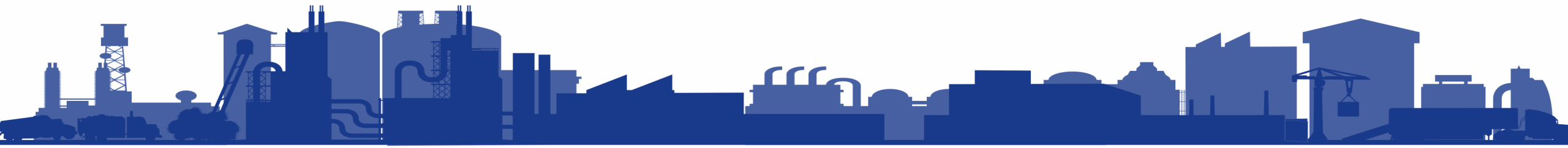
Better Plants
U.S. DEPARTMENT OF ENERGY

VIRTUAL PROCESS HEATING INPLT
Session 4

U.S. DEPARTMENT OF ENERGY

Training Module # 5
Process Heating Systems Data Collection



Outline

- **Process Heating Data Requirement**
- Measurements
  - Temperature
  - Pressure
  - Flow
  - Flue Gas
- Suggested Diagnostic Tools

Process Heating Energy Assessment

- Process heating energy assessment or audit is conducted to identify current performance or energy use and losses for a targeted heating system such as a furnace, an oven, etc.
- In many cases the furnace or oven is operated at different loading (operating) conditions. Hence, it is necessary to collect data for “representative” operating conditions.
- The data and results are analyzed to make a heat balance and to recommend energy saving measures.
- The following presentation gives information on most common instruments and measurements used during a process heating assessment.

Process Heating Data Requirement

- Load or product material
  - Moisture content for solids, vapor content for gases, and mixed liquid for liquids
  - Production rate on per hour basis
  - Details of reactions if any occur during the process
  - Thermal properties (available in database for commonly-used materials)
- Energy type, heating value, and unit cost
- Heating system information (burners and operating data)
  - Number and size (rated or design heat input) of burners
  - Average firing rate
  - Number of operating hours

Collecting data at “representative” operating conditions is necessary.

Process Heating Data Requirement

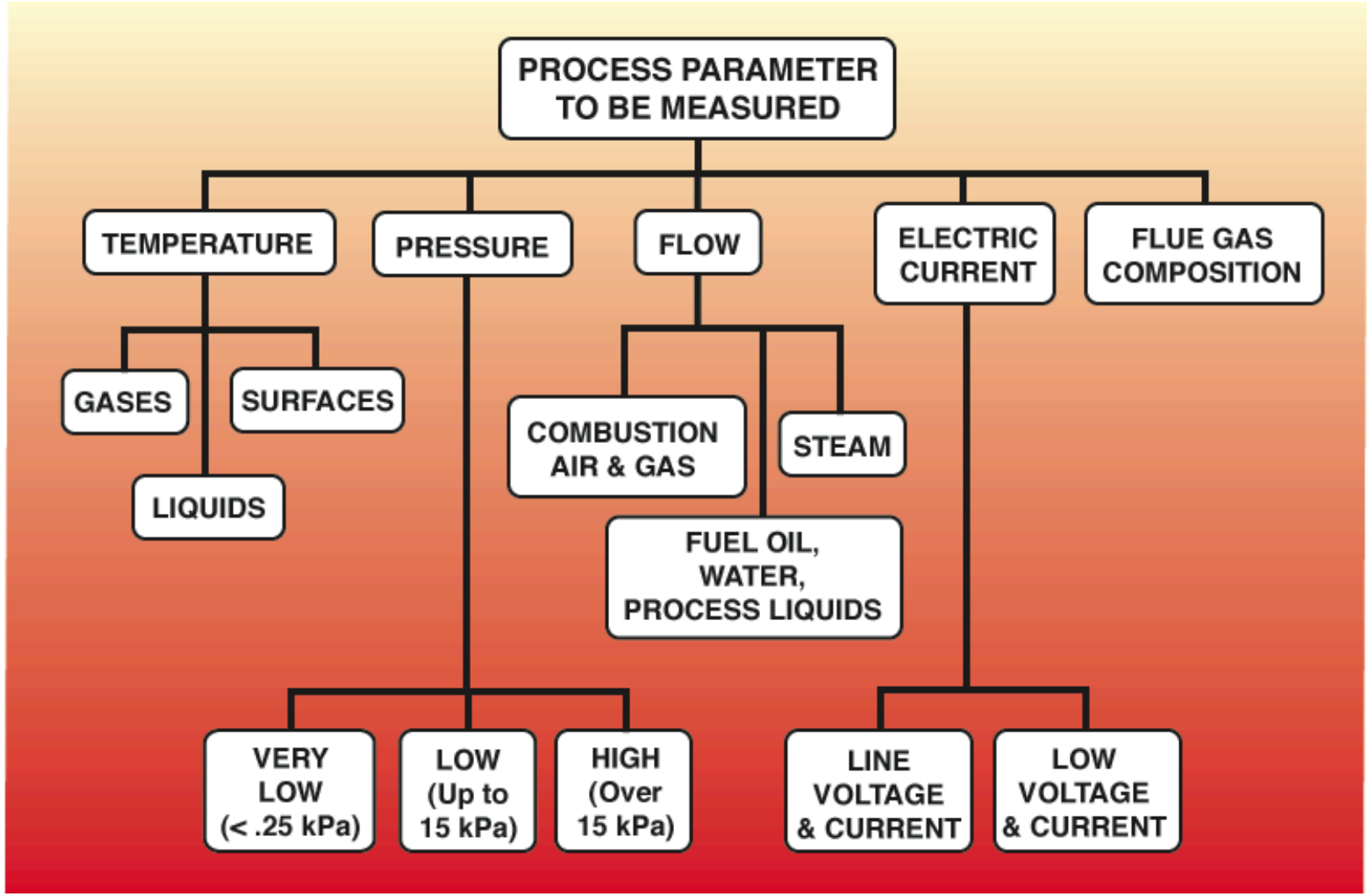
- Heating equipment dimensions and wall insulation construction details
- Temperatures of product or load, combustion air, outside surfaces of furnace walls, flue gases, cooling water (if used), other hot surfaces and furnace interior
- Flow rates:
  - Optional – combustion air, make-up air, and fuel
  - Furnace process atmosphere gases
  - Cooling water
- Flue gas analysis (oxygen and combustibles)

Collecting data at "representative" operating conditions is necessary.

Outline

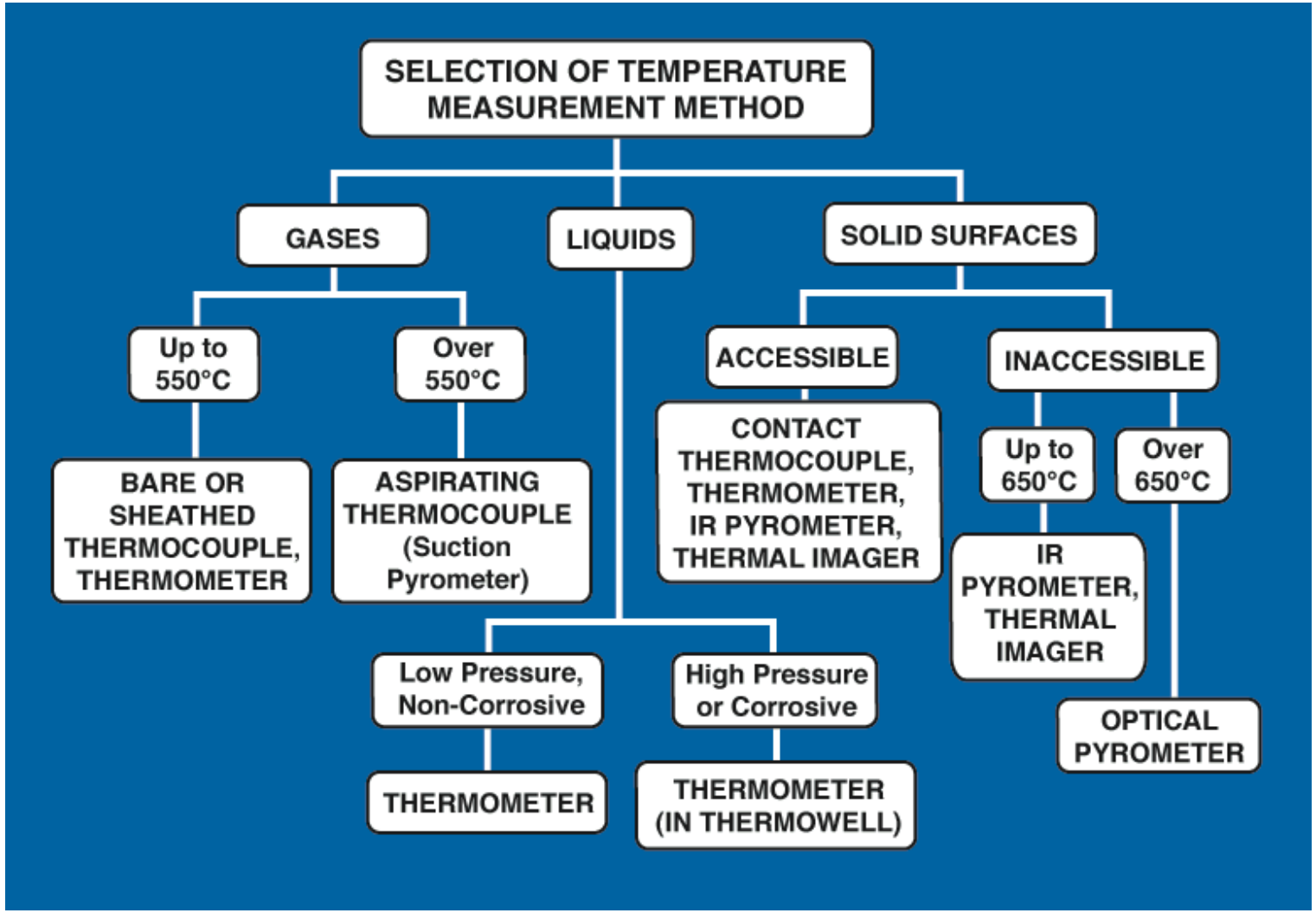
- Process Heating Data Requirement
- **Measurements**
  - Temperature
  - Pressure
  - Flow
  - Flue Gas
- Suggested Diagnostic Tools

Data Collection Parameters for Process Heating



0.25 kPa = 1” wc, 15 kPa = 2 psig

Temperature Measurement



550°C = 1000°F, 650°C = 1200°F

Temperature Measurement Sensors

Thermocouples

- Temperature Range:
  - Up to 3100°F depending on type selected.
- Uses:
  - Surface Contact Measurements
  - Furnace & Flue Gas Temperatures
  - Liquid Temperatures

Temperature Measurement Sensors

Thermocouples

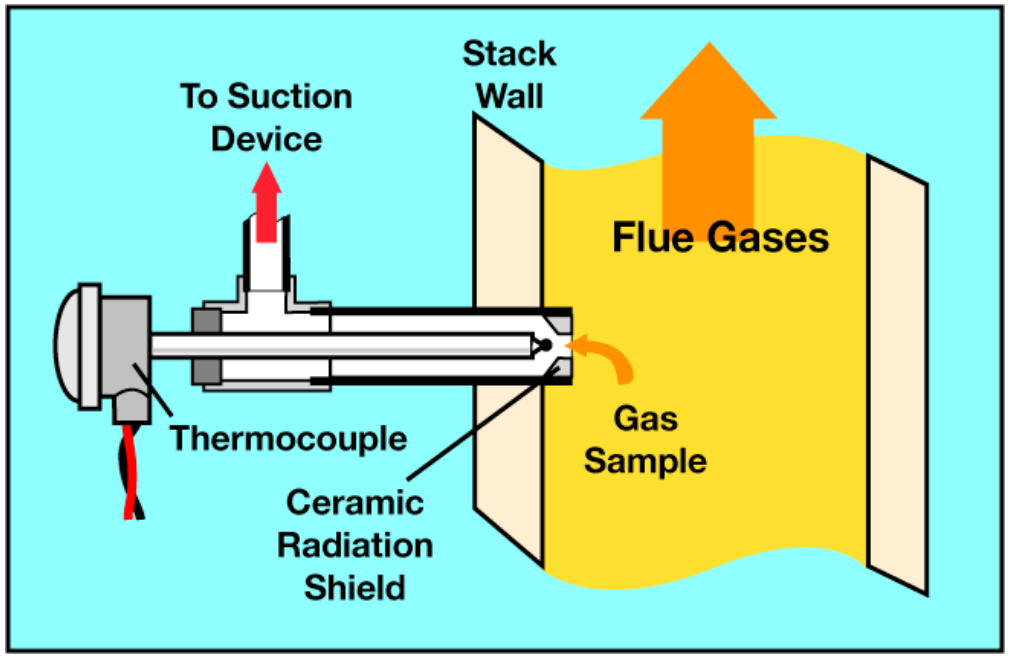
- Advantages
  - Wide variety of configurations and ranges
  - Inexpensive
  - Can be placed at location where temperature is measured
- Disadvantages
  - Depending on location, accuracy of readings may be negatively affected by temperatures of nearby surfaces and gases
  - Thermocouple or lead wire cold end termination must be located remotely from high temperature locations

Temperature Measurement Sensors

Thermocouples

Aspirating (suction) Thermocouple

Used for most accurate measurements of hot gas temperatures. Gas sample is drawn over a thermocouple shielded from nearby radiant surfaces.



Temperature Measurement

Digital Instruments

- Hand-held
- Accept thermocouple inputs
- Allow selection of several thermocouple types
- Most modern meters will accept simultaneous input from two or more thermocouples of different types

Temperature Measurement

Infrared Pyrometer

- Wall temperature
- Furnace interior
- Material - charge

Infrared Instruments

- "Point & Shoot" temperature measurement
- Models available for up to 1200°F
- Advantages:
  - Quick response, convenient to use
  - Readings can be taken at a distance from the target
- Disadvantages:
  - Readings sensitive to target emissivity
  - Readings sensitive to steam, vapors, dust, etc., in air between pyrometer & target
  - Field of View issues – surface area being measured increases with distance between pyrometer & target

Temperature Measurement

Infrared Instruments

Cost range:
$2,500 to $4,000 and up
(Approx. 62,500 to 100,000 UAH and higher)

Advantages:

- Gives temperature distribution for the entire surface.
- Can be used to see relative temperature distribution, quick response, convenient to use.
- Images can be taken remotely.
- Allows easy calculation of heat loss since many units give this information as a printout.
- Easy to study and correct localized hot spots or cold spots.

Disadvantages:

- Target emissivity must be assumed
- Readings sensitive to steam, vapors, dust, etc., in air between the imager and target
- More expensive
- Requires training to use and analyze the data.

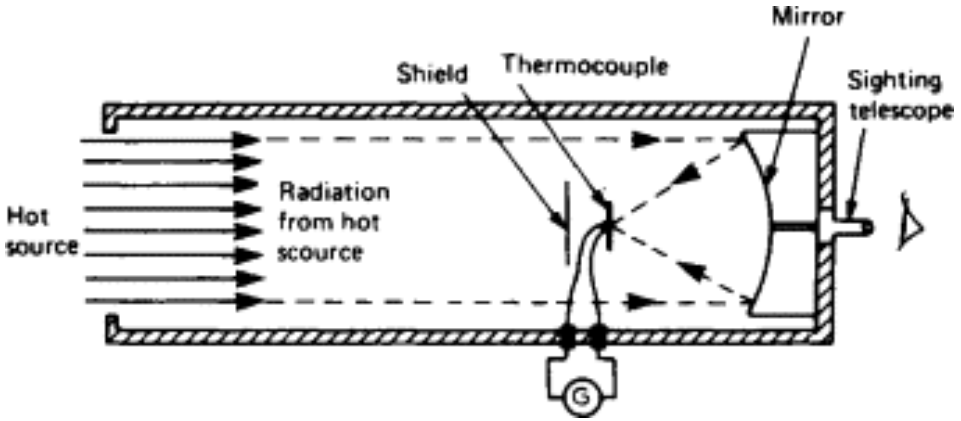
Temperature Measurement

Radiation Pyrometers

For remote or non-intrusive measurement of:

- Load temperatures
- Inside furnace wall temperatures
- Surface temperatures of electrical elements, radiant tubes & muffles

…from 1000 to 4500°F



Radiation Measurement

Radiation Pyrometers

Advantages:

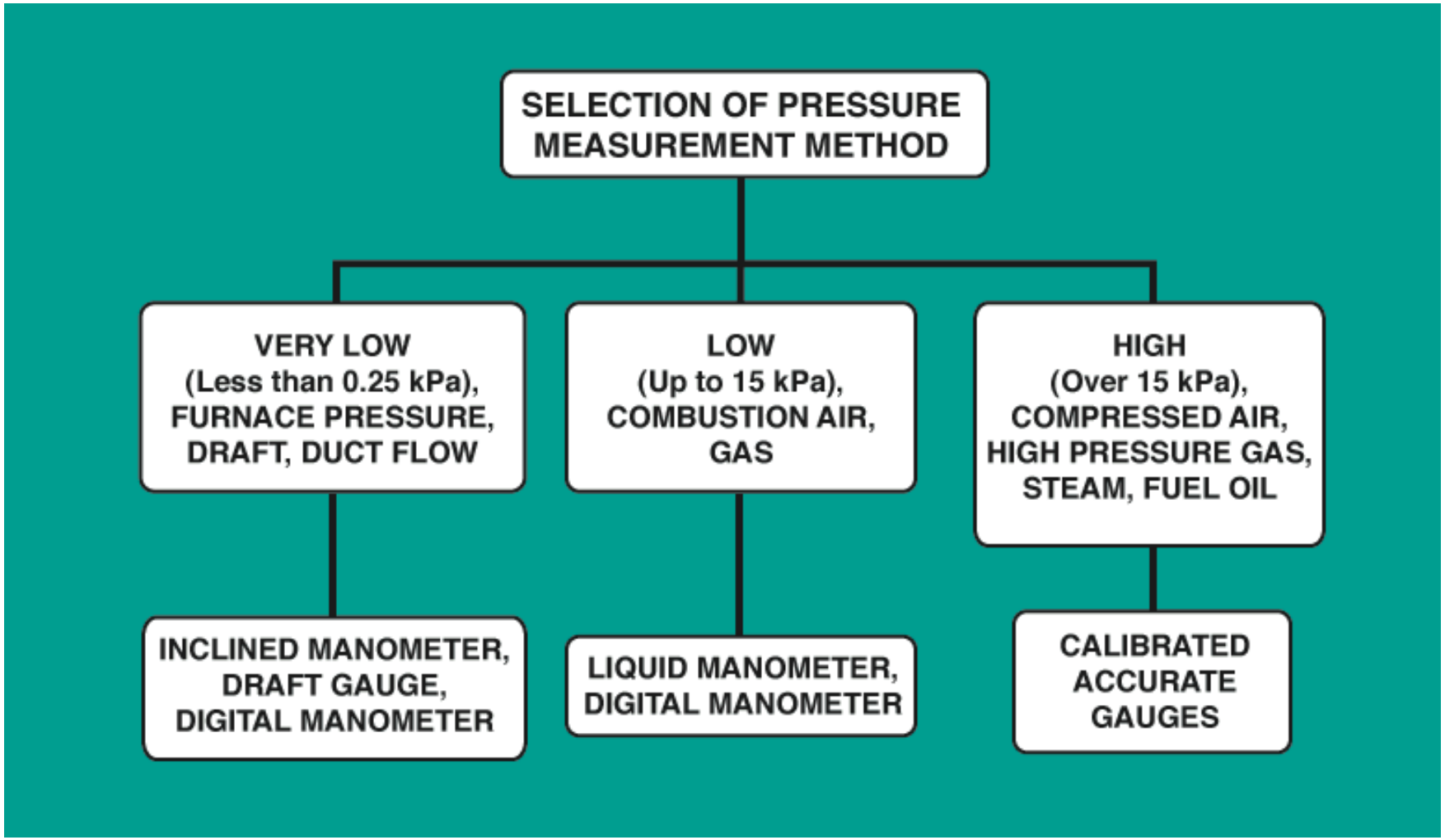
- Convenient “point & shoot” temperature measurement
- Quick response, convenient to use
- Readings can be taken remotely
- Through-the-lens sighting of target improves measurement accuracy.

Disadvantages:

- Target emissivity must be assumed
- Readings sensitive to steam, vapors, dust, etc., in air between pyrometer & target
- Field of View issues – surface area being measured increases with distance between pyrometer & target.
- Minimum usable temperature of 1000°F to deliver accurate readings

Cyclops C160L – 400 to 2500 °F

Pressure Measurement



0.25 kPa = 1” wc, 15 kPa = 2 psig

Pressure Measurement

Very Low Pressures & Furnace Draft

Draft Gauges & Inclined Manometers

Permit accurate resolution of pressures below 1” wc, such as:

- Furnace pressure or draft
- Very low line pressures or differentials
- Duct & pipe velocities & flows when used in conjunction with a pitot-static tube.

Advantages:

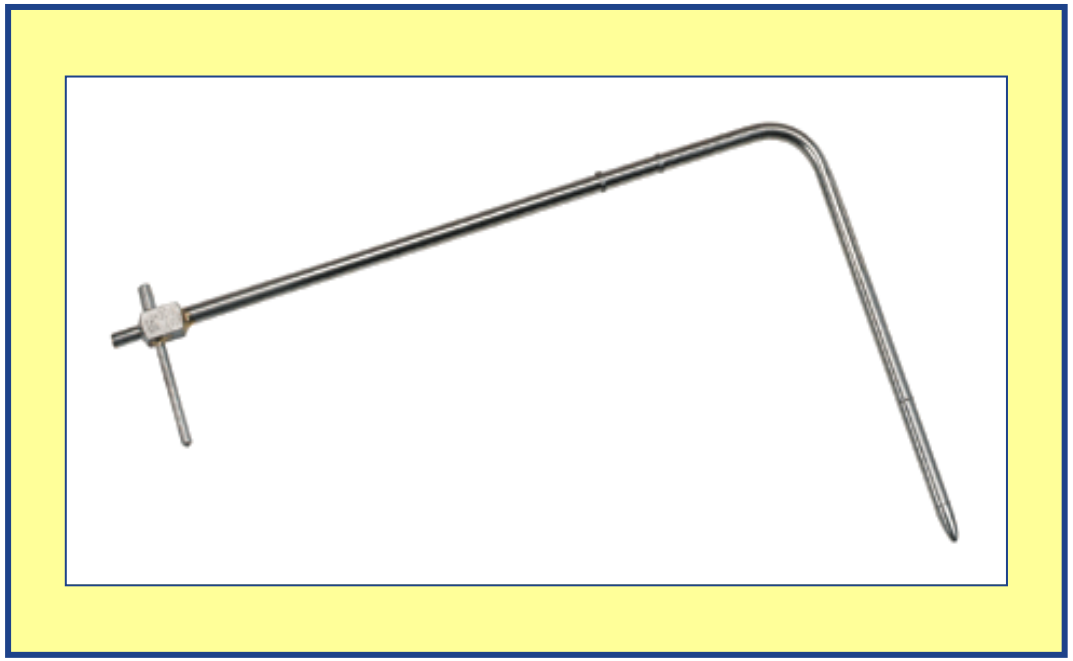
- Highly accurate, simple to use

Disadvantages:

- Requires careful leveling & zeroing, which must be rechecked periodically
- Fluid easily blown out by overpressure

Gas Flow (Velocity) Measurement

Pitot-Static Tubes



- Used with Differential Manometer to Measure the Velocity of Air or Flue Gases in Ducts, Piping, or Flues.
- Pressure differentials are read at several predetermined points in duct. Values are averaged.
- Differentials are converted to velocities with a chart or using the equation below.

$$\textbf{Gas Velocity}\ (\mathbf{ft}/\boldsymbol{min}) = \mathbf{1096.2}\sqrt{\frac{\textbf{Velocity Pressure}\ (\text{"}\boldsymbol{wc})}{\textbf{Gas Density}\ (\mathbf{lb}/\mathbf{ft^3})}}$$

Pressure Measurement

Pressures up to About 2 psig (55” wc)

Manometer

- Static Pressures
- Pressure Differentials

Fluid Manometers – U-Tube (shown) or Straight Tube for Measuring:

- Air & Gas Pressures
- Air & Gas Differential Pressures (Orifice Meters)

Advantages:

- Easy to set up & use – virtually “idiot-proof”
- No calibration problems or drift

Disadvantages:

- Awkward to use in cramped locations
- Pressures tubing subject to melt-through on hot surfaces

Electronic Pressure Gauge (Digital Manometer)

Alternative to liquid-filled manometer

Available in ranges as low as 0 – 1” wc and up to 10 bar

Advantages:

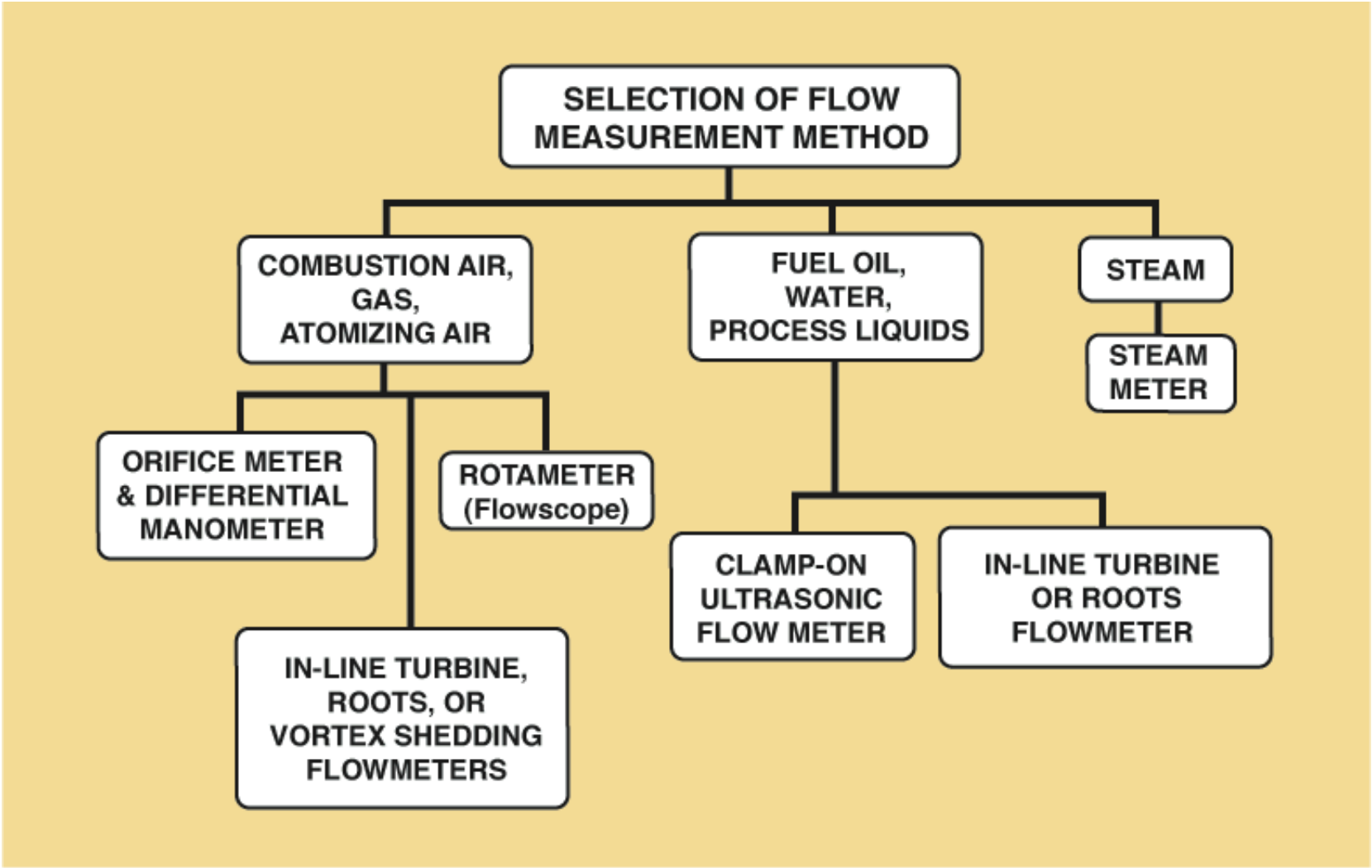
- More compact, easier to transport & handle than liquid manometer
- No filling or spilling of fluid
- No guessing at pressure readings

Disadvantages:

- Like all electronic instruments, subject to drift – requires periodic recalibration
- Not as wide a selection of pressure ranges/resolutions as liquid manometers

It’s wise to have a liquid manometer on hand to use as a calibration standard for the electronic gauge.

Flow Measurement



Flow Measurement

Orifice Type Flow Meters

- Orifice meters are available for any commercially available pipe size; virtually unlimited flow range
- A wide variety of plate bore diameters permits selecting an orifice that's a good compromise between readability and moderate pressure loss.
- Plates are interchangeable in the field.
- Orifice meters are available from many combustion equipment manufacturers who provide charts or tables for determining flows.

Accuracy of orifice meter readings will be negatively affected by:

1. Pipe fittings or valves too close upstream or downstream of the orifice.
2. Too-short runs of straight piping upstream & downstream of the orifice.
3. Poorly-centered, reversed or nicked orifice plates.

Flow Measurement

Rotameters or Flowscopes

Direct-Reading Flow Meters for Air, Gases, and Liquids

Flow is read directly from a scale on or below the rotameter tube.

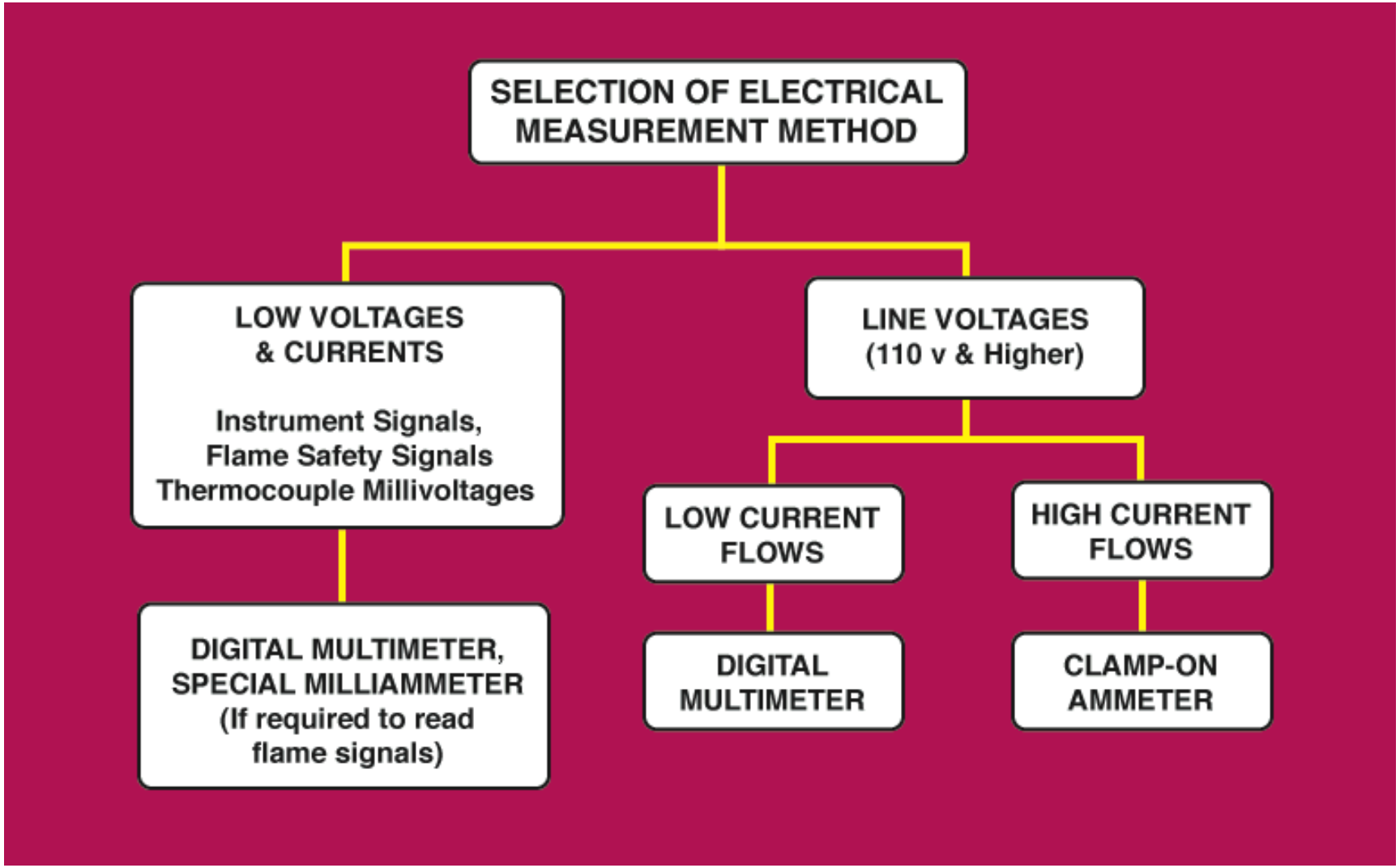
Advantages Compared to Orifice Meters:

- Readings quicker to obtain
- No need for a calibration chart or graph
- Readings not subject to calculating errors
- More likely to be read regularly

Disadvantages Compared to Orifice Meters:

- Most costly
- Limited availability in large sized, especially those needed to read combustion air flows
- More susceptible to breakage in harsh environments

Electrical Measurement



Flue Gas Measurements

Flue Gas Analysis

- Burner-fuel/air ratio is directly related to the percentages of oxygen & carbon dioxide in the combustion products.
- A flue-gas analyzer can be used to determine the ratio.
- Ratio adjustments can be made, using the analyzer as a diagnostic tool.

Flue Gas Measurements

Combustion Analyzers measure & display components of the furnace flue gases.

Depending on the model, these include:

- Oxygen
- Carbon Monoxide
- Carbon Dioxide
- Total Combustibles
- NOx
- Sulfur Dioxide
- Flue Gas Temperature

- Some units calculate the thermal efficiency (actually, the Available Heat) of the process
- Results are displayed by the analyzer
- Some models can print out the readings, store them in memory or download them directly to a computer.

Outline

- Process Heating Data Requirement
- Measurements
  - Temperature
  - Pressure
  - Flow
  - Flue Gas
- **Suggested Diagnostic Tools**

Suggested Diagnostic Tools

Temperature Measurements		
Parameter to be measured	**Basic Equipment**	**Advanced Equipment**
General Temperature Measurement	Multi-range Digital Pyrometer	
Furnace or Oven Skin	Contact Thermocouple	Infra-red Pyrometer
Flue Gases	Sheathed Thermocouple	Aspirating Thermocouple
Furnace Interior and Workload	Thermocouple, Infra-red or Radiation Pyrometer	
Temperature Profiles in Continuous Ovens	Long Thermocouple Wire and Digital Pyrometer	Traveling Data Loggers

Suggested Diagnostic Tools

Pressure, Flow, and Velocity Measurements		
Parameter to be measured	**Basic Equipment**	**Advanced Equipment**
Air and Gas Pressures, Pressure Differentials	Liquid Manometer	Electric Manometer
Manometer Calibration Standard	---	Liquid Manometer
Draft, Furnace Pressure	Inclined Manometer	Electric Manometer
Compressed Air, Fuel Oil, and Steam Pressures	Calibrated Dial Pressure Gauge	
Low Temperature Air Velocity	Pitot-Static Tube and Manometer	Anemometer
Heated Air Velocity	Alloy Pitot-Static Tube and Manometer	

Suggested Diagnostic Tools

Flue Gas Analysis		
Parameter to be measured	**Basic Equipment**	**Advanced Equipment**
Oxygen	Flue gas analyzer	In-situ O2 analysis system
Combustibles	Flue gas analyzer	In-situ CO/combustible analysis system
Flow rate	Pitot tube survey	Annubar or similar equipment
Temperature	Thermocouple	Suction thermocouple for higher temperatures
Particulates	Gas sampling system	
Other components/gases	Sampling with special gas analyzers	

Suggested Diagnostic Tools

Electrical Measurements		
Parameter to be Measured	**Basic Equipment**	**Advanced Equipment**
General Electrical Measurements	Digital Multimeter	
Electric Motor Current	Clamp-on Ammeter	
Flame Signal Strength	Digital Multimeter, Microammeter*	

*Required by certain types of flame monitoring systems.

Acknowledgements

- Information used in this presentation has been derived from several sources including websites of equipment manufacturers, published literature, and handbooks.

- Special thanks to Arvind Thekdi (E3M Inc.) and Mr. Richard Bennett (Janus Technologies) for preparing part of the presentation and graphics used.

Optical Pyrometer Working Principle