Project DISS (DIrect Solar Steam)

Present Status and Future Planning

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The DISS (DIrect Solar Steam) Project

DISS is a complete R+D program aimed at developing a new generation of Solar Thermal Power Plants with improved parabolic trough collectors and Direct Steam Generation (DSG) in the solar field, thus reducing costs while increasing the efficiency.

PROJECT PHASES AND PARTNERS:

- **DISS-phase I** (with E.U. financial support under JOULE contract JOR3-CT95-058)

  Duration: from January 1996 to November 1998

  Partners: CIEMAT, DLR, ENDESA, IBERDROLA, INABENSA, PILKINGTON, SIEMENS, U.E.FENOSA, ZSW

- **DISS-phase II** (with E.U. financial support under JOULE contract JOR3-CT98-277)

  Duration: from December 1998 to August 2001

  Partners: CIEMAT, DLR, ENDESA, IBERDROLA, INABENSA, INITEC, PILKINGTON, ZSW

- **DISS-phase III**: not yet decided in detail

The DISS (DIrect Solar Steam) Project

PROJECT TASKS :

- **Coordination and Management**

  Project coordination, contracting, controlling and reporting

- **Design and Implementation of the PSA DISS Test Facility**

  Design and implementation of a life-size DSG test facility at the PSA to investigate the three basic DSG processes (e.g. Once-through, Injection and Recirculation)

- **O&M of the PSA DISS test facility**

  Test campaign to evaluate the DSG processes under real solar conditions at the PSA

- **DSG Applied Research**

  Research on thermohydraulic aspects of the DSG process to optimise the technology

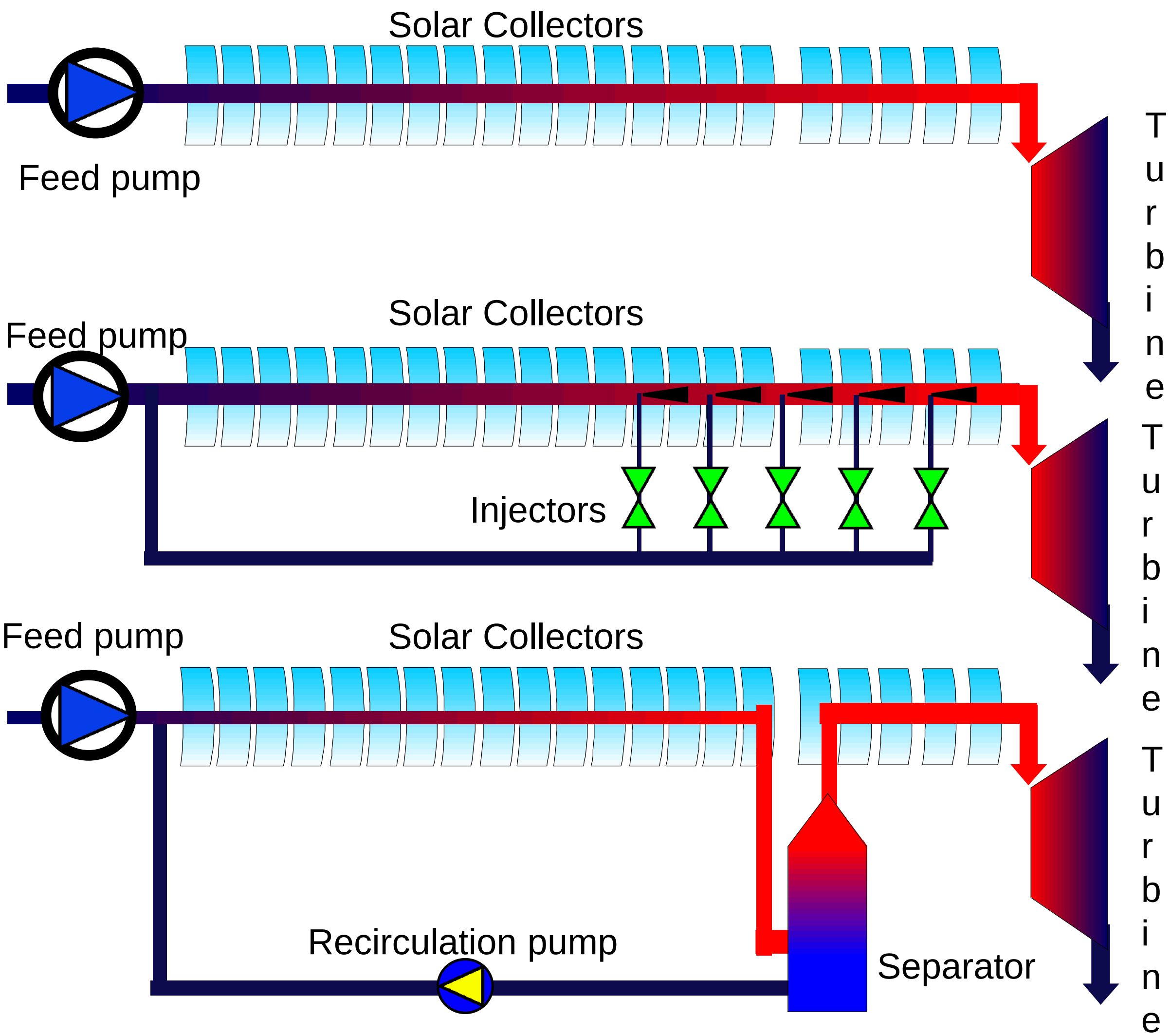
- **Collector Improvements**

  Development and testing of improved components for parabolic-trough collectors

- **System Integration**

  Study and design of different integration concepts for a solar DSG system, including control and cost analysis, as well as O&M issues.

The Three DSG Basic Options



Once Through Boiler

- Lowest Costs
- Least complexity
- Best Performance
- Controllability ?
- Flow Stability ?

Injection Process

- Better Controllability
- Flow stability equally good
- More complex
- Higher investment costs

Recirculation Process

- Better Flow Stability
- Better Controllability
- More complex
- Higher investment costs
- Higher parasitics

DISS-Phase I: achievements and findings

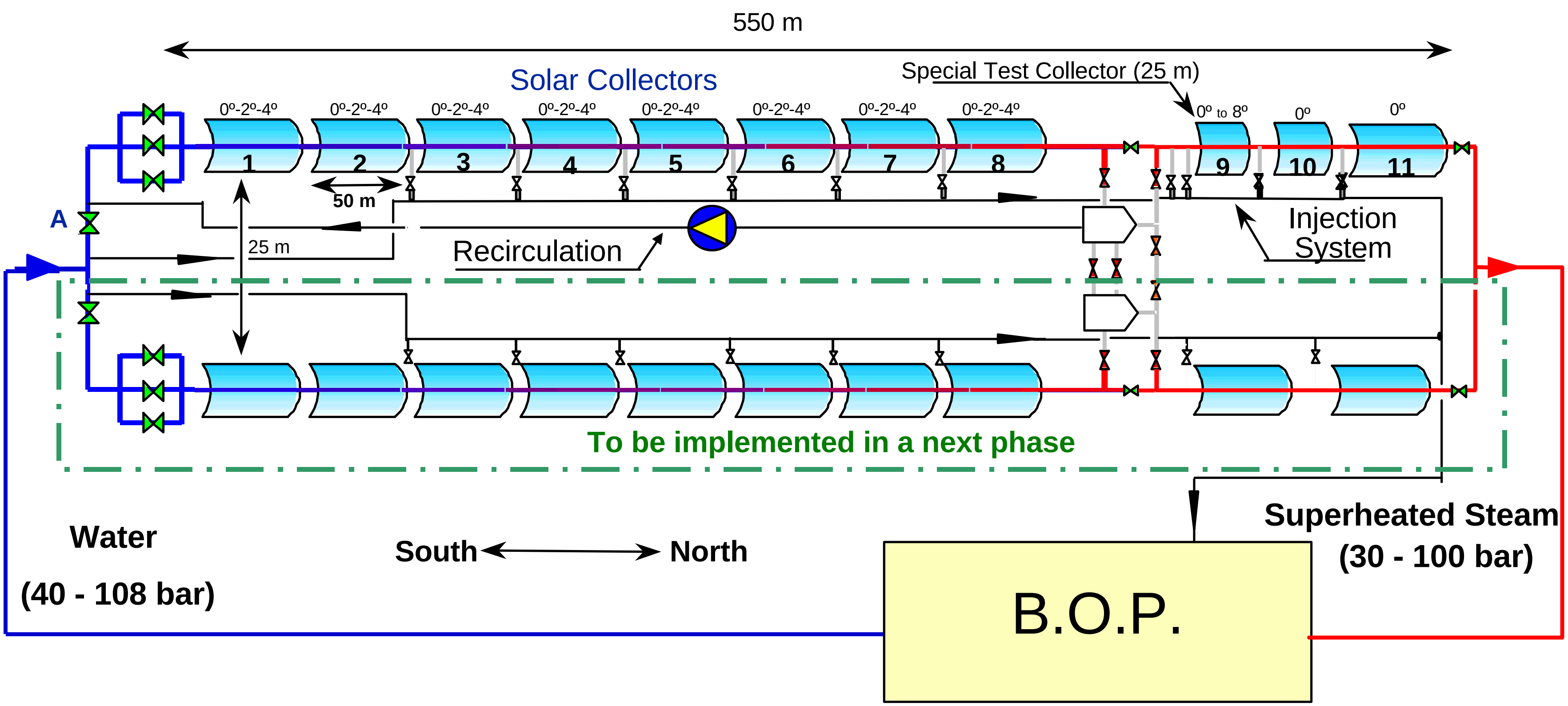
Task: “Design and Implementation of the PSA DISS test facility”

Objective: Design and implementation of a life-size test facility at the PSA to evaluate the three basic DSG processes (once-through, recirculation and injection) under real solar conditions

Achievements and findings:

- A single-row life-size test facility was implemented at the PSA to investigate the three DSG processes (it was inaugurated in April 1999)
- Significant extra cost and delay were faced during the implementation of the facility
- Selection of raw material for piping and vessels is very critical
- Technical specifications issued by LUZ in the past for LS-3 collectors must be updated in accordance to what is currently available at the market
- The use of several standards in the system design provoked mistakes

Actual Configuration of the PSA DISS Test Facility



The PSA DISS Test Facility

Aerial View of the PSA DISS Test Facility

Technical Characteristics of the PSA DISS Test Facility

No. of parabolic-trough modules	40
Module aperture/length:	5.76 m /12 m
No. of solar collectors	11
Total row length:	550 m
Inclination of the tracking axis:	0º,2º,4º,6º,8º
Orientation:	North-South
Absorber pipe inner/outer diameter:	50/70 mm
Mass flow per row (once-through configuration)	1 kg/s
Max. recirculation rate:	4
Max. outlet steam temperat./pressure:	400ºC/100 bar

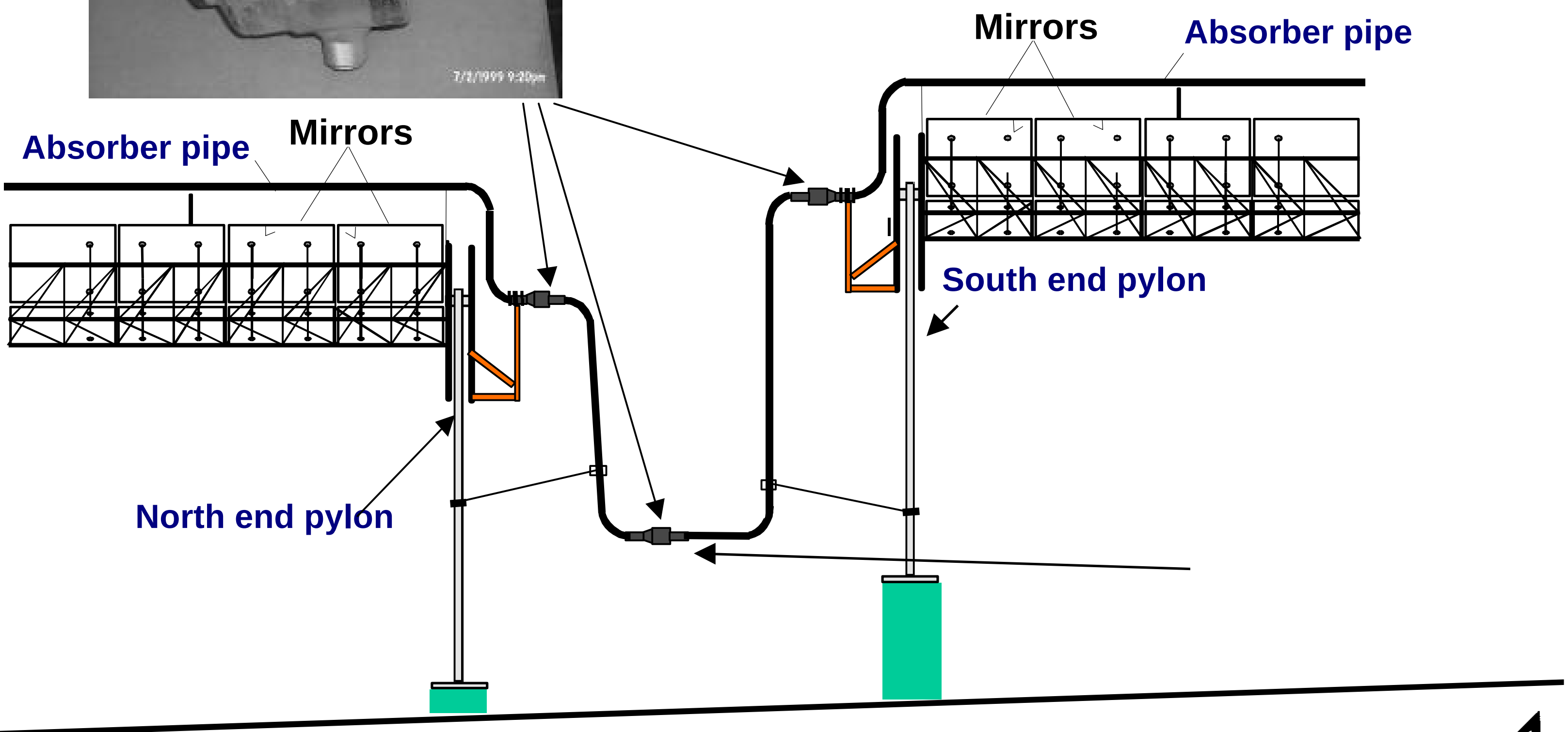
The PSA DISS Test Facility

FRONT VIEW OF ONE OF THE DISS COLLECTORS

The PSA DISS Test Facility

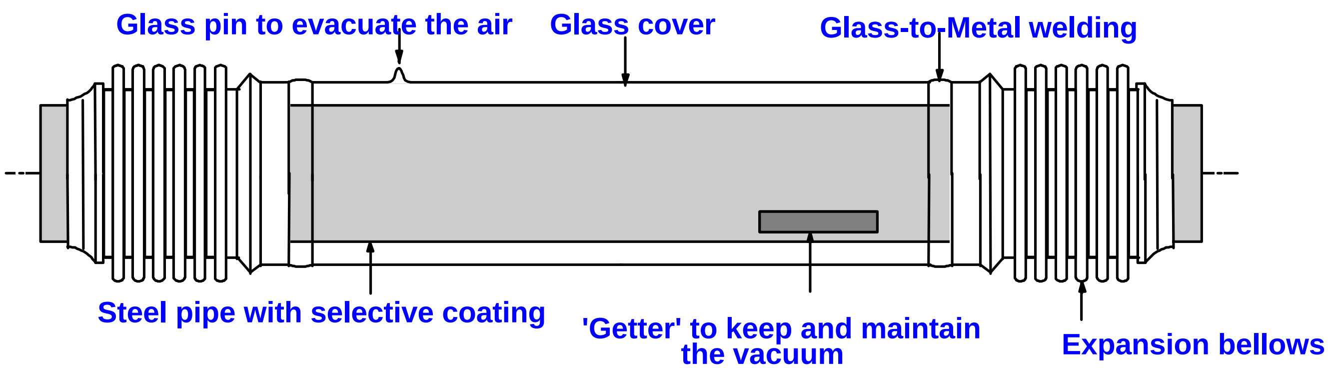
View of the BOP equipment

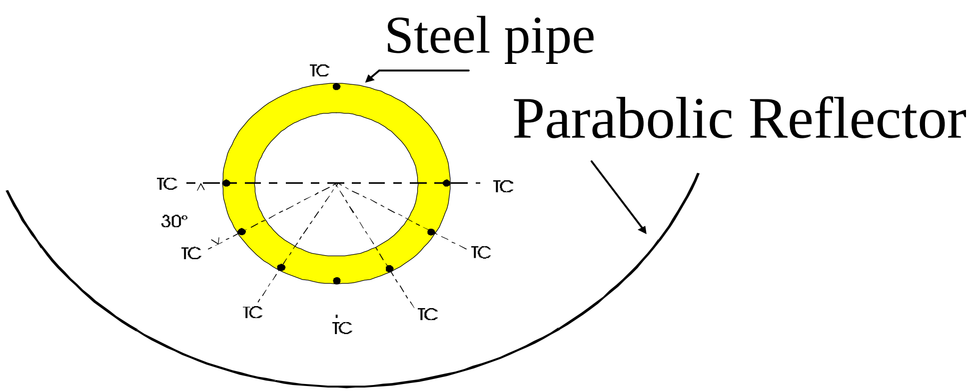
Ball-joints installed at the solar collectors



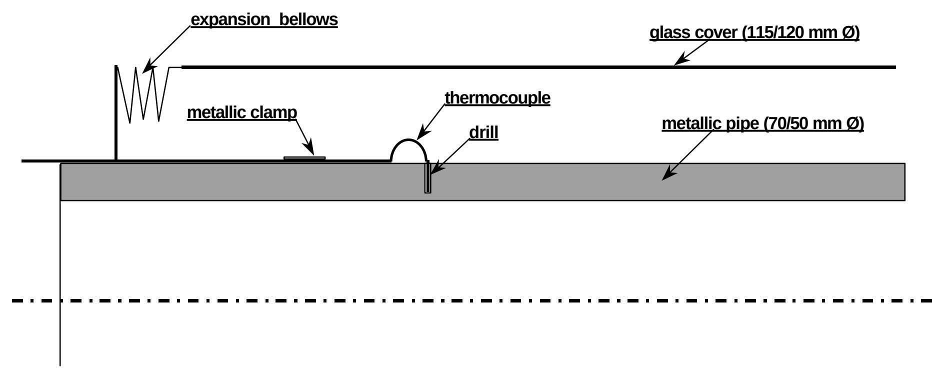
The PSA DISS Test Facility

The thermocouples installed at the absorber pipes
(the so-called Test Cross Sections)





Thermocouples lay out at a *Test Cross Section*



Thermocouple installation at a *Test Cross Section*

Task: "Collector Improvements"

Objective: Development and testing of improved components for parabolic-troughs

Achievements and findings:

- Front surface mirrors with ρ = 0.96 have been obtained with sol-gel technique
- Development of a new selective coating stable in air at 500ºC was almost completed
- Thin stretched metallic membrane does not seem a good option for parabolic trough concentrators.
- Economic comparison between selected HTF and advanced DSG systems was done
- A new sun tracking system developed at the PSA was implemented at the solar collectors It is based on calculation of the sun position by software
- A HTF test loop was implemented at the PSA to evaluate improved components. New absorbers and reinforced mirrors will be evaluated in DISS-phase II

The PSA HTF Test Loop

Task: “DSG Applied Research”

Objective: Investigation of thermohydraulic aspects of the DSG processes

Achievements and findings:

- Dynamic and static simulation models have been developed for the PSA test facility
- Special devices to measure the steam quality inside the absorbers have been developed
- Several ways to enhance heat transfer in DSG HCEs (*Tube inserts*, *Porous Coatings and microgrooves)* have been investigated with good results. A small test stand to evaluate porous coatings has been implemented
- Accurate simulation computer programs have been developed to predict temperature gradients at the absorber pipes, pressure drops and other two-phase flow parameters

Preliminary results of DISS-phase II

The test facility implemented at the PSA in the first phase was put into operation in 1999. Saturated steam at 100 bar and superheated steam at 350ºC/60bar have already been produced in recirculation mode without major problem. Nevertheless, some modifications are required to monitor the temperature gradients at the HCEs with accuracy. The thermal inertia of the facility has demanded an optimization of the operation procedure in order to shorten the start-up time. This required training, together with bad weather conditions and a failure of the recirculation pump in May 1999, has introduced a delay in the test campaign to be performed in the second phase of the project. The DISS test facility has proven its usefulness to investigate the DSG process under real solar conditions.

The Pieces to Electricity Cost Reduction

A) COLLECTOR IMPROVEMENTS:

- **Cheaper mirrors**
- **Better tracking system**
- **Lighter structures**
- **New absorber pipes**
- **More cost-effective cleaning procedure**

B) OVERALL SYSTEM IMPROVEMENTS:

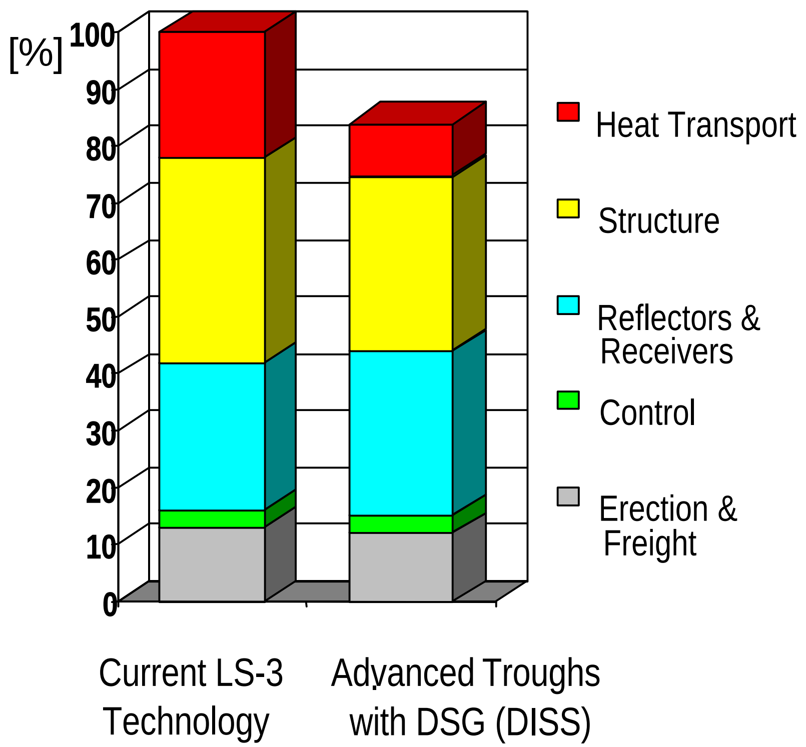
- **Better coupling between solar field and power block**
- **Advanced control system**
- **Optimised start-up and shut-down procedures**

C) DIRECT STEAM GENERATION (DSG) AT THE SOLAR FIELD

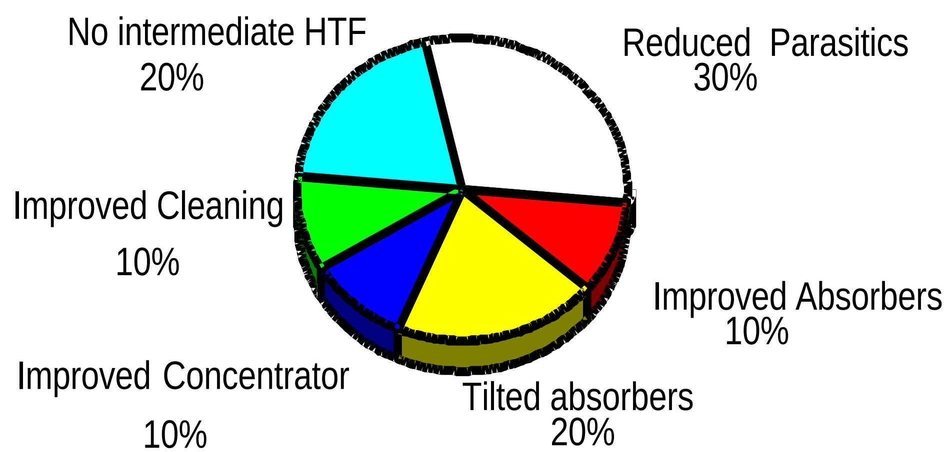
Expected Benefits (Cost reduction)

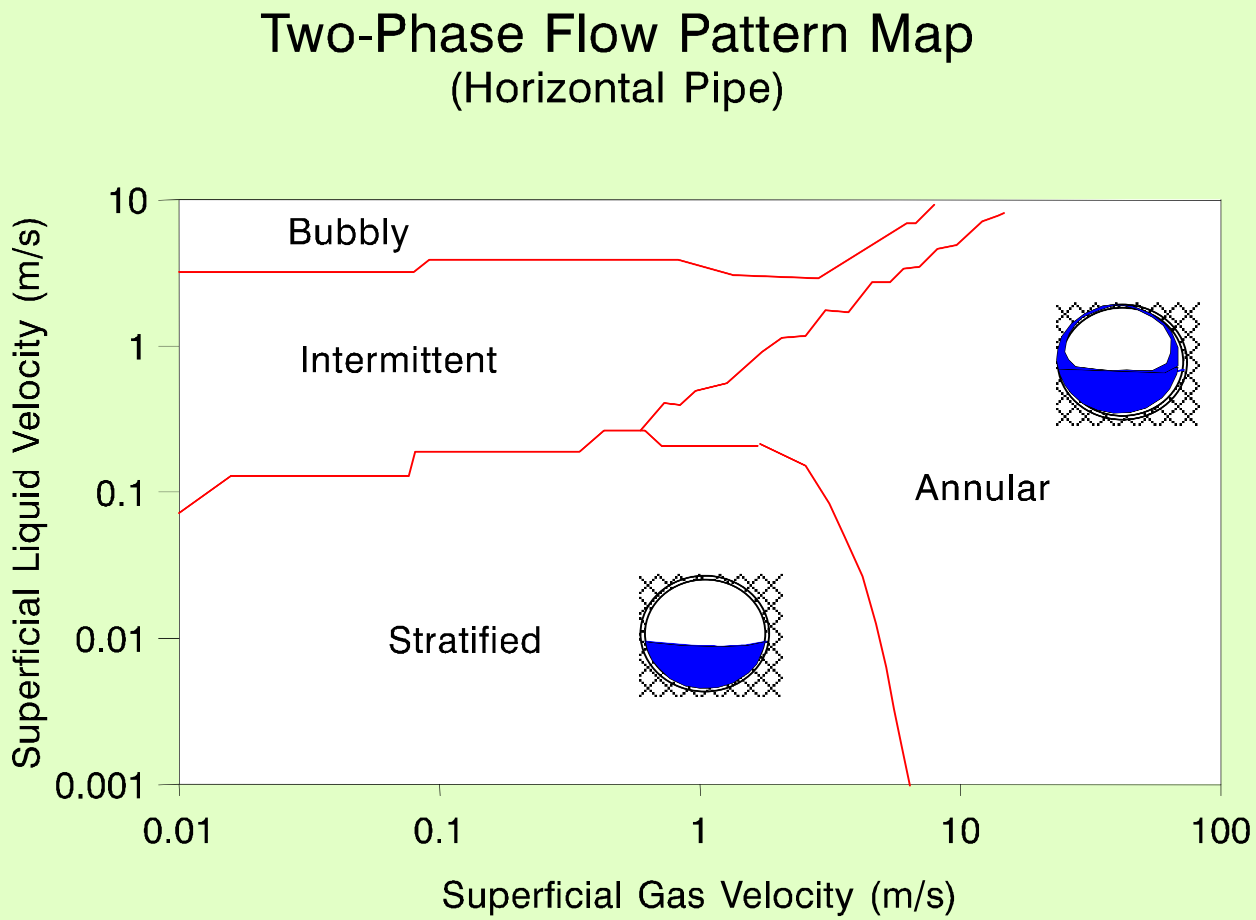
30% Levelized Electricity Cost (LEC) reduction

15 % Reduction of solar field investment cost



20% Increase of annual solar field output





Two-Phase Flow Pattern Map
(Horizontal Pipe)
Bubbly
Intermittent
Annular
Stratified
Superficial Liquid Velocity (m/s)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Superficial Gas Velocity (m/s)