Draft Trip Report

UKRAINE STEAM PARTNERSHIP:
Workshop on International experience of energy efficiency improvements of generation and consumption of heat in steam systems

January 16 – 19th, 2000, Kiev, Ukraine.

For

THE ALLIANCE TO SAVE ENERGY
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Prepared By

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February 15, 2000

PREFACE

The work described in this trip report was carried out by Mr. Gurvinder Singh within the framework of the U.S. Department of Energy (USDOE) Ukraine Steam Partnership program, under contract to Alliance to Save Energy.

This report summarizes the in-country activities of Mr. Gurvinder Singh during his trip to Kiev, Ukraine from January 16th to 21st, 2000. The author would like to acknowledge the assistance of Mr. David Jaber of the Alliance to Save Energy, Washington DC, who assisted in collecting valuable information for the use in the workshop, and Messrs. Artem Kharchenko, Andriy Vasylego of the Alliance office in Kiev and Mr. Alexander Gloukhov who manages Alliance activities in Russia for translating the workshop materials into Russian.

INTRODUCTION

The Ukraine Steam Partnership program is designed to implement energy efficiency improvements in industrial steam systems. These improvements are to be made by the private plants and local government departments responsible for generation and delivery of energy to end-users. One of the activities planned under this program was to provide a two-day training workshop on industrial steam systems focusing on energy efficiency issues related to the generation, distribution, and consumption of steam. The workshop was geared towards plant managers, who are not only technically oriented, but are also key decision makers in their respective companies.

The Agency for Rational Energy Use and Ecology (ARENA-ECO), a non-governmental, not-for-profit organization founded to promote energy efficiency and environmental protection in Ukraine, in conjunction with the Alliance staff in Kiev sent out invitations to potential participants in all the regions of Ukraine. Approximately 32 participants signed up for the workshop (Appendix 1) representing all of the major regions of Ukraine in a diverse range of industrial sectors.

(Note: In Appendix 1, delete the comments column and describe what each company is; some companies have names, but no descriptions)

The purpose of this report is the describe the proceedings from the workshop and provide recommendations from the workshop's roundtable discussion.

The workshop was broken down into two main areas:
- Energy efficient boiler house steam generation
- Energy efficient steam distribution and consumption

The workshop also covered the following topics.
- Ukrainian boilers
- Water treatment systems
- A profile of UKRESCO (Ukrainian Energy Services Company)
- Turbine expanders and electricity generation
- Enterprise energy audit basics
- Experience of steam use in Donetsk oblast

Mr. Gurvinder Singh prepared and presented the boiler steam generation portion of the workshop. Representatives from Armstrong International SA, Mr. Alexander Zygmuntowicz, Sales Manager for Eastern Europe and CIS, and Mr. Petrovich Soshnikov, a local representative in Ukraine, presented opportunities for saving energy in steam distribution and consumption of industrial operations. Local representatives from various other organizations made the remaining presentations, which covered the types of efficient steam system technologies currently available on the Ukrainian market and how these technologies can help solve common energy efficiency problems.

A day prior to the workshop, Mr. Gurvinder Singh met with the ARENA-ECO translators to discuss the main points of the presentations and to clarify the appropriate Ukrainian translation for some of the difficult and unfamiliar technical terms used in the presentation materials. Mr. Singh also met with the Armstrong team to ensure that the two presentations would not overlap. The following steps were taken to support the portion of the workshop related to boilers:

- All presentation materials were translated into Russian.
- A copy of the overheads translated into Russian was handed out to each of the workshop participants.
- Literature in Russian on boiler equipment from a U.S. boiler manufacturer (Cleaver-Brooks) was distributed to each participant.

The workshop was held at ARENA-ECO's offices on January 18th and 19th, 2000. The workshop was opened with a welcome address by Mr. Mykola Raptsun, President of ARENA-ECO, followed by a welcome and opening remarks by Mr. Tom Lemley, Resident Advisor of the Alliance to Save Energy in Ukraine.

Mr. Gurvinder Singh gave six presentations over the two days:

- Introduction to industrial boiler energy use in Ukraine and the U.S.
- Basic overview of boiler efficiency and combustion controls.
- Combustion efficiency improvements: boiler tune-up/maintenance.
- Combustion efficiency improvements: high efficiency burner systems and controls and stack heat recovery economizers.
- Metering equipment and insulation systems.
- Chemical treatment and blowdown heat recovery.

The overheads for these presentations are included in appendices 3-8.

PARTICIPANT QUESTIONNAIRE EVALUATION

Prior to the workshop, Mr. Gurvinder Singh gave the workshop participants a questionnaire. The purpose of this questionnaire was to collect information on the boiler types, sizes and existing energy efficiency practices to help tailor future workshops on boiler systems to the most prevalent boiler systems. A copy of the questionnaire is included in Appendix 9.

It is important to acknowledge that the original intent was to have the questionnaire completed before any boiler presentations were made; however, since some time was lost in the beginning of the workshop, the presentation material was given priority over the questionnaire. Thus, the answers to questions relating to energy efficiency (Question Nos. 9 and 10) may not be considered objective. Most of the answers reflect the topics that were covered in the boiler presentations.

Also, the number of responses to each question varies as not all questions were answered by all the participants. Therefore, it is difficult to establish correlation between the answers to the various questions. Thus, the answers can and should be interpreted keeping in mind the limitations.

In general, based on answers in the questionnaire and further discussion with workshop participants, the boiler characteristics for the plants represented at the workshop were as follows:

- The boiler operating pressure ranged from 200 psig upwards.
- The reported efficiency was generally near the mid-80s. The convention in Ukraine, as in Western Europe, is to use lower heating value (LHV) in calculating the energy efficiency. In the U.S., the convention is to use higher heating values (HHV), which result in equivalent energy efficiencies 6 to 11 percent lower then the Ukrainian boilers. Thus, the reported efficiencies when corrected to U.S. standard are mid-70s to 80, indicating that there is significant room for energy efficiency improvements.
- The average load numbers were hard to interpret, as the respondents did not specify whether the load was the average per boiler or for the total battery of boilers.
- The reported stack temperatures were very low. These are temperatures that are typically observed in systems that have economizer heat recovery systems. Based on the author of this report's prior experience of working in Ukrainian plants, these numbers appear very optimistic.
- The most common fuels were natural gas and mazout (No. 6 fuel oil). There were no boilers operated on coal. Although coke gas was reported, this was only used at the steel plants represented at the workshop.
- The level of excess air reported is not reliable as this topic was discussed in detail at the workshop and is likely to have biased the answer. Most respondents to the questionnaire answered that excess air levels were below 20 percent.
- The resources used to obtain information on operating boilers efficiently provide valuable insights. The resource used most was the one with the lowest score, since 1 was designated for *used most* and 5 stood for *used least*. The responses yielded the following results:

  - Guidelines from government agencies (Average score 1.83)
  - Boiler Inspector (Average score 2.28)
  - Boiler Manufacturer's Guidelines (Average score 2.62)
  - Boiler Operator Experience (Average score 3.12)

The boiler water treatment is handled by a separate department than the boiler operation department. There is a high probability that there is a communication gap between the boiler operation staff and the water treatment staff. It is likely that water treatment needs are not well established and could lead to improved operation.

INSIGHTS FROM ROUNDTABLE DICUSSION WITH PARTICIPANTS

Mr. Sergei Surnin, Executive Director of ARENA-ECO, led a roundtable discussion at the conclusion of the workshop. In general, the participants were enthusiastic about the workshop. The participants did provide some useful comments and suggestions for future workshops, which are outlined below.

- One participant suggested that more information on metering equipment be included in future workshops, due to the lack of good metering equipment available locally for industrial applications.
- There was also a suggestion to include hot water boiler systems in addition to steam boilers.

Other general comments were:

- Incorporate refrigerant and cooling systems into the workshop agenda.
- Increase the diversity of industry represented at the workshops.
- Target college level students to get them thinking about energy efficiency early in their careers.
- Provide more information on valves, as there are no good quality valves available in Ukraine.

CONCLUSIONS AND RECOMMENDATIONS

The steam and boiler workshop was well received; however, based on the questionnaire and feedback, the following recommendations are made regarding future workshops:

- The boiler materials were based on gas and oil fired boilers. These seem to be appropriate for Ukraine, as these fuels are the most common representative fuels used in Ukraine's industrial facilities.

- The main energy efficiency areas that were covered in this workshop are appropriate based on the reported efficiency levels. However, in future workshops, the main areas that can be addressed are combustion efficiency and water treatment/blowdown.

- Based on the response to the question of where the plant personnel receive their boiler energy efficiency data, there seems to be need for further research and investigation into the quality of the most commonly referenced resource for such data: government guidelines. The participants reported that they get their information from government guidelines followed by boiler inspectors. The boiler inspectors are most likely enforcing the government guidelines, although this is a speculation derived from the limited data we have from the questionnaire. It is recommended that these guidelines be obtained and evaluated, which is a task that will be proposed in a second year work plan for the Ukraine Steam Partnership. It is possible that the guildelines may be outdated, therefore it is necessary to update them to reflect the current technologies and practices, both considering what is presently available on the Ukrainian market and what corresponds to European and other Western standards. A carefully updated edition of the guidelines, as a joint effort of Ukrainian and Western experts, may be a good way to influence the boiler room practices in Ukrainian industries.

- It is conceivable there is a communication gap between the boiler operator and the boiler water treatment team. This must be studied to verify if indeed there is a gap. If a gap exists then the appropriate measures should be taken to better integrate the water treatment and boiler operation practices.

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Appendix 1
List of Participants

LIST of PARTICIPANTS
Steam Efficiency Workshop
January 18-19, 2000 Kyiv

No	Name	Company	Comments
1	**2**	**3**	**4**
1	Michael Boyko Deputy Chief Powerman	**Armyansk, JSC «TYTAN»**	
2	Oleg Bezsmertny Inspector	**Sumy, State Energy Conservation Inspection**	
3	Volodimir Vyfanyk Deputy Chief Designer	**Monastyrysche JSC «??K? ? »**	
4	Ivan Grygoryev Chief Engineer	**Romny Milk Plant**	
5	Valery Dubenko Chief Powerman	**Donetsk ?.?.?.**	
6	Dmytro Eremenko Chief Powerman	**Mariupol Sea port**	
7	Gennady Genylo Deputy Chief Engineer	**Mariupol Bakery plant**	
8	Alexander Zenkov Chief Powerman	**Krasnoperekopsk, JSC «Crimea soda plant»**	
9	Valery Zynovyev Engineer	**Donetsk JSV «?.?.?.»**	
10	Victor Yschenko, Deputy Chief Powerman	**Dniprodzherzynsk, Coke plant**	
11	Alexander Kyrichok, Head of Inspection Department	**Donetsk, State Energy Conservation Inspection**	
12	Mykola Kytaev ? ????? Deputy of the Head of Inspection Department	**Mariupol, State Energy Conservation Inspection**	
13	Mykola Korgyk, President	**Ivano-Frankivsk ESCO West**	
14	Sergey Korolyov, Engineer	**Sumy "OilGasTechnology"**	
15	Taras Levytsky Head of the Boiler House	**Mykolayiv Brewery «Yantar»**	

1	2	3	4
16	Victor Mykhaylichenko Chief Engineer	**Mykolayiv** **Alumina plant**	
17	Victor Mykhaylovksy Director	**Kyiv** **? ? ? ?? ? ?**	
18	Vasyl Movchan Head of the Department	**Sumy** **Chemical Plant**	
19	Alexander Novoseltsev Menager	**Kyiv,** **Ukr?SCO**	
20	Alexander Omelynsky Deputy Chief Powerman	**Mariupol** **AZOVSTAL**	
21	Vitaly Parafeynyk Chief Powerman	**Mariupol** **Illicha Plant**	
22	Igor Pydguyny Head of the Boiler House	**Yamnytsa** **Cement Plant**	
23	Alexander Razgyvin	**Malyn** **Paper Plant**	
24	Alexander Rogachevsky	Dnipropetrovsk **ARMSTRONG**	
25	Igor Sery Chief Powerman	**Kyiv** **«? VIANT»**	
26	Volodymir Strygonov Chief Engineer	**Donetsk** **Bakery plant No.3**	
27	Olga Toteva Engineer	**Kyiv** **? ? ? ?? ? ?**	
28	Alexander Khadgynov Director	**Mariupol** **«Energy Saving»**	
29	Oleg Sherbanov Deputy Chief Powerman	**Donetsk** **I&S Plant**	
30	Alexey Yurchenko Deputy Chief Powerman	**Pology** **Oil Extraction Plant**	
31	Lidia Yakimchuk	**Kyiv** **«? rgharchprom»**	
32	Igor Yarynovsky	**Kyiv** **«? rgharchprom»**	

Appendix 2
Schedule of Workshop

Alliance to Save Energy (USA)
Agency for Rational Energy Use and Ecology
ARENA-ECO (Ukraine)

SCHEDULE OF WORKSHOP

"International experience of energy efficiency improvement of generation and consumption of heat in steam systems".

January 18 – 19th, 2000.

First Day: 18th of January 2000

Time	**Title of report, content of measure**	Lecturer
9.00 – 10.00	Registration of participants	
10.00 – 10.20	Opening of workshop. Opening address.	Representatives of Alliance to Save Energy and the Agency for Rational Energy Use and Ecology
10.20 - 10.40	Problems of steam use in Ukraine	Representative of The State Committee of Ukraine for Energy Conservation
10.40 – 11.20	Boiler houses, steam production and consumption in USA. Measures to increase energy efficiency of steam boilers.	Representative of Alliance to Save Energy
11.20 – 11.40	Coffee break.	
11.40 – 12.20	Energy efficiency equipment in boiler houses. Combustion process. Fuel saving measures at steam production	Representative of Alliance to Save Energy
12.20 – 13.00	Steam from CHP or from own boiler house. Estimation on investments required for boiler house upgrade.	Representative of Armstrong
13.00 – 13.10	Questions and answers	
13.10 – 14.00	Lunch-break.	
14.00 – 14.40	Energy efficient steam systems	Representative of Armstrong
14.40 – 15.20	Videofilm "Let's talk steam traps/update" (main types and operating principles)	Armstrong
15.20 – 15.40	Coffee break.	
15.40 – 16.20	Boiler automatic control system. Burners control. Highly efficient boiler houses.	Representative of Alliance to Save Energy
16.20 – 17.00	Measures to reduce heat consumption. Equipment for heat recovery. Economizers.	Representative of Alliance to Save Energy
17.00 – 17.30	Gas-and-oil fired steam boilers, their types, characteristics and equipment, produced in Ukraine.	OJSC "Tekom" Monastyrische
17.30 – 18.00	About experience of preparing and implementing investment projects in industry of Ukraine	Volodymir Laskarevskiy Lead expert Agency for Rational Energy Use and Ecology (ARENA-ECO)
18.00 – 18.30	Organization issues.	
18.30 – 20.00	Reception	

Second Day: 19th of January 2000

Time	Title of report, content of measure	Lecturer
9.00 – 9.10	Discussion of first day information.	
9.10 – 9.50	Systems and units to measure gas, steam and condensate. Heat insulation of pipelines and equipment. 3? Plus Program.	Representative of Alliance to Save Energy
9.50 – 10.30	Equipment and feed water processing and monitoring methods	Representative of Alliance to Save Energy
10.30 – 11.10	Characteristics of domestic enterprises steam systems. Energy efficient steam distribution system. Characteristics of condensate drainage with the control of steam inflow.	Representative of Armstrong
11.10 – 11.30	Coffee break.	
11.30 – 12.10	Influence of steam quality on technological process. The right way to vent condensate. Diagnostics of steam traps state. Obtaining and consumption of second boiling steam.	Representative of Armstrong
12.10 – 12.30	Videofilm.	Armstrong
12.30 – 12.40	Questions and answers	
12.40 – 13.10	Domestic equipment for feed water monitoring	(ENVITEK Kyiv)
13.10 – 14.00	Lunch break	
14.00 – 14.20	Experience of steam consumption in Donezk oblast	Oleksandr Kirichok Chief of the oblast inspection on energy saving, Donezk city
14.20 – 14.50	Basics of process of production management and energy consumption (Energy management).	Representative of Armstrong
14.50 – 15.20	Enterprise energy inspection (Energy audit)	Volodymir Deriy Lead specialist Agency for Rational Energy Use and Ecology (ARENA-ECO)
15.20 – 15.35	Domestic designs for efficient steam consuming equipment. Turbine expanders.	Scientific and production enterprise "Naftagaztechnologiya" Sergiy Korolyov
15.35 – 15.50	Coffee break	
15.50 – 16.30	Round table. Questions and answers	Representatives of: -State Committee of Ukraine for Energy Conservation; -Alliance to Save Energy; -Agency for Rational Energy Use and Ecology
16.30 – 17.00	Workshop closing	

Appendix 3
Module 1: Introduction

MODULE 1: INTRODUCTION

Ukraine

??Energy intensity trend (Fig 1.1)
??Fuel prices
??Major energy consumption areas

USA

??Fuel used in manufacturing plants to produce steam (%)
??Manufacturing energy end-use (Fig 1.3)
??Estimated unmanaged steam system efficiency improver
(Fig 1.4)

Economic/Technical/Market Potential

??Barriers

??Human potential gap (Fig 1.5)

Boiler Operation vs Management

??Perception:Boilers are operated not managed

??U.S. Survey: More attention to operation then managing

??Evidence: Lack of instrumentation

Boiler Energy Management Program (BEMP)

??Accountability

??Central to success of BEMP

??Energy use, not just supply

??Knowledge of spotting waste and corrective Action

Achieving Accountability: Measure and Manag

??Establish a system to collect data: Instrumentationand

??Interpret data: Make sense of data; identify waste; grap

??Act on the information to control losses

Key Elements of an Effective Energy Managemer

Commitment from management

??Communication of energy savings potential
??Speak their language: Minimum Return on Investment

Boiler System Testing

??Benchmark existing operating parameters
??Fuel data; maximum consumption rate
??Boiler hours of operation; annual fuel use, fuel unit cos

Economic evaluation and project ranking

??Life cycle costs vs first costs

Complete Energy Management Plan

??Take a long term view
??Measurement and verification

Issues/Definitions/Overview

- ??HHV vs LHV
- ??Certification of boilers
- ??Definitions of boiler terms: stack, burner, economizer, blo
- ??General layout of the boiler workshop
- ??Sheet of unit conversions

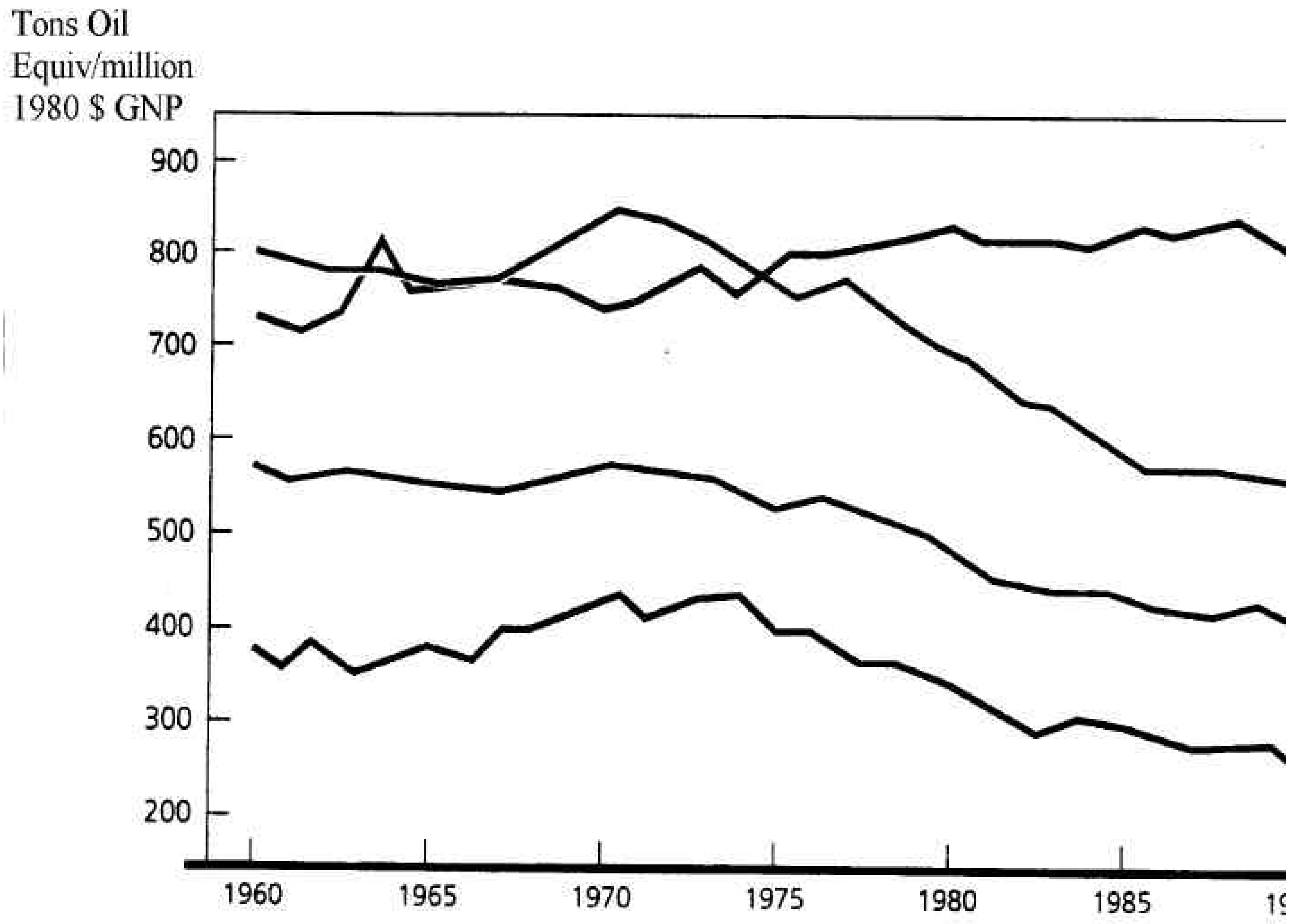

Fig 1.1: Energy Intensity Comparison

Fig 1.2: Fuel Used in Manufacturing Plants to P Steam (%)

1. **Forest Products: 81%**
2. **Food Processing: 54%**
3. **Chemicals: 46%**
4. **Textiles: 41%**
5. **Petroleum: 26%**
6. **Steel: 22%**

Fig 1.3: Manufacturing Energy End-Use

Sector	Fuel Energy Input (10^9 BTU)				
	Process Heating	Process Cooling	Machine Drive	Facility HVAC	Light
1994					
Food Products	192	49	102	50	
Pulp and Paper	140	4	191	28	
Chemicals	680	43	380	38	
Petroleum	535	6	109	9	
Steel	487	2	81	29	
1991					
Food Products	148	43	81	33	
Pulp and Paper	134	3	173	10	
Chemicals	621	29	342	21	
Petroleum	519	5	88	14	
Steel	371	1	58	21	

Boiler fuel inputs comprise the greatest fuel use in Food Products, Pulp and Paper and Chemical Industries; second greatest in Petroleum and Steel to Process Heating

Fig 1.4 Estimated Unmanaged Steam System Ef
Improvement Potential

Generation	**2-**
??boiler tune-ups and heat recovery	2-
??load controls	1-
??emissions monitoring	1-
Distribution	**12**
??steam leaks	2-
??steam traps	8-
??insulation	5
Recovery	**9-**
??water treatment	5-
??condensate return	5-
Total	**20**

Note that system efficiency is not additive, due to the interrelated nature of the parts. Most system efficiency
Distribution and Recovery

Fig 1.6: BOILER RATING & ENERGY FLOW RATE CONV
(1 HP = .746 KW = 2.17 x 10^{-4} Btu/hr)

Multiply	By	(Reciprocal Conversion)	To Obtain
Boiler HP	34.5	(0.029)	lbs. steam/hr F&A
Boiler HP	33,475	(0.0000299)	Btu/hr (output)
Boiler HP	15.64	(0.0639)	kg steam/hr F&A 1
Boiler HP	9.81	(0.102)	KW
Boiler HP	139.5	(0.000717)	EDR sq. ft. steam
Boiler HP	223	(0.000448)	EDR sq. ft. hot wa

Source: Garay, 1995. Handbook of Industrial Power and Steam Systems

The following table provides conversion factors to and from the metric quantiti

1 equals	**kJ/hr**	**kW**	**kg CE / hr**	**Btu/hr**	**kcal/hr**
kJ/hr		0.00028	0.000034	0.948	0.239
kW	3,600		0.123	3,412	860
HP	0.000229	0.746		0.000217	0.0000547
Btu/hr	1.055	0.00029	0.000036		**0.252**
kcal/hr	4.18	0.00116	0.00014	3.97	

1 petajoule (PJ) = .278 terawatt-hour (tWh) = 34.1 million kg Coal Equivalent (CE) = 0.948 Quad

Appendix 4

Module 2: Basic Overview of Boiler Efficiency and Combustion Controls

MOD 2: BASIC OVERVIEW OF BOILER EFFICI
COMBUSTION CONTROLS

Boiler efficiency vs system efficiency

??Boiler efficiency is part of the system

??System efficiencyincludes generation, distribution, and c

??Keep the larger picture in mind

Starting Point For Boiler Plant Optimization is the

As-found Efficiency:

??Is the efficiency for a boiler in its existing state of repair a
maintenance

??Use as a benchmark

??Make documentation

??As-found boiler efficiency is site specific

??U.S. DOE survey Fig 2.1 and Fig 2.2

??What we see from these figures:

??Efficiency decreases as the bottom of the turndown ratio
approached. Mixture not good at low turbulence-compens
excess air

??At maximum firing rate-reduced "RESIDENCE TIME"

Tuned up or Baseline Efficiency

??Is the efficiency after making operating adjustments, lowe
air, and minor repairs have been completed.

??Baseline efficiency for estimating all future capital impro
savings

??Future savings estimates hinge on the accuracy of this n
(delete space)

Theoretical vs Technical vs Economical Efficienc

??Theoretical research level

??Technical efficiency is the goal of manufacturers

??Economic efficiency is of value to the plant managers

??There is another aspect we call the market efficiency, wh
interest to policy makers and is concerned with institution
structural issue

Maximum Technical Efficiency

Fuel	Rated Capacity Million BTU's/Hr		
	10-16	16-100	100-250
GAS	86 %	86 %	86 %
OIL	89 %	89 %	90 %

Maximum Economic Efficiency

Fuel	Rated Capacity Million BTU's/Hr		
	10-16	16-100	100-250
GAS	80 %	82 %	84 %
OIL	84 %	87 %	88 %

- ??Larger boilers economic efficiencies closer to technical e
- ??Smaller boilers the techno-economic gap is 5-6 %
- ??Oil burns at a higher flame temperature of 4200 F so rad transfer rate and efficiency is higher for oil fired burners s

Boiler losses can be grouped in three broad area

??Stack losses: (excess) air and high stack temperature (m

??Blowdown (second most loss)

??Surface losses(least loss)

??Stack losses

- ??25 % of the boiler efficiency loss…Higher priority
- ??Ukraine, and FSU (Former Soviet Union?) high losses much excess air
- ??Higher stack temperature ✍ poor heat transfer: soot or deposits Fig 2.3

??Blowdown losses

- ??Often overlooked-hard to measure
- ??Usually the losses range from 4 to 6 percent
- ??Rate depends on condensate recovery and water chem

Surface losses

??Consist Of convective and radiative losses from the boile
valves and piping in the boiler plant

??Usually account for 1 To 3 Percent of total losses

??However,this loss increases as load decreases…as high

Combustion controls schemes:

Basic burner firing rate is controlled from steam pressure. controller then sends a signal to the control system. There levels of control systems available, from the most basic to the art microprocessor based. The most basic is the jacksh (also known as single-point control system control). The ne parallel positioning, independent or multi-point control syst the most efficient is the metered or O2 trim system.

Jackshaft or Single-Point Control Fig 2.4:

??Mechanical linkage simultaneously controls air and fue

??Open control loop;no feedback loop from combustion c ensure proper ratio

??Cam ratios preset, wear over time and affect the air/fue

??Non-linear characteristics of flow control devises leads at low load conditions.

??This maybe the most common type of control scheme i

??An improvement over this is to eliminate the non-linear characteristics of the mechanical linkage and provide c independent control devises on the air and fuel.

Parallel or Multi-Point Control Fig 2.5:

- ??Most common type of control used on boilers in the U.S
- ??Open control loop, No feedback loop from combustion ensure proper ratio
- ??Employs mechanical, pneumatic, electronic and DDC b elements
- ??AUTOFLAME® microprocessor based, can program it a requires calibration (due to open loop setup)
- ??Use only on variable boiler load applications to justify c

The O2 trim control scheme Fig 2.6

- ??Incorporates feedback “closes the loop”
- ??See combustion chapter from steam challenge regardi changes with amb temp, O2 trim can account for these
- ??Manufacturers and costs.

Burner Turndown Ratio:

- ??Low Turndown Ratio (inefficiency at low loads: purge cyc heat transfer by combustion air from boiler up the stack)
- ??TDR in older US boilers is 3-4:1 the new ones have a TD
- ??For a boiler that operates at part load a fair portion of the savings from going to a high TDR burner can be significa neighborhood of 3 to 10 percentage point improvement i has been seen
- ??Experience in the FSU countries-excess air quantities ad manually and are usually set very high. The control syst air pressure as a substitute for airflow measurement and operator has to make an airflow set point adjustment afte change.

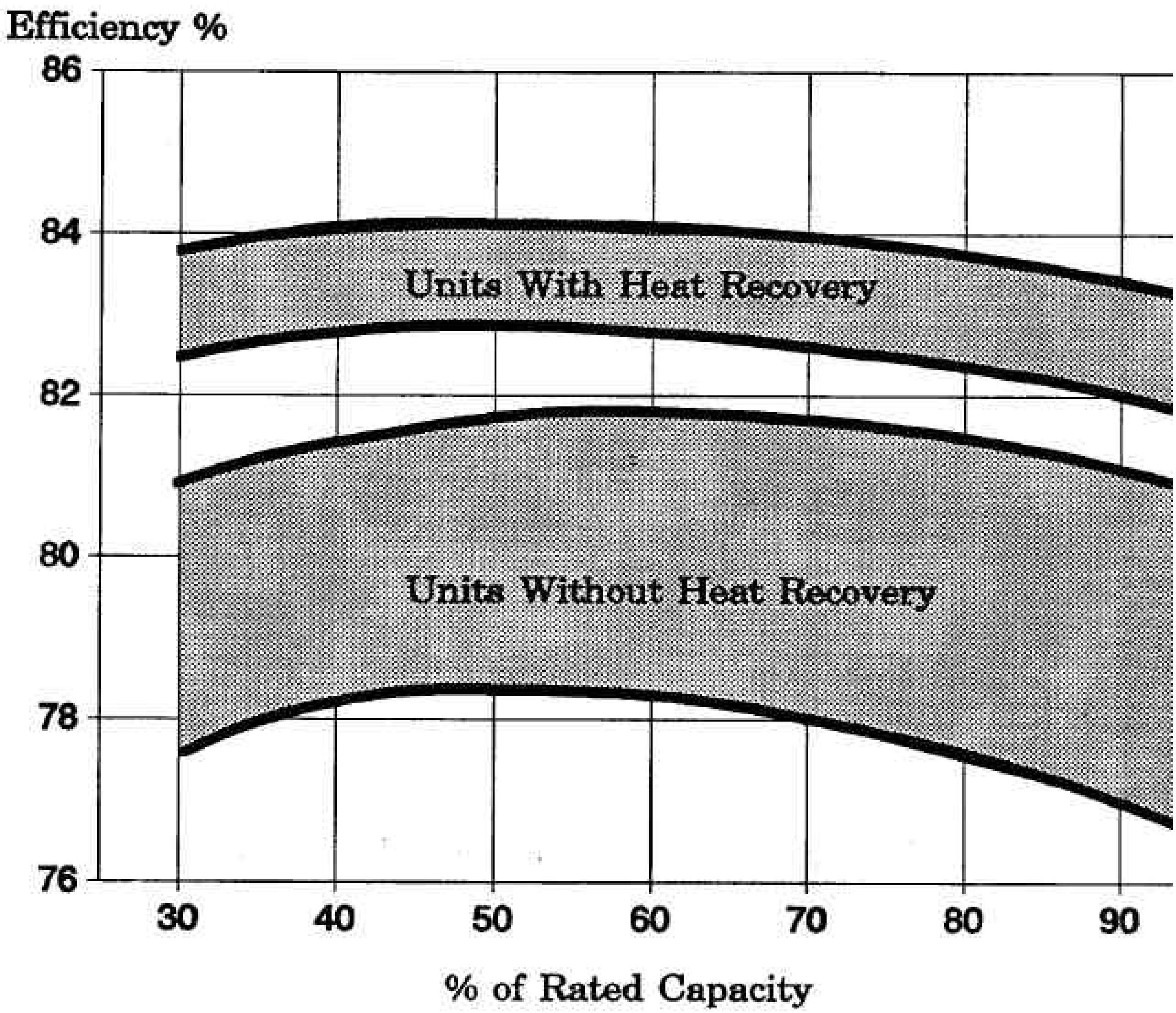

Fig 2.1 **Source: Taplin, Fairmont Press**

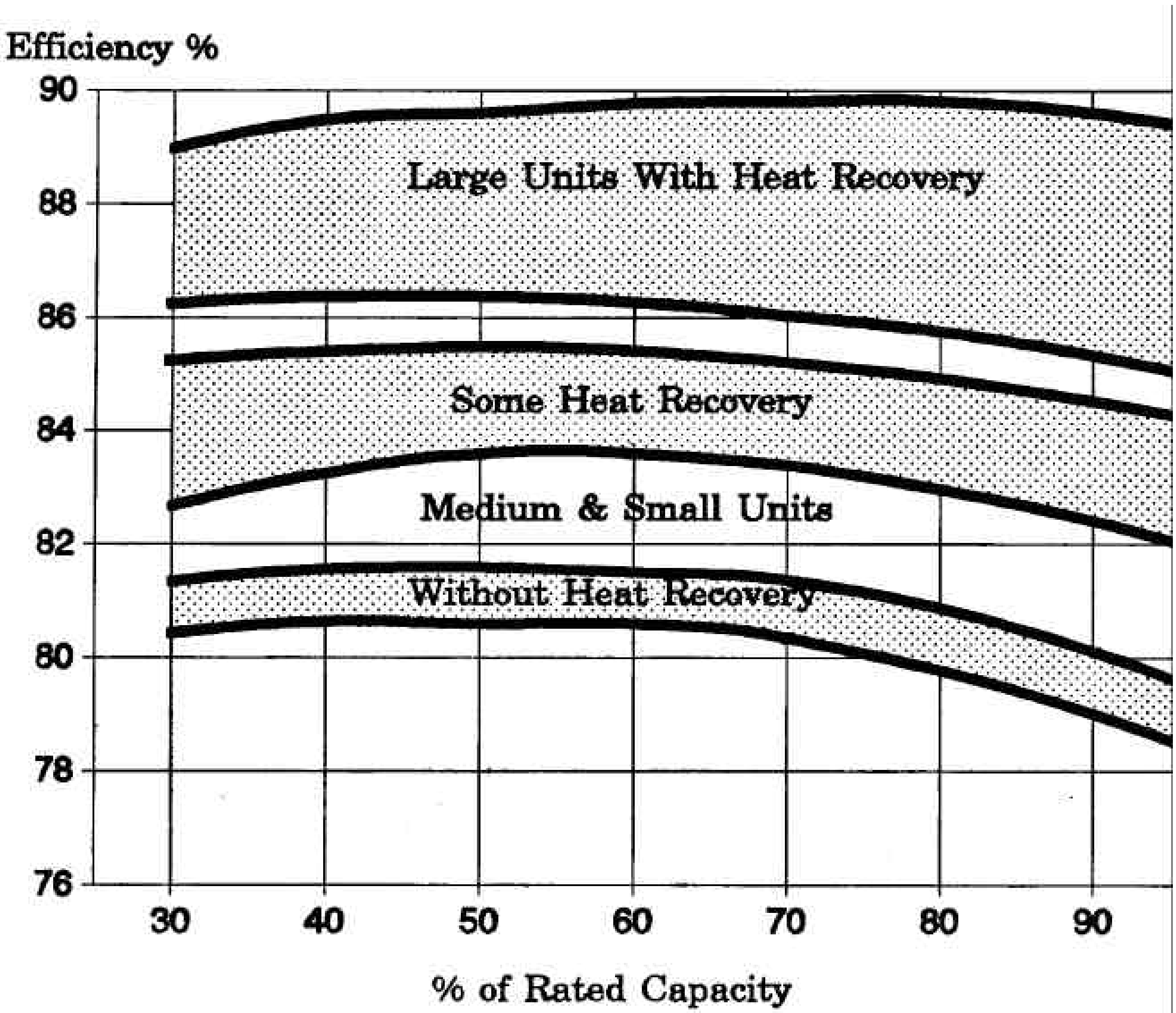

Fig 2.2 **Source: Taplin, Fairmont Press**

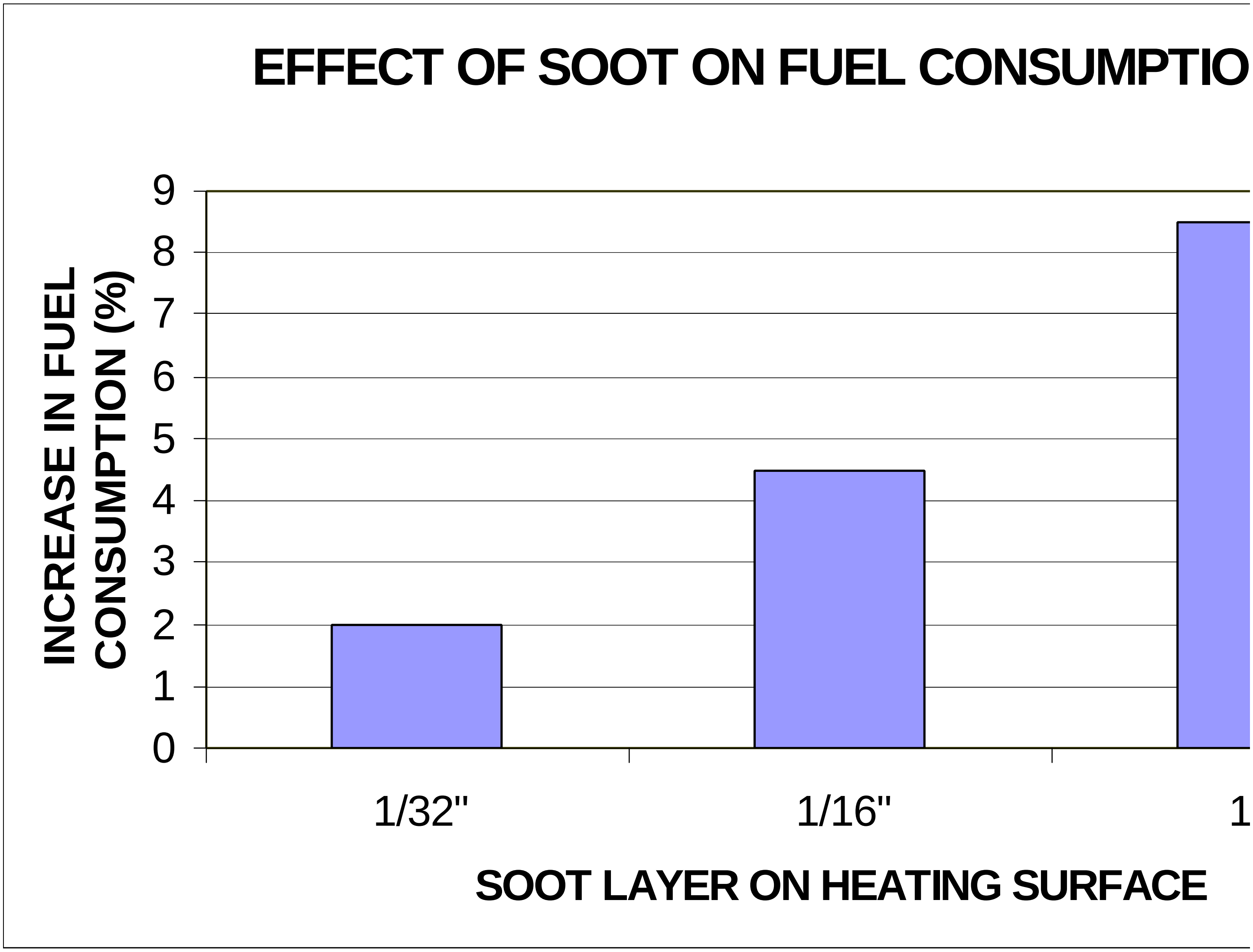

Fig 2.3 Source: Taplin, Fairmont Press

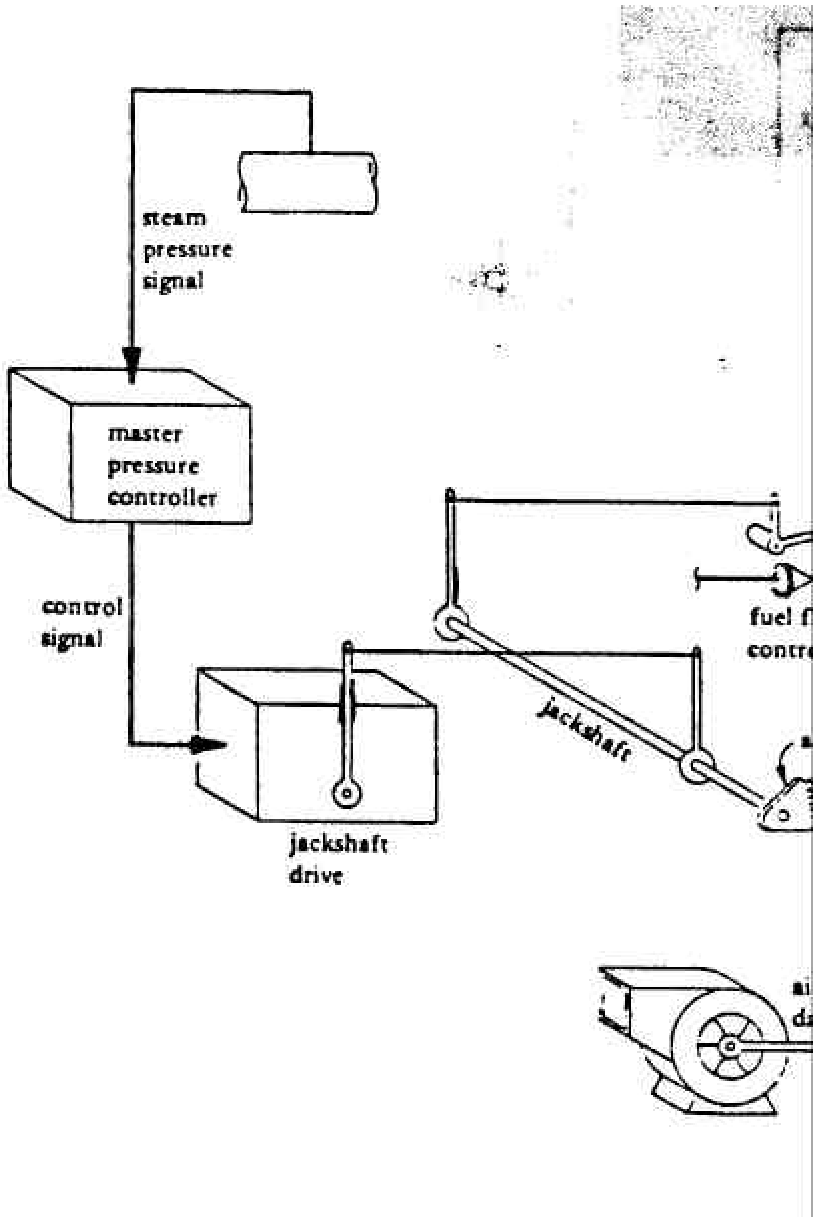

Fig 2.4 **Source: Taplin, Fairmont Press**

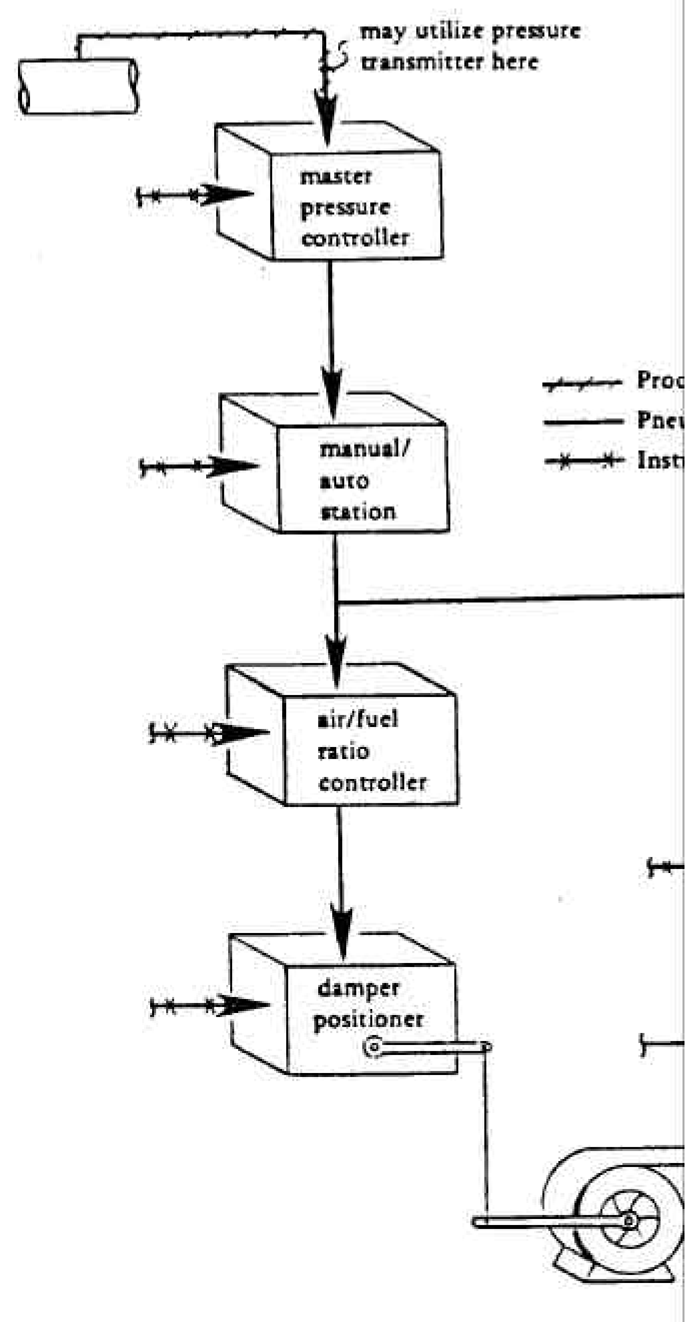

Fig 2.5 **Source: Taplin, Fairmont Press**

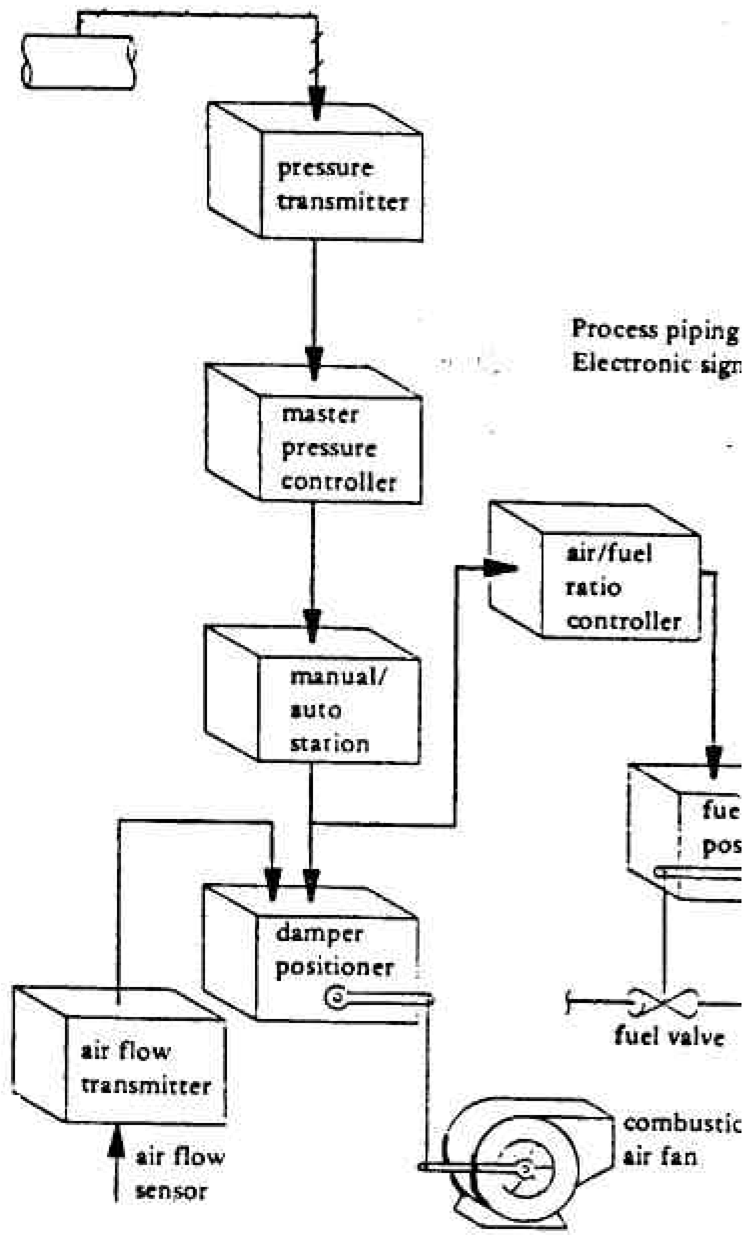

Fig 2.6 **Source: Taplin, Fairmont Press**

Appendix 5

Module 3: Combustion Efficiency Improvements: Boiler Tune-Up/Maintenance

MOD 3: COMBUSTION EFFICIENCY IMPROV
BOILER TUNE-UP/MAINTENANCE

Two steps to improving boiler efficiency:

??Tune-up/maintenance, and
??Equipment Modifications

??Reducing excess (XS) air-most cost effective boiler effic improvement
??Low cost
??First proper maintenance and operation

??Inspecting the burner assembly

Check to make sure that the:

??Clean: gas injection orifices, H_2O traps, oil tip passag
??Reduce excessive play on air/fuel control linkages
??Oil gun is positioned properly within the burner throa
??Right oil temperature and pressure is maintained
??Eliminate any air leakage into the boiler furnace/stac

- ??Stack Temperature
  - ??Stack temperature: indication of cleanliness of boiler tu
  - ??should ideally be in the range of 150 F– 200 F range
  - ??Tube fouling can be on both the fireside and the waters fouling and scale (Fig 3.1)
  - ??Efficiency gains from stack temperature reduction:
    - ??Example: what will the efficiency change be with an e 60 % if the stack temperature is reduced by 100 F?
    - ??Solution: The factor from the chart at 60 % XS air is (efficiency improvement: 100 F/10 * 0.325 is

Boiler Tune-Up

??Chemistry of Combustion

??Stoichiometric point: Perfect combustion is the proper and fuel under exacting conditions where both the O2 are completely consumed in the combustion process. combustion.

??The combustion reaction for natural gas is

$CH_4 + 2O_2 + 7.53N_2$ ✍ $CO_2 + 2H_2O + 7.53N_2 + 1{,}013$ E

??Below the stoichiometric point : Incomplete combustior H_2 combustibles

??Real world: stoichiometric point combustion is unattain imperfect mixing, need excess air

The fundamental rule is:

Maximum combustion efficiency is achieved when the corre
excess air is supplied so the sum of both unburned fuel los
heat loss is minimized.

The relationship of CO and O_2 is given by (Fig 3.3)

The question then becomes how much excessair is approp
It depends on several limiting factors:

- ??Flame stability
- ??Level of CO in gas fired units known as the *CO Thresh*
- ??Smoke in the stack in oil fired units or *Smoke Threshol*
- ??Equipment-related limitations such as too low windbox
  pressure differential

Reducing Excess air Step by Step

1. Boiler in manual mode, set firing rate, check safety
2. Record boiler steam pressure, load, stack temp, C
   (If O2 and CO level are at a minimum then go to n
3. Reduce airflow in small increments and note:
   ??Any signs of smoke in stack or unstable flame op
   ??Record CO or SSN readings at various O2 settin
   ??Record corresponding stack temperature
4. Draw the CO/O2 or Smoke/O2 curves and find the excess O2 level (Fig 3.4 and Fig 3.5)
5. Set the excess air quantity - provide buffer zone
6. On boilers with independent or parallel positioning systems repeat steps 1-5 at different firing rates. A rates.
7. Test the settings by imposing false loading on the that the new burn ratio settings do not enter into ar operating condition. Reset controls as necessary.

Demo of Combustion Analyzer

- ??Principle components including the various sensors
- ??No LHV so efficiency readings lower
- ??Input fuel parameters: Heat content and composition
- ??Proper location of probe in stack
- ??Maintenance and calibration
- ??Costs. Best way to use a combustion analyzer is to hire service instead of purchase.

Estimating Energy Savings Calculations

$$CS = W_f \times \left(\frac{E_n - E_o}{E_n} \right) \times C_f \times H_r$$

CS: Energy Savings potential per year ($)
W_f: Average fuel use rate over the year (million Btu/Hr
E_n: New or improved efficiency (%)
E_o: Old or Existing or As-Found efficiency (%)
C_f: Cost of fuel (per million Btu)
H_r: Average annual hours of boiler operation (hours/ye

?? Efficiency improvements can be obtained from the combustion analyzer print out o efficiency improvement from stack temperature reduction can be estimate from (F
?? The average fuel use rate and the hours of operation multiplied also give the annu and this data can be obtained from utility billing information.
?? The annual hours of operation can be obtained from the boiler operator.

Example: Energy savings from reducing too much Excess
Example: Energy savings from tube cleaning-stack temp re
Example: Energy savings from optimizing multiple boiler lo

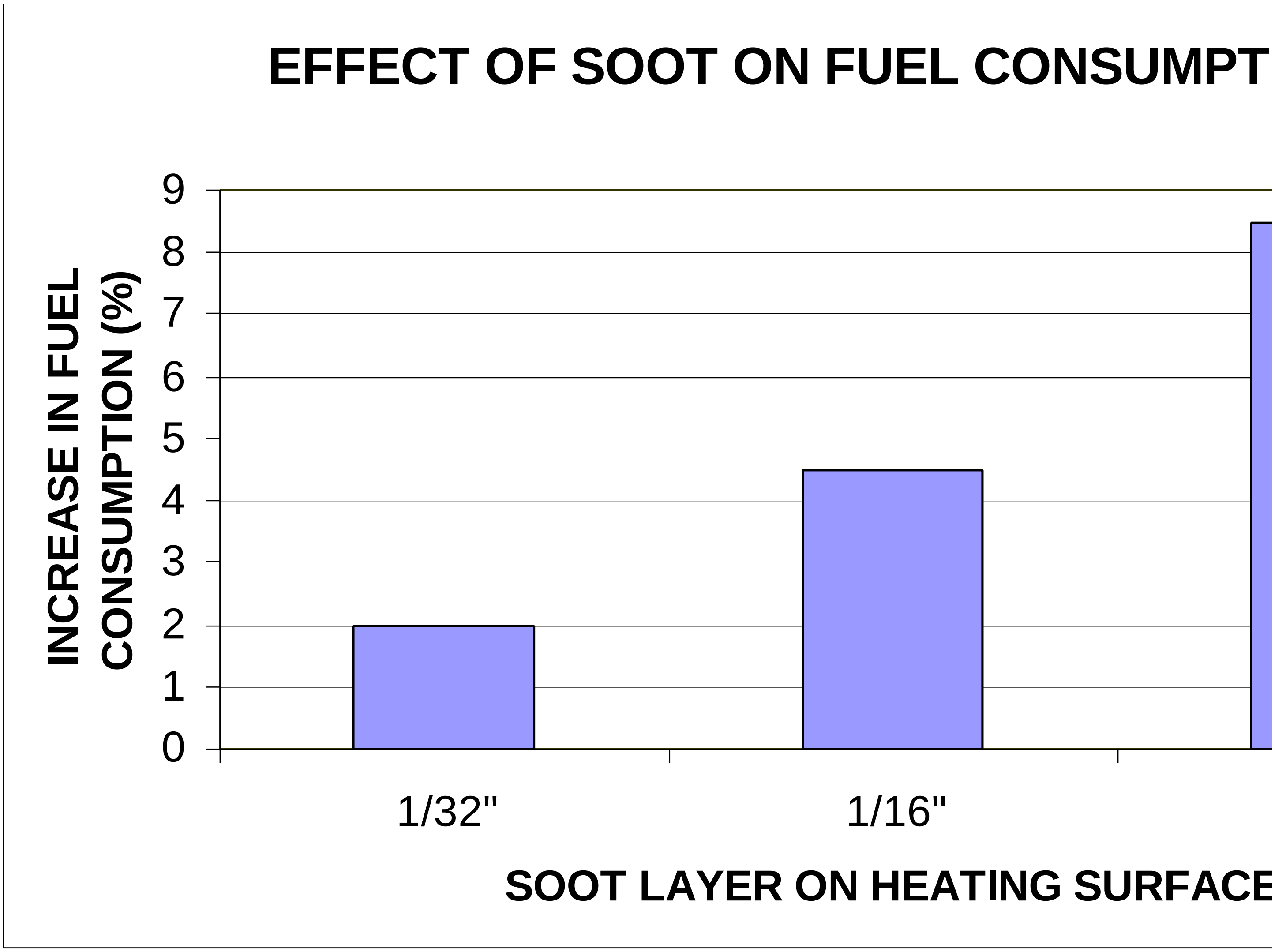

Fig 3.1 ***Source: Taplin, Fairmount Press***

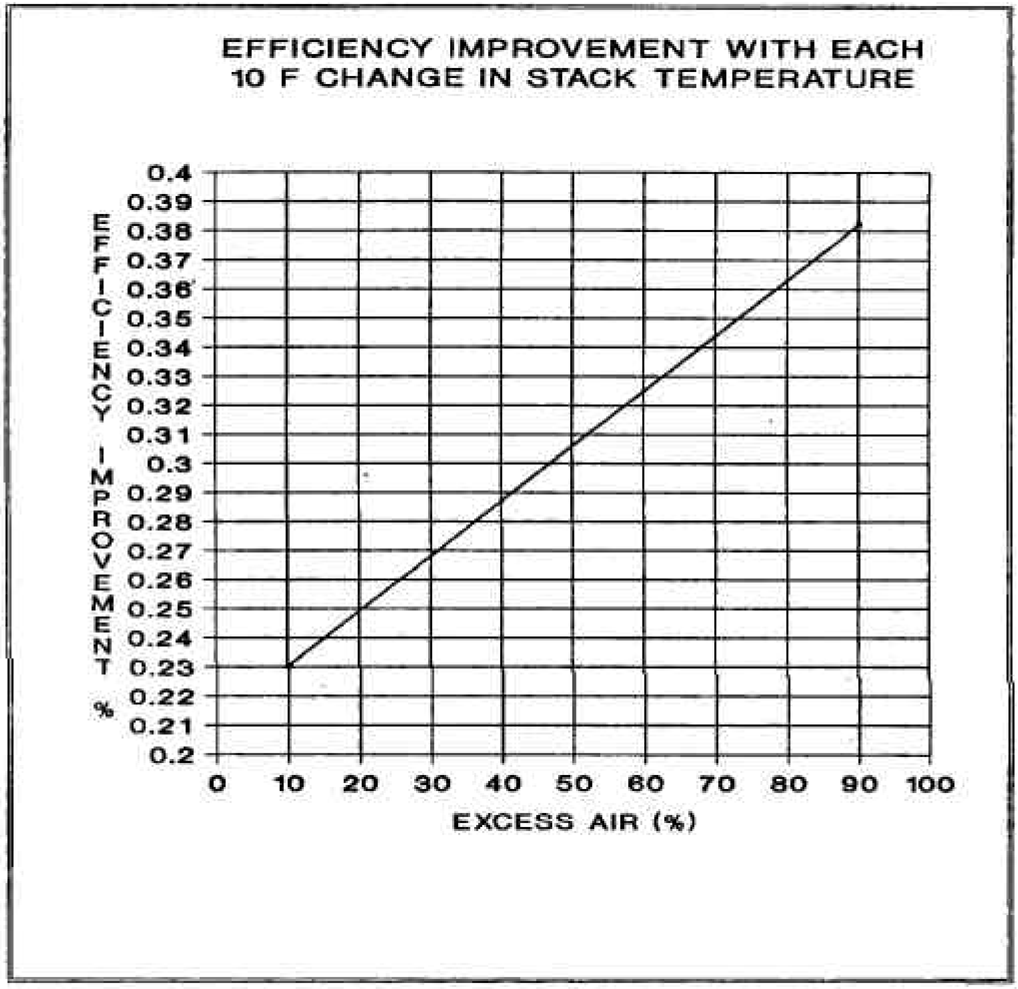

Fig 3.2 ***Source: Taplin, Fairmount Press***

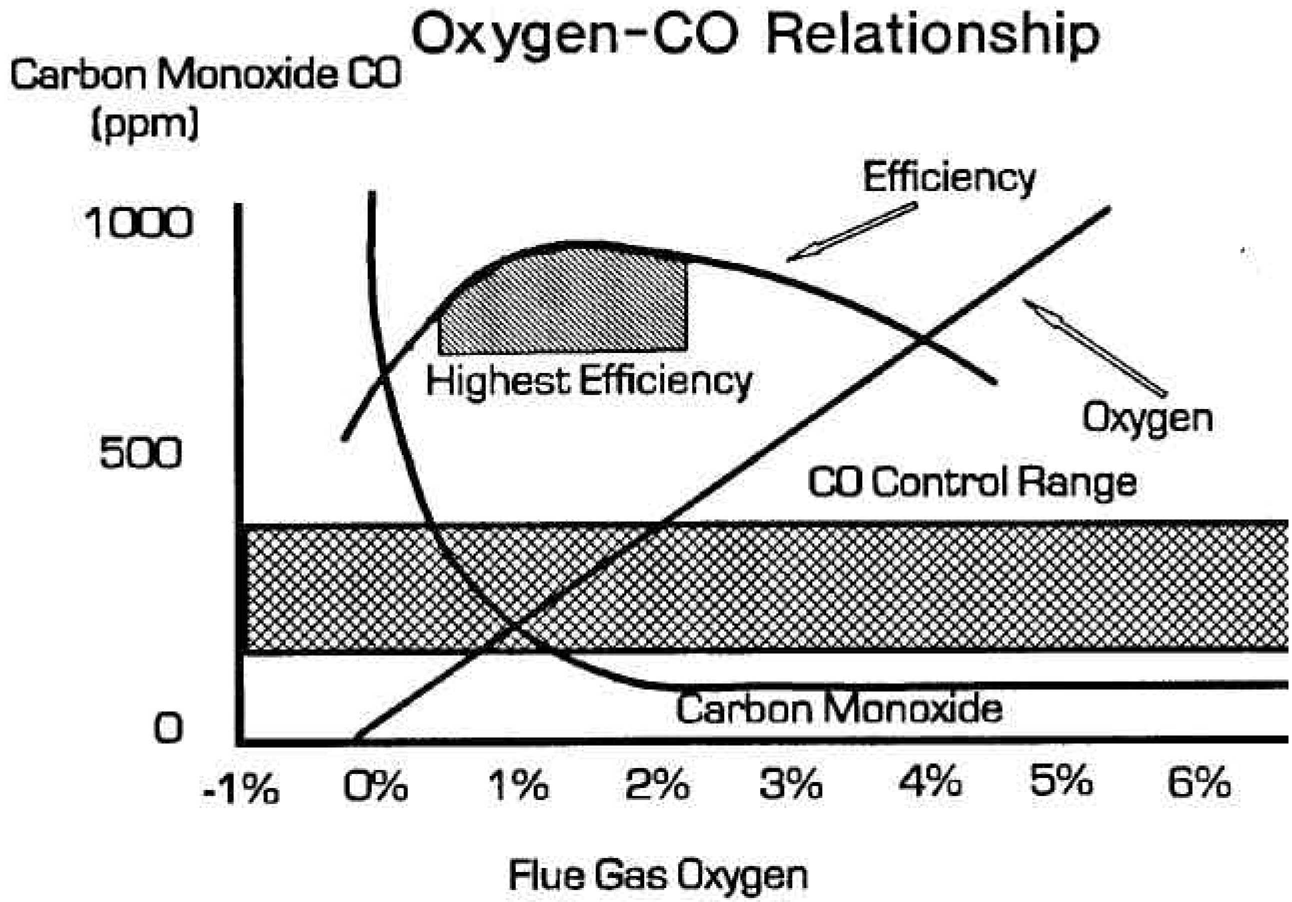

Fig 3.3 ***Source: Taplin, Fairmount Press***

Combustion Efficiency
Oxygen-Smoke limit Relationshi

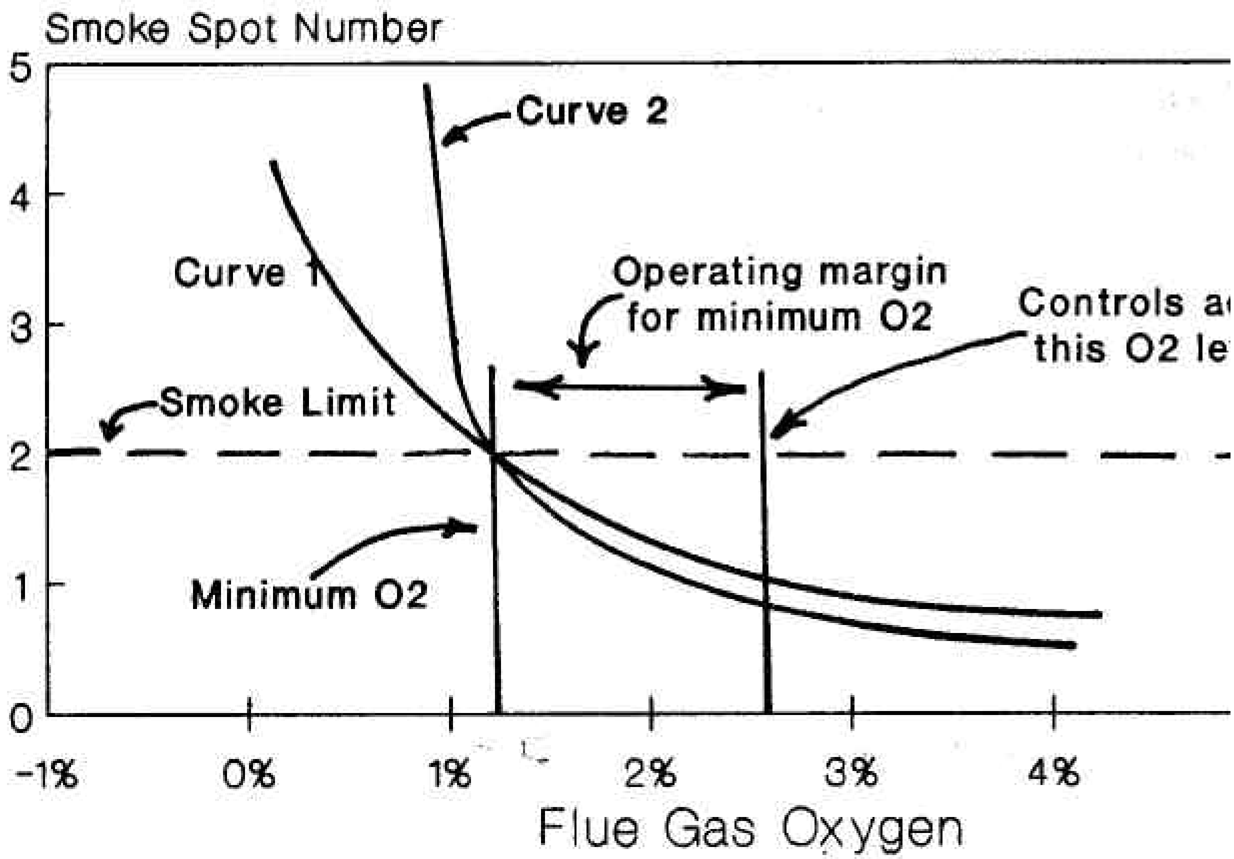

Fig 3.4 ***Source: Taplin, Fairmount Press***

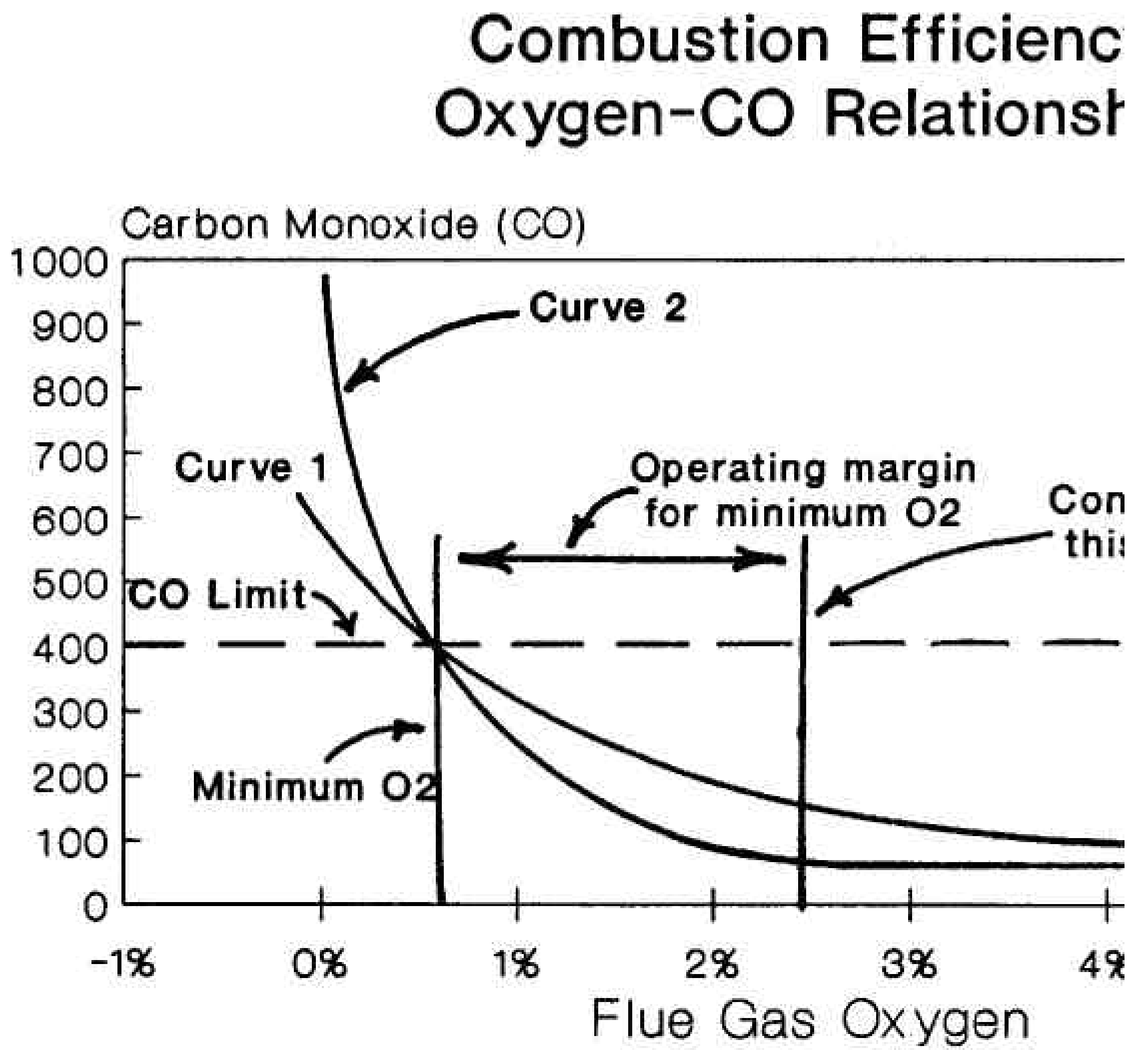

Fig 3.5 ***Source: Taplin, Fairmount Press***

Appendix 6
Combustion Efficiency Improvements

MOD 4: COMBUSTION EFFICIENCY IMPROV
HIGH EFFICIENCY BURNER SYSTEMS AND C
AND STACK HEAT RECOVERY ECONOM

HIGH EFFICIENCY BURNER SYSTEMS AND C(

General characteristics of good control systems:

??Accurate air/fuel input measurement & control-flow meas

??Correct synchronization of fuel and air input

??Consistent reliability and repeatability

??Auto trim of excess oxygen to a preset minimum under al
steady-state conditions

??Continuous optimization of the combustion efficiency des
in fuel Btu, ambient air temperature, and relative humidit

Modern Ways Of Achieving Better Combustion E

??High turndown ratio burners

??Multi-point positioning controls

??Over fire draft control

??O2 trim

??Caveat: variable load

High turndown ratio burners

??Avoid cycling losses at low loads: pre-purge & post-purge

??Ukraine TDR is 3:1 (cycle below 33% load)

??Average TDR of US Burner is 8:1

??Retrofit Issues: Furnace geometry, physical characteristi
certification issues

??Example: Energy savings potential in FSU plant

Multi-Point Positioning Controls

??Independent controls

??Repeatability improved: No mechanical linkage

??Calibrate setting at various firing rates

??Retrofit valve actuators and add controller

Overfire Draft Control

??Compensates for varying conditions

??Useful in high stacks: >40 feet

??Precursor to O2 Trim

O2 trim

??Ultimate in precise combustion control

??Feedback loop provides dynamic control: accounts for ch
environment

Boiler Economizer Heat Recovery

??Recover heat from hot stack gases
??Simple technology
??Pre-heat the feedwater
??Coincidental heat source and demand
??Boiler above 75 psig good application potential
??Paybacks usually less than two years

Acid Corrosion Concerns
??Condensation of sulfuric acids (Fig 4.1)
??Particularly oil- based fuels
??Acid dew point limit
??Worst case is cold-end connection
??300 F lower exit gas temperature limit

Mitigating Cold-End Acid Corrosion in Economize

Fuel Type	Minimum Inlet Water Temperature, F	Maximum E: Temperature
Natural Gas	210	300
No. 2 Oil	220	325
No. 5&6 Oil (Mazut)	240	350

Other Means Of Minimizing Acid Corrosion

??Stack design: Drain collar section or Off-set

??Insulate stack metal: Raise metal skin temperature above point

??Parallel flow through the economizer: Raises pipe surfac on the inlet (cold-end) side

??Corrosion resistant materials: Corrosion resistant alloy st costly

??Preheating feedwater: Larger size systems (Fig 4.2)

Example: Energy savings calculations for stack economizer heat

Boiler Efficiency and Management Program

These appear in the logical sequence in which boiler efficie
improvement should be approached and start with the leas
options to the energy efficiency equipment installation/inve

Operation and maintenance improvements

- ??Tube cleaning and maintenance
- ??Reduce air leakage
- ??Repair damaged insulation
- ??Multiple boiler load management
- ??Boiler tune-Up
- ??Combustion analysis

Technology Upgrades

- ??High turndown ratio burner retrofit
- ??Overfire draft control
- ??O2 trim
- ??Economizer heat recovery

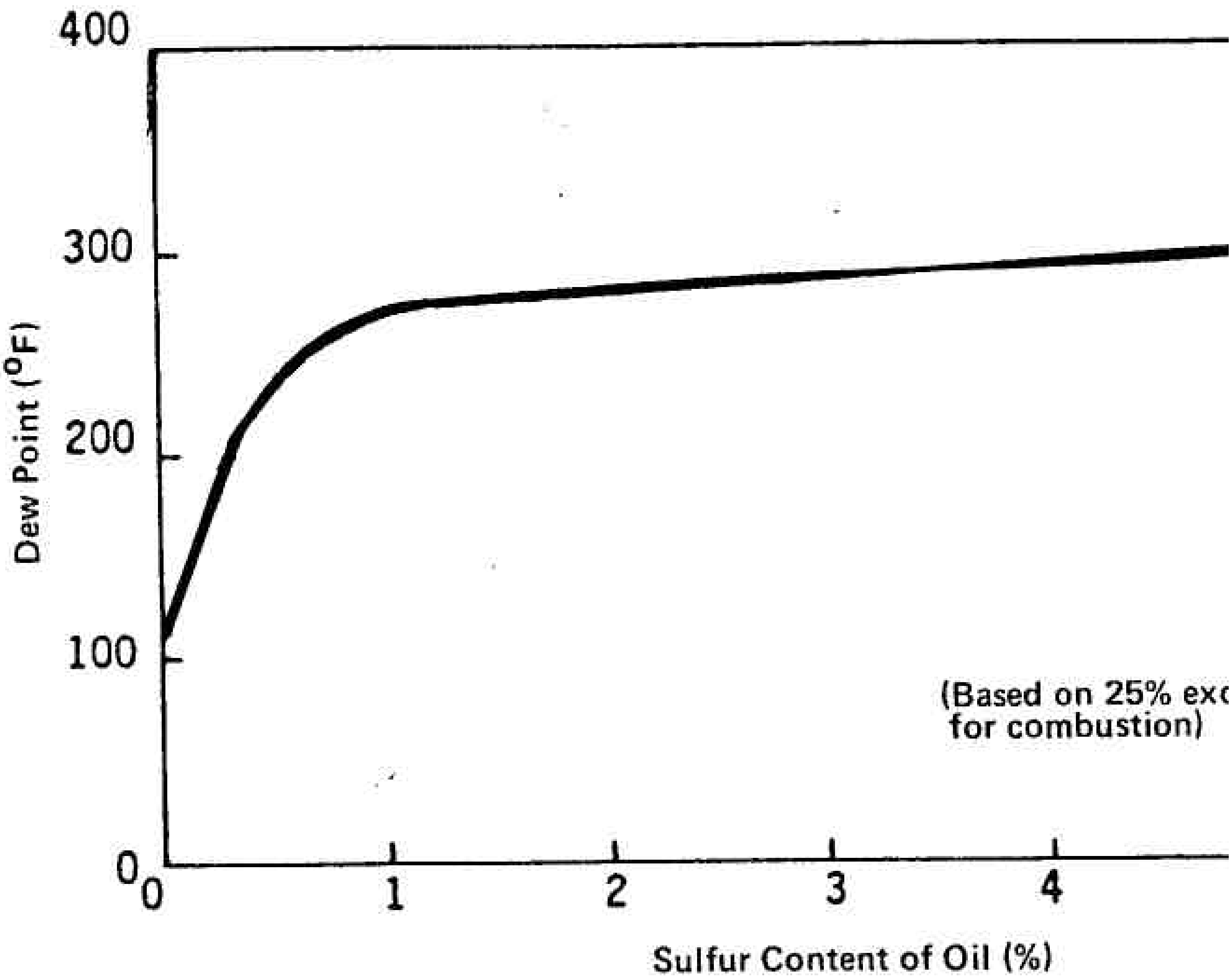
400
300
200
100
0
Dew Point (°F)
0
1
2
3
4
(Based on 25% exc
for combustion)
Sulfur Content of Oil (%)

Fig 4.1

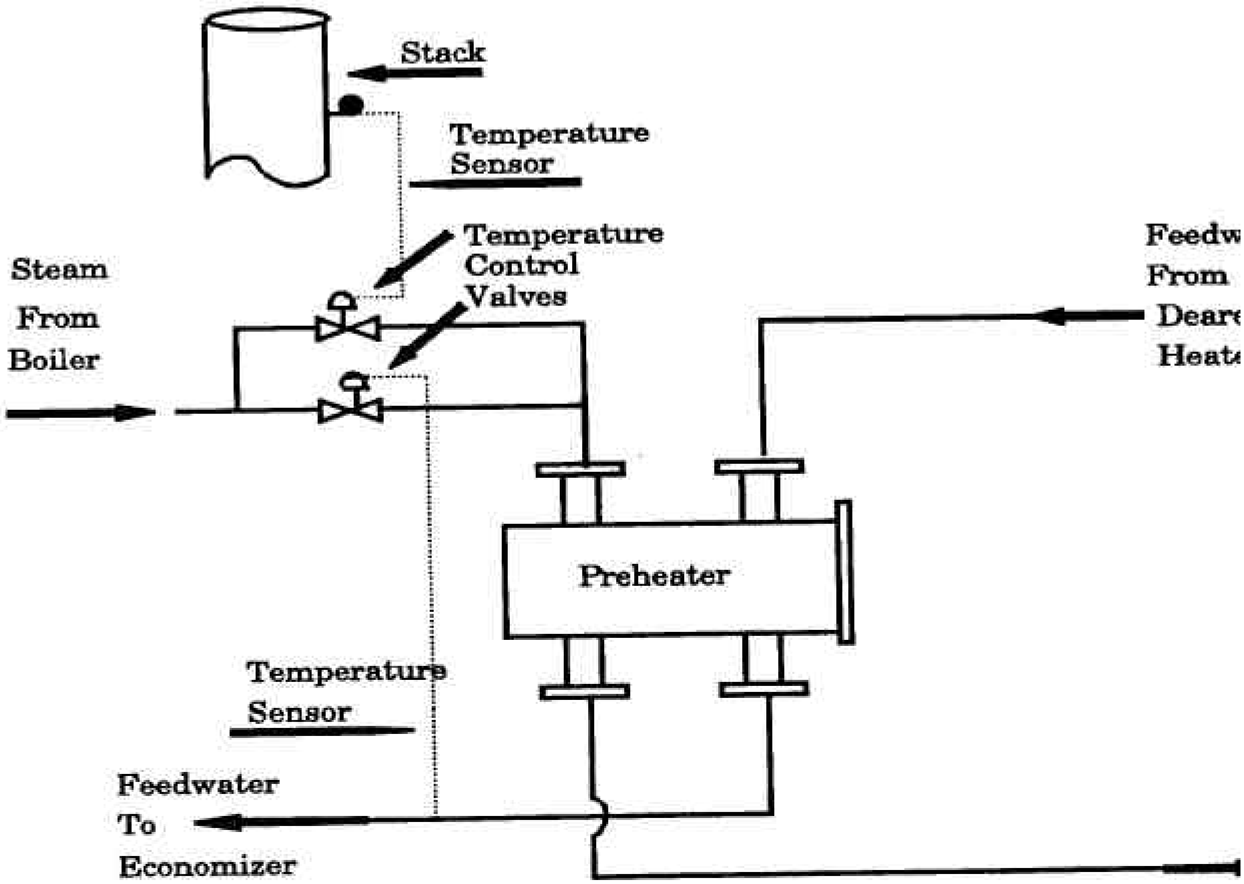
Stack
Temperature Sensor
Temperature Control Valves
Steam From Boiler
Preheater
Temperature Sensor
Feedwater To Economizer

Fig 4.2

Appendix 7

Module 5: Metering Equipment and Insulation Systems

MOD 5: METERING EQUIPMENT AND INSU SYSTEMS

Brief Recap of the Previous Day

Operation and maintenance improvements

??Tube cleaning and maintenance
??Reduce air leakage
??Repair damaged insulation
??Multiple boiler load management
??Boiler tune-up
??Combustion analysis

Technology Upgrades

??High turndown ratio burner retrofit
??Overfire draft control
??O2 trim
??Economizer heat recovery

Role of Metering as an Energy Management Tool
??Creates awareness of energy use
??Continuous process unlike an audit
??Results in better control cnd commitment to energy efficie
??Better energy use information helps in forecasting & decis
??Invariably leads to reduction in energy use and cost

What to Meter?
??Steam use
??Boiler feedwater
??Fuel use
??Stack temperature

Types Of Metering Equipment:
??Steam-(1) Orifice Plate, or (2) Vortex Meter
??Natural Gas- Turbine
??Boiler Feedwater-(1) Turbine, or (2) Vortex Meter

Insulation Systems

??Basic function-retard flow of unwanted heat energy

- ??Minimize 3 modes of energy transfer: conduction, convec radiation

Heat flow =	$\frac{\text{Temperature Difference}}{\text{Resistance to Heat Flow}}$

- ??Thermal conductivity, or k value
  - ??Amount of heat that passes through 1 square foot of 1- material in 1 hour when there is a temperature differen across the insulation thickness.

$$k = \text{Btu-in/hr-ft}^2$$

The lower the k value, the more efficient the insulation.

- ??Thermal Resistance
  - ??Heat flow is reduced by increasing the thermal resistan
  - ??The two types of resistances - mass and surface

??Mass for Homogeneous material

$$R_I = \text{thickness} * 1/k$$

Represents total resistance to heat flow for a given thicknes

??Surface resistance and this is defined as:

$$R_s = 1/f$$

f is the surface film coefficient

??Total resistance of the insulating system is:

$$R_{total} = R_I + R_s$$

??Overall coefficient of heat transmission of the insulation s
defined as:

$$U = \frac{1}{R_I + R_s}$$

Important Properties of Insulating Materials

- ??Temperature Use-Range: On thermal systems the upper important. Physical degradation can take place gradually compromising performance.
- ??Degradation of thermal conductivity: some foam products additives over time and develop an "aged k" value over t higher than the original value.
- ??Compressive Strength: Need to consider this where the in experience a physical load, such as buried pipe applicati

Common Industrial Insulation Types and Prope
in Thermal Applications

Insulation Type	Temp Range F	Thermal Conductivity at Temperature Btu-in./hr- 75 F	200 F	
Glass Fiber Blankets	To 1200	0.24 – 0.31	0.32 – 0.49	0
Glass Fiber Boards	To 1000	0.22	0.28	0
Glass Fiber Pipe Covering	To 850	0.23	0.30	
Mineral Fiber Blocks	To 1900	0.23 – 0.34	0.28 – 0.39	0

Protective Coating and Jackets

- ??Ensure proper life and performance of the insulation syst outside
- ??Seen many installations in Ukraine where the insulation is deteriorated
- ??Waterproof aluminum jacketing

3E Plus Program Demo

- ??Optimal Insulation thickness
- ??Energy savings estimate from insulation

Appendix 8

Module 6: Chemical Treatment and Blowdown Heat Recovery

MOD 6: CHEMICAL TREATMENT AND BLOV
HEAT RECOVERY

Need for chemical treatment

- ??Hardness
- ??Oxygen
- ??Dissolv edsolids
- ??Alkalinity

Hardness

- ??Scale build-up on the heat transfer tubes-impair heat tran
- ??Calcium and magnesium are the main elements
- ??Ability of water to hold hardness decreases with water ter
- ??Overheating of the tubes - failure (Fig 6.1)
- ??Water softners: Sodium ion exchangers that zeolites
- ??Phosphate treatment forms sludge; phosphate residual: 3

Oxygen

??Pitting boiler drum metal and tubes-eventual failure

??Oxygen solubility decreases with water temperature-so c

??Mechanical deaeration: 98 % removal of dissolved oxyge

??Chemical oxygen scavengers: sodium sulfite (NaSO3) : S
residue Of 20 to 60 ppm

Dissolved Solids

??Present in the make-up water and left in the boiler by the
steam

??Accumulate at surface ✍ Carried by steam into system: D
strainers and control valves

??Top continuous blowdown

??Level of Solids measured by conductivity

??Manual control : ? 20% of the desired dissolved solids lev

??Automatic operation: ? 5%.

Alkalinity

??Can lead to “caustic embrittlement” failure

??Proper alkalinity is maintained by adding NaOH.

Factors That Minimize Boiler Blowdown & Imp rov Efficiency:

Minimize blowdown by manual adjustment

??Establishing operating procedure & frequent water qual

??Minimize blowdown by automatic adjustment (Fig 6.2)

??Av erage boiler plant can sav e about 20 percent in blow

??Decrease blowdow n by recov ering more condensate

??Essentially free of water impurities -dilutes the concentr impurities

??Most cost effectiv e: Sav e in energy and chemical costs

??Energy efficiency improv ement potential is enormous.

Estimating BD Reduction:

$$\text{Percent BD} = \frac{A}{(B-A)} * 100$$

A = ppm of impurity in BFW
  = (Makeup water impurities in ppm * percent makeup)
B = ppm of impurities limit in boiler drum

Example: Say we improve the condensate recovery rate system from 50 % to 75 %, and the makeup wa ter impurity ppm and the boiler drum maximum allowable limit is 100 pp the change in the BD requirements?

Solution:

A(old) =10 x (1-0.5) = 5 ppm
B(old) = 5/(100-5) = 5.3 %

A(new) = 10 x (1-0.75) = 2.5 ppm
B(new) = 2.5/(100-2.5) = 2.6 %

The BD rate can be reduced by (5.3-2.6)/5.3 x 100 = 51 %.

BD = Percent BD * lbs/hr Steam

For a 100,000 lbs/hr steam system the reduction is

BD = (5.3-2.6)/100 * 100,000 = 2700 lbs/hr

Annual boiler fuel savings from reduced blowdown rate due
condensate recovery:

$$ES = \frac{BD * HR * C_p * (T_{fw} - T_{mu})}{\text{Boiler Average Efficiency}}$$

ES = Annual Energy Savings, Btu
BD = Blowdown Rate, lbs/hr
HR = Annual hours of operation, hours/year
C_p = Heat capacity of water, Btu/lb-F-Hr. For water this va
T_{fw} = Temperature of boiler feedwater, degree F
T_{mu} = Temperature of makeup water, degree F

Increase Allowable Drum Solids Level

??It may be possible to increase the maximum allowable im

??Consult a chemical treatment specialist

Heat Recovery from Blowdown

Example of Blowdown 2 -Stage Heat recovery (Fi

Using the example system of condensate recovery find the heat recovery potential. We have:

Steam rate = 100,000 lbs/hr

Boiler Pressure = 200 psig

Makeup water temperature = 60 F

New rate of BD after condensate recovery = 2.6 % (note th with above ECO)

Boiler efficiency = 80 %

Annual hours of operation = 4000

Fuel cost = $4/million Btu

Solution:

The first step is to calculate the flashed steam recovery am

$$\% \text{ Flash steam} = \frac{Hs - Hf}{Hg} * 100$$

Hs = enthalpy of liquid at boiler pressure, Btu/lb

Hf = enthalpy of liquid at flash tank pressure, Btu/lb

Hg = latent heat of vaporization at flash tank pressure, Btu

At a flash tank pressure of 5 psig (using steam tables):

% Flash steam = (362-196)/960 = 17.3 %

Flashed steam = 0.173 * 100,000 lbs/hr * (0.026) = 450 lbs/

The total heat of the flash steam at 5 psig (from Steam tabl
Btu/lbs

Heat saved in flashed steam = 450 lbs/hr * 1156 Btu/lb = 5

Similarly, the blowdown or drain from the flash tank is passe
heat exchanger and then dumped into the sewer. The tem
the water leaving the heat exchanger is 20 F higher then th
water or 80 F. Heat recovered in the heat exchanger:

Drain rate from flash tank (blowdown rate – flash steam) =
2150 lbs/hr

Heat of liquid leaving the heat exchanger at 80 F = 48 Btu/

Heat of flash tank drain liquid entering heat exchanger at 5
Btu/lb

Total heat recovery potential = 196-48 = 148 Btu/lb

Actual heat recovery with 0.7 heat exchanger effectiveness
= 0.7 * 148 * 2150 lbs /hr
= 222,740 Btu/hr

Total heat recovered in 2-stages = 520,000 + 222,740 = 74

ES = (742000 * 4000)/0.8 = 3700 million Btus

Cost savings = $4/million Btu * 3700 million Btu = $14,800

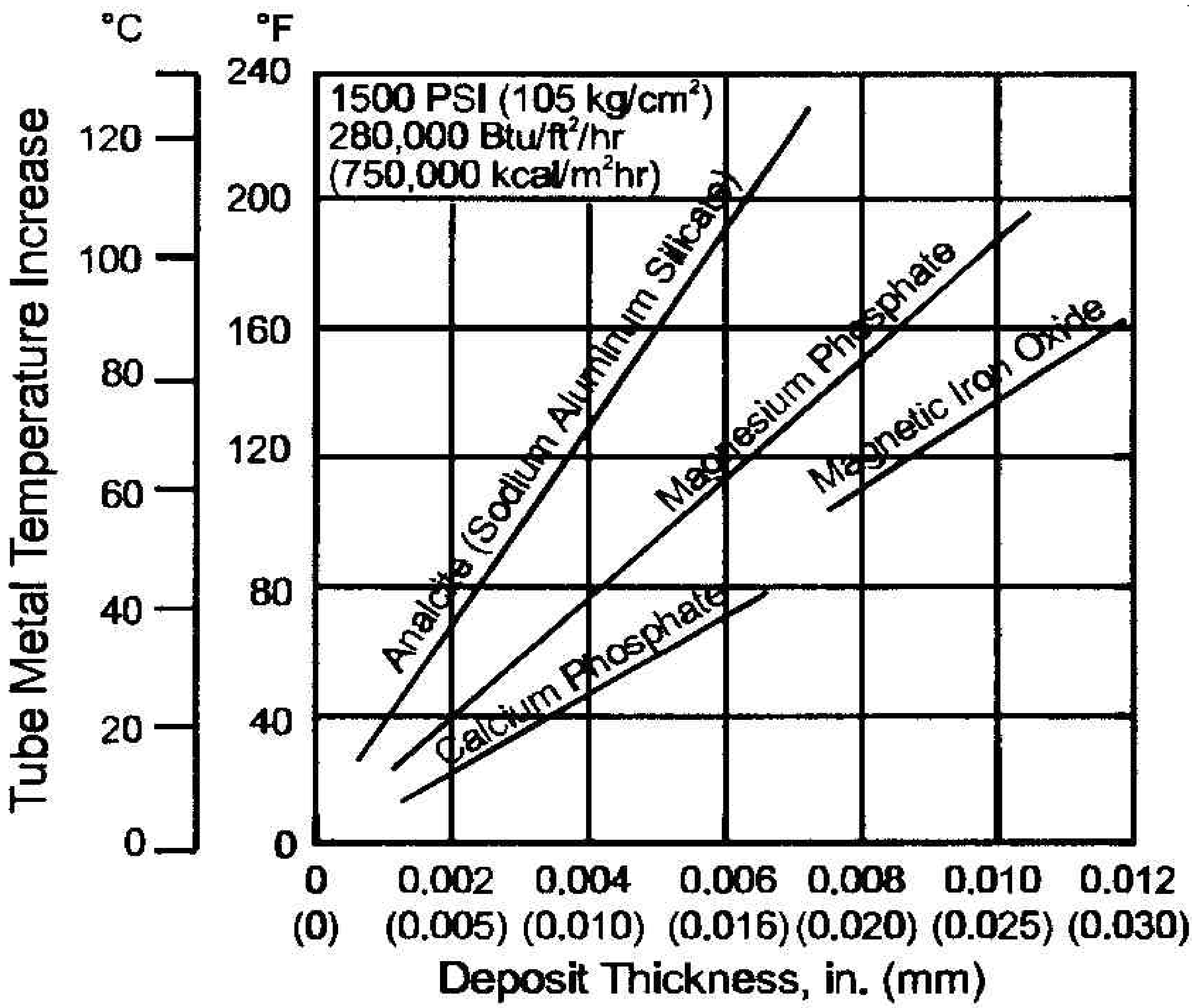

Fig 6.1 *Source: Steam Challenge Website*

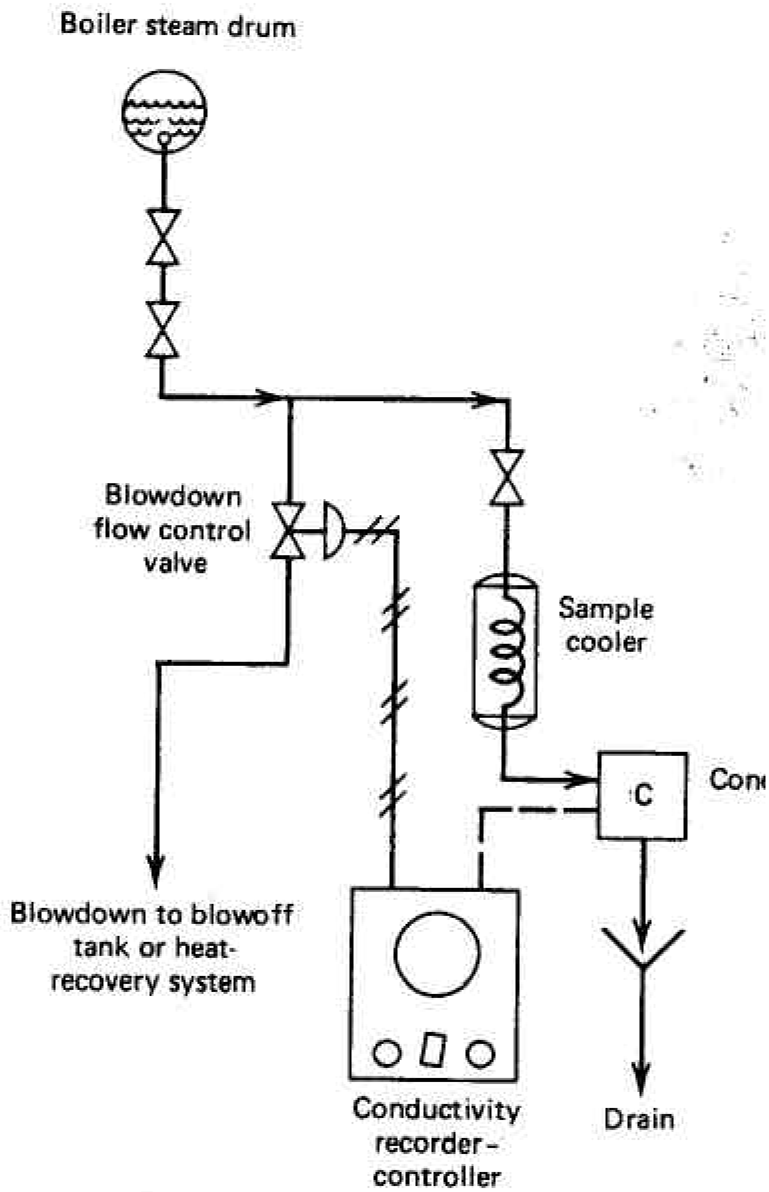

Fig 6.2 *Source: Turner, Fairmount Press*

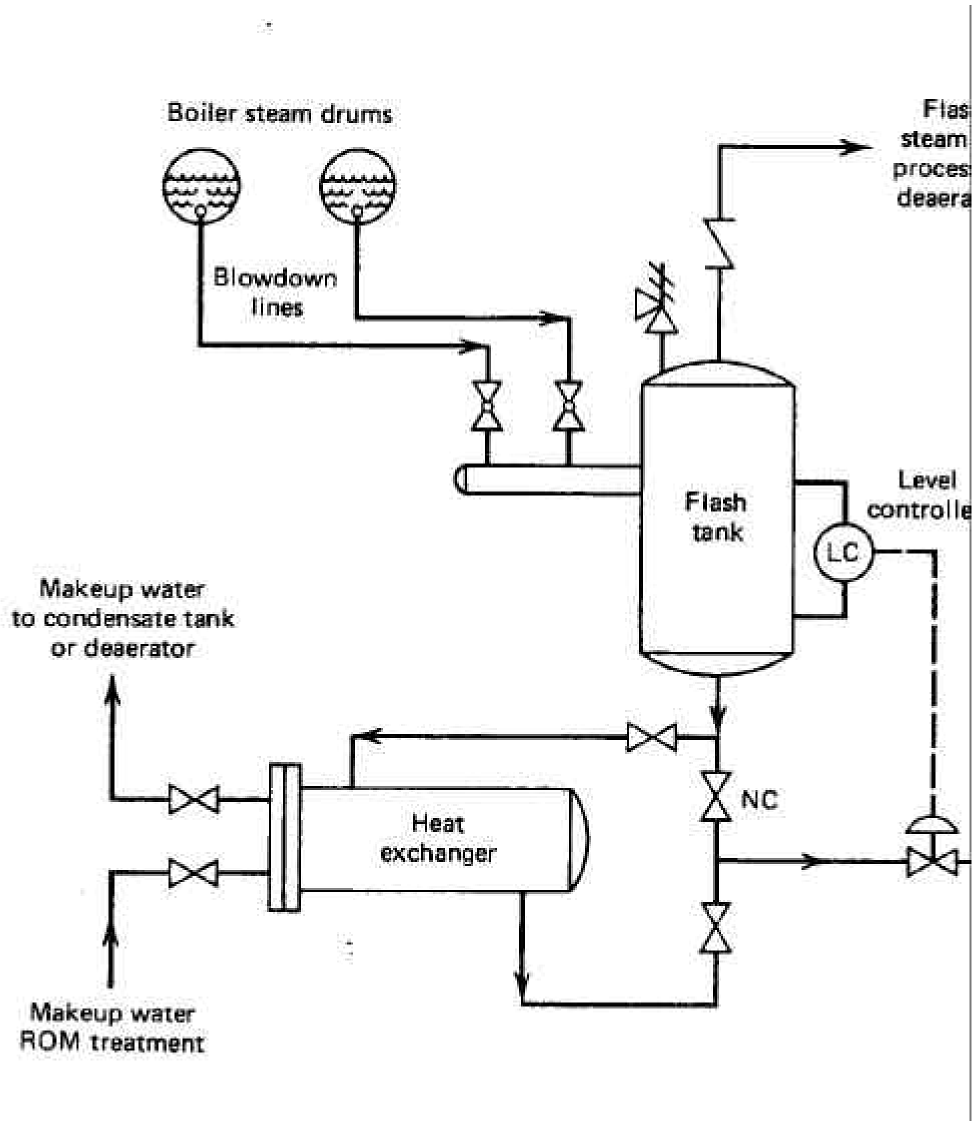

Fig 6.3 Source: Turner, Fairmount Press

Appendix 9
Participant Questionnaire

Participant Questionnaire
Steam Workshop Kiev 1/18-1/19/2000

1. How many boilers does your facility have _____
2. What is the capacity of your Boilers ______ Psi ______ metric tons/hr ______ Average load
3. Main Fuel (check one) ? Natural Gas ? Mazut ? Other __________
4. Back-up Fuel (check one) ? Natural Gas ? Mazut ? Other __________
5. On average, how many months a year do you have to run the boiler on back-up fuel?

   ? less than 1month ? 1 to 2 months ? 2 to 4 months ? > 4 months
6. Do you know the efficiency of your boiler? ? Yes ? No

   If yes, please indicate percent efficiency _______ %
7. What areas in your opinion offer the greatest opportunities for improving your boiler efficiency?

   ____

   ____
8. What is the average temperature of the stack gases? _______ deg C
9. What is the level of Excess air (not oxygen) that you provide to the air/fuel mixture in the burner? (check one)

   ? < 20 % ? 20-40 % ? 40-60 % ? 60-80 % ? > 100% ? not sure
10. Indicate which resources you use for information on operating your boiler efficiently (where 1=use most and 5=use least):

    ? Boiler Operator Experience

    ? Guidelines from Government Agency

    ? Boiler Inspector

    ? Boiler Manufacturer's Guidelines

    ? Other specify_____________________________________
11. Who is responsible for boiler water treatment at your plant?

    ? Boiler Operator ? Separate Department
12. How often is the water tested? (check one)

    ? monthly ? 2-4 months ? 4-6 months ? Once a year ? Not sure
13. List any energy efficiency measures you may have implemented in the last 5 years.

    ____

    ____

Participant Questionnaire Evaluation
Steam Workshop Kiev, Ukraine 1/18-1/19/2000

1. Boiler parameters

#Boilers	Bar	tons/hr	Av.load	Efficiency*	Stack t.C	Fuel
5	40/90	75/200	60/160	85	150	mazout
9	40	35/50/75	30	60	130	coke gas
6	30/100	150/220	100/160	85-88	200	coke & BFG
8	30/100	150/220	100/150	86	200	BFG
4	13	10	6-16	82-86	180-210	mazout
12	13	20	18	89	155	mazout
3	14	10	10	86	170	mazout
6	13	20	20	91-94	92-98	gas
8	14	146	20	89-91	170	gas
3	14	10	10	96	130	mazout
5	23	20	60	85	150-180	mazout

*Are these corrected to the U.S. standard? Please add a footnote about this, as you described in the report.

2. **Main Fuel** Natural Gas - 6 mazout- 4 Other (blast furnace, coke) -4
3. **Back-up Fuel** Natural Gas - 4 Mazut (mazout) - 6 Other -
4. **On average, how many months a year do you have to run the boiler on back-up fuel?**
   less than 1month -3 1 to 2 months - 2 2 to 4 months - > 4 months –5*
   *Format is confusing. Can we adjust fonts or underscore/highlight the responses so that we can tell them apart from the questions?
5. **What is the level of Excess air (not oxygen) that you provide to the air/fuel mixture in the burner?**
   < 20 % -7 20-40 % - 40-60 % - 1 60-80 % - > 100% - not sure-3
6. **Indicate which resources you use for information on operating your boiler efficiently**(where 1=use most and 5=use least):
   Boiler Operator Experience – 4,4,2,2,4,2,3 ,4 ✍ Average = 3.125
   Guidelines from Government Agency- 3,1,1,1,2,5 ✍ Average = 1.83
   Boiler Inspector –2,2,2,1,5,3,1 ✍ Average = 2.28
   Boiler Manufacturer's Guidelines – 4, 1,3,3,5,3,1,1 ✍ Average = 2.625

Other specify: regime instructions, inspections reports

7. **Who is responsible for boiler water treatment at your plant?**

   Boiler Operator - Separate Department – 11*

   Should we have a " please specify line, but we have concluded it is the water department based on….

8. **How often is the water tested?**

   monthly-10 2-4 months- 4-6 months- Once a year- Not sure-

9. **What areas in your opinion offer the greatest opportunities for improving your boiler efficiency?**

- automatical control of gas/fuel ratio
- flue gas analyzer
- retrofit
- improving combustion efficiency
- boiler turn-up
- metering system
- combustion control/monitoring
- burners improvement

10. **List any energy efficiency measures you may have implemented in the last 5 years.**

- boiler leakages reduction
- installation of turboblowers electrical drives
- local heating by hot water instead of steam
- installation pump drives
- natural gas meters
- ultrasonic unit for waste water measuring
- boiler heating surfaces cleaning
- utilization of the flash steam heat
- steam traps
- flash steam utilization
- steam pipes insulation
- economizer installations
- pressure control system

- air pre-heater installation
- heat exchanger installation
- mazout *preheaters utilizing flash steam
- *please keep spelling consistent.

*****