Better Plants
U.S. DEPARTMENT OF ENERGY

VIRTUAL PROCESS HEATING INPLT
Session 5

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

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- **Measurements**
  - Temperature
  - Pressure
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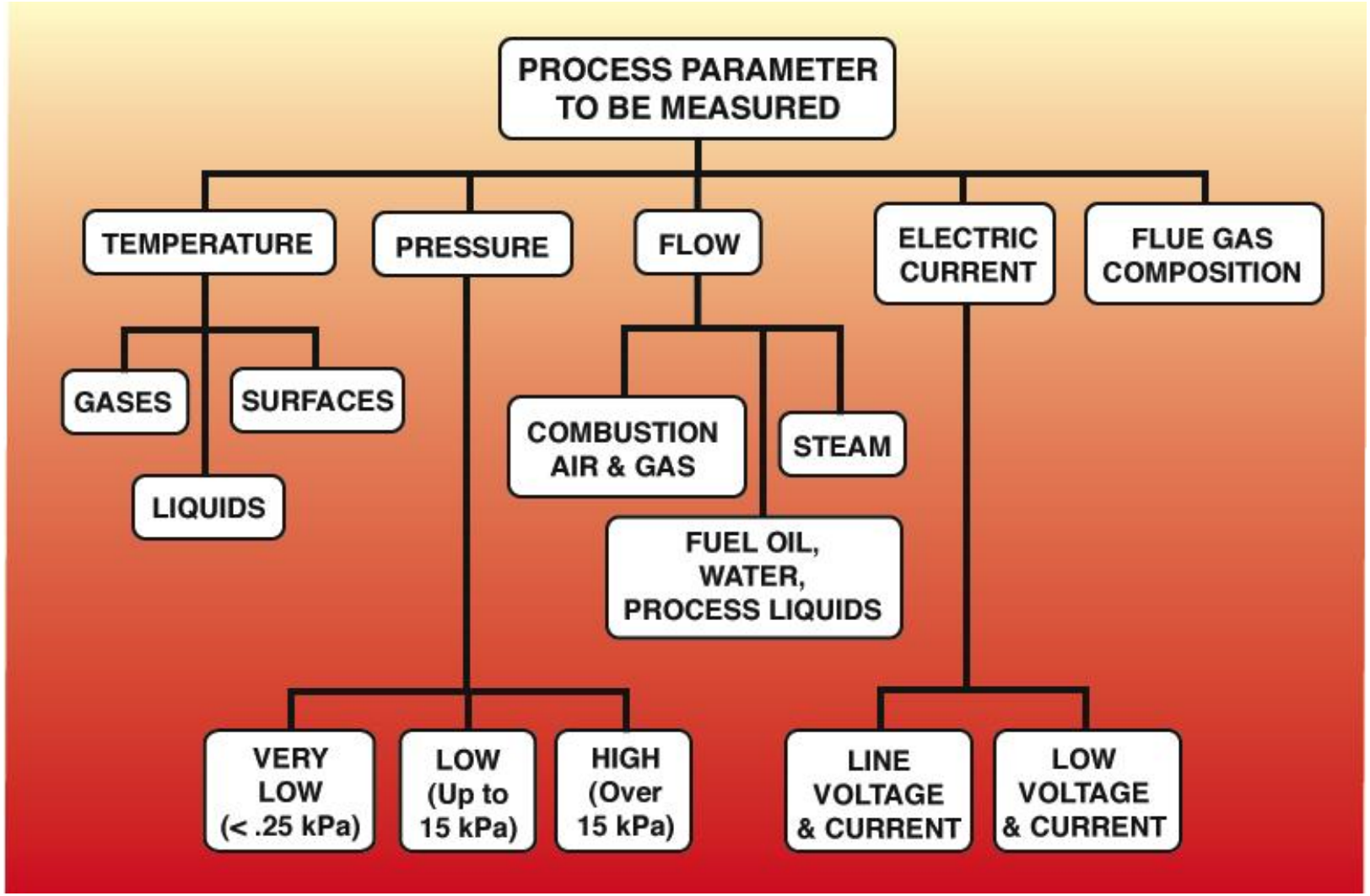
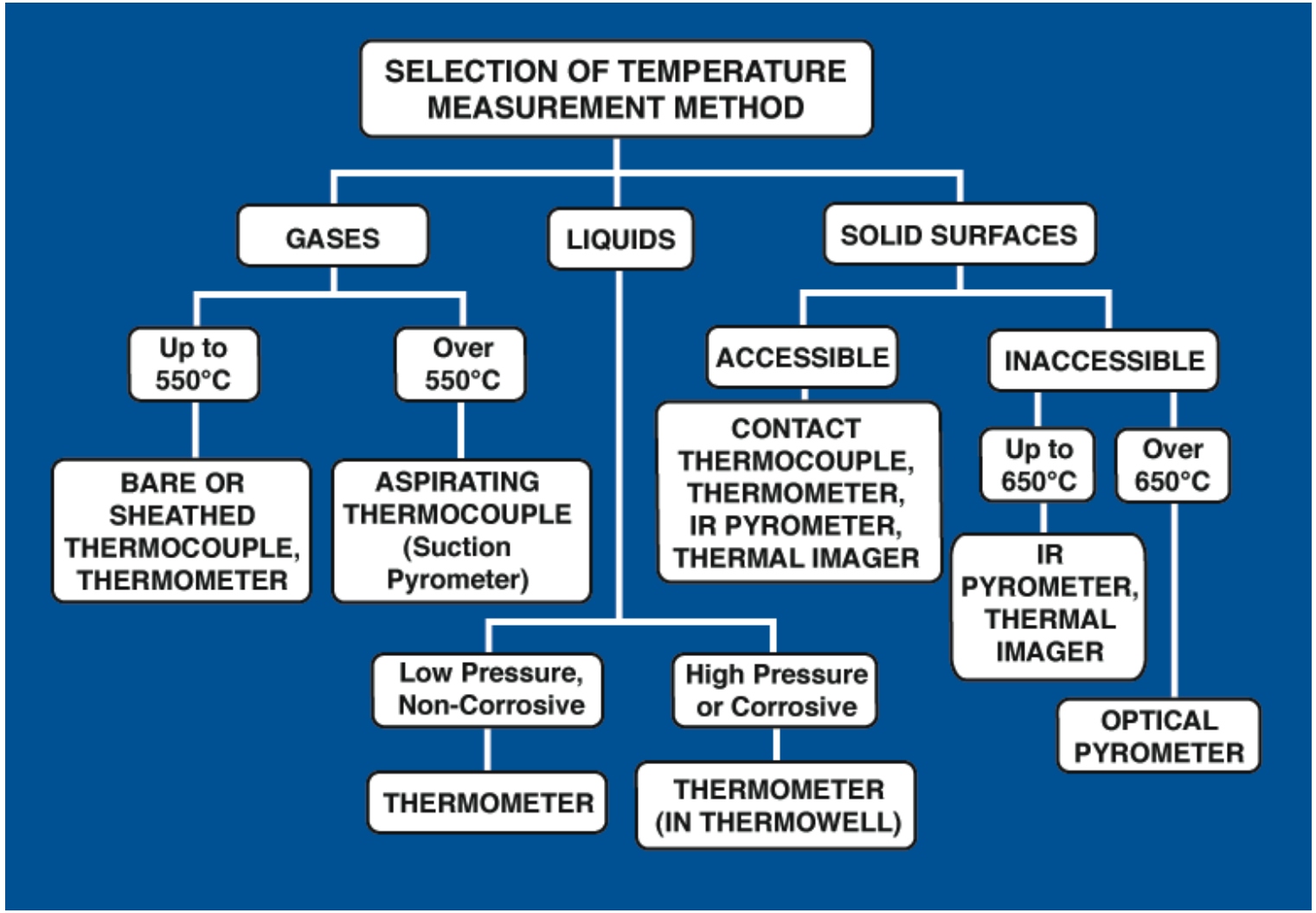
- Suggested Diagnostic Tools

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

Thermocouple Types			
Type	Conductor Combination	Temperature Range	
		°F	°C
B	Platinum 30% Rhodium / Platinum 6% Rhodium	2500 to 3100	1370 to 1700
E	Nickel-chromium / Constantan	32 to 1600	0 to 870
J	Iron / Constantan	32 to 1400	0 to 760
K	Nickel-chromium / Nickel-aluminium	32 to 2300	0 to 1260
N	Nicrosil / Nisil	32 to 2300	0 to 1260
R	Platinum 13% Rhodium / Platinum	1600 to 2640	870 to 1450
S	Platinum 10% Rhodium / Platinum	1800 to 2640	980 to 1450
T	Copper / Constantan	-75 to +700	-59 to +370

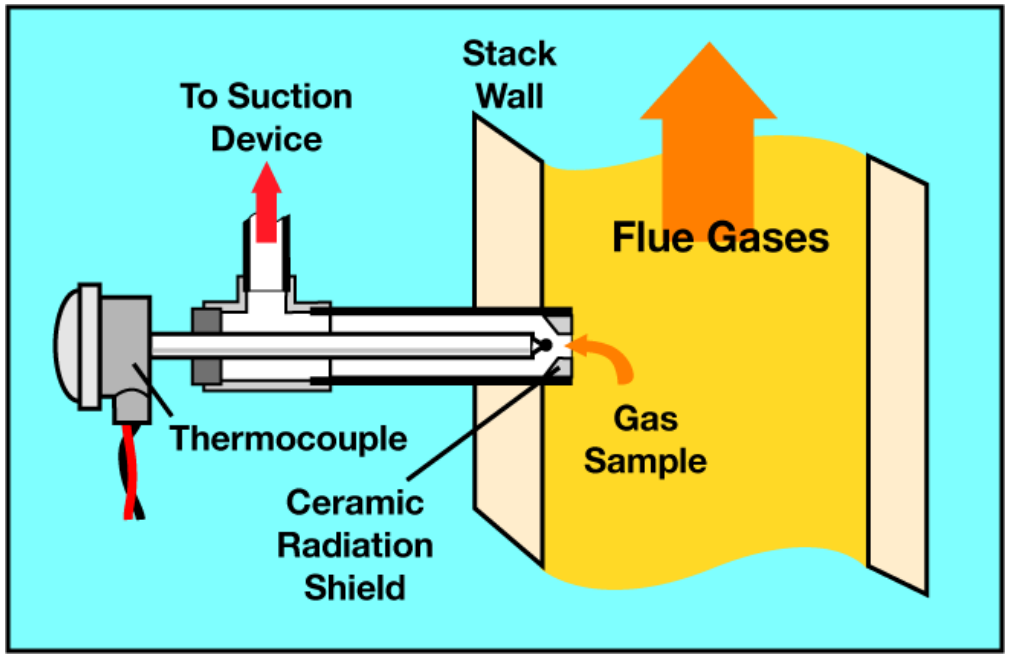
www.Control and Instrumentation.com

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.

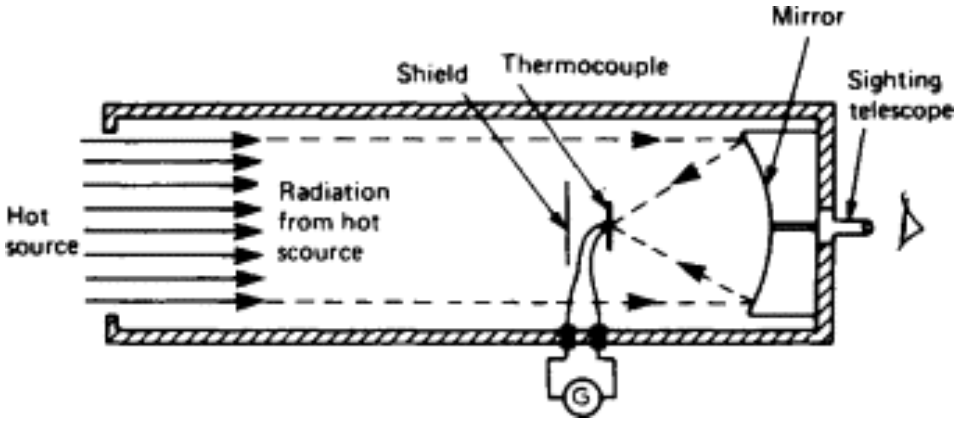
Temperature Measurement

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:

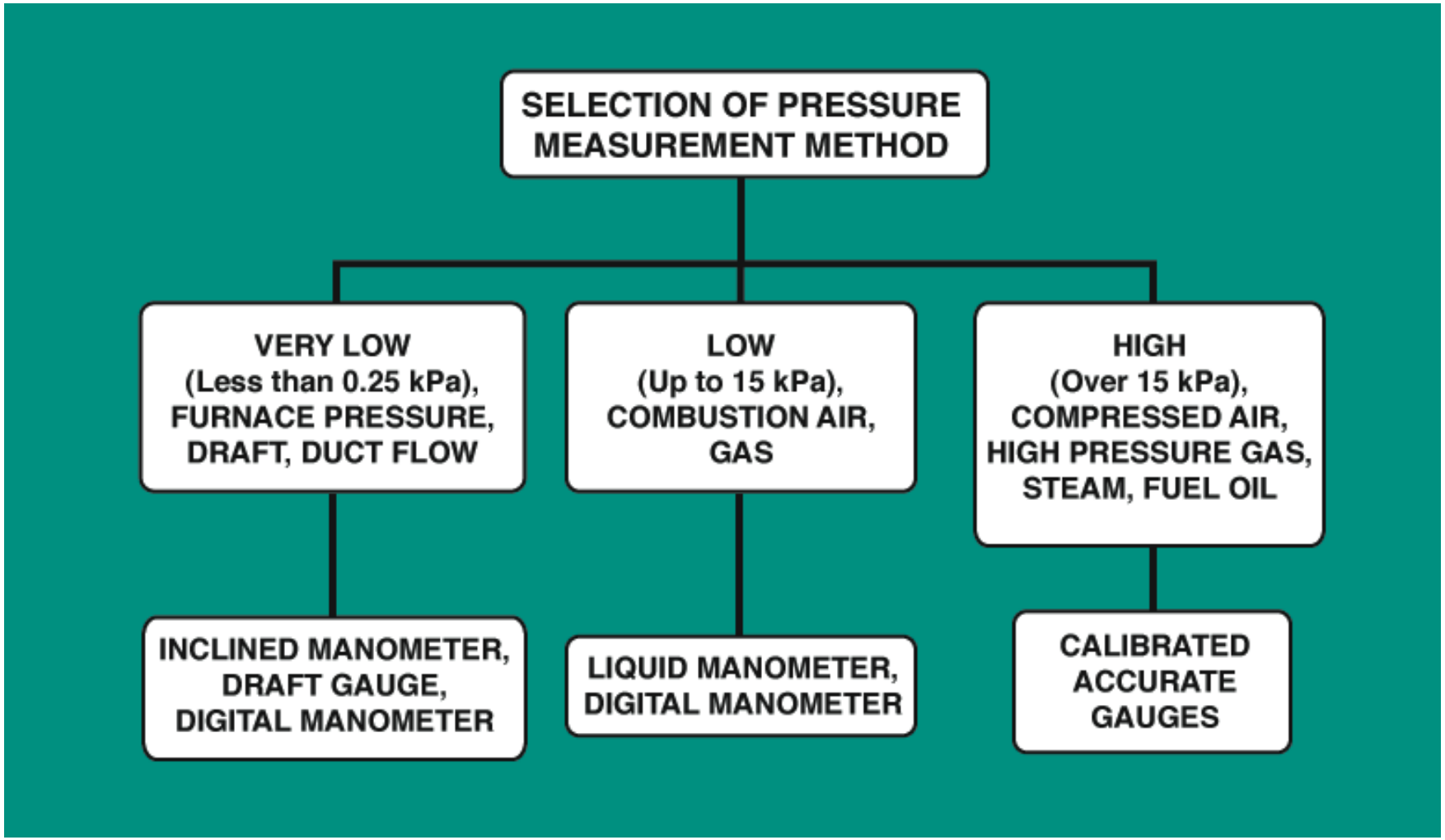
- Convenient “point & shoot” temperature measurement
- Quick response, convenient to use
- Readings can be taken remotely
- Through-the-lens sighting of target improves measurement accuracy.

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:

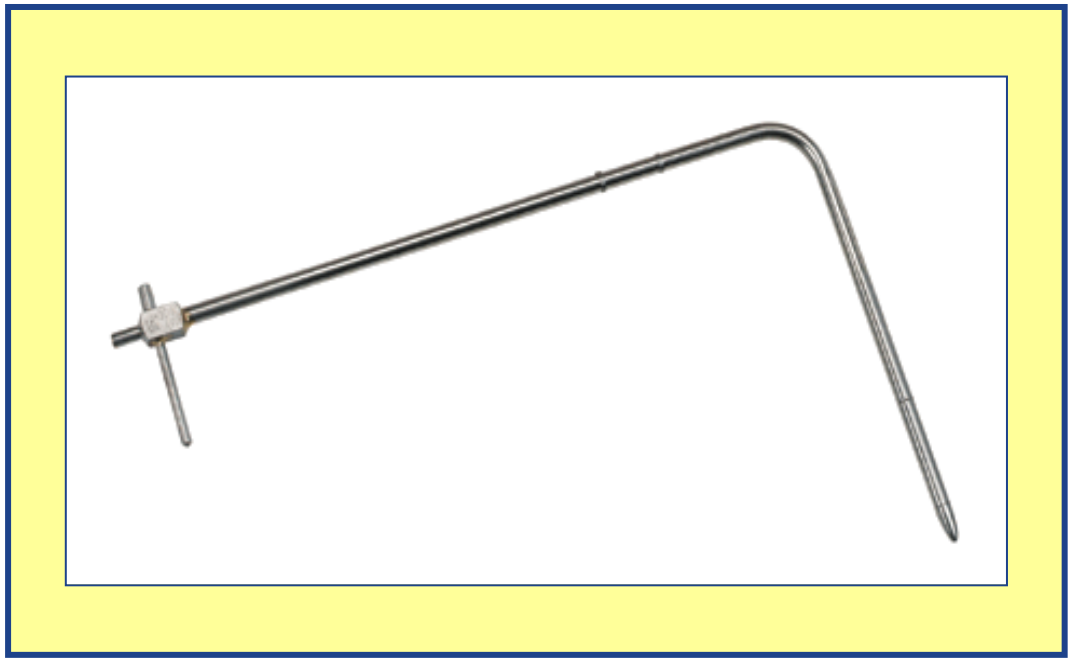
- Highly accurate, simple to use

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:

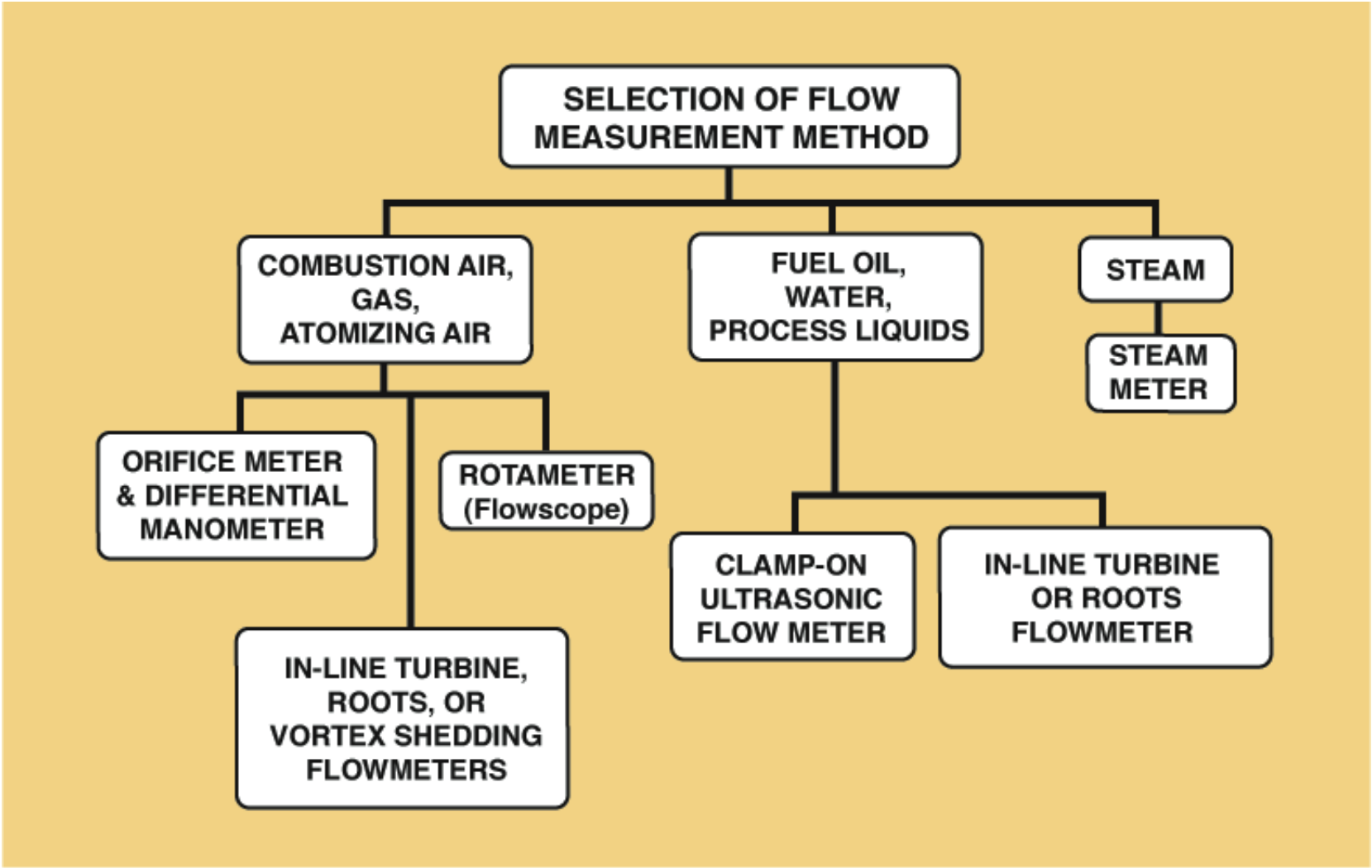
- More compact, easier to transport & handle than liquid manometer
- No filling or spilling of fluid
- No guessing at pressure readings

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.

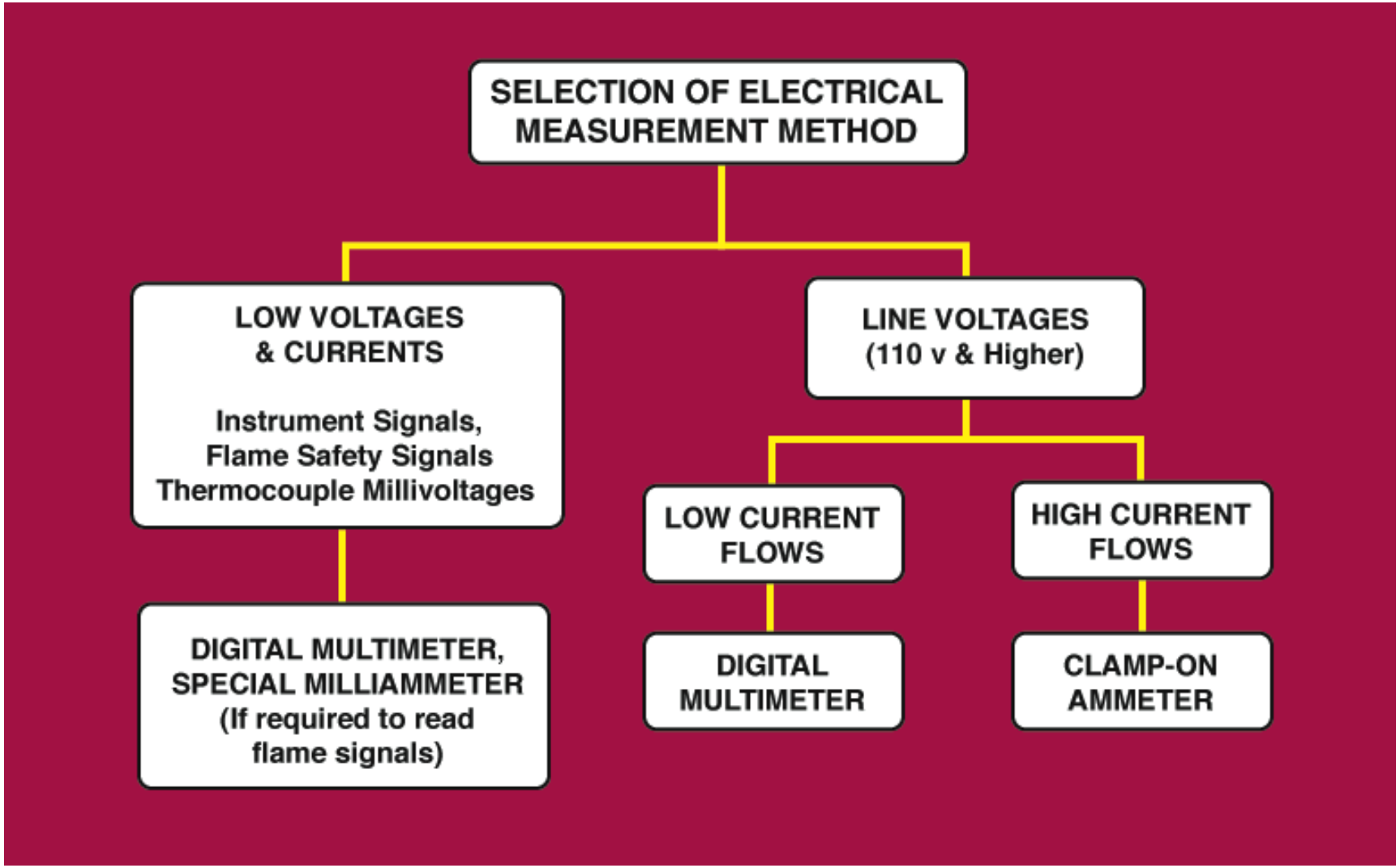
Advantages Compared to Orifice Meters:

- 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.

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- **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

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Optical Pyrometer Working Principle