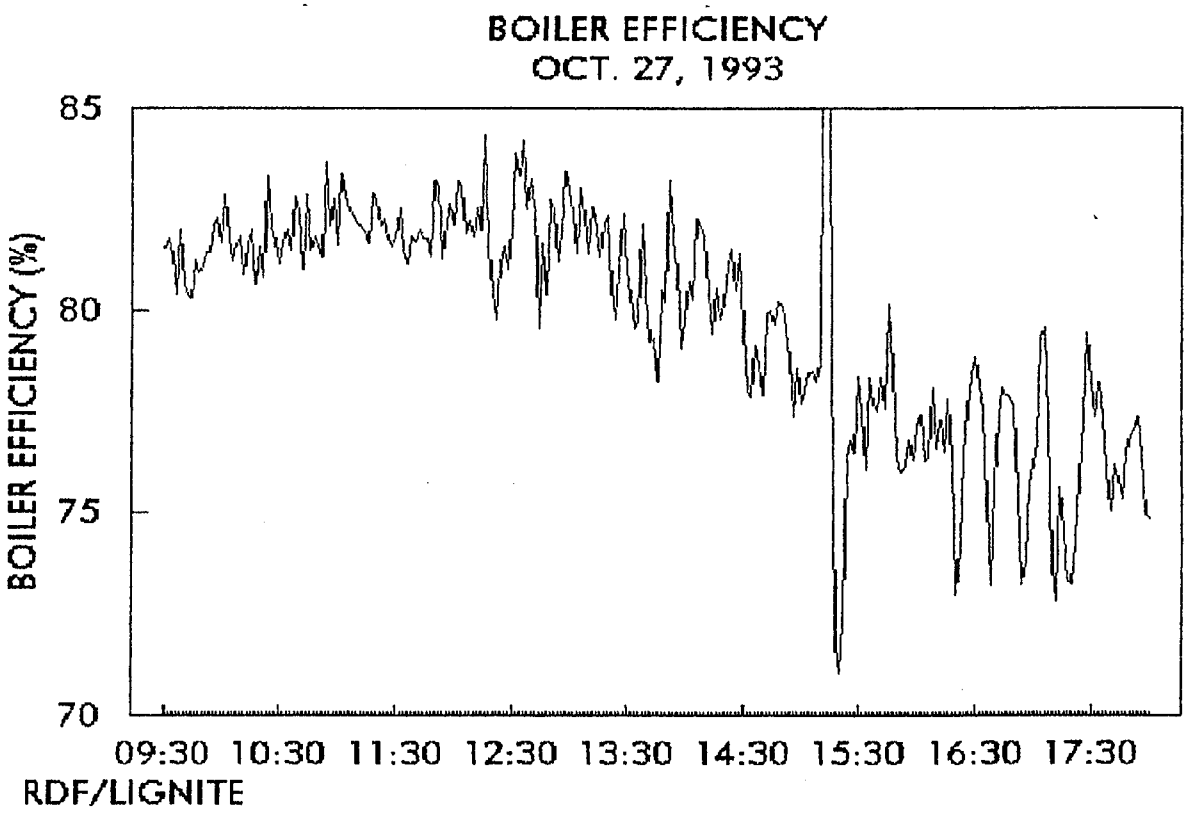
BOILER EFFICIENCY
OCT. 27, 1993
85
80
75
70
BOILER EFFICIENCY (%)
09:30 10:30 11:30 12:30 13:30 14:30 15:30 16:30 17:30
RDF/LIGNITE

Figure 3

RDF COFIRING EXPERIENCE AT OTTER TAIL POWER'S BIG STONE PLANT

PRESENTED BY:
DEAN PAWLOWSKI

BIG STONE PLANT FUELS

- PRIMARY FUEL
  - LIGNITE COAL
- ALTERATIVE FUELS
  - TIRE DERIVED FUEL
  - REFUSED DERIVED FUEL
  - WASTE TONER
  - AGRICULTURAL WASTE

ALTERNATIVE FUELS (TONS BURNED)

1990	2,713
1991	26,439
1992	58,160
1993	55,700
1994	55,000

ALTERNATIVE FUELS

- ENVIRONMENTALLY
- OPERATONALLY
- ECONOMICALLY

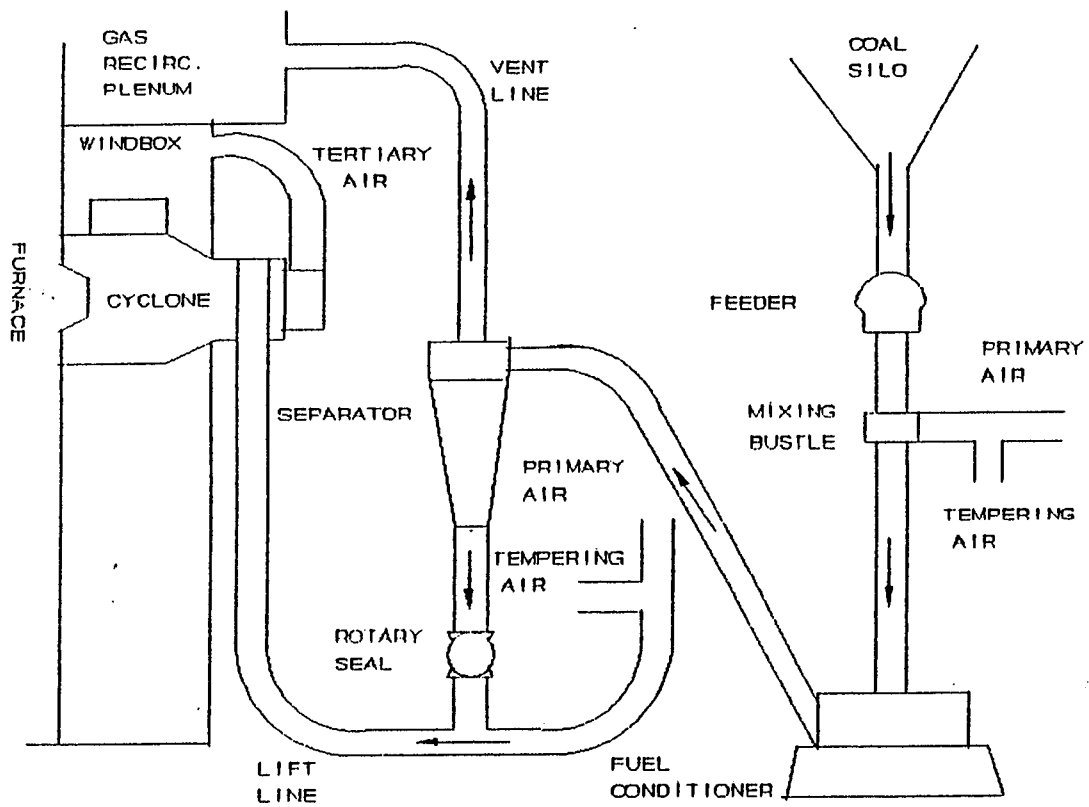

Figure 1

Coal Handling System

ACKNOWLEDGEMENTS

- EPR, INC
- WASTE SYSTEMS
- ARGONNE NATIONAL LABORATORY
  OSCAR OHLSSON
- INTERPOL LABORATORIES
  DAN DESPEN

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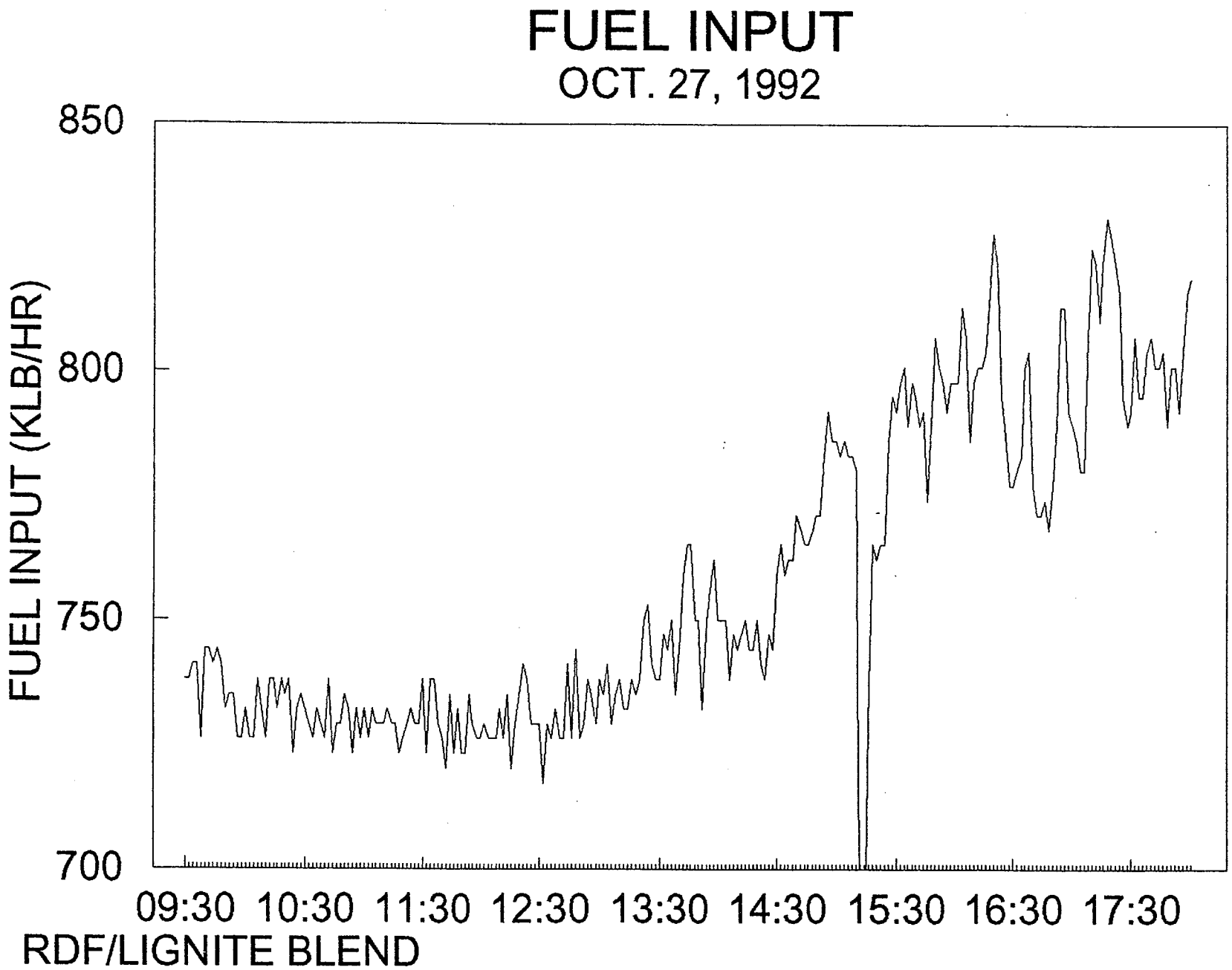
SILVER	0.99	0.3	1.3	0.42
ZINC	23	107	190	116.96
TOTAL CHLORINE	0.008	0.005	2.16	0.26

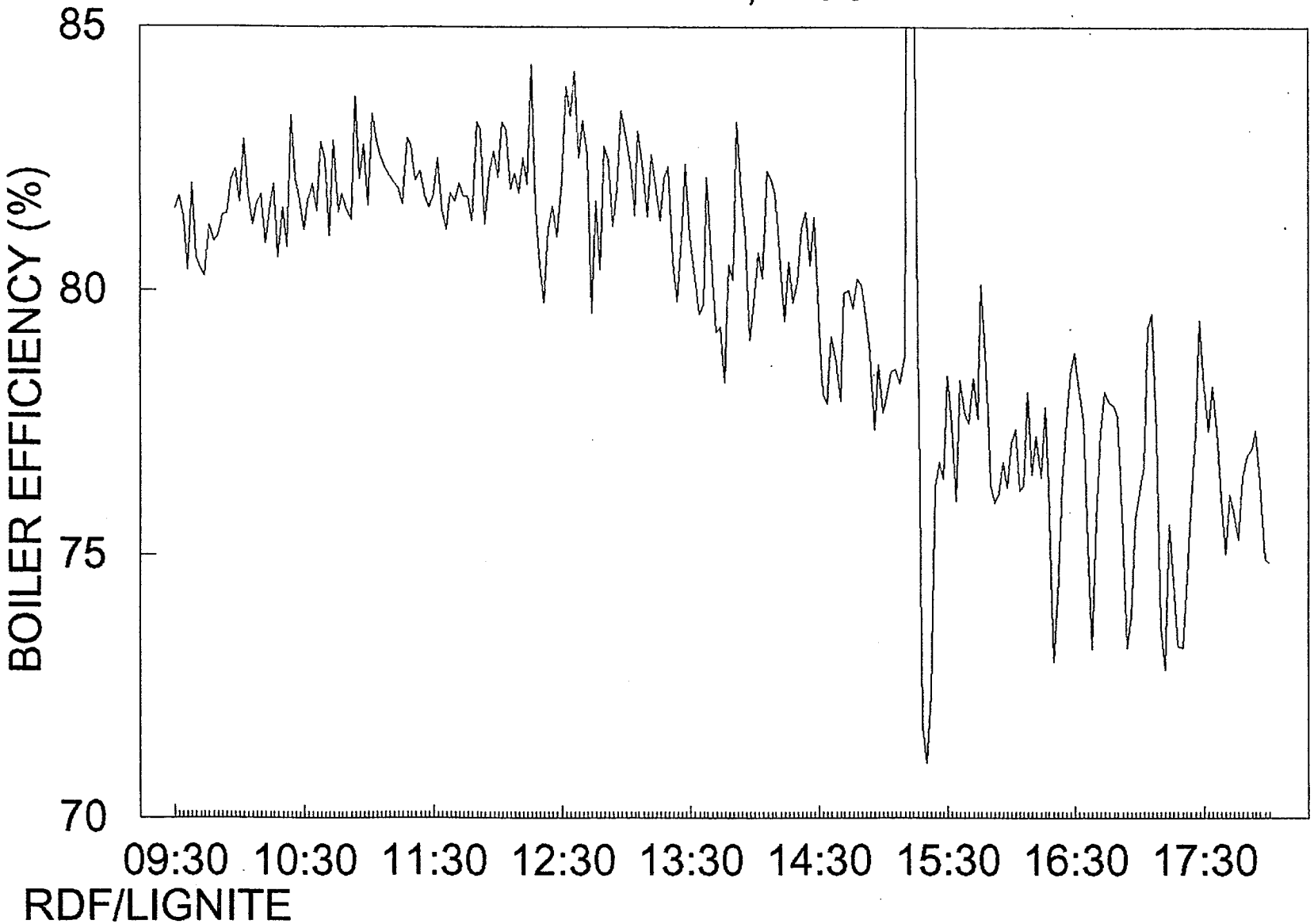
PROBLEMS ENCOUNTERED DURING TEST

- MAIN PROBLEM WAS CONTAMINATION
- PLUGGED YARD CRUSHERS
- PLUGGED COAL SILOS
- PLUGGED ROTARY SEALS
- UNDERWEIGHT TRIPS ON FEEDERS


FUEL INPUT
OCT. 27, 1992
850
800
750
700
FUEL INPUT (KLB/HR)
09:30
10:30
11:30
12:30
13:30
14:30
15:30
16:30
17:30
RDF/LIGNITE BLEND

BOILER EFFICIENCY

OCT. 27, 1992



TEST RESULTS

- DEREASE IN BOILER EFFICIENCY
- SO2 REDUCTION
- OPACITY REMAINED THE SAME
- INCREASE IN PARTICULATE EMITTED
- NO INCREASE IN PCB'S
- ASH SAMPLES BELOW TCLP LIMITS

PROBLEMS WITH BURNING RDF FOR AN EXTENDED PERIOD

- HOUSEKEEPING
- PLUGGED RADIATORS
- PLUGGED AUXILIARY AIR LINES
- COLLECTED ON AIR PREHEATER COILS
- BRIDGED ACROSS IN DUST COLLECTORS
- COLLECTED IN SILOS

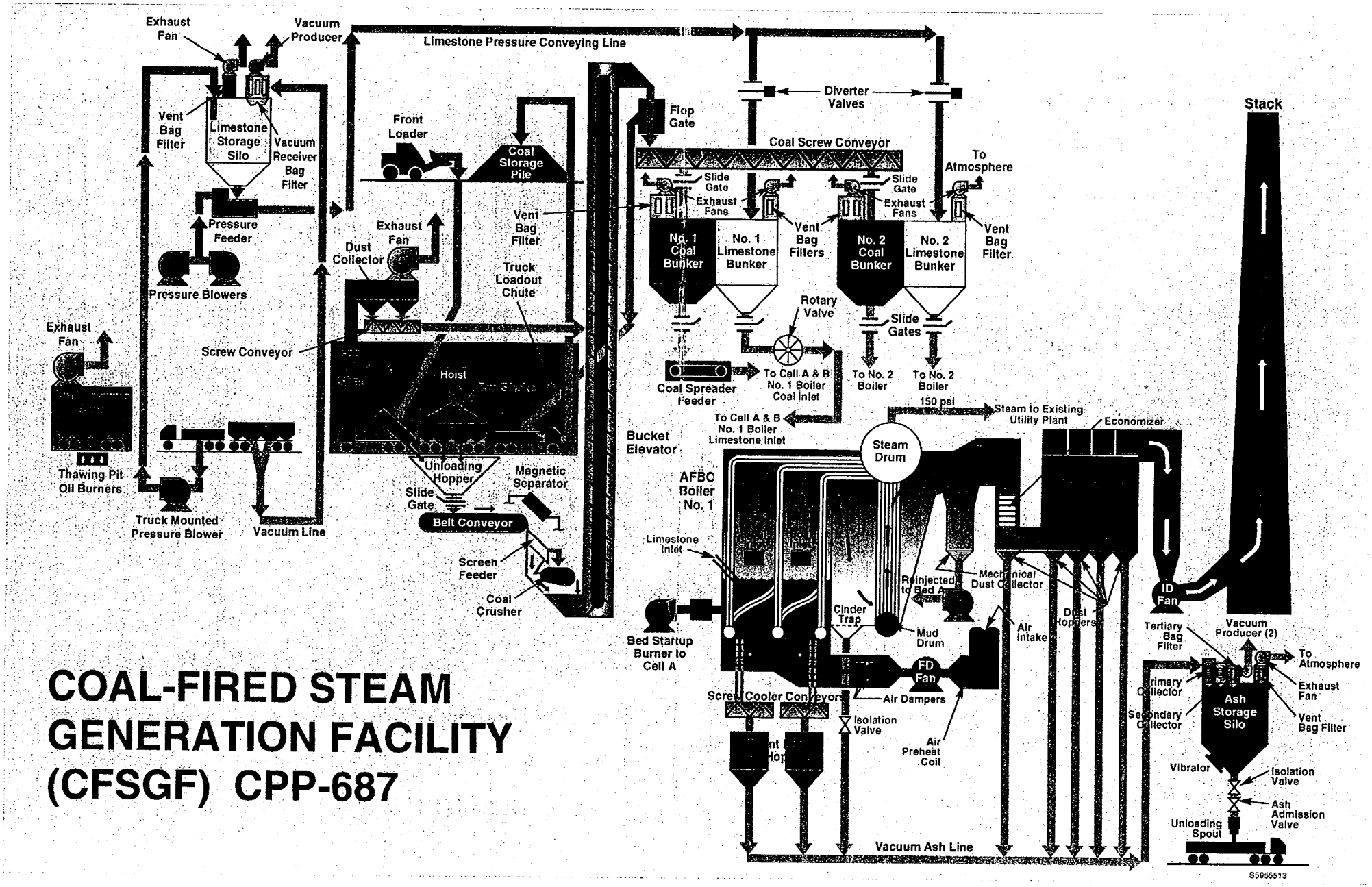
CONCLUSION

- RDF IS POSSIBLE TO BURN AT A PLANT
- IMPROVED EMISSIONS
- PCB'S DID NOT INCREASE
- ASH WITHIN TCLP LIMITS
- COAL QUALITY HAS A LARGE EFFECT ON EMISSIONS

Idaho Test Burn Center

Presented by:

Jim Hopla
Lockheed-Martin Idaho Technologies



COAL-FIRED STEAM GENERATION FACILITY (CFSGF) CPP-687

IDAHO NATIONAL ENGINEERING LABORATORY
WASTE TO ENERGY PROJECT

- Started with a question: "How come you folks are not pelletizing your cold waste and burning in your Coal Plant?

- Research

- America discards 100 million tons of paper products per year; only 28% is recycled; the rest of this valuable fuel is landfilled.

- Municiple Solid Waste Contents *(BTU Content)
  - *36% Paper
  - *20% Yard Wastes
  - *9% Plastics
  - 9% Food Wastes
  - 8% Metals
  - 7% Glass
  - *5% Rubber/Textiles
  - *4% Wood
  - 2% Misc

ICPP PAPER PELLET TEST BURN QUESTIONS, ISSUES

Test burn team: Company should assign the right people up front. Team should determine what assignments each person has. Environmental, legal, operations, projects, operations support, applied technology (tech transfer) at the minimum.

Locate and list pellet manufacturers; set pellet dimensions, pellet composition, find pellet cost and shipping cost.

Test burn program and procedures. What procedures are needed? Who will write them? USQs?

Pellet storage until test burn, assuring compatibility of pellets with classifier, bucket lift, screw auger, bins, boiler feed mechanism.

Method of pellet loading during test burn.

How to accurately load various percentages of pellets into the system?

Possible partners, how to locate them and secure their participation.

Legal agreements, what kind and with whom.

Combustion control and monitoring, emissions control and monitoring, all types of sampling (what kind, amount, frequency, and what to test samples for). Who samples and what is the cost? Who analyzes and what is the cost?

Training needed by operators, loader, maintenance personnel related to test burn. How much, who provides it, who pays for it, when scheduled, etc.

Internal interfaces, internal communications about the test burn; who, when, what, why, how, where.

- INEL Cold Waste Streams - (Possible 45% Reduction)
  - Average of 68,000 cubic yards per year
  - At 3 million dollars per year
  - Possible savings 1.2 million per year

- Advertised in the Commerce Business Daily for CRADA Partners.

- Partnered with NREL, R. W. Beck (Engineering), and Solid Waste Integrated Systems via CRADA

- The Coal Fired Steam Generating Facility (CFSGF), State of Idaho EPA Air Quality Permit changed to allow 30% feed of RDF.

CFSGF PAPER PELLET TEST BURN

Purpose:
Identify any operational problems associated with burning a 30% by wt. mixture of paper pellets and coal at the CFSGF.

Description:
The test burn will consist of operating on CFSGF boiler at a base load of 60,000 lbs/hr using a 10%, 20%, and 30% mixtures of paper pellets and coal. Each mixture will be burned for approximately 24 hours. 100% coal will be burned at the start of the test and between each paper burn to establish base line data and to allow for a clear separation between the paper burns.

Coal and paper pellets will be mixed in the yard area using the front end loader. The mixture will be sampled in the yard area and at the coal feed stokers to determine the actual feed ratio of Paper/Coal and to determine if any segregation of the paper and coal occurs in the material handling system.

Normal boiler operating data will be used to evaluate the test except for additional stack sampling for carbon monoxide and hydrocarbon emissions.

The test is expected to take one week to run and require 100 tons of paper pellets.

Expectations:

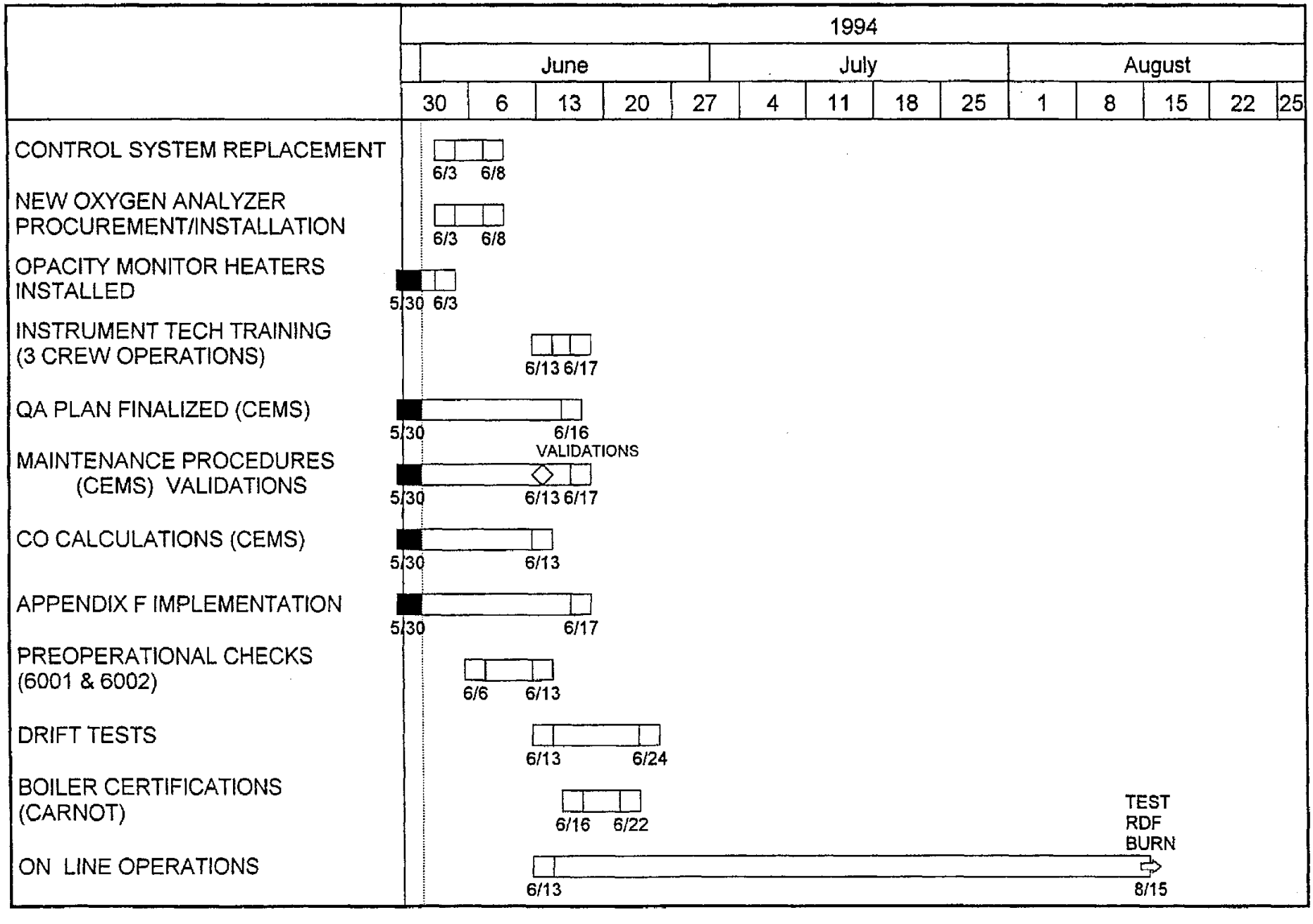
- Evaluate combustion performance of fluidized bed boiler.
- Emissions signature of fluidized bed boiler.
- Laboratory analysis of ash.
- Mechanical equipment to move coal, limestone and RDF.

- Test Burn conducted first week of March 1995.

- Test Burn showed its suitability to burn RDF
  - All emission signatures were lowered.

CFSGF RESTART SCHEDULE

5/31/1994



CFSGF PAPER PELLET TEST BURN

2/3/1995

ACTIVITY	Feb'95		Mar'95			
	27	28	1	2	3	4
PERFORM *RATA ON BOILER B-CFG-6001 WITH 100% COAL	2/27	2/28				
START TEST WITH90% COAL AND 10% PAPER FEED		2/28	3/1			
START TEST WITH 80% COAL AND 20% PAPER FEED			3/1	3/2		
START TEST WITH 75% COAL AND 25% PAPER FEED				3/2	3/3	
STARTUP BOILER B-CFG-6002 AND PERFORM *RATA					3/3	3/4
Continuous Emission Monitoring of SO2, NOx,CO AND 02	2/27					3/4
Grab Samples taken for HCL,Pb, Hg, Cd Total Mass	2/27					3/4

[redacted]

☆ Relative Accurrcy Test Audit

FUTURE PLANS

- Objectives
  - More efficiently produce steam.
  - Installation of equipment for burning RDF (feed systems)
  - Line up sources of RDF
  - Establish a test facility for DOE, NREL, and Private Sector test using RDF.
  - Convert to Co-Gen
  - Ash sales/uses at the INEL

BOREALIS

Third International Conference on
Combustion Technologies for a Clean Environment
3 - 6 July 1995
Lisbon, Portugal

"Integrated Solutions for Fuels Flexibility:
Combined Utilization of Coal/Biomass/Residues/Wastes Mixtures"
Organized by J.M. Bemtgen
European Commission, DG XII, Clean Coal Technology R&D

FUEL RECOVERY: VALORIZATION OF RDF AND PDF

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Abstract

Energy recovery of used materials can be performed as mixed municipal solid waste (MSW) incineration or as fuel recovery for co-combustion with conventional fuels. Recovered fuels are refuse derived fuel (RDF) which is mechanically separated and processed from MSW, as well as packaging derived fuel (PDF) which is the source separated, processed, dry combustible part of MSW.

A one year long co-combustion test of RDF with peat and coal has been carried out in a 65 MW CFB power plant in Kauttua, Finland. The efficiency of the combustion process and corrosion behaviour of the boiler were of particular interest in this study. Five different PDFs were also tested. A wide analytical programme was carried out including solid and gaseous emission measurements.

The results are encouraging, showing that RDF and PDFs are technically and economically feasible and environmentally friendly fuels for co-combustion. Low CO emissions showed clean and efficient combustion. SO_2 emissions decreased, because part of the coal was replaced by RDF and PDFs. HCl emissions increased when the chlorine content of the fuel mixture increased. Heavy metals were concentrated to the fly ash in unleachable form. PCDD/F (dioxin) emissions were at the normal power plant level and far below the strictest incineration limit.

Long-term co-combustion of 10 % RDF did not cause any high temperature chlorine corrosion of the superheater (500°C) of the boiler. Soot blowing sequences did not change and no fouling was detected.

The results show that it is useful, technically possible and environmentally friendly to combine resource and waste management in the form of fuel recovery for energy production in solid fuel fired power plants.

Introduction

A packaging system is designed for efficient distribution, protection of the packed product and for saving energy and other resources in the distribution chain. Light weight one-way packaging is often the best solution for long distance deliveries of consumer goods. "Source reduction" of packaging waste is a continuous process, because packaging materials are being constantly developed for strength and weight reduction. Short range distribution can utilize re-usable packaging, and industrial raw materials are increasingly transported in bulk without packaging.

Modern lightweight packaging materials are often difficult to recycle. The packaging itself has a high surface-to-weight ratio and used packaging is often contaminated with product residues. This makes separate collection and recycling costly and environmentally burdening. Energy recovery is therefore often the preferable recovery option for post consumer packaging waste.

In the combustion process, organic carbon (C) is oxidized to carbon dioxide (CO_2). The release of CO_2 from combustion for energy conversion is a much discussed issue. It is important to realise that a high energy conversion efficiency in any combustion process gives a low fuel consumption and consequently low CO_2 release per unit energy produced. One should also remember that organic carbon under anaerobic landfill conditions is converted to landfill gas, mainly methane (CH_4), which is considered a much more severe greenhouse gas compared to CO_2.

The nature of the released CO_2 is also debated. Carbon in wood based combustible materials is of recent origin and the use of these materials as fuel is therefore generally considered CO_2 neutral. This means that the released CO_2 will be assimilated by growing biomass within a reasonable time. The use of fossil fuels increases the content of CO_2 in the atmosphere.

Plastics are today mostly made of oil fractions which are less suitable for liquid fuel products. The production of plastics requires roughly the same amount of energy as contained in the oil fraction transformed to polymer. Plastics in packaging, automotive, construction, insulation, etc., however, during it's lifespan saves a many times greater amount of energy in the form of oil-based fuels, gasoline, diesel fuel and heating oil. The avoided fuel consumption due to use of plastics leads to a decreased extraction of crude oil and consequently to a decreased overall CO_2 release.

The use of modern lightweight packaging materials, paper, board, plastics and composites of these, is sustainable. Energy recovery of used combustible packaging is part of the larger system and it could be shown that net CO_2 release may even be negative when total system fuel consumption is taken into calculation, compared to a system using non-combustible packaging. This is, in most cases, also true when compared to open loop recycling of small post consumer packaging.

Source Separation for Fuel Recovery

Energy recovery from used products and packaging can be performed in two principally different ways. It is, however, common to consider only incineration of mixed municipal solid waste, when addressing the subject. This is often called Waste-To-Energy.

Energy recovery can also be realized as fuel recovery for co-combustion with conventional fuels. In this case, the recovered fuel is refuse derived fuel, or packaging derived fuel, (ref. CEN-CR 1460). RDF is mechanically separated from MSW. PDF is the source-separated, processed, dry combustible fraction, otherwise ending up in MSW. This solution is natural when the wet organic part of MSW is diverted to composting or anaerobic digestion for biogas production. The system is cost efficient compared to separate collection aimed at material recycling, because the yield per bin and collection trip is high. Fuel recovery has a low environmental impact because of the high collection efficiency and because of the high energy efficiency of conventional industrial boilers and utility plants.

Fuel recovery will contribute to resource conservation by substituting fossil fuels. Acceptable environmental standards for co-combustion can be based on proper sorting instructions, permitted fuel processing and maintaining or even improving the clean front end combustion of the boiler plant, meeting emission regulations set for the primary fuel of the plant. The scheme can be fulfilled under the concept of shared responsibility as suggested in the "Packaging Directive".

Full Scale Co-Combustion Test
Power Plant and Fuels

Combustion tests were carried out in a 65 MW Pyroflow CFB boiler in the Kauttua power plant in Finland in order to verify the technical and environmental aspects of fuel recycling. The unit consisted of a furnace, two hot cyclones, a 500°C, 84 bar steam boiler and electrostatic precipitators (ESP) for dust control. Fuels normally used in the plant include peat, wood waste, coal and mixed scrap from a paper mill and a packaging production plant. The boiler load consisted of steam provided to the two plants, heat supplied to the district heating network of the municipality of Kauttua and electricity for the grid.

Polish coal and milled peat are the primary fuels of the power plant. The following recovered fuels were tested.

PDF/LPB (liquid packaging board) - Separately collected post-consumer milk and juice cartons from Helsinki. The cartons were shredded to about half of their original size.

PDF/PE Separately collected post-consumer polyethylene bottles. The material contained mainly bottles and canisters from gasoline stations and households, but also some film material was included. The material was shredded to a 40 mm mean particle size.

PDF/PET One-way polyethylene terephthalate bottles from the soft drink industry. The material also contained polypropylene caps and it was shredded to a 10 mm mean particle size.

PDF/YTV The Helsinki Metropolitan Area Council operates a separate collection scheme for wet organic waste. Metals and glass were separated from the remaining dry fraction of MSW by hand. The fuel contained a large amount of organic components in spite of the separate collection scheme. The material was shredded to a 50 mm mean particle size.

PDF/Ekorosk Collected by the Ekorosk-company in Pietarsaari. The wet and dry fractions of MSW were source separated into black and white bags. Both bags were collected in a normal one-bin system by a compacting lorry. The bags were mechanically separated by colour in the Ekorosk plant. The dry fraction was baled, transported to Stormossen (see below) and shredded to a 50 mm mean particle size.

RDF/ASJ Mixed MSW was collected and processed in the Stormossen, Vaasa mechanical waste sorting plant, where metals, glass and organic components were separated out. RDF was shredded to a 50 mm mean particle size.

Test programme

The research project was divided into two parts: a one-year long-term study and two short-term emission measurement periods. The long-term study was carried out from September 1993 to July 1994. Primary fuels were peat, coal and wood and the secondary recovered fuel was RDF. Availability of the boiler, efficiency of the combustion process, and corrosion susceptibility of the super heater were of particular interest in this long-term study.

One-day combustion test runs for RDF and PDFs from different sources were carried out during the emission measurement campaigns. Gaseous and solid emissions were extensively analyzed. Continuous flue gas analyses and other samplings were performed by the Combustion and Thermal Engineering Laboratory of the Technical Research Centre of Finland (VTT Energy). The samples were analyzed by the Department of Environmental Sciences of the University of Kuopio (organic components), University of Jyväskylä, Outokumpu Oy, Hans Ahlström Laboratory and Neste Scientific Services. The first measurement period took place in November 1993 and the second one in April 1994. The test matrix is presented in Table 1.

Table 1. Test Matrix.

RUN	TIME	Secondary fuel	Amount %-thermal	Duration hours	Remarks
1	Nov/93	-	-	26	Peat+coal/ reference
2	Nov/93	PDF/LPB	13	24	
3	Nov/93	PDF/YTV	12	21	
4	Nov/93	RDF/ASJ	13	24	
5	April/94	PDF/PE	19	24	
6	April/94	PDF/PET	19	16	
7	April/94	PDF/Ekorosk	26	28	
8	April/94	RDF/ASJ	26	17	

PDF = Packaging Derived Fuel
RDF = Refuse Derived Fuel
LPB = Liquid Packaging Board
YTV = Helsinki Metropolitan Area Council
ASJ = Ab Avfallsservice Stormossen Jätehuolto Oy
PE = Polyethylene
PET = Polyethylene terephthalate

Peat and coal only were combusted for two days before the emission measurement campaigns. Test runs for each recycled fuel lasted 16-28 hours. The change-over to the new fuel mixture was made in the evening, the process was stabilized over night and the emissions sampling and on-line measurements started the next morning. The first run was a reference test employing peat, coal and wood waste as fuels.

Results

Long Term

Feeding and combustion of coarse, fluff RDF did not cause any drawbacks to the effective operation of the plant during the whole year of co-combustion. Visual inspections and wall thickness measurements of the boiler before and after the one-year co-combustion of 10 % RDF did not show any signs of abnormal corrosion of superheater (500°C) or boiler tubes. Corrosion probe tests (600 h) at 500°C and 550°C did not show corrosion or chlorine containing deposits.

Emissions

Heat value, moisture and ash contents of the tested PDFs and RDF were between the values of peat and coal. Sulphur and nitrogen contents of RDF and PDFs were lower and chlorine and certain heavy metal contents, especially chromium, copper, lead and zinc, were higher than the respective values of peat and coal. The basic analysis of the fuel mixtures are given in Table 2.

Table 2. Basic analyses of the fuel mixtures.

Run	1	2	5	6	3	7	4	8
Secondary fuel %-thermal	Ref	PDF LPB 13	PDF PE 19	PDF PET 19	PDF YTV 12	PDF Ekor 26	RDF ASJ 13	RDF ASJ 26
Moisture, wt-%	43.5	40.3	39.0	36.7	41.5	37.2	41.9	38.9
Volatile, wt-%	67.7	61.1	64.2	68.4	57.7	61.4	59.6	61.6
Ash, wt-%	5.8	6.1	5.8	4.7	8.2	8.5	7.8	9.1
HHV, MJ/kg	23.0	22.7	24.0	22.0	22.8	21.6	22.5	21.9
LHV, MJ/kg	21.8	21.5	22.6	20.7	21.6	20.3	21.3	20.6
C, wt-%	60.1	59.3	57.7	55.1	59.5	53.4	58.9	53.7
H, wt-%	5.5	5.6	6.7	6.1	5.4	6.0	5.5	6.0
N, wt-%	1.0	1.1	1.6	1.6	1.3	1.6	1.2	1.6
S, wt-%	0.37	0.36	0.35	0.27	0.40	0.36	0.37	0.37
O, wt-% (as difference)	27.2	27.5	27.7	32.1	25.1	29.9	26.1	29.0
Cl, wt-%	0.06	0.07	0.10	0.11	0.20	0.33	0.18	0.29
Cr, ppm	24	26	22	20	43	58	36	55
Cu, ppm	< 10	< 10	< 10	< 10	10	38	12	61
Ni, ppm	11	12	11	10	15	16	15	18
Pb, ppm	31	33	36	32	66	236	50	157
Zn, ppm	17	18	35	38	110	124	121	105
S/Cl_2,mol/mol	14	12	8	6	4	2	4	3

All results in dry solids

The feeding line limited the amount of secondary fuel to 25 % because of an increased number of CO peaks at higher rates, so the original goal of 30 % could not be reached. Operation at the upper limit caused uneven feeding and consequently somewhat unstable combustion conditions.

The basic level of carbon monoxide (CO) in flue gas (Table 3) was low (15-40 mg/m^{3}n) in all tests proving clean and efficient combustion. Operation near to the maximum capacity of PDF and RDF feeding line caused CO peaks increasing the mean CO level near to 200 mg/m^{3}n. Sulphur dioxide (SO_2) emissions were lower in co-combustions than in the reference test (560 mg/m^{3}n). Nitrogen oxide (NO_x) emissions were at the same level in all tests (below 200 mg/m^{3}n).

Hydrogen chloride (HCl) emissions increased from 20 mg/m^{3}n to about 150 mg/m^{3}n when the chlorine content of the fuel mixture increased. HCl emission results are mean values of three samples. The scatter was rather high, indicating the heterogeneous chlorine content of RDF/PDFs and somewhat unstable feeding. According to Cl-balance calculations, the HCl content in the flue gas should have been higher in tests with high contents of recycled fuel which, on the other hand, contained larger amounts of Ca which binds chlorine. HCl should not be a problem in a plant using desulphurization technology. HBr was not detected and HF values were very low.

Table 3. Flue gas analyses of the test runs.

Run	1	2	5	6	3	7	4	8
Secondary fuel %-thermal	Ref	PDF LPB 13	PDF PE 18	PDF PET 21	PDF YTV 12	PDF Ekor 26	RDF ASJ 13	RDF ASJ 26
H_2O, %	15.8	15.4	15.4	16.1	15.5	16.4	15.5	16.3
CO_2, %	12.2	12.8	12.2	13.7	12.6	12.8	12.2	12.3
CO, mg/m³n, mean value[1]	49	73	58	155	44	185	44	160
CO, mg/m³n, basic level[2]	40	35	15	30	25	35	30	30
CH_4, mg/m³n	2	4	6	16	2	20	2	19
SO_2, mg/m³n	560	520	450	460	550	480	520	480
NO_2, mg/m³n	170	180	180	180	200	150	190	160
N_2O, mg/m³n	ND	ND	ND	ND	ND	ND	ND	ND
Particles, mg/m³n	2	3	5	2	2	5	3	4
HCl, mg/m³n	17	40	34	30	154	140	60	120
HBr, mg/m³n	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5
HF, mg/m³n	0.5	0.8	0.3	0.4	1.2	0.4	0.5	0.3

Results corrected to 11 % O_2 dry gas [1] including peaks [2] basic level without peaks

Heavy metals did not volatilize into the gas phase, and due to the efficient dust separation by the ESP and consequently low outgoing dust load (5 mg/m³n), the total concentrations in the flue gas were well below present EC incineration limits.

Table 4. Heavy metals in flue gas

Run	1	2	5	6	3	7	4	8
Secondary fuel %-thermal	Ref	PDF LPB 13	PDF PE 18	PDF PET 21	PDF YTV 12	PDF Ekor 26	RDF ASJ 13	RDF ASJ 26
Hg, µg/m³n	<1	<1	<1	<1	<1	<1	<1	<1
Cd, µg/m³n	1	<1	<1	<1	<1	<1	<1	<1
Ni+As, mg/m³n	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr+Cu+Mn+Pb mg/m³n	1.61	0.74	0.20	0.08	0.06	0.12	0.17	0.13

Fly ash (Table 5) showed enriched amounts of heavy metals. The EPA-TCLP tests showed no adverse leaching of these elements, and the ashes can be disposed of in normal landfills.

Table 5. Fly ash analyses.

Run	1	2	5	6	3	7	4	8
Secondary fuel %-thermal	Ref	PDF LPB 13	PDF PE 19	PDF PET 19	PDF YTV 12	PDF Ekor 26	RDF ASJ 13	RDF ASJ 26
Main components	%	%	%	%	%	%	%	%
C[1]	15.0	12.2	7.2	7.7	12.2	5.9	6.1	4.8
H[1]	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
N[1]	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.2
S[1]	1.0	0.8	0.7	0.7	1.0	1.1	1.0	1.2
Cl[2]	0.02	0.01	0.07	0.05	0.03	0.38	0.12	0.22
Al	9.75	11.1	9.47	9.48	10.6	11.2	11.3	11.0
Ca[2]	4.42	4.52	6.49	6.19	4.85	8.53	6.40	7.91
Fe	6.50	6.30	10.2	10.9	6.15	8.22	6.20	8.57
K	2.05	2.06	1.49	1.42	1.97	1.80	2.07	1.81
Mg	1.63	1.68	1.89	1.76	1.62	1.94	1.76	1.79
Na	0.64	0.70	0.51	0.47	0.76	1.12	1.12	1.21
P	0.29	0.30	1.01	1.07	0.34	0.94	0.58	0.93
Si	17.8	18.5	16.6	16.4	18.5	14.9	18.8	16.4
Ti	0.45	0.48	0.61	0.57	0.50	0.85	0.64	0.70
S/Cl_2, mol/mol	141	151	22	31	85	7	18	12

[1] by Leco analyzer [2] by chemical methods All other by XRF

The emissions of PCDD/Fs, "dioxins" (Table 6), were far below the strictest incineration regulation limit 0.1 mg/m^{3}n I-TEQ in all tests. The dioxin values were close to the detection limit in most cases, but increased slightly at higher contents (26 %) of PDF and RDF. Increased frequency of CO peaks because of mechanical problems, increased chlorine content of the fuel mixture, decreased sulphur to chlorine ratio and most significantly increased content of heavy metals like copper and lead in the fly ash are the probable reasons for the increase.

Table 6 Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs)

Run	1	2	5	6	3	7	4	8
Secondary fuel % thermal	Ref.	PDF LPB 13	PDF PE 19	PDF PET 19	PDF YTV 12	PDF Ekor 26	RDF ASJ 13	RDF ASJ 26
PCDD/Fs								
Actual concentrations								
Flue gas, ng/m³n	<0,01	<0,01	0,19	0,06	0,09	31,7	0,16	1,87
Fly ash, ng/g	0,85	0,31	1,94	1,11	1,17	38,3	0,96	18,4
I-TE								
Flue gas, ng/m³n	<0,01	<0,01	0,02	<0,01	<0,01	0,02	<0,01	0,04
Fly ash, ng/g	0,01	0,01	0,06	0,06	0,01	0,77	0,01	0,37

Conclusions

The test programme was the third full scale co-combustion test co-financed by the Finnish Ministry of Trade and Industry through its LIEKKI combustion research programme and by the industry. All tests with scrap and real waste, RDF and PDF, at a co-combustion rate of around 20 % together with coal containing primary fuel have shown good combustion efficiency, sufficient heavy metals capture in fly ash and PCDD/F emissions clearly below the strictest suggested incineration regulation. This test has also shown the long term technical feasibility of co-combustion in a CFB system. It is important that the recovered fuel is processed to a physical form compatible with the primary fuel and fuel feeding system of the plant in order to accomplish a steady combustion without CO-peaking. The results indicate that fuel recovery is a valuable alternative for resource management complementing biological treatment of the wet organic fraction of MSW and separate collection for recycling materials to products with a real market value.

The results show that used packaging contain higher amounts of certain heavy metals than conventional fuels. These metals mostly do not play a functional role in the packaging material itself but come form colouring pigments and printing inks. Although it is shown that these metals are efficiently concentrated to ash and filter residues it can be concluded that a consumer driven reduction of excessive "cosmetics" could even further decrease the environmental impact of all resource and waste management routes.

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Laboratory scale characterisation of plastic-derived fuels

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ABSTRACT

In this project the combustion and gasification behaviour of the most common plastics is studied and compared with the performance of conventional fuels such as coal, peat and wood. The aim is to give background data for finding the optimum conditions for co-combustion or co-gasification of a conventional fuel with a certain amount of plastic-derived fuel. Atmospheric or pressurised fluidised bed co-combustion of conventional fuels and plastics are regarded as a possible future application.

The plastics that were investigated in this study were poly(ethylene) (PE), poly(propylene) (PP), poly(styrene) (PS) and poly(vinyl chloride) (PVC), with some of the samples having a print or colour. The reference fuels were Polish bituminous coal, Finnish peat and Finnish pine wood. In the first series of tests the time scales of atmospheric combustion were determined using video recordings of the combustion process of small samples at various temperatures and oxygen partial pressures. In the second set of tests a sample was pyrolysed at atmospheric pressure in nitrogen at various holding times and temperatures. From this data the char yields were obtained. The third set of experiments were done in a pressurised thermogravimetric reactor (P-TGR), where the samples were gasified at typical gasifier conditions. Results from atmospheric and pressurised tests were compared. Chemical and proximate analyses were made of the plastics and reference fuels and their chars and ashes.

PE, PP and PS were found to burn like oil. The particles shrank to a droplet and burned completely during the pyrolysis stage, leaving no char. Printing and colouring left a small portion of ash. PVC was the only plastic that produced a char and its timescales for heating, devolatilisation and char burning were of the same order as those for peat and wood, being much shorter for the other plastics studied. An important result is that char from PVC contains less than 1% chlorine, being 99% hydro-carbon. The gasification rate of PVC char (at 1 bar and 25 bar) was of the same order as that of char from coal. Peat-char and wood-char were gasified one order of magnitude faster.

1. INTRODUCTION

In Western Europe 6 - 10% of the municipal waste is composed of plastics (9.3 million tonnes in 1992) which for the largest part (72%) is disposed of by landfill. In Finland the annual yield of plastics in municipal waste is 6%, which equates to 90000 tonnes (APME, 1994). Increased environmental consideration and stricter regulation during the latest years is resulting in efforts towards the reduction of landfill disposal of plastic waste and an increased recycling or recovery.

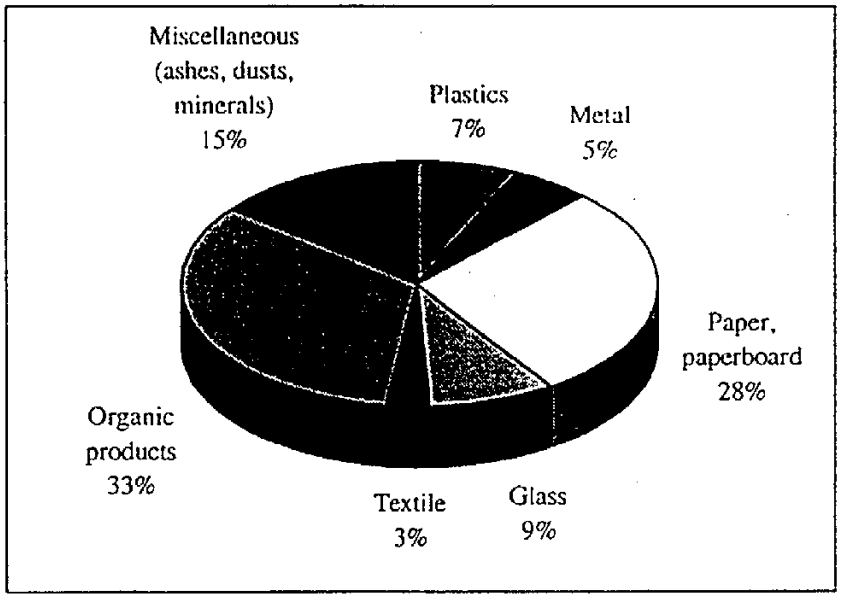


Figure 1 The composition of municipal waste in Western Europe, 1992. Data from APME (1994).

Recovery of resources contained in plastics waste can be separated into product recycling (*e.g.* plastic bottles), material recycling (in the form of plastic particles), feedstock recycling (depolymerisation intermediates or monomers) or energy recovery. Energy recovery is standard procedure in municipal waste incineration, older incinerators are facing operational problems on increasing plastic content in MSW (municipal solid waste). Reasons for this are the high caloric value of plastics (of the order of 40 MJ/kg) which reduces throughput in a heat restricted conventional waste incinerator (Mosbacher, 1989). Therefore, there is increasing interest in methods where plastic waste is separated from the municipal waste and is added as a prepared fuel (up to 30%) to the solid fuels that are burnt in power plants for thermal power and electricity production.

The composition of municipal waste in Western Europe (in 1992) is given in Figure 1 and can be separated into 3 parts: an organic fraction that can be composted, a combustible fraction mainly composed of plastics and paper, and a non-combustible fraction of metals, minerals etc. Depending on the separation method the combustible fraction is referred to as either RDF (refuse derived fuel) or PDF (packaging derived fuel). RDF is municipal waste from which organic waste and non-combustible material has been separated, and PDF is obtained from the separated collection of combustible waste, being mainly paper and plastic packaging. Due to their caloric value both RDF and PDF must be considered as high-grade fuels, although the technologies for optimal large scale combustion or gasification still need

basic research directed towards thermal efficiency of the system, operational problems and pollutants emission control.

The present work gives the result of a laboratory study in which the most commonly encountered plastics are characterised with respect to their behaviour during pyrolysis, gasification and combustion, in comparison with conventional fuels such as wood, peat and coal. Considering the distribution of the consumption of base plastics in Western Europe in 1992, given in Figure 2, it was decided to consider the plastics poly (ethylene), poly (propylene), poly (styrene) and poly (vinyl chloride). Throughout the following text these will be referred to by their abbreviations PE, PP, PS and PVC, respectively.

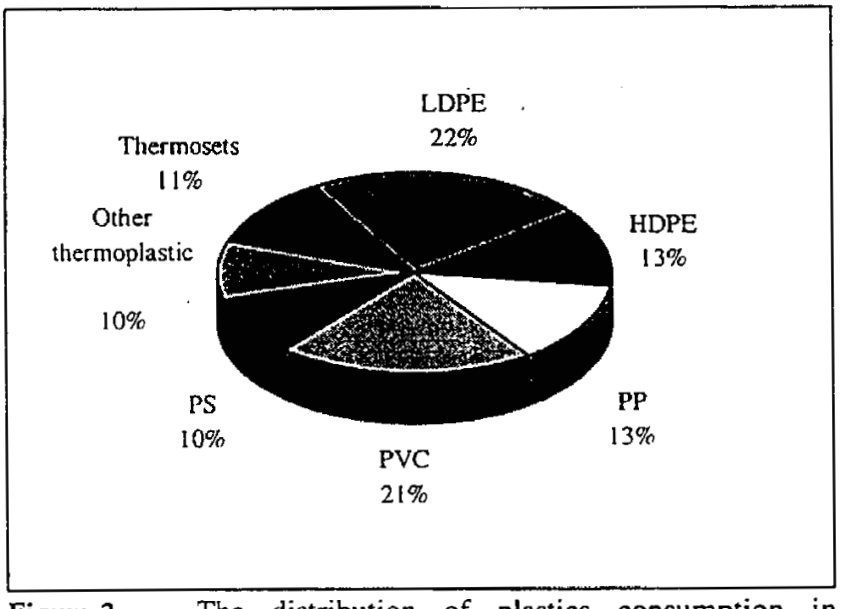


Figure 2 The distribution of plastics consumption in Western Europe, 1992. Data from APME (1994)

There where two major objectives for this work : the first objective was to verify if the test methods for fuel characterisation used in our laboratory were suitable for plastic fuels. The second objective was to obtain quantitative data to be used in assessing the possibilities for and consequences of co-combustion or co-gasification of plastics waste with peat, wood or coal. More specifically, atmospheric or pressurised fluidised bed combustion or gasification was considered to be the major application, which explains why experimental conditions chosen here correspond to these systems: temperatures 750-950°C, pressure up to 25 bar and heating rates of the order of 100-1000 K/s.

2. LITERATURE REVIEW

The goal of the major part of the work reported in literature on the thermal decomposition of plastics so far was to retrieve monomers or other valuable products through thermal processes in various types of reactors. In that work the temperature levels and heating rates were generally lower than in combustion systems (Kaminsky, 1992; Darivakis *et al.*, 1990; Scott *et al.*, 1993; Redepenning, 1994).

Mechanisms for thermal decomposition of plastics and pyrolysis product compositions have been given by Cullis and Hirschler (1981). The pyrolysis of PE gives alkanes and alkenes, whilst PP gives a very small amount of its monomer during pyrolysis. PS yields more than 50% styrene during pyrolysis, together with its dimers and trimers. The pyrolysis of PVC, gives HCl, aromatic hydrocarbons (*e.g.* benzene) and a considerable amount of char. Kaminsky found up to 56% HCl and 9% solid char residue resulting from pyrolysis of PVC in a fluidised bed at 740°C (Kaminsky, 1992). Under the same conditions PS gave 65% styrene and 0.6% solid residue, for PE and PP the solid residues found were 1.8% and 1.6% of the initial mass, respectively. Darivakis *et al.* pyrolysed PE and PS samples at a heating rate of 1000 K/s and report a complete pyrolysis without solid residue for final temperatures higher than 700°C (Darivakis *et al.*, 1990).

McGhee *et al.* (1995) gave a very simple model for the pyrolysis of municipal waste on the basis of co-pyrolysis tests with PVC and cellulose-based material. At the same time it was concluded that co-pyrolysis gives an increased amount of solid char residue with a lower reactivity as compared to the char residue of the separate materials. Typical product compositions for the complete combustion of PE, PP, PS and PVC were given by Elomaa (1991): carbon dioxide and water plus HCl for the PVC. Moreover, PS and PVC showed a considerable tendency to form soot during burning.

Panagiotou and Levendis (1994) investigated the combustion properties of PS, PVC, PE and PP. Spherical particles with a size from 53 to 300 μm were burnt at 930 - 1230°C in 21%, 50% and 100% oxygen in an atmospheric drop-tube furnace with a laminar flow. The progress of the combustion process, the flame temperature and the particle diameter was measured. It was found the time required for combustion was comparable to that of an equally sized droplet of light oil. PVC and PS burned with a luminous yellow flame, giving a lot of soot. PVC was reported to give the shortest time for combustion. PE and PP appeared to burn at a slower rate with a less clear flame.

Frankenhaeuser *et al.* (1993) investigated the co-combustion of PDF and RDF with coal, peat and wood in a full-scale circulating fluidised bed combustor (65 MW_{th}). The tests showed no significant harmful side-effects with respect to pollution as compared to firing with conventional fuel. Emissions (less than 500 mg SO_2/m^3_{STP} and less than 200 mg NO_2/m^3_{STP}) were of the same level as obtained from conventional fuels although HCl emissions increased with increasing chloride content in the fuel mixture. It was also found that the emissions of poly-chlorinated di-benso-p-dioxines and di-benso-furanes (PCDD/F) did not correlate noticeably with the chloride content of the fuel mixture, but were more related to the combustion process conditions. Fuel sulphur appeared to have a clear reducing effect on PCDD/F emissions. The same was found when limestone was added to the bed for the capture of SO_2 and HCl (see also Kojo, 1992), giving increased PCDD/F concentrations in the ash. No increased levels in corrosion were found (Frankenhaeuser *et al.*, 1995).

The gasification of municipal waste in a fluidised bed was investigated by (among others) Czernik *et al.* (1994). In an atmospheric fluidised bed wood waste and wood waste containing 10% PE and RDF was gasified at 50 kg/h. The facility operated satisfactorily at 700-850°C, producing 1.7-2.4 m^3_{STP} dry gas per kg dry solids, at a caloric value of 5.2-8.2 MJ/m^3_{STP}.

3. EXPERIMENTAL PROCEDURES

3.1 The equipment and procedure

For this study three different experimental devices were used :

1. An atmospheric pressure, electrically heated laboratory furnace (Multitherm® N7) suitable for temperatures up to 1260°C, with an internal volume of 7 liters. PtRh / Pt thermocouples were used for temperature measurement and control. The gas flow through the furnace was 100 or 200 $liters_{STP}/h$. Samples were fed to the furnace from the top as a single particle or as stainless steel sample holder filled with material. Through a quartz window the progress of the conversion process was recorded on VHS video tape. From these recordings the times to ignition, the duration of the pyrolysis (*i.e.* volatiles burning) and the duration of char burning was determined as a function of temperature (750°C, 850°C, 950°C), oxygen content (0%, 2%, 7% and 12% O_2) and sample mass (30 to 70 mg). The test facility is illustrated by Figure 3.

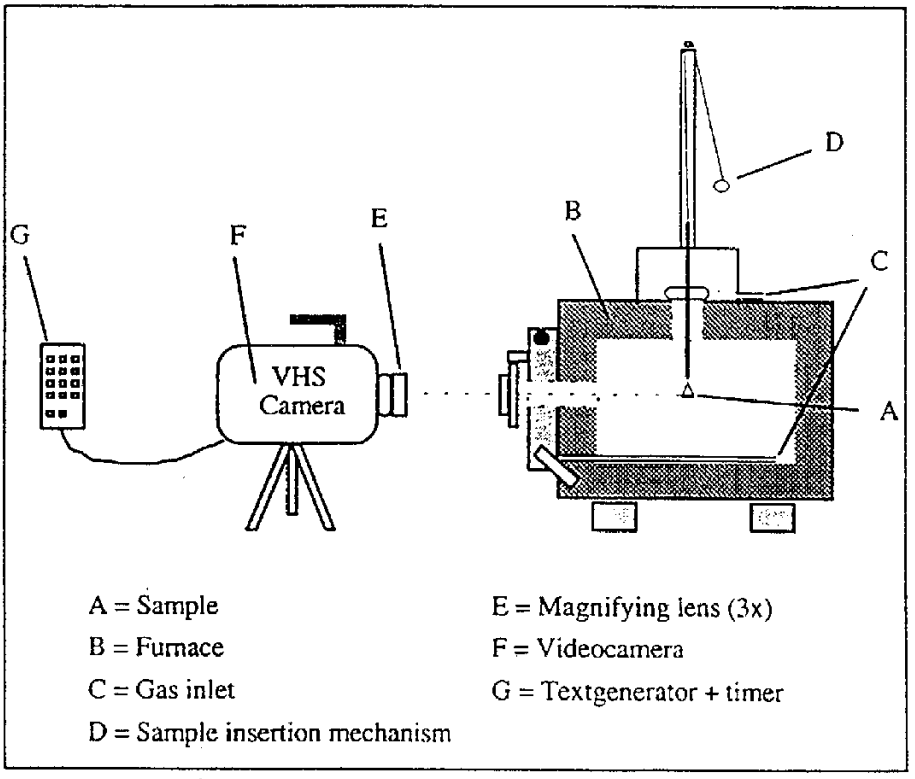


Figure 3 The experimental set-up for the video recordings

2. An atmospheric pressure laboratory reactor designed at our laboratory, which is composed of a quartz tube (length 600 mm, diameter 25 mm) and an electrically heated furnace (Figure 4). The gas flow used here was 100 $liters_{STP}/h$, which corresponds to a flow velocity of approx. 0.2 m/s. An option for this facility that has not been used here is to analyse the exhaust gases with respect to CO_2 + CO, $NO+NH_3$ and SO_2. In this device dried samples (30-80 mg) were lowered into a nitrogen purge and taken out after 15 sec. From the mass change the char + ash (%) yield was determined, furthermore some of the chars were submitted to chemical analysis. Tests were done at 750°C, 850°C and 950 °C.

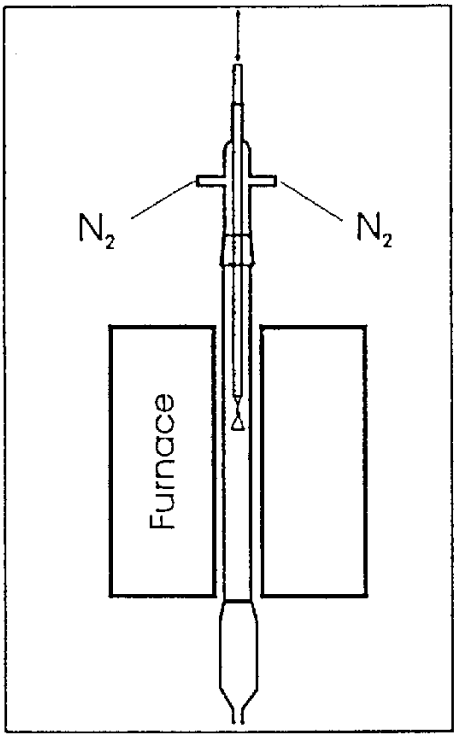


Figure 4 The pyrolysis reactor

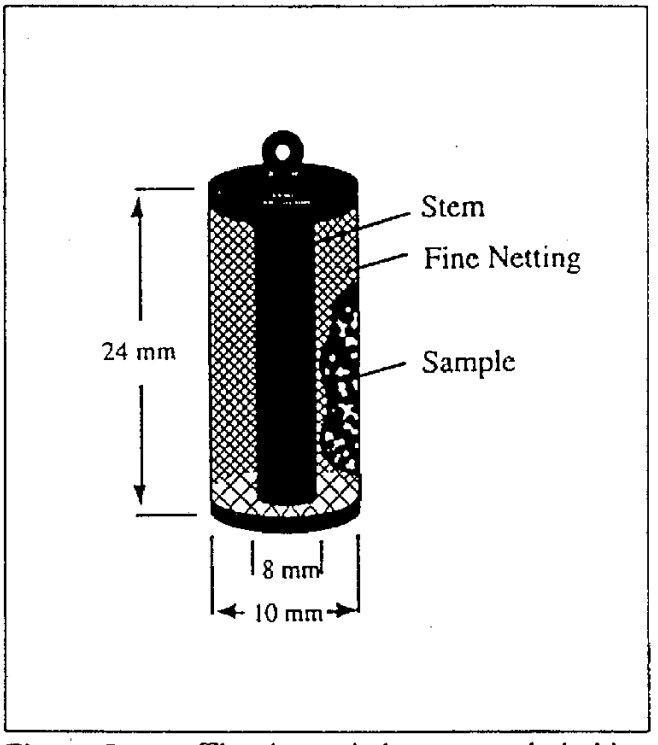


Figure 5 The thermobalance sample holder

3. A pressurised thermogravimetric reactor (P-TGR) , see Figure 6, that can be used for temperatures and pressures up to 1100°C and 100 bar. Four gases plus steam and a purge gas can be fed to the furnace. The inner diameter of the reactor is 17 mm. The sample can be lowered from a water-cooled and purged top section into the reactor by an electrical spindle within 10 s. The mass of the filled sample holder is measured by a Sartorius 4406 MP8 balance (maximum mass 1100 mg, resolution 0.01 mg). The flow through the furnace was 3.3 $liters_{STP}/min$. The sample holder is shown in Figure 5.In this facility char gasification reactivities were measured as a function of temperature and pressure. The char was produced by lowering the sample (approx. 200 mg) into the heated (pressurised) reactor section with a gas composition of 95% N_2 and 5% CO. After approx. 400 s a stable weight signal was obtained, *i.e.* the end of the devolatilisation stage. Then the gas composition was instantaneously changed to 80% N_2, 18% CO_2 and 2% CO.

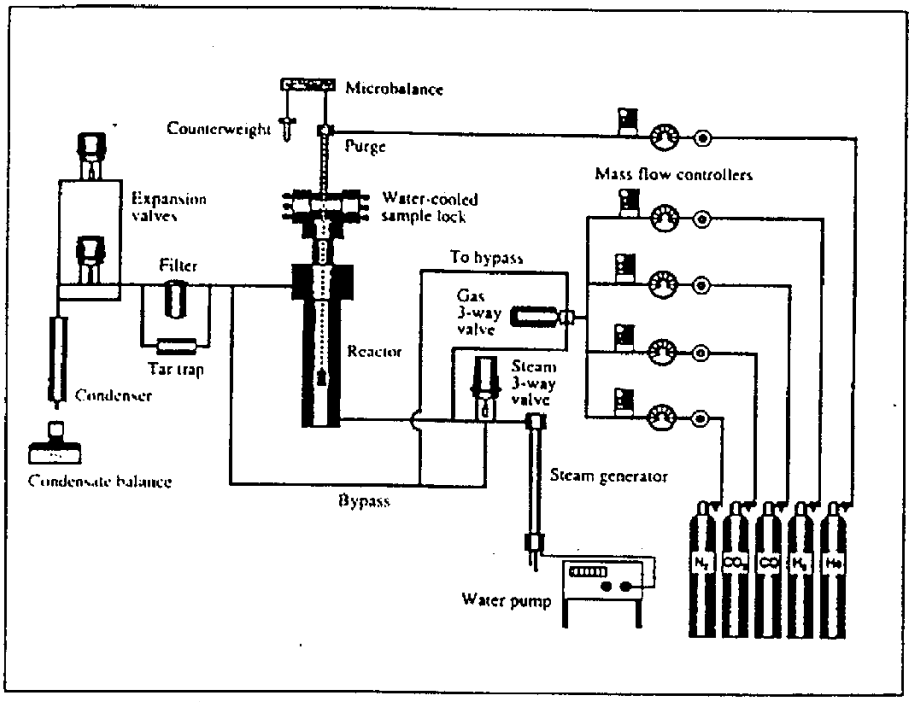


Figure 6 The pressurised thermobalance: experimental set-up

The gasification rate was then determined from the maximum of the slope in the measured weight vs. time curve, as illustrated by Figure 7 (Whitty, *et al.*, 1993). (a. represents the devolatilisation stage, b. shows a buoyancy effect from changing the gas composition, c. represents the gasification stage).

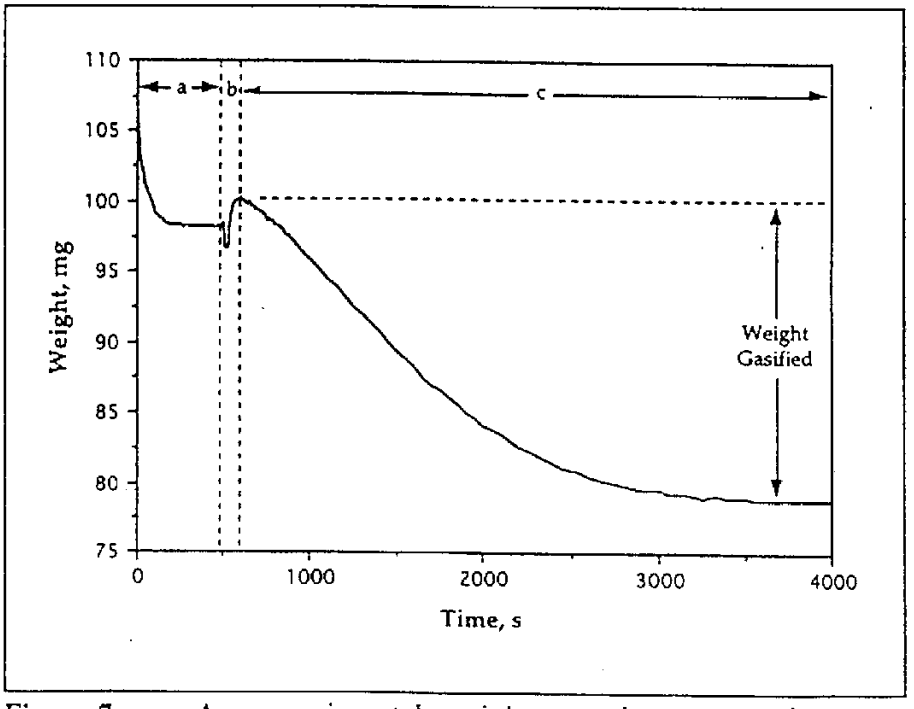


Figure 7 An experimental weight vs. time curve from the thermobalance

3.2 The plastics and other fuel samples

In this study 7 types of plastic materials and 3 types of conventional fuel, being coal, peat and wood were used : see Table 1. The results of standard tests (done at an external laboratory) for proximate analysis and chemical analysis are given in Table 2 and 3, respectively.

Table 1 The plastics and other fuel samples

1. LDPE (low density PE)	sheet 0.7 mm thick	density 924 kg/m³	666 g/m²
2. HDPE (high density PE)	film 16 µm thick	density 952 kg/m³	15.3 g/m²
3. HDPE printed	as 2. with 10 µm colour print on one side		25.0 g/m²
4. PP	sheet 1 mm thick	density 910 kg/m³	912 g/m²
5. PP white 3%wt colour*	sheet 0.45 mm thick	density 950 kg/m³	429 g/m²
6. PS white 3%wt colour*	sheet 0.52 mm thick	density 1070 kg/m³	557 g/m²
7. PVC	sheet 0.3 mm thick	density 1370 kg/m³	417 g/m²
8. Polish bituminous coal	particle size 0.5-0.7 mm		
9. Finnish peat	particle size up to 1 mm		
10. Finnish pine wood	fibres 3 mm long and 0.5 mm thick		

* 50% TiO_2 and 50% organics

Table 2 Proximate analysis of the fuels
(%wt in dry samples, C_{fix} determined from char, not by difference)

	Volatiles	Ash	C_{fix}	Moisture	HHV (MJ/kg)
LD PE	99.9	< 0.05		0.10	46.0
HD PE	99.9	< 0.05		0.16	43.1
HD PE printed	97.4	2.33	0.34	0.21	41.9
PP	99.9	< 0.05		0.13	46.5
PP white	97.8	2.21		0.10	46.7
PS white	97.0	2.89		0.11	40.6
PVC	92.3	< 0.05	7.5	0.18	21.2
Coal	28.3	18.4	47.9	2.35	26.2
Peat	72.1	2.35	23.2	27.9	24.1
Wood	85.8	0.45	12.6	6.15	19.1

Table 3 **Chemical analysis of the plastics and other fuels**
(%wt in dry samples, oxygen measured, not by difference)

	C	H	N	O*	S	Cl	Ti	Sn**	Total
LD PE	85.7	14.3		0.16					100
HD PE	85.6	14.2		0.30					100
HD PE printed	82.4	13.6	0.34	1.28					97.6
PP	85.5	14.3		0.19					100
PP white	83.6	14.1		0.18			1.31		99.2
PS white	88.9	8.3		0.16			1.69		99.1
PVC	40.1	5.1		0.65		53.8		0.20	99.9
Coal	66.6	4.0	1.07	8.85	1.22				81.7
Peat	57.8	6.1	1.79	31.5	0.19				97.4
Wood	48.9	6.0	0.17	43.8	0.06				99.0

* Excluding oxygen from TiO_2
** Measured since Sn is a stabiliser in PVC

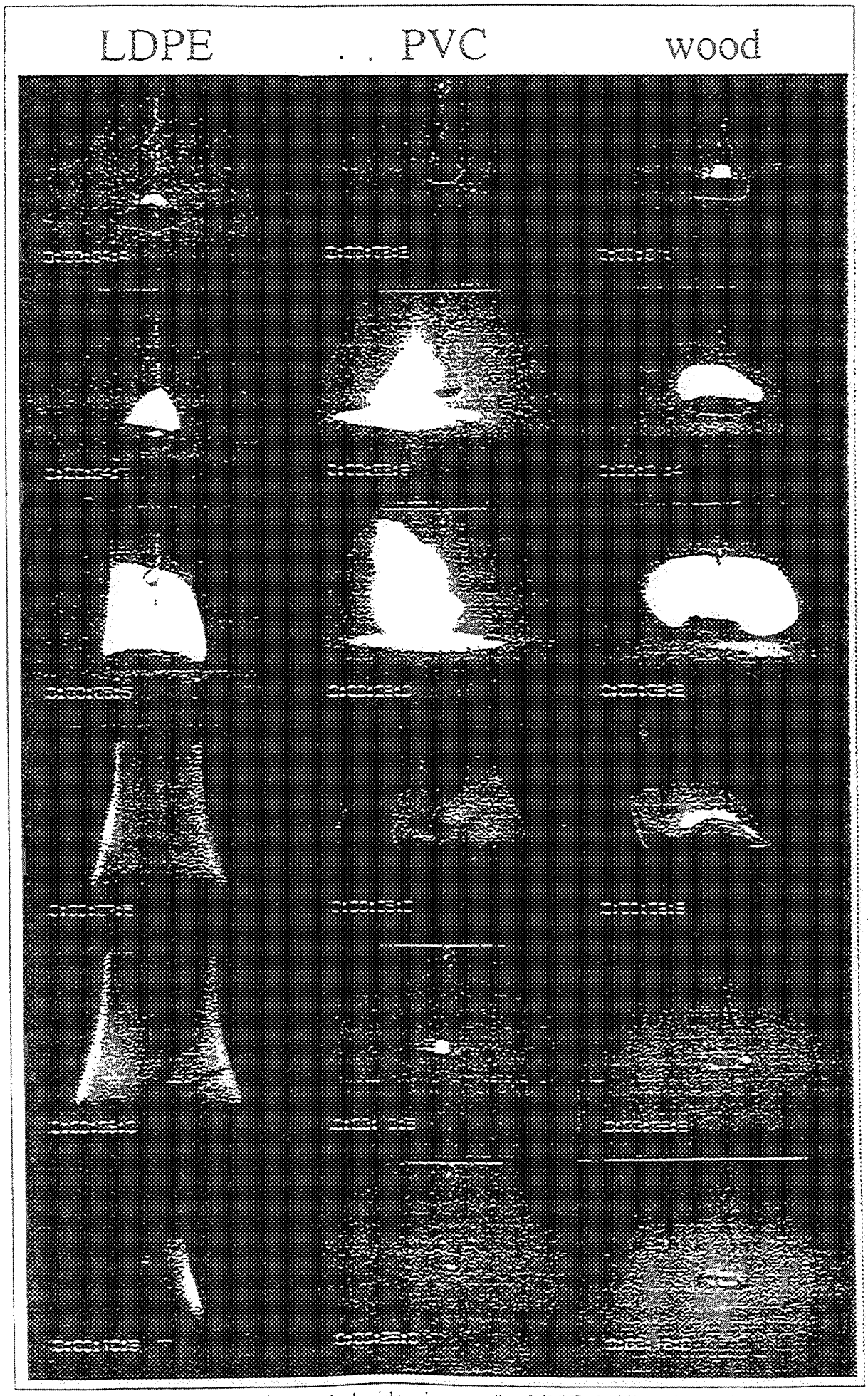


Figure 9 Examples of recorded video images for LDPE, PVC and wood
Temperature 850°C, 7%oxygen. Note different times

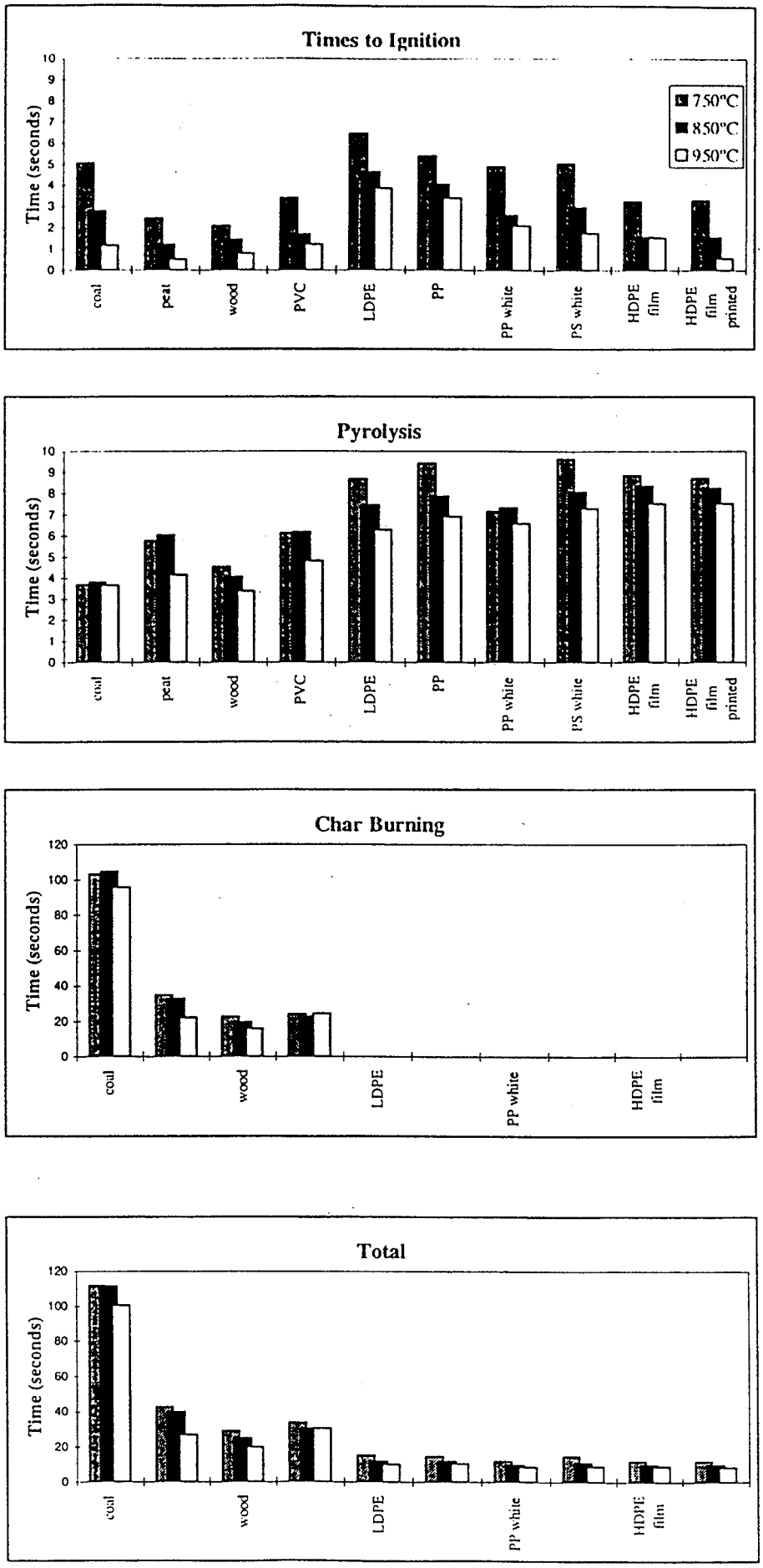
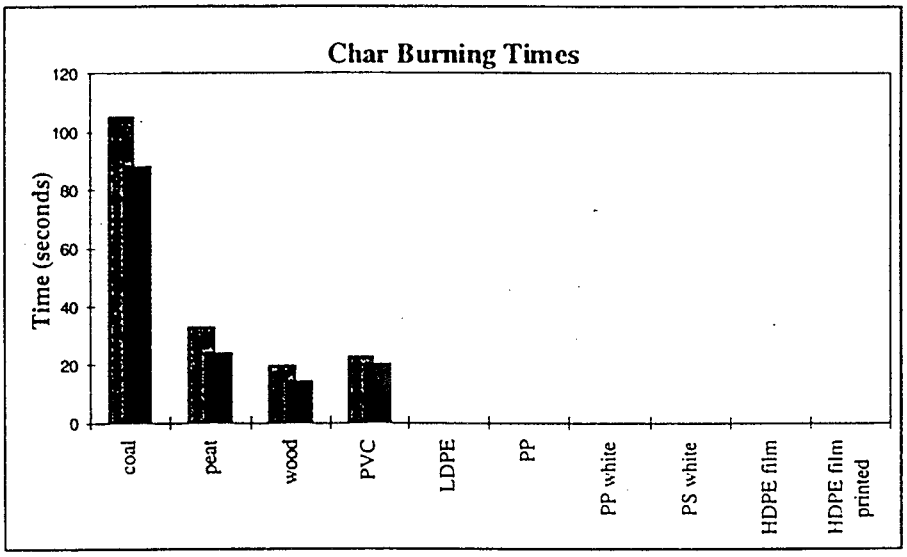


Figure 10 Total time for combustion at 750°C, 850°C and 950°C in 7% oxygen

The effect of the oxygen concentration was as expected: a higher oxygen concentration speeds up the combustion as shown in Figure 11. There was no on time for ignition or duration of the pyrolysis, indicating that intra-particle mass (and heat transfer ?) is limiting. Measurements at 2% O_2 gave a very unstable flame and a very slow char burning. 0% O_2 in nitrogen didn't produce any visible phenomena except for the PVC, where a slight swelling was seen.



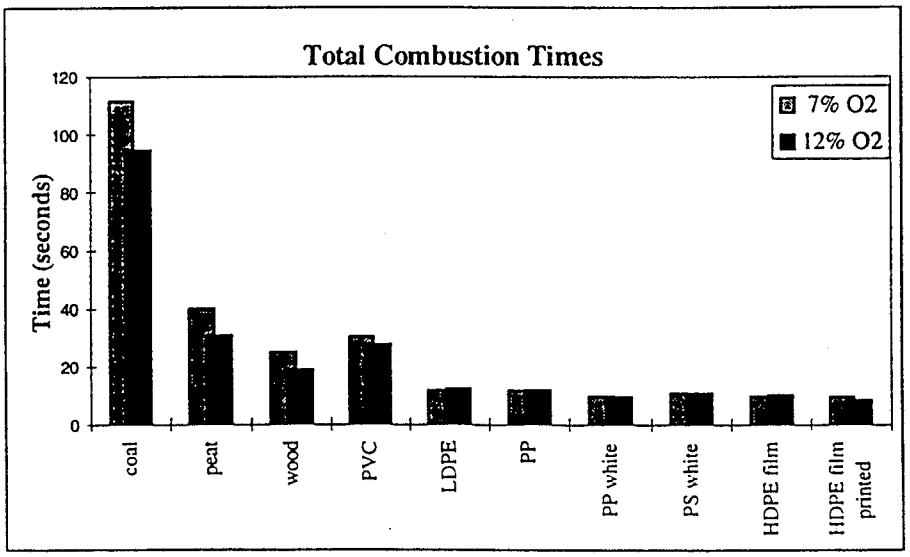


Figure 11 Char burning time and total time for combustion at 850°C in 7% and 12% oxygen

Varying the sample size give information on the effect of intra-particle heat and mass transfer limitations. An increasing sample mass from 10 mg to 70 mg, given in Figure 12 shows little effect on time to ignition but a significant effect on the duration of pyrolysis and char burning. Since the time to ignition is mainly a drying and heating process, intra-particle and external heat transfer limitations can be neglected. The char burning time roughly increases linear with mass to the power ⅔ (*i.e.* with particle external surface): increasing the mass from 10 to 70 mg leads to a 3 to 4 times longer char burning time.

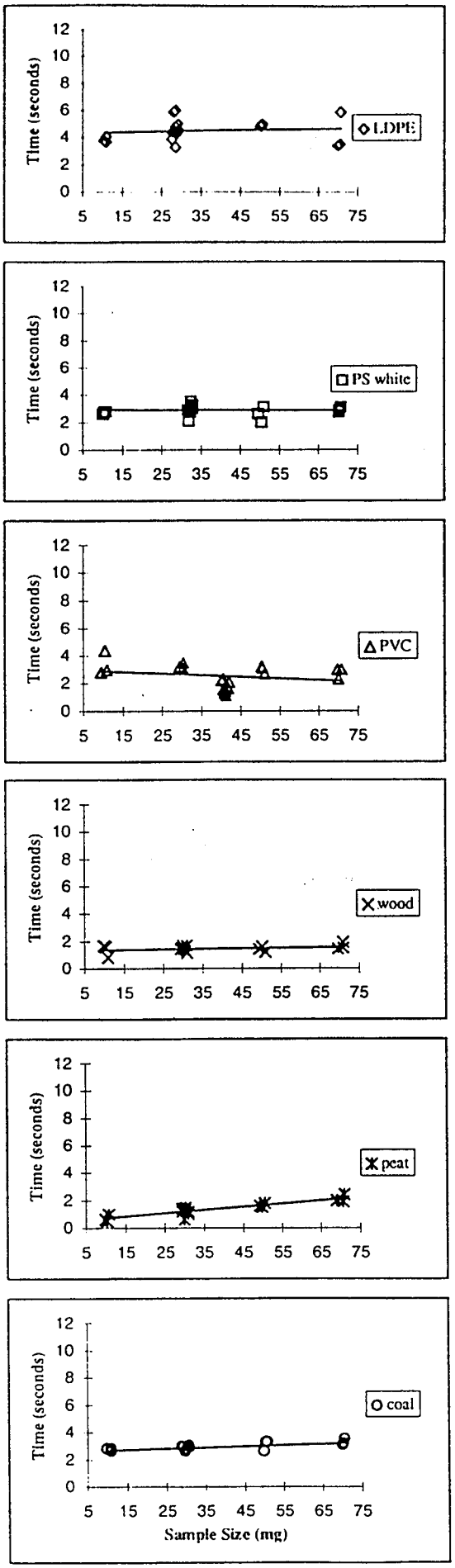


Figure 12a Time to ignition vs. sample size at 850°C, 7% oxygen

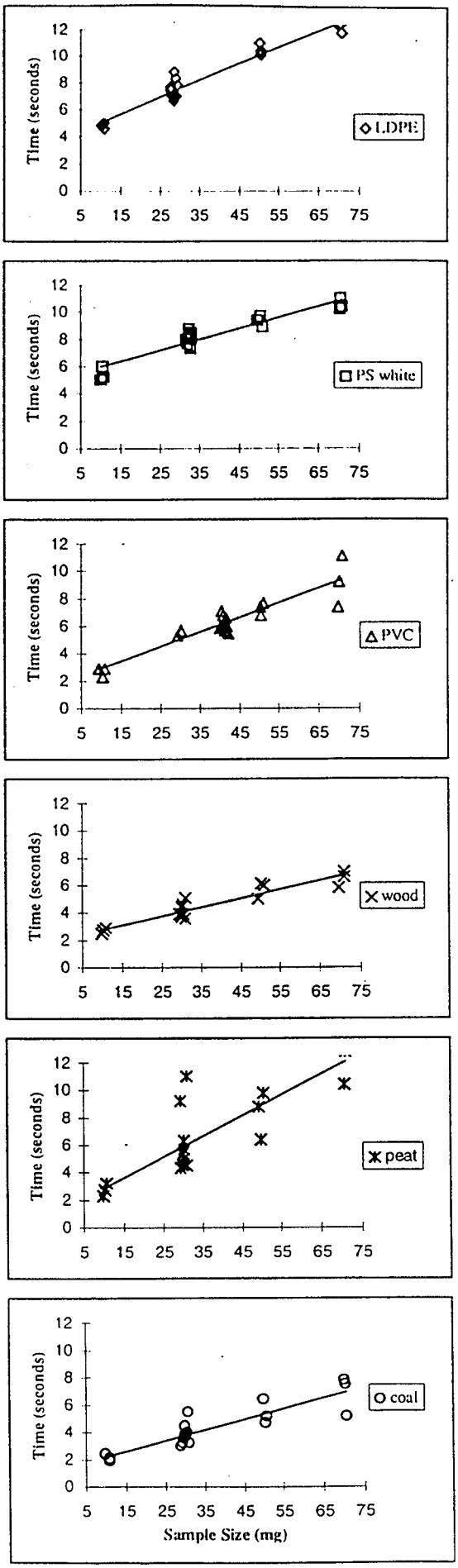


Figure 12b Pyrolysis duration vs. sample size at 850°C, 7% oxygen

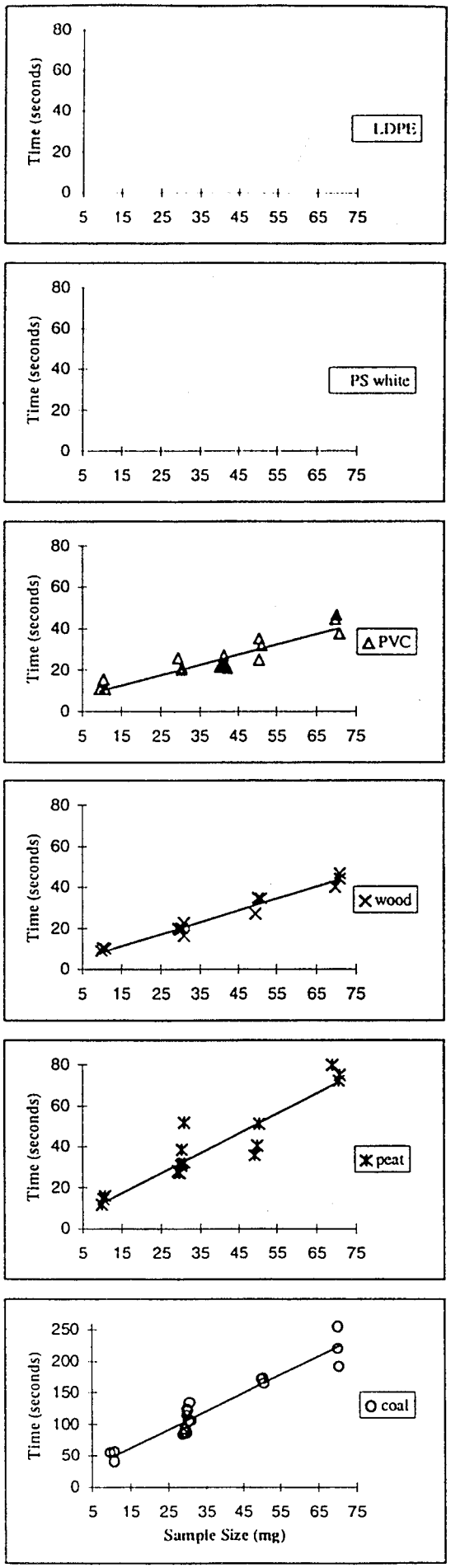


Figure 12c Char burnout time vs. sample size at 850°C, 7% oxygen

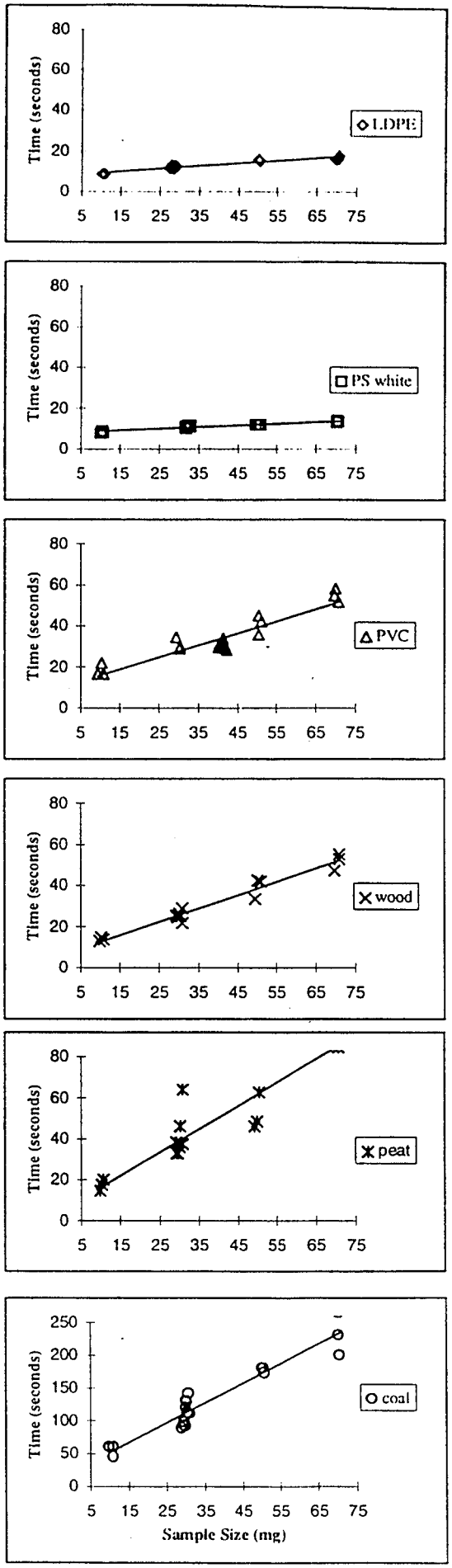


Figure 12d Total combustion time vs. sample size at 850°C, 7% oxygen

4.2 The measurement of char yields, char composition

The result of the devolatilisation during 15 s of 50 mg samples in a nitrogen purge flow at 850°C is given in Figure 13. The distinction between char and ash was made using the ash content from the proximate analysis of the fuels (Table 2). It is seen that only the reference fuels produce a residue that contain char and ash. The PVC plastic produces a char without ash whilst only the printed plastics produce an ash without char. The amount of ash found from the coloured PP and PS corresponded to the mass of inorganic colour agent.

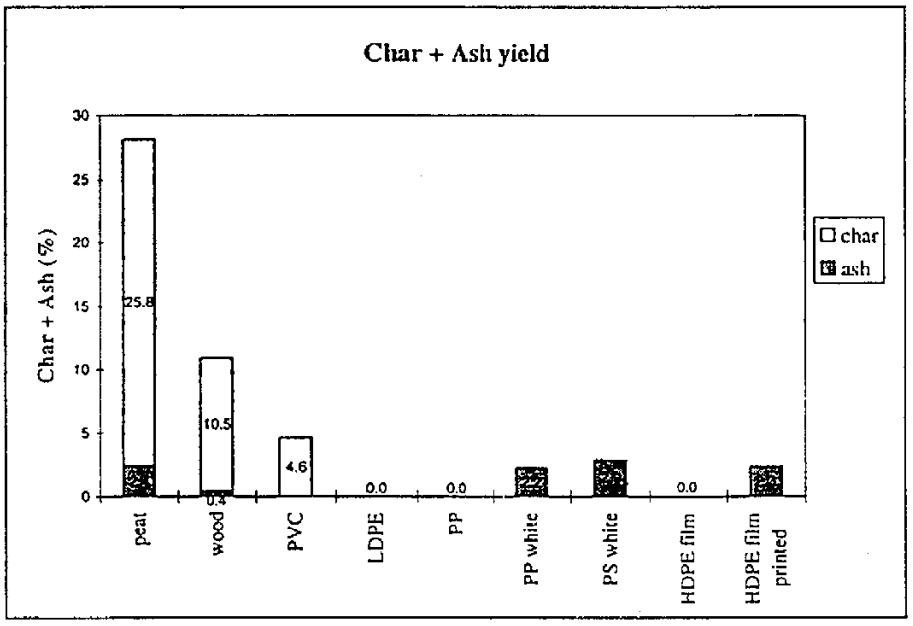


Figure 13 Char + ash yield for all the fuels after devolatilisation in nitrogen during 15 s at 850°C. (Ash fraction from proximate analysis).

There is an effect of temperature on the char+ash yield for the fuels that produce a char, as shown in Figure 14 for a 50 mg sample in nitrogen during 15 s at 750°C, 850°C, 950°C. The char+ash yield was measured also after 30 s and by varying the sample size between 30 mg and 80 mg. No effect of eithe effect was found.

The results from elemental analysis of the chars produced from the 15 s devolatilisation tests are given in Table 4. An interesting result is that the char from PVC does not contain significant amounts of chlorine.

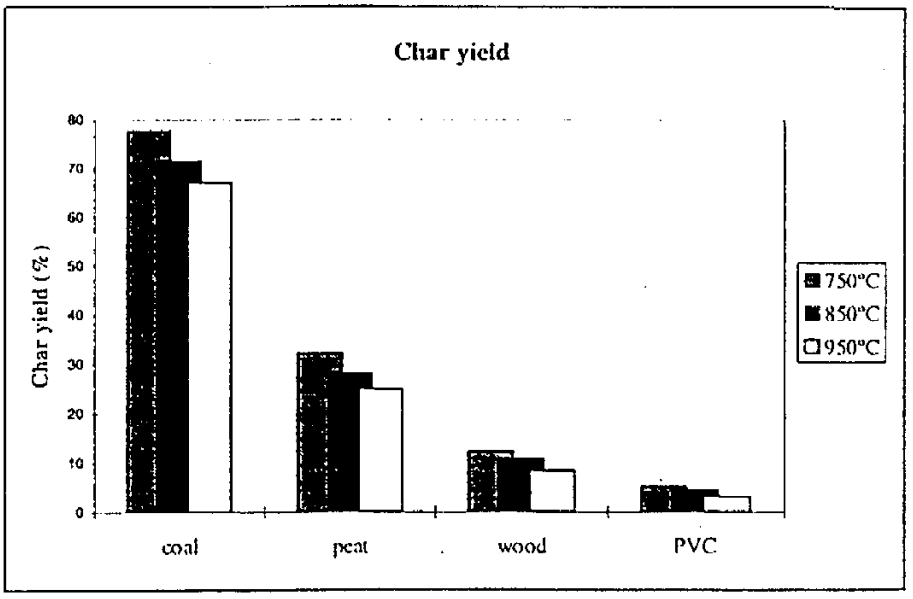


Figure 14 Char + ash yield from after devolatilisation in nitrogen for coal, peat, wood and PVC: 15 s, 750, 850, 950°C

Table 4 **Elemental analysis of the solid residues from devolatilisation in N_2**

	C %wt	H %wt	N %wt	O %wt	Cl %wt	Sn %wt
PVC 750 °C	92.2	6.65		0.79*	0.31*	< 0.4*
PVC 850 °C	92.5	2.46		1.98*	0.14*	< 0.4*
PVC 950 °C	94.4	1.68		2.00*	0.21*	< 0.4*
HDPE printed 850 °C	76.4	11.3	0.35	1.54		
HDPE printed 950 °C	20.4*	0.96*	1.02*	6.51*		
coal 750 °C	71.3	2.83		7.43		
coal 850 °C	66.9	2.00		4.64		
coal 950 °C	73.6	1.55		2.56		
peat 750 °C	71.6	3.10		16.3		
peat 850 °C	78.3	2.19		9.76		
peat 950 °C	80.6	1.36		8.49		
wood 750 °C	80.6	2.96		12.5		
wood 850 °C	87.2	2.26		6.40		
wood 950 °C	88.5	1.34		5.86		

* All results are averaged from 2 tests, except * for which too little material was available.

4.3 Measurement of char yield and char reactivity in a pressurised thermobalance

Char+ash yield measurements were carried out in the pressurised thermobalance at 2 temperature levels (850°C and 950°C) and 2 pressures (1 bar, 25 bar) in 95% N_2 + 5%CO, with the LDPE, HDPE printed, PVC, PS and peat samples. From earlier tests data on wood and coal at 1 bar and 20 bar were available. Table 5 gives the amount of char+ash residue found, with the results of the atmospheric tests in the entrained gas flow reactor (see previous section) included. A clear effect of pressure is seen : increased pressure hinders the devolatilisation. Furthermore it is seen that no significant amounts of gasifiable material is found for the plastics except for the PVC. For that reason gasification tests were only done with the PVC and for comparison with the peat.

Table 5 Char + ash yield measured after pyrolysis in a pressurised thermobalance

	Thermobalance				Tube reactor
	1 bar 850°C char+ash % wt	25 bar 850°C char+ash % wt	1 bar 950°C char+ash % wt	25 bar 950°C char+ash % wt	1 bar 850 °C char+ash % wt
PVC	5.9	15.5	5.1	13.6	4.6
LDPE	0.2	0.4			
HDPE printed	2.3	2.6			
PS		2.1			
coal	69.4	72.4 (20 bar)			71.6
peat	24.5	37.4	25.6	30.5	28.2
wood	13.3	23.0 (20 bar)			10.9

The gasification rate, r (unit 1/s), here defined as

$$r = -\frac{1}{mass_{char,initial}} \frac{d\,mass_{char}}{dt}$$

was determined from the maximum slope of the mass vs. weight curve for the gasification stage (see Karlsson, 1995, Whitty *et al.*, 1993). The gas phase during the gasification was 18% CO_2, 2% CO and 80% N_2, the temperature and pressure levels were the same as during the pyrolysis tests : 850°C, 950°C and 1 bar, 25 bar. Test results for the PVC and the peat are shown in Figures 15 to 18, in some cases combined with earlier results obtained with the Polish coal and wood (1 bar and 20 bar). The (maximum) gasification reactivities that were determined are given in Table 6.

Table 6 **Gasification rates measured in the pressurised thermobalance**

	Gasification rate x 10000 (s^{-1})			
	1 bar 850°C	25 bar 850°C	1 bar 950°C	25 bar 950 °C
PVC	bad data	0.80	2.71	4.23
Coal	0.067	0.27 (20 bar)		
Peat	17.6	15.9	60.3	62.3
Wood	4.21	5.81 (20 bar)		

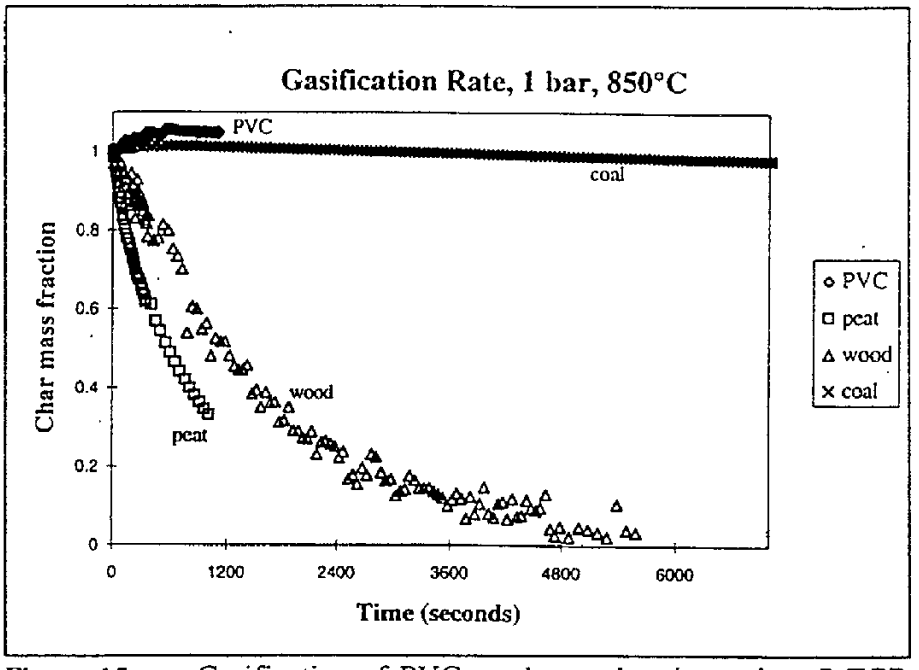


Figure 15 Gasification of PVC, coal, wood and peat in a P-TGR at 1 bar, 850°C

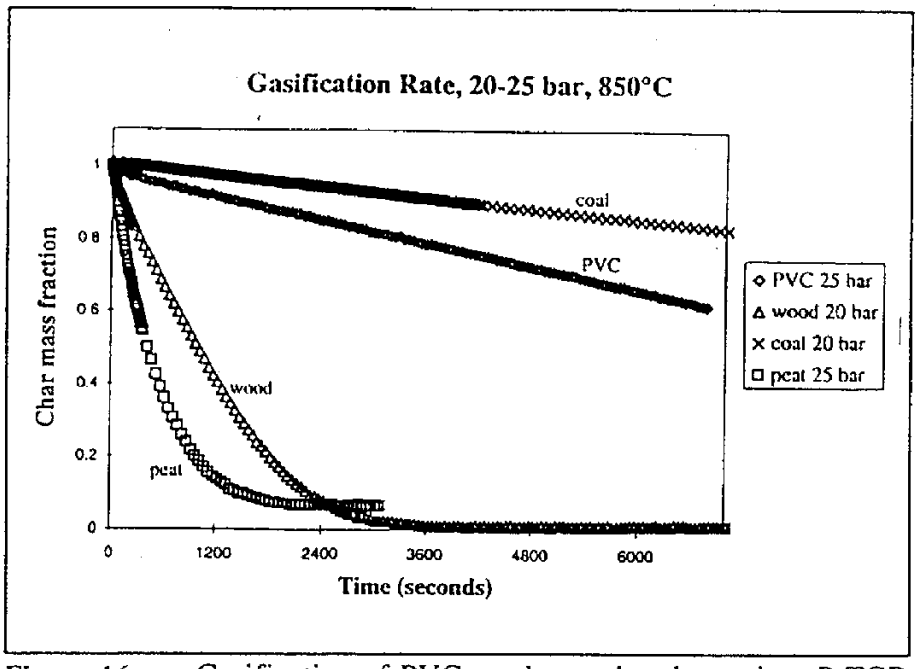


Figure 16 Gasification of PVC, coal, wood and peat in a P-TGR at 20/25 bar, 850°C

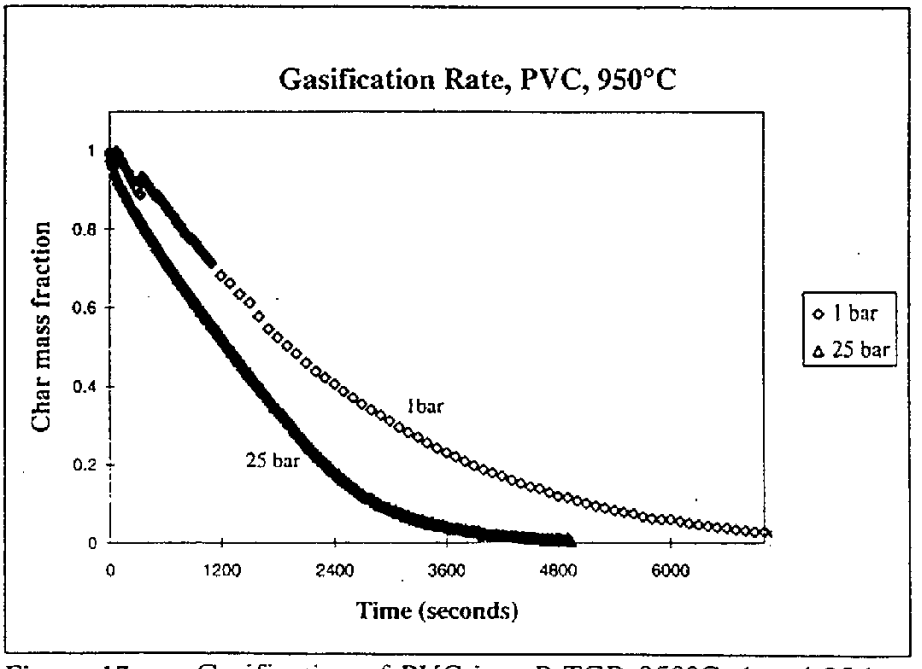


Figure 17 Gasification of PVC in a P-TGR 950°C, 1 and 25 bar

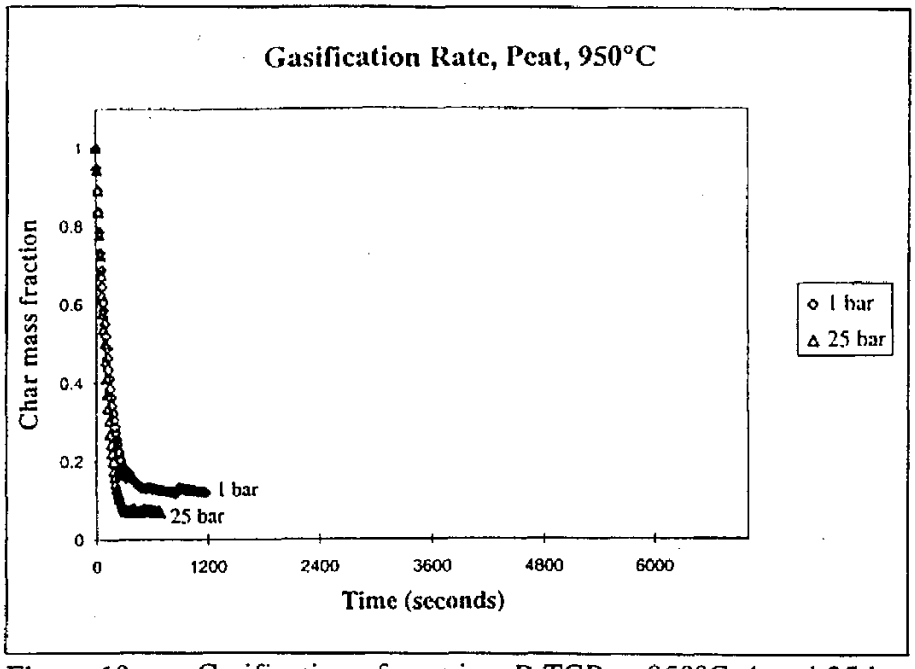


Figure 18 Gasification of peat in a P-TGR at 950°C, 1 and 25 bar

These results show that the gasification rate for the char from PVC is more than 10 times slower than the gasification rate of a char from wood and peat, being roughly of the same order as the gasification reactivity of coal char. Also, increased pressure has a negative effect on the char gasification rate.

5. CONCLUSIONS

Having studied the combustion properties of 7 types of plastics (based on 4 different polymers) with 3 reference fuels it can be concluded that the experimental facilities used are well suited for the broad range of analyses presented here. Valuable information on the burning behaviour of plastics was obtained. It was found that PE, PP and PS without a colour agent or printing burned completely during the pyrolysis phase. Ashes found related directly to colour agents and inks. Only PVC produced a char during devolatilisation, the PVC particles showed a faster ignition than a similar size particle of another plastic. Plastic particle shape had no effect which can be explained from a re-formation into a molten droplet during heating and early stages of the pyrolysis as was seen in the video recordings.

An important result is that char from PVC contains less than 1% chlorine, being 99% hydrocarbon. During atmospheric and pressurised pyrolysis and gasification tests with PVC and coal, peat and wood a significant effect of pressure on char+ash yield after pyrolysis and also on gasification rate was found. The gasification rate of PVC char appears to be of the same order as that of char from coal. Peat-char and wood-char are gasified one order of magnitude faster.

Co-firing with plastics-derived fuels will increase the amount of volatiles in the freeboard of an FBC, giving an upper limit to how much PDF or RDF can be fed to the furnace. Co-firing with low-volatile coals will allow for higher mass ratios of PDF/RDF. PVC has the disadvantage, as compared to the other plastics, of the heavy HCl emissions and a lower caloric value but produces a char which could help in reducing certain gaseous emissions.

6. ACKNOWLEDGEMENTS

This text was produced from the M.Sc. (Chem.Eng.) thesis work of Magnus Karlsson (Karlsson, 1995) at Åbo Akademi University. The authors want to thank Borealis Polymers Oy, Neste Oy Chemicals and VAPO, Finland for funding this project, Kristoffer Sandelin is acknowledged for his experimental work on the pressurised thermobalance.

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SECTION 6: INDUSTRY STAKEHOLDER ISSUES AND CONCERNS

This section includes notes and publications submitted by conference speakers . Brief summaries of each presentation can be found in Section 1: Overview and Outcomes.

PAPER INDUSTRY

Remarks by Gary Grifith, Georgia Pacific, on behalf of the American Forest Products Association

PLASTICS INDUSTRY

Remarks by Don Goodman, Occidental Chemical Corporation, on behalf of the American Plastics Council

BOILER INDUSTRY

Remarks by Bob Bessette, President, Council of Industrial Boiler Operators (CIBO)

POWER UTILITY INDUSTRY

Written Remarks Submitted by Charles McGowain, Manager, Biomass Conversion, EPRI

Pellet Fuels Conference
Washington, DC - 11/17/95
Garry Griffith, Georgia-Pacific Corp.

How do we work together to promote this technology?

1. Why G-P is promoting this technology: The entire spectrum of the pellet fuel process fits G-P's vision for sustainable development in the paper industry.

   - P2 aspect - the right thing to do

   - Public perception - need to reduce paper to landfills - Recycling not enough.

   - Broker of waste paper - Buyer/seller of recyclable - include non-recyclables

   - Generator of waste - Mill byproducts (OCC rejects, wastewater treatment plant (WWTP) residuals)
     -Paper Converters - waxed coated boxes

   - Consumer - Many boilers located at paper mills are capable of firing solid fuels (wood waste). Easy to mix pellet fuel and co-fire.

2. How G-P is promoting use of pellet fuels. Developed partnerships on local level. (example of 2)

   2.1 Big Island, VA
   - 1992 long term contract with The Montcalm Corp. to purchase pellet fuel

   - Co-fire pellets (90 tpd) in 190,000 LB/HR stoker boiler with wood waste (360 tpd), Tire Derived Fuel (TDF) (20 tpd) and coal (10 tpd)

   - Pellets contain up to 20% dewatered secondary sludge from WWTP

   - Investigating firing rejects from new OCC processing facility.

   - Investigate how we can get waxed coated boxes from customers to the mill to co-fire.

   2.2 Crossett, Ark. - P & P Mill
   - Partnership with Ashley County

   - County located a MURF on land the company sold to them, located next to mill.

- County was facing high tipping fee and long transport to landfill.

- Mill sends them non-recyclable waste

- Mill purchases fuel pellets

2.3 G-P has done a considerable amount of work to promote through media/conferences, etc.

- Trade Association - AF & PA

- Media
  - local during Montcalm's zoning hearings, etc.
  - national CNN interviews
  - Earth Day '95

- Conferences
  - TAPPI
  - Chemical Engineering Society
  - Test data shared

- Developed Literature
  - Video sent out to G-P employees and outside (1994)
  - Brochure (1994)

- Internal Company Environmental Excellence Awards Program
  - Big Island and Crossett are finalists (1995) - P2 area.

3. Where to go from here

- Need to develop data of boiler operation and emissions when firing pellet fuels.

- Distribute to boiler operators, environmentalists, public and regulating agencies.

American Plastics Council®

Pellet Fuels -- Plastics Industry Perspective

Pellet Fuels Conference
November 16-17, 1995

Presented by

Donald Goodman
Oxychem

American Plastics Council

Resource Conservation

Maximizing the Life-Cycle Value of Plastics

- Source Reduction
- Material Recovery
- Reuse
- Energy Recovery

American Plastics Council

APC Energy Recovery

Goals and Objectives

- Support integrated resource management strategies
- Minimize barriers to the environmentally and economically responsible and sustainable[1] recovery of energy from plastics
- Ensure the energy value of plastics is captured where practical
- Help to establish effective coalitions and alliances to implement sound resource management strategies which include the recovery of energy and fuel values from post-consumer plastics
- Facilitate open discussion of the issues

1 = EERS

American Plastics Council

Pellet Fuels Objectives

- Develop environmentally responsible alternative fuels
- Demonstrate favorable economics
- Demonstrate no regulatory barriers in effluents and ash
- Establish an information/technology base
- Determine maximum plastics loadings in pellets

American Plastics Council

Energy Recovery Project Team

Mr. Donald Goodman, OxyChem

Dr. Gerard Reinert, Bayer

Mr. Arun Singhania, Amoco

Dr. Jose Sosa, FINA

Dr. Michael Fisher, APC

Mr. Ole Ohlsson, (Consultant-Fuel Pellets), ANL

American Plastics Council

Process Technology Committee

Mr. Peter W. DeLeeuw, (Chairman), Shell

Dr. Roger Smith, (Vice-Chair), DuPont

Dr. Michael Fisher, APC

American Plastics Council

Energy Recovery Task Force

Mr. Andy Adams, (Chairman), Chevron

Mr. John J. DiFazio, (Vice-Chair), Dow

Mr. Dick Dauksys, BASF

Mr. Allen H. Gray, Mobil

Mr. Thomas (Jerry) Hassell, DuPont

Mr. Thomas L. Kornegay, Amoco

Dr. Jose Sosa, Fina

Ms. Sarah Friedell, APC

American Plastics Council

Pellet Fuels Tactical Approach

- Establish plastics/fuel pellets sources
- Characterize plastics/fuel pellets
- Conduct test burns
- Analyze effluents and ashes
- Establish economics
- Prepare reports in easy english

American Plastics Council

Pellet Fuels

Wish List Summary

- Establish plastics/fuel pellets as a responsible resource recovery option
- Earn EERS[1] credits for plastics/fuel pellets
- Create favorable electricity rates with plastics/fuel pellets
- Nurture favorable attitudes toward combustion technologies

Bob Bessette, Council of Industrial Boiler Operators (CIBO)

PRESSURES ON TODAY'S INDUSTRIAL BOILER USER

- CHANGES IN OPERATOR KNOWLEDGE AND EXPERIENCE
- INCREASING ENVIRONMENTAL REGULATIONS
  NOx, SO2, ROx, VOC, HAP's,
  CI, OPACITY, CO, & MORE
- INCREASING GLOBAL COMPETITION
- DEMANDS FOR INCREASED EFFICIENCY
- DEGRADATION OF FUEL SUPPLY QUALITY AND CONSISTENCY

COAL APPLICATION COSTS
HEAT RATE ASSOCIATED COSTS

- BOILER & FUEL COMBUSTION EFFICIENCY
- COAL PULVERIZATION AND CRUSHING
- COMBUSTION AIR HANDLING
- FLUE GAS HANDLING
- SOOTBLOWING REQUIREMENTS
- STEAM -- TEMP., PPH & CAPACITY

COAL APPLICATION COSTS
ASSOCIATED SYSTEM COSTS

- STORAGE & HANDLING
- SAMPLING AND ANALYSIS
- INVENTORY COSTS
- ASH HANDLING & DESPOSAL
- PARTICULATE EMISSIONS
- NOx & SULFUR EMISSIONS

Each can have fixed & variable components

RECOMMENDED ABMA
COAL GUIDE SPECIFICATION FORM

Source (State/County/Company/Mine/Seam)

_____

_____

Classification by Rank _____

Proximate Analysis - As received (percent by weight)

Volatile Matter	_____
Fixed Carbon	_____
Ash	_____
Moisture (Total)	_____
Equilibrium Moisture	_____

Grindability - Hardgrove

Feed Size (Sieve Analysis) _____

Sulfur

Forms of Sulfur

Pyritic	_____
Organic	_____
Sulfates	_____

Heating Value - Btu/lb.

as received _____

Ultimate Analysis - as received (percent by weight)

Moisture	_____
Carbon	_____
Chlorine	_____
Hydrogen	_____
Nitrogen	_____
Oxygen	_____
Sulfur	_____
Ash	_____

Float Sink Fraction

(1.6 sp.gr.) _____

Ash Fusion Temperatures (°F)

	Reducing	Oxidizing
Initial deformation	_____	_____
Softening (H=w)	_____	_____
Hemispherical (H=½w)	_____	_____
Fluid	_____	_____

Ash Analysis (percent by weight)

SiO_2	_____
Fe_2O_3	_____
Al_2O_3	_____
CaO	_____
MgO	_____
P_2O_5	_____
Na_2O	_____
K_2O	_____
TiO_2	_____
SO_3	_____
NAF[c]	_____
Viscosity[d]	_____

Burning Profiles _____

Bulk Density (as delivered) _____

Free Swelling Index _____

Reactivity Index _____

Cofiring Pellet Fuels and Coal in Utility Boilers: Electric Utility Requirements and Issues

Charles R. McGowin
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Prepared for discussion at the American Plastics Council Conference, November 17, 1995, Washington, D.C.

Introduction

Electric utilities have been firing alternate fuels in a variety of boiler types for many years. During the 1970s, the industry began to cofire refuse-derived fuel and coal in a variety of stoker and pulverized coal boilers with mixed results. In recent years, the utility cofiring experience has shifted to other alternate fuels, including paper, plastic, and wood residues and tire-derived fuel, and the boiler experience now includes cyclone and fluidized bed boilers. This experience has shown that the technical and economic success of alternate fuel cofiring in utility boilers depends on a number of technical and economic factors. They include the boiler type, alternate fuel and coal properties and delivered costs, and retrofit and added operation and maintenance costs.

Utility Requirements and Issues (Slide 1)

What will electric utilities look for in considering pelletized fuels made from clean waste paper and plastics? The most important factors are cost, and fuel properties, and compatibility with the boiler operation.

Cost. Increasing competition in the power industry is forcing electric utilities to focus on the bottom line and reduce costs. Thus the delivered pellet fuel cost and the impact of cofiring pellet fuels on power plant performance, availablility, and capital and O&M costs are of primary importance. With delivered coal prices near and below $1.00/million Btu in some cases, electric utilities can't afford to pay very much for the pellet fuel without increasing

the cost of generation. They are also concerned about the incremental capital and O&M costs required to retrofit the unit to cofire the pellet fuel.

Fuel Properties and Compatibility with Boiler. Due to concerns about environmental emissions, electric utilities are likely to favor alternate fuels that have low sulfur and toxics contents. They also prefer fuels with low moisture, alkali, chloride, and ash contents and a high heat content relative to the primary coal fuel. In addition, the pellet fuel should be easy to handle and store, and be compatible with the fuel handling and injection requirements of the boiler. For cofiring in stoker, fluidized bed, and cyclone boilers, it is likely that the pellet fuel can be cofired with little if any modification to the unit, provided cofiring doesn't increase boiler slagging or fouling of the boiler heat transfer surfaces. For cofiring in pulverized coal units, if the pellet fuel is grindable, it may be possible to blend and copulverize the pellets with the coal for firing rates up to 5-10% by mass. Above 5-10% mass input, it is usually necessary to install a dedicated pulverizer for the pellet fuel.

Other Issues. Electric utilities are also concerned about the impacts of alternate fuel cofiring on sulfur and nitrogen oxide emissions, the disposal and use of bottom and fly ash from the boiler, and the potential for derating the unit during cofiring.

Example: Impact of Delivered Pellet Cost on Power Generation Cost (Slide 2)

Using EPRI's BIOPOWER model of biomass and waste-fired power plant performance and cost (EPRI TR-102774, 1995), we developed a simple example to illustrate the significant impact of delivered pellet cost on the levelized cost of power generation. The unit is a 200 MW pulverized boiler unit cofiring 70% paper/30% plastic pellets at 15% heat input with Pittsburgh bituminous coal. Other key assumptions include a delivered coal cost of $1.18/million Btu, coal and pellet heat contents of 11,110 and 12,648 Btu/lb, respectively, and no boiler or fan limitations that would result in unit derating during cofiring. The third slide illustrates the summary table generated by the BIOPOWER cofiring model for the base case, assuming the delivered cost of the pellet fuel is $25.00/ton or $1.15/million Btu.

The horizontal dashed line represents the generation cost for the baseline coal unit (2.3¢/kWh). The three sloped lines show how the generation cost increases linearly as the delivered pellet cost increases from zero to $1.50/million Btu for three cases. The cases vary according to whether the utility absorbs the incremental capital and O&M costs associated with cofiring. A utility would consider cofiring to be an attractive opportunity, if the generation cost decreases during cofiring relative to the baseline cost for the coal unit.

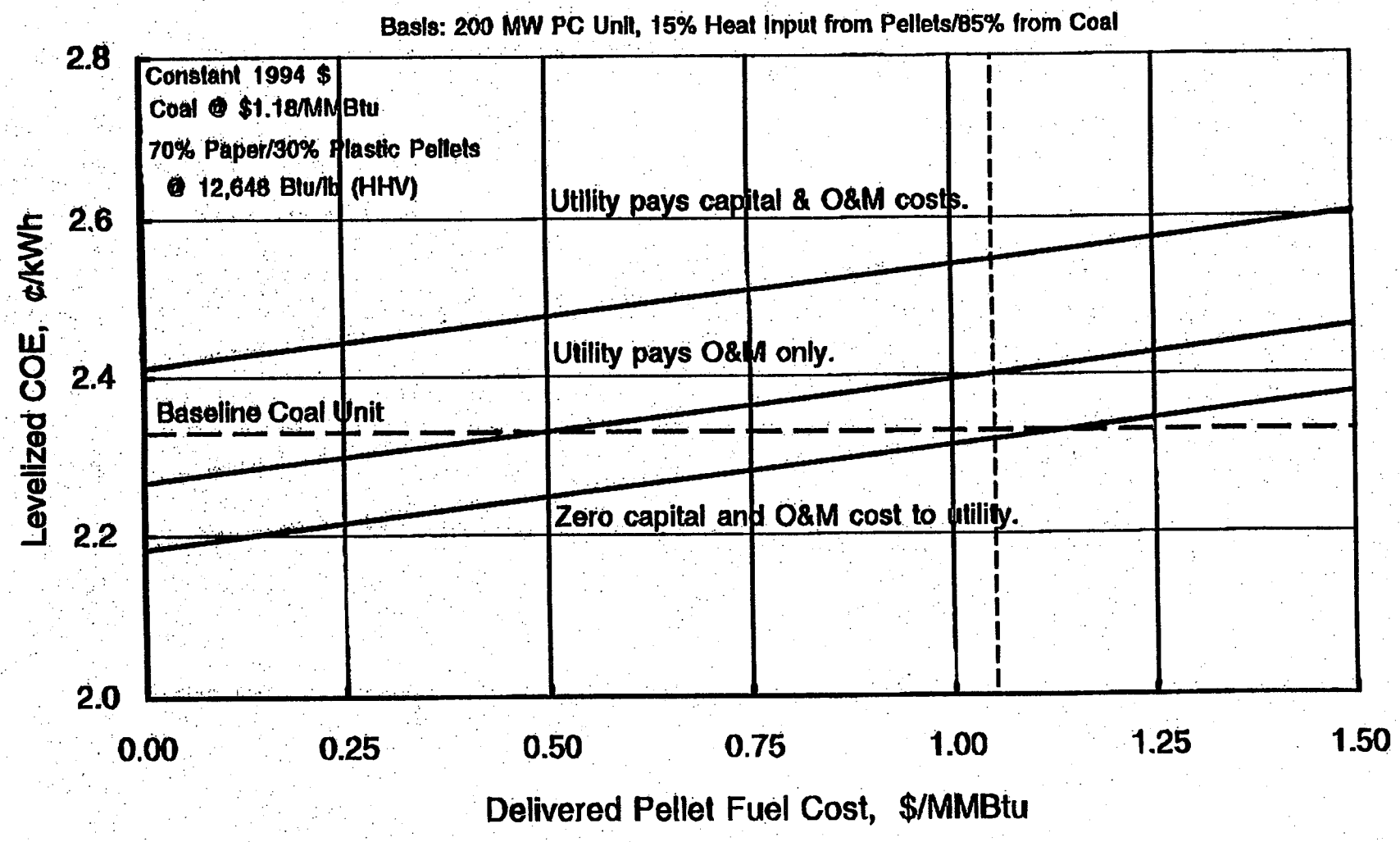
The top sloped curve represents the case where the utility absorbs the incremental capital and O&M costs. The power cost exceeds the baseline cost for all values of the pellet cost, and thus cofiring would not be attractive to the utility. However, cofiring becomes attractive for delivered pellet costs below about $0.50/million Btu, when the utility absorbs only the O&M costs (middle curve), and below about $1.15/million Btu, when the utility absorbs neither capital or O&M costs (lower curve). Thus if the utility's added capital and O&M costs are subsidized by the fuel supplier or other agency, cofiring may become an attractive economic opportunity.

COFIRING PELLET FUELS AND COAL IN UTILITY BOILERS

Utility Issues and Fuel Requirements

- Competition in power markets forcing cost reductions.
- Delivered fuel cost << coal cost (coal @$1.00/MM Btu).
- Low or zero capital investment by utility.
- Pellet fuel specs: low moisture & ash; high HHV; low S, Cl, & Na/K; zero toxic metals and organics.
- Pellet fuel compatibility depends on boiler type:
  - OK for most stoker, fluid bed, and cyclone boilers.
  - OK for some pulverized coal boilers, may need separate pulverizer for pellets.
- Other concerns: Impacts on SO2 & NOx emissions, ash disposal and unit derating.

COFIRING PELLET FUELS AND COAL IN UTILITY BOILERS



Paper/Plastic Cofiring with Coal
Alternate Fuel/Coal-Cofired Utility Boiler
200 MW PC, Cyclone, or Stoker
Pellets

Summary - Performance and Economics	Retrofit Plant Baseline Coal Only	Alt. Fuel Cofired	Baseline Coal Only	Alt. Fuel Cofired
System Performance				
Alternate Fuel Heat Input during Cofiring, %				15.0
Power Generation from Cofiring, % of Total				85.0
Gross Power, MW			212.8	212.8
Auxiliary Power, % / MW	6.0%	6.0%	12.8	12.8
Net Power, MW			200.0	200.0
Boiler Efficiency, %			88.8	88.6
Net Heat Rate, Btu/kWh			10,127	10,152
Thermal Efficiency, %			33.7	33.6
Annual Capacity Factor, %			65.0	65.0
Fuel and Air Supply (as received basis)	Tons/year	Tons/year	Tons/day	Tons/day
Pellets (dry)		55,354		274.5
Coal	518,995	453,752	2,187.6	1,864.0
Air to boiler			23,803.9	23,518.5
Limestone	0	0	0.0	0.0
FBC Ca/S			0.00	0.00
Emissions				
Flue Gas			25,742.9	25,428.7
Carbon Dioxide	1,156,733	1,133,679	4,875.6	4,761.3
Sulfur Oxides	33,700	29,819	142.0	122.8
Nitrogen Oxides	3,460	2,976	14.6	12.2
Particulates	173	173	0.7	0.7
Bottom Ash	11,418	16,270	48.1	72.2
Fly Ash	47,545	41,533	200.4	170.6
Gypsum	0	0	0.0	0.0
Economics Cost year: 1994				
Undepreciated value of plant, $/kW			100	100
Total Capital Requirement				
Total Plant Cost, $/kW			100	165
Total Capital Requirement, $/kW			100	168
Operating Costs - Annual Basis				
Fixed, $/kW-yr			45.5	50.3
Consumables, mills/kWh			1.1	1.1
Average Fuel Cost, Coal/Alternate Fuel:		$/dry ton	30.20	27.96
		$/million Btu	1.18	1.05

Levelized Cost of Electricity, mills/kWh (1995-2004)

	Constant 1994 $ Coal Only	Constant 1994 $ Cofired	Current 1994 $ Coal Only	Current 1994 $ Cofired
Carrying Charges	2.3	3.7	3.4	5.5
Fuel Cost: Coal	12.0	10.5	15.2	13.3
Pellets		1.4		1.7
Operation and Maintenance Costs	9.1	9.9	11.5	12.6
Electricity Cost	23.3	25.4	30.1	33.2
Capacity Loss Energy Charge		0.0		0.0
Emissions Charges	0.0	0.0	0.0	0.0
Renewable Energy Production Credit		0.0		0.0
Net Electricity Cost	23.3	25.5	30.1	33.2

Breakeven Alternate Fuel Value		
$/ton Pellets (dry)	(16.73)	(27.84)
$/million Btu	(0.63)	(1.05)

APPENDIX A:

CONFERENCE PARTICIPANT LIST

Pellet Fuels Conference
November 16-17, 1995
Washington, D.C.
Attendee List

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APPENDIX B:

BIOGRAPHICAL INFORMATION ON CONFERENCE PARTICIPANTS

Biographical Information on Conference Particpants

Andrew Adams

Andrew (Andy) Adams is policy coordinator for solid waste issues for Chevron Chemical Company. Since 1990 he has been actively involved in issues management in this area. For the past year, he has been vice chairman of the Energy Recovery Task Force of the American Plastics Council; recently, he assumed the chairmanship of that group.

Harvey Alter

Harvey Alter is the manager of the resources policy department of the U.S. Chamber of Commerce, where he is responsible for a publishing and book-marketing function. He has served on U.S. Environmental Protection Agency regulatory policy advisory committees on hazardous waste recycling and management, and is chairman of the International Chamber of Commerce delegation to the United Nations Basel Convention on transboundary movement of hazardous waste.

During his tenure as director of research programs for the former National Center for Resource Recovery, Inc., a not-for-profit organization, Dr. Alter developed an international reputation in solid waste management. For 13 years he was a vice president with the Gillette Company, where he had profit and loss responsibility for contract research for government, industrial, and trade association clients. Prior to that, he was with the plastics division of the development department of Union Carbide Corporation.

Dr. Alter received his B.S. degree from Queens College, City University of New York, and his M.S. and Ph.D. degrees (in physical chemistry) from the University of Cincinnati. He was a lecturer in physics, City College of New York; has lectured in the United States, Europe, and Japan; and has helped present short courses at several U.S. universities.

Barbara Arnold

Barbara Arnold holds B.S., M.S., and Ph.D. degrees in mineral processing from Penn State University. She is the project manager for CQ Inc. in Homer city, Pennsylvania. Her expertise is in coal cleaning, flow-sheet modeling, and flow-sheet design. Dr. Arnold will serve as project manager for a project with New York State Electric & Gas and the New York State Energy Research Development Authority to develop markets and test E-fuel in the state of New York. E-Fuel combines coal fines and paper mill wastes into a beneficial pelletized fuel for stoker boilers.

Larry Beaumont

Larry Beaumont is a nationally recognized expert in refuse-derived fuels, or RDF. He is the founding director of PEF. Mr. Beaumont is interested in commercializing pellet fuels for home-cooking fuel in poor, arid countries. He is also reviewing the potential for a pellet plant in Colorado.

Robert Bessette

Robert Bessette, who graduated from the West Virginia Institute of Technology with a degree in physics, has worked in the energy industry for 25 years. He joined the Council of Industrial Boiler Owners (CIBO) on January 1, 1995, and was named president on July 1, replacing Bill Marx, CIBO's founder.

His past activities include: 7 years with a boiler manufacturer working with aspects of sales for industrial and utility power plants; 11 years working with major coal companies in applications, technical service, and technology development; and 7 years as a consultant specializing in fuel and technology evaluation, application and development, and problem solving for the energy industry.

Stemming from his involvement with virtually all fuels, technologies, and problems over the full range of industrial and utility applications, Mr. Bessette has written numerous papers and presented short courses on fuels utilization, evaluation, and application; he also contributed the greater portion of the coal technology section of *Wiley's 1985 Energy Systems Handbook.*

Michael Carter

Michael Carter is a research and development engineer with Duke Power Company. His areas of responsibility include renewable energy technologies, including biomass and waste fuels. Mr. Carter's particular interest involves cofiring with coal in PC boilers.

Lee Cunningham

Lee Cunningham, a partner at Gardner, Carton & Douglas, has been practicing solely in the area of environmental law for 15 years. He was the assistant to the chairman of the Pollution Control Board from 1980 through 1987, and has been in private practice since that time. Mr. Cunningham is chair of the Process Engineered Fuels Committee of the Pellet Fuels Institute, and has represented various clients on issues related to pellet fuels.

Betsy Curlin

Betsy Curlin has 10 years of experience in design engineering/R&D with Duke Power Company in Charlotte, North Carolina. She is a registered mechanical engineer in North Carolina. She spent 3 years with the Argonne National Laboratory (ANL) in the energy systems division of the industrial & power technologies section. She was also chair of ANL's utility committee.

Kenneth Daugherty

Kenneth Daugherty received his B.S. degree in chemistry from Carnegie Tech (Carnegie-Mellon University), and his Ph.D. in analytical chemistry (minor in ceramic engineering) from the University of Washington. He worked at Rohm and Haas Corporation prior to serving in the military. Dr. Daugherty served two years in the army as captain and section chief of an analytical laboratory at Aberdeen Proving Ground (APG). He is a full colonel in the U.S. Army Reserve and consults regularly for the Toxic and Hazardous Material Agency at APG. He has consulted on many hazardous waste problems including superfund sites and incineration methods.

Dr. Daugherty has a Master of Business Economics in international economics from Claremont Graduate School. He was a tenured associate professor of analytical chemistry at the University of Pittsburgh. Following that, he was director of research and development at General Portland, Inc.–Canada Cemet Lafarge in Dallas, Texas. In September of 1986, he was named Distinguished Research Professor. In 1992, he was named Regents Professor, the highest professorship on campus.

His university research programs have generated over 90 refereed publications and are concerned with the studies of energy and materials science, chemically bonded ceramics, hazardous wastes, forensic science, construction materials, air pollution control, catalysis in calcination processes, lipid chemistry, and analytical techniques.

Dr. Daugherty is active in: four committees of the American Society for Testing and Materials; the American Ceramic society; Sigma Xi; and the polymer and analytical divisions of the American Chemical Society. He is also a member of honorary scientific societies.

Roger Davis

Roger Davis began his professional career as a college professor, spending more than 10 years specializing in state, local, urban and regional planning, and federal grants administration. He also worked for 6 years in construction management of heavy industrial facilities and private sector development, primarily in energy-related products. More recently, Mr. Davis has been serving as director of government relations for one of the largest solid-waste-recycling, compost, and refuse-derived fuel facilities in the United States. Overall, Mr. Davis brings over 21 years of management experience to the Institute.

William Demarest, Jr.

William Demarest, Jr. is a partner in the Washington, D. C. office of Holland & Hart. His practice is focused on energy and environmental law and legislation.

Mr. Demarest is a magna cum laude graduate of Boston College Law School where he was a Presidential Scholar and articles editor of the Law Review. His undergraduate degree is from the University of Scranton, where he

majored in chemistry and graduated with honors. Following graduation from law school, Mr. Demarest clerked for the Honorable Ruggero Aldisert of the U.S. Court of Appeals for the Third Circuit.

Following his judicial clerkship, Mr. Demarest was appointed counsel to the Select Committee on Small Business of the U.S. House of Representatives. In that position, Mr. Demarest staffed hearings on petroleum marketing and other energy issues. In 1975, he was appointed counsel to the Subcommittee on Energy and Power of the House Committee on Interstate and Foreign Commerce (now the Committee on Commerce) chaired by Representative John Dingell. Mr. Demarest worked on numerous energy bills during the mid-1970's, including oil price and allocation and energy conservation bills.

In private practice Mr. Demarest has represented clients in a wide range of administrative, legislative, and ligation matters. This work has included representing clients in various administrative proceedings involving energy and environmental issues, and on energy and environmental legislation pending before Congress. He also has represented clients in judicial proceedings to review agency actions under the Administrative Procedure Act.

Mr. Demarest is a member of the Massachusetts Bar, the D.C. Bar, the bars of the Courts of Appeals for the Fifth, Tenth, Eleventh, Federal and District of Columbia Circuits, the bar of the court of International Trade, and the bar of the U.S. Court of Federal Claims. Mr. Demarest is also a member of the American Bar Association and the Federal Energy Bar Association.

Michael Fisher

Michael Fisher, Ph.D., is director of process technology for the American Plastics Council (APC), a joint initiative with the Society of the Plastics Industry, Inc. (SPI). Dr. Fisher is responsible for the development and implementation of technology programs in the areas of mechanical recycling, advanced recycling technology systems, and energy recovery. He joined APC in May of 1990.

Dr. Fisher is a graduate of Hobart College in Geneva, New York. In 1970, he received his doctorate in polymer and physical chemistry from the State University of New York College of Environmental Science and Forestry in Syracuse. He held postdoctoral appointments at the University of Uppsala, Sweden; the University of Notre Dame, South Bend, Indiana; and Northeastern University, Boston, Massachusetts.

His previous experience includes 15 years with American Cyanamid Company, where he held management positions in the United States and Europe in product and process research and development, technical service, manufacturing, and commercial development (all in the areas of polymer and resin products and technology).

Harry Francis

Harry Francis is technical manager of the National Lime Association and is responsible for information regarding the use of lime in refuse-derived fuel pellets.

Martin Frankenhaeuser

Martin Frankenhaeuser works as corporate coordinator of energy recovery for Borealis Polymers in Finland, and also for energy recovery with the Association for Plastics Manufacturers in Europe (APME). As part of his work, several full-scale cocombustion trials with various recovered fuels and coal have been performed and reported.

Simon Friedrich

The last five years, Mr. Friedrich has provided oversight and direction to the Department of Energy's Municipal Solid Waste (MSW) Program. A key activity has been the supporting the combustion of waste for energy recovery. This has include the development of pellet fuels derived from wastes. In support of this, the MSW program co-sponsored the densified refuse-derived-fuel and coal emission test at Big Stone, South Dakota and this conference. Simon considers pellet fuels as part of an integrated waste management strategy that includes both recycling and other energy recovery technologies including beneficial use of landfills gas.

Sarah Friedell

Sarah Friedell is associate director of marketing and communications for the American Plastics Council. She has been with the plastics industry since 1989, and has expertise in managing plastics recovery issues.

At the American Plastics Council, Ms. Friedell has directed advertising, marketing, and public relations programs at national as well as local levels. She has an expertise in strategic planning, goal setting, and measurements and currently oversees all communications related to the recovery of durable plastics goods. Ms. Friedell is also the staff executive for the Energy Recovery Task Force of the American Plastics Council, and, as such, manages the activities of that committee.

Ms. Friedell earned her Bachelor of Arts degree from the College of William and Mary in Williamsburg, Virginia, where she majored in English and sociology.

Sue Lawson Gonzales

Sue Gonzales will serve as the conference facilitator. She is a utility Policy analyst for R.W. Beck, specializing in facilitated policy dialogues and decision science. In this role, Ms. Gonzales draws on 14 years experience in the fields of resource and waste management. Serving as an adjunct professor at the University of Denver, she developed a course entitled environmental mediation and dispute resolution.

Don Goodman

Don Goodman is manager of technical projects for the Occidental Chemical Company (OxyChem) located at the Technical Center in Pottstown, Pennsylvania. As such, he is responsible for PVC R&D for Tenneco and Conoco.

Mr. Goodman has an A.B. degree in chemistry form Harvard. He has been awarded 24 patents in PVC and other polymer technologies. He has written three encyclopedic chapters on PVC and one chapter on vinyls recycling; he has also written several other publications. He is a frequent speaker at industry functions on topics ranging from fire science to solid waste management to PVC markets.

Mr. Goodman is active in the Vinyl Institute, the American Plastics Council (APC), SPI, SPE, and other industry groups. He will be speaking about his experiences and plans for plastics fuel pellets as developed in the (APC) Process Technology Committee and the APC Energy Recovery Project Team and Task Force.

Garry Griffith

Garry Griffith has a B.S. degree in civil engineering from the University of Toledo (1975), and an M.S., also in civil engineering, from the University of Hawaii (1978). He has 20 years of experience in the environmental engineering field, with 15 of those years in the paper industry. The G-P Big Island Mill has fired pellet fuel for 2 years. Mr. Griffith coordinated the air-permitting effort and worked with the pellet supplier (The Montcalm Company) to locate a pellet manufacturing facility near the paper mill.

Clark Harrison

Clark Harrison is the president of CQ Inc., a company that has developed and is commercializing E-Fuel technology. E-Fuel is a pellet fuel made from coal, paper-making by-products, and other nonhazardous combustible wastes; it is currently in use as an industrial boiler fuel.

Thomas Hassell

Thomas Hassell is a senior consultant for DuPont Energy & Environment Engineering. He provides all types of energy consulting services (design, procurement, operations, renewal) to DuPont's strategic business units and sites throughout the world.

Mr. Hassell is a member of DuPont's: corporate energy leadership team (and the group's strategy team); specialty chemicals energy team and energy strategy evaluation resource; white pigments technical team; and thermal treatment team. He is chairman of DuPont's acid gases emissions team, and coleader of DuPont's process safety management team for Dowtherm and Steam Systems. He is also a member of the American Plastic Council's Energy Recovery Task Force.

Before coming to DuPont, Mr. Hassel was a principal in his own successful undersea technology company. He spent 20 years in the submarine service of the U.S. Navy. He is qualified for command of nuclear submarines and is a naval nuclear chief engineer. He is a graduate of Purdue University with a B.S. in chemical engineering and attended the University of New Haven in the M.B.A. program.

Jim Hopla

Jim Hopla is the department manager of maintenance and facility operations for Lockheed Martin Idaho Technologies. He has been with the Idaho National Engineering Laboratory (INEL) and Idaho Chemical Processing Plant for 20 years. In March of 1995, he was involved in conducting a week-long test burn of densified refuse-derived fuel (DRDF) at the Laboratory's fluidized-bed, coal-fired, steam generating plant (supplemented 30% of coal/limestone feed with DRDF). Mr. Hopla is currently working through DOE to fund an "INEL Waste to Energy" project in FY-96 for "cold" waste at the INEL.

Shawn Hulst

Shawn Hulst is the controller and corporate office manager of The Montcalm Corporation (TMC). Mr. Hulst is involved with many day-to-day financial activities, but he is also heavily involved in the budgeting and forecasting of overall operations.

TMC recycles and recovers combustible postindustrial byproducts and residues normally destined for disposal in landfills. These are materials that cannot be separated cost effectively by traditional recycling services; they include coated papers, paper mill screen offs and sludges, films, adhesives, mixed plastics, fabrics, and wood materials. TMC converts these waste materials into a clean-burning pellet fuel known as Enviro-Fuel. Enviro-Fuel is an environmentally sound, cost-competitive fuel which is used as an alternative to coal or wood in industrial stoker-fired boilers. Enviro-Fuel burns cleaner than coal and produces less ash.

Joseph Malizia

Joseph Malizia has been in the waste business for 23 years, was Vice President at Cemtech of Richmond. Mr. Malizia built and operated a 60,000 ton per year capacity fiber fuels plant in Richmond VA.

Mr. Malizia works for Industrial Recycling Services, Inc. (IRSI) matches generators with markets for nontraditional recycling needs. IRSI works with industries involved in packaging, laminating, and production of products that leave a commingled paper and plastic waste that is suitable for production of fiber fuels or pellet fuels.

Robert Massengill

Robert Massengill is a graduate of Indiana University and has 36 years' experience in densification equipment. He is a cofounder of the Fiber Fuels Institute. In 1980- he oversaw the merger with the association of Pellet Fuels Industry. He is a five time President of Fiber Fuels Institute (now called the Pellet Fuels Institute).

Blake McBurney

Blake McBurney earned a B.S. degree in building construction from the Georgia Institute of Technology (Georgia Tech) in 1978. He has been employed by The McBurney Corporation since 1975. For over 80 years, The McBurney Corporation has provided engineering, procurement, construction, and maintenance services for boiler and power plant facilities. McBurney's nontraditional fuel-firing experience includes wood waste, peanut hulls, rice husks, bagasse, waste paper, industrial sludges, tire-derived fuel, waste gas, agricultural wastes, and plastics.

Mr. McBurney is currently an executive vice president with The McBurney Corporation. His previous experience and job functions within McBurney include design engineer, project engineer, site project manager, startup engineer and sales.
He is actively involved in: the American Boiler Manufacturers Association (ABMA); the Council of Industrial Boiler Owners (CIBO); the National BioEnergy Industries Association (NBIA); and the Technical Association of the Pulp & Paper Industry (TAPPI).

William McGraw

William McGraw is the plant technician at a fossil-fuel-fired electric generating plant. LG&E-Westmoreland is currently analyzing pelletized fuel to supplement coal in stoker-fired boilers.

Jeremy Metz

Jeremy Metz is director of the energy materials and technology departments of the American Forest & Paper Association (AF&PA). In this position, he manages an energy policy and technology program to lower the

industry's energy processes. Mr. Metz develops and articulates industry policy positions on energy, technology, and solid waste issues; directs industry involvement on their legal, legislative, and regulatory aspects; and serves as a liaison between the forest products industry and governmental officials and other industries on those issues.

Prior to joining AF&PA in 1983, Mr. Metz was an environmental attorney for Envirosphere Company, the environmental consulting division of Ebasco Service, Inc. He received a Juris Doctor degree from Hofstra University School of Law in 1982, and a Bachelor of Arts degree in bio-psychology from the State University of New York at Albany in 1977. He is admitted to the Bar of the State of New York and the U.S. District Court for the Southern District of New York.

Nathan Mundy

Nathan Mundy is president of LMI Associates, an independent marketing representative for Lundell Manufacturers. The company specializes in waste separation and pelletizing systems, and successfully lobbied to have wastepaper pellets declared a "recovered material," (and therefore count toward recycling goods) in South Carolina, Georgia, and Florida. He is currently working with several utility companies as a consultant on alternative fuels.

George Nassos

George Nassos was formerly the director of the fiber fuels division of Cemtech LP. While there, he was responsible for sales and marketing, operations, and project development for a company that operated pellet-fuel production plants (with a total capacity of 60,000 tons per year) in Menasha, Wisconsin, and Richmond, Virginia.

Dr. Nassos has more than 14 years of experience in the waste industry with WMX Technologies, Inc. and subsidiaries. His formal education includes a Ph.D. in chemical engineering and an M.B.A. from Northwestern University.

Edwin Niemann

Edwin Niemann is a principal engineer doing R&D with the plastics business unit of ARCO Chemical Company. He has 26 years of industrial experience, mostly in plastics R&D and applications development. While evaluating disposal options for class "7" plastics, the American Plastic Council suggested his company look into pellet fuel. His company's knowledge of this field is minimal.

Ole Ohlsson

Ole Ohlsson joined Argonne National Laboratory (ANL) in 1974. He served as project engineer for ANL's pressurized fluidized-bed combustor project, and as project manager for the design and construction of a high voltage electron microscope laboratory. He has been the project manager of ANL's municipal solid waste program since 1981 and project manager for ANL's recovery and reuse of fibrous solid waste program for the textile industry's AMTEX R& D program since 1994.

Prior to joining ANL, he was in the aerospace industry serving successively as project engineer for four major aircraft programs. He was chief engineer of the systems design branch of the Apollo Program with the National Aeronautics and Space Administration, and chief design engineer for the Viking Mars landing project.

Lance Olson

Lance Olson is a graduate of Monmouth College in Monmouth, Illinois and holds a B.A. degree in chemistry and a B.A. in Geology. His M.S. degree in analytical chemistry is from Governors State University in University Park, Illinois.

Mr. Olson has worked at Marblehead Lime Company since 1982. In 1992, he became the company's manager of technical services for quality systems, and in 1995 he was named vice president of sales and marketing.

He is a member of: the American Water Works Association; the Iron Steel Society–American Institute of Mining & Metallurgical Engineers; the National Lime Association–Technical Committee; and the Pellet Fuels Institute–Engineered Fuels Group.

Niranjan Patel

Niranjan Patel obtained his doctorate in chemistry from the Loughborough University of Technology in 1985. He then joined the Harwell Laboratory of AEA Technology and worked on the development of an industrial wastewater treatment process.

In 1989, he transferred to the Energy Technology Support Unit (ETSU) working on DTI-funded programmes on energy recovery from solid wastes. As manager of the wastes combustion and resource recovery section, he has undertaken various review and assessment studies on the technological, economic, and environmental aspects of energy recovery from waste combustion.

Dr. Patel is the UK representative to the International Energy Agency Activity on MSW and RDF Combustion.

Dean Pawlowski

Dean Pawlowski graduated from the University of North Dakota in 1991 with a B.S.M.E. degree. During his college career, he worked for Northern States Power at the Riverside Station in Minneapolis, Minnesota as an intern engineer. He began work as an engineer at the Big Stone Power Plant in May of 1991, and has been involved in the testing of alternative fuels.

Jim Pennington

Jim Pennington is business development manager for Warren & Baerg Manufacturing, Inc. When Mr. Pennington came to Warren & Baerg, he brought a unique combination of administrative, sales, and manufacturing experience with him. Throughout his lengthy career and association with four national corporations, he has been dedicated to two principles—to associate with a top-notch company and to deliver an excellent product. After starting at Warren & Baerg in 1988 as the plant operations manager, he blended his standard for product excellence with a thorough knowledge of the equipment and the manufacturing process.

With his promotions to sales manager and then business development manager, he now applies his technical knowledge and administrative skills to the cultivation of the cubing process in the waste-to-energy industry. Mr. Pennington has put together more than 18 projects and established successful corporate alignments that will maintain Warren & Baerg's leading position in the densified waste-to-energy industry.

Louis Perez

Louis Perez is Vice President of marketing and sales for Norton Environmental, which is part of the Dalad group. His responsibilities incorporate business development for recycling plants and expanding the marketing effort for future projects.

Prior to joining Norton Environmental, Mr. Perez was employed by Lindermann Recycling Equipment, Inc. Lindermann Recycling is a German-based manufacturer of recycling equipment, and one of the largest recycling equipment manufactures in the world. As regional manager for the northeast territory, Mr. Perez was responsible for equipment sales in that area. He also recruited several key dealers, which subsequently expanded the Lindermann dealer network. His knowledge of equipment and recycling systems integration can be attributed to hands-on field experience and his background in industrial engineering.

Mr. Perez's background in technical sales also includes the aluminum industry. As product manager of machinery and equipment for Pechiney World Trade, he was responsible for equipment sales in the United States and Canada. Other duties included technical support and marketing research for the aluminum industry. Pechiney is a French-based, billion-dollar company and is the third largest aluminum producer in the world.

Mr. Perez has international sales experience and speaks fluent Spanish. He received his Master of Business Administration from the New York Institute of Technology in 1994 while conducting a concentration in marketing. In 1990, Mr. Perez graduated with a Bachelor of Science in industrial engineering from the New York Institute of Technology. He also holds an Associates in Applied Science in machine tool technology from New York City Technical College.

Stephen Potter

Stephen Potter is an engineer who is involved in Duke Power's alternative fuels cofiring efforts. He is interested in pelletized fuels that are compatible with cofiring in "pulverized-coal" boilers using Raymond bowl mills. He is also interested in processes to shred alternative fuels prior to pelletizing.

Kathryn Powell

Kathryn Powell is a research associate with the University of South Carolina's Institute of Public Affairs, and is also the coordinator of the South Carolina textile industry pollution prevention project. Ms. Powell has a degree in mechanical engineering. This is her first involvement in pellet fuels.

Douglas Roll

Douglas Roll is presently manager of station operations at Greenidge Station (160 m, two units, coal-fired). He is project manger of the E-fuel Pelleting Project. This joint effort with CQ, Inc. involves making pellets from paper sludge and coal; NYSERDA funding is imminent.

Mr. Roll's experience includes serving as manager of mechanical engineering for NYSEG Corporate Engineering.

Philip Shepherd

Philip Shepherd is a senior project coordinator for municipal solid waste management (MSW) systems at the National Renewable Energy Laboratory (NREL). The MSW program at NREL focuses on the responsible and productive use of garbage as a renewable energy and materials resource. In this regard, NREL manages the MSW programs for the U.S. Department of Energy.

Mr. Shepherd's responsibilities include placing and managing the program's subcontracts, which includes work in data collection and analysis, technology developments, and technology transfer. He currently manages nearly 30 subcontracts with an annual budget of more than $3 million.

Establishing and maintaining relationships with industry and waste management officials in the public sector is another important component of his work. Mr. Shepherd is an active participant in planning annual meetings of the Solid Waste Association of North America and the Northeast Resource Recovery Association. One of his most important functions is communicating the results of many studies to decision makers and planners in the MSW management field.

Prior to joining NREL, Mr. Shepherd worked in the research laboratory of the Manville Corporation where he developed the fiberglass shingle. After moving into the marketing department, he introduced the fiberglass shingle and implemented programs that have made it the largest selling residential roof covering in the United States. Mr. Shepherd's final assignment with Manville was as director of a consortium of corporations registered under the National Cooperative Research Act. This consortium developed a commercial process for recycling factory asphalt roofing waste. This process has the potential of significantly reducing the volume of waste that ends up in landfills and to conserve a significant amount of energy.

Arun Singhania

Arum Singhania is the manager of Amoco's chemicals–polymers business group. His responsibilities involve the technical programs of plastics solid waste management of Amoco Polymers in Alpharetta, Georgia. He has also held positions in operations, engineering, and R&D with Amoco and other companies.

Mr. Singhania is a member of the Process Technology Committee and Energy Recovery Project Team of the American Plastics Council.

Jose Sosa

Jose Sosa is a senior research scientist for Fina Oil and Chemical Company. He has 25 years of experience in research (10 years academic, 15 years industrial) in the areas of synthesis, processing characterization, and recycling of thermoplastics.

Mr. Sosa has 32 publications in scientific journals, 16 patents in polymer processes, and more than 50 technical presentations at scientific meetings. He has managed long-range contract research with universities in the area of polymer characterization, and has evaluated technologies in the area of polymers. He is an internal consultant in polymer science.

Since 1992, Mr. Sosa has served as a representative to the American Plastics Council's Process Technology and Waste-to-Energy Committees. His first published work in 1972 on the subject of mechanical recycling.

Walter Stevenson

Walter Stevenson is a staff engineer with the Environmental Protection Agency (EPA). He has a degree in mechanical engineering from the University of Maryland.

Mr. Stevenson is a registered professional engineer and has been working on the EPA's new source performance standards (NSPS) program for 15 years. He has been involved in the development of various standards, including new source performance standards for utility and industrial boilers, and, most currently, standards for new and existing municipal waste combustors.

David Suhre

David Thomas Suhre is the utilities technical support supervisor at the Idaho Chemical Processing Plant (ICPP) at the Idaho National Engineering Laboratory (INEL) in Idaho Falls, Idaho. He currently has engineering responsibility for ICPP steam, water, and compressed air systems. His primary areas of expertise are in the operation of coal-fired, fluidized-bed steam power plants and steam distribution systems.

During his 12 years at the ICPP, he has worked as the steam plant engineer responsible for training operations and assisting with the start up of a new coal-fired, fluidized-bed boiler. Mr. Suhre holds a B.S. degree in chemistry from the College of Idaho and an M.S. in science teaching (chemistry) from the University of New Hampshire. He has a total of 16 years' experience in utility systems.

Gregg Sutherland

Gregg Sutherland earned an M.B.A. degree in strategic planning and decision sciences. He served as the vice president of the largest independent recycling company in North America at that time. He is now the national director of solid waste management for R.W. Beck. Mr. Sutherland consults with industry and local governments to plan and implement solid waste management systems, including the development of material and energy recovery systems. He cofacilitated the 1994 Pellet Fuel Forum, and has worked with national trade associations to assess the technical, financial, and regulatory viability of processed paper and plastic fuels.

R.W. Beck is a 600-person engineering consulting firm with offices across the country. The company also provides consulting services for water, power, and environmental compliance. Mr. Sutherland works in R.W. Beck's Denver Office.

Steven Timyan

Steven Timyan is the president and chief operating officer of The Montcalm Corporation (TMC). He has developed and maintained the vision of the company, overseeing marketing, product development, operations, finance, and customer service. He also approves all financial obligations; seeks business opportunities and strategic alliances with other companies and organizations; plans, develops, and establishes policies and objectives of business organization in accordance with board directives and company charter; and directs and coordinates financial programs to procure funding for new and continuing operations in order to maximize return on investments and increase productivity.

TMC recycles and recovers combustible post-industrial by-products and residues normally destined for disposal in landfills. These are materials that cannot be cost effectively separated by traditional recycling services; they include

coated papers, paper mill screen offs and sludges, films, adhesives, mixed plastics, fabrics, and wood materials. TMC converts these waste materials into a clean-burning, pellet fuel known as Enviro-Fuel. Currently, TMC has two manufacturing facilities, one located in Michigan and the other in Virginia. The company expects to add 15 –18 new facilities over the next 5 years, beginning in mid-1996. Enviro-Fuel is an environmentally sound, cost-competitive fuel used as an alternative to coal or wood in industrial stoker-fired boilers. Enviro-Fuel burns cleaner than coal and produces less ash.

Steven Viny

Steven Viny is currently president of the Norton Construction Company. He has a broad range of experience in the fields of solid waste management and construction including siting, landfill design and construction, landfill gas design and construction, permits, operations, and new legislation in the state of Ohio. Mr. Viny is also familiar with all phases of construction and is a principal in the ownership of over two million square feet of commercial, industrial, and historic real estate.

Mr. Viny was a pioneer in landfill gas management in the state of Ohio. In 1980, he designed and built a landfill gas migration control system at the Royalton Road Sanitary Landfill that is still in operation today. That system was later expanded to recover gas for the generation of electricity and for a medium-Btu fuel. He has assisted on the design and construction of other such facilities in the state including two systems for the city of Garfield Heights. In 1990, he became a Certified Cogeneration Professional by the Association of Energy Engineers. He has served on the Advisory Committee for the State and Local Government Commission Local Information Network and has served as an interested party to the Ohio EPA in developing BAT standards and new legislation.

He also served as a pioneer in the development of mixed-waste processing in the state of Ohio. He developed the Medina County Central Processing Facility, which, in its first year of operation, has already received international attention. He has published several articles and has spoken at many conference including Biocycle, SWANA and NRC.

Mr. Viny is a graduate of the Arizona State University, and has received several awards including the Special Award from the Association of Ohio Recyclers, SWANA Professional Achievement Award, and the 1994 Enterprise Development Inc. Innovation Award.

Guy Wentworth

Guy Wentworth is vice president of National Recovery Technologies, Inc (NRT). NRT's technology is used to remove contaminants from municipal solid waste streams.

Carlton C. Wiles

Since October 1993, Carlton Wiles has served as the program manager for the Municipal Solid Waste (MSW) Management Program at the National Renewable Energy Laboratory (NREL). This DOE-funded laboratory is located in Golden, Colorado, and is dedicated to the research, development, and implementation of renewable sources of energy.

The MSW program conducts studies to evaluate and develop technologies for the responsible management of MSW, including recycling, waste-to-energy, bioconversion, combustion-ash management, and landfill technologies. NREL is also managing DOE's RD&D activities for Action Item 37 of the Climate Change Action Plan, which is concerned with increased recovery and use of landfill gas.

Prior to his employment with NREL, Mr. Wiles was with the U.S. Environmental Protection Agency (EPA), where he managed numerous research programs concerned with MSW management (e.g., waste-to-energy, resource recovery, land disposal, recycling) and hazardous waste treatment (e.g., solidification/stabilization, land treatment, surface impoundment, remediation). These included the treatment, disposal, and use of waste-to-energy combustion residues.

In addition to managing the hazardous waste solidification/stabilization (s/s) research during his last several years at the EPA, Mr. Wiles also formulated and directed the agency's research program concerned with the characterization, treatment, disposal, and use of residues from combusting MSW. This included the more than $1.5 million study "Evaluation of Solidification/Stabilization Treatment Processes for Municipal Waste Combustion Residues," which involved participation by s/s vendors, national and international experts, and the Army Corp of Engineers.

Chuck Williams

Charles (Chuck) Williams, the Minnestoa Pollution Control Agency (MPCA) Commissioner, administers Minnesota's statewide environmental policy and regulations in the areas of air, water, solid waste, and hazardous waste. As commissioner, he represents the governor's office and the state on environmental regulatory issues.

Mr. Williams came to the MPCA in February of 1991 after serving as executive director of the Western Lake Superior Sanitary District (WLSSD) in Duluth for 4 years. At WLSSD he was responsible for all aspects of the facility's operations, which provide wastewater treatment and solid waste management for Duluth and surrounding communities. Prior to being appointed executive director, he was WLSSD's manager of maintenance and engineering.

During his career Mr. Williams has also worked as superintendent of mechanical maintenance at Reserve Mining Company, and as a plant superintendent for Harford Brick and Tile.

Ronald Williams

Ronald Williams is manager of special projects for Kimberly-Clark Corporation. His responsibilities include identifying waste-to-energy options as a landfill-diversion strategy for industrial wastes.

Chris Zygarlicke

Chris Zygarlicke is currently working as a research manager at the Energy & Environmental Research Center of the University of North Dakota; he has worked there for the last 7 years.

He received his M.S. degree in geology from the University of North Dakota in 1987, and his B.S. in geology from the University of Wisconsin in 1983. His principal areas of expertise include fossil and biomass fuel combustion, with a special emphasis on ash-related issues. His involvement in the area of pellet fuels has included research on developing techniques for assessing pellet-fuel quality as related to ash clinkering and fouling and air toxic metal emissions.

APPENDIX C:

ANNOTATED BIBLIOGRAPHY OF REFUSE-DERIVED FUEL (RDF) REFERENCES AND DENSIFIED REFUSE-DERIVED FUEL (DRDF) PELLET TEST FINDINGS

Annotated Bibliography of Refuse-Derived Fuel (RDF) References and Densified Refuse Derived Fuel (dRDF) Pellet Test Firings

Prepared for the:

Pellet Fuels Conference

Prepared by:

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I also wish to express my appreciation to Mr. Simon Friedrich, Program Manager, Municipal Solid Waste, U.S. DOE who provided funding support for the preparation of the individual literature references contained in the database.

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1.0 INTRODUCTION

This database of annotated references of Refuse-Derived Fuel (RDF) and Densified Refuse Derived Fuel (RDF) Pellet Test Firings was developed from publicly available literature sources. The literature sources which were used to develop this database included the following: National Technical Information Service (NTIS), U.S. Biomass Energy Research Abstracts, U.S. Department of Energy, Office of Industrial Technologies, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Government Printing Office, Knight-Ridder Information Service™, Trade and Industry™, Compendex*Plus™, Office of Scientific and Technical Information, and Energy SciTec. Over 280 citations are covered.

The database has been divided into two sections, the first section contains general RDF related references. Subject matter contained in this section include: references related to gaseous emissions and ash products resulting from the firing of RDF, both alone, and together with other fossil fuels; economic data relative to firing RDF; ash management resulting from the combustion of RDF; and, the comparison of RDF firing versus other methods of municipal solid waste disposal in terms of economic, environmental concerns, and financing considerations.

The second section contains citations of densified refuse derived fuel (dRDF) pellet test firings. The citations cover the combustion of 100 percent dRDF pellets as well as the firing of various blends of dRDF with coal. A variety of combustion systems are cited, including spreader stoker systems, cyclone fired units, fluidized bed combustors and pulverized coal fired units.

As noted earlier, all references cited in the database are in the public domain and may be obtained by contacting the publication source noted. However, a number of dRDF test burns have been funded by private companies and as a result may, or may not be made available to the general public. These citations have not been included in the database, but a listing of these trial burns is given for informational purposes in Section 2.3.

The database was completed with the assistance of a grant provided by the American Plastics Council.

2.0 DATABASE DESCRIPTION

The database was designed to be thorough yet flexible enough to allow the user to add additional references as necessary in the future. Each annotated reference contains six fields. The fields are labeled according to the type of bibliographic information they contain. Following is a list of these fields; title of the report, book, journal article or conference paper; author of the citation, or in the case of a conference paper, the person who presented the paper; source where the citation can be obtained; abstract of the citation's content and scope; abstract number; and keywords which will allow the user to search for the required citations.

Each reference is arranged in alphabetical order by author. Literature within the database can be searched, sorted and printed in a number of ways, including title, author, etc. A list of keywords was used to better categorize the citations. The preferred method of searching is by the use of keywords.

2.1 Keywords

The keywords field contains words or phrases used to categorize the references. A list of keywords that have been used to categorize the references is as follows:

1. **Gaseous emissions**
   - HCl emissions
   - Particulate
   - Flue gas emissions
   - Chlorine
   - Inorganic emissions
   - PCDD
   - PCDF
   - Dioxins
   - Toxic metals
   - Acid gas emission
   - Furans
   - RDF emissions
   - Mercury
   - Emissions

2. **Ash**
   - Flyash
   - Solid waste management
   - Ash residue
   - Trace metals
   - Ash
   - Metals
   - Metals emission
   - Ash residue
   - Ash management
   - TCLP

3. **Feedstock characteristics**
   - Thermodynamic data
   - RDF
   - RDF moisture content
   - RDF processing
   - Binders
   - Embrittlement agents
   - Binder enhanced RDF
   - RDF specifications
   - Deinking sludge
   - Waste characteristics
   - Biomass

4. **Combustion Systems**
   - Boiler performance
   - Cyclone furnace
   - Combustion
   - Operational
   - Boiler operations
   - Boiler efficiency
   - Performance
   - Fluidized bed combustion (FBC)
   - Incinerators
   - Mass burn
   - RDF combustion
   - RDF systems
   - Boiler operations
   - Cogeneration

5. **Conversion Systems**
   - Pyrolysis
   - Gasification

6. **Processing systems and characteristics**
   - Plastic processing systems
   - Processing
   - Conversion technologies
   - Resource recovery
   - Glass recovery
   - Metal recovery
   - Materials recovery facility
   - Shear shredders
   - Air classifier
   - Screens
   - System modeling
   - Computer model
   - Waste-to-energy plants
   - Recyclables
   - MSW

7. **Pollution control**
   - NO_x control
   - Continuous emission monitoring
   - Pollution control
   - Activated carbon systems

8. **Economics**
   - Economics
   - Contracts
   - Financing
   - Marketing
   - Cost analysis
   - Costs

9. **Permitting and Regulatory Issues**
   - CAAA 1990
   - Permitting
   - Regulatory issues
   - Regulations

10. **Feedstock Firing systems**
   - Co-combustion RDF/wood
   - RDF/coal cofiring
   - Cofiring RDF/coal
   - dRDF/coal
   - Cofiring
   - RDF cofiring

11. **Plastics and Industrial waste**
   - Industrial waste
   - Waste plastics
   - Applications of waste plastics
   - PVC
   - PE

12. **Research and development**
   - Research plans
   - R&D

The user is not limited to the above. If new keywords are needed to describe a new citation, they can be added by inputting the new keyword into the field

2.2 Database System Requirements and System Use

The database was developed using Microsoft Word 6.0's Built-in-Database Commands. The first section of the database is designated RDF File and contains 253 abstracts. The second section designated TBS File contains 28 abstracts.

The files have been converted to Macintosh Word 6.0 format. The disk contained in the back of this report contains four files. These files are RDF and TBS for the IBM PC, and RDF MCW and TBS MCW for the MacIntosh. Instructions for opening and using the files are also included as a file.

The user is advised to consult the Word Manual to use Mail Merge and Database Commands to perform simple Search and Find routines. Since Word 6.0 does not function as a relational database, it does not have the capability of SQL or ACIs - 4th Dimension Databases. The File has six Fields; namely, Abstract No., Title, Author, Source, Abstract and Keywords. Simplified searches can be carried out in these fields.

Please call the Knight Owl Computers at 713-479-8507, if you experience problems with the disk.

2.3 Test Burns of dRDF Pellets Funded by Private Companies

Densified RDF pellet test burns have also been conducted at the following locations. These tests were generally conducted to satisfy compliance requirements and as such tend to address only those gaseous emissions and solid waste residues required by state regulatory agencies to obtain operating permits for the facilities. Because these test burns were funded by private companies and are not readily available to the general public, they have not been included in the database. All tests are arranged in chronological order.

1. Weyerhauser Corporation, Rothschild, Wisconsin. Tests conducted during 1988-1992 with dRDF and wood chips.
2. District Energy of St. Paul, Minnesota Tests conducted in 1989 with dRDF and coal.
3. Fort Howard Paper Company, Green Bay, Wisconsin. Tests conducted in 1989, 1990 and 1992. Cofired with dRDF, coal and wood chips.
4. Iowa Department of Natural Resources at John Deere Plant in Waterloo, Iowa. Test conducted in 1990. Cofired dRDF and coal.
5. Champion Paper Company, Sartell, Minnesota. Test conducted in 1990. Cofired dRDF and coal.
6. ADM, Walholla, North Dakota. Tests conducted with dRDF and coal. Conducted in 1990.
7. Minnesota Power Company, Duluth, Minnesota. Conducted in 1991. dRDF cofired with coal.
8. Cargill Company, Eddyville, Iowa. dRDF cofired with coal.
9. Georgia Pacific Co., Jarrett, Virginia. Conducted in 1991. Cofired with dRDF and coal.
10. International Paper Company, Texarkana, Texas. Conducted in 1992. Test burn conducted with dRDF and hog fuel.
11. Ohio Edison, Niles, Ohio. Cofired dRDF and coal. Tests conduced in 1993.
12. United Power/NSP, Elk River, Minnesota. Conducted in 1993. Cofired dRDF and coal.

3.0 LIST OF ABBREVIATIONS

APC	Air Pollution Control
BA	Bottom Ash
CAAA 1990	Clean Air Act Amendments of 1990
CO	Carbon Monoxide
dRDF	Densified Refuse-Derived Fuel
EP toxicity	Extraction Procedure Toxicity Test
FASR	Flyash Scrubber Residue
FBC	Fluidized Bed Combustor
HCl	Hydrochloric Acid
Hg	Mercury
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
NO_x	Nitrogen Oxides
PAC	Powdered Activated Carbon
PCDD	Polychlorinated Dibenzo-p-dioxin
PCDF	Polychlorinated Dibenzofuran
PE	Polyethylene
PVC	Polyvinyl Chloride
RDF	Refuse Derived Fuel

APPENDIX D:

US EPA CLEAN AIR ACT FACT SHEETS
(1) NEW MUNICIPAL WASTE COMBUSTORS, SUBPART EB STANDARDS OF PERFORMANCE

(2) EXISTING MUNICIPAL WASTE COMBUSTORS, SUBPART CB EMMISSIONS GUIDELINES

MAY -2 1996

Nov. 3, 1995

FACT SHEET

New Municipal Waste Combustors -- Subpart Eb Standards of Performance (1995)

APPLICABILITY

Subpart Eb regulates emissions from all new MWC[1] units at MWC plants with aggregate plant capacities greater than 35 Mg/day of MSW that commence construction, modification, or reconstruction after September 20, 1994. Plants with Federally-enforceable permits limiting the amount of MSW that may be combusted to less than 10 Mg/day are not subject to the rule.

BACKGROUND

Initial standards of performance for new MWC's were promulgated under subpart Ea of 40 CFR part 60 on February 11, 1991 (56 FR 5488). The subpart Ea standards were developed under section 111(b) of the Act as amended in 1977, and applied only to MWC units with greater than 225 Mg/day combustion capacity for which construction, modification, or reconstruction commenced after December 20, 1989. The subpart Eb standards were developed under sections 111(b) and 129 of the Act as amended in 1990 and (1) reflect MACT; (2) regulate emissions of nine listed pollutants; (3) include siting requirements; and (4) apply to MWC's with capacities to combust greater than 35 Mg/day of MSW. The subpart Ea and Eb requirements do not overlap and apply to different MWC populations. Subpart Ea now applies to MWC's constructed, modified, or reconstructed between December 20, 1989 and September 20, 1994. Subpart Eb applies to those MWC's constructed, modified, or reconstructed after September 20, 1994. The subpart Eb standards are more stringent than the subpart Ea standards.

MUNICIPAL WASTE COMBUSTOR SIZE CATEGORIES

New MWC's located at plants with aggregate plant capacities to combust more than 35 Mg/day of MSW are subject to provisions for GCP, emission limits, and siting requirements under subpart Eb. The subpart Eb standards do not apply to new MWC's at MWC plants with aggregate plant capacities to combust 35 Mg/day or less of MSW.

---

[1]Abbreviations are defined at the end of this fact sheet.

The subpart Eb standards subcategorize the population of new MWC's into two size categories: (1) MWC's located at MWC plants with aggregate plant capacities to combust more than 35 Mg/day of MSW but less than or equal to 225 Mg/day of MSW (referred to as small MWC plants), and (2) MWC's located at plants with aggregate capacities to combust more than 225 Mg/day of MSW (referred to as large MWC plants). Slightly different requirements apply to each source category.

REGULATED POLLUTANTS

The subpart Eb standards establish requirements for MWC metals (PM, Cd, Pb, Hg, opacity), MWC organics (dioxins/ furans), MWC acid gases (SO2, HCl), MWC operating practices (CO, flue gas temperature, load level), NOx, and MWC facility siting requirements. The standards also require control of fugitive ash emissions.

EMISSION LIMITS

Subpart Eb numerical emission limits and operating standards are summarized in the attached table -- Summary of Standards for New MWC's. Additional discussions of the operator training and certification and siting requirements are presented below.

Operator Training and Certification

The operator training and certification requirements under subpart Eb are more stringent than the subpart Ea requirements. Under subpart Eb, all MWC chief facility operators and shift supervisors are required to obtain full operator certification from the ASME or an equivalent State program within 1 year after promulgation or 6 months after MWC startup, whichever is later, or, within the same timeframe, be provisionally certified and be scheduled to take the full certification exam. Additionally, the standards allow a control room operator who has obtained provisional certification from ASME or a State program to "stand in" during times the chief facility operator or shift supervisor is offsite. A certified individual must be onsite at all times while the MWC is operating. All MWC chief facility operators, shift supervisors, and control room operators are required to complete the EPA or a State MWC operator training course. Also, the standards require that a site-specific training manual be developed for each MWC. Each MWC employee involved with the operation of the MWC is required to review the training manual developed for the MWC. The site-specific manual and training are required to be updated annually. (The site-specific training requirements are unchanged from the subpart Ea standards.)

Siting Requirements

The siting requirements include preparation and submittal of a materials separation plan and siting analysis, as well as public meeting requirements. The siting requirements require the owner or operator of a planned facility to prepare a materials separation plan, which must include a strategy for materials separation activities for the area served by the MWC. The materials separation plan is to be tailored to the area served by the MWC and does not have to be uniformly applied to the service area. Additionally, the standards do not include any prescriptive performance levels, program types, or materials specifications for collection. All of these factors can be considered in the public hearing process and incorporated into the design and sizing of the MWC. The public meetings are held early in the planning process.

In order to limit potential risks to public health and the environment, the standards require MWC owners or operators to conduct and prepare a siting analysis of the impact of the proposed facility on ambient air quality, visibility, soils and vegetation, and other factors that may be relevant in determining the benefits of the proposed facility and the environmental and social costs imposed by the facility.

The MWC owner or operator is required to make the siting analysis and materials separation plan available to the public and the EPA (or State) for review. Two public meetings are to be held for public review of the materials separation plan. The second public meeting may also address the siting analysis. The first public meeting will cover the preliminary draft materials separation plan. The final draft materials separation plan and the summary of responses to public comments about the plan are to be submitted to the EPA prior to submittal of the MWC's application for a construction permit under New Source Review (NSR) (40 CFR part 51, subpart I, or part 52, as applicable). The second public meeting is to be held after submission of the application for a construction permit under NSR, and is to cover both the siting analysis and final draft materials separation plan. The siting analysis, the final materials separation plan, and the summary of responses to public comments on the siting analysis and the final draft materials separation plan are to be submitted as part of the initial notification of construction.

Nov 3, 1995

FACT SHEET

Existing Municipal Waste Combustors -- Subpart Cb Emission Guidelines (1995)

APPLICABILITY

The subpart Cb emission guidelines apply to existing MWC's[1] with aggregate plant capacities to combust greater than 35 Mg/day of MSW, that commence construction, modification, or reconstruction on or before September 20, 1994. Municipal waste combustors that commenced construction between December 20, 1989 and September 20, 1994 are also subject to the requirements of the subpart Ea standards of performance for new sources.

The intent of the guidelines is to initiate State action to develop State regulations controlling MWC emissions from existing MWC's. Modification of an existing MWC to comply with State regulations that result from these guidelines would not bring an existing MWC unit under the standards for new MWC's. Plants with Federally-enforceable permits limiting the amount of MSW that may be combusted to less than 10 Mg/day are not subject to the guidelines. The State regulations developed in response to these guidelines would apply to about 370 existing MWC units located at about 180 existing MWC plants.

BACKGROUND

On February 11, 1991, subpart Ca guidelines were promulgated for MWC's with unit combustion capacities above 225 Mg/day (56 FR 5514). The subpart Ca guidelines were developed under section 111(d) of the Act. These subpart Cb guidelines are developed under both section 111(d) and section 129 of the Act as amended in 1990. Section 129 of the Act required that the 1991 guidelines be revised to: (1) reflect MACT; (2) specify guideline emission levels for additional pollutants not covered under subpart Ca; and (3) apply to MWC's with capacities to combust less than 225 Mg/day of MSW. Thus, the subpart Cb guidelines are more stringent and cover more MWC's than the subpart Ca guidelines. The subpart Ca guideline have been withdrawn and are replaced with the subpart Cb guidelines.

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[1]Abbreviations are defined at the end of this fact sheet.

The siting requirements (siting analysis, materials separation plan, and public meeting requirements) apply to all new MWC's located at plants with capacities above 35 Mg/day that apply for a permit for construction after the date of promulgation of the standards. The siting requirements do not apply to MWC's subject to subpart Ea.

COMPLIANCE, TESTING, AND REPORTING

The standards include testing and monitoring requirements for MWC acid gases (SO2 and HCl), MWC metals (PM, opacity, Cd, Pb, and Hg), MWC organics (dioxins/furans), MWC operating parameters (CO, load level, flue gas temperature), and NOx (the NOx testing and monitoring requirements apply only to MWC's at large plants). Sulfur dioxide, NOx, and CO are required to be measured using a CEMS. Opacity is required to be monitored using a COMS and measured by an annual visible emissions test. The standards also require annual visible emissions testing to determine compliance with the fugitive ash emissions requirements. Emissions of other pollutants are determined by an annual stack test. However, if an MWC at a small plant passes the annual performance test for PM, Cd, Pb, Hg, dioxins/furans, or HCl for three years in a row, it can elect not to conduct the annual test for that particular pollutant for the next two years. If any subsequent annual test indicates noncompliance for that particular pollutant, then annual testing will again be required until three annual tests in a row indicate compliance. In addition to this 3-year testing option, less frequent dioxin/furan testing is possible for small plants if all MWC units at a plant achieve emission levels lower than 7 ng/dscm total mass for two years in a row. If emissions are less than 7 ng/dscm total mass, only one unit must be tested per year. All MWC units at large plants are tested annually but, like small plants, reduced dioxin/furan testing would be allowed if all units at the plant demonstrated less than 7 ng/dscm total mass for 2 years in a row. Reporting requirements are annual; however, if any emission limits are exceeded, then semiannual reports are required.

SUMMARY OF STANDARDS FOR NEW MWC's (SUBPART Eb)a

Applicability

The final standards apply to new MWC units located at plants with capacities to combust greater than 35 Mg/day of residential, commercial, and/or institutional discards.b Industrial manufacturing discards are not covered by the standards. Any medical, industrial manufacturing, municipal, or other type of waste combustor plant with capacity to combust greater than 35 Mg/day of MSW and with a federally enforceable permit to combust less than 10 Mg/day of MSW is not covered.

Plant Size (MSW combustion capacity)	Requirement
≤ 35 Mg/day	Not covered by standards
> 35 Mg/day but ≤ 225 Mg/day (referred to as small MWC plants)	Subject to provisions listed below
> 225 Mg/day (referred to as large MWC plants)	Subject to provisions listed below

Good Combustion Practices

- Applies to large and small MWC plants.
- A site-specific operator training manual is required to be developed and made available to MWC personnel.
- The EPA or State MWC operator training course must be completed by the MWC chief facility operator, shift supervisors, and control room operators.
- The ASME (or State-equivalent) operator certification must be obtained by the MWC chief facility operator (mandatory), shift supervisors (mandatory), and control room operators (optional).
- The MWC load level is required to be measured and not to exceed 110 percent of the maximum load level measured during the most recent dioxin/furan performance test.

- The PM control device inlet flue gas temperature is required to be measured and not to exceed the temperature 17oC above the maximum temperature measured during the most recent dioxin/furan performance test.

SUMMARY OF STANDARDS FOR NEW MWC's (SUBPART Eb)a
(CONTINUED)

o The CO level is required to be measured using CEMS, and the concentration in the flue gas is required not to exceed the following:

MWC type	CO level	Averaging time
Modular starved-air and excess-air	50 ppmv	4-hour
Mass burn waterwall and refractory	100 ppmv	4-hour
Mass burn rotary refractory	100 ppmv	4-hour
Fluidized-bed combustion	100 ppmv	4-hour
Pulverized coal/RDF mixed fuel-fired	150 ppmv	4-hour
Spreader stoker coal/RDF mixed fuel-fired	150 ppmv	24-hour
RDF stoker	150 ppmv	24-hour
Mass burn rotary waterwall	100 ppmv	24-hour

MWC Organic Emissions (measured as total mass dioxins/furans)c

o Dioxins/furans (performance test by EPA Reference Method 23)	
Large and small MWC plants	13 ng/dscm total mass (mandatory)d or 7 ng/dscm total mass (optional to qualify for less frequent testing)e
o Basis for dioxin/furan limit	GCP and SD/FF/carbon injection

MWC Metal Emissions

o PM (performance test by EPA Reference Method 5)	
Large and small MWC plants	24 mg/dscm (0.010 gr/dscf)
o Opacity (performance test by EPA Reference Method 9)	
Large and small MWC plants	10 percent (6-minute average)
o Cd (performance test by EPA Reference Method 29)f	
Large and small MWC plants	0.020 mg/dscm (8.7 gr/million dscf)
o Pb (performance test by EPA Reference Method 29)f	
Large and small MWC plants	0.20 mg/dscm (87 gr/million dscf)

SUMMARY OF STANDARDS FOR NEW MWC's (SUBPART Eb)a
(CONTINUED)

o Hg (performance test by EPA Reference Method 29)f	
Large and small MWC plants	0.080 mg/dscm (35 gr/million dscf) or 85-percent reduction in Hg emissions
o Basis for PM, opacity, Cd, Pb, and Hg limits	
Large and small MWC plants	See basis for dioxin/furan limit
MWC Acid Gas Emissions	
o SO2 (performance test by CEMS)	
Large and small MWC plants	30 ppmv or 80-percent reduction in SO2 emissions
o HCl (performance test by EPA Reference Method 26)	
Large and small MWC plants	25 ppmv or 95-percent reduction in HCl emissions
o Basis for SO2 and HCl limits	See basis for dioxin/furan limit
Nitrogen Oxides Emissions	
o NOx (performance test by CEMS)	
Large MWC plants	150 ppmv, except 180 ppmv is allowed for the first year of operation.
Small MWC plants	No NOx control requirement
o Basis for NOx limit	
Large MWC plants	SNCR
Small MWC plants	No NOx control requirement
Fugitive Ash Emissions	
o Fugitive emissions (performance test by EPA Reference Method 22)	
Large and small MWC plants	Visible emissions less than 5 percent of the time from the ash transfer system except during maintenance and repair activities
o Basis for fugitive emissions limit	Wet ash handling or enclosed ash handling
Siting Requirements	
o Large and small MWC plants	(1) Siting analysis, (2) materials separation plan, and (3) public meetings (including response to comments)g

SUMMARY OF STANDARDS FOR NEW MWC's (SUBPART Eb)a
(CONTINUED)

Performance Testing and Monitoring Requirements		
o	Reporting frequency	Annual (semiannual if violation)
o	Load, flue gas temperature	Continuous monitoring, 4-hour block arithmetic average
o	CO	CEMS, 4-hour block or 24-hour daily arithmetic average, as applicable
o	Dioxins/furans, PM, Cd, Pb, HCl, and Hge,h	
	Large MWC plants	Annual stack test (see reduced testing option for low emitters of dioxins/furans)
	Small MWC plants	Annual or third year stack testi
o	Opacity	COMS (6-minute average) and annual stack test
o	SO2	CEMS, 24-hour daily geometric mean
o	NOx (large MWC plants only)	CEMS, 24-hour daily arithmetic average
o	Fugitive ash emissions	Annual test

a All concentration levels in the table are corrected to 7 percent O2, dry basis.

b Air curtain incinerators that combust only yard waste are subject only to an opacity limit. Air curtain incinerators that combust other MSW are subject to all requirements under the final standards (clean wood is not a MSW).

c Although not part of the dioxin/furan limit, the limit of 13 ng/dscm total mass is equal to about 0.1 to 0.3 ng/dscm in 2,3,7,8-tetrachlorinated dibenzo-p-dioxin toxic equivalents, based on the 1989 international toxic equivalency factors. The optional reduced testing limit of 7 ng/dscm total mass is equal to about 0.1 to 0.2 ng/dscm in 2,3,7,8-tetrachlorinated dibenzo-p-dioxin toxic equivalents, based on the 1989 international toxic equivalents.

d For MWC's constructed after September 20, 1994, but on or before September 22, 1997, the standard is 30 ng/dscm total mass for the first 3 years of operation of the MWC. After the first 3 years, the standard is 13 ng/dscm total mass. For all MWC's constructed after September 22, 1997, the standard at startup is 13 ng/dscm total mass.

e The standards include provisions that allow large and small plants to conduct performance tests for dioxins/furans on only one unit per year if all units at the plant achieve emission levels of 7 ng/dscm total mass for 2 consecutive years.

f Method 29 is scheduled to be promulgated in a separate notice in the near future.

g Two public meetings will be held for review of the materials separation plan. The first public meeting will focus on review of a draft materials separation plan. The draft materials separation plan and the summary of responses to public comments about the plan will be submitted to the EPA prior to application for a construction permit under New Source Review (NSR). A second public meeting will be held after submission of the application for a construction permit and will focus on both the final materials separation plan and the siting analysis. The siting analysis, the materials separation plan, and the summary of responses to public comments on the siting analysis and the materials separation plan will be submitted as part of the initial notification of construction.

h For Hg and dioxins/furans, the hourly carbon injection rate must be determined and compared to the hourly carbon injection rates established during the most recent performance tests for Hg and dioxins/furans. If the primary parameter(s) (e.g., screw feeder speed) used to estimate the hourly carbon feed rate falls below the rate established during either the Hg or dioxin/furan performance test, then the MWC owner or operator is required to notify the regulatory authority, and may be required to retest for dioxins/furans and mercury.

i The standards include provisions that allow small MWC plants to conduct performance tests for dioxins/furans, PM, Cd, Pb, Hg, or HCl every third year if the MWC passes the annual performance test for the pollutant for three years in a row. If any subsequent annual test indicates noncompliance, then annual testing will again be required until three annual tests in a row indicate compliance.

Abbreviations Used in this Fact Sheet and Summary Table

Act	=	Clean Air Act
ASME	=	American Society of Mechanical
Cd	=	cadmium
CEMS	=	continuous emission monitoring
CO	=	carbon monoxide
COMS	=	continuous opacity monitoring
GCP	=	good combustion practices
gr/dscf	=	grains per dry standard cubic foot
gr/million dscf	=	grains per million dry standard
HCl	=	hydrogen chloride
Hg	=	mercury
Mg/day	=	megagrams per day (1 Mg/day = 1.1
mg/dscm	=	milligrams per dry standard cubic meter (100 mg/dscm = 0.044 gr/dscf)
MSW	=	municipal solid waste
MWC	=	municipal waste combustor
ng/dscm	=	nanograms per dry standard cubic
NOx	=	nitrogen oxides
Pb	=	lead
PM	=	particulate matter
ppmv	=	parts per million by volume
RDF	=	refuse-derived fuel
SD/FF/CI	=	spray dryer/fabric filter/activated carbon injection
SNCR	=	selective noncatalytic reduction
SO2	=	sulfur dioxide
Total mass	=	total mass of tetra- through octa-

SUMMARY OF GUIDELINES FOR EXISTING MWC's (SUBPART Cb)a
(CONTINUED)

MUNICIPAL WASTE COMBUSTOR SIZE CATEGORIES

Existing MWC's located at plants with aggregate plant capacities to combust 35 Mg/day or less of MSW are not subject to State regulations required by the guidelines. Existing MWC's located at plants with aggregate capacities to combust more than 35 Mg/day are subject to State plans containing both GCP and air emission limits required by the guidelines.

The guidelines divide the population of existing MWC's into two size categories: (1) existing MWC's located at MWC plants with aggregate plant capacities to combust more than 35 Mg/day but less than or equal to 225 Mg/day of MSW (referred to as small MWC plants); and (2) existing MWC's located at MWC plants with aggregate plant capacities to combust more than 225 Mg/day of MSW (referred to as large MWC plants).

POLLUTANTS TO BE REGULATED

Consistent with section 129 of the Act, the subpart Cb guidelines establish emission limits for MWC acid gases (SO2 and HCl), MWC metals (PM, opacity, Cd, Pb, and Hg), MWC organics (dioxins/furans), MWC operating practices (CO, flue gas temperature, and load level), and NOx. Guideline emission levels are also included for fugitive ash emissions.

EMISSION LIMITS

The guidelines reduce emissions from MWC's by requiring States to develop regulations that would limit MWC emissions from existing MWC's at MWC plants with aggregate plant capacities greater than 35 Mg/day. The subpart Cb emission limits are equal to or more stringent than the subpart Ca limits adopted in 1991 for dioxins/furans, opacity, PM, SO2 and HCl. Emission limits have also been added for Cd, Pb, Hg, and NOx. For NOx, provisions have been added allowing States to include emissions averaging between MWC units at large plants and emissions trading between plants. In addition, the guidelines require visible emissions from ash handling to be limited to no more than 5 percent of the time. The guidelines have minor changes in the MWC operating practice guidelines as compared to the subpart Ca guidelines. Numerical emission levels and operating guidelines are summarized in the attached table -- Summary of Guidelines for Existing MWC's.

In addition, the guidelines require provisional ASME or State operator certification of the MWC chief facility operator and shift supervisors by 18 months after State plan approval for small plants and by 1 year after State plan approval for large plants or by 6 months after startup (small and large plants), whichever is later. The guidelines also require full ASME or State operator certification of the MWC

chief facility operator and shift supervisors by 18 months after State plan approval for small plants and 1 year after State plan approval for large plants or by 6 months after startup (small or large plants), whichever is later. Alternatively, State plans may require that chief facility operators and shift supervisors be scheduled to take the full certification exam within the same timeframe. The State plans may also allow control room operators who have obtained provisional certification from the ASME or a State program to "stand in" during times the chief facility operator or shift supervisor is offsite. A certified individual is required to be onsite at all times during operation of the MWC. The guidelines require that State plans require all MWC chief facility operators, MWC shift supervisors, and control room operators to complete the EPA or a State MWC training program. Also, the guidelines require that State plans require a site-specific training manual be developed for each MWC. Each employee involved with the operation of the MWC is required to review the training manual developed for the MWC. The site-specific manual and training are required to be updated annually.

COMPLIANCE, TESTING, AND REPORTING

The guidelines require that State regulations include testing and monitoring requirements for MWC organic emissions (dioxins/furans), MWC metal emissions (PM, opacity, Cd, Pb, and Hg), MWC acid gas emissions (SO2 and HCl), MWC operating parameters (CO, load level, and flue gas temperature), and NOx (the NOx monitoring requirements apply only to large plants). Sulfur dioxide, NOx, and CO emissions are required to be determined using a CEMS. Opacity is required to be monitored using a COMS and measured annually by a visible emissions test. The guidelines also require that State regulations require annual visible emissions testing to determine compliance with fugitive ash emissions requirements. Emissions of other pollutants are to be determined by an annual stack test. However, if an MWC at a small MWC plant passes all three annual performance tests in a 3-year period, then the MWC can elect not to conduct the annual test for that particular pollutant for the next two years. If any subsequent test indicates noncompliance, then annual testing is again required until three annual tests in a row indicate compliance. In addition to this 3-year testing option for small plants, less frequent dioxin/furan testing is possible for small and large plants if all MWC units at a plant consistently achieve emission levels lower than 15 ng/dscm for large plants and 30 ng/dscm for small plants. Other than this provision, all MWC units at large plants are to be tested annually. Reporting requirements are annual; however, if any emission limits are exceeded, then semiannual reports are required.

COMPLIANCE SCHEDULE

The guidelines require that State plans for large MWC plants include one of the following three retrofit schedules for compliance with the guideline requirements: (1) Full compliance or closure within 1 year following EPA approval of the State plan; (2) full compliance in 1 to 3 years following issuance of a revised construction or operation permit if a permit modification is required or in 1 to 3 years following EPA approval of the State plan if a permit modification is not required, provided the State plan includes measurable and enforceable incremental steps of progress toward compliance; or (3) closure in 1 to 3 years following approval of the State plan, provided the State plan includes a closure agreement. If a State plan allows the second or third scheduling options (i.e., more than 1 year), the State plan submittal to the EPA must contain post-1990 dioxins/furans test data for all MWC units at large plants under the extended schedule. (See § 60.21(h) of subpart B of 40 CFR 60 for additional information relating to measurable and enforceable incremental steps of progress toward compliance).

State plans for small MWC plants must require full compliance or closure with regulatory requirements in 3 years or less following issuance of a revised construction or operation permit if a permit modification is required, or within 3 years following EPA approval of the State plan if a permit modification is not required.

Due to recent concern about dioxin/furan and Hg emissions, the guidelines require that State plans include an accelerated compliance schedule for large plants for these two pollutants. Under the accelerated schedule, existing MWC units for which construction commenced after June 26, 1987 (i.e., those facilities equipped with spray dryer/fabric filters or spray dryer/electrostatic precipitators as required by the New Source Review program) and that are located at large MWC plants would be required to be in compliance with the dioxin/furan and Hg guidelines within 1 year following issuance of a revised construction or operation permit, if a permit modification is required, or within 1 year following approval of the State plan, whichever is later.

SUMMARY OF GUIDELINES FOR EXISTING MWC's (SUBPART Cb)a
(CONTINUED)

MWC Organic Emissions (measured as total mass dioxins/furans)

o Dioxins/furans (performance test by EPA Reference Method 23)

Large MWC plants	
MWC units utilizing an ESP-based air pollution control system	60 ng/dscm total mass (mandatory) or 15 ng/dscm total mass (optional to qualify for less frequent testing)c,d
MWC units utilizing a nonESP-based air pollution control system	30 ng/dscm total mass (mandatory) or 15 ng/dscm total mass (optional to qualify for less frequent testing)c,d
Small MWC plants	125 ng/dscm total mass (mandatory) or 30 ng/dscm total mass (optional to qualify for less frequent testing)c,d

o Basis for dioxin/furan limits

Large MWC plants	GCP and SD/ESP or GCP and SD/FF, as specified above
Small MWC plants	GCP and DSI/ESP

MWC Metal Emissions

o PM (performance test by EPA Reference Method 5)

Large MWC plants	27 mg/dscm (0.012 gr/dscf)
Small MWC plants	70 mg/dscm (0.030 gr/dscf)

o Opacity (performance test by EPA Reference Method 9)

Large and small MWC plants	10 percent (6-minute average)

o Cd (performance test by EPA Reference Method 29)e

Large MWC plants	0.040 mg/dscm (18 gr/million dscf)
Small MWC plants	0.10 mg/dscm (44 gr/million dscf)

SUMMARY OF GUIDELINES FOR EXISTING MWC's (SUBPART Cb)a
(CONTINUED)

o Pb (performance test by EPA Reference Method 29)e	
Large MWC plants	0.49 mg/dscm (200 gr/million dscf)
Small MWC plants	1.6 mg/dscm (700 gr/million dscf)
o Hg (performance test by EPA Reference Method 29)e	
Large and small MWC plants	0.080 mg/dscm (35 gr/million dscf) or 85-percent reduction in Hg emissions
o Basis for PM, opacity, Cd, Pb, and Hg limits	
Large MWC plants	GCP and SD/ESP/CI or GCP and SD/FF/CI
Small MWC plants	GCP and DSI/ESP/CI
MWC Acid Gas Emissions	
o SO2 (performance test by CEMS)	
Large MWC plants	31 ppmv or 75-percent reduction in SO2 emissions
Small MWC plants	80 ppmv or 50-percent reduction in SO2 emissions
o HCl (performance test by EPA Reference Method 26)	
Large MWC plants	31 ppmv or 95-percent reduction in HCl emissions
Small MWC plants	250 ppmv or 50-percent reduction in HCl emissions
o Basis for SO2 and HCl limits	
Large and small MWC plants	See basis for MWC metals
Nitrogen Oxides Emissions	
o NOx (performance test by CEMS)	
Large MWC plants	
Mass burn waterwall	200 ppmvf
Mass burn rotary waterwall	250 ppmvf
Refuse-derived fuel combustor	250 ppmvf
Fluidized bed combustor	240 ppmvf
Mass burn refractory	No NOx control requirementf
Other	200 ppmvf
Small MWC plants	No NOx control requirement
o Basis for NOx limits	
Large MWC plants	SNCR
Refractory MWC plants	No NOx control requirement
Small MWC plants	No NOx control requirement

SUMMARY OF GUIDELINES FOR EXISTING MWC's (SUBPART Cb)a
(CONTINUED)

Fugitive Ash Emissions	
o Fugitive Emissions (performance test by EPA Reference Method 22)	
Large and small plants	Visible emissions less than 5 percent of the time from ash transfer systems except during maintenance and repair activities
o Basis for fugitive emission limit	Wet ash handling or enclosed ash handling
Performance Testing and Monitoring Requirements	
o Reporting frequency	Annual (semiannual if violation)
o Load, flue gas temperature	Continuous monitoring, 4-hour block arithmetic average
o CO	CEMS, 4-hour block or 24-hour daily arithmetic average, as applicable
o Dioxins/furans, PM, Cd, Pb, HCl, and Hgc,g	
Large MWC plants	Annual stack test
Small MWC plants	Annual or third year stack testh
o Opacity	COMS (6-minute average) and annual stack test
o SO2	CEMS, 24-hour daily geometric mean
o NOx (large MWC plants only)	CEMS, 24-hour daily arithmetic average
o Fugitive ash emissions	Annual test

Compliance Schedule

o Large MWC plants

State plans for large MWC plants are required to include one of the following three retrofit schedules for compliance with the guideline requirements: (1) Full compliance or closure within 1 year following EPA approval of the State plan; (2) full compliance in 1 to 3 years following issuance of a revised construction or operation permit if a permit modification is required or in 1 to 3 years following EPA approval of the State plan if a permit modification is not required, provided the State plan includes measurable and enforceable incremental steps of progress toward compliance; or (3) closure in 1 to 3 years following approval of the State plan, provided

the State plan includes a closure agreement. If a State plan allows the second or third scheduling options (i.e., more than 1 year), the State plan submittal must include post-1990 dioxins/furans test data for all MWC units at large plants under the extended schedule. (See § 60.21(h) of subpart B of 40 CFR 60 for additional information relating to measurable and enforceable incremental steps of progress toward compliance).

State plans for large MWC plants are required to specify that all MWC's at large MWC plants for which construction was commenced after June 26, 1987 comply with the guidelines for Hg and dioxins/furans within 1 year following issuance of a revised construction or operation permit if a permit modification is required, or within 1 year following EPA approval of the State plan, whichever is later.

State plans for large MWC plants are required to specify that owners or operators of large MWC plants comply with the ASME (or State) operator training and certification requirements by 6 months after startup or 1 year after State plan approval by the EPA, whichever is later.

o Small MWC plants

State plans for small MWC plants must require full compliance or closure with regulatory requirements in 3 years or less following issuance of a revised construction or operation permit if a permit modification is required, or within 3 years following EPA approval of the State plan if a permit modification is not required.

State plants for small MWC plants are required to specify that owners or operators of small MWC plants comply with the ASME or State operator training and certification requirements by 6 months after startup or 18 months after State plan approval by the EPA, whichever is later.

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a All concentration levels in the table are converted to 7 percent O2, dry basis.

b Air curtain incinerators that combust only yard waste are subject only to an opacity limit. Air curtain incinerators that combust other MSW are subject to all requirements under the final emission guidelines (clean wood is not a MSW).

c The emission guidelines include provisions that allow large and small MWC plants to conduct performance tests for dioxins/furans on only one unit per year if all units at the MWC plant achieve an emission level of 15 ng/dscm total mass (large plants) or 30 ng/dscm total mass (small plants) for 2 consecutive years.