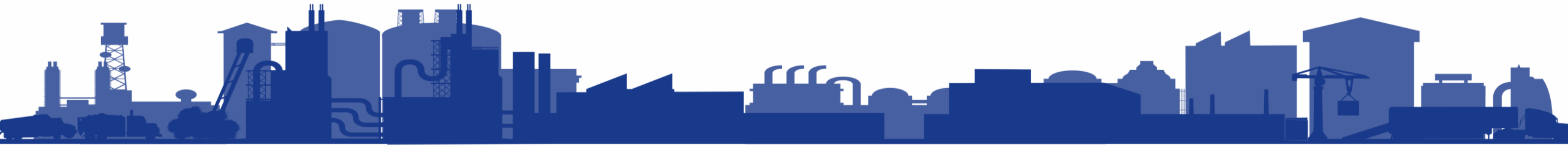
Better Plants
U.S. DEPARTMENT OF ENERGY

VIRTUAL PROCESS HEATING INPLT
Session 4

U.S. DEPARTMENT OF ENERGY

Training Module # 4
Process Heating Systems Assessment Methodology



Assessment Standard and Guidance

- An assessment standard has been developed by The American Society of Mechanical Engineering (ASME) in collaboration with the U.S. Department of Energy
- It is issued as ASME-EA-1-2009, “Energy Assessment for Process Heating Systems”
- The standard has a Guidebook that guides a user on how to use the standards and related technical information.

Assessment Standard and Guidance

- The Guidebook, “Guidance for ASME EA-1, Energy Assessment for Process Heating Systems”, is issued as document ASME EA-1G-2010 with ANSI designation: ASME TREA-1G-2010
- The U.S. Department of Energy has conducted more than 400 process heating assessments from 2005 to 2011 for all major industrial sectors.
- The assessment process is very similar to the standards mentioned above.

US DOE's Energy Saving Assessment (System Type)

System Type (No. of SENAs)	Average Identified Source Energy Savings (MMBtu/plant per year)	Average Percent Source Energy Savings Identified (%)	Average Identified Cost Savings ($/plant per year)	Average Natural Gas Savings Identified (MMBtu/plant per year)	Average CO2 Savings Identified (Metric Tons/plant per year)	Average Payback Period Identified (Years)
Compressed Air (174)	32,300	2.7	$192,000	400	1,800	1.1
Fans** (50)	105,000	3.1	$624,000	33,000	6,000	2.6
Process Heating (237)	218,600	7.7	$1,474,000	167,200	12,400	1.5
Pumps (94)	38,800	1.2	$210,000	1,000	2,300	1.7
Steam (343)	256,000	6.1	$2,000,000	199,900	17,900	1.6
Multi-System-Paper (31)	354,900	5.2	$2,259,000	173,200	18,600	0.5

** Fan results are based on 48 ESAs instead of 50 ESAs. Two large outliers are not considered in this analysis.
Source: Based on Save Energy Now assessments conducted between 2006 to 2011. Numbers are as of October 1, 2011.

TOP TEN FREQUENTLY IDENTIFIED PROCESS HEATING OPPORTUNITIES SAVE ENERGY NOW ASSESSMENTS - 2006 to 2011

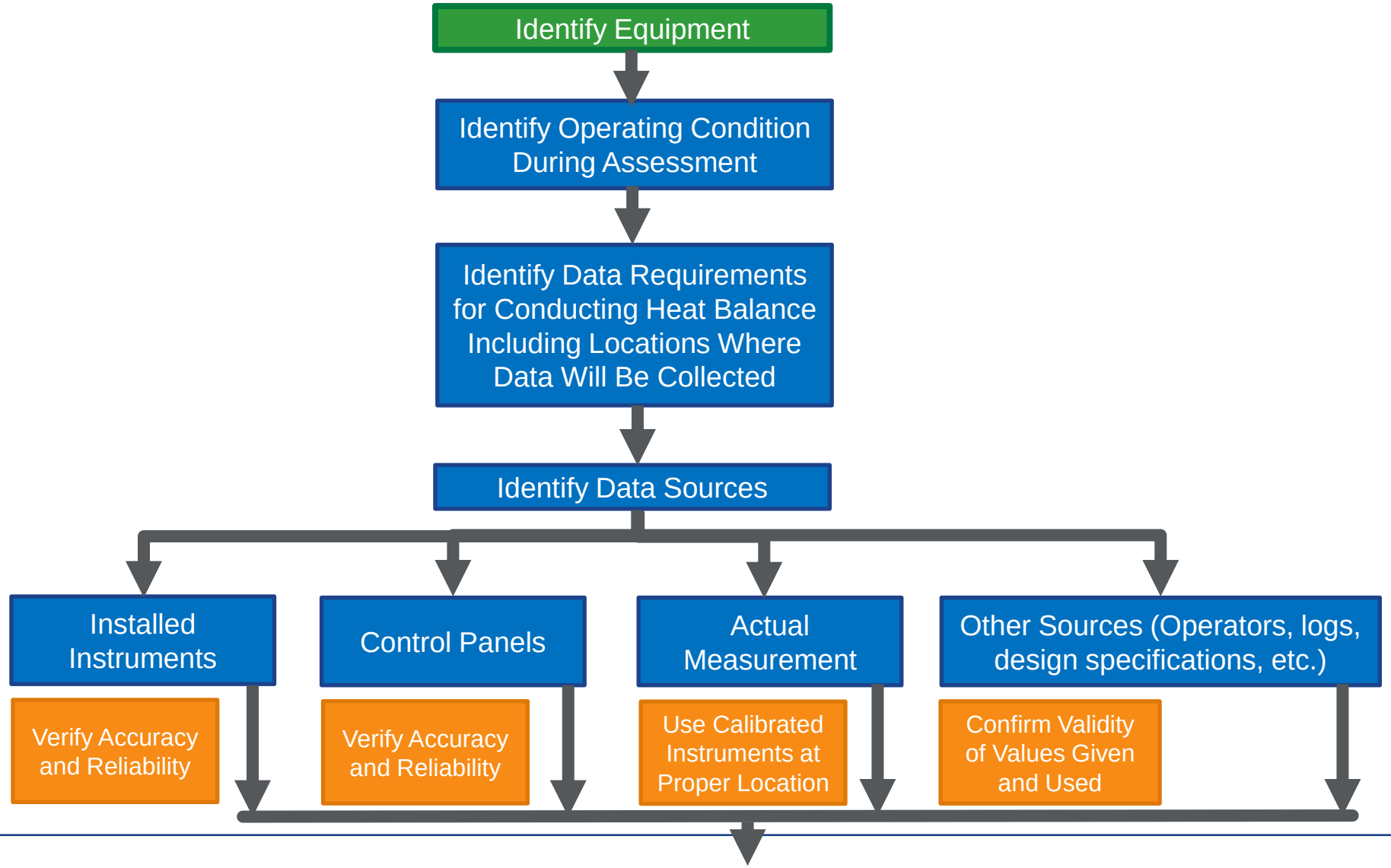
Top Ten Frequently Identified Process Heating Opportunities (ESAs - 2006 to 2011)	No. of Times Identified	Average Energy MMBtu Savings Identified (Source)	Average Source Energy Savings % Identified (%)	Average Energy Cost Savings Identified ($)	Average Energy Cost Savings % Identified (%)	Average of Payback Period Actual (yr)
Reduce oxygen content of flue (exhaust) gases	183	24,415	1.2	$177,471	1.3	0.9
Use of flue or Exhaust gas heat for combustion air preheating	123	67,325	3.6	$407,062	2.6	1.9
Proper insulation and maintenance of furnace structure or parts	120	24,476	1.0	$166,469	1.1	1.4
Reduce-eliminate openings and air leakage in the furnace	76	20,343	1.1	$154,529	1.3	1.0
Load or charge preheating using heat from flue or exhaust gas or other source of waste heat	72	30,173	1.5	$245,646	1.8	2.0
Heat cascading - use of flue or Exhaust gas heat from higher temp. process to supply heat to lower temperature processes	61	53,680	2.1	$407,020	2.3	1.5
Use of proper heating methods - replace inefficient and uneconomical methods with economical/efficient system	54	83,061	6.5	$407,523	3.6	3.0
Heat recovery from hot products or other heat sources (i.e. from walls) from a furnace - oven	44	82,963	2.8	$558,684	3.3	1.8
Furnace scheduling, loading, shut down - avoiding delays, waits, cooling between operations etc.	40	36,058	2.3	$323,857	2.8	0.4
Use of oxygen for combustion	37	85,949	2.6	$598,268	3.2	1.9

* Based on Save Energy Now assessments conducted between 2006 to 2011. Numbers are as of October 1, 2011.

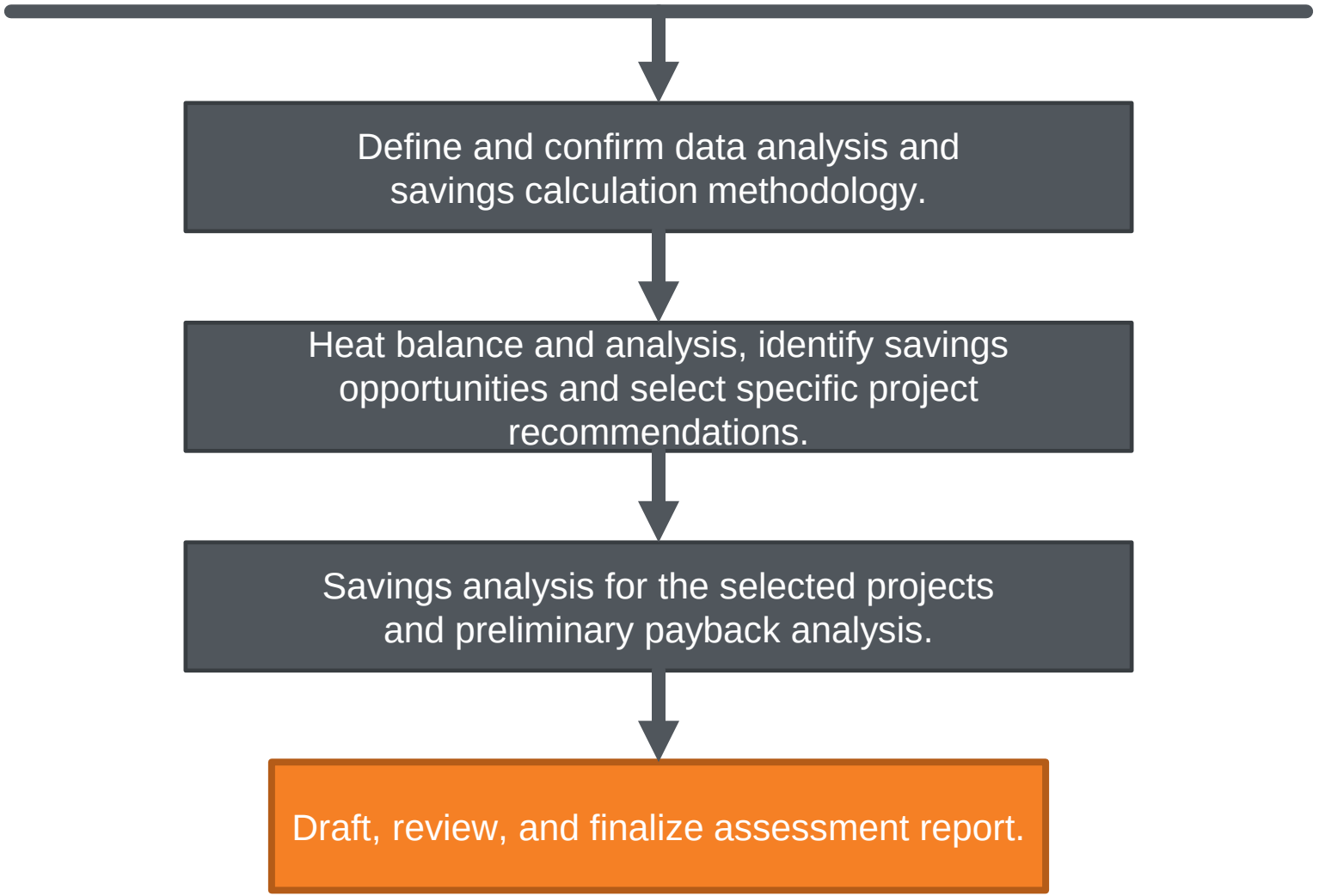
Organizing the Assessment

1. Identification of assessment team members
2. Getting the plant support
3. Definition of assessment goals and scope
4. Assessment Plan of Action
   - Identification of equipment/system
   - Definition of data collection requirements and methods
   - Initial measurement plan: Where and when to collect data
   - Assessment schedule
   - Key personnel interviews

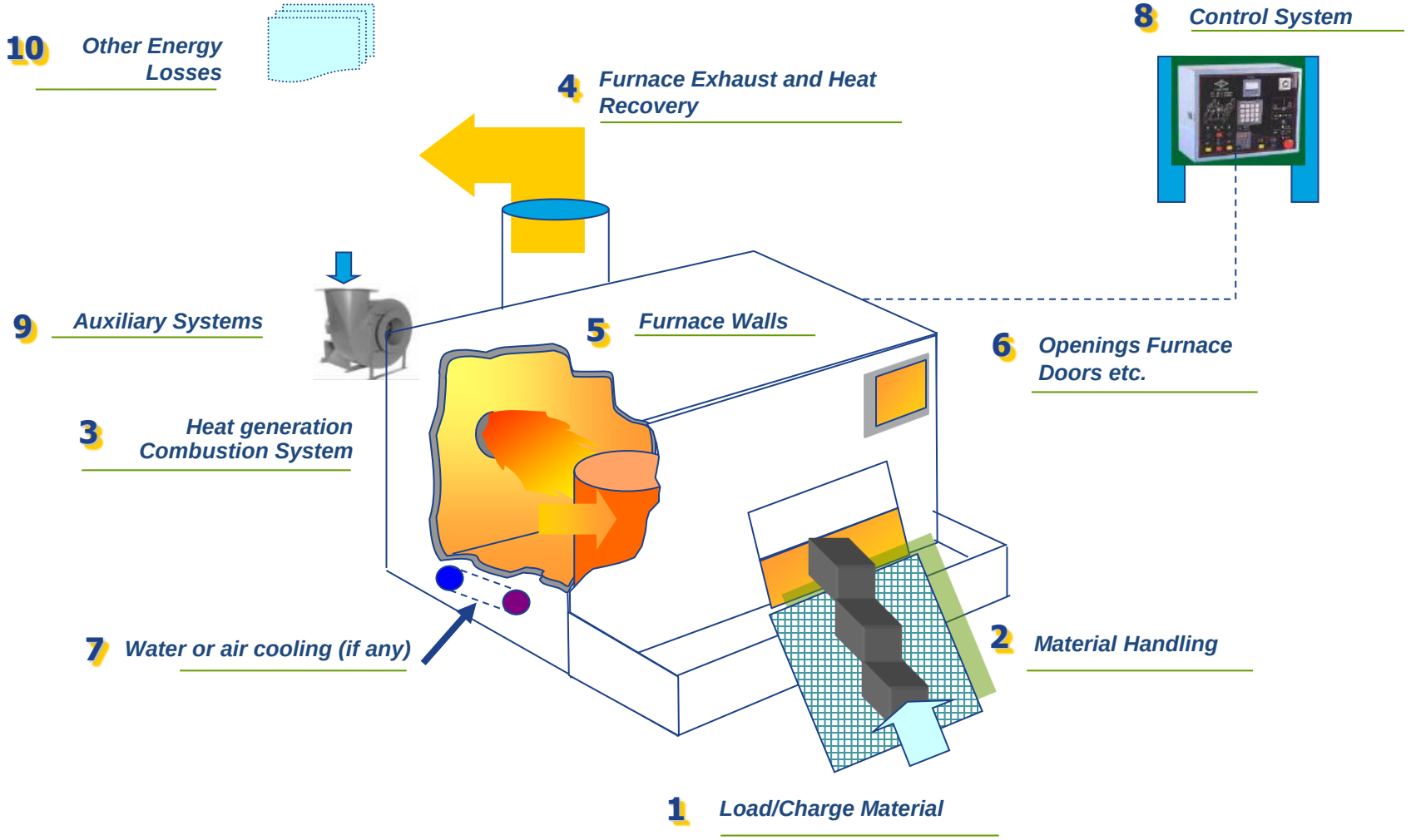
Conducting the Assessment



Conducting the Assessment



Areas Considered for Process Heating Assessment



Conducting the Assessment Data Collection and Measurements

Load – Charge Material

If Type of Material is: Solid
Name of material:
Charge (wet) - Feed Rate (lb/hr)
Water Content as Charged (%)
Water Content as Discharged (%)
Initial temperature (°F)
Charge material discharge temperature (°F)
Water vapor discharge Temperature (°F)
Charge Melted (% of Charge)
Charge Reacted (% of Dry)
Heat of Reaction (Btu/lb)
Endothermic/exothermic?

If Type of Material is: Liquid
Charge (Liquid)-Feed Rate (lb/hr)
Initial temperature (°F)
Discharge Temperature (°F)
Charge Liquid Vaporized (% of Charge)
Charge Liquid Reacted (% of Charge)
Heat of Reaction (Btu/lb)
Endothermic/exothermic?

If Type of Material is: Gas
Feed Rate for Gas Mixture (lb/hr)
Vapor in Gas Mixture (% of Total)
Initial temperature (°F)
Discharge Temperature (°F)
Specific Heat of Vapor (Btu/lb-F)
Feed Gas Reacted (% of Total)
Heat of Reaction (Btu/lb)
Endothermic/exothermic?

Conducting the Assessment Data Collection and Measurements

Material Handling

Fixture, Trays, Baskets etc. Losses*
Material Name (if necessary, give sp. heat below)
Fixture Weight- Feed Rate (lb/hr)
Initial temperature (°F)
Final temperature (°F)
Specific Heat of material (Btu/lb-F) - if required

Combustion Systems

Combustion System Information*
Type of fuel used
Number of zones
The following information is given for EACH zone:
Number of burners
Size or firing rate of burners (MMBtu/hr) for ALL burners
Duty factor (as % of operating hours)
Load factor (as % of firing rate)

Conducting the Assessment Data Collection and Measurements

Flue – Exhaust Gases

Flue Gas Losses (for Fuel Fired Furnace only)
Furnace flue gas temperature (°F)
% oxygen in flue gas
% of excess air (%XS)
Combustion air temperature (°F)
Fuel temperature (°F)
Moisture in combustion air (%) – solid/liquid fuels
Ash discharge temperature (°F) – solid/liquid fuels
Unburned carbon in ash (%) – solid/liquid fuels
User defined fuel if not natural gas – need to provide fuel composition

Wall Losses

Wall Surface Heat Losses
Average surface temperature (measured) (°F)
Ambient Temperature (°F)
Wind velocity (mph)
Surface shape/Orientation
Surface emissivity (default =0.9)
Total outside surface area (ft^2)
Correction factor (based on local conditions)
Number of surfaces

Conducting the Assessment Data Collection and Measurements

Opening Loss: Fixed and Variable

Opening Losses (Rectangular)
Number of openings **of same size and shape**
Average inside temp (°F)
Ambient temperature (°F)
Wall thickness or opening depth (in)
Length of Opening (L) (in)
Height of Opening (H) (in)
View factor - known or from chart
Emissivity of the source (Default=0.9)
% Open time (Default=100%)

Opening Losses (Round)
Number of openings of same size and shape
Average inside temp (°F)
Ambient temperature (°F)
Wall thickness or opening depth (in)
Diameter of Opening (in)
View factor - known or from chart
Emissivity of the source (Default=0.9)
% Open time (Default=100%)

Conducting the Assessment Data Collection and Measurements

Water/Air Cooling

Water- or Air-Cooling Losses *
Cooling Medium (Water, air, other liquid or gas)
Cooling Liquid Flow (gal/min)
Cooling Gas Flow (SCFM)
Inlet Temperature (°F)
Outlet Temperature (Below boiling point) (°F)
Specific heat of gas or liquid (Btu/lb-F) if required

Auxiliary Systems

Fixture, Trays, Baskets etc. Losses *
Material Name (if necessary, give sp. heat below)
Fixture Weight- Feed Rate (lb/hr)
Initial temperature (°F)
Final temperature (°F)
Specific Heat of material (Btu/lb-F) if required

Conducting the Assessment Data Collection and Measurements

Additional Information

Atmosphere Losses*
Type of gas
Initial temperature (°F)
Final temperature (°F)
Flow Rate (SCFH)
Makeup Air Losses
Initial temperature (°F)
Final temperature (°F)
Flow Rate (SCFH)
Specific heat (Btu/lb-F) of gas if required

Other Losses (from extended or other surfaces of furnace)
Approx. Area (ft^2)
Average temperature (°F)
Ambient temperature (°F)

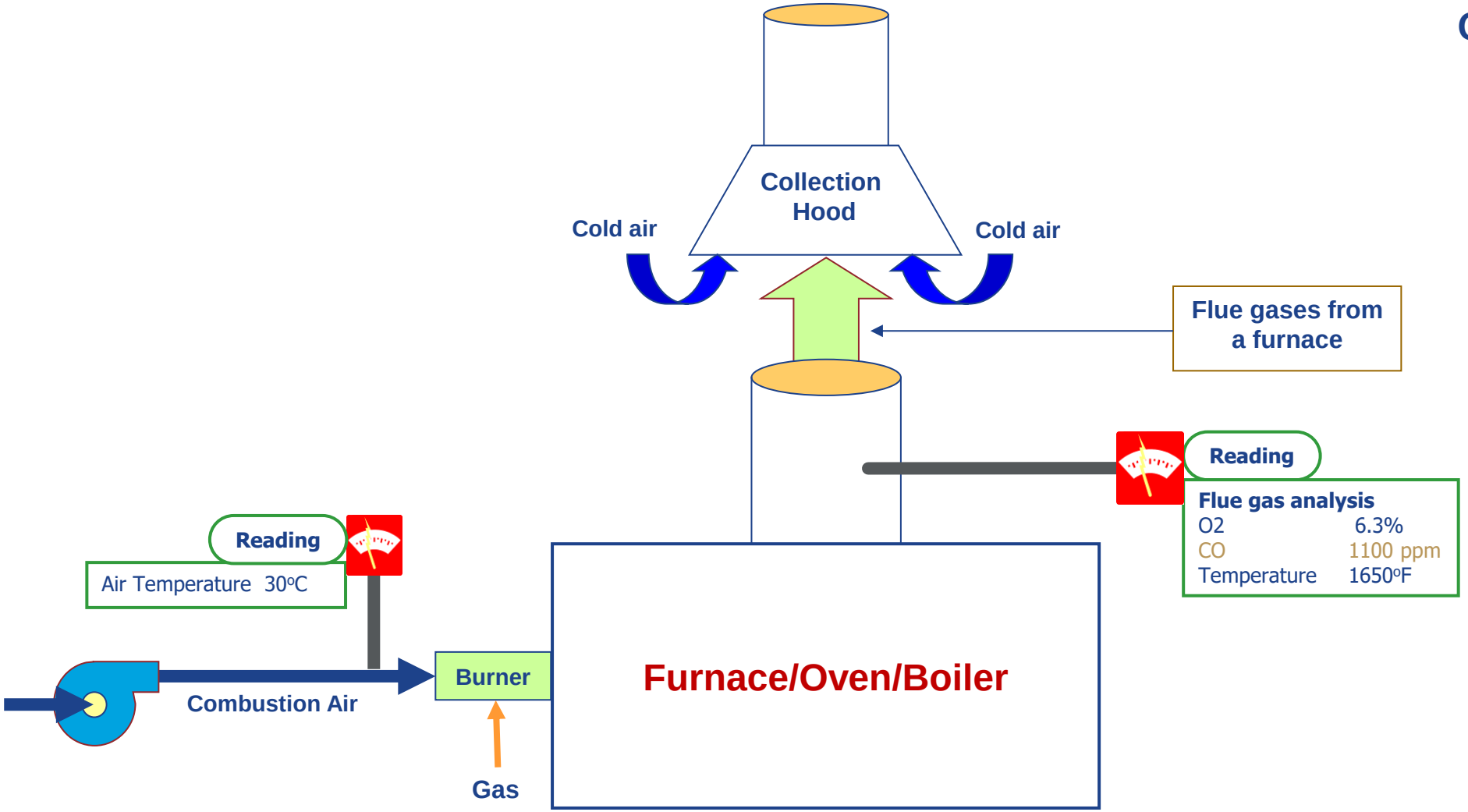
Furnace Flue Gas Analysis

- Flue gas analysis is used to identify burner combustion efficiency and presence of air leaks (if any) in a furnace or boiler.
- There are many different options for location where we should take flue gas analysis.
- The location depends on available ports for inserting the probes, presence of recuperator, economizer or other type of heat recovery system.
- Data of most interest for the flue gas analysis is flue gas temperature, % oxygen and % CO and/or combustibles. Other data can be collected but it is secondary interest for energy savings opportunities.

Flue Gas Analysis

No Recuperator or Economizer

Option 1



Flue Gas Analysis

No Recuperator or Economizer

Option 2

Example of Actual Furnace

Observation

Flue gas analysis

O2	6.3%
CO	**1100 ppm**
Temperature	1650°F

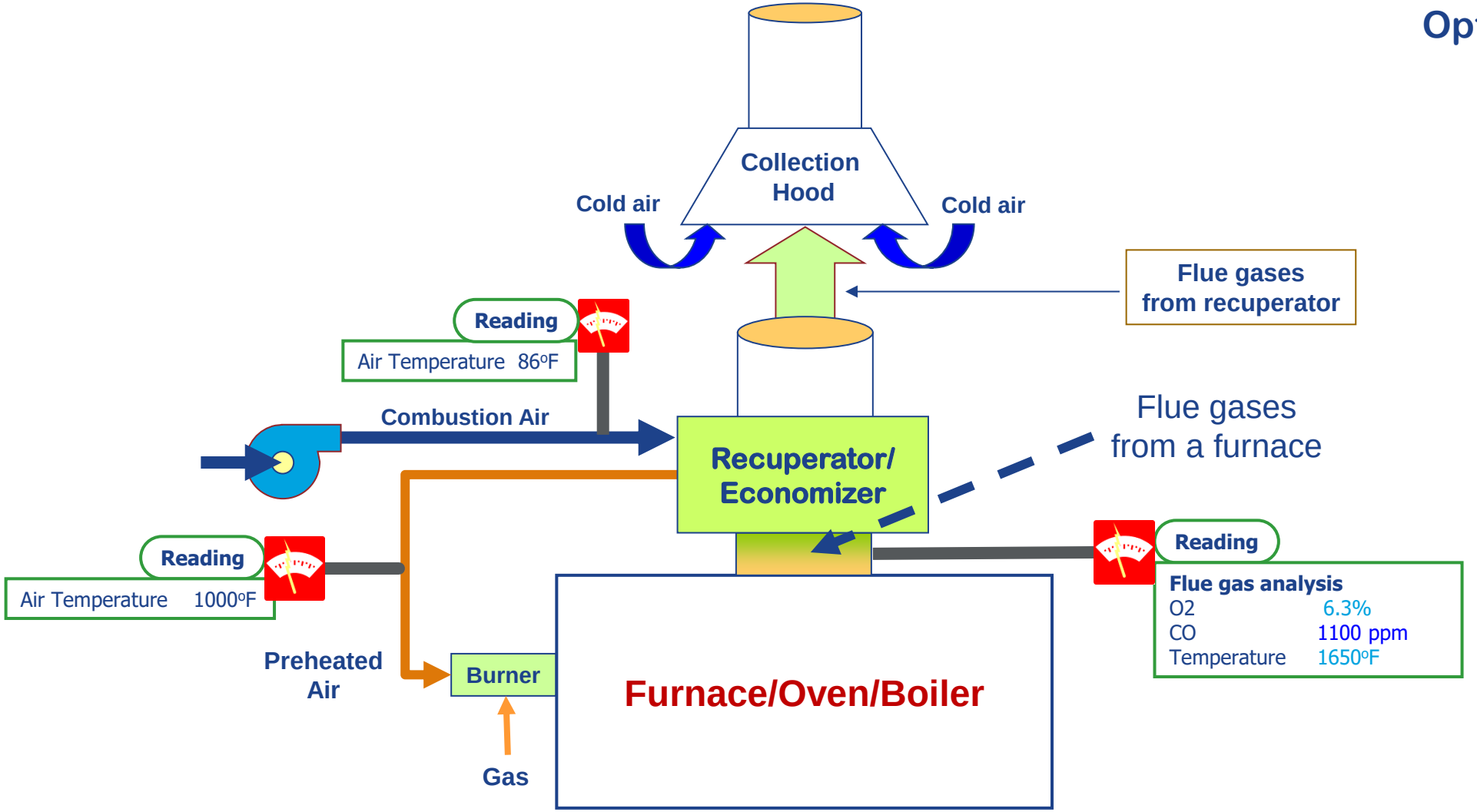
Caution

Note high CO in flue gases.

Contact technical specialist for further discussions.

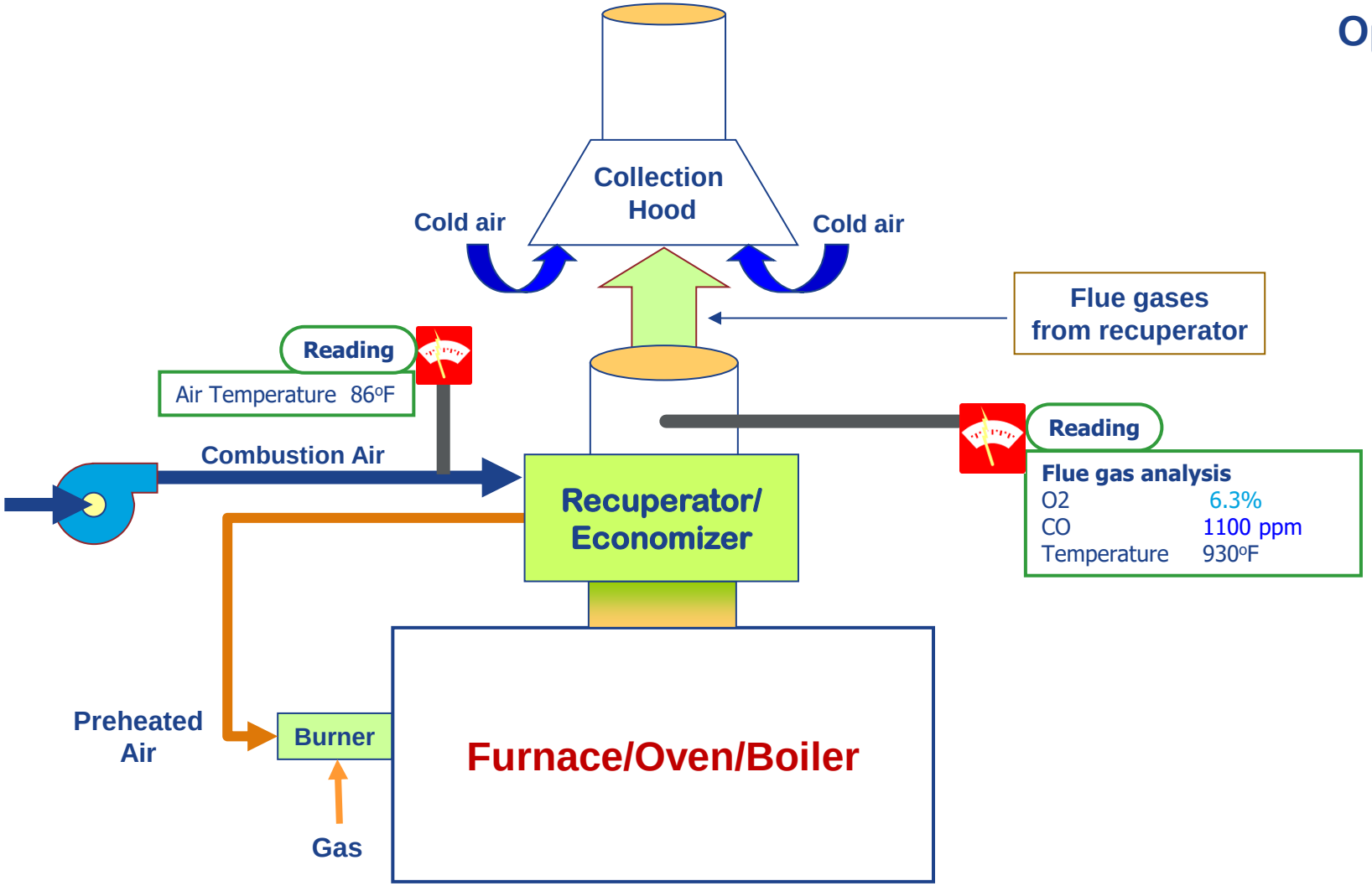
Flue Gas Analysis
With Recuperator/Economizer

Option 3



Flue Gas Analysis
With Recuperator

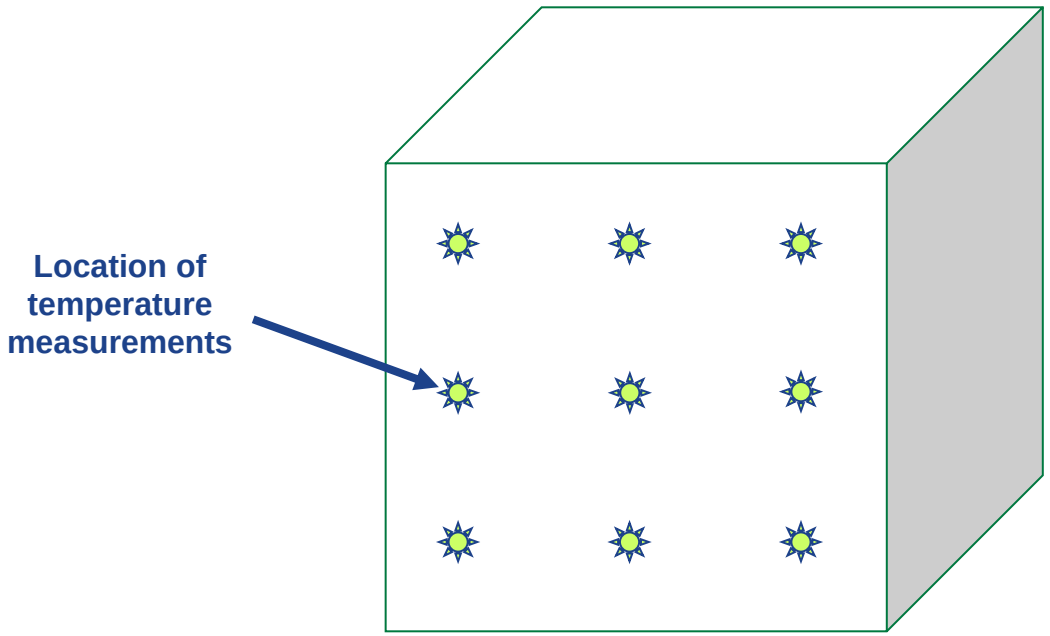
Option 4



Wall Heat Losses

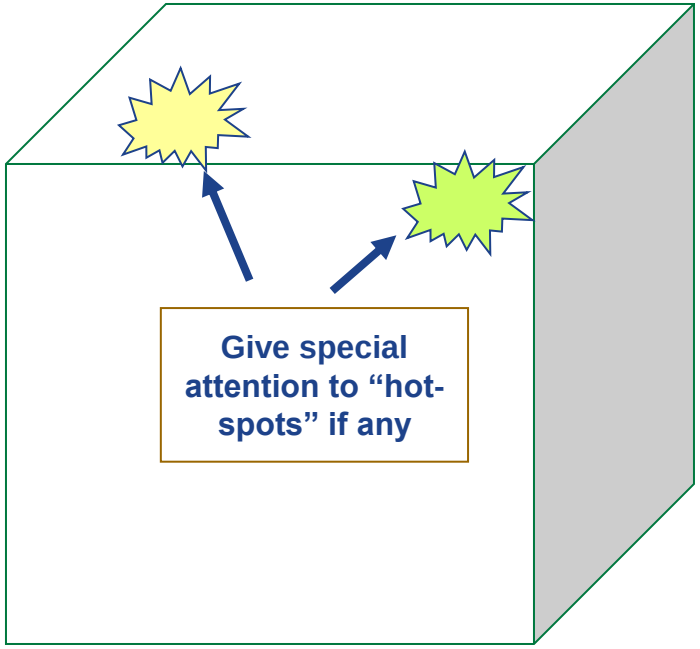
- Wall heat losses can be estimated by measuring furnace/boiler wall temperature and surface area.
- It is also necessary to take notice of any hot spots on the walls.
- The measurements involve use of an infra-red temperature measuring instrument (pyrometer or “gun”) to measure temperature at key locations shown in the following slides.
- It is possible to use a contact thermocouple or a thermographic camera to get wall surface temperature distribution.
- Use the data sheets to collect data.
- It is not necessary to know details of the wall insulation (thickness, type, etc.)

Wall Heat Losses



1. Measure temperatures at nine (or more) locations on a wall.
2. Measure dimensions of the area for which temperature is measured.

Wall Heat Losses



1. Notice areas of hot spots – areas where paint is peeled off, wall color is different or where hot gases are leaking out of the furnace.
2. Estimate or measure area of each of the hot spots and measure temperature at the center of such areas.

Opening Heat Losses

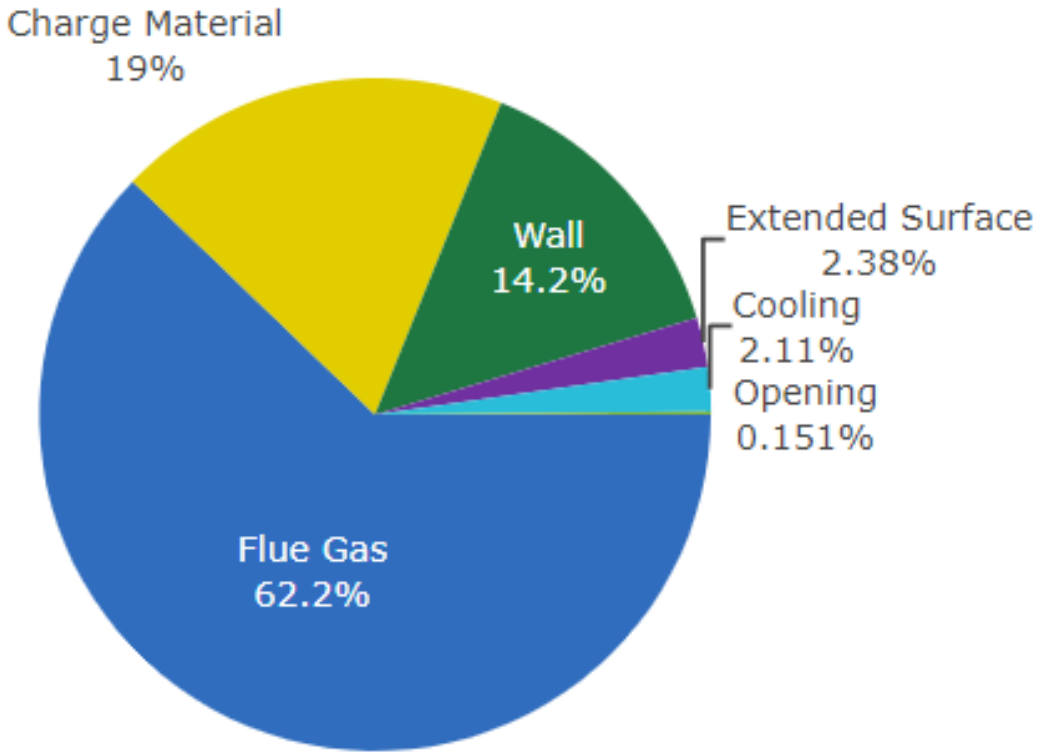
- Opening heat losses can be estimated by measuring furnace/boiler inside temperature.
- It is necessary to measure or estimate dimensions (such as diameter, width, length) of the openings.
- It is also necessary to collect data for furnace/boiler wall thickness notice of any hot spots on the walls.
- The measurements involve use of an infra-red temperature measuring instrument (pyrometer or “gun”) or you can use furnace/boiler temperature from the control panel or chart.
- Use the data sheets to collect data.

Other Data

- **For water- and air-cooling loss** it is necessary to measure flows and inlet – outlet temperature for water or air. In most cases it is enough to collect data in the main inlet and outlet pipes.
- For **other radiation loss** measurement of exposed or open surface areas and temperature is enough.
- The burner information is collected by using existing drawings, manufacturer's operating manuals or actual name-plate data from the burners.
- The burner operating data requires fuel flow or other information that gives actual firing rate at average operating conditions. In some cases, it may be necessary to use "educated" estimates.

Heat Balance Report

Current Operation



MEASUR or other methods can be used to develop a heat balance for the heating equipment

Savings Analysis - Energy

- Identify relatively large areas of heat loss. Use information discussed in Energy Efficiency Improvement section.
- Example:
  - In the heat balance shown in previous slides areas of “high” heat loss are flue gas loss, wall loss, and fixture heat loss.
- Possible improvements: Use information discussed in Energy Efficiency Improvement section to make recommendations for energy savings.
- Calculate energy savings using MEASUR or other similar methods.

Savings Analysis - Other

- In many cases the energy saving projects may result into **additional savings** in areas such as:
  - Productivity increase
  - Higher product yield – lower product losses
  - Improved product quality
  - Reduced emissions
  - Savings through lowering of “peak” rates
  - Reduction of operating and maintenance cost
- Total cost savings must include energy cost savings and other savings mentioned above.

Savings Analysis and Report

- Perform preliminary cost analysis.
- Discuss applicability of recommendations with the assessment team and the plant personnel
- Select final acceptable recommendations.
- Prepare a draft report as per instructions given in the guidance document.
- Review draft report with the plant and after making suggested changes (if any) prepare a final report.

Guidance Document

- The document provides an application guide on how to utilize ASME EA-1 Energy Assessment for Process Heating Systems.
- It gives detail information on:
  - Selection of measurement instruments (temperatures, flow, etc.)
  - Suggested data sheets for collecting the required information to prepare a heat balance.
  - Detailed instructions on conducting an assessment.
  - Instructions on presentation of results in the form of a table and charts.
  - Information on possible areas of energy savings or reduction of heat losses in process heating equipment.

Acknowledgements

- Some material used in this presentation is obtained from ASME Process Heating Energy Assessment Standards.
- The ASME – ANSI standards were developed by using contributions from Dr. Arvind Thekdi and Mr. Richard Bennett (both Co-chair for the committee) and review by a committee of more than a dozen individuals.
- We appreciate contributions by all these individuals who conducted assessments for the US DOE and contributed to the material used in this presentation.