Welcome to

Energy Production Systems Engineering

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USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC

Session 9: Instrumentation

Spring 2012

Session 9: Instrumentation

- **Instrumentation**

Instrumentation Systems

Instrumentation

Level
Gage Glasses – direct reading
Temperature difference – Density Difference
For given pressure at bottom tap,
Lower Temp fluid, more dense, lower level ind
Difficult to read, cloud over time
No remote indication (exception, wave guided xmtr)

Instrumentation

Simple – sight glasses

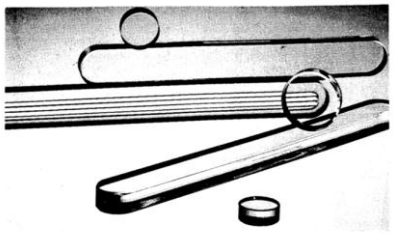


FIGURE 5.1.20 Gage glasses.

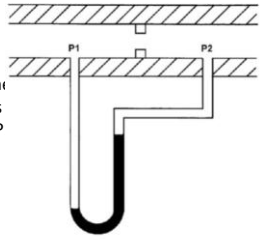
Instrumentation

Manometric Gages:
Compare reference head to measured head
Boiler drum level common app.
Slow response
Issue with Boiler Shrink / Swell

With load increase, steam flow increase, Increase in boiling, less dense water in tubes, initial swell in boiler drum level
Alternate is true with load decrease.

Instrumentation

A differential pressure manometer is installed across an orifice in a ventilation duct. With th ventilation conditions as shown, the pressure at P is greater than P2, and airflow is from left to right.



DIFFERENTIAL PRESSURE MANOMETER

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Instrumentation

Electronic Gages:
Water is conductive – conductivity probe
Discrete D/O

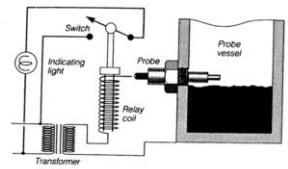

FIGURE 5.1.21 Conductivity measurement begins when water makes contact with probe. Electric circuits are completed, which energizes the level indicator light.

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Instrumentation

Liquid Level:
Dipstick
Gage Glass
Floats – Free vs.. Displacer
Free – stays out of liquid, movement measured
Displacer – stays in liquid, changes force on spring

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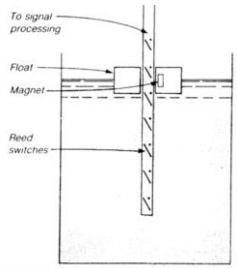

FIGURE 5.1.23 Free float.

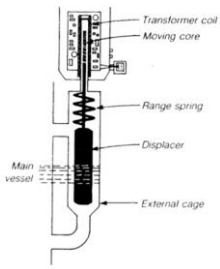

FIGURE 5.1.24 Displacer float.

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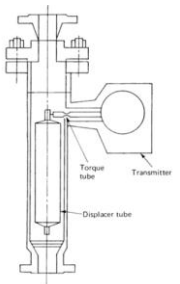

FIGURE 5.1.25 Displacer used for level measurement. (Courtesy J. A. Moore.)

Instrumentation

Liquid Level Detection

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Instrumentation

Liquid Level;
Probes – Digital output
Low Low, Low, High, High High typical
Pump or valve control common application

Hydraulic head P = pgh
H(inches) = P(psig) / SG * 27.678
Differential pressure for closed tanks
Gage for atmospheric tanks

LVDT – float detects position of float, moves core in winding (also used on valve position)

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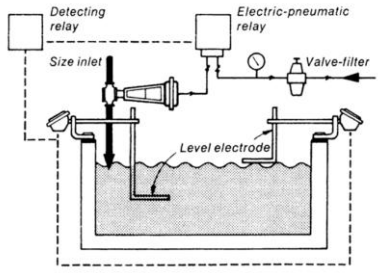

FIGURE 5.1.26 Electrode-type probes.

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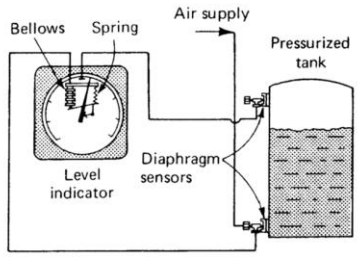

FIGURE 5.1.27 Diaphragm sensors detect hydraulic head to measure level.

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Non-contact level sensors
RF, Laser, Optic, Microwave, Ultrasonic

Radiation – Gamma source to detector.
Lead shielding required.

Ultrasonic – Liquid level echo ranging

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Instrumentation

Level Detection using Radiation

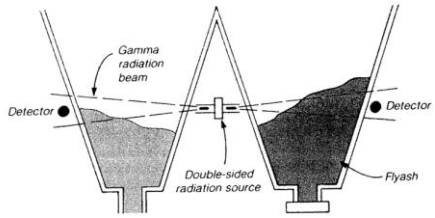

FIGURE 5.1.28 Radiation gage.

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Ultrasonic

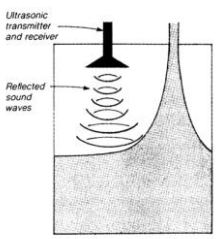

FIGURE 5.1.29 Ultrasonic meter.

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Instrumentation

Solids Level Measurement
Flyash, coal, limestone – irregular surface
Rotating paddle – stoppage of wheel indicates material
RF probes – sensing section / shield section
Microwave Probe (described before)
Ultrasonic (described before)

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Instrumentation

Fiber optic sensor:
Intrinsic – fiber performs measurement
Extrinsic – external transducer performs measurement
Non-electric, small, high capacity, multiplexing, non-intrusive

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Temperature –
Acoustic Pyrometer – sound waves to detect gas temperature – density changes cause change in speed of sound
Optical sensor – thermal radiation of light emitting device
O2 / CO monitoring – combustion control – air flow

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Example - A water storage tank is vented to atmosphere. The tank is located at sea level and contains 100,000 gallons of 80 °F water (specific gravity of 1.0). A pressure gauge at the bottom of the tank reads 10 psig. What is the approximate water level in the tank?

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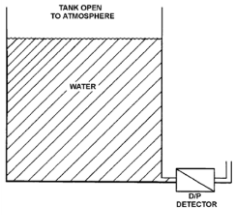
H(inches) = P(psig) / SG * 27.678

H = 276.78 inches (23 feet)



TANK DIFFERENTIAL PRESSURE LEVEL DETECTOR

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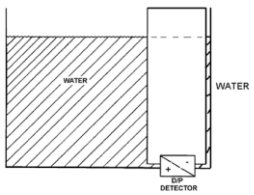
Instrumentation

Temperature - density



TANK DIFFERENTIAL PRESSURE LEVEL DETECTOR

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Combustion Control / Burner Management
Two main functions:
1)Maintain constant steam flow or pressure under varying load through proper input of fuel and air
2) To maintain safe and efficient operation throughout the boiler's load range

NFPA85 – Boiler and Combustion Systems hazards Code

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Three types of control schemes –
Series –
Steam pressure -> air flow -> fuel flow
Pickup Load quickly – reduce load slowly
Steam pressure -> fuel flow -> air flow
Pickup Load slowly – reduce load quickly
Good for constant BTU/lbm fuel
Parallel – steam pressure -> both air and fuel flow
Good for constant BTU/lbm fuel
Series –Parallel – steam pressure -> fuel flow
steam flow ->air flow
Good for varying BTU/lbm fuel (coal)

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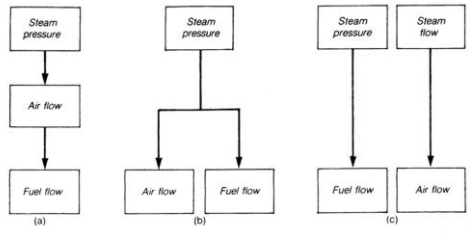

FIGURE 5.2.1 Combustion controls input fuel and air in (*a*) series, (*b*) parallel, or (*c*) series and parallel.

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Control Hardware:
On/Off – Fuel / Air flow on/off
Positioning systems – Simultaneous position of FD damper and fuel valve based on header pressure.
Metering System – measures fuel / air flow for combustion control. Feedback to ensure flow meets demand.
Steam Pressure – setpoint
Steam Flow Feed Forward signal for transient control.

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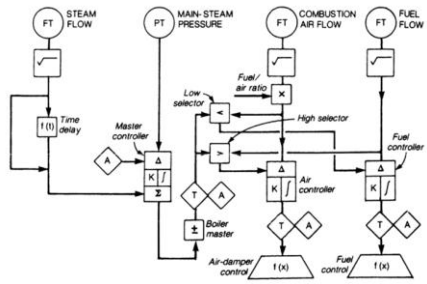

FIGURE 5.2.2 Metering control systems regulate combustion in accordance with fuel flow and airflow to maintain efficiency over a wide load range.

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Instrumentation

Instrumentation Symbols and Identification –
ISA 5.1 1984 (R1992)

A B C – 1 D

A = Measured or Initiating Variable (May have modifier)
B = Readout or Passive Function
C = Output Function (May have modifier)
1 = Loop number
D = Sequence letter

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Notes:
1.The functional ID of an instrument based on FUNCTION and not CONTRUCTION – therefore a differential pressure device to measure flow is a FE not a PE.
2.The functional ID of an instrument (first letter) is based on measured or initiating variable, not manipulated value. – therefore a valve to control of tank is an LV, not an FV.

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Instrumentation

	FIRST LETTER	(MODIFIER)	SECOND LETTER	THIRD LETTER	(MODIFIER)
A	Analysis		Alarm		
B	Burner Flame		User Choice	User Choice	User Choice
C	Conductivity			Control	
D	Density or S.G.	Differential			
E	Voltage		Primary Element		
F	Flow Rate	Ratio (Fraction)			
G	Gaging		Glass		
H	Hand				High
I	Current		Indicate		
J	Power	Scan			
K	Time			Control Station	
L	Level		Light (Pilot)		Low
M	Moisture (Humidity)				Middle (Intermediate
N	User Choice		User Choice	User Choice	User Choice
O	User Choice		Orifice (Restriction)		
P	Pressure (Vacuum)		Point (Test Connection)		
Q	Quantity (Event)	Integrate (Totalize)			
R	Radioactivity		Record (Print)		
S	Speed (Frequency)	Safety		Switch	
T	Temperature			Transmit	
U	Multivariable		Multifunction	Multifunction	Multifunction
V	Viscosity			Valve, Damper, Louver	
W	Weight (Force)		Well		
X	Unclassified		Unclassified	Unclassified	Unclassified
Y	User Choice			Relay (Compute)	
Z	Position			Drive, Actuate, Unclass Final Ctrl Ele	

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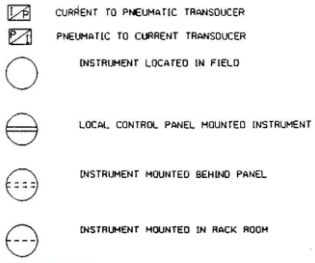
Standard Symbols

Instrumentation



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Standard Symbols

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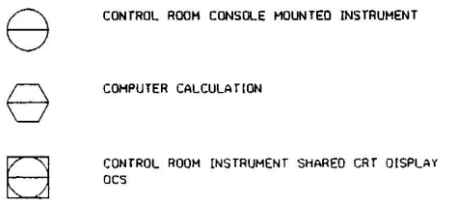

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Standard Symbols

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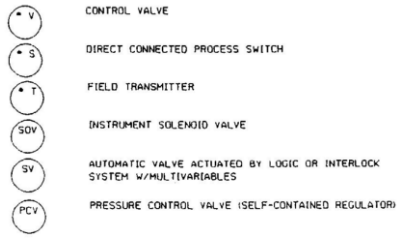

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Standard Symbols

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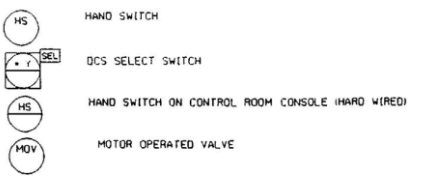

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Standard Symbols

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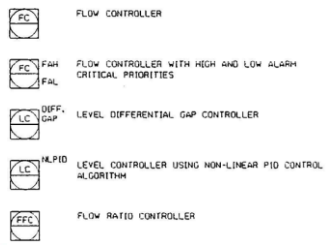

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Standard Symbols

Instrumentation

LINE SYMBOLS

- PRIMARY PROCESS LINE
- SECONDARY PROCESS OR UTILITY LINE
- INSTRUMENT PNEUMATIC LINE
- FLEXIBLE HOSE
- INSTRUMENT CAPILLARY TUBING
- HYDRAULIC SIGNAL
- ELECTRICAL SIGNAL
- INTERNAL SIGNAL (SOFTWARE OR DATA LINK)

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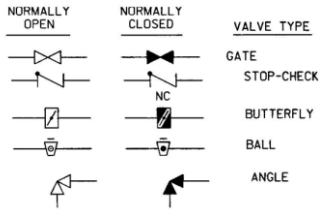
Standard Symbols

Instrumentation



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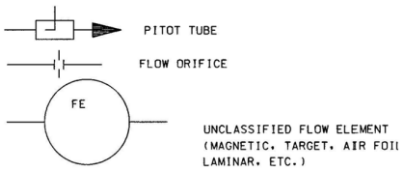

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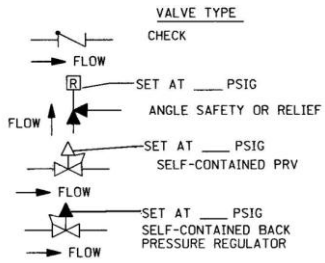

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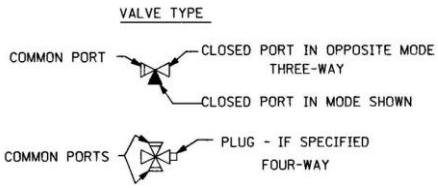

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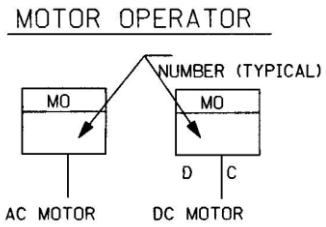

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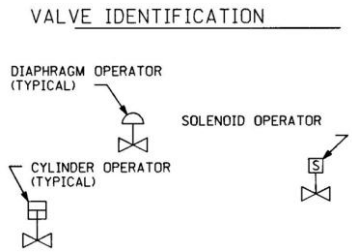

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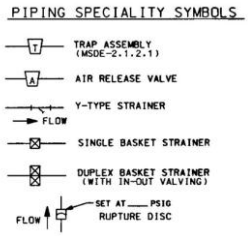

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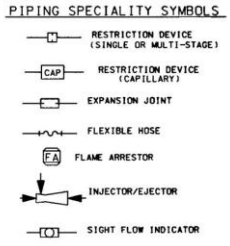

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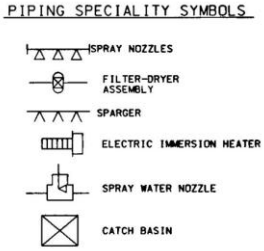

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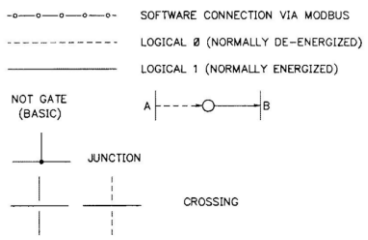

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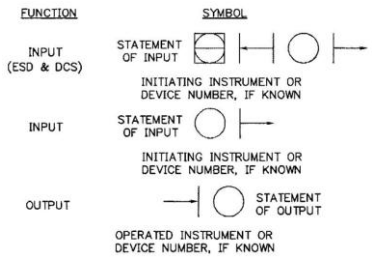

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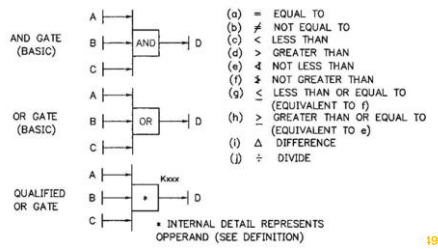

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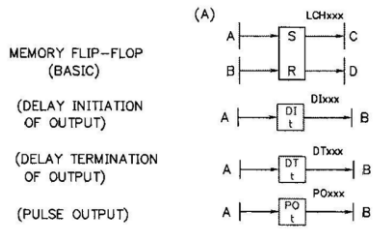

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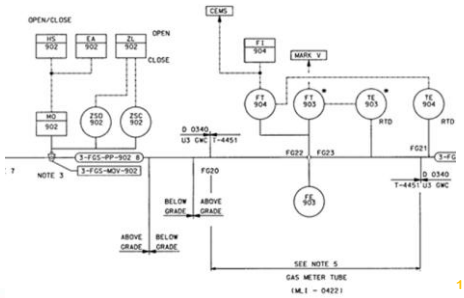

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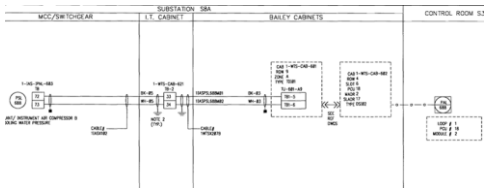
Instrumentation

Instrument Loop Diagram



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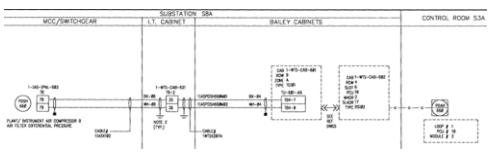
Instrument Loop Diagram



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Instrumentation

Optimizing Combustion –
Excess air ensure complete combustion
Adds mass flow – loss of energy
Operate at area of maximum efficiency

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Instrumentation

Optimizing Combustion

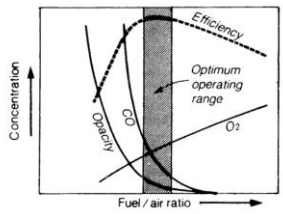

FIGURE 5.2.3 The optimum operating point falls to the air-rich side of the efficiency curve, depending on the boiler, control system, and fuel.

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Instrumentation

O2 and CO are common monitoring gases to determine excess air –
CO unaffected by air infiltration
CO narrow range of operation
CO independent of fuel type

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Instrumentation

CO better indicator than excess air

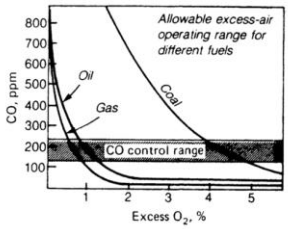

FIGURE 5.2.4 Excess-air operating point varies for different fuels, whereas CO set point is always at the knee or break point in curve.

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Instrumentation

Burner Management – Provides for safe startup, operation, and shutdown of the fuel supply system to a boiler. Consists of following systems
-Prefire Purge - purge air in boiler of combustibles before light off
-Ignition – Permissive, Ignition time trial, flame verification
-Main Fuel – permissive, startup, operation, shutdown
-MFT – Trip boiler fuel system when unsafe
-Postfiring purge – purge air in boiler after shutdown to remove combustibles.

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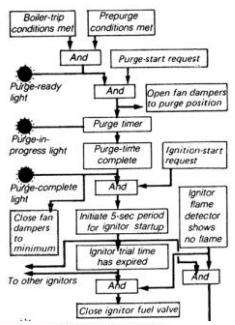

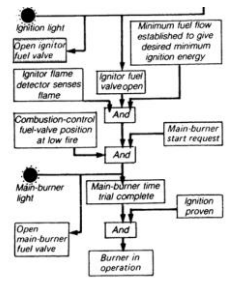

FIGURE 5.2.5 Interlock diagram for a unit start-u shows complexity of the prepurge, pure, prelight, an light-off phases.

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Instrumentation

NFPA 85 section application

8501 Single Burner Boiler Operation
8502 Multiple Burner Boiler-Furnaces
8503 Pulverized Fuel Systems
8504 Atmospheric Fluidized-Bed Boiler Operation
8505 Stoker Operation
8506 Heat Recovery Steam Generator Systems

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Instrumentation

Flame Monitoring –
Wall Fired units – individual monitor (one igniter & one main burner)
Tangential fired – Tilting burner, on startup, monitor individual burners, monitor main flame (about 30% load)
Ionic flame rod – monitor conductivity to detect flame
Optic sensor – monitor for IR (coal) or UV(gas) radiation

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Instrumentation

Governors – control operating parameters of prime movers (speed on islanding, power when synched)

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Instrumentation

Machine Control

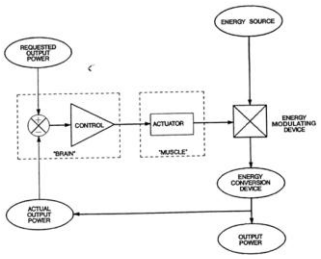

FIGURE 5.3.1 Energy-modulating device.

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Instrumentation

Governors – control operating parameters of prime movers (speed on islanding, power when synched)

Transient Operation –
1.Change of load torque
2.Change of speed (Lag)
3.Change in governor output
4.Change in modulating device
5.Change in Developed Torque (Lag)
6.Change in speed (go to item 3)

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Instrumentation

Lag between prime mover and control system

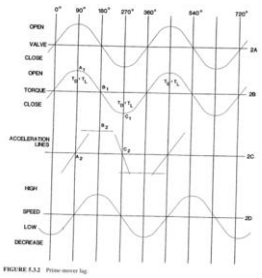

FIGURE 5.3.2 Prime-mover lag.

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As speed increases, valve shuts

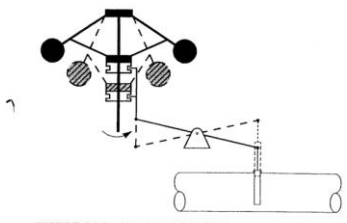

FIGURE 5.3.3 Principle of flyweights.

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Instrumentation

As speed increases, pilot valve raises and dumps oil from power piston, reducing fuel

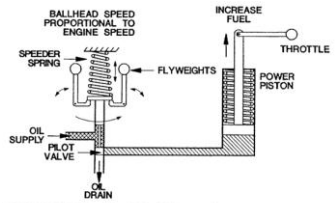

FIGURE 5.3.4 Traditional flyweight controller.

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Instrumentation

Key Systems & Components
Sensors – field interface with process variable
Transducers resolve sensor output to level used by control system
(Sensor + Transducer = Transmitter)
Pneumatic Signals – convert process variable – mechanical motion – pneumatic signal
Electric Signals (analog) – low maintenance – zero / span
2 wire vs.. 4 wire design

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Instrumentation

Smart Transmitter – transmit signal to control system
Note Manifold with isolation and equalizing valve.

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Instrumentation

Electric Signals (Digital) – Dry vs. wetted
Pulse (totalizer – i.e. KWH, fuel flow)
Smart Transmitters – Communication – Linearization, diagnostics, multiple process variable input
Final Control Device – pneumatically or motor driven
Pneumatic positioner (piston operators)
I/P converter (feedback P/I converter)
Fail open, Fail closed, Fail in place

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Instrumentation

Valve Positioner – Device that takes feedback from valve stem and modified signal to actuator to move valve to required position

Valve Actuator – Cylinder on valve stem provides force to move valve

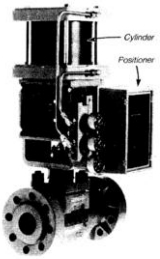

FIGURE 5.4.2 Piston operator.

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Instrumentation

Electric Drives (Positioners) (MOV)
4-20 mA signal to position valve
Fail in place on loss of power.

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Instrumentation

Control Systems & Feedback

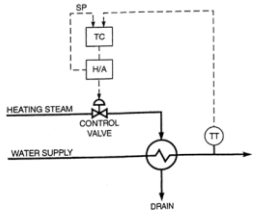

Fig. 18-2. Modulating (closed loop) control. SP = set point; TC = temperature controller; TT = temperature transmitter; H/A = hand/auto control station; controlled variable—water temperature measured by TT; manipulated variable—heating steam flow; final control element—heating steam control valve.

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Instrumentation

Proportional Control

$$P = (K_p)E$$

where

P = output

E = error (set point deviation), and

K_p = proportional gain.

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Instrumentation

Integral (reset) control

$$dP/dt = (1/T_i)E$$

where

T_i = integral (or reset) time.

$$p = (1/T_i)\int E\,dt$$

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Derivative control

$$P = (T_d)dE/dt$$

where

T_d = rate (or derivative) time.

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Instrumentation

Pre 80's Field instrumentation sent to control room bench board.
Post 80's, more common Distributed Control System (DCS)
Additionally Stand alone controllers
Typical functions PID

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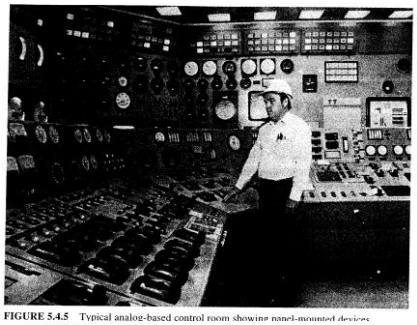

FIGURE 5.4.5 Typical analog-based control room showing panel-mounted devices

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Instrumentation

Modern DCS

FIGURE 5.4.7 Modern control room with DCS operator's console.

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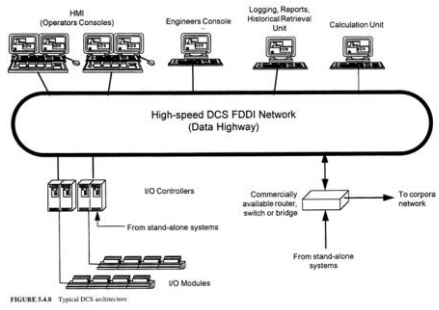

FIGURE 5.4.8 Typical DCS architecture.

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Instrumentation

HMI – Operators console (process view)
Engineering Work Stations – (logic view)
Redundancy – loop, power supplies, microprocessors
Multiple functions

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Instrumentation

Display Convention –
Typical Color Convention for Back Background

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TABLE 5.5.2 Color Convention for Black Background[a]

Color	Use
Black	Display background, auto/manual background
Magenta	Reserved color for target icons used for control stations, windows, trends, and display links
Light green	Text, tag names, engineering units Status: off, not running, open circuit, closed motor-operated valve (MOV)
Bright green	Data: normal data
Light green (flashing)	Status: circuit breaker tripped
Light orange	Status: remote control, MOV traveling Data: intermediate high-low limit (no alarm)
Light red	Status: on, running, closed circuit, open MOV, permissive satisfied Data: high or low alarm (acknowledged)
Bright red (flashing)	Data: high or low alarm (unacknowledged)
Bright orange	Status: permissive not satisfied Data: bad data
White	Data: manually fixed data
Cyan	Symbol building
Most blues	Symbol building, selected bar chart background, flow path, fluid paths

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Instrumentation

Valve Position colors

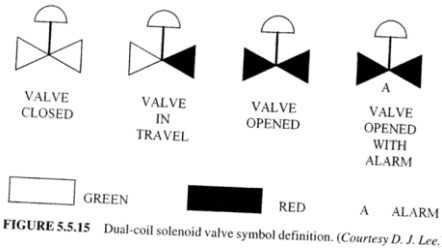

FIGURE 5.5.15 Dual-coil solenoid valve symbol definition. (*Courtesy D. J. Lee.*)

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Instrumentation

Alarm Management

TABLE 5.5.1 Automatic Rest Alarm Sequence

Process condition	Sequence state	Visual display (light)	Audible state
Normal	Normal	Off	Silent
Abnormal	Alarm	Flashing	Audible
Abnormal	Acknowledge	On	Silent
Normal	Acknowledge	Off	Silent
Normal again	Normal	Off	Silent

Source: International Society for Measurement and Control.[1]

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Instrumentation

Typical Display

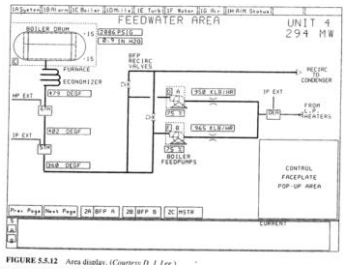

FIGURE 5.5.12 Area display. (Courtesy D. J. Lee.)

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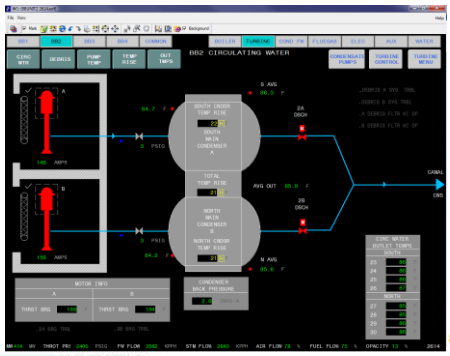

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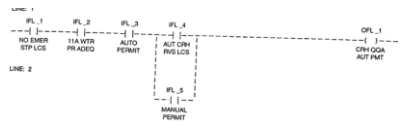
Instrumentation

Furnace Draft Control – Ladder Logic



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Control Logic

Instrumentation

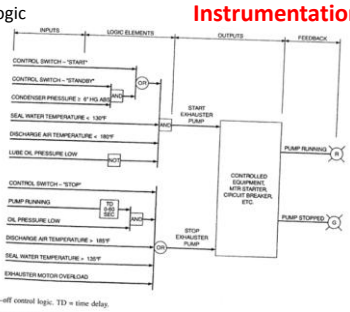

Fig. 18-1. Basic on–off control logic. TD = time delay.

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End of Instrumentation Systems

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End of Session 9: Instrumentation

Spring 2012