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 – 19\textsuperscript{th}, 2000, Kiev, Ukraine.

For

THE ALLIANCE TO SAVE ENERGY
1200 18\textsuperscript{th} Street, NW, Suite 900, Washington, DC 20036. 202-857-0666. Fax:202-331-9588

Prepared By

Gurvinder Singh
Industrial Energy Efficiency Expert

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 to 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 than 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 DISCUSSION 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.

 далеко 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.
 далеко There was also a suggestion to include hot water boiler systems in addition to steam boilers.

Other general comments were:
 далеко Incorporate refrigerant and cooling systems into the workshop agenda.
 далеко Increase the diversity of industry represented at the workshops.
 далеко Target college level students to get them thinking about energy efficiency early in their careers.
 далеко 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:

 далеко 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.

 далеко 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.

 далеко 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 guidelines 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.
Appendix 1
List of Participants
**LIST of PARTICIPANTS**  
Steamp Efficiency Workshop  
January 18-19, 2000 Kyiv

<table>
<thead>
<tr>
<th>No</th>
<th>Name</th>
<th>Company</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Michael Boyko</td>
<td>Armyansk, JSC «TYTAN»</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Oleg Bezsmertny Inspector</td>
<td>Sumy, State Energy Conservation Inspection</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Volodimir Vyfanyk</td>
<td>Monastyrysche JSC «??K?? »</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ivan Grygoryev</td>
<td>Romny Milk Plant</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Valery Dubenko</td>
<td>Donetsk ?..?.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Dmytro Eremenko</td>
<td>Mariupol Sea port</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Gennady Genylo</td>
<td>Mariupol Bakery plant</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Alexander Zenkov</td>
<td>Krasnoperekopsk, JSC «Crimea soda plant»</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Valery Zynovyev</td>
<td>Donetsk JSV «?.?.?.»</td>
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<tr>
<td>10</td>
<td>Victor Yschenko, Deputy Chief Powerman</td>
<td>Dniprodzherynsk, Coke plant</td>
<td></td>
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<tr>
<td>11</td>
<td>Alexander Kyrichok, Head of Inspection Department</td>
<td>Donetsk, State Energy Conservation Inspection</td>
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</tr>
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<td>12</td>
<td>Mykola Kytaev, Deputy of the Head of Inspection Department</td>
<td>Mariupol, State Energy Conservation Inspection</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Mykola Korgyk, President</td>
<td>Ivano-Frankivsk ESCO West</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Sergey Korolyov, Engineer</td>
<td>Sumy “OilGasTechnology”</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Taras Levytsky</td>
<td>Mykolayiv Brewery «Yantar»</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------</td>
<td>--------------------------</td>
<td>--------------------------</td>
</tr>
</tbody>
</table>
|16 | Victor Mykhaylichenko  
Chief Engineer                      | Mykolayiv                | Alumina plant            |
|17 | Victor Mykhaylovksy  
|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                 | Illica 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                     | «? VIAN'T»                |
|26 | Volodymir Strygonov  
Chief Engineer                               | Donetsk                  | Bakery plant No.3        |
|27 | Olga Toteva  
|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
**SCHEDULE OF WORKSHOP**

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


First Day: 18th of January 2000

<table>
<thead>
<tr>
<th>Time</th>
<th>Title of report, content of measure</th>
<th>Lecturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00 – 10.00</td>
<td>Registration of participants</td>
<td>Representatives of Alliance to Save Energy and the Agency for Rational Energy Use and Ecology</td>
</tr>
<tr>
<td>10.00 – 10.20</td>
<td>Opening of workshop. Opening address.</td>
<td>Representatives of Alliance to Save Energy and the Agency for Rational Energy Use and Ecology</td>
</tr>
<tr>
<td>10.20 - 10.40</td>
<td>Problems of steam use in Ukraine</td>
<td>Representative of The State Committee of Ukraine for Energy Conservation</td>
</tr>
<tr>
<td>10.40 – 11.20</td>
<td>Boiler houses, steam production and consumption in USA. Measures to increase energy efficiency of steam boilers.</td>
<td>Representative of Alliance to Save Energy</td>
</tr>
<tr>
<td>11.20 – 11.40</td>
<td>Coffee break.</td>
<td></td>
</tr>
<tr>
<td>11.40 – 12.20</td>
<td>Energy efficiency equipment in boiler houses. Combustion process. Fuel saving measures at steam production</td>
<td>Representative of Alliance to Save Energy</td>
</tr>
<tr>
<td>12.20 – 13.00</td>
<td>Steam from CHP or from own boiler house. Estimation on investments required for boiler house upgrade.</td>
<td>Representative of Armstrong</td>
</tr>
<tr>
<td>13.00 – 13.10</td>
<td>Questions and answers</td>
<td></td>
</tr>
<tr>
<td>13.10 – 14.00</td>
<td>Lunch-break.</td>
<td></td>
</tr>
<tr>
<td>14.00 – 14.40</td>
<td>Energy efficient steam systems</td>
<td>Representative of Armstrong</td>
</tr>
<tr>
<td>14.40 – 15.20</td>
<td>Videofilm “Let’s talk steam traps/update” (main types and operating principles)</td>
<td>Armstrong</td>
</tr>
<tr>
<td>15.20 – 15.40</td>
<td>Coffee break.</td>
<td></td>
</tr>
<tr>
<td>15.40 – 16.20</td>
<td>Boiler automatic control system. Burners control. Highly efficient boiler houses.</td>
<td>Representative of Alliance to Save Energy</td>
</tr>
<tr>
<td>16.20 – 17.00</td>
<td>Measures to reduce heat consumption. Equipment for heat recovery. Economizers.</td>
<td>Representative of Alliance to Save Energy</td>
</tr>
<tr>
<td>17.00 – 17.30</td>
<td>Gas-and-oil fired steam boilers, their types, characteristics and equipment, produced in Ukraine.</td>
<td>OJSC “TeKom” Monastyrsche</td>
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<tr>
<td>17.30 – 18.00</td>
<td>About experience of preparing and implementing investment projects in industry of Ukraine</td>
<td>Volodymir Laskarevskiy</td>
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<tr>
<td>18.00 – 18.30</td>
<td>Organization issues.</td>
<td>Lead expert</td>
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<tr>
<td>18.30 – 20.00</td>
<td>Reception</td>
<td>Agency for Rational Energy Use and Ecology (ARENA-ECO)</td>
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Second Day: 19th of January 2000

<table>
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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>9.00 – 9.10</td>
<td>Discussion of first day information.</td>
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<tr>
<td>9.10 – 9.50</td>
<td>Systems and units to measure gas, steam and condensate. Heat insulation of pipelines and equipment. 3? Plus Program.</td>
<td>Representative of Alliance to Save Energy</td>
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<tr>
<td>9.50 – 10.30</td>
<td>Equipment and feed water processing and monitoring methods</td>
<td>Representative of Alliance to Save Energy</td>
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<tr>
<td>10.30 – 11.10</td>
<td>Characteristics of domestic enterprises steam systems. Energy efficient steam distribution system. Characteristics of condensate drainage with the control of steam inflow.</td>
<td>Representative of Armstrong</td>
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<tr>
<td>11.10 – 11.30</td>
<td>Coffee break.</td>
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<td>11.30 – 12.10</td>
<td>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.</td>
<td>Representative of Armstrong</td>
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<tr>
<td>12.10 – 12.30</td>
<td>Videofilm.</td>
<td>Armstrong</td>
</tr>
<tr>
<td>12.30 – 12.40</td>
<td>Questions and answers</td>
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<tr>
<td>12.40 – 13.10</td>
<td>Domestic equipment for feed water monitoring</td>
<td>(ENVITEK Kyiv)</td>
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<tr>
<td>13.10 – 14.00</td>
<td>Lunch break</td>
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<tr>
<td>14.00 – 14.20</td>
<td>Experience of steam consumption in Donezk oblast</td>
<td>Oleksandr Kirichok Chief of the oblast inspection on energy saving, Donezk city</td>
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<tr>
<td>14.20 – 14.50</td>
<td>Basics of process of production management and energy consumption (Energy management).</td>
<td>Representative of Armstrong</td>
</tr>
<tr>
<td>15.20 – 15.35</td>
<td>Domestic designs for efficient steam consuming equipment. Turbine expanders.</td>
<td>Scientific and production enterprise “Naftagaztechnologiya” Sergiy Korolyov</td>
</tr>
<tr>
<td>15.35 – 15.50</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>15.50 – 16.30</td>
<td>Round table. Questions and answers</td>
<td>Representatives of: State Committee of Ukraine for Energy Conservation; Alliance to Save Energy; Agency for Rational Energy Use and Ecology</td>
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<tr>
<td>16.30 – 17.00</td>
<td>Workshop closing</td>
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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 improvement (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 Manage**

Establish a system to collect data: Instrumentation and

Interpret data: Make sense of data; identify waste; graph
Act on the information to control losses
Key Elements of an Effective Energy Management Program

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 cost

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, blc
- 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 Produce 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

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<tr>
<td>Food Products</td>
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<td>49</td>
<td>102</td>
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<td>Pulp and Paper</td>
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<td>535</td>
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<tr>
<td>Steel</td>
<td>487</td>
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<tr>
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<td>Chemicals</td>
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<td>Petroleum</td>
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<td>14</td>
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<tr>
<td>Steel</td>
<td>371</td>
<td>1</td>
<td>58</td>
<td>21</td>
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</tr>
</tbody>
</table>

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 Efficiency Improvement Potential

<table>
<thead>
<tr>
<th>Generation</th>
<th>2-</th>
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<tbody>
<tr>
<td>boiler tune-ups and heat recovery</td>
<td>2-</td>
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<tr>
<td>load controls</td>
<td>1-</td>
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<td>emissions monitoring</td>
<td>1-</td>
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<td>Distribution</td>
<td>12</td>
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<tr>
<td>steam leaks</td>
<td>2-</td>
</tr>
<tr>
<td>steam traps</td>
<td>8-</td>
</tr>
<tr>
<td>insulation</td>
<td>5</td>
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<td>Recovery</td>
<td>9</td>
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<td>water treatment</td>
<td>5</td>
</tr>
<tr>
<td>condensate return</td>
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<tr>
<td>Total</td>
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</tr>
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</table>

Note that system efficiency is not additive, due to the interrelated nature of the parts. Most system efficiency potential is in Distribution and Recovery.
Fig 1.6: BOILER RATING & ENERGY FLOW RATE CONV.
(1 HP = .746 KW = 2.17 x 10⁻⁴ Btu/hr)

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By (Reciprocal Conversion)</th>
<th>To Obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler HP</td>
<td>34.5</td>
<td>(0.029)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lbs. steam/hr F&amp;A</td>
</tr>
<tr>
<td>Boiler HP</td>
<td>33,475</td>
<td>(0.0000299)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Btu/hr (output)</td>
</tr>
<tr>
<td>Boiler HP</td>
<td>15.64</td>
<td>(0.0639)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>kg steam/hr F&amp;A</td>
</tr>
<tr>
<td>Boiler HP</td>
<td>9.81</td>
<td>(0.102)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KW</td>
</tr>
<tr>
<td>Boiler HP</td>
<td>139.5</td>
<td>(0.000717)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EDR sq. ft. steam</td>
</tr>
<tr>
<td>Boiler HP</td>
<td>223</td>
<td>(0.000448)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EDR sq. ft. hot water</td>
</tr>
</tbody>
</table>

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

The following table provides conversion factors to and from the metric quantities.

<table>
<thead>
<tr>
<th>1 equals</th>
<th>kJ/hr</th>
<th>kW</th>
<th>kg CE / hr</th>
<th>Btu/hr</th>
<th>kcal/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>kJ/hr</td>
<td>0.00028</td>
<td>0.000034</td>
<td>0.948</td>
<td>0.239</td>
<td></td>
</tr>
<tr>
<td>kW</td>
<td>3,600</td>
<td>0.123</td>
<td>3,412</td>
<td>860</td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>0.000229</td>
<td>0.746</td>
<td>0.000217</td>
<td>0.0000547</td>
<td></td>
</tr>
<tr>
<td>Btu/hr</td>
<td>1.055</td>
<td>0.00029</td>
<td>0.000036</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kcal/hr</td>
<td>4.18</td>
<td>0.00116</td>
<td>0.00014</td>
<td>3.97</td>
<td></td>
</tr>
</tbody>
</table>

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
Boiler efficiency vs system efficiency

- Boiler efficiency is part of the system
- System efficiency includes generation, distribution, and consumption
- 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 benchmark?
- 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—compensate with excess air
- At maximum firing rate—reduced “RESIDENCE TIME”
Tuned up or Baseline Efficiency

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

Baseline efficiency for estimating all future capital improvement savings

Future savings estimates hinge on the accuracy of this number

Theoretical vs Technical vs Economical Efficiency

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, which is of interest to policy makers and is concerned with institutional structural issue
## Maximum Technical Efficiency

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Rated Capacity Million BTU’s/Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-16</td>
</tr>
<tr>
<td>GAS</td>
<td>86 %</td>
</tr>
<tr>
<td>OIL</td>
<td>89 %</td>
</tr>
</tbody>
</table>

## Maximum Economic Efficiency

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Rated Capacity Million BTU’s/Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-16</td>
</tr>
<tr>
<td>GAS</td>
<td>80 %</td>
</tr>
<tr>
<td>OIL</td>
<td>84 %</td>
</tr>
</tbody>
</table>

Larger boilers economic efficiencies closer to technical efficiencies. Smaller boilers the techno-economic gap is 5-6%. Oil burns at a higher flame temperature of 4200 F so radiative heat transfer rate and efficiency is higher for oil fired burners.
Boiler losses can be grouped in three broad areas:

- Stack losses: (excess) air and high stack temperature (most loss)
- 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 $\Rightarrow$ 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 cherr
Surface losses
??Consist of convective and radiative losses from the boiler 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. A master controller then sends a signal to the control system. There are three levels of control systems available, from the most basic to the art microprocessor based. The most basic is the jackshaft (also known as single-point control system control). The next parallel positioning, independent or multi-point control system. The most efficient is the metered or O2 trim system.
Jackshaft or Single-Point Control Fig 2.4:

- Mechanical linkage simultaneously controls air and fuel.
- Open control loop; no feedback loop from combustion to ensure proper ratio.
- Cam ratios preset, wear over time and affect the air/fuel ratio.
- Non-linear characteristics of flow control devices leads to issues at low load conditions.
- This may be the most common type of control scheme in Ukraine.
- An improvement over this is to eliminate the non-linear characteristics of the mechanical linkage and provide calibrated independent control devices 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 to ensure proper ratio

Employs mechanical, pneumatic, electronic and DDC control elements

AUTOFIAME® microprocessor based, can program it at start

Requires calibration (due to open loop setup)

Use only on variable boiler load applications to justify cost
The O2 trim control scheme Fig 2.6
  Incorporates feedback “closes the loop”
  See combustion chapter from steam challenge regarding changes with amb temp, O2 trim can account for these
  Manufacturers and costs.

**Burner Turndown Ratio:**
Low Turndown Ratio (inefficiency at low loads: purge cycle heat transfer by combustion air from boiler up the stack)
TDR in older US boilers is 3-4:1 the new ones have a TDR of 10:1
For a boiler that operates at part load a fair portion of the savings from going to a high TDR burner can be significant neighborhood of 3 to 10 percentage point improvement in has been seen
Experience in the FSU countries-excess air quantities adjusted manually and are usually set very high. The control system air pressure as a substitute for airflow measurement and operator has to make an airflow set point adjustment after change.
Fig 2.1 Source: Taplin, Fairmont Press
Fig 2.2 Source: Taplin, Fairmont Press
EFFECT OF SOOT ON FUEL CONSUMPTION

INCREASE IN FUEL CONSUMPTION (%)

SOOT LAYER ON HEATING SURFACE

Fig 2.3 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 IMPROVEMENTS
BOILER TUNE-UP/MAINTENANCE

Two steps to improving boiler efficiency:
??Tune-up/maintenance, and
??Equipment Modifications

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

??Inspecting the burner assembly
  Check to make sure that the:
  ??Clean: gas injection orifices, H₂O traps, oil tip passages & strainers
  ??Reduce excessive play on air/fuel control linkages
  ??Oil gun is positioned properly within the burner throat
  ??Right oil temperature and pressure is maintained
  ??Eliminate any air leakage into the boiler furnace/stack
Stack Temperature

Stack temperature: indication of cleanliness of boiler tubes should ideally be in the range of 150 F– 200 F range. Tube fouling can be on both the fireside and the waterside: fouling and scale (Fig 3.1).

Efficiency gains from stack temperature reduction:

Example: what will the efficiency change be with an excess of 60 % if the stack temperature is reduced by 100 F?

Solution: The factor from the chart at 60 % XS air is 0.325. 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

\[ \text{CH}_4 + 2\text{O}_2 + 7.53\text{N}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 7.53\text{N}_2 + 1,013 \text{ E} \]

Below the stoichiometric point: Incomplete combustion

H\(_2\) combustibles

Real world: stoichiometric point combustion is unattainable due to imperfect mixing, need excess air
The fundamental rule is:

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

The relationship of CO and O$_2$ is given by (Fig 3.3)

The question then becomes how much excess air is appropriate. It depends on several limiting factors:

- Flame stability
- Level of CO in gas fired units known as the CO Threshold
- Smoke in the stack in oil fired units or Smoke Threshold
- 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, CO (If O2 and CO level are at a minimum then go to next)
3. Reduce airflow in small increments and note:
   ? Any signs of smoke in stack or unstable flame operation
   ? Record CO or SSN readings at various O2 settings
   ? Record corresponding stack temperature
4. Draw the CO/O2 or Smoke/O2 curves and find the minimum 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. Avoid low rates.
7. Test the settings by imposing false loading on the boiler to see that the new burn ratio settings do not enter into an 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/year)

Efficiency improvements can be obtained from the combustion analyzer print out or corresponding efficiency improvement from stack temperature reduction can be estimate from (Fig 3.2)

The average fuel use rate and the hours of operation multiplied also give the annual fuel consumption 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 air

Example: Energy savings from tube cleaning-stack temp reduction

Example: Energy savings from optimizing multiple boiler load
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 Relationship

Fig 3.4 Source: Taplin, Fairmount Press
Combustion Efficiency
Oxygen-CO Relations

Fig 3.5 Source: Taplin, Fairmount Press
Appendix 6
Combustion Efficiency Improvements
General characteristics of good control systems:

- Accurate air/fuel input measurement & control-flow measurement
- Correct synchronization of fuel and air input
- Consistent reliability and repeatability
- Auto trim of excess oxygen to a preset minimum under all steady-state conditions
- Continuous optimization of the combustion efficiency depending on fuel Btu, ambient air temperature, and relative humidity
Modern Ways Of Achieving Better Combustion Efficiency

- 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 characteristic, 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 changing 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 Economizers

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Minimum Inlet Water Temperature, F</th>
<th>Maximum Exit Flue Gas Temperature, F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>210</td>
<td>300</td>
</tr>
<tr>
<td>No. 2 Oil</td>
<td>220</td>
<td>325</td>
</tr>
<tr>
<td>No. 5&amp;6 Oil (Mazut)</td>
<td>240</td>
<td>350</td>
</tr>
</tbody>
</table>

Other Means Of Minimizing Acid Corrosion

- Stack design: Drain collar section or Off-set
- Insulate stack metal: Raise metal skin temperature above acid dew point
- Parallel flow through the economizer: Raises pipe surface temperature on the inlet (cold-end) side
- Corrosion resistant materials: Corrosion resistant alloy steels 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 efficiency improvement should be approached and start with the least cost/no cost options to the energy efficiency equipment installation/investment.

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
Fig 4.1

Dew Point (°F)

Sulfur Content of Oil (%)

(Based on 25% ex for combustion)
Fig 4.2
Appendix 7
Module 5: Metering Equipment and Insulation 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 and commitment to energy efficiency
??Better energy use information helps in forecasting & decision making
??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, convection, and radiation.

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

Thermal conductivity, or \( k \) value

Amount of heat that passes through 1 square foot of 1-inch material in 1 hour when there is a temperature difference of 1°F 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 resistance.

The two types of resistances - mass and surface.
Mass for Homogeneous material

\[ R_I = \text{thickness} \times \frac{1}{k} \]

Represents total resistance to heat flow for a given thickness.

Surface resistance and this is defined as:

\[ R_s = \frac{1}{f} \]

\( f \) is the surface film coefficient.

Total resistance of the insulating system is:

\[ R_{\text{total}} = R_I + R_s \]

Overall coefficient of heat transmission of the insulation is defined as:

\[ U = \frac{1}{R_I + R_s} \]
Important Properties of Insulating Materials

??Temperature Use-Range: On thermal systems the upper limit is 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 time higher than the original value.

??Compressive Strength: Need to consider this where the insulation will experience a physical load, such as buried pipe applications.
## Common Industrial Insulation Types and Properties Used in Thermal Applications

<table>
<thead>
<tr>
<th>Insulation Type</th>
<th>Temp Range F</th>
<th>Thermal Conductivity at Temperature Btu-in./hr-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass Fiber Blankets</td>
<td>To 1200</td>
<td>0.24 – 0.31 0.32 – 0.49 0</td>
</tr>
<tr>
<td>Glass Fiber Boards</td>
<td>To 1000</td>
<td>0.22 0.28 0</td>
</tr>
<tr>
<td>Glass Fiber Pipe Covering</td>
<td>To 850</td>
<td>0.23 0.30</td>
</tr>
<tr>
<td>Mineral Fiber Blocks</td>
<td>To 1900</td>
<td>0.23 – 0.34 0.28 – 0.39 0</td>
</tr>
</tbody>
</table>
Protective Coating and Jackets

- Ensure proper life and performance of the insulation system especially 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 BLOWDOWN
HEAT RECOVERY

Need for chemical treatment

??Hardness
??Oxygen
??Dissolved solids
??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 comes out
??Mechanical deaeration: 98 % removal of dissolved oxygen
??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: Ω
           strainers and control valves
??Top continuous blowdown
??Level of Solids measured by conductivity
??Manual control : ? 20% of the desired dissolved solids level
??Automatic operation: ? 5%.
Alkalinity
??Can lead to “caustic embrittlement” failure
??Proper alkalinity is maintained by adding NaOH.

Factors That Minimize Boiler Blowdown & Improve Efficiency:
Minimize blowdown by manual adjustment
  ??Establishing operating procedure & frequent water quality testing
??Minimize blowdown by automatic adjustment (Fig 6.2)
  ??Average boiler plant can save about 20 percent in blowdown
??Decrease blowdown by recovering more condensate
  ??Essentially free of water impurities - dilutes the concentration of impurities
??Most cost effective: Save in energy and chemical costs
??Energy efficiency improvement potential is enormous.
Estimating BD Reduction:

Percent BD = \( \frac{A}{B-A} \times 100 \)

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 water impurity ppm and the boiler drum maximum allowable limit is 100 ppm. What is the change in the BD requirements?
Solution:

\[
A_{\text{old}} = 10 \times (1 - 0.5) = 5 \text{ ppm}
\]
\[
B_{\text{old}} = \frac{5}{(100 - 5)} = 5.3\%
\]

\[
A_{\text{new}} = 10 \times (1 - 0.75) = 2.5 \text{ ppm}
\]
\[
B_{\text{new}} = \frac{2.5}{(100 - 2.5)} = 2.6\%
\]

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

\[
BD = \text{Percent BD} \times \text{lbs/hr Steam}
\]

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

\[
BD = \frac{(5.3 - 2.6)}{100} \times 100,000 = 2700 \text{ lbs/hr}
\]
Annual boiler fuel savings from reduced blowdown rate due to condensate recovery:

\[
ES = \frac{BD \times HR \times C_p \times (T_{fw} - T_{mu})}{Boiler \ Average \ Efficiency}
\]

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 value is
\(T_{fw}\) = 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 impurity limit. Consult a chemical treatment specialist.

Heat Recovery from Blowdown

Example of Blowdown 2 - Stage Heat recovery (Fig 6.3)

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 the interaction 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 amount.

\[
\% \text{ Flash steam} = \frac{H_s - H_f}{H_g} \times 100
\]

\(H_s\) = enthalpy of liquid at boiler pressure, Btu/lb
\(H_f\) = enthalpy of liquid at flash tank pressure, Btu/lb
\(H_g\) = latent heat of vaporization at flash tank pressure, Btu/lb

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

\[
\% \text{ Flash steam} = \frac{362 - 196}{960} = 17.3\%
\]
Flashed steam = 0.173 * 100,000 lbs/hr * (0.026) = 450 lbs/hr

The total heat of the flash steam at 5 psig (from Steam tables) = 1156 Btu/lbs

Heat saved in flashed steam = 450 lbs/hr * 1156 Btu/lb = 520,000 Btu/hr

Similarly, the blowdown or drain from the flash tank is passed through a heat exchanger and then dumped into the sewer. The temperature of the water leaving the heat exchanger is 20 F higher than the incoming water or 80 F. Heat recovered in the heat exchanger:

Drain rate from flash tank (blowdown rate – flash steam) = 2600 - 2150 lbs/hr
Heat of liquid leaving the heat exchanger at 80 F = 48 Btu/lb

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 = 740,740 Btu/hr

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 __________
5. On average, how many months a year do you have to run the boiler on back-up fuel?
   ? less than 1 month   ? 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.
    _____________________________________________________________
    _____________________________________________________________
1. **Boiler parameters**

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

*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?**

<table>
<thead>
<tr>
<th></th>
<th>less than 1 month</th>
<th>1 to 2 months</th>
<th>2 to 4 months</th>
<th>&gt; 4 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-3</td>
<td>-2</td>
<td>-2</td>
<td>-5*</td>
</tr>
</tbody>
</table>

*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?**

<table>
<thead>
<tr>
<th></th>
<th>&lt; 20 %</th>
<th>20-40 %</th>
<th>40-60 %</th>
<th>60-80 %</th>
<th>&gt; 100 %</th>
<th>not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-7</td>
<td>-4</td>
<td>-1</td>
<td>-1</td>
<td>-</td>
<td>-3</td>
</tr>
</tbody>
</table>

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.

*****