Industrial Energy Audit Workshop

Missouri Industrial Assessment Center
College of Engineering
University of Missouri-Columbia

January 30, 2007
Introduction

Bin Wu, PhD

Director
Missouri Industrial Assessment Center

College of Engineering, University of Missouri-Columbia
## Session Schedule

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenter</th>
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<tr>
<td>10:00 - 10:15 am</td>
<td>Introduction/Welcome</td>
<td>Bin Wu, Director</td>
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<td>Missouri Industrial Assessment Center</td>
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<td>MU Professor of Industrial Engineering</td>
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<td>University of Missouri-Columbia</td>
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<tr>
<td>10:15 – 11:00 am</td>
<td>Overview of industrial energy audit: processes, best practice, resources and tools</td>
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<td></td>
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<td>Roger Korenberg, Frank Cunningham</td>
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<td>State Energy Engineer</td>
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<td>MoDNR</td>
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<td>11:00 – 12:00 am</td>
<td>Energy audit tools and techniques/Infrared camera application</td>
<td>Sanjeev Khanna, Assistant Director</td>
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<td>Missouri Industrial Assessment Center</td>
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<td>MU Professor of Mechanical Engineering</td>
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<tr>
<td>12:00 – 12:30 pm</td>
<td>LUNCH</td>
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<td>12:30 – 1:30 pm</td>
<td>Audit areas/analysis I</td>
<td>Chatchai Pintuprapa</td>
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<td></td>
<td>Efficient generation of steam</td>
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<td>Waste recovery</td>
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<td>Lighting</td>
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<td>Productivity</td>
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<td>1:30 – 2:15 pm</td>
<td>Audit areas/analysis II</td>
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<td>HVAC + Building Envelopes</td>
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<td></td>
<td>Compressed Air</td>
<td></td>
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<tr>
<td></td>
<td>Motors</td>
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<td></td>
<td>DOE IAC DataBase</td>
<td></td>
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<tr>
<td>2:15 – 2:30 pm</td>
<td>Conclusion/Case Review</td>
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<td>2:30 pm</td>
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Overview of Industrial Energy Audit

Processes, Best practices, Resources and Tools
1. Overview of Missouri Industrial Assessment Center

2. Industrial Energy Audit Processes and General Considerations

3. Best Practices, Resources and Tools
1. Overview

Missouri Industrial Assessment Center

College of Engineering
University of Missouri-Columbia
Missouri IAC is one of the five new centers founded by the U.S. DOE in the nation.
According to the US Department of Energy’s requirement, the ultimate goal of Missouri Industrial Assessment Center is to be a “center of resources and services in industrial energy efficiency” for industries in the state and the surrounding areas.

Specifically, the aim of Missouri IAC is to promote best practices in energy efficiency, reusable energy, waste reduction and productivity through integration of activities involving the University and all other interested parties.
Advisory Board
- Missouri Industrial Assessment Center
- Advisory Board (TBN)

State Agency
- Missouri Department of Natural Resources Energy Center
- Missouri Department of Economic Development

Industry Relations
- Ameren UE
- Associated Industries
- City of Columbia Utilities

Missouri Industrial Assessment Center
MU College of Engineering

MU Students
- Energy Conservation Society
- National Society of Black Engineers
- Society for Hispanic Professional Engineers

Outreach
- Missouri Enterprise (Manufacturing Extension Program)
- Missouri Small Business Development Centers
- Procurement Technical Assistance Centers
- Market Development Program
- Cooperative Extension Business Development Programs
- Economic Development Administration University Center
The Center carries out activities in four areas: research, education, outreach and industrial energy audit.

In particular, the audit is free, with summary recommendation presented to the company upon the completion of the audit, and a detailed analysis and recommendation report delivered within the following 60 days.
More information about the Missouri IAC program and the others (such as ITP, EERE, Save Energy Now) can be found on IAC and DOE websites:

http://iac.missouri.edu
2. Industrial Energy Audit

– Processes & General Considerations

Pre-audit analysis

On-site audit

Recommendation & follow-up
Pre-audit analysis

**Obtain Pre-Assessment Data**
- Send introductory letter
- Send Pre-Assessment Form
- Obtain client permission for uploading case material
- Obtain and check completeness of pre-assessment data (including bills)
## Pre-audit analysis

### PRE-AUDIT ASSESSMENT

<table>
<thead>
<tr>
<th>Analyze utility bills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify problems, key areas/issues &amp; Check IAC Case Base and Best Practice Guidelines</td>
</tr>
<tr>
<td>Motors</td>
</tr>
<tr>
<td>Lighting</td>
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<tr>
<td>Boilers &amp; Steam</td>
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<tr>
<td>Compressed air</td>
</tr>
<tr>
<td>HVAC</td>
</tr>
<tr>
<td>Building envelop</td>
</tr>
</tbody>
</table>

### General areas of concern
Pre-audit analysis – utility bills

Common Utilities

Electricity
Natural Gas
Fuel Oil
Water

(Require bills of the past 12 months)
Pre-audit analysis – utility bills

**Electricity**

- Energy Consumption
  - The total amount of electricity used by a system over a period of time
  - Measured in Kilowatt-hour (kWh)
- Demand
  - The instantaneous power draw by a system
  - Measured in Kilowatt (kW)
- Power Factor (kVar)
  - The ratio of the actual power consumed by the equipment to the power supplied to the equipment.

**Natural Gas/Fuel Oil**

- British Thermal Unit (Btu)
- Therms
Energy Consumption

• If a motor uses 50 kW of power for 8600 hrs in a year, then the energy consumption of the motor would be:

\[
\text{Consumption} = 50 \text{ kW} \times 8600 \text{ hrs/year} \\
= 430,000 \text{ kWh}
\]

• Energy Consumption Charge is based on each kWh ($/kWh)
However, this figure shows that the total electric cost is not determined by electric usage.
Demand

- Demand is measured over a period of time
- Demand charges are averaged over a specified period of time - Some local utilities measure it every 15 minutes, but others may measure it every 30 minute.
- Demand is measured where electricity enters the plant
- Demand Charge is base on highest kW used in the facility in a month. ($/kW)
## Pre-audit analysis – utility bills

### Example: electricity

<table>
<thead>
<tr>
<th>Date</th>
<th>Consumption</th>
<th>Consumption Cost</th>
<th>Peak Demand</th>
<th>Demand Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>(months)</td>
<td>kWh</td>
<td>($)</td>
<td>kW</td>
<td>($)</td>
</tr>
<tr>
<td>Jan</td>
<td>198,800</td>
<td>$12,975</td>
<td>948</td>
<td>$8,759</td>
</tr>
<tr>
<td>Feb</td>
<td>331,200</td>
<td>$20,374</td>
<td>912</td>
<td>$8,427</td>
</tr>
<tr>
<td>Mar</td>
<td>245,000</td>
<td>$13,951</td>
<td>710</td>
<td>$6,560</td>
</tr>
<tr>
<td>Apr</td>
<td>305,600</td>
<td>$18,902</td>
<td>948</td>
<td>$8,759</td>
</tr>
<tr>
<td>May</td>
<td>368,000</td>
<td>$22,621</td>
<td>1,222</td>
<td>$11,290</td>
</tr>
<tr>
<td>Jun</td>
<td>318,400</td>
<td>$19,651</td>
<td>888</td>
<td>$8,205</td>
</tr>
<tr>
<td>Jul</td>
<td>289,200</td>
<td>$18,855</td>
<td>890</td>
<td>$8,223</td>
</tr>
<tr>
<td>Aug</td>
<td>335,600</td>
<td>$21,720</td>
<td>964</td>
<td>$8,907</td>
</tr>
<tr>
<td>Sep</td>
<td>367,600</td>
<td>$23,638</td>
<td>952</td>
<td>$8,796</td>
</tr>
<tr>
<td>Oct</td>
<td>387,200</td>
<td>$25,384</td>
<td>1,144</td>
<td>$10,570</td>
</tr>
<tr>
<td>Nov</td>
<td>350,000</td>
<td>$22,583</td>
<td>824</td>
<td>$7,613</td>
</tr>
<tr>
<td>Dec</td>
<td>374,400</td>
<td>$24,701</td>
<td>1,105</td>
<td>$10,210</td>
</tr>
<tr>
<td>Totals</td>
<td>3,871,000</td>
<td>$245,355</td>
<td>11,507</td>
<td>$106,319</td>
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</tbody>
</table>
Pre-audit analysis – utility bills

Since the total cost is the sum of assumption AND demand costs, the demand cost can easily increase the bill by 50%!
Pre-audit analysis – utility bills

**Demand Management**

- Does the rate schedule of the plant show a demand charge?

- If there is a demand charge on the bill, is there information on what time of day or part of the month demand maximum occurs?

  *If not, get a printout of the hourly variation of the demand for an average month where production is fairly uniform. With this information:*

- (a) Is the demand maximum significantly greater at one time of day each day?

- (b) Is the maximum demand significantly greater than the average demand during each day?

- (c) Is the monthly maximum demand significantly greater on one day than any other?
Pre-audit analysis – utility bills

Things to do to avoid demand charge

- Use plant owned transformer or lease transformer
- Pay bill on time
- Purchase electricity from a third party supplier
- Use thermal energy storage to take advantage of low off-peak rates
- Use power factor controllers and optimize plant power factor
- Shift operation off-peak to benefit from lower energy prices
Pre-audit analysis – utility bills

Other considerations: electric power factor, gas & fuels, etc.

More details can be found in:

*Self-Assessment Workbook*
Pre-audit analysis

QuickPEP (Quick Plant Energy Profiler): an easy to use tool for initial analysis and identification of possible improvements

http://www1.eere.energy.gov/industry/quickpep

- Provides first step for a plant looking into saving energy
- Outputs to PDF reports
Pre-audit analysis

**INPUTS**
- Plant description
- Utility supply data – electricity, fuel & steam
- Energy consuming system information
- Scorecard responses

**OUTPUTS**
- Overall picture of plant energy use
- Summary of energy cost distributions
- Preliminary assessment & comparison
- Areas for energy efficiency improvement
- Energy cost reduction potential

Quick PEP

Missouri Industrial Assessment Center

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable
On-site audit

In most cases we aim to complete the audit in a one-day session

Morning
- Introductions & Description of program - 20 minutes
- Plant overview - 30 minutes to tell us what you do, more about your company, products and customers, etc
- Questions about program - 15 minutes
- Plant Tour - 1 1/2 to 2 hours
- Meeting room debriefing – 30 minutes

Lunch break and discussion to identify key issues and areas (1 ½ hour)

Afternoon
- Key areas study/data gathering – 1 ½ hour
- Team discussion – 1 hour
- Summary presentation to company and discussion – 1 hour
Follow-up

Requirements set by the Dept of Energy (for IAC clients)

- A case summary be made available to the public, with any reference to the company and any confidential data removed (Please see http://iac.rutgers.edu/database for the previous case summaries).

- Need to carry out follow-up interview(s) – maybe a couple of times 6-12 months after the audit (through email/phone/visit).
3. Best Practices, Resources and Tools

The U.S. DOE launched Save Energy Now to help American businesses, factories, and manufacturing facilities save energy during this time of diminished supplies and rising energy costs.

It is part of the national campaign called Easy Ways to Save Energy unveiled by Secretary of Energy Samuel W. Bodman.

The Save Energy Now initiative will provide U.S. industry with technical assistance and information to save energy and money and increase productivity.

http://www.eere.energy.gov/industry/saveenergynow/

http://www1.eere.energy.gov/industry/bestpractices/
Ways to Save Energy
Boost the Bottom Line: Lower your plant’s energy bills
Reducing energy costs can be as easy as adjusting a dial. Get started today with simple, low-or no-cost steps to energy savings:

- 20 Ways to Save Energy now for quick and easy cost savings

Learn How Others Have Saved Facilities Like Yours Can Save Big
Energy-efficiency projects can deliver large returns to your business. Find out more about how these companies are benefiting from DOE-sponsored plant-wide energy assessments and projects that they implemented on their own:

- Alcoa
- Augusta Newsprint Company
- ExxonMobil
- Cooper Cammren
- Ford Motor Company
- Nalco Chemical Company
- Progressive Powder Coating
- Rohm and Haas
- Vulcan Chemicals

For more information visit the Industrial Energy Savers website.
Industry Plant Managers & Engineers

20 Ways to Save Energy Now

Think saving energy will require costly new equipment or complicated changes to your operating practices? Think again!

Here are twenty steps you can take this year for little or no cost, using in-house expertise. You’ll be amazed to discover how some simple changes can cut your energy bills.

Find out how to save energy in all your combustion systems, or focus more specifically on your steam boiler system or process heating system.

All Combustion Systems  [Read More]

1. Operate furnaces and boilers at or close to design capacity
2. Reduce excess air used for combustion
3. Clean heat transfer surfaces
4. Reduce radiation losses from openings
5. Use proper furnace or boiler insulation to reduce wall heat losses
6. Adequately insulate air or water-cooled surfaces exposed to the furnace environment and steam lines leaving the boiler
7. Install air preheat or other heat recovery equipment

Steam Generation Systems  [Read More]

1. Improve water treatment to minimize boiler blowdown
2. Optimize deaerator vent rate
3. Repair steam leaks
4. Minimize vented steam
5. Implement effective steam trap maintenance program
6. Use high-pressure condensate to make low-pressure steam
7. Utilize backpressure turbine instead of pressure-reducing or release valves
8. Optimize condensate recovery

Process Heating Systems  [Read More]

1. Minimize air leakage into the furnace by sealing openings
BestPractices

Case Studies

The U.S. Department of Energy collaborates with U.S. industry to implement energy-efficiency demonstration projects in operating plants. BestPractices participates in plant-wide assessments and the demonstration projects. Once an assessment or project is complete, the BestPractices team publishes a case study, which often shows that the project:

- Yields significant energy and cost savings
- Reduces energy consumption
- Improves productivity
- Reduces environmental impacts
- Demonstrates the usefulness of BestPractices tools
- Improves public relations for industry partners

See what others in your industry have done to increase their energy savings by reading their case studies.

Case Studies Search
- Case Studies by Industry
- Case Studies by Industrial System
- Plant-Wide Assessment Case Studies and Summaries
- Corporate Energy Management Case Studies
- Performance Spotlights

Case Studies by Industry

Plant-Wide Assessment Case Studies and Summaries
Plant-wide assessments (PWA) investigate overall energy use in industrial facilities and identify energy- and cost-saving opportunities for best practices in energy management for industry, including the adoption of new, energy-efficient technologies and process and equipment improvements. The U.S. Department of Energy cost-shares such assessments, usually through an annual competitive...
DOE BestPractices Software Tools

- AIRMaster+
- Chilled Water System Analysis Tool (CWSAT)
- Combined Heat and Power Application Tool (CHP)
- Fan System Assessment Tool (FSAT)
- MotorMaster+ 4.0
- MotorMaster+ International
- NOx and Energy Assessment Tool (NxEAT)
- Plant Energy Profiler for the Chemical Industry (ChemPEP Tool)
- Process Heating Assessment and Survey Tool (PHAST)
- Pumping System Assessment Tool 2004 (PSAT)
- Steam System Tool Suite
For example: Motormaster +
Motormaster +

- Energy-efficient motor selection and management tool,
- Includes a catalog of over 20,000 AC motors
- Features:
  - Motor inventory management tools
  - Maintenance log tracking
  - Efficiency analysis
  - Savings evaluation
  - Energy accounting, and
  - Environmental reporting capabilities
PHAST: Process Heating Assessment and Survey Tool

- Analyzes furnaces in a plant for fuel usage and losses.
- PHAST will not tell you what to do, but it will tell show effects of “playing” with process heating system
PHAST – Introduction (a bunch of calculators)

- **Energy Equivalency** – change equipment from natural gas → electric or from electric → natural gas

- **Efficiency Improvement** – alter combustion products (i.e., O2 content, flu gas temp) and shows change in energy input

- **O2 Enrichment** – shows effect of increasing O2 in combustion air on available heat. Converts to show fuel savings

- **Flow Calculations** – calculates fuel flow rate
PHAST - Plant/Equipment Information

- **General Info:** Location, SIC code, contact
- **Energy Source:** Input purchased energy streams along with heating values and costs
- **Furnace Information:** Record info on furnaces, including usage, operating hours, heat zone and auxiliary equipment served by furnace (i.e., compressors, fans, blowers, motors)
PHAST - Furnace Analysis

- Allows the user to vary different parameters concerning the furnace (such as size of opening, weight of fixtures, temperature of surface walls, temperature of incoming water or air, etc)
- Allows user to vary the same parameters to see the effects on furnace(s)
PHAST - Reports

- Software will take your inputs and illustrate them in charts and graphs
- Can view reports on whole facility or just on single furnace
- PDF format
DOE BestPractices Publications

- Energy Matters
  - BestPractices' quarterly newsletter

- Technical Publications
  - Technical fact and tip sheets,
  - Industrial energy-efficiency sourcebooks
  - Market assessments

- Case Studies
  - Describes successful company efforts to reduce energy costs
Conclusion

Let us not forget process improvement:

\[ \text{Lean}^2 = \text{Lean production processes} \]
\[ \text{&} \]
\[ \text{Lean energy consumption} \]
Questions?

Missouri Industrial Assessment Center

Director: Bin Wu, Ph.D., Professor

College of Engineering
Department of Industrial and Manufacturing Systems Engineering
E3437 Lafferre Hall, University of Missouri-Columbia, MO 65211,
Voice: 573-882-5540. Fax: 573-882-2693. Email: wubi@missouri.edu
Steam Generation

Sanjeev K. Khanna
Assistant Director, Missouri Industrial Assessment center
University of Missouri
Columbia, MO 65211

573.884.9109  khannas@missouri.edu
Safety Concerns

• Boiler systems are large.
• They contain as much water as steam and are therefore heavy.
• Compact and efficient systems require pressures need to be very high.
• In the early days, boiler explosions were frequent
• IAC assessment at Bridgewater Protective Coating
  • Missed an explosion by about a year!!!
Cost of Steam

• Very useful to give plant a number
• Estimate operational costs by just using energy, 1500 Btu/lbm for saturated steam (includes losses in boiler)
• If high pressure condensate is recovered, this can be reduced by 25%
Basic Boiler Questions

• Do you need steam?
  • High pressure hot water an alternative?
• Do you need all that pressure?
• What firing modes does your boiler handle?
• Is the system designed for the current building/plant load?
• What type of boiler do you have?
Typical Boiler Plant Cost Factors

Fuel 75%

- Labor 9.5%
- Equipment Depreciation 9.5%
- Electricity 2.5%
- Water Treatment Chemicals 1.5%
- Sewer 1.2%
- Water 0.8%
Fire-in-tube boiler

- Generally have 2-inch diameter or larger tubes.
  - Tubes are usually straight and short
    - necessary so that hot gases of combustion see low pressure drop
  - Baffles or turbulators are inserted in the tubes to control gas velocity and improve the heat transfer
- Used in applications that require moderate pressures and moderate demand.
  - For more than 300 psi, the required wall thickness would be too excessive.
Firetube Boilers (cont)

- The water space surrounding the tubes is usually contained by a large cylindrical or flat surfaced vessel.
- Have a fairly large amount of contained water
  - Large amount of stored heat energy.
- This is good where large amounts of steam or hot water are required in a short period of time, as often happens in process applications
No Economy of Scale!

With no appreciable economy of scale, large boilers are being replaced by gangs of smaller boilers!
Water-tube boilers

• In a water-in-tube boiler, the hot combustion gases are directed over the tubes in which the boiler water circulates.
  • These tubes are often headered in parallel to make-up a complete wall or panel of heat absorbing water-tubes
• All high pressure boilers above 300 psi are of watertube design
• Will usually have drums
  • Gravity used to separate liquid from vapor
• Can be used for superheated steam
Industrial Water-In-Tube Boiler
Industrial Boiler
Boiler Sizing

- A boiler cycle consists of air purges, idle time and firing time…
  - Only the last of these makes money
- Boiler "short cycling" occurs when an oversized boiler prematurely satisfies space heating demands and then shuts down until heat is again required
- Efficiency decreases when short cycling occurs
  - Radiation-type fixed energy losses are magnified under lightly loaded conditions.
    - 1% at full load becomes 4% at 25% load
  - pre- and post-purge losses occur due to the fan forcing air through the boiler to flush out any combustible gas mixture that may have accumulated
Determining Boiler Efficiency

• Necessary data is often hard to obtain
  • Individual fuel flow to boilers
  • Steam usage (in mmbtu/hr or lbs)
• Often efficiency is estimated by summing over known losses
  • Efficiency = 100 – Losses (in % of fuel fired)
• What losses are common to all fuel fired boilers?
  • Radiation (1% at full load – more at partial load)
  • Blowdown (3% - depends on water quality and treatment)
  • Stack (15-20%)
Minimizing Stack losses

- **Two main ways**
  - Lower exhaust temperature
    - Utilize waste heat as air preheater
    - Utilize waste heat as boiler feedwater heater
    - Both
  - Lower exhaust flowrate
    - Trim excess air
  - Flue gas analyzer is an important tool…
  - Getting the measurement is not always easy
    - Sometimes you have to drill
    - A temperature port is usually ok!
Stack Temperature

• Dropping it 35 – 40 °F = 1% in boiler efficiency
• But going too low can cause condensation
  • Of water
  • Or of acid components (sulfur)
• One rule of thumb – stack temp must be 100 °F above saturation temperature of the steam at full load
  • Temperature of the stack should decrease with decreasing load
Excess Air

- Zero oxygen in the flue gas is ideal, but not practical
- Less oxygen than needed puts unburned fuel in the stack
  - Not all that uncommon
- Some excess air is needed to insure complete combustion
  - More if fuel switching is common
- Excess air reduces the stack temperature –
  - reducing it may increase temperature but it is a good tradeoff
Excess Air

### Table 1. Levels of Excess Air Possible on Well-Designed, Well-Tuned Systems

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Minimum Excess Air, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>10%</td>
</tr>
<tr>
<td>#2 Oil</td>
<td>12%</td>
</tr>
<tr>
<td>#6 Oil</td>
<td>15%</td>
</tr>
</tbody>
</table>

### Table 2. Combustion Efficiency Table for Natural Gas

<table>
<thead>
<tr>
<th>Excess %</th>
<th>Air</th>
<th>Oxygen</th>
<th>Combustion Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flue gas temperature less combustion air temperature, °F</td>
</tr>
<tr>
<td>9.5</td>
<td>9.5</td>
<td>2.0</td>
<td>85.4</td>
</tr>
<tr>
<td>15.0</td>
<td>15.0</td>
<td>3.0</td>
<td>85.2</td>
</tr>
<tr>
<td>28.1</td>
<td>28.1</td>
<td>5.0</td>
<td>84.7</td>
</tr>
<tr>
<td>44.9</td>
<td>44.9</td>
<td>7.0</td>
<td>84.1</td>
</tr>
<tr>
<td>81.6</td>
<td>81.6</td>
<td>10.0</td>
<td>82.8</td>
</tr>
</tbody>
</table>

*Assumes complete combustion with no water vapor in the combustion air.*
Steam System Optimization
Steam System Management

- Nearly one-half of industrial energy is for producing steam for process heating or consumption in the process
- Most is dry, saturated steam
  - Superheated steam is rarer
- Steam is valuable—if you don’t need to use it, find a way to turn it off
- Multiple pressure needs create an opportunity to use backpressure turbines
Steam System Management

• Three things can happen to steam
  • steam condenses to supply heat
    • at boiler pressure
    • at lower pressure
  • steam is consumed in process
  • steam is leaked
• Three things can happen to the liquid condensate
  • Returned to boiler at boiler pressure
  • Returned to boiler at lower pressure
  • Discarded
Typical System
Steam pressure – what is needed?

- There is a “Rule of Thumb” about reducing boiler operating steam pressure.
  - “for every 10 psig pressure drop (in boiler operating steam pressure) “equals” 1% reduction in fuel cost
- After saying that, the problems begin
  - Lower pressure = higher flow rates
    - Can result in droplet carryover
    - Systems might not be deliver enough energy
      - Check duty cycle
- Interestingly, higher pressure boilers are cheaper
Insulating Steam Lines

• Very inexpensive – very short paybacks
• Adding additional insulation is usually not cost effective
• Wet insulation is worse than none!!
  • Increases the effective size of uninsulated piping
  • Result of untreated steam leak – doubles the damage!
Losses from uninsulated surfaces

- Calculating undesired energy losses from uninsulated surfaces can be done
  - Geometry and other complications make this usually impractical
- Simple estimators are all around

<table>
<thead>
<tr>
<th>Distribution Line Diameter (inches)</th>
<th>Heat Loss per 100 feet of Uninsulated Steam Line (MMBtu/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steam Pressure (psig)</td>
</tr>
<tr>
<td>1</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>235</td>
</tr>
<tr>
<td>4</td>
<td>415</td>
</tr>
<tr>
<td>8</td>
<td>740</td>
</tr>
<tr>
<td>12</td>
<td>1,055</td>
</tr>
</tbody>
</table>

Based on horizontal steel pipe, 75°F ambient air, no wind velocity, and 8,760 operating hr/yr.
Insulating Steam Lines

- Most plants will have insulated pipes – but most will have some open spots – easy cash!!
Removable Insulation for Valves and Fittings
Steam Leaks

- Visible and obvious, steam leaks are a good way to measure energy awareness of the plant
- Low paybacks make this a “no-brainer”
- There is also no useful device for measuring losses due to leaks.
  - Sometimes, losses can be obtained by difference if condensate and make up water rates are known
- Techniques used include:
  - Hole size or equivalent circle method
  - Plume height method
- Always a big guess!
## Steam Leaks

<table>
<thead>
<tr>
<th>Hole Size Method</th>
<th>Steam Pressure</th>
<th>Hole Size</th>
<th>Steam Loss</th>
<th>$/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>115 psi</td>
<td>1/16&quot;</td>
<td>15</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>115 psi</td>
<td>1/8&quot;</td>
<td>60</td>
<td>1600</td>
<td></td>
</tr>
<tr>
<td>115 psi</td>
<td>1/4&quot;</td>
<td>240</td>
<td>6400</td>
<td></td>
</tr>
<tr>
<td>115 psi</td>
<td>1/2&quot;</td>
<td>1010</td>
<td>27000</td>
<td></td>
</tr>
<tr>
<td>115 psi</td>
<td>1&quot;</td>
<td>3900</td>
<td>104,000</td>
<td></td>
</tr>
<tr>
<td>415 psi</td>
<td>1/16&quot;</td>
<td>55</td>
<td>1450</td>
<td></td>
</tr>
<tr>
<td>415 psi</td>
<td>1/8&quot;</td>
<td>220</td>
<td>5800</td>
<td></td>
</tr>
<tr>
<td>415 psi</td>
<td>1/4&quot;</td>
<td>880</td>
<td>23,200</td>
<td></td>
</tr>
<tr>
<td>415 psi</td>
<td>1/2&quot;</td>
<td>3520</td>
<td>92,000</td>
<td></td>
</tr>
<tr>
<td>415 psi</td>
<td>1&quot;</td>
<td>14,080</td>
<td>372,000</td>
<td></td>
</tr>
</tbody>
</table>

## Plume Length Method

<table>
<thead>
<tr>
<th>Plume Length</th>
<th>45°F Ambient</th>
<th>70°F Ambient</th>
<th>90°F Ambient</th>
</tr>
</thead>
<tbody>
<tr>
<td>115 psi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 ft</td>
<td>10</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>6 ft</td>
<td>30</td>
<td>170</td>
<td>250</td>
</tr>
<tr>
<td>9 ft</td>
<td>70</td>
<td>420</td>
<td>700</td>
</tr>
<tr>
<td>12 ft</td>
<td>110</td>
<td>650</td>
<td>1,100</td>
</tr>
<tr>
<td>415 psi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 ft</td>
<td>20</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>6 ft</td>
<td>50</td>
<td>170</td>
<td>250</td>
</tr>
<tr>
<td>9 ft</td>
<td>130</td>
<td>500</td>
<td>800</td>
</tr>
<tr>
<td>12 ft</td>
<td>220</td>
<td>870</td>
<td>1,400</td>
</tr>
</tbody>
</table>

*Loss $/year

| 115 psi      |              |              |              |
| 3 ft         | 200          | 790          | 1,300        |
| 6 ft         | 790          | 4,420        | 7,280        |
| 9 ft         | 1,820        | 10,920       | 18,700       |
| 12 ft        | 2,800        | 16,000       | 28,600       |
| 415 psi      |              |              |              |
| 3 ft         | 520          | 910          | 1,300        |
| 6 ft         | 1,300        | 4,420        | 7,540        |
| 9 ft         | 3,330        | 13,000       | 20,800       |
| 12 ft        | 5,720        | 22,620       | 36,400       |

*Annual loss is based on a steam value of $3.00/kilogram. 
Boiler Blowdown

- Lots of noise – little bang!
- Continuous blowdown rate can be too high
  - Throwing hot water away
  - Use TDS meter to check
- Periodic blowdown is maintenance issue
• Blowdown flow can be flashed to reduce water losses
Steam traps

- Traps have one main purpose: to remove spent steam (condensate) from steam systems
  - Normally condensate is returned to the boiler
- Steam traps often fail
  - Some studies have shown >25% annual steam trap failure
  - When they fail open, they pass live steam—a major source of leaks.
    - If they fail closed
      - No real energy losses – other traps will do the job
      - Water could back up and degrade or damage a process
Evaluating steam trap performance

- Infrared
  - This trap is operating properly

- Ultrasonics
  - Traps should discharge condensate periodically – and have no flow other times
Evaluating steam trap performance

- Temperature
  - Condensate return lines will be hot if steam is present – cooler if not
  - Look for temperature jump across trap
  - Use contact thermocouple or point infrared gun
Condensate Return

- Normally cost effective unless very long distances are needed
- Once condensed, hot water needs to be insulated to reduce losses
Condensate Return

• Tank tells the health of the entire steam system
• If tank is uninsulated or venting large amounts of steam, there are system problems
Should the system have a deaerator?

- The removal of dissolved gases from boiler feedwater is an essential process in a steam system.
  - The presence of dissolved oxygen in feedwater causes rapid localized corrosion in boiler tubes.
  - Carbon dioxide will dissolve in water, resulting in low pH levels and the production of corrosive carbonic acid.
    - Low pH levels in feedwater causes severe acid attack throughout the boiler system.
  - Dissolved gases and low pH levels in the feedwater can be controlled or removed by the addition of chemicals
    - Cheaper to mechanically deaerate
Deaeration Process

- Steam heats incoming feedwater and purges gasses
  - Modelled as an “open” feedwater heater
- Gasses leave through top vent
  - Some steam loss inevitable
Steam Resources from BestPractices
Steam System Tool Suite

- Steam System Assessment Tool (SSAT)
  - Steam analysts can model real steam systems.
  - Contains key features of typical steam systems.
  - Quantify potential steam improvement opportunities—energy, cost, and emissions-savings.
Waste Reduction

Sanjeev K. Khanna
Assistant Director, Missouri Industrial Assessment Center
University of Missouri
Columbia, MO 65211

573.884.9109  khannas@missouri.edu
Sources of Waste Materials

- Raw Materials
  - Containers, packing
  - Off-spec and expired lots
  - Spoiled batches

- Processes
  - Cleaning
  - Reactions
  - Machining
  - Testing
  - Printing
  - Coating/Painting
  - Plating/Anodizing/Chromating
  - Casting/Molding
  - Extracting/Refining
  - Packaging
Process Wastes

- Cleaning
  - Alkaline baths
  - Solvents
  - Sludges
  - Grit
  - Acidic baths
  - Rags
  - Oil and Grease
  - Rinse water

- Painting
  - Thinner
  - Overspray
  - Containers
  - Paint stripper
  - Paint sludge
  - Filters
  - Unused paint
  - Masking

- Machining
  - Metal chips
  - Cutting coolants
  - Hydraulic oil
  - Filters
  - Trimming waste
  - Tapping oil
  - Tramp oil
  - Rags
<table>
<thead>
<tr>
<th>General industrial category</th>
<th>Unit operation</th>
<th>Common waste streams</th>
<th>Pollution prevention and recycle/reuse measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical processing (SIC: 28,29)</td>
<td>• Blending/mixing &lt;br&gt; • Reaction to form product &lt;br&gt; • Vessel cleaning</td>
<td>• Tank cleanout solutions &lt;br&gt; • Tank cleanout solids &lt;br&gt; • Reagent (liquid and powder) spills to floor &lt;br&gt; • Reaction byproducts &lt;br&gt; • Air emissions &lt;br&gt; • Dust from powdered raw material</td>
<td>• Use Teflon lined tanks &lt;br&gt; • Clean lines with &quot;Pigs&quot; instead of solvents or aqueous solutions &lt;br&gt; • Use squeegees to recover clinging product prior to rinsing &lt;br&gt; • Use Clean In Place (CIP) systems &lt;br&gt; • Clean equipment immediately after use &lt;br&gt; • Treat and reuse equipment cleaning solutions &lt;br&gt; • Use cylindrical tanks with height to diameter ratios close to one to reduce wetted surface &lt;br&gt; • Use tanks with a conical bottom outlet section to reduce waste associated with the interface of two liquids &lt;br&gt; • Increase use of automation &lt;br&gt; • Convert from batch operation to continuous processing &lt;br&gt; • Use dry cleaning methods whenever possible &lt;br&gt; • Use squeegees, mops and vacuums for floor cleaning &lt;br&gt; • Use pumps and piping to decrease the frequency of spillage during material transfer &lt;br&gt; • Install dedicated mixing equipment to optimize</td>
</tr>
</tbody>
</table>
Hazardous wastes

<table>
<thead>
<tr>
<th>Categories</th>
<th>Examples</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosive</td>
<td>$\text{H}_2\text{SO}_4$</td>
<td>D002</td>
</tr>
<tr>
<td>Reactive</td>
<td>$\text{NaClO}_4$</td>
<td>D003</td>
</tr>
<tr>
<td>Ignitable</td>
<td>$\text{C}_6\text{H}_6$</td>
<td>F005</td>
</tr>
<tr>
<td>Toxic</td>
<td>$\text{Cr}$</td>
<td>D007</td>
</tr>
</tbody>
</table>
- Rust removers, which contain concentrated acid or alkaline solutions
- Equipment cleaners, which contain flammable or combustible liquids
- Waste oil, lubricants, and fluids
- Spent solvents
- Spent caustic parts washing detergent solution
- Parts cleaning tank sludge
- Oily waste sump sludge
- Spent antifreeze
- Used rags, containing combustible or flammable solvents
Responsibilities of HazMat Generators

- Identify and quantify hazardous wastes
- Determine Status: CESQG (conditionally exempt SQG), SQG (small quantity generator), LQG (large quantity generator)
- Comply with regulations
  - On-site storage
  - On-site treatment
  - On-site disposal
  - Transport
  - Offsite disposal at approved TSDF
- Plan for accidents, emergencies
- Pollution prevention plan (CA)
We operate from left to right on this hierarchy chart.
Phase II
- process control
- equipment mod.
- source treatment

Phase III
- complex recycling
- process changes
- raw material changes
- catalysts
- reformulation
Top Waste Recommendations

- Close water cycle
- Recycle Cardboard / Install Cardboard Baler
- Recycle Wood Pallets
- Increase amount of waste available for resale
- Change procedures / operation to decrease hazardous material use
- Remove contaminants before disposal
- Convert to HVLP Paint Guns
- Clean / Recycle Solvents
Example: Acid Treatment

- Acid baths become “dirty” after 2-3 weeks
- Proper disposal requires acids be sent to treatment center
- Plant currently uses 8,000 gallons per year
- Additional man hours needed for tank changes
- Acid purchase and disposal costs ~ $28,000 per year
Acid Treatment Applications

- Galvanizing, anodizing, electroplating, wire rode plants, steel mills, circuit board printing, gravures & all industries requiring acids
- Activation, passivation, stripping, pickling & cleaning
- Effective in sulfuric, hydrochloric, nitric, citric, phosphoric & exotic blends
How Acid Treatment Works

• PRO-pHx drops metals, organics & other impurities out of solution

• “Frees up” remaining available acid solution

• Filtration removes impurities

• Some additional acid still needed for
  – Post titration spiking
  – Loss during drag out
  – Evaporation losses
Acid Life Extender Benefits

- Eliminates costly and hazardous acid dumps
- Reduces acid make-up requirements, 70 – 90%
- Reduces filter cake in waste treatment, 50 – 98%
- Maintains acids at optimum effectiveness
- Alleviates environmental issues
- Low capital costs for system

2 – yr old acid
Contact Information

Wagner Environmental Technologies LLC
19722 One Norman Boulevard # 220
Suite 166 Cornelius NC 28031
704 -987-9686
E-Mail: WagTec A2Z @ aol.com
FAX: 704 -987 – 9682
http://www.pro-phx.com/
Lighting

Sanjeev K. Khanna
Assistant Director, Missouri Industrial Assessment Center
University of Missouri
Columbia, MO 65211

573.884.9109  khannas@missouri.edu
Overview

- Lighting terminology
- Common light sources
- Exit sign lighting
- Common recommendations
Lighting stuff

• Always important – but easy to quantify
  – 3rd parties will pay for upgrades
  – Many have already done the big projects
• But what about smaller jobs?
  – Often still see T-12 fluorescent lamps and magnetic ballasts
  – with more efficient T-8 lamps and electronic ballasts.
  – But how do you know what kind of ballast you have without opening the fixture?
• Get a $30 D-1 Discriminator from SensorSwitch™, www.sensorswitch.com
Illuminating Engineer Society

- [http://www.iesna.org/](http://www.iesna.org/)
Lighting Terminology

• **Luminaire**—or light fixture, is a complete, functional lighting unit, including lamp(s), housing & electrical components.

• **Efficacy** (lm/watt) - a measure of the lamp’s ability to convert electrical power into visible light.
• Quantity of visible light is measured in lumens
  – Natural daylight has luminous efficacy of 110 lm/W
  – Electric lighting has luminous efficacy of 10 – 100 lm/W

• Common measure of illuminance is the footcandle (fc)
  – 1 fc = 1 lm/ft²
  – Illuminance can be measured with inexpensive light meters, some suggested values are listed next.
**Light Levels**

<table>
<thead>
<tr>
<th>Location</th>
<th>Task</th>
<th>Minimum Footcandles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>Regular office work</td>
<td>50</td>
</tr>
<tr>
<td>Assembly</td>
<td>Rough, easy seeing</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Rough, difficult seeing</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>100</td>
</tr>
<tr>
<td>Inspection</td>
<td>Ordinary</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Difficult</td>
<td>100</td>
</tr>
<tr>
<td>Material Handling</td>
<td>Loading / unloading</td>
<td>20</td>
</tr>
<tr>
<td>Warehousing</td>
<td>Rough</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>25</td>
</tr>
</tbody>
</table>
Light Levels

- Recommendations by the IES have caused many facilities to be over-lit
- Reducing lighting is a common AR, but we have never met a plant manager who agreed
Efficacy Values of Common Lamp Types
# Efficacies of Common Lights

<table>
<thead>
<tr>
<th>Light Type</th>
<th>Lm/W*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candle</td>
<td>0.15</td>
</tr>
<tr>
<td>Incandescent</td>
<td>4 - 24</td>
</tr>
<tr>
<td>Mercury vapor</td>
<td>19 - 43</td>
</tr>
<tr>
<td>T12 Fluorescent</td>
<td>58</td>
</tr>
<tr>
<td>Metal halide</td>
<td>38 - 86</td>
</tr>
<tr>
<td>High-pressure sodium</td>
<td>22 - 115</td>
</tr>
<tr>
<td>T8 Fluorescent</td>
<td>100</td>
</tr>
</tbody>
</table>
Incandescent

• A glass-enclosed tungsten filament glows when a voltage is applied across it, producing visible light.
• Least energy-efficient light source with a relatively short life.
• 70%-90% of the power consumed is lost as heat.
Ballasts

- All gaseous discharge lamps require an electrical device called a **ballast**.
- **Ballast**—an electrical device designed to convert line current into the proper voltage, amperage, and waveform.
- A connected ballast still consumes energy even if no lamp is connected.
- Electronic ballasts have replaced magnetic ballasts and improve efficiency by up to 15%
- Also allow for dimming and other control strategies
- Allow for 1 4 lamps per ballast
One Common Strategy is Group Re-lamping
Color Rendering Index (CRI) describes the effect of a light source on the color appearance of an object

- CRI varies from 0 to 100
- Various CRI values are listed below

<table>
<thead>
<tr>
<th>Light Type</th>
<th>CRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunlight</td>
<td>100</td>
</tr>
<tr>
<td>Incandescent</td>
<td>98+</td>
</tr>
<tr>
<td>T8 Fluorescent</td>
<td>75</td>
</tr>
<tr>
<td>Metal halide</td>
<td>65-70</td>
</tr>
<tr>
<td>T12 Fluorescent (cool white)</td>
<td>60</td>
</tr>
<tr>
<td>High-pressure sodium</td>
<td>22-85</td>
</tr>
</tbody>
</table>
Color Rendering Index (CRI)
Compact Fluorescent

Direct replacement for incandescent

Many include ballasts

Rebates in NJ require that ballast be separate
High Energy Discharge (HID)

this is what you will see in factories

- Mercury – Twice as Eff as Incandescent
- Metal Halide- CRI ratings from 65 – 90
- High Pressure Sodium – Higher Eff.
  Common in warehouses
  CRI - 20
- Low Pressure Sodium – Security
  CRI = 0
LED coming in future –
decorative, traffic lights
Diffusers
Controls

- On / off
- Timer
- Dimmer
- Occupancy
- Photosensor

*SquareD Distributed Logic Panel*

*Most controls do not reduce electric demand*
### Top 10 Recommendations in the IAC program

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilize higher efficiency lamps / ballasts</td>
<td>$6,747</td>
</tr>
<tr>
<td>Install occupancy sensors</td>
<td>$1,814</td>
</tr>
<tr>
<td>Use more efficient light source</td>
<td>$5,762</td>
</tr>
<tr>
<td>Reduce illumination to minimum levels</td>
<td>$6,012</td>
</tr>
<tr>
<td>Make a practice of turning off</td>
<td>$5,035</td>
</tr>
<tr>
<td>Use photocell controls</td>
<td>$5,196</td>
</tr>
<tr>
<td>Utilize daylight whenever possible</td>
<td>$5,251</td>
</tr>
<tr>
<td>Install skylights</td>
<td>$7,980</td>
</tr>
<tr>
<td>Disconnect ballasts</td>
<td>$2,743</td>
</tr>
<tr>
<td>Install timers on light switches</td>
<td>$3,687</td>
</tr>
</tbody>
</table>
Day lighting

• Give it another chance – technology has improved significantly
  – Has eliminated leaking
  – Reduced degradation with time
• Lots of fun toys
  – Can track the sun or port light deep into the building
• Must be integrated with building lighting reduce costs
Skylights
Photovoltaic

- Has been recommended, never implemented
- We like the DC system
- Three largest problems with PV are:
  - Inverter
  - Inverter
  - Inverter
- Some ESCOs will finance them
Productivity

Sanjeev K. Khanna
Assistant Director, Missouri Industrial Assessment Center
University of Missouri
Columbia, MO 65211

573.884.9109  khannas@missouri.edu
Productivity

• Introduced at the IAC Directors Meeting in 1996
• Basis is the Productivity Training Manual, CAES – Rutgers
• Is not traditional “productivity”
• Interested in productivity as it relates to energy conservation
• Created tricky accounting
  – Savings were reported as positive numbers
  – Idea of energy intensity was introduced
## Definition

<table>
<thead>
<tr>
<th>Increases Pieces/Person/Hour</th>
<th>Decreases Cost/Piece</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Bottleneck Mitigation</td>
<td>a. Purchasing</td>
</tr>
<tr>
<td>b. Defect Reduction</td>
<td>b. Floor Layout</td>
</tr>
<tr>
<td>c. Quick Changes</td>
<td>c. Inventory</td>
</tr>
<tr>
<td>d. Labor Optimization</td>
<td>d. Burden/overhead</td>
</tr>
<tr>
<td>e. Preventive/Predictive Maintenance</td>
<td>e. Scheduling</td>
</tr>
</tbody>
</table>
## Principle Metrics

1. **Labor Costs** -
   - Skilled union, unskilled union
   - Skilled non-union, unskilled non-union
   - Also like to know Fringe Cost of Labor.

2. **Cost of Inventory**
   - Carrying Cost
   - Cost of Raw Material

3. **Cost of Space** -
   - Warehouse
   - Manufacturing
   - Office

4. **Cost Per Piece**
   - \((\text{Overhead}+\text{Labor}+\text{Materials})\) Cost/Piece

5. **Overhead** -
   - Cost of virtually everything besides direct raw material and direct labor. Includes energy and waste.

6. **Profit** -
   - \((\text{Sales Price/Piece})\) minus \((\text{Cost/Piece})\)
Step 1 – Determine the cost of the product

Cost per Part = Gross Sales / # of Pieces
PRODUCTIVITY METRICS SHEET

Labor Costs:

<table>
<thead>
<tr>
<th>Type of Labor</th>
<th>Actual</th>
<th>Assumed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Worker</td>
<td></td>
<td>(11$/hr)</td>
</tr>
<tr>
<td>Skilled Technician</td>
<td></td>
<td>(12$/hr)</td>
</tr>
<tr>
<td>Engineering (contracted)</td>
<td></td>
<td>(100$/engineer-hour)</td>
</tr>
<tr>
<td>Engineering (in-house)</td>
<td></td>
<td>(8$/hr)</td>
</tr>
</tbody>
</table>

Cost Rate: ______________% (55%)

Raw Material Costs:

<table>
<thead>
<tr>
<th>Material/Resource</th>
<th>Yearly Usage</th>
<th>Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Water Treatment

Water Usage: ____________________/hcf

($2.50/hcf, 1 hcf = 1008")

Production Information:

Overhead (includes ____________%: ____________%: ____________%)

Profit Margin: ____________________% (10%)

Cost per Piece to Produce: ____________________

Inventory and Floor space:

Value of Floor space: ____________________/$/yr (15$/square foot)

Inventory Carrying Cost: ____________________% (5%)

Raw Material Inventory: Quantity = ______ Value = ______

Work-in-Progress Inventory: Quantity = ______ Value = ______

Finished Goods Inventory: Quantity = ______ Value = ______
Getting Sensitive Information

• First Try – Request this information before visiting plant
• Second Try – Attempt to get numbers during interview
• Third Try – Your metrics sheet should have default numbers
  – Try to get management to attest to the reasonableness of the numbers
  – This should allow you to make judgments that are within order of magnitude
  – Remember to write the AR in such a way that management can modify the calculation
Increasing Pieces / Person / Hour

- Bottleneck Mitigation
- Defect Reduction
- Quick Change
- Labor Optimization
- Preventive / Predictive Maintenance
Decreasing Cost per Piece

- SCHEDULING
- PURCHASING
- BURDEN ANALYSIS
- INVENTORY
- FLOOR LAYOUT

These recommendations often do not save energy
Questions to Ask

General

• If you can make more product, can you sell it?
• Do you ever run overtime to meet production goals or compensate for defective batches? (related costs)
• Do you have any plans for expansion?
• Average value and quantity of each type of inventory (raw materials, purchased components, in-process products, finished goods)?
• What is the lead time of the product / process?
Increasing Pieces/Person/Hour

**Bottleneck Mitigation**

- How has the operation changed over time? (product, equipment, procedure)

- What is the optimal rate of this process/procedure?

- Why is this process/procedure the bottleneck?
Example: Bottleneck Mitigation

Automotive batteries

- After manufacture, they had to charge them
- This took longer in summer, and was the bottleneck

_Bottleneck Mitigation often requires equipment installation_

- Recommendation: install air conditioning in the charging room
- Includes capital costs
- Also includes on going cost to operate.
Defect Reduction

- What percentage of products are inspected?
- In what stages/locations of the process do the most rejects (or clean-up) occur?
- What are the most common types of defects?
- How much does each type of defect or clean-up cost per year?
- What causes each type of defect?
- Are in-process and/or finished goods inventories built up due to potential defect problems in the production process (to ensure that the customer gets the products on time)?
- Do standardized procedures exist for the processes where defects most often occur?
- Does one machine operator produce significantly fewer defects than others?
Example: Defect Reduction

- Manufacturer of Boogie Boards
- Painting defects caused 5% reject rate
- Company was re-working product
- Considering selling inferior product under another name
- Monitoring where defects took place, identified problem
- $45,000 investment in air filtering equipment resolved problem

*Very typical in some industries (bottle making, eg.*)
Reduce Change-over time (our favorite)

**Principles** (Divide into Internal and External)

- Adjustment cannot depend on feeling or experience (art)
- Functional clamps should be used over screws
- If screws are necessary, design them in such a way that one turn will fasten and unfasten the fixture
- Dovetail connectors, pins, cams, wedges should be used
- Intermediary jigs should be used, that is external setup application
- Movements should be combined or linked together
- Parallel operations should be conducted
- Setups should produce defect free products from the very beginning of the run
- Quick connect and disconnect
- Centering adjustments should not have to be made, it should be automatic when part are pressed together (using pins, etc.)
Quick Changes

- How much time does it typically take to setup XYZ machine?
- Do you need to do any adjustment to the machine?
- Do you need to use any gauges or other measurement devices to adjust the machine?
- How many different tools do you need for the setup of XYZ machine?
- Can the setup be performed by the operator or is a specialist needed?
- Do you need a period of time when you run pieces that are not useful?
- Do you need to idle the machine for a while to bring it up to speed or to a proper temperature?
- How do you clamp pieces to the machine? Do you use the same fasteners in all the cases?
Preventive/Predictive Maintenance

• Are there shutdowns of the production process?
• Are these shutdowns unscheduled?
• What are the duration and frequencies of these shutdowns?
• What are the reasons for the unscheduled stoppages?
• What is the cost/hour of production downtime?
Decreasing Cost/Piece

- **Purchasing**
- **Floor Layout**
- **Inventory**
- **Burden**
- **Scheduling**

Identify processes or operations which you feel are more costly than they should be.

Do you use push or pull system in your manufacturing process?

If overhead cost is too high, why?

Do you experience multiple handling or multiple inspection?

*Remember, we are only interested in these if they save energy*
P3 Accounting for the database

- P3 is a new production resource code. The P3 code was not intended to replace any of the other production resource codes. Its intention was to segregate non-energy production increases with energy production increases. By doing this, the database will automatically calculate the effective energy savings due to production increases. Effective energy savings are savings due to a decrease in energy intensity by optimizing the plants' production. Thus, recommendations where the additional energy to create a new unit of production will be less by the recommendation than by the plants' current methods are encouraged. If the energy intensity increases, this will have an increased negative effect on your metrics. An example is also available at the end of the guideline.
P3 Accounting in the database

- Use the P3 code when a productivity recommendation has an effect on the plants' energy consumption. This includes increases as well as decreases in energy consumption.
- Include the P3 code in the primary resource code column.
- The primary resource savings for P3 codes will be in percentages of increasing production. For example, a 100 piece per year increase in a plant that produces 1000 pieces/year will yield a 10% increase in production.
- The primary resource savings will be represented by a whole number. In the previous example, 10% will be written as 10 in the primary resource savings.
- In the secondary, tertiary and quaternary resource columns, include the energy savings or increases. Make sure increases are denoted as a negative.
- The primary cost savings shall remain the same as savings resulting from production increases.
P3 Accounting in the database

- **Example**
- *A recommendation to increase the plants production by 10% will yield additional sales of $65,000/year. The plant will consume an additional 50,000 kWh/year at an increased cost of $4,500/year. Below is how the upload form should correctly be filled out.*

Primary Resource Code =  P3  Secondary Resource Code =  EC
Primary Resource Saved = 10  Secondary Resource Saved =  -50000
Primary Cost Savings =  65000  Secondary Cost Savings =  -4500
Waste and Productivity Example

- Manufacture of cooking utensils

- In the painting of skillets, excess paint was applied
- 5% needed to be reworked.
- The recommendation is to manufacture a high temp clamp that would hold the skillet and lid together.

Recommendation saved labor, paint, and reduced rework to 1%
Example: Reduce change over time

AR 1: Reduce Changeover Time on the Structural Foam Presses
The current method of attaching the cooling hoses to each mold without a mandrel takes about 2 hours. In addition, tools, heaters, tooling checks and storage of the molds are often not complete resulting in additional downtime. If the changeover time was reduced on the structural foam presses, the company could sell the additional product being produced. We recommend the following changes:

- Prepare for mold changes ahead of time utilizing a check sheet/packet to ensure equipment is operating properly and staged next to the press prior to the press going down for the mold change.
- Install “rapid water” mandrels on 15 structural foam molds.
- Standardize the changeover procedures and train the operators using “Best Practices”.

We estimate that this would save about $409,000 per year with a 1 month payback.
HVAC Systems

Chatchai Pinthuprapa
Lead Graduate Student
cp2nf@mizzou.edu
Energy Audit Workshop
Kansas City, February 7, 2007
Introduction

- Potential for energy conservation in the air conditioning unit(s)
  - Design of the systems
  - Method of operation
  - Maintenance of control systems
  - Monitoring of system
Operate systems when needed

- Operates only when area occupied
  - Example
    - Saving from reduced fan Operation
      \[ \text{Saving} = (\text{Supply fan hp})(\text{Cost, $/hr-yr})[\text{(hrs/wk shut off) / (hrs/wk current operation)}] \]
      \[ = (6.8)(360)[(168-50) / 168] = 1,720/yr \]
  - Total Saving
    - Fans = $1,720
    - Space heating = $357
    - Preheater = $410
    - Space Cooling = $607
    - Total = $3,274 per year
Eliminating overcooling and overheating

- Adjust your thermostat
  - Heating should be maintain below 68°F to 70°F
  - Cooling should be maintain exceeding 78°F to 80°F
- During the unoccupied period, the standard should specify minimum conditions necessary to protect the building’s contents, if necessary.
Balance Air Flows

- Shut off Fans
  - Exhaust fans are often left running even if
    the equipment they are ventilating is down.
- Reduce volume
  - Reduce exhaust rates to minimum, but
    adequate amount to satisfy ventilation needs
  - Improve hood design
Recover Energy

- The use air-to-air heat exchangers
  - Exchange of the exhaust airstream(s) and makeup airstream(s)
  - Varies from 55 percent to 90 percent
    - Depend on the type of exchanger and the face velocity
Maintain Equipment

- Physical condition = efficient operation
  - Coils cleaning, Filters changing
    - Dirty coils and filters cut efficiency, reduce the air flow and could create many thousands of dollars in extra costs.
  - Fan motors and drive belts need maintenance
    - A worn belt can mean 10% extra motor operating cost
  - Damper should be sealed tightly
    - Air leaks can cause additional loading of the air handling unit.
- REMOVE HEAT SOURCE FROM UNDERNEATH THEMOSTAT.
- REMOVE OBSTRUCTIONS TO RADIATORS, AIR DIFFUSERS, AIR INTAKES.
Controlling Systems

- Programmable 7-day Thermostats
  - Control your temperature at an appropriate levels for the whole week
  - Can cost around $50 - $200 per unit
  - Included with manual override
  - Protection the locking system

- Building Automation System
  - Can control HVAC, Lighting, Equipment
  - Can access remotely
Building Automation System

- Controller
- Occupancy sensors
- Lighting
- Air handlers
- Constant Volume Air-Handling Units
- Variable Volume Air-Handling Units
- VAV Hybrid Systems
- Central plant
- Chilled water system
- Condenser water system
- Hot water system
- Alarms and security
Retrofit existing HVAC system to VSD

- Typical installations are designed for worst case conditions that occur less than 5% of the time
- Systems typically operate at less than designed levels
- Variable Speed Drive simple pay back period is 2 years for 3 x 500 hp fans
  - Changed from damper to VSD
  - Installation cost $390,000. Energy savings $225,000 per year
  - Increased equipment life
  - Reduce maintenance / Noise / Vibration
  - $225,000 on the bottom line every year after payback!

- Benefits
  - Increases efficiency reflecting in saving energy cost
  - Provides accurate flow control
  - Longer pump and seal life
  - Reduce wear
  - Less noise
Compressed Air

Chatchai Pinthuprapa
Lead Graduate Student
cp2nf@mizzou.edu
Energy Audit Workshop
Kansas City, February 7, 2007
Introduction

- 70% of manufacturers have a compressed air system.
- DOE suggest 50% of compressed air systems in small to medium sized facilities have efficiency opportunities with low implementation cost.
- About 8 hp generates 1 hp of compressed air
- Find system improvements that increase energy efficiency
Understand your system

- **System supply**
  - Types of compressor, settings of capacity controls and other operating conditions
  - Not oversized
  - Match the demand side uses of compressor air
Understand your system

- System Demand
  - Identify all the uses of compressed air
  - Generate a demand profile
    - Volume and time
    - Highlight peak and low demand
  - The assessment will reveal inappropriate use of air
System diagram

- Develop a sketch of your compressed air system
  - Compressors, air supply line with dimensions, and compressed air end uses
- Will provide an overview of compressed air process
Leaks

- Can waste 20% to 30% of output
- Leaks cause a drop in system pressure
- Check your system for leaks
  - Couplings, hoses, tubes, fitting, pressure regulator, values, joints, thread sealants
- Ultrasonic detector may be needed to locate leaks
- System with 100 psig of pressure running 40 hrs/week with ¼ inch leak can cost over $2,800 per year
Leaks

- Simple Calculation

\[
\text{Leakage (\%)} = \left[ \frac{T \times 100}{T + t} \right]
\]

- Where, 
  - \(T\) = on-load time (mins)
  - \(t\) = off-load time (mins)
Inappropriate use of CA

- Look for inappropriate uses
- Tips:
  - Use air conditioning or fans to cool electrical cabinets
  - Use blower to agitate, aspirate, cool, mix and inflate packaging
  - Use low-pressure air for blow guns and air lances
  - Disconnect the compressed air source from unused equipment
Establish a regular routine maintenance program
- Strictly follow the program to maintain the performance of the system.
- Daily, weekly, monthly, 3 months, 6 months, 12 months

Find the criteria from your vendor
- Varies from the type of compressed air system
Inlet Air filters

- Maintain inlet air filters to prevent dirt from causing pressure drops
- Retrofit the compressor with large area air-intake
V-Belts

- Routinely check the compressor’s v-belts for proper tightness
- Loose belts slip more frequently which reduce compressor efficiency
Compressor size

- If compressor is oversized, add a smaller compressor and sequence-controls for partially loaded
- Sequence Controls will regulate a number of compressor to match the air needs
Baselining Compressed Air Systems

- Establish the performance levels and costs of a compressed air system and compare with the present production levels.
- Measurements are power, pressure, flow and temperature under different operating conditions, and also estimating leak load.

**Tools**
- Infrared gun, differential pressure gauges, amp/volt meter, ultrasonic leak detector, flow meter
Measuring

- **Power**
  - Amp/Volt meter or Wattmeter

- **Pressure**
  - Pressure gauge
    - Inlet to compressor
    - Differential across air/lubricant separator
    - Aftercooler, Treatment equipment, distribution system

- **Temperature**
  - Infrared gun
    - Aftercooler and intercoolers, inlet air temperature

- **Flow**
  - Flow meter
    - During various shifts; for leaks during non-production period

- **Leak**
  - Ultrasonic leak Detector
Compressed Air System controls

- Start/Stop
- Load/Unload
- Modulating Control
- Dual-Control/Auto-Dual
- Variable Displacement
- Variable speed Drives
- Network Control
- System Master Controls
AirMaster+

- Provides comprehensive information on assessing compressed air systems, including modeling, existing and future system upgrades
- Evaluate savings and effectiveness of energy efficiency measures
- [http://www1.eere.energy.gov/industry/bestpractices/software.html](http://www1.eere.energy.gov/industry/bestpractices/software.html)
Motors

Chatchai Pinthuprapa
Lead Graduate Student
cp2nf@mizzou.edu
Energy Audit Workshop
Kansas City, February 7, 2007
Introduction

- Largest single use of electricity in most plants
Idle Running

- Shutting off idling motors
- Constant supervision
- no-load power consumption is frequently the same as the full-load
Replace oversized motor

- Motors rarely operate at their full-load point.
- Efficiency is reduced
- Cause by various reasons
- Should be replaced with appropriate size
- Information are required to complete an assessment of energy saving
Replaced oversized motor

- Calculation
  - Estimating Motor Load

\[
MotorLoad = \frac{amps_{\text{measured}}}{amps_{\text{full load, nameplate}}} \times \left[ \frac{Volts_{\text{measured}}}{Volts_{\text{nameplate}}} \right] \times 100
\]
Replaced oversized motor

- **Calculation**
  - **Estimate Saving**

  \[ L_{FL} = 0.746(hp)\left(\frac{1}{Eff_{FL} - 1}\right) \]
  \[ L_{PL} = 0.746(hp)(PL)\left(\frac{1}{Eff_{PL} - 1}\right) \]

  - **Reduction in losses = 0.58 kW**
  - **Annual Savings = 0.58 kW \times 6,000 \text{ hrs/yr} \times $0.05/\text{kWh} = $174**
High-Efficiency Motors

- Standard practice with any new purchase
- Premium payback is less than two years for motor operated at least 4,000 hrs and 75% load
- Standard design = lower power factor more difficult to rewind
Reduce speed/Variable drives

- If equipment can be operated in reduced speeds, the opportunity to save money is existed
- Customize the speed with particular process
- Adjustable Speed Drives (ASDs)
- Two-Speed motors
- Replace motor parts
  - Gear Reducer
  - Motor Change
  - Belt drives
Load Reduction

- One of the best means of reducing electric cost
- Proper maintenance will reduce the motor load by eliminating friction losses
  - Misalignment, frozen bearings and belt drag
  - Proper lubrication for all moving parts
  - Substitution of ball or roller bearings
High-Starting Torque

- When high-inertia loads are involved, consider high-Starting Torque.
- A NEMA B motor will operate at less-than-rated capacity once accelerated to full speed.
- NEMA C or D have same starting Torque but will operate closer to the full-rated load under normal running conditions.
Rewound Motors

- Determine the size of motors, small size may not justify rewinding
- Can reduce motor efficiency depend on the procedure at particular shop
- Comparison of efficiency before and after
- Techniques among repair shops should be investigated before making decision
- Compare with other opportunities
Solid-State rectifiers

- The solid-state rectifiers are preferred source of DC for DC motors
- Motor-generator sets are less efficient.
- Motor-generator = 70% efficiency at full load
- Solid-State rectifiers = 96% efficiency at full load
Bels

- Overbelting
  - Higher-rated belts, increase in efficiency

- Tension
  - Can cause efficiency losses of up to 10%
  - Lowest tension with full load

- Friction
  - Misalignment, worn sheaves, poor ventilation or rubbing belts against the guard

- Sheave Diameter
  - The lager, the better
Replacement Before it fails

- Evaluate motors in your facility
- Develop a replacement plan for all critical motors
- Consider correct size and energy-efficient models
MotorMaster+ 4.0

- Energy-efficient motor selection and management tool
- Includes a catalog of more than 20,000 AC motors
- Features motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting and environmental reporting capabilities
- [http://www1.eere.energy.gov/industry/bestpractices/software.html](http://www1.eere.energy.gov/industry/bestpractices/software.html)