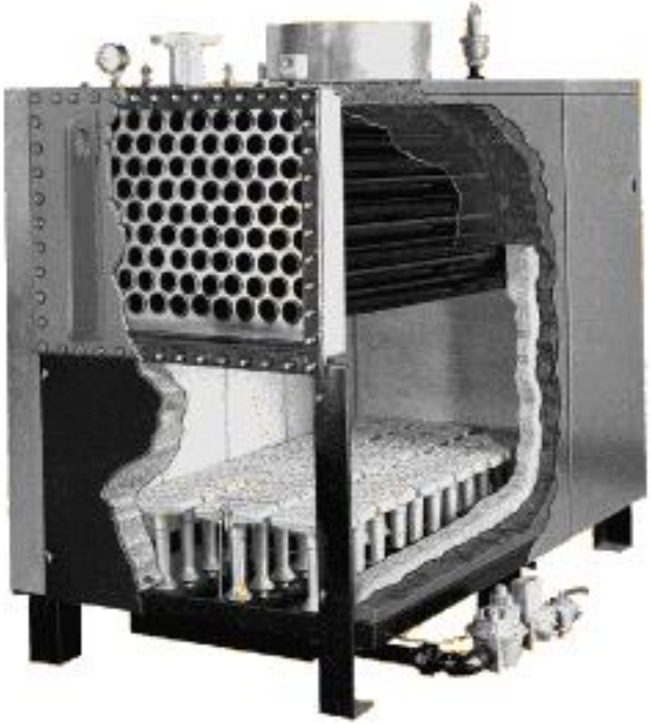
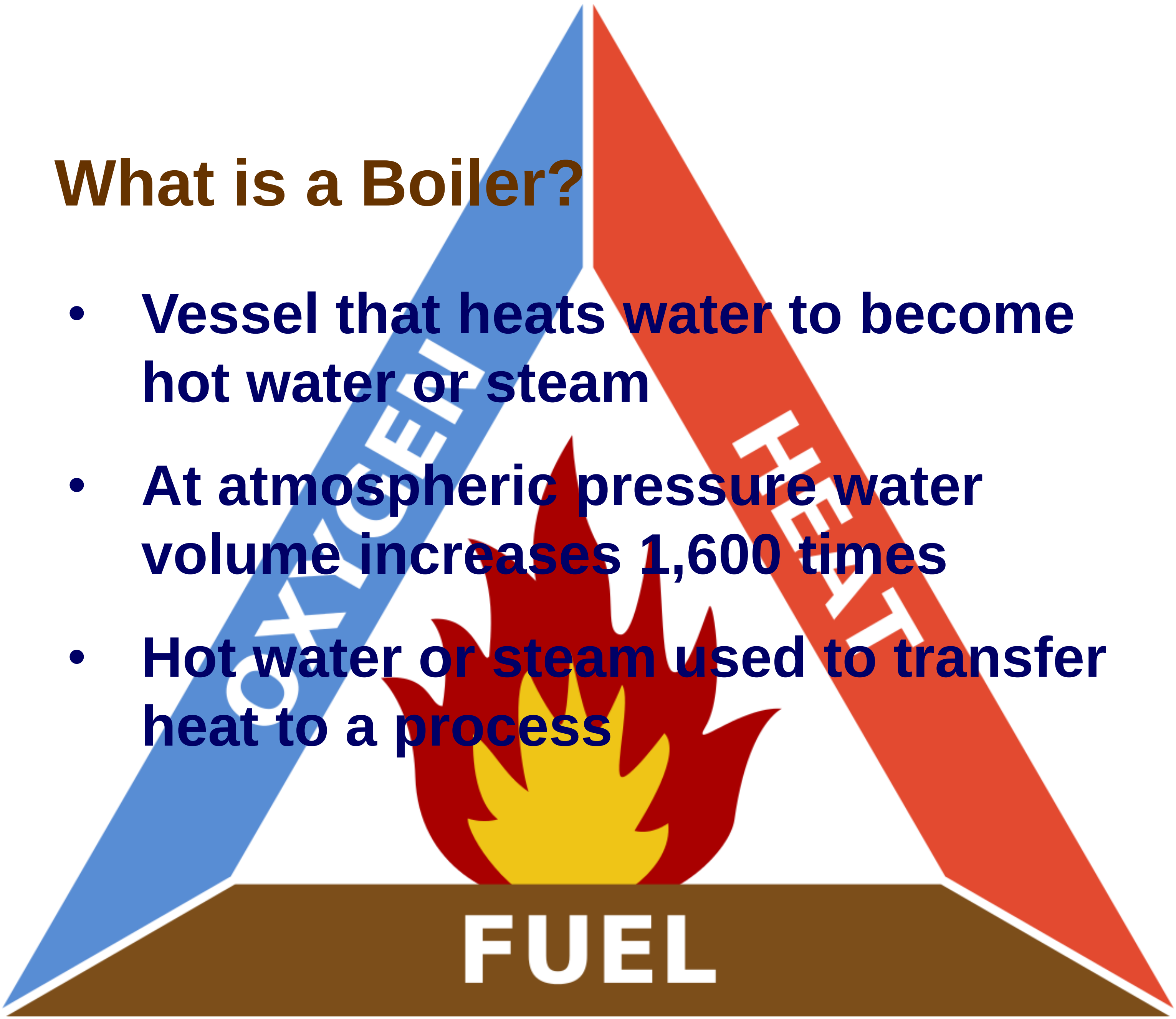
Boilers

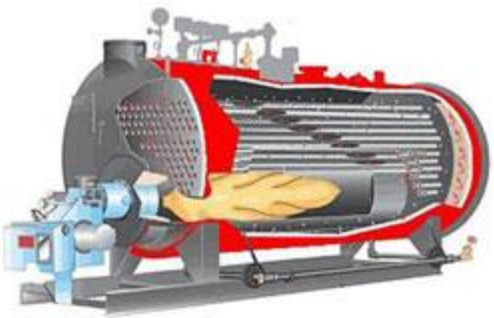
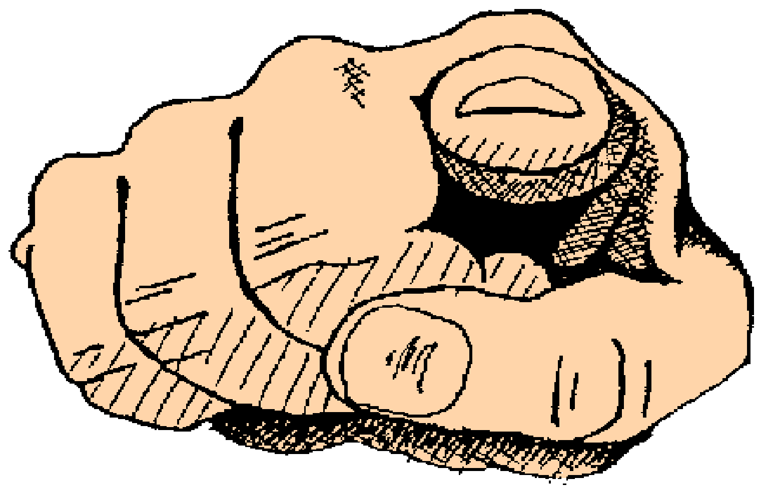



What is a Boiler?

- Vessel that heats water to become hot water or steam
- At atmospheric pressure water volume increases 1,600 times
- Hot water or steam used to transfer heat to a process



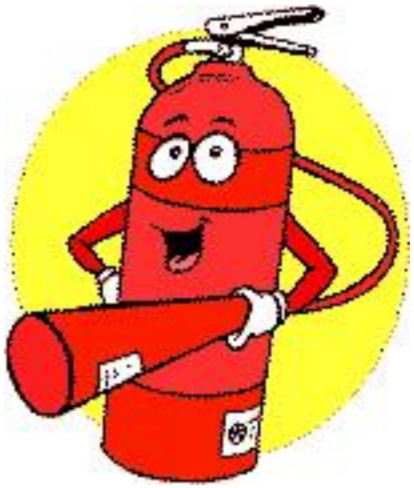
What would you

like to get out of the class?

Boiler Safety !

- Heat – “Ouch that’s HOT !”
- Fuel / Gas
- Electricity
- Exhaust Gas
- Moving Parts

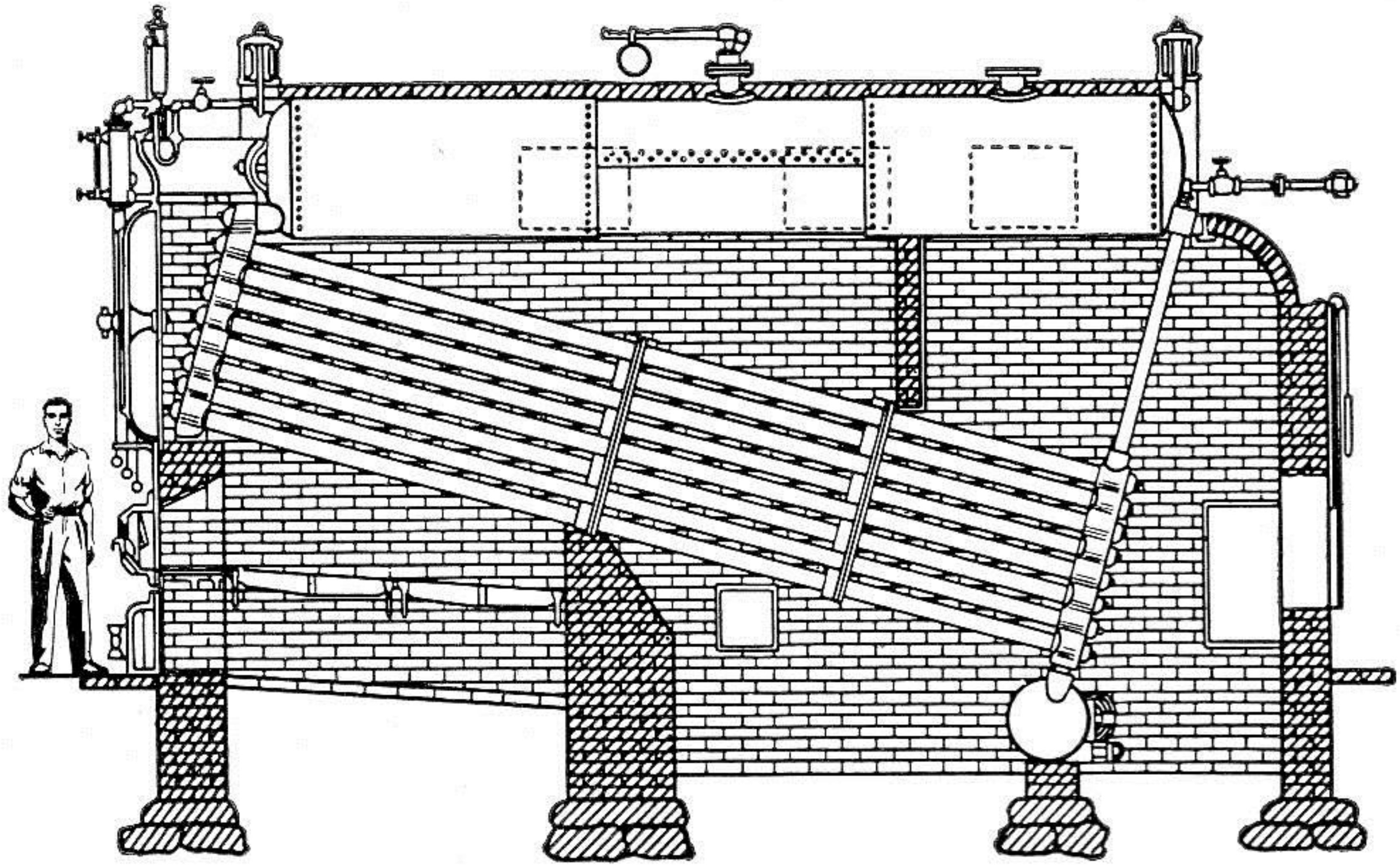


BOILER EXPLOSION AT BEAVER MILLS, KEENE, N. H., MAY 22, [illegible]
Photo includes Milan Cory, night fireman and Milan Johnson, foreman of Cheshire Chair Co. which occupied one of the buildings. Two men were killed in the explosion.

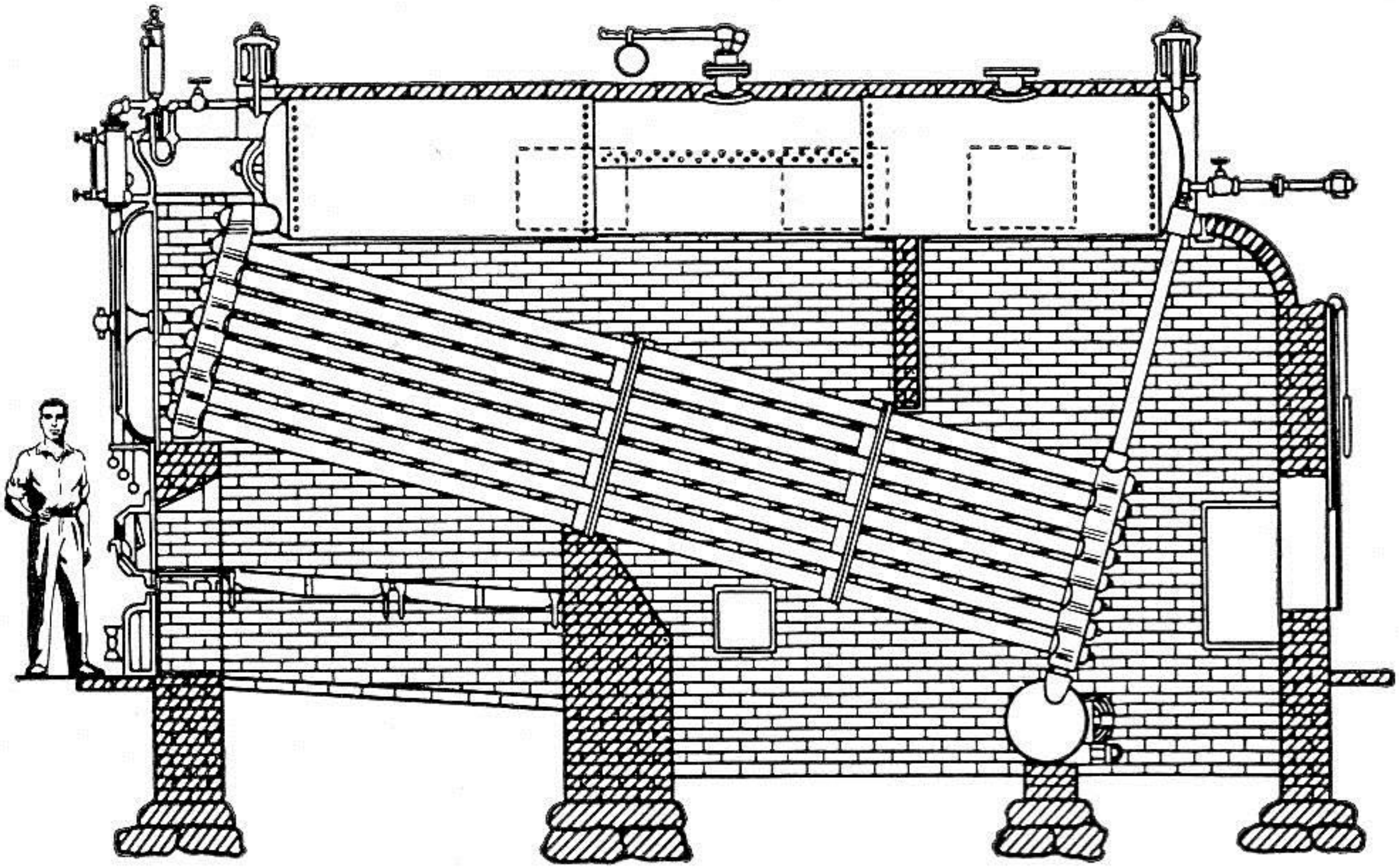
Boilers

Boilers used from 1891 to 1901 were Horizontal Return Tube [HRT] Boiler

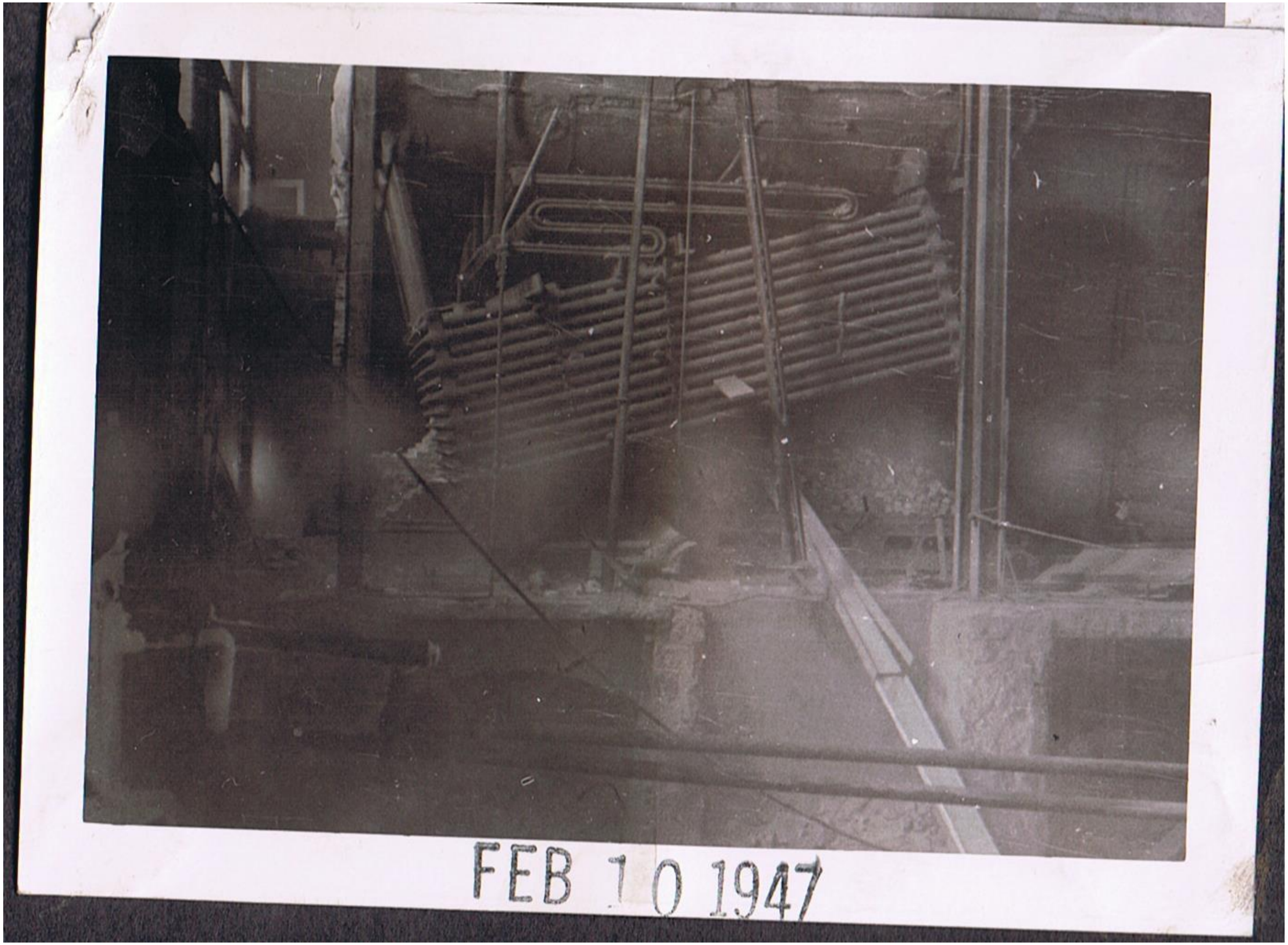
Boiler
for 1902 plant



Babcock & Wilcox Straight Tube Boiler

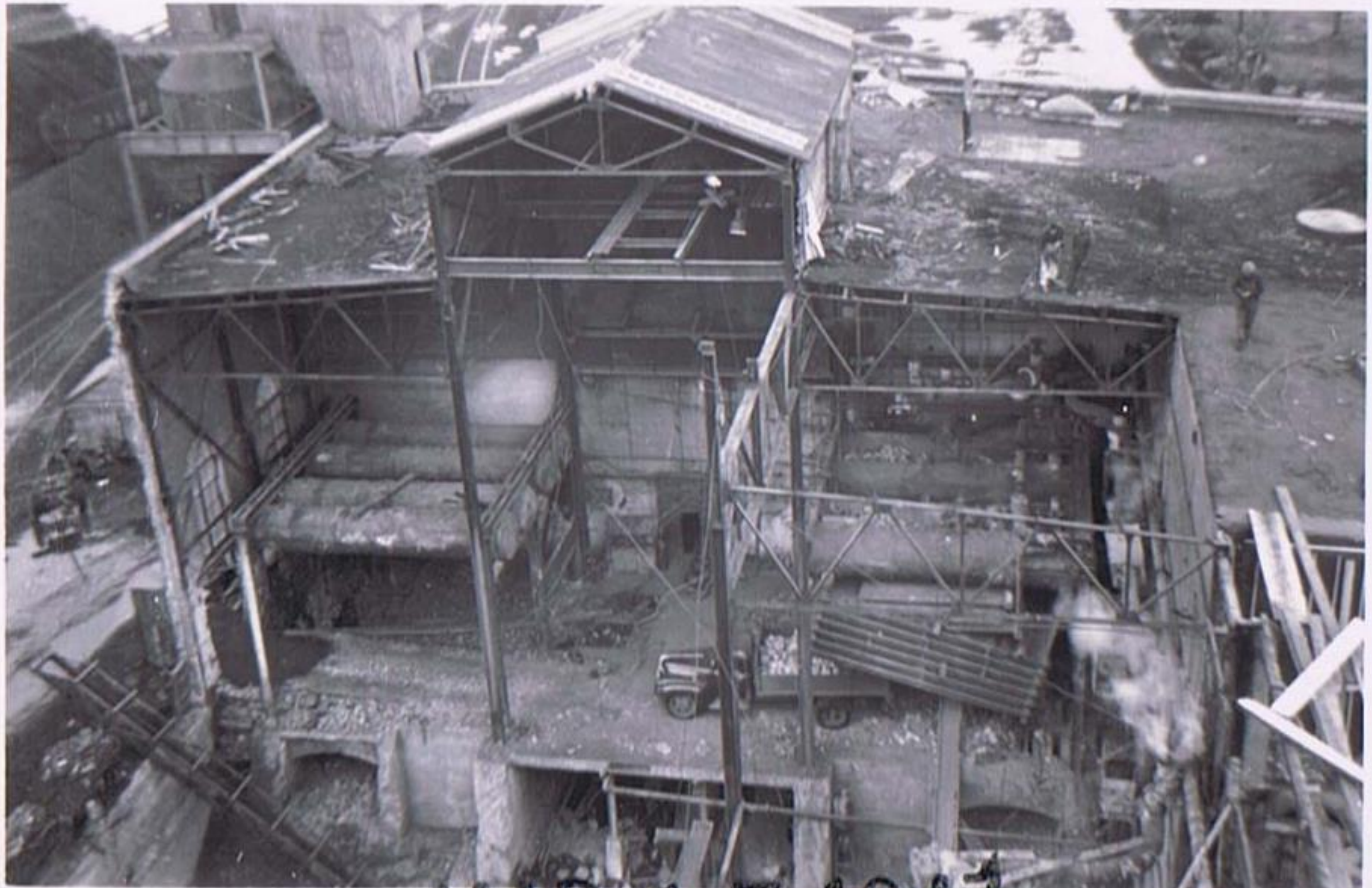


Rossdale had 16 of these boiler installed between 1908 & 1914



1914 Boiler room

B & W straight tube boilers

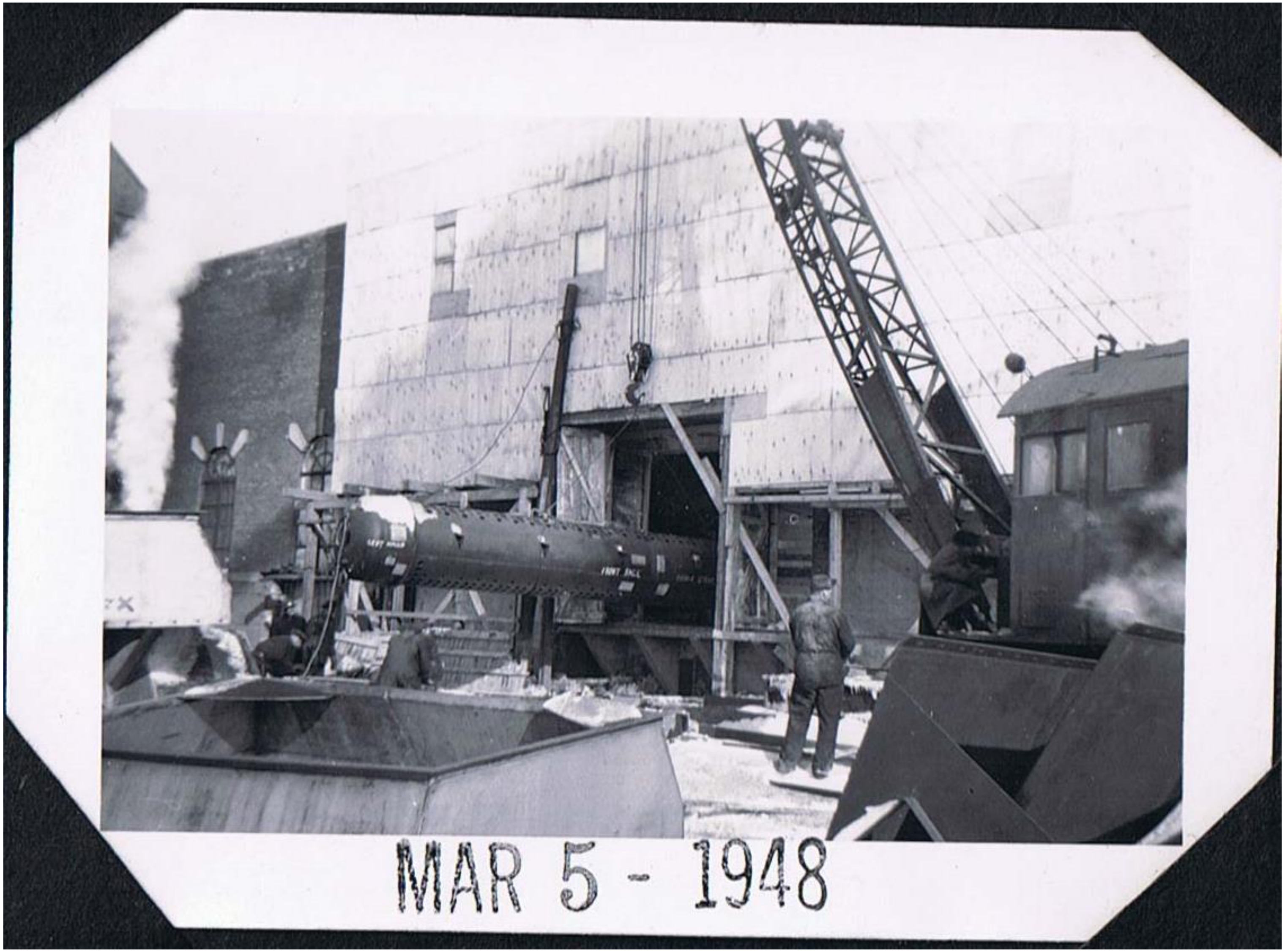


Boiler room MAR 17 1947

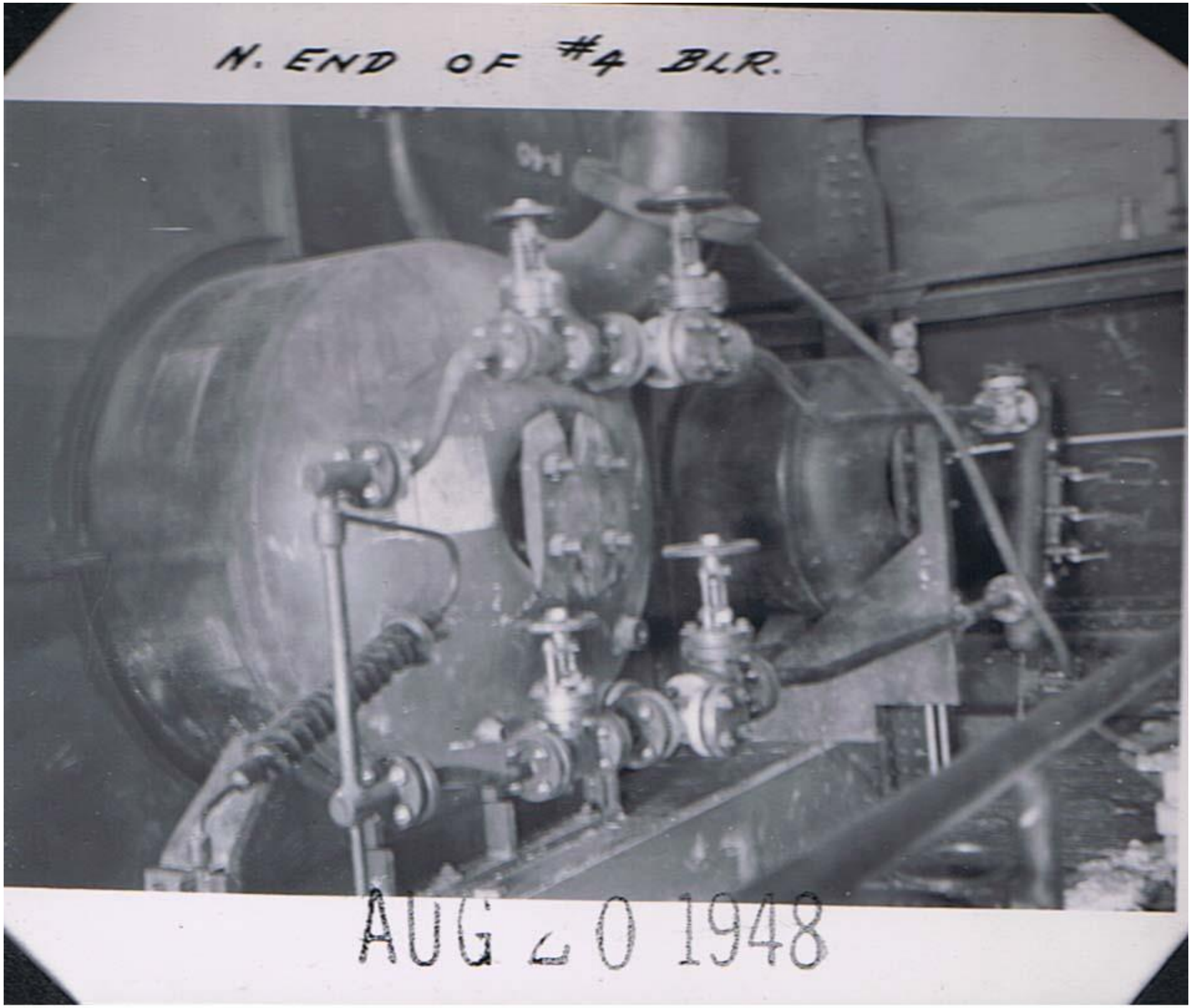
1914 Boiler room

B & W straight tube boilers

Crane lifting Boiler Drum



Crane lifting Boiler Drum



4 Boiler Steam Drums

The Classifications

- Pressures and temperatures
- Heat Exchanger Type
- Fuel
- Materials
- Draft Type
- Burner Type
- Chamber Type

Boiler Types and Classifications

- Water flow through tubes
- Water Tubes surrounded by hot gas

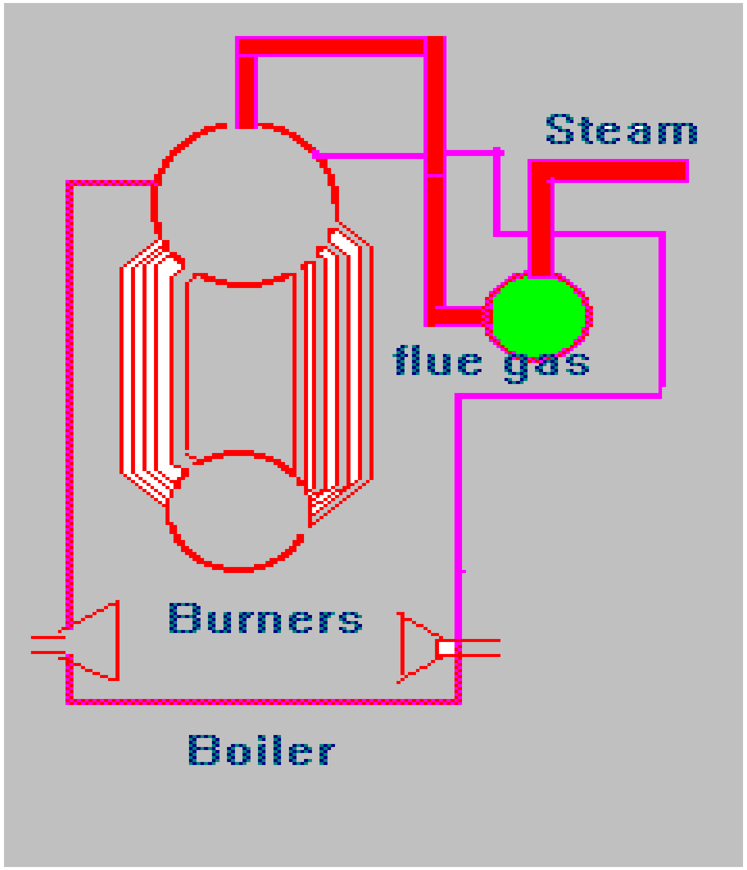
Application

- Used for Power Plants
- Steam capacities range from 4.5- 120 t/hr

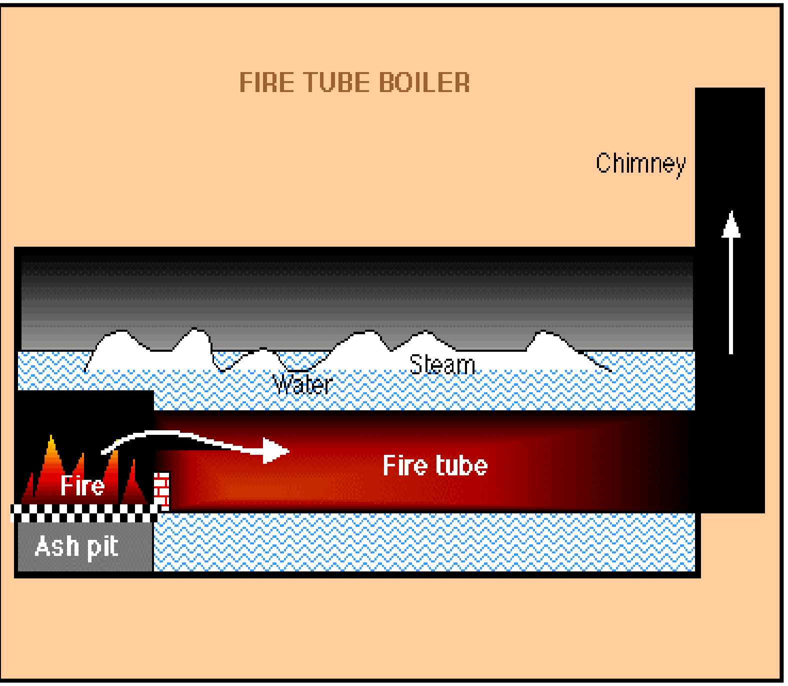
Characteristics

- High Capital Cost
- Used for high pressure high capacity steam boiler
- Demands more controls
- Calls for very stringent water quality

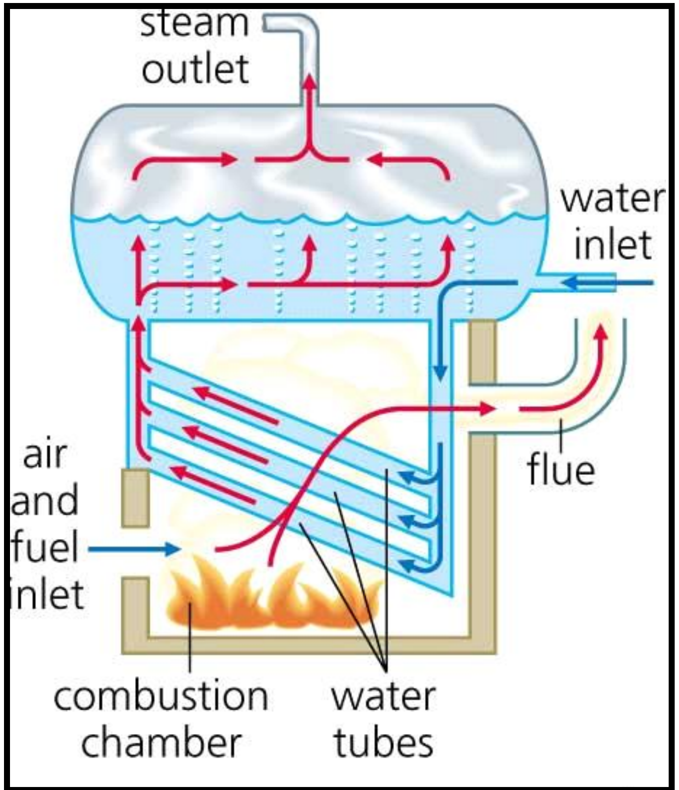
Water Tube Boiler



1. Fire Tube Boiler



2. Water Tube Boiler



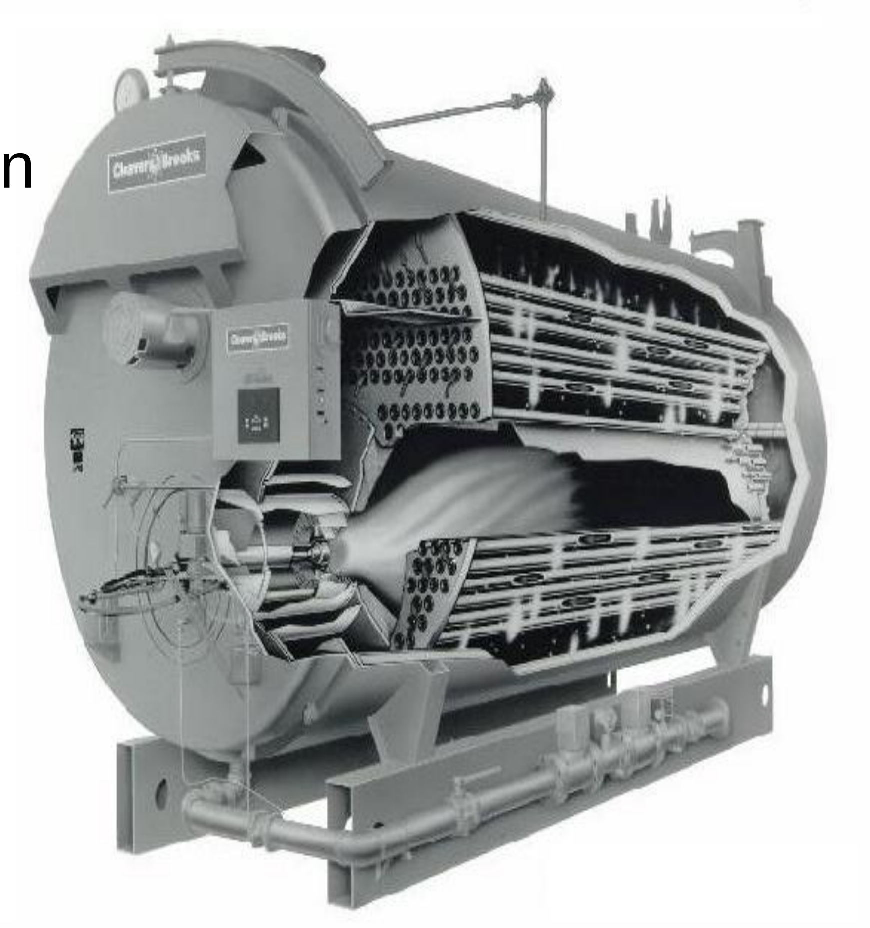
Packaged Boiler

- Package boilers are generally of shell type with **fire tube design**
- High heat release rate in small combustion space

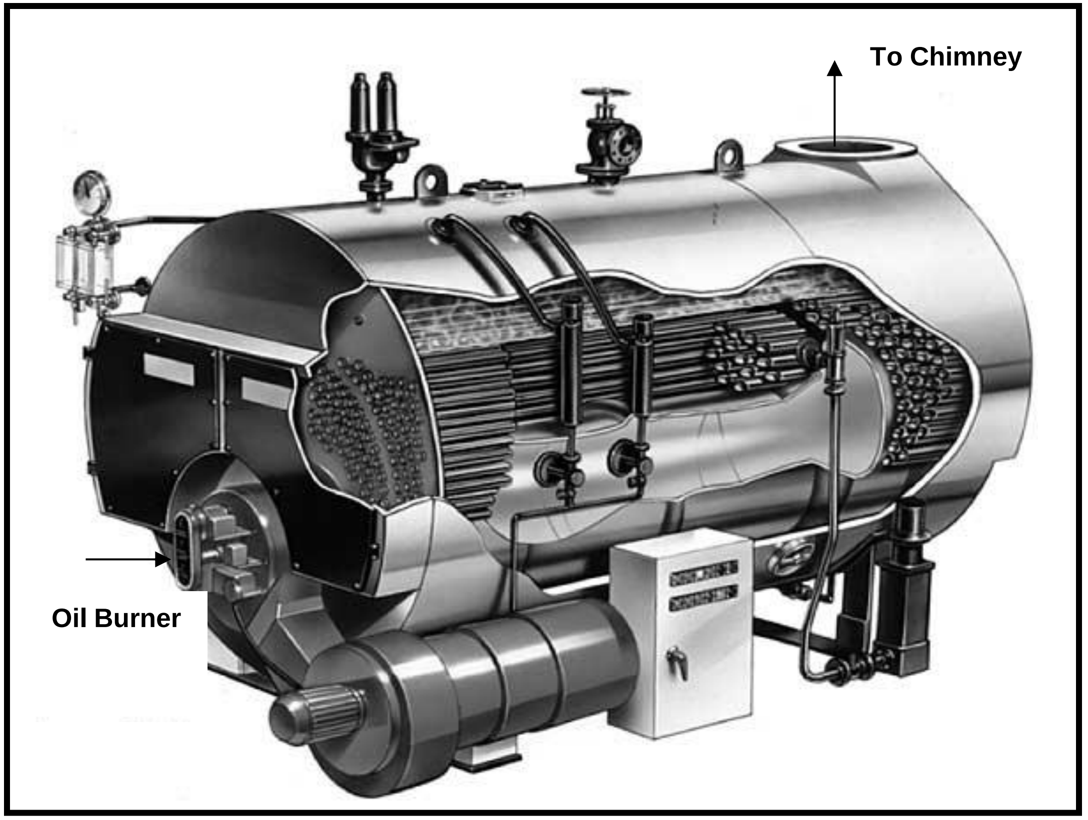
✓ More number of passes-so more heat transfer

✓ Large number of small diameter tubes leading to good convective heat transfer.

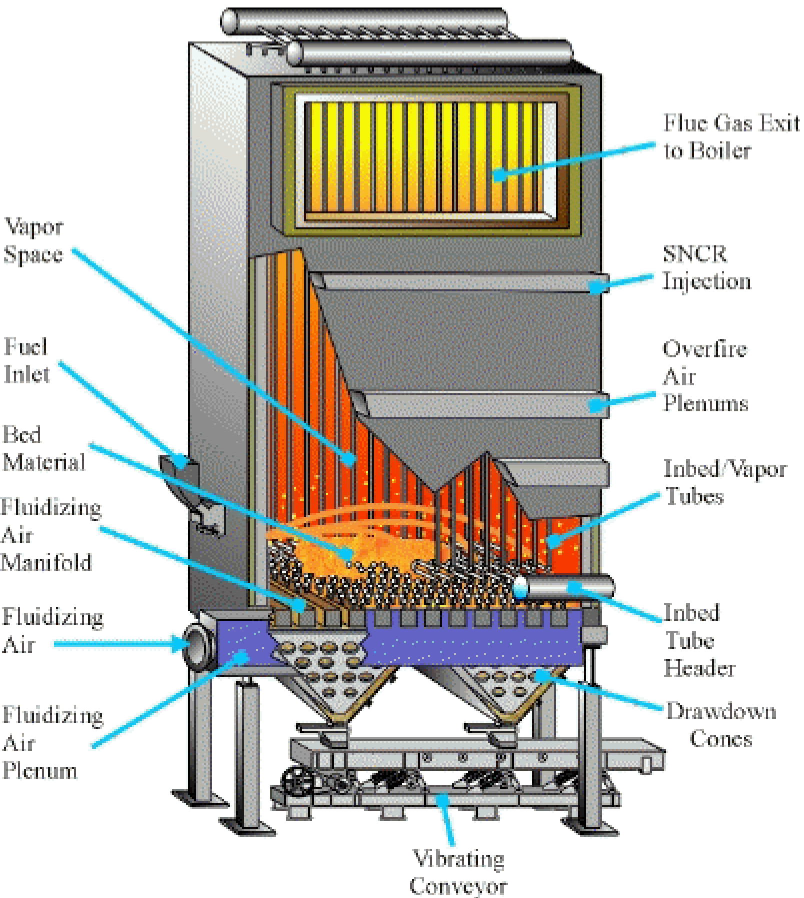
✓ Higher thermal efficiency

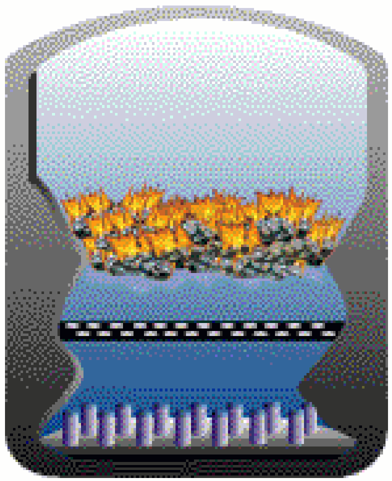


3. Packaged Boiler



4. Fluidized Bed Combustion (FBC) Boiler



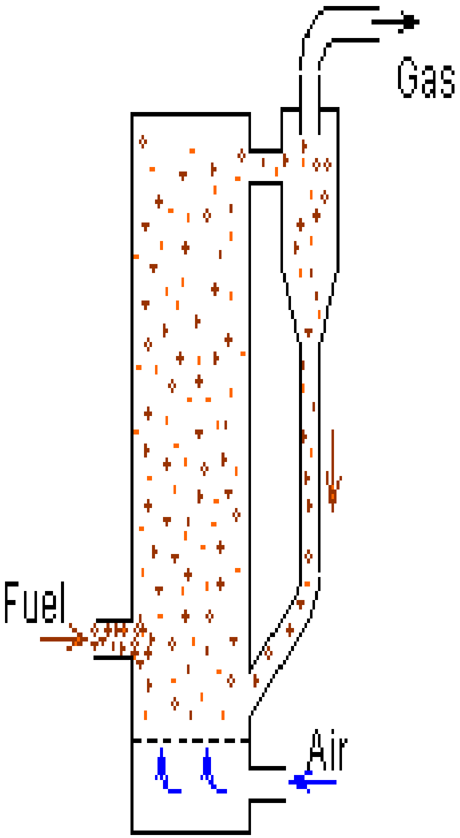


- Suspend solid fuels on upward-blowing jets of air during the combustion process

Fluidized-bed boiler (Contd..)

Advantages :

- Higher rates of heat transfer between combustion process and boiler tubes (thus reduced furnace area and size required),
- combustion temperature 850^{o}C is lower than in a conventional furnace. The lower furnace temperatures means reduced NO_x production.
- In addition, the limestone ($CaCO_3$) and dolomite ($MgCO_3$) react with SO_2 to form calcium and magnesium sulfides, respectively, solids which do not escape up the stack; This means the plant can easily use high sulfur coal.
- Fuel Flexibility: Multi fuel firing



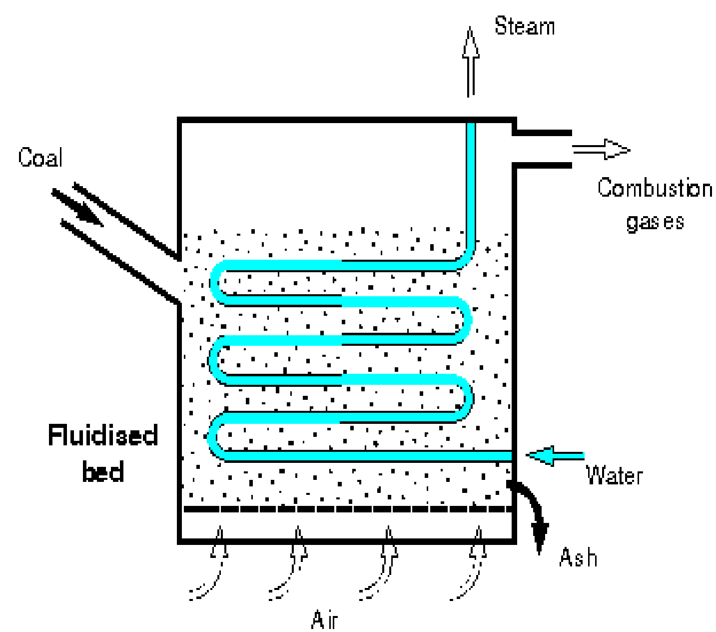
Circulating Fluidized Bed Boiler

Fluidized bed Combustion (FBC) boiler

When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles are undisturbed at low velocity. As air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream

Further, increase in velocity gives rise to bubble formation, vigorous turbulence and rapid mixing and the bed is said to be fluidized.

Coal is fed continuously in to a hot air agitated refractory sand bed, the coal will burn rapidly and the bed attains a uniform temperature



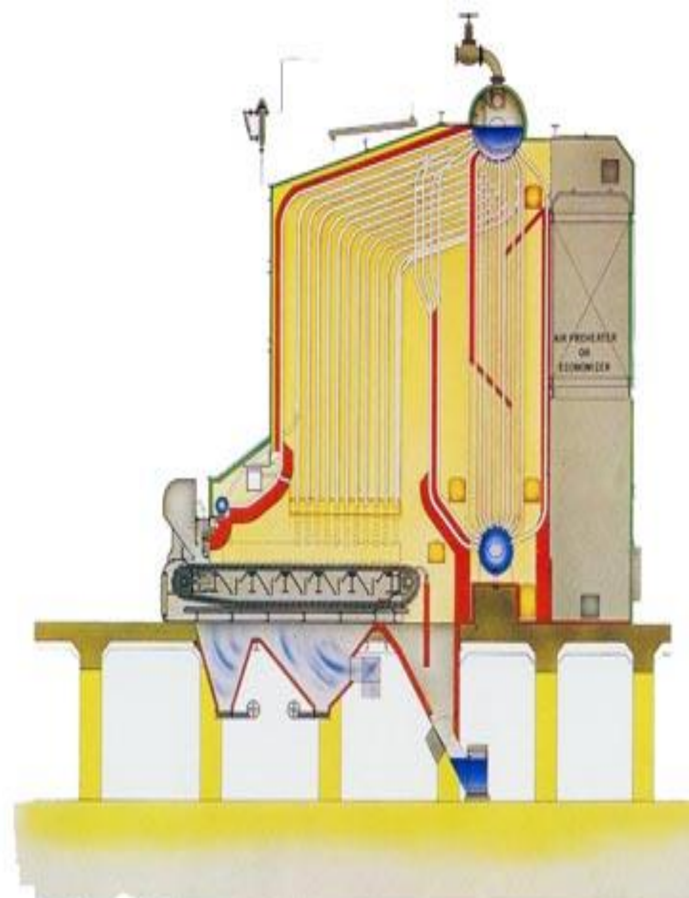
Fluidized Bed Combustion

Stoke Fired Boilers

Coal is first burnt in suspension then in coal bed
Flexibility to meet load fluctuations
Favored in many industrial applications

Chain Grate or Traveling Grate Stoker Boiler

- ✓ Coal is fed on one end of a moving steel chain grate
- ✓ Coal burns and ash drops off at end
- ✓ Coal grate controls rate of coal feed into furnace by controlling the thickness of the fuel bed.
- ✓ Coal must be uniform in size as large lumps will not burn out completely
- ✓ Bed thickness decreases from coal feed end to rear end and so more air at front and less air at rear end to be supplied
- ✓ Water tube boiler



6. Pulverized Fuel Boiler

- **Pulverized coal powder blown with combustion air into boiler through burner nozzles**
- **Combustion temperature at 1300 - 1700 °C**
- **Benefits: varying coal quality coal, quick response to load changes and high pre-heat air temperatures**

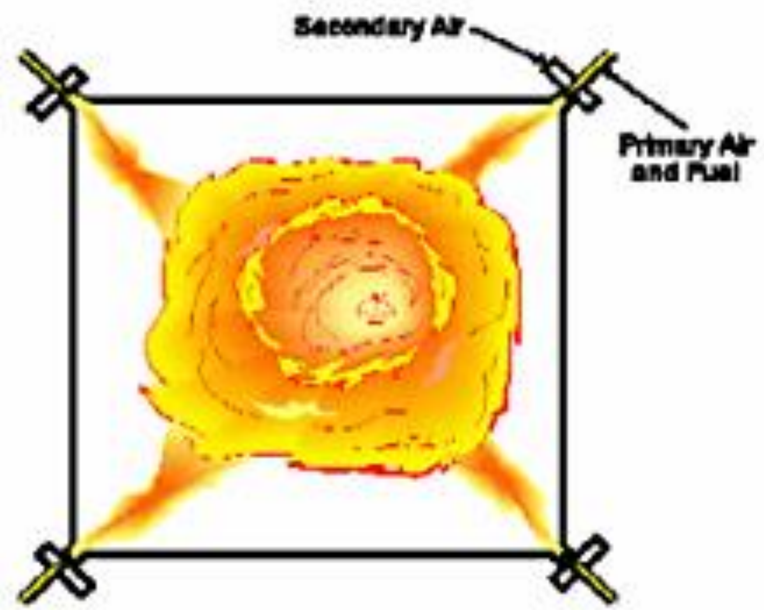


Fig: Tangential Firing for Pulverized Fuel

Pulverized Fuel Boiler (Contd..)

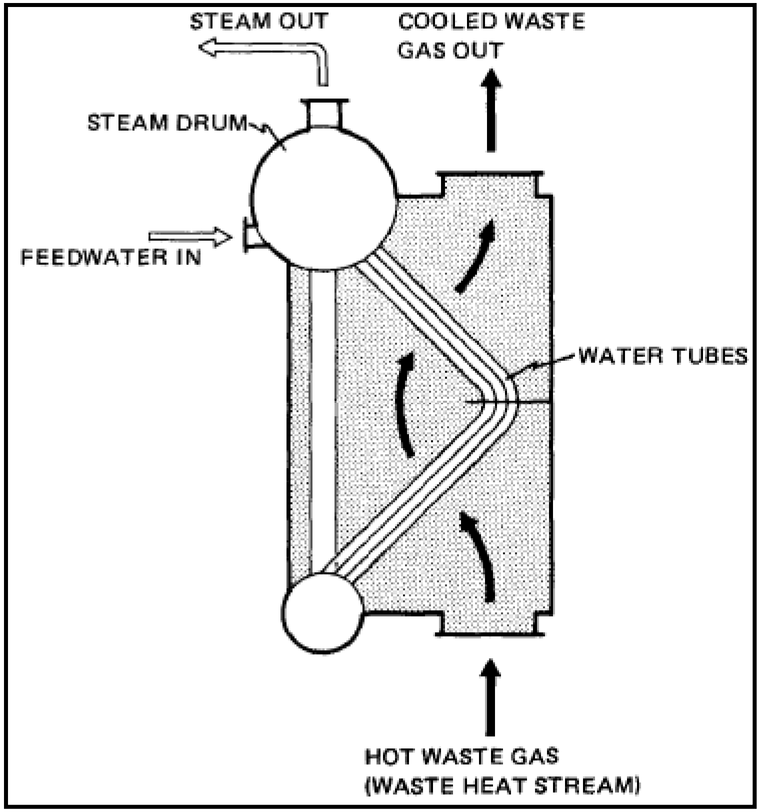
Advantages

- Its ability to burn all ranks of coal from anthracitic to lignitic, and it permits combination firing (i.e., can use coal, oil and gas in same burner). Because of these advantages, there is widespread use of pulverized coal furnaces.

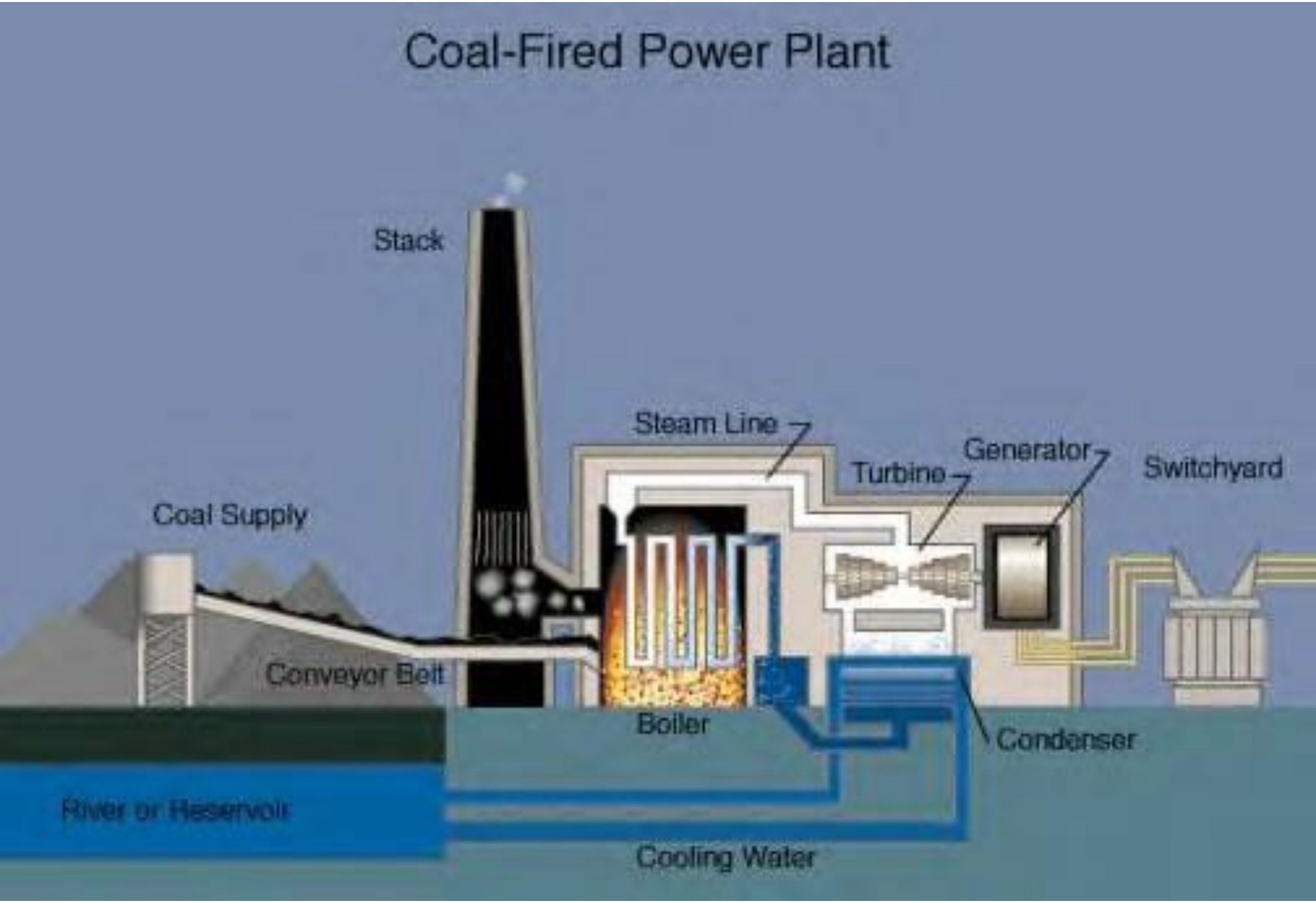
Disadvantages

- High power demand for pulverizing
- Requires more maintenance, flyash erosion and pollution complicate unit operation

7. Waste Heat Boiler

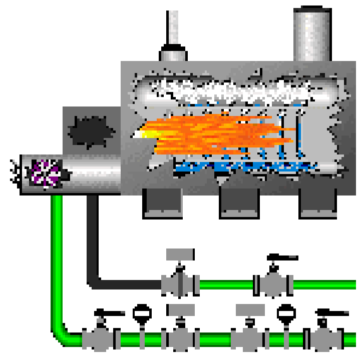


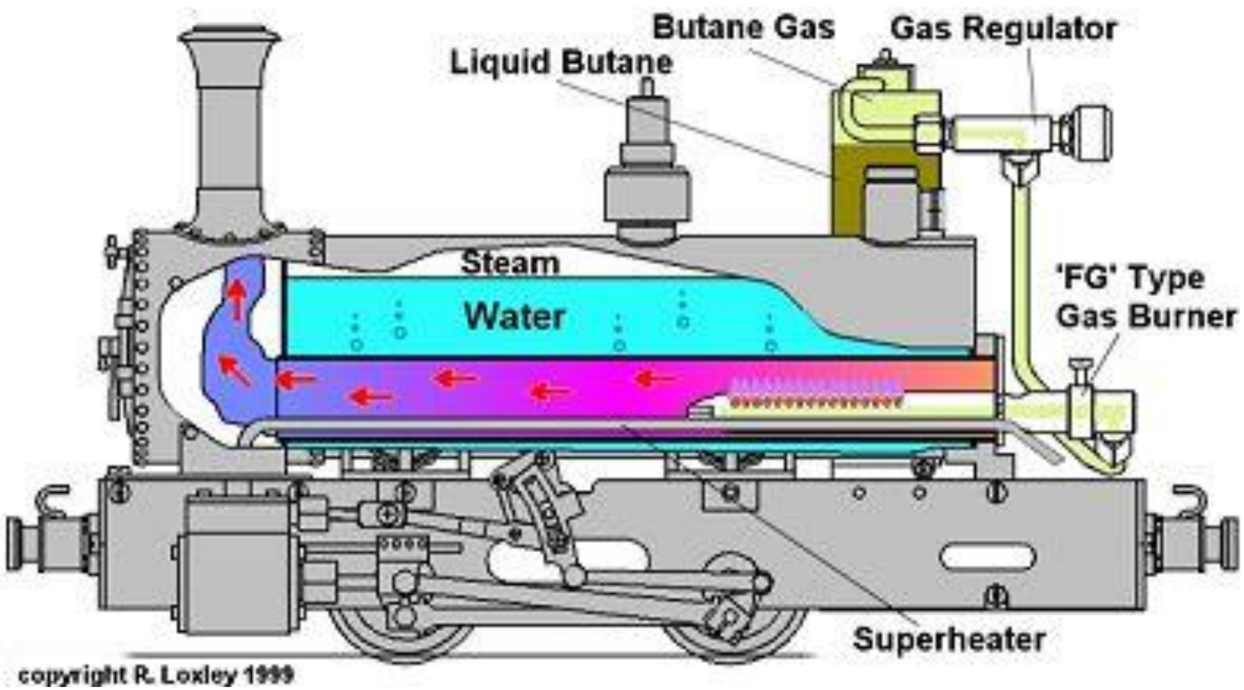
- Used when waste heat available at medium/high temp
- Auxiliary fuel burners used if steam demand is more than the waste heat can generate
- Used in heat recovery from exhaust gases from gas turbines and diesel engines


Coal-Fired Power Plant
Stack
Steam Line
Generator
Switchyard
Turbine
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water

Pressure & Temperature

- Steam
  - Low Pressure (< 15 psig)
  - Medium Pressure (15- 160 psig)
  - High Pressure (> 160 psig)
- Hot Water
  - Low Temperature (< 250F and < 160 psig)
  - Medium Temperature (250 to 350F)
  - High Temperature (> 350F)

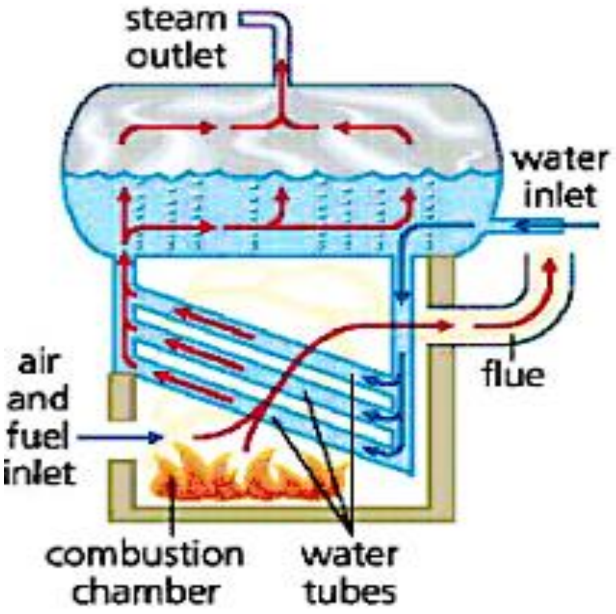



Butane Gas
Gas Regulator
Liquid Butane
Steam
Water
'FG' Type
Gas Burner
Superheater
copyright R. Loxley 1999

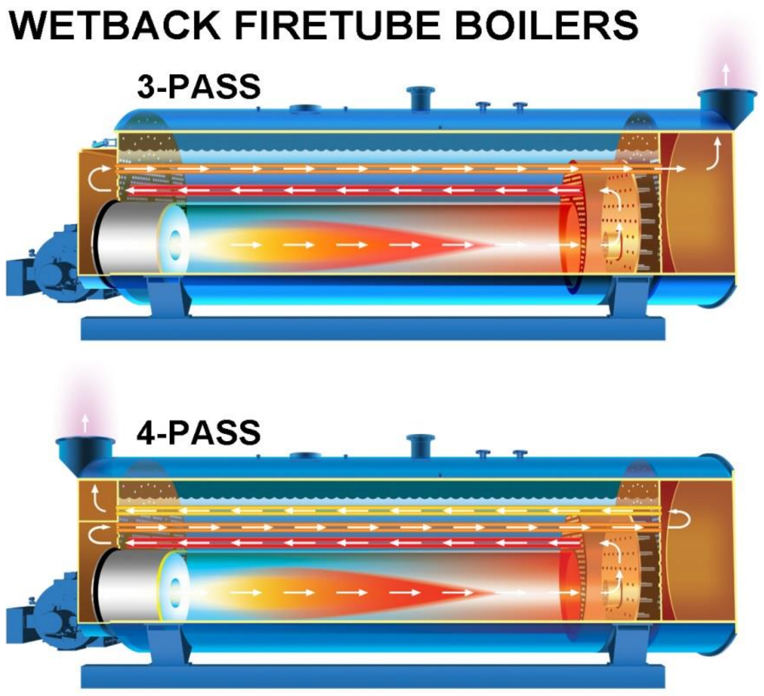
Fuel

- Fuel
  - Oil
  - Natural gas
  - Propane
  - Electric
  - Coal
  - Wood

Heat Exchanger



- Water Tube
  - Straight tube
  - Bent tube
- Fire Tube
  - Sing pass
  - Multiple pass
- Modular / Sectional

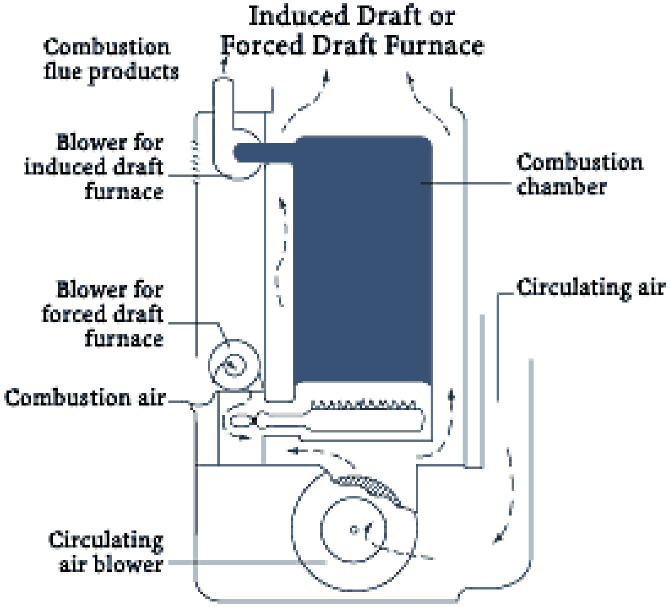


Materials

- Non-Condensing
  - Carbon Steel
  - Copper
  - Cast Iron
- Condensing
  - Stainless Steel
  - Aluminum
  - Cast Iron
  - Plastic

Draft Type

- Natural (Atmospheric)
- Forced
- Induced



Burner Type

- One Stage
- High/Low Fire
- Modulating

Chamber Type

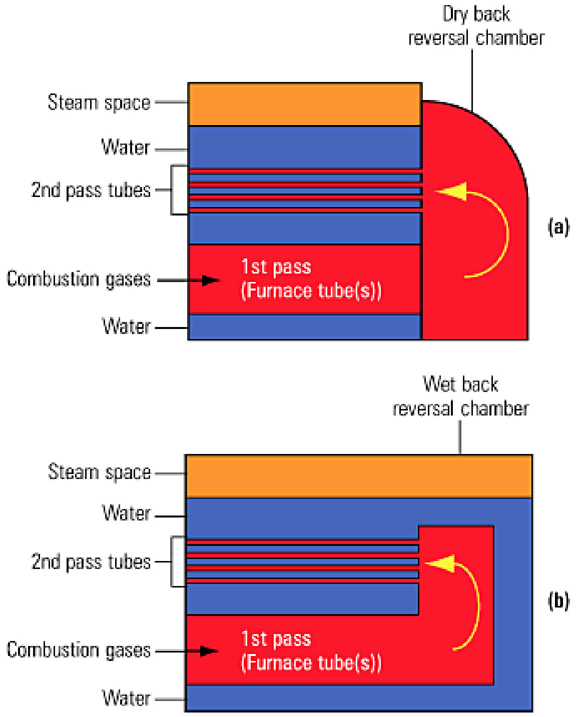
- Dry Based Combustion

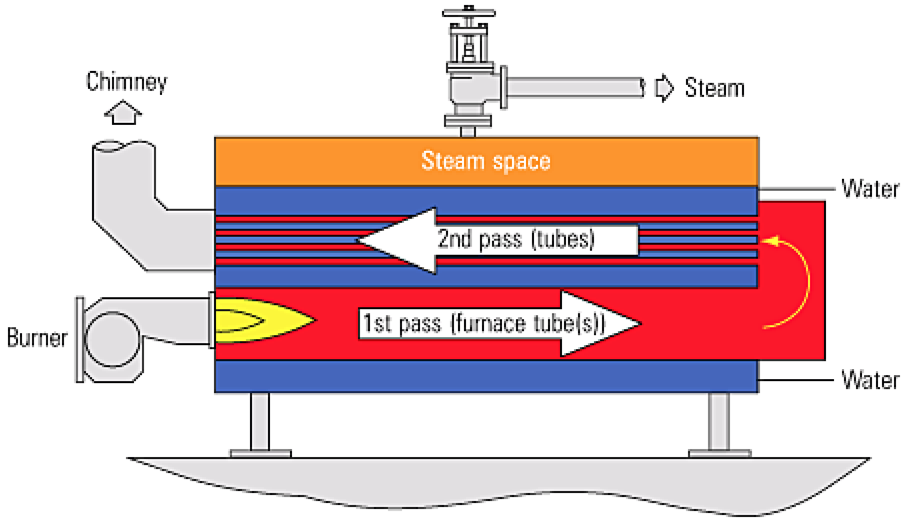
  Fire box under the boiler and will need refractory material opposite the burner to absorb and help distribute the heat back up into the bottom of the boiler

- Wet Based Combustion
  – Boiler water surround

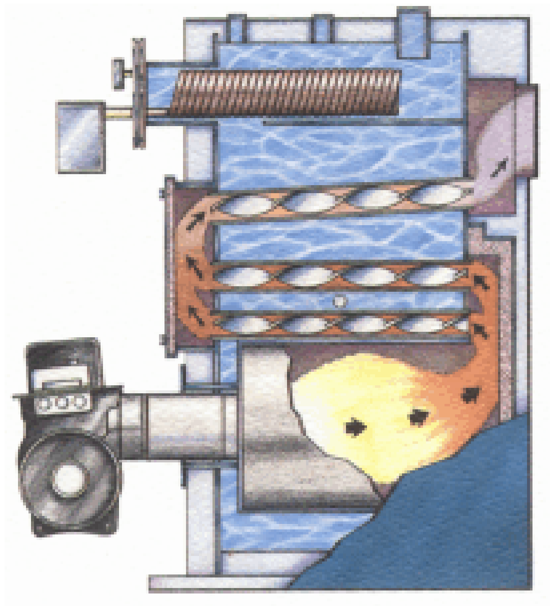
    the burner flame.

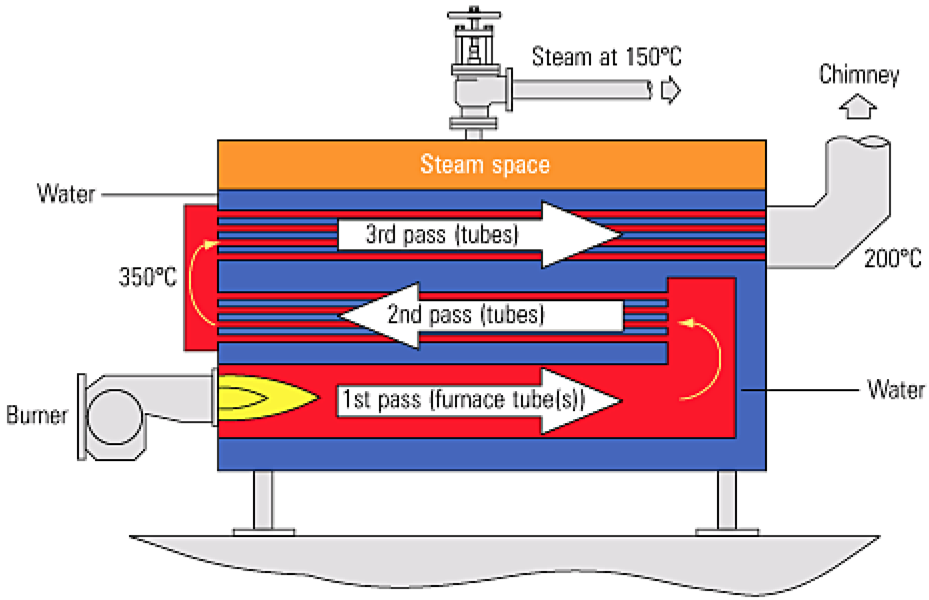
- Wet Leg (mud leg)
- Dry Back
- Wet Back





Chimney
Steam
Steam space
Water
2nd pass (tubes)
Burner
1st pass (furnace tube(s))
Water

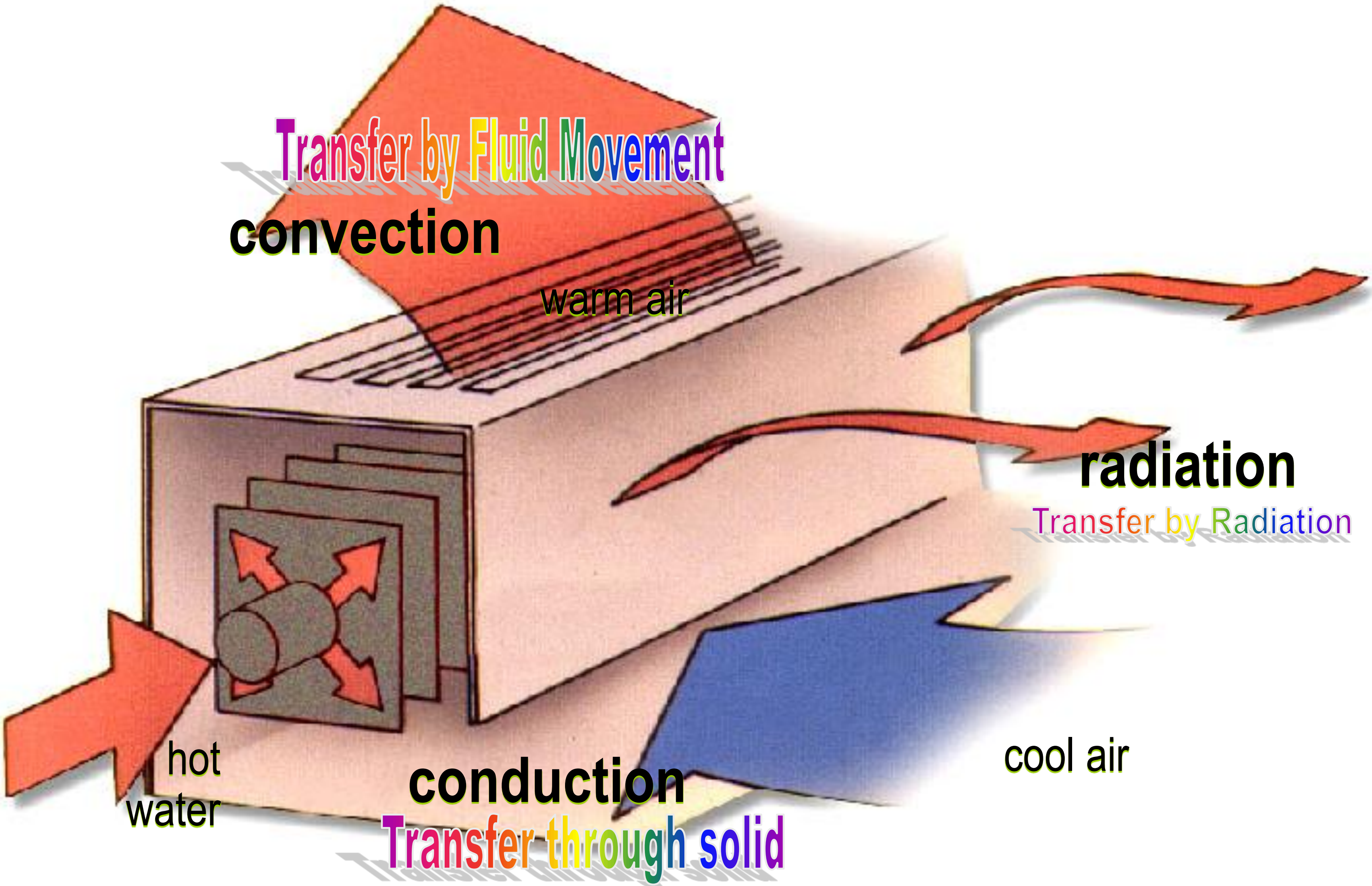




Steam at 150°C
Chimney
Steam space
Water
3rd pass (tubes)
200°C
350°C
2nd pass (tubes)
Burner
1st pass (furnace tube(s))
Water

Boiler performance

- **Causes of poor boiler performance**
  - -Poor combustion
  - -Heat transfer surface fouling
  - -Poor operation and maintenance
  - -Deteriorating fuel and water quality
- **Heat balance: identify heat losses**
- **Boiler efficiency: determine deviation from best efficiency**

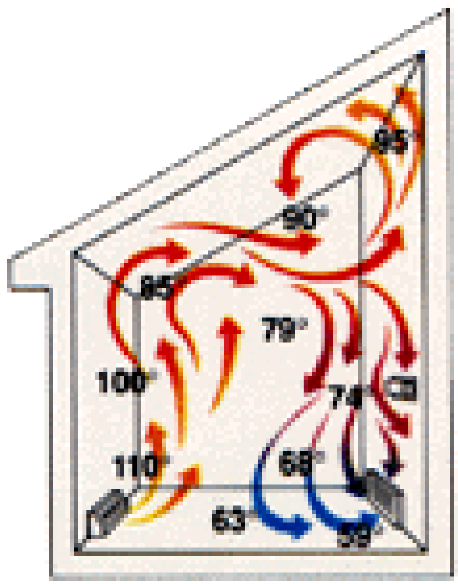


Transfer by Fluid Movement
convection
warm air
radiation
Transfer by Radiation
hot water
conduction
Transfer through solid
cool air

Principles of Heat Transfer

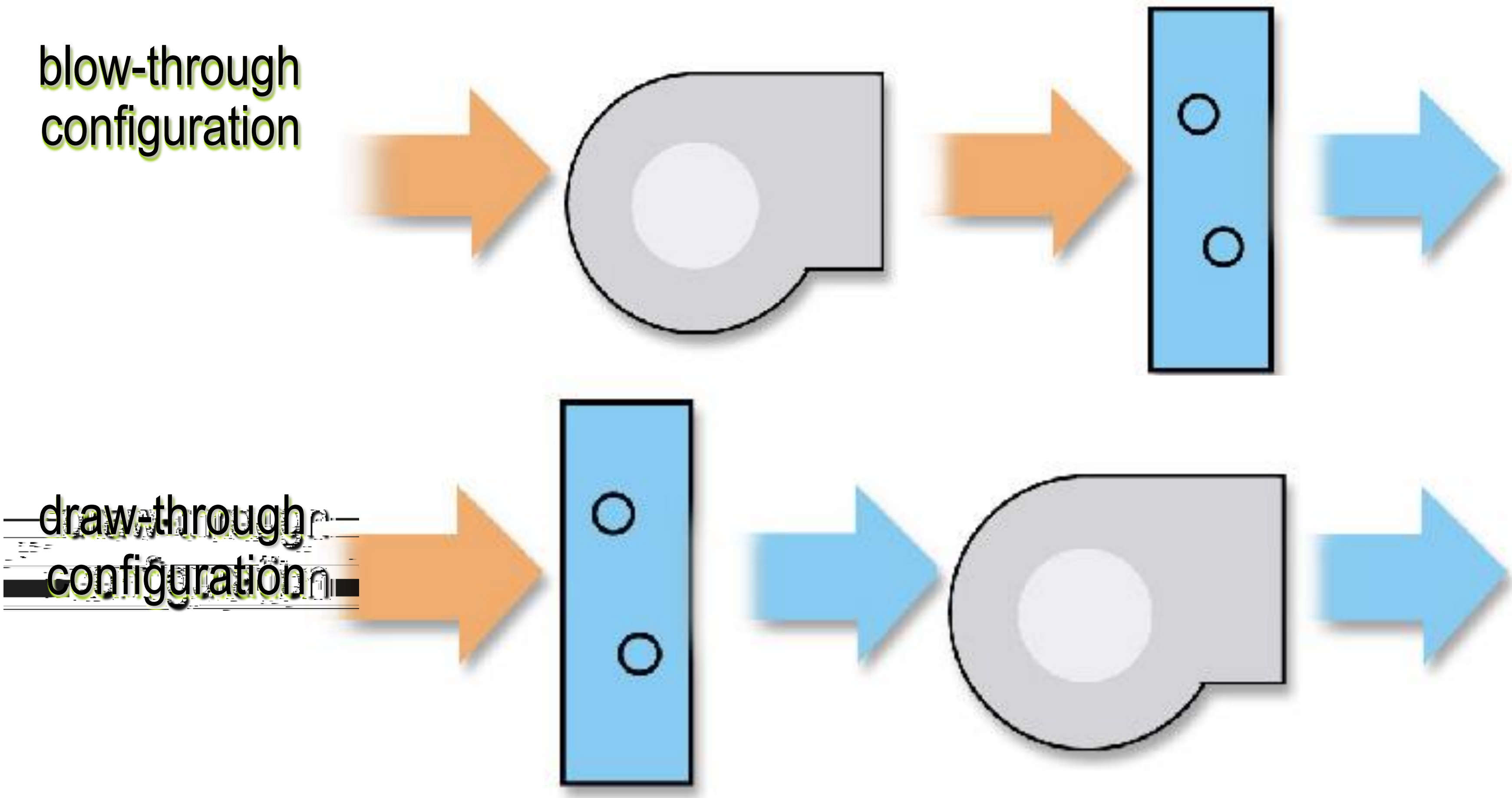
- Heat energy cannot be destroyed
- Heat always flows from a higher temperature substance to a lower temperature substance
- Heat can be transferred from one substance to another

Warm Air Units



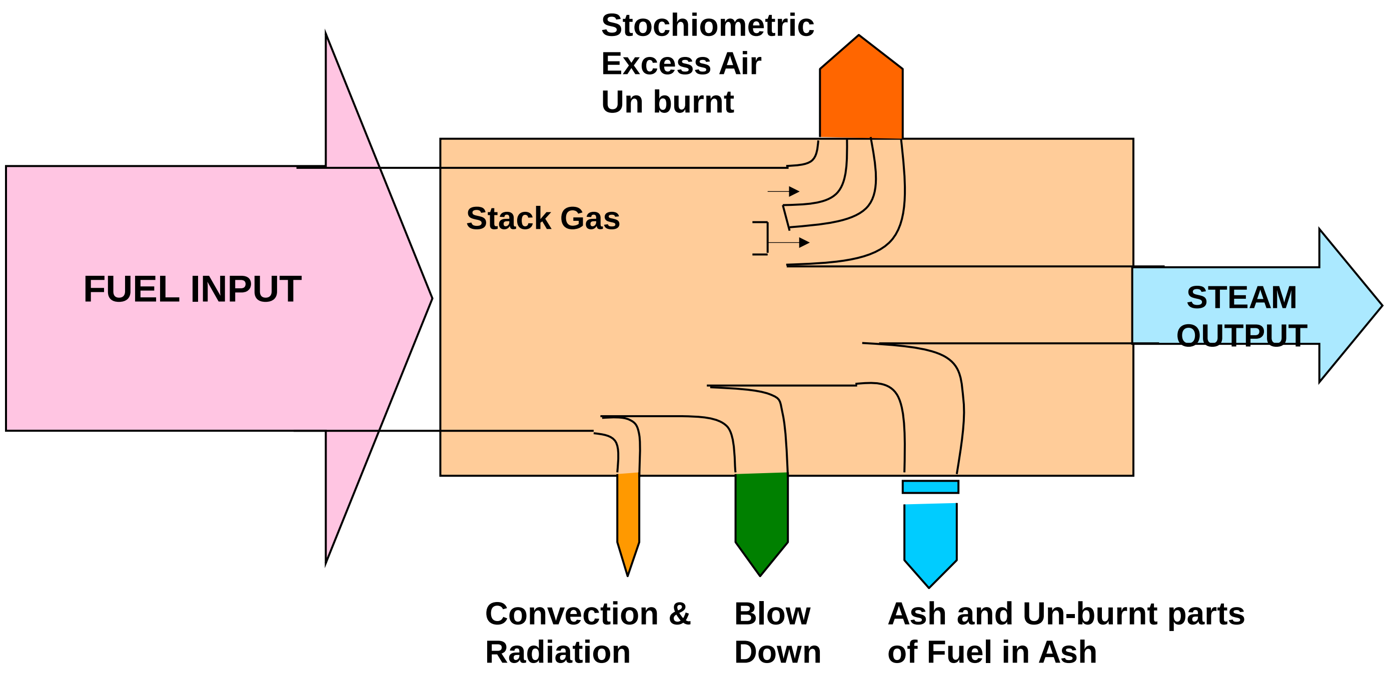
Forced Air

Components of Fan Heat



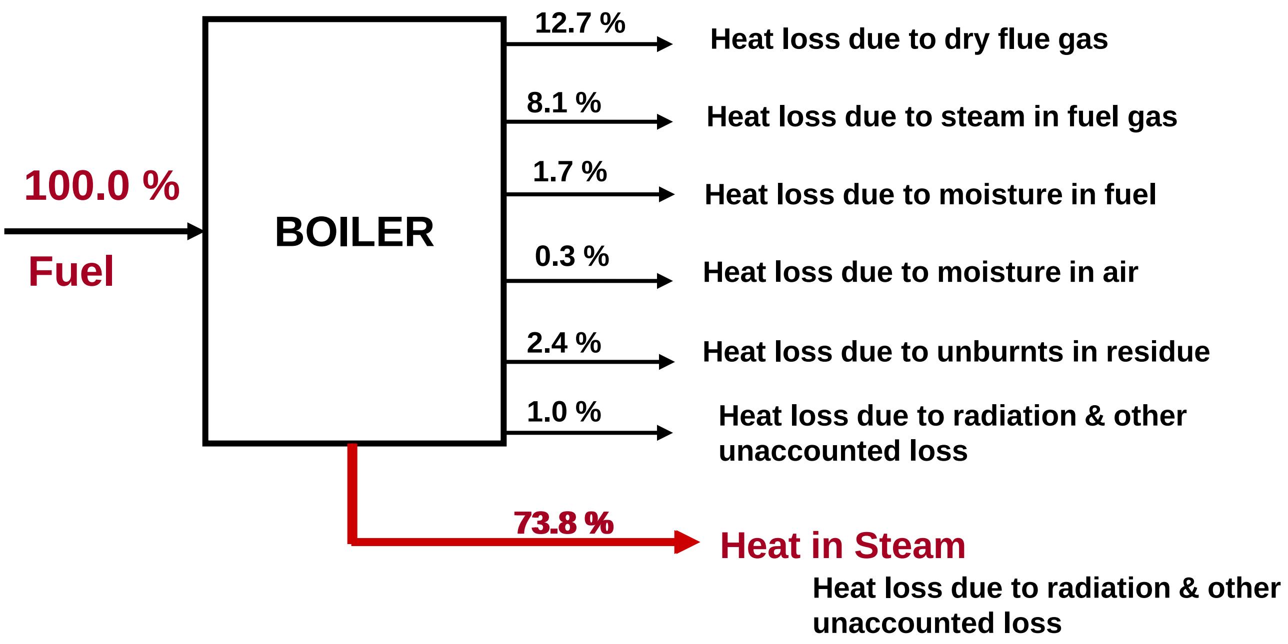
Heat Balance

An energy flow diagram describes geographically how energy is transformed from fuel into useful energy, heat and losses



Heat Balance

Balancing total energy entering a boiler against the energy that leaves the boiler in different forms



Goal

Heat Balance

Goal: improve energy efficiency by reducing *avoidable* losses

Avoidable losses include:

- **Stack gas losses (excess air, stack gas temperature)**
- **Losses by unburnt fuel**
- **Blow down losses**
- **Condensate losses**
- **Convection and radiation**

Boiler Efficiency

Thermal efficiency: % of (heat) energy input that is effectively useful in the generated steam

BOILER EFFICENCY CALCULATION

1) DIRECT METHOD:
The energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.

2) INDIRECT METHOD:
The efficiency is the different between losses and energy input

Boiler Efficiency: Direct Method

$$\text{Boiler efficiency } (\eta) = \frac{\text{Heat Input}}{\text{Heat Output}} \times 100 = \frac{Q \times (hg - hf)}{Q \times GCV} \times 100$$

h_g -the enthalpy of saturated steam in kcal/kg of steam

h_f -the enthalpy of feed water in kcal/kg of water

Parameters to be monitored:

- Quantity of steam generated per hour (Q) in kg/hr
- Quantity of fuel used per hour (q) in kg/hr
- The working pressure (in kg/cm2(g)) and superheat temperature (oC), if any
- The temperature of feed water (oC)
- Type of fuel and gross calorific value of the fuel (GCV) in kcal/kg of fuel

Boiler Efficiency: Direct Method

Advantages

- Quick evaluation
- Few parameters for computation
- Few monitoring instruments
- Easy to compare evaporation ratios with benchmark figures

Disadvantages

- No explanation of low efficiency
- Various losses not calculated

Boiler Efficiency: Indirect Method

Required calculation data

- Ultimate analysis of fuel (H_2, O_2, S, C, moisture content, ash content)
- % oxygen or CO_2 in the flue gas
- Fuel gas temperature in ◦C (Tf)
- Ambient temperature in ◦C (Ta) and humidity of air in kg/kg of dry air
- GCV of fuel in kcal/kg
- % combustible in ash (in case of solid fuels)
- GCV of ash in kcal/kg (in case of solid fuels)

Boiler Efficiency: Indirect Method

Advantages

- Complete mass and energy balance for each individual stream
- Makes it easier to identify options to improve boiler efficiency

Disadvantages

- Time consuming
- Requires lab facilities for analysis

The Opportunities

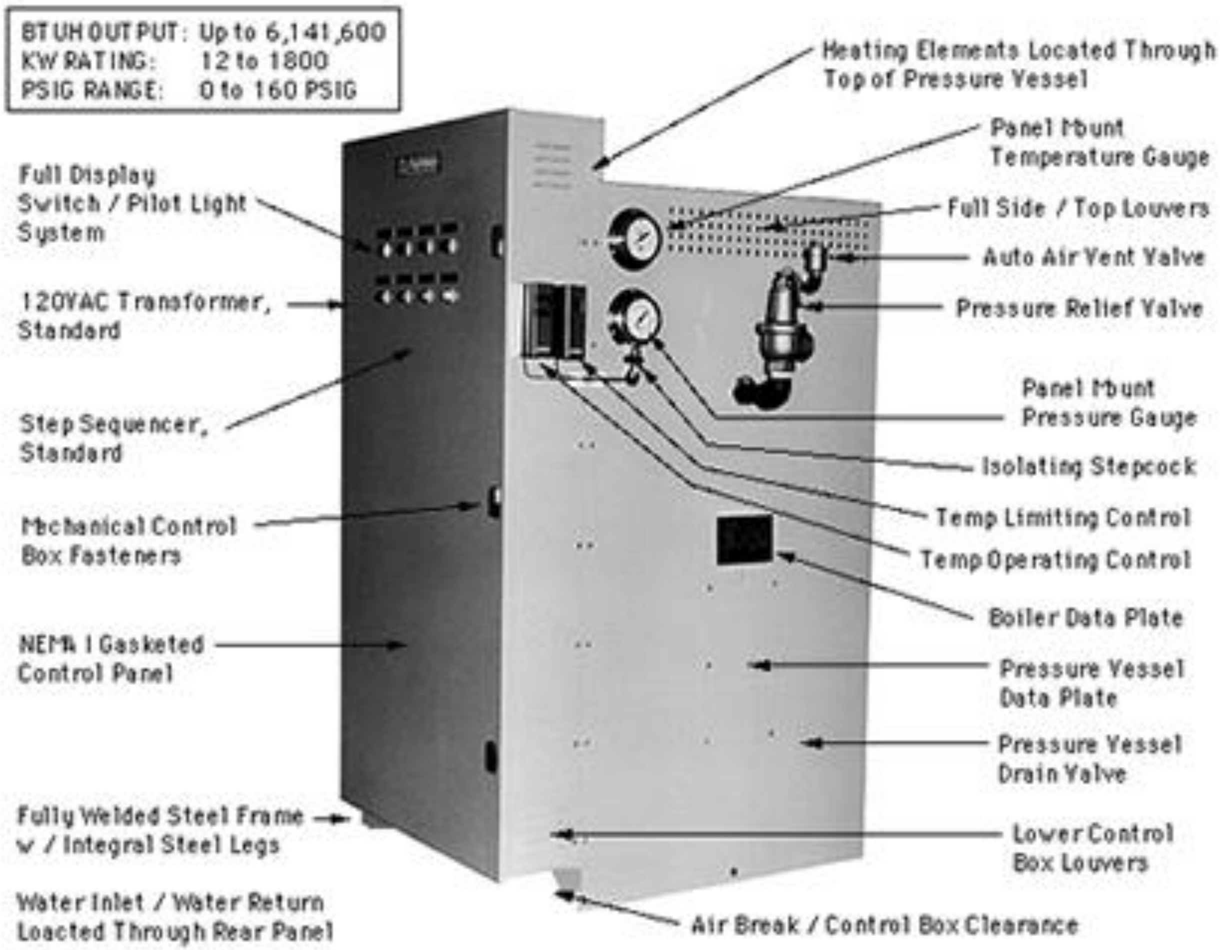
1. **Stack temperature control**
2. **Feed water preheating using economizers**
3. **Combustion air pre-heating**
4. **Incomplete combustion minimization**
5. **Excess air control**
6. **Avoid radiation and convection heat loss**
7. **Automatic blow down control**
8. **Reduction of scaling and soot losses**
9. **Reduction of boiler steam pressure**
10. **Variable speed control**
11. **Controlling boiler loading**
12. **Proper boiler scheduling**
13. **Boiler replacement**

Boiler solutions

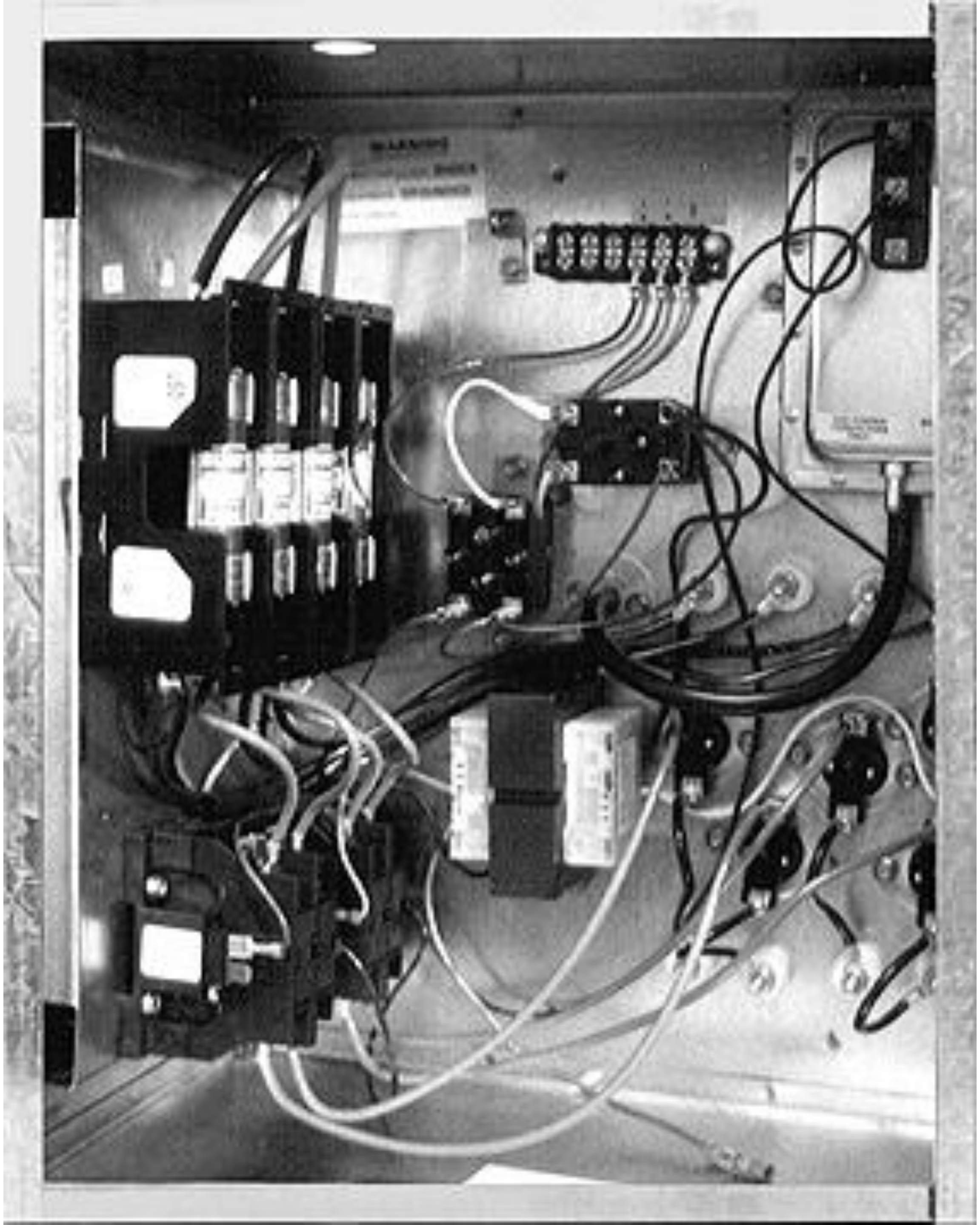
- Control Products of combustions
- Control Water treatment
- Control heat loss
- Control blow down
- Control water loss
- Control boiler control schedule
- Control heat transfer surfaces

Electric Heat

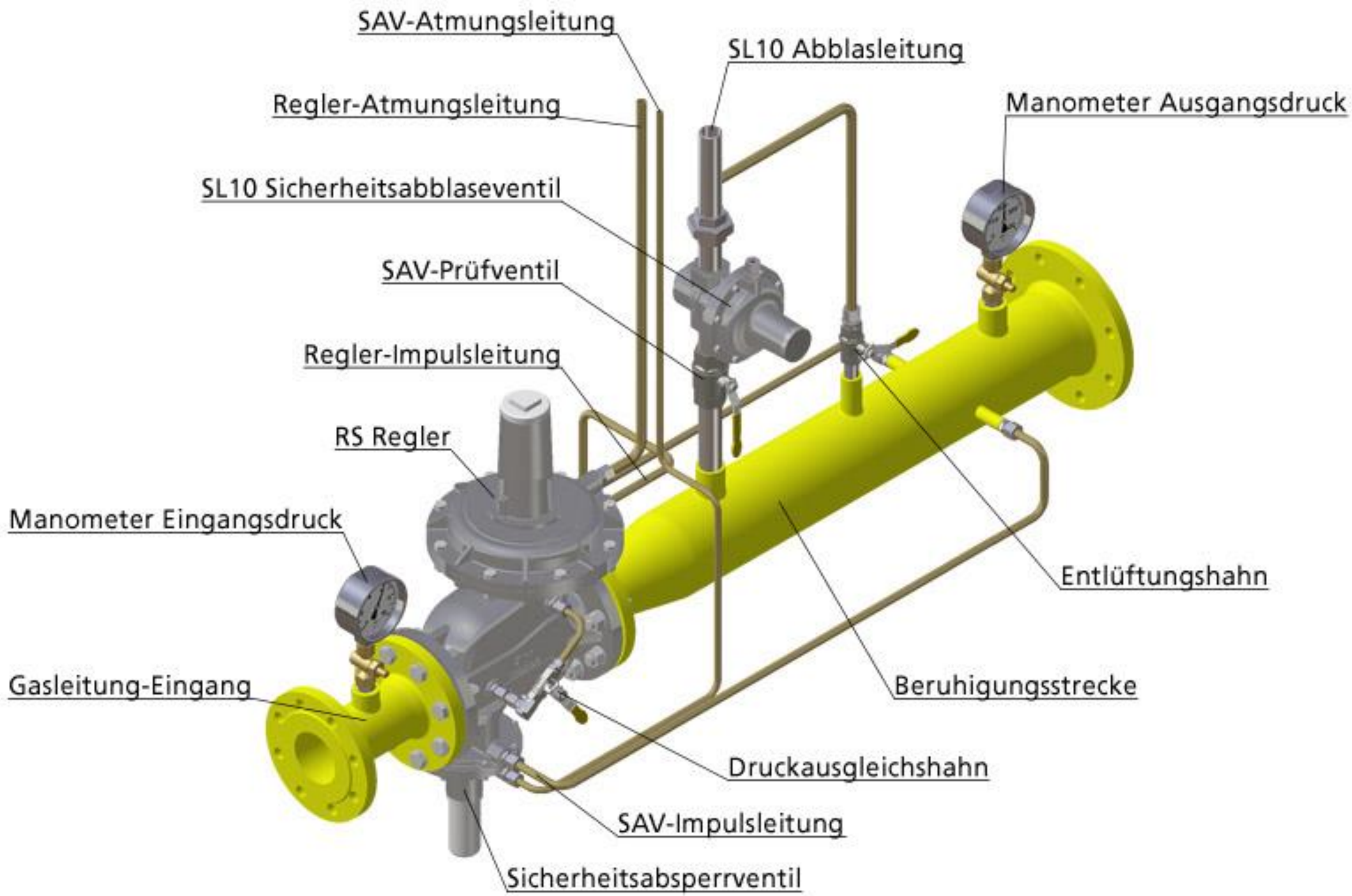
Electric Boiler



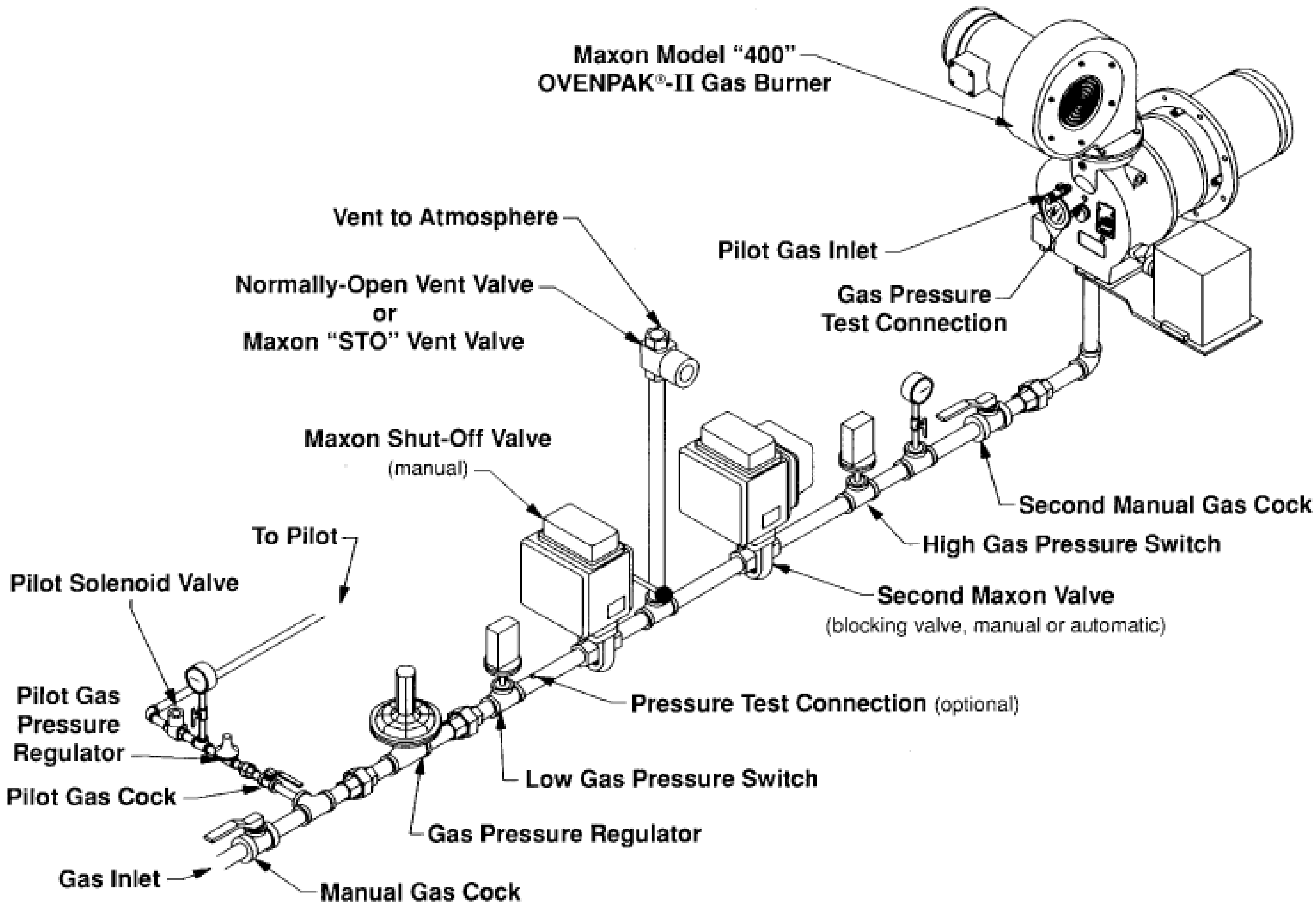

DANGER
high voltage



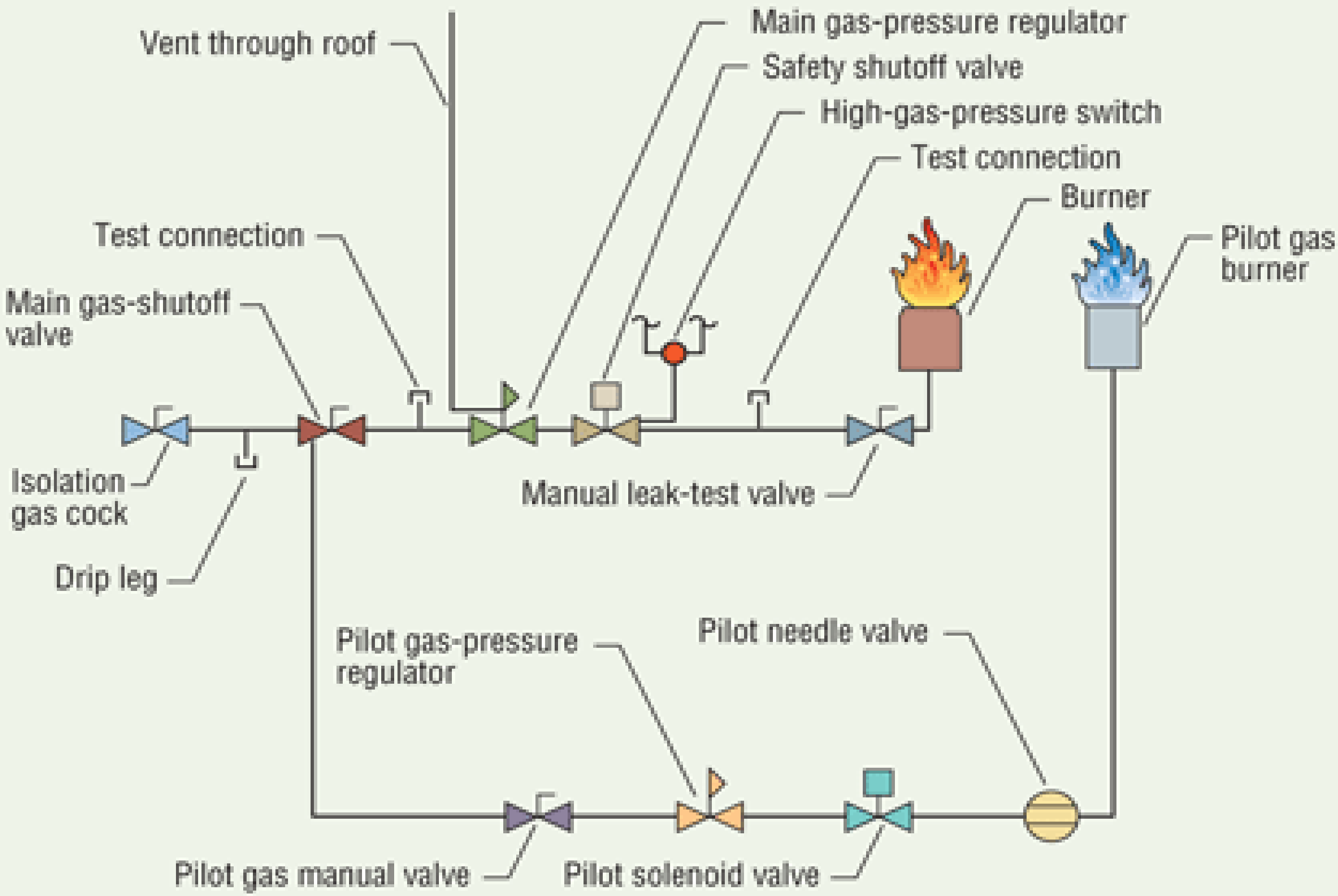
Gas Heat


SAV-Atmungsleitung
SL10 Abblasleitung
Regler-Atmungsleitung
Manometer Ausgangsdruck
SL10 Sicherheitsabblaseventil
SAV-Prüfventil
Regler-Impulsleitung
RS Regler
Manometer Eingangsdruck
Entlüftungshahn
Gasleitung-Eingang
Beruhigungsstrecke
Druckausgleichshahn
SAV-Impulsleitung
Sicherheitsabsperrventil


Regulator
Low Pressure Safety
Gas Control Valve
High Pressure Safety
Gas Safety Valve



Maxon Model "400"
OVENPAK®-II Gas Burner
Vent to Atmosphere
Pilot Gas Inlet
Normally-Open Vent Valve
or
Maxon "STO" Vent Valve
Gas Pressure
Test Connection
Maxon Shut-Off Valve
(manual)
Second Manual Gas Cock
To Pilot
High Gas Pressure Switch
Pilot Solenoid Valve
Second Maxon Valve
(blocking valve, manual or automatic)
Pilot Gas
Pressure
Regulator
Pressure Test Connection (optional)
Low Gas Pressure Switch
Pilot Gas Cock
Gas Pressure Regulator
Gas Inlet
Manual Gas Cock


Vent through roof
Main gas-pressure regulator
Safety shutoff valve
High-gas-pressure switch
Test connection
Burner
Pilot gas burner
Test connection
Main gas-shutoff valve
Isolation gas cock
Drip leg
Manual leak-test valve
Pilot gas-pressure regulator
Pilot needle valve
Pilot gas manual valve
Pilot solenoid valve

RayPak Hi Delta

	Recovery Rates (GPH)																
	Hi Delta Model	MBTUH Input	Temperature Rise (°F)														
			10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
85% AFUE	HD101	100	1020	510	340	255	204	170	146	128	113	102	93	85	78	73	68
	HD151	150	1531	765	510	383	306	255	219	191	170	153	139	128	118	109	102
	HD201	199	2031	1015	677	508	406	338	290	254	226	203	185	169	156	145	135
	HD251	250	2551	1276	850	638	510	425	364	319	283	255	232	213	196	182	170
	HD301	299	3051	1526	1017	763	610	509	436	381	339	305	277	254	235	218	203
84% EFFICIENCY (TYPE H)	HD401	399	4024	2012	1341	1006	805	671	575	503	447	402	366	335	310	287	268
	302B	300	3055	1527	1018	764	611	509	436	382	339	305	278	255	235	218	204
	402B	399	4063	2031	1354	1016	813	677	580	508	451	406	369	339	313	290	271
	502B	500	5091	2545	1697	1273	1018	848	727	636	566	509	463	424	392	364	339
	652B	650	6618	3309	2206	1655	1324	1103	945	827	735	662	602	552	509	473	441
	752B	750	7636	3818	2545	1909	1527	1273	1091	955	848	764	694	636	587	545	509
	902B	900	9164	4582	3055	2291	1833	1527	1309	1145	1018	916	833	764	705	655	611
	992B	990	10080	5040	3360	2520	2016	1680	1440	1260	1120	1008	916	840	775	720	672
	1262B	1260	12829	6415	4276	3207	2566	2138	1833	1604	1425	1283	1166	1069	987	916	855
	1532B	1530	15578	7789	5193	3895	3116	2596	2225	1947	1731	1558	1416	1298	1198	1113	1039
	1802B	1800	18327	9164	6109	4582	3665	3055	2618	2291	2036	1833	1666	1527	1410	1309	1222
	2002B	1999	20353	10177	6784	5088	4071	3392	2908	2544	2261	2035	1850	1696	1566	1454	1357
	2072B	2070	21076	10538	7025	5269	4215	3513	3011	2635	2342	2108	1916	1756	1621	1505	1405
	2342B	2340	23825	11913	7942	5956	4765	3971	3404	2978	2647	2383	2166	1985	1833	1702	1588

Water Flows
2.31 PSI = 1 Foot

Model No.	10°FΔT		20°FΔT		30°FΔT		40°FΔT		Min. Flow			Max Flow		
	gpm	ΔP (ft)	gpm	ΔP (ft)	gpm	ΔP (ft)	gpm	ΔP (ft)	gpm	ΔP (ft)	ΔT	gpm	ΔP (ft)	ΔT
302B	50	3.3	25	0.8	N/A	N/A	N/A	N/A	20	0.5	25	90	9.8	6
402B	67	5.8	34	1.4	22	0.6	N/A	N/A	20	0.5	34	90	10.0	7
502B	84	9.1	42	2.3	28	1.1	21	0.6	21	0.6	40	90	10.4	9
652B	N/A	N/A	55	4.1	36	1.8	27	1.1	27	1.1	40	90	10.8	12
752B	N/A	N/A	63	5.7	42	2.6	32	1.5	32	1.5	40	90	11.3	14
902B	N/A	N/A	76	8.3	50	3.8	38	2.2	38	2.2	40	90	11.7	17

Notes:
1. Basis for minimum flow is 20 gpm or 40°F ΔT. Basis for maximum flow is 90 gpm. Flow switch will not operate if flow is less than 20 gpm.
2. Rear-mounted pumps may provide higher flow rates on smaller models than the system requirements.

Example

Annually

1. Test flame failure detection system and pilot turn-down. (See "Pilot Turn-Down Test Procedure," page 48.)

2. Test high limit and operating temperature. (See "Post Start-Up Check," page 49.)

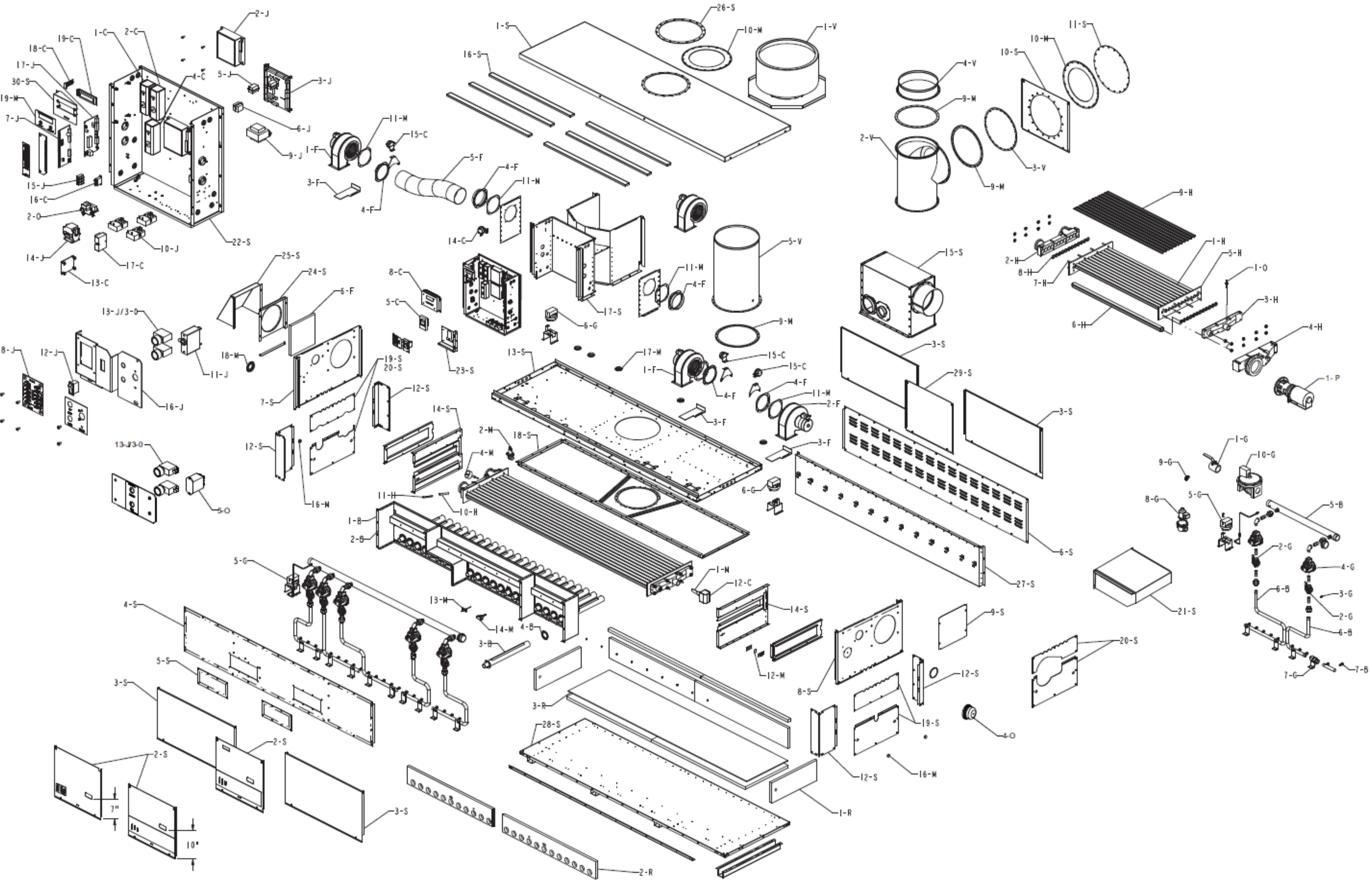
3. Check flame sensors.

4. Conduct a combustion test at full fire. Carbon dioxide should be 8.2% ± 0.5% at full fire for natural gas, and 9.4% ± 0.5% for propane gas; Carbon monoxide should be < 150 ppm).

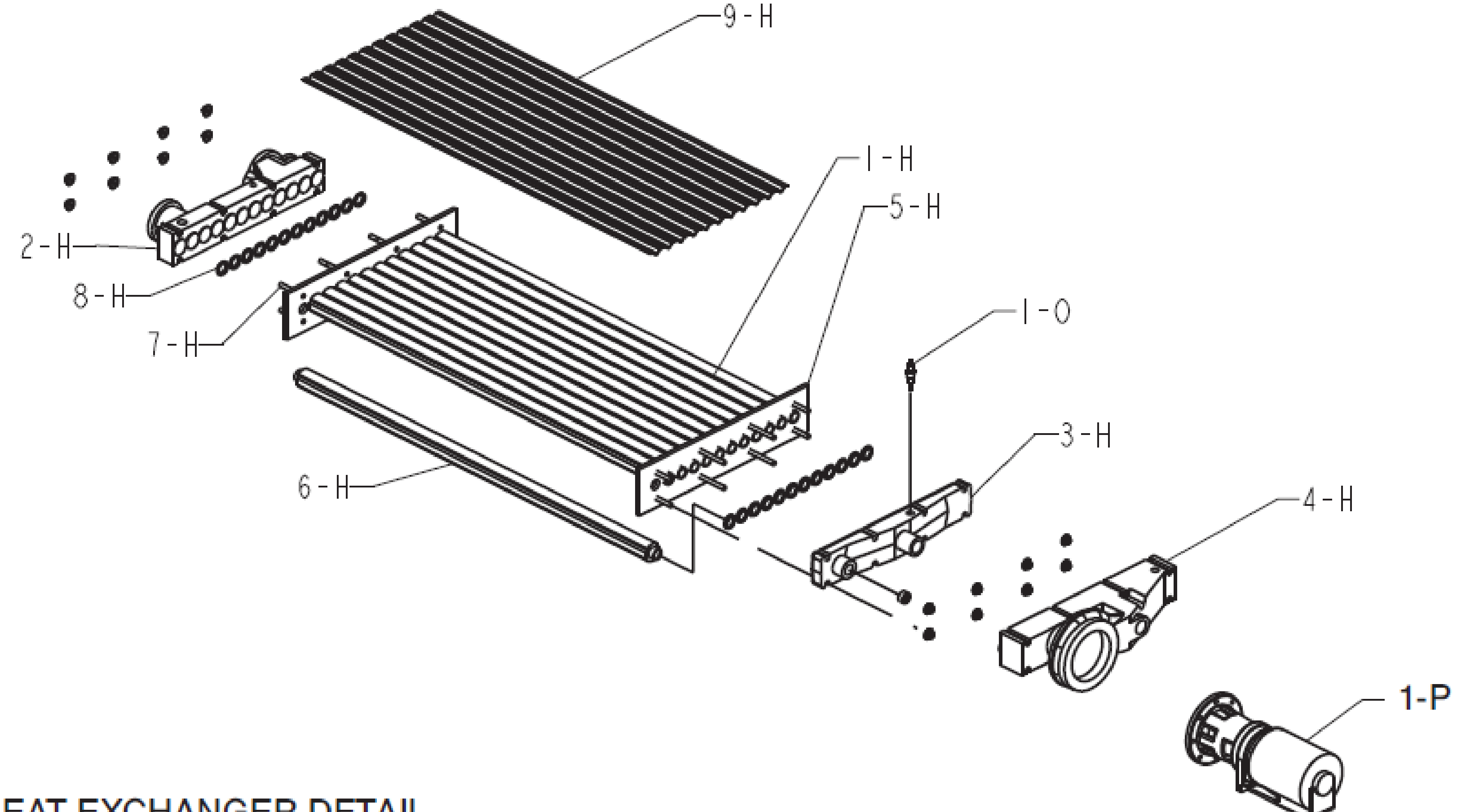
5. Check coils for 60 cycle hum or buzz. Check for leaks at all valve fittings using a soapy water solution. Test other operating parts of all safety shut-off and control valves and increase or decrease settings (depending on the type of control) until the safety circuit opens. Reset to original setting after each device is tested.

6. Perform leakage test on gas valves. (See Fig. 43.)

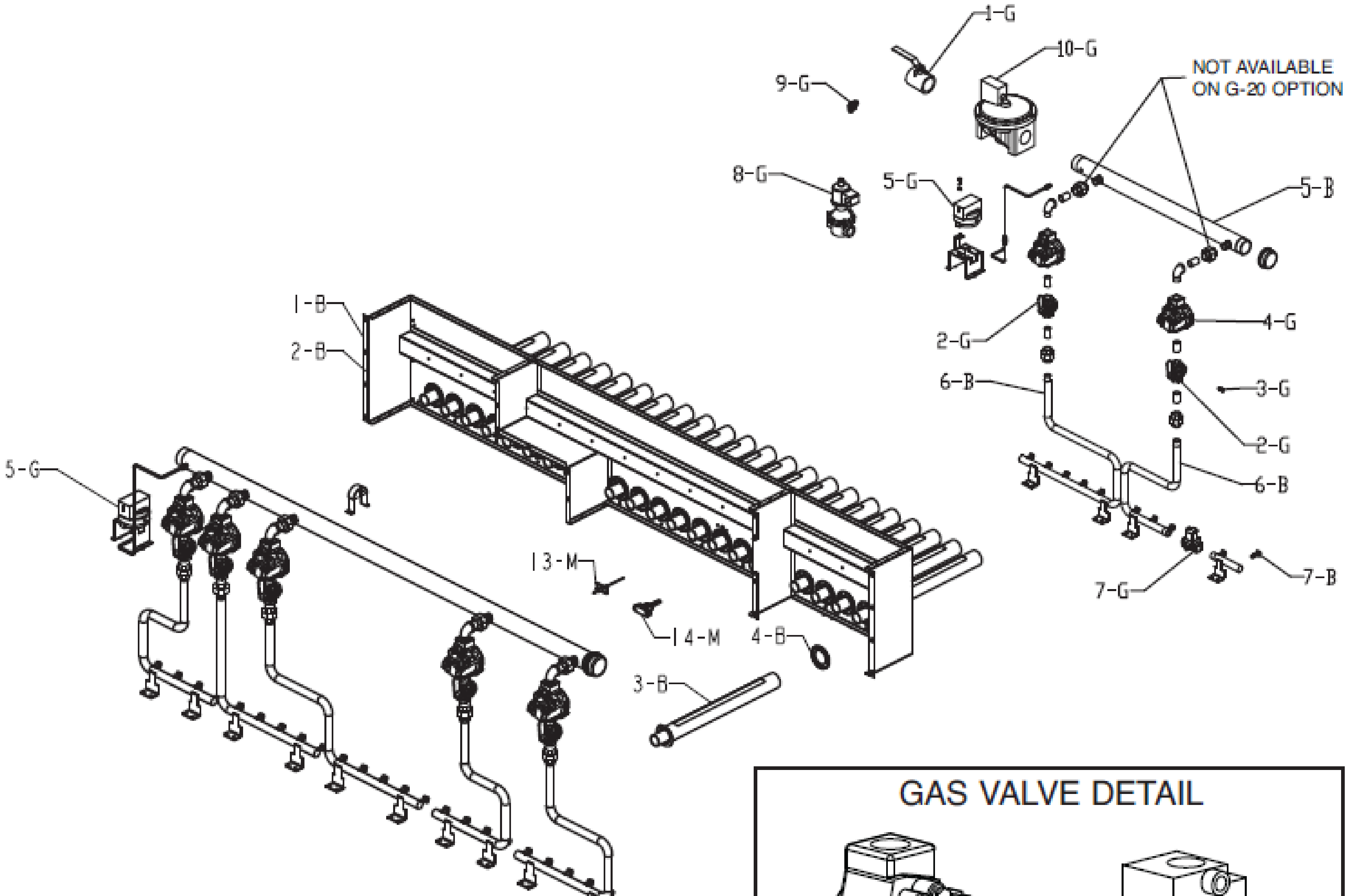
7. Test air switch in accordance with manufacturer's instructions. (Turn panel switch to the "On" position until blower is proven, then turn the switch to "Off".



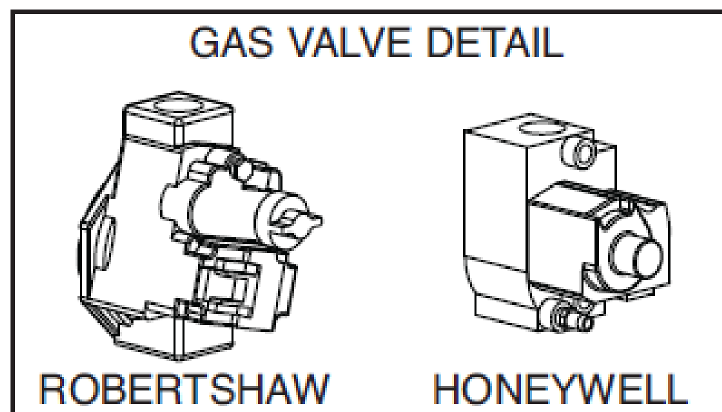
2-J
1-S
26-S
10-M
1-V
11-S
1-C
2-C
19-C
18-C
17-J
30-S
19-M
7-J
4-C
5-J
3-J
16-S
4-V
10-M
10-S
9-M
6-J
9-J
11-M
15-C
1-F
2-V
3-V
9-M
5-F
4-F
11-M
3-F
4-F
15-J
16-C
2-O
14-C
9-H
14-J
10-J
22-S
17-C
13-C
5-V
1-H
15-S
5-H
2-H
8-H
7-H
1-O
3-H
25-S
24-S
6-F
8-C
5-C
11-M
4-F
17-S
6-G
9-M
6-H
4-H
13-J/3-O
8-J
12-J
11-J
18-M
16-J
7-S
19-S
20-S
23-S
13-S
17-M
15-C
15-C
1-F
4-F
3-S
29-S
1-P
12-S
14-S
2-M
4-M
18-S
3-F
4-F
11-M
2-F
3-F
3-S
1-G
9-G
10-G
12-S
13-J/3-O
16-M
11-H
10-H
6-G
5-G
8-G
5-B
1-B
2-B
6-S
2-G
4-G
5-G
27-S
1-N
12-C
13-M
21-S
6-B
3-G
4-S
14-S
14-M
4-B
3-B
2-G
6-B
9-S
12-M
5-S
20-S
3-S
3-R
8-S
12-S
7-G
7-B
19-S
28-S
2-S
2-S
4-O
7"
10"
3-S
12-S
16-M
1-R
2-R



HEAT EXCHANGER DETAIL

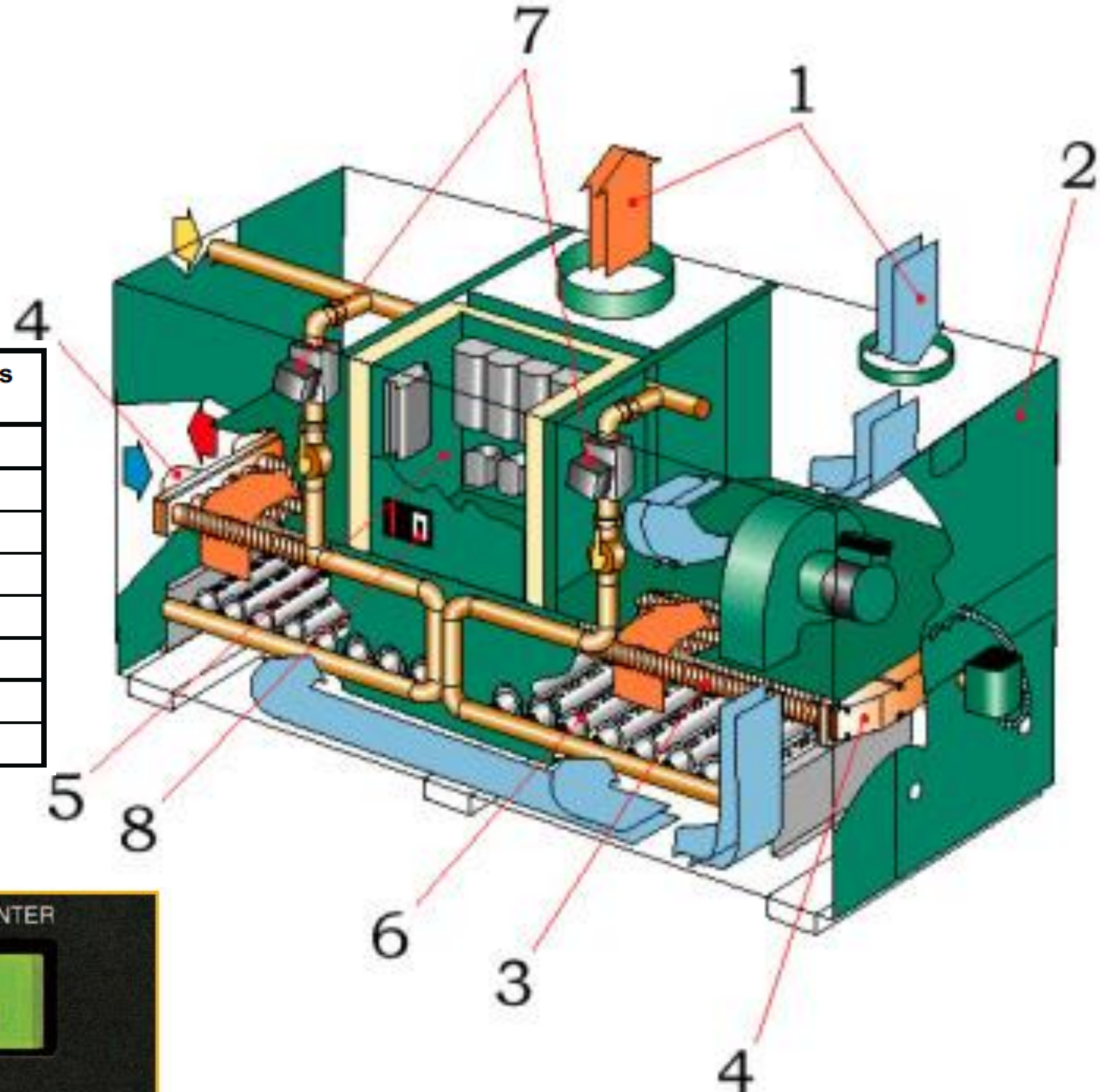


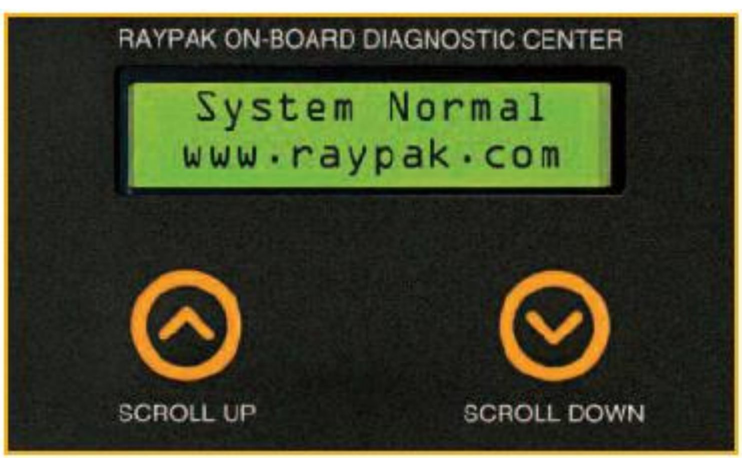
BURNER ASSEMBLY DETAIL

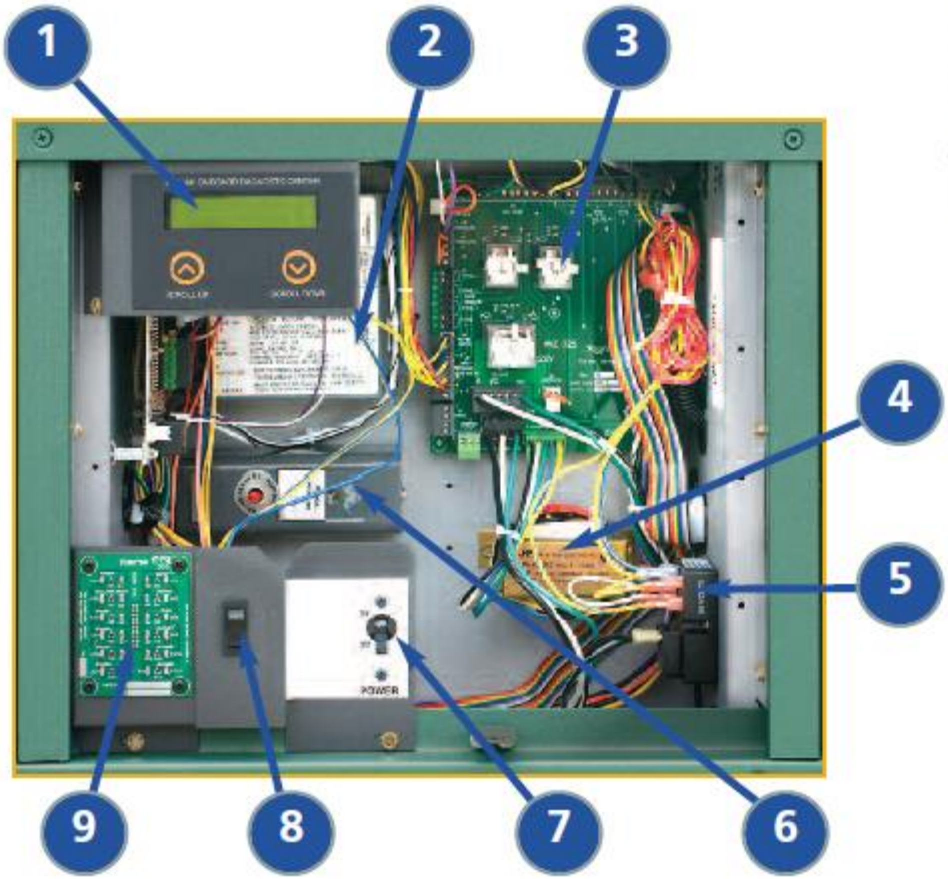


Forced Draft

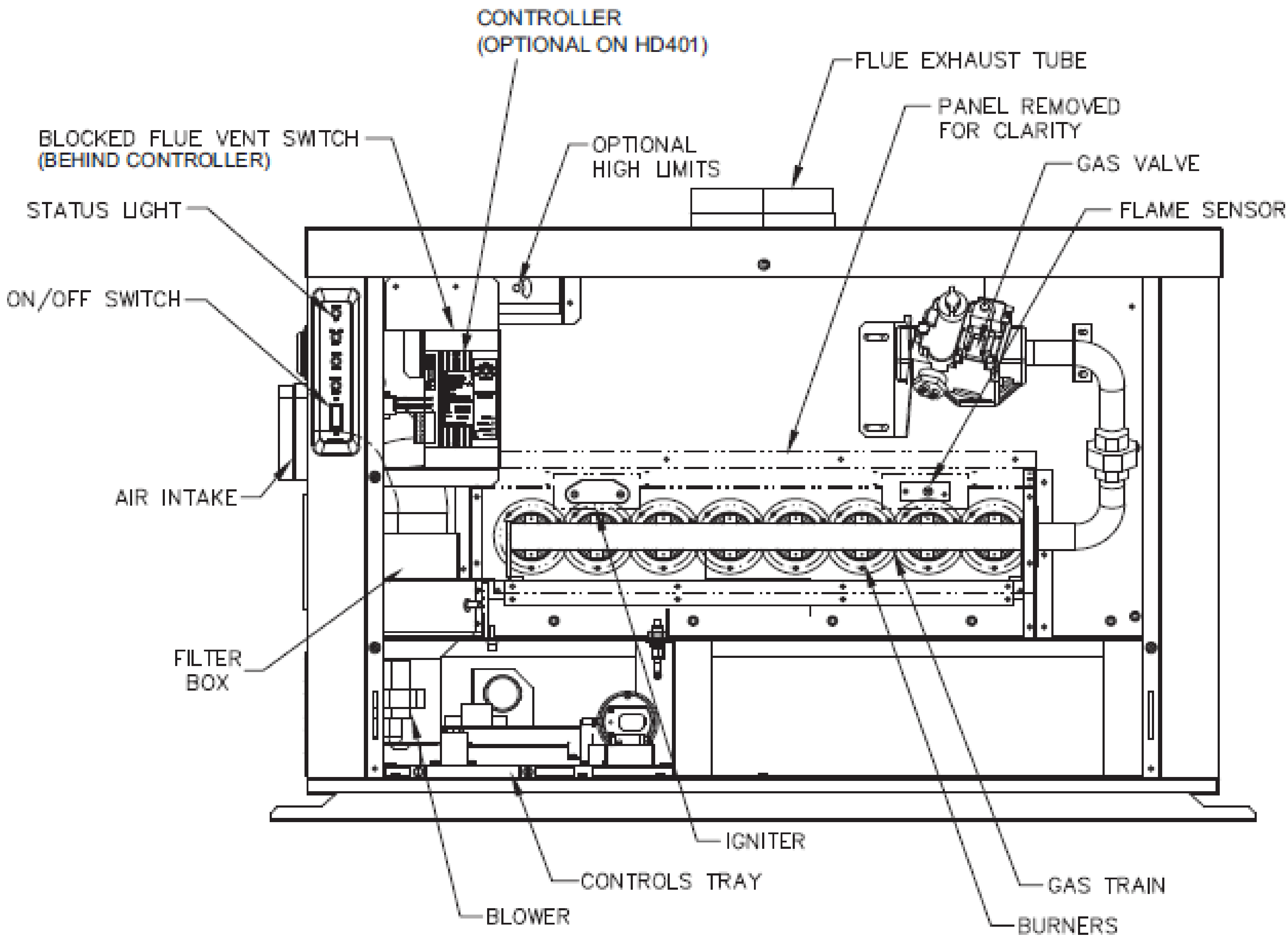
Water Temp.	Time to Produce Serious Burn
120°F	More than 5 minutes
125°F	1-1/2 to 2 minutes
130°F	About 30 seconds
135°F	About 10 seconds
140°F	Less than 5 seconds
145°F	Less than 3 seconds
150°F	About 1-1/2 seconds
155°F	About 1 second

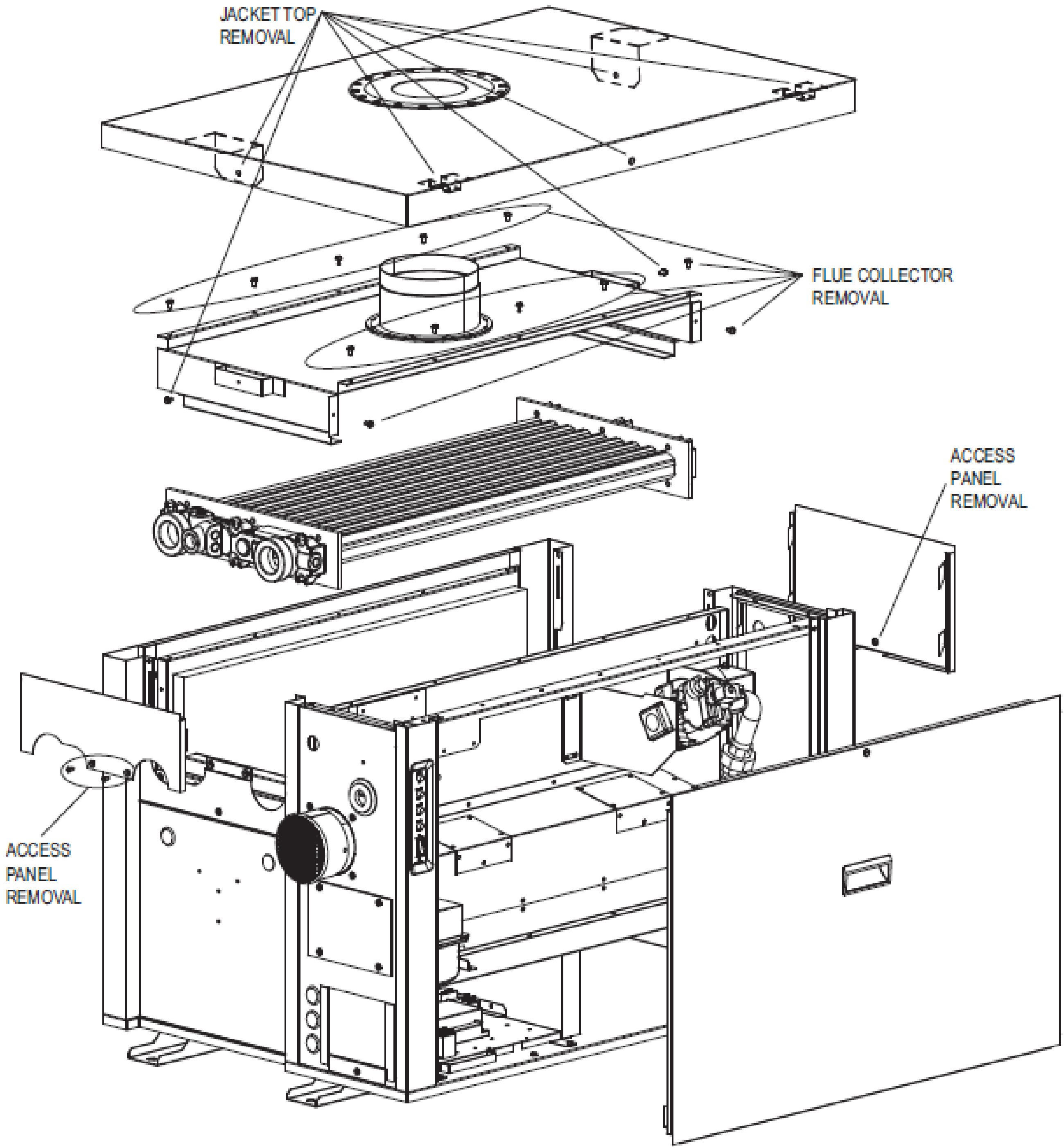


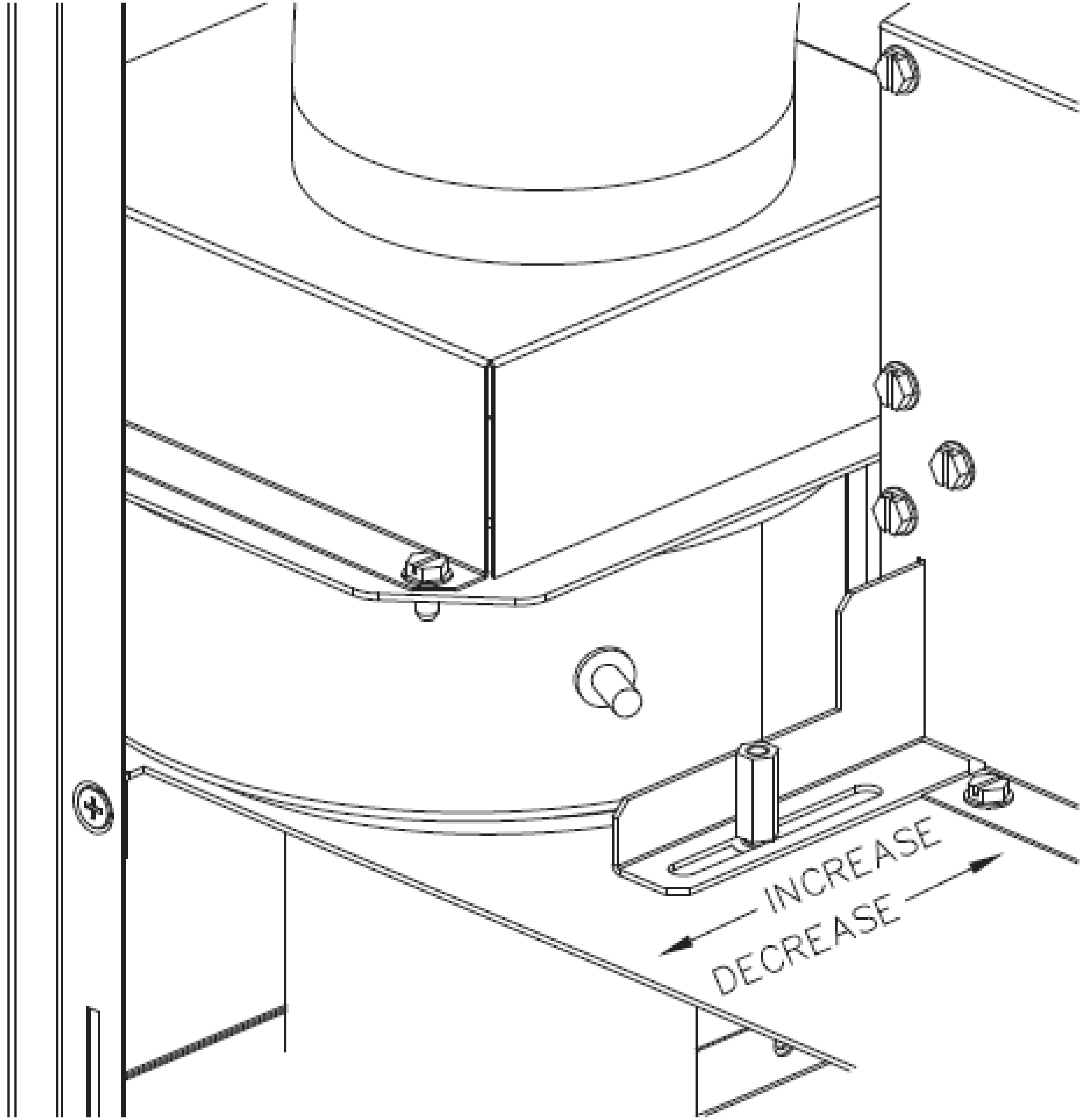


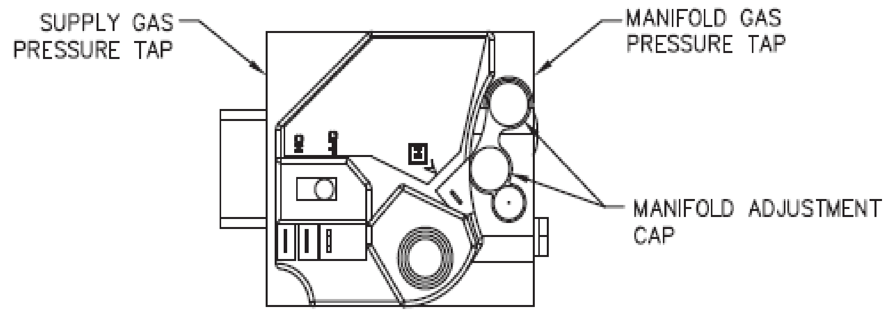


1 Diagnostic Control Center
2 Fenwal ignition control
3 Central point wiring board
4 Transformer
5 Pump delay relay
6 Manual reset high limit
7 Main power disconnect
8 Standby power switch
9 Status lights

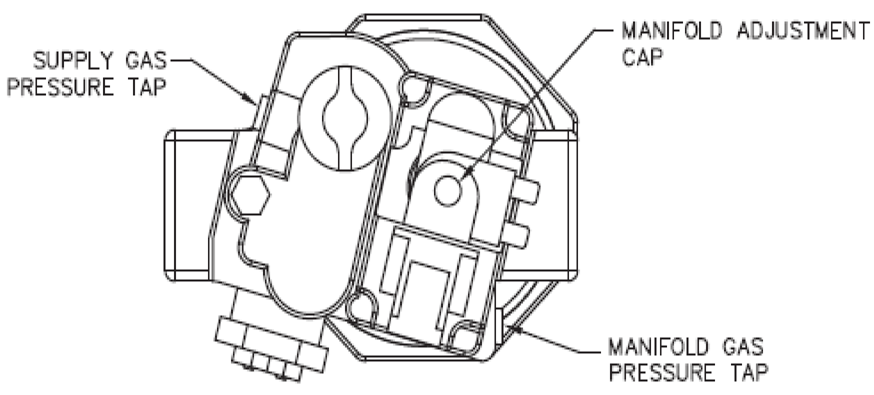

CONTROLLER
(OPTIONAL ON HD401)
FLUE EXHAUST TUBE
PANEL REMOVED
FOR CLARITY
BLOCKED FLUE VENT SWITCH
(BEHIND CONTROLLER)
OPTIONAL
HIGH LIMITS
GAS VALVE
FLAME SENSOR
STATUS LIGHT
ON/OFF SWITCH
AIR INTAKE
FILTER
BOX
IGNITER
CONTROLS TRAY
GAS TRAIN
BLOWER
BURNERS


JACKET TOP REMOVAL
FLUE COLLECTOR REMOVAL
ACCESS PANEL REMOVAL
ACCESS PANEL REMOVAL

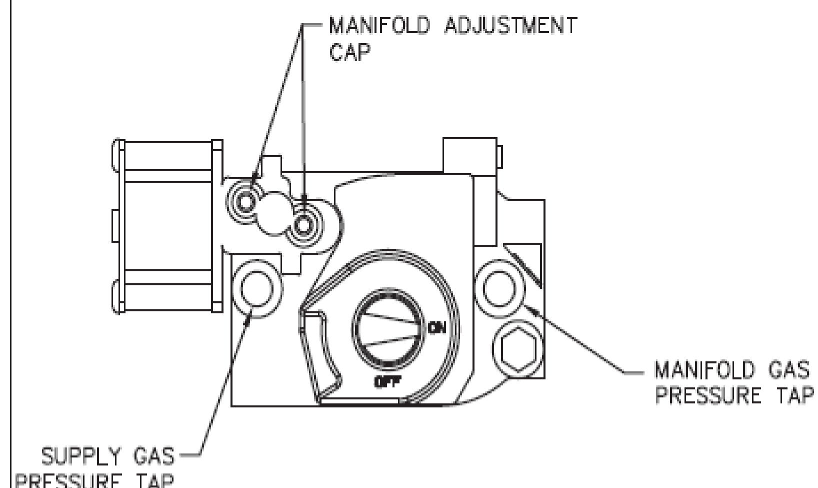

INCREASE
DECREASE



WHITE RODGERS
GAS VALVE

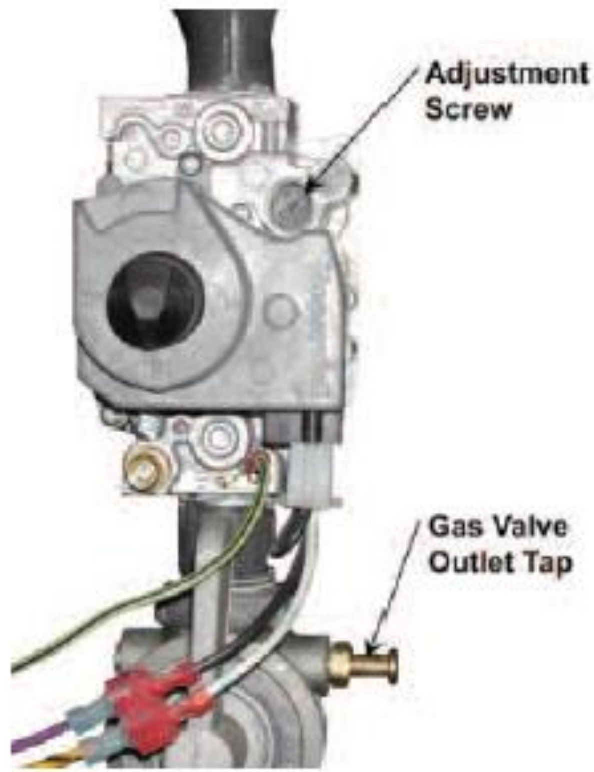


INVENSYS
GAS VALVE



HONEYWELL
GAS VALVE

Gas pressure



TempTracker

Designed to sequence multiple boilers up to four total stages, whether it's one to four on/off boilers, two two-stage boilers, or one boiler with up to four stages. It is available factory-mounted or loose. (See Cat. 5100.22)

RayTemp

Demand-based set-point control maximizes energy savings in domestic hot water applications (See Cat. 5100.18)

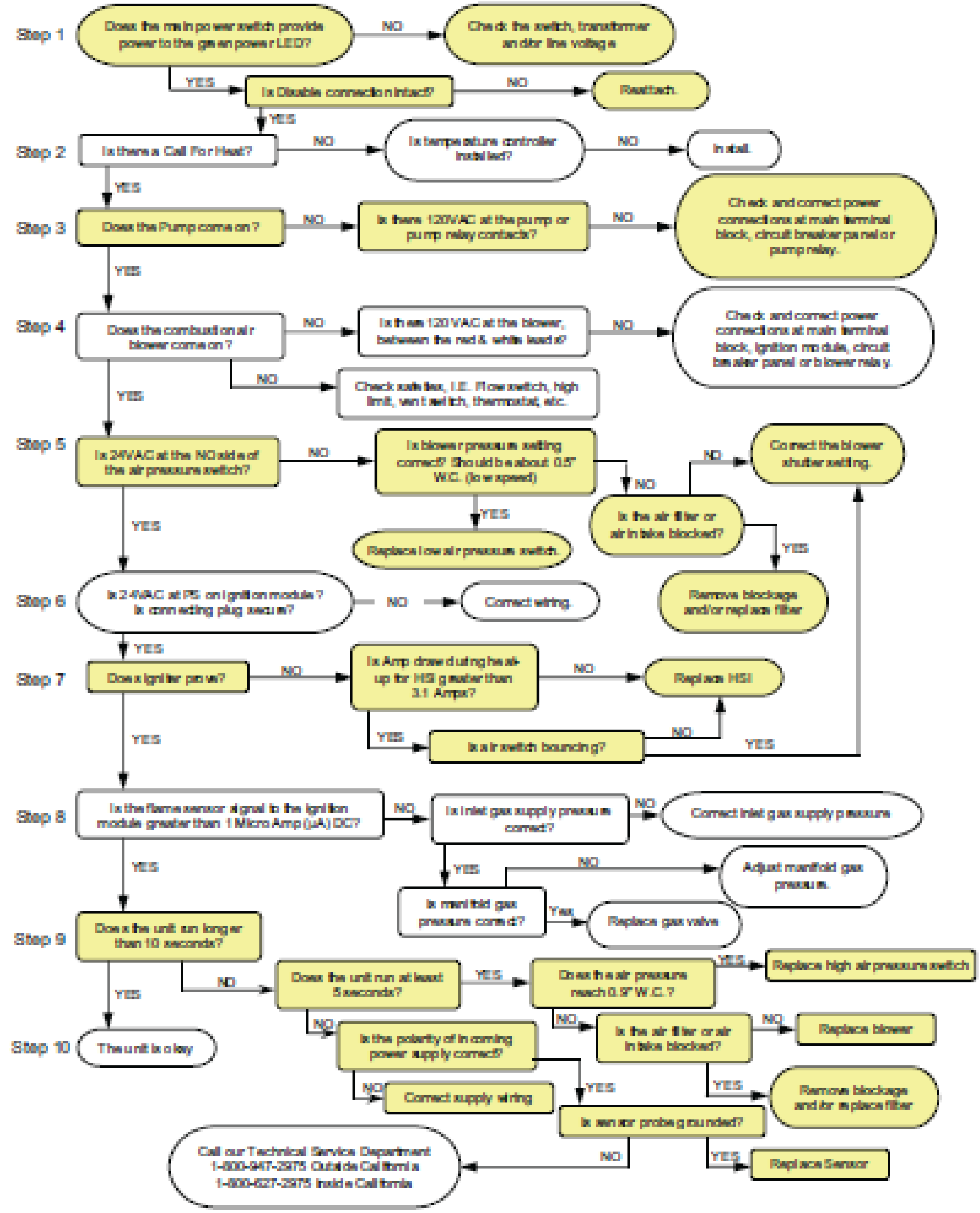
Y-200 Boiler Sequencer

Provides additional functionality for multiple-boiler installations. Compatible with LonWorks® Building Management Systems (BMS) (See Cat. #5100.22)

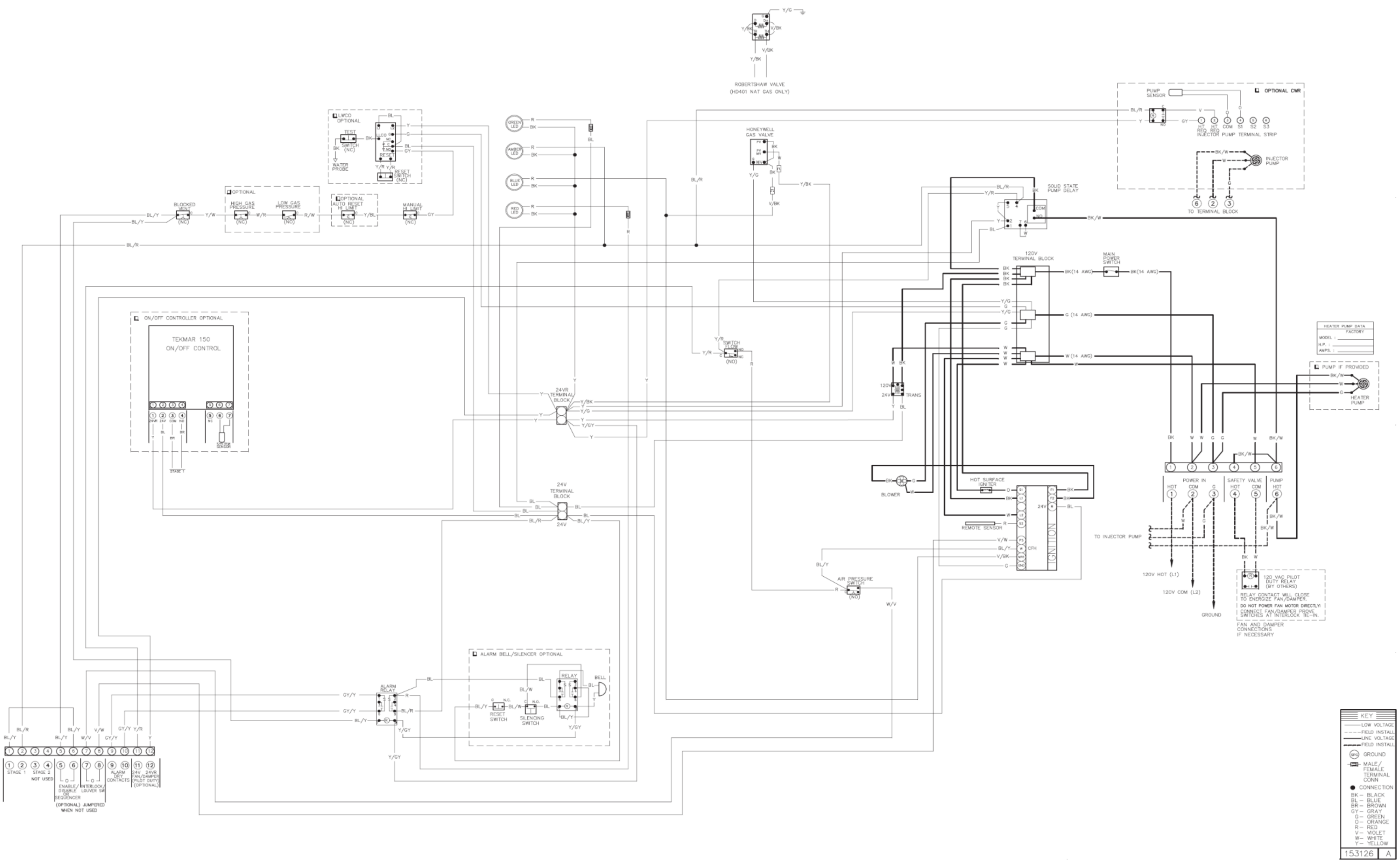
Example Diagnostic Fault Report

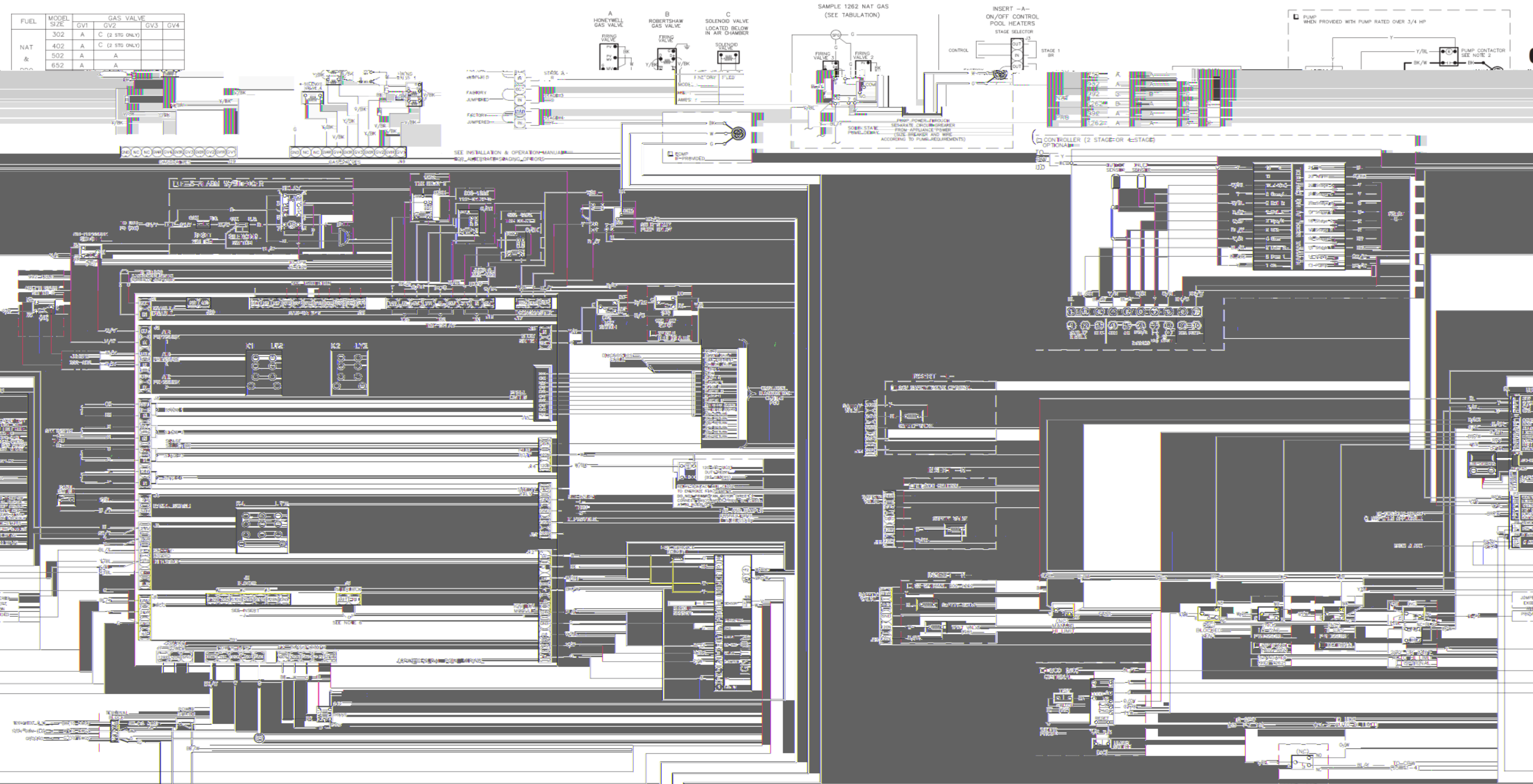
Water Flow Sw Fault
Check Boiler Pump, Purge Air, Replace Flow Switch

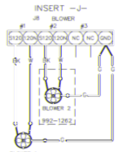
HD101-HD401 Troubleshooting



Code	Condition
On	System OK No faults present
Off	Possible control fault Check power
1 Flash	Low air pressure, brief flashing normal on startup
2 Flashes	Flame in combustion chamber, no Call For Heat
3 Flashes	Ignition lockout
4 Flashes	Low igniter current
5 Flashes	Low 24 VAC, check control supply voltage
6 Flashes	Internal fault Replace module


ROBERTSHAW VALVE
(HD401 NAT GAS ONLY)
HONEYWELL
GAS VALVE
OPTIONAL CWR
PUMP
SENSOR
HIT REQ
HIT REQ
COM
S1
S2
S3
INJECTOR PUMP TERMINAL STRIP
INJECTOR
PUMP
TO TERMINAL BLOCK
SOLID STATE
PUMP DELAY
LWCO
OPTIONAL
TEST
SWITCH
(NC)
WATER
PROBE
RESET
SWITCH
(NC)
GREEN
LED
AMBER
LED
BLUE
LED
RED
LED
BLOCKED
VENT
(NC)
OPTIONAL
HIGH GAS
PRESSURE
(NC)
LOW GAS
PRESSURE
(NO)
OPTIONAL
AUTO RESET
HI LIMIT
(NC)
MANUAL
HI LIMIT
(NC)
120V
TERMINAL BLOCK
MAIN
POWER
SWITCH
BK(14 AWG)
G (14 AWG)
W (14 AWG)
HEATER PUMP DATA
FACTORY
MODEL :
H.P. :
AMPS. :
PUMP IF PROVIDED
HEATER
PUMP
ON/OFF CONTROLLER OPTIONAL
TEKMAR 150
ON/OFF CONTROL
SYSTEM
SENSOR
STAGE 1
24VR
TERMINAL
BLOCK
SWITCH
FLOW
(NO)
TRANS
BLOWER
HOT SURFACE
IGNITER
REMOTE SENSOR
IGNITION
24V
TERMINAL
BLOCK
POWER IN
HOT
COM
G
SAFETY VALVE
HOT
COM
PUMP
HOT
TO INJECTOR PUMP
120V HOT (L1)
120V COM (L2)
GROUND
120 VAC PILOT
DUTY RELAY
(BY OTHERS)
RELAY CONTACT WILL CLOSE
TO ENERGIZE FAN/DAMPER.
DO NOT POWER FAN MOTOR DIRECTLY!
CONNECT FAN/DAMPER PROVE
SWITCHES AT INTERLOCK TIE-IN.
FAN AND DAMPER
CONNECTIONS
IF NECESSARY
AIR PRESSURE
SWITCH
(NO)
ALARM BELL/SILENCER OPTIONAL
ALARM
RELAY
RELAY
BELL
RESET
SWITCH
SILENCING
SWITCH
STAGE 1
STAGE 2
NOT USED
ENABLE/
DISABLE
OR
SEQUENCER
INTERLOCK/
LOUVER SW
ALARM
DRY
CONTACTS
24V
24VR
FAN/DAMPER
PILOT DUTY
(OPTIONAL)
(OPTIONAL) JUMPERED
WHEN NOT USED
KEY
LOW VOLTAGE
FIELD INSTALL
LINE VOLTAGE
FIELD INSTALL
GROUND
MALE/
FEMALE
TERMINAL
CONN
CONNECTION
BK– BLACK
BL– BLUE
BR– BROWN
GY– GRAY
G– GREEN
O– ORANGE
R– RED
V– VIOLET
W– WHITE
Y– YELLOW
153126
A





INSERT -J-

NOTES:

7. CORRECT OPERATIONAL STATUS OF SAFETIES SHOWN AS ( )
6. ALL INTERLOCK SWITCHES MUST BE WIRED IN SERIES AT J9
5. IF ANY OF THE ORIGINAL WIRE AS SUPPLIED WITH THE HEATER MUST BE REPLACED, IT MUST BE REPLACED WITH ITS EQUIVALENT 105°C.
4. ☑ CHECK CONTROLS PROVIDED (WIRED AS SHOWN)
3. PUMP DELAY 10 MINUTES MAX.
2. PUMP CONTACTOR MUST BE RATED FOR APPROPRIATE PUMP SIZE.
1. USE GROUND CONNECTION PROVIDED. FAILURE TO PROVIDE PROPER GROUND MAY RESULT IN LOCK-OUT.

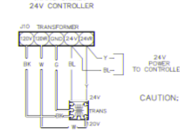
KEY

LOW VOLTAGE
FIELD INSTALL
LINE VOLTAGE
FIELD INSTALL
GROUND
CONNECTION
MALE/FEMALE TERMINAL CONN

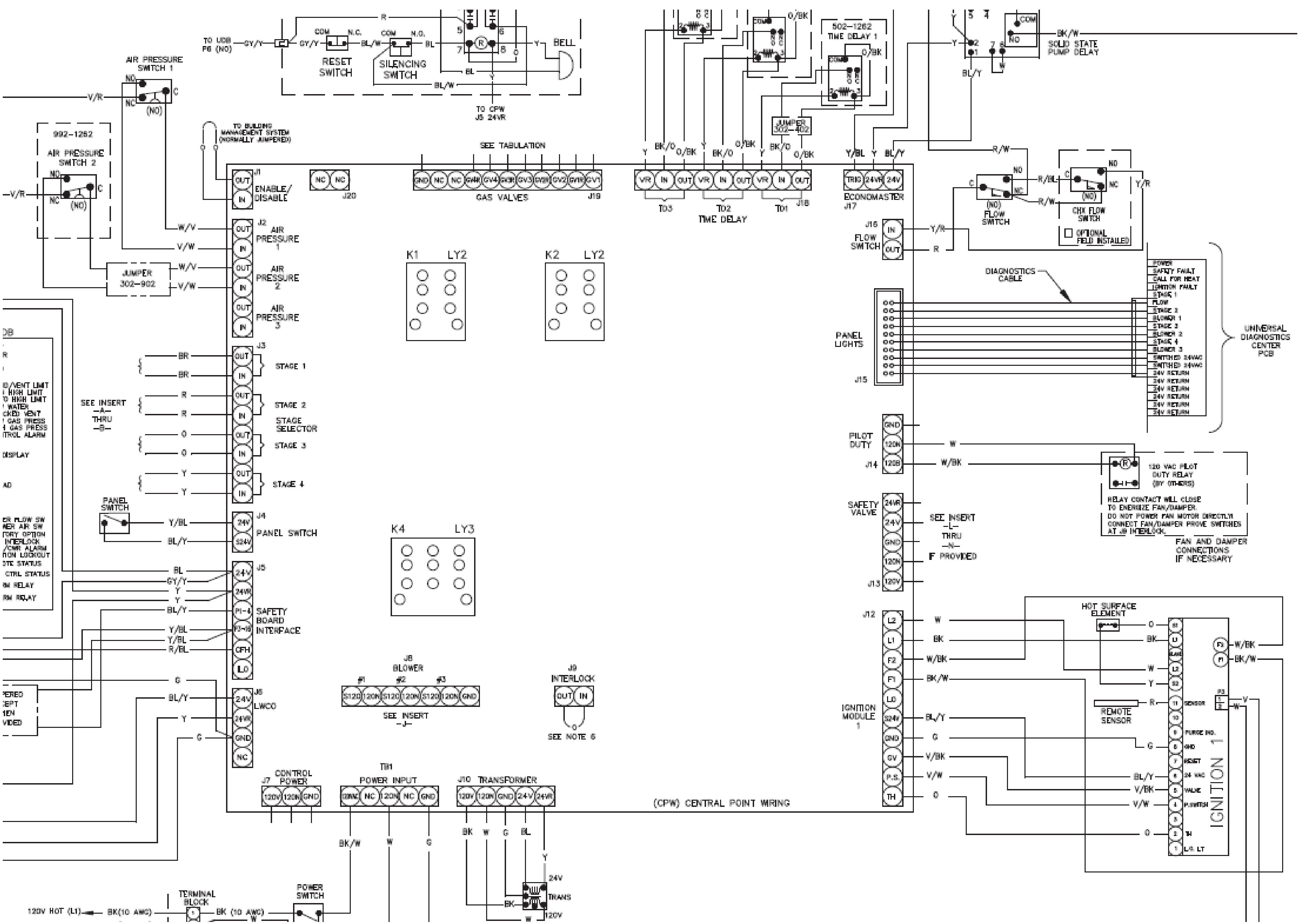
BK – BLACK
BL – BLUE
BR – BROWN
GY – GRAY
G – GREEN
O – ORANGE
R – RED
V – VIOLET
W – WHITE
Y – YELLOW

152958 | 11

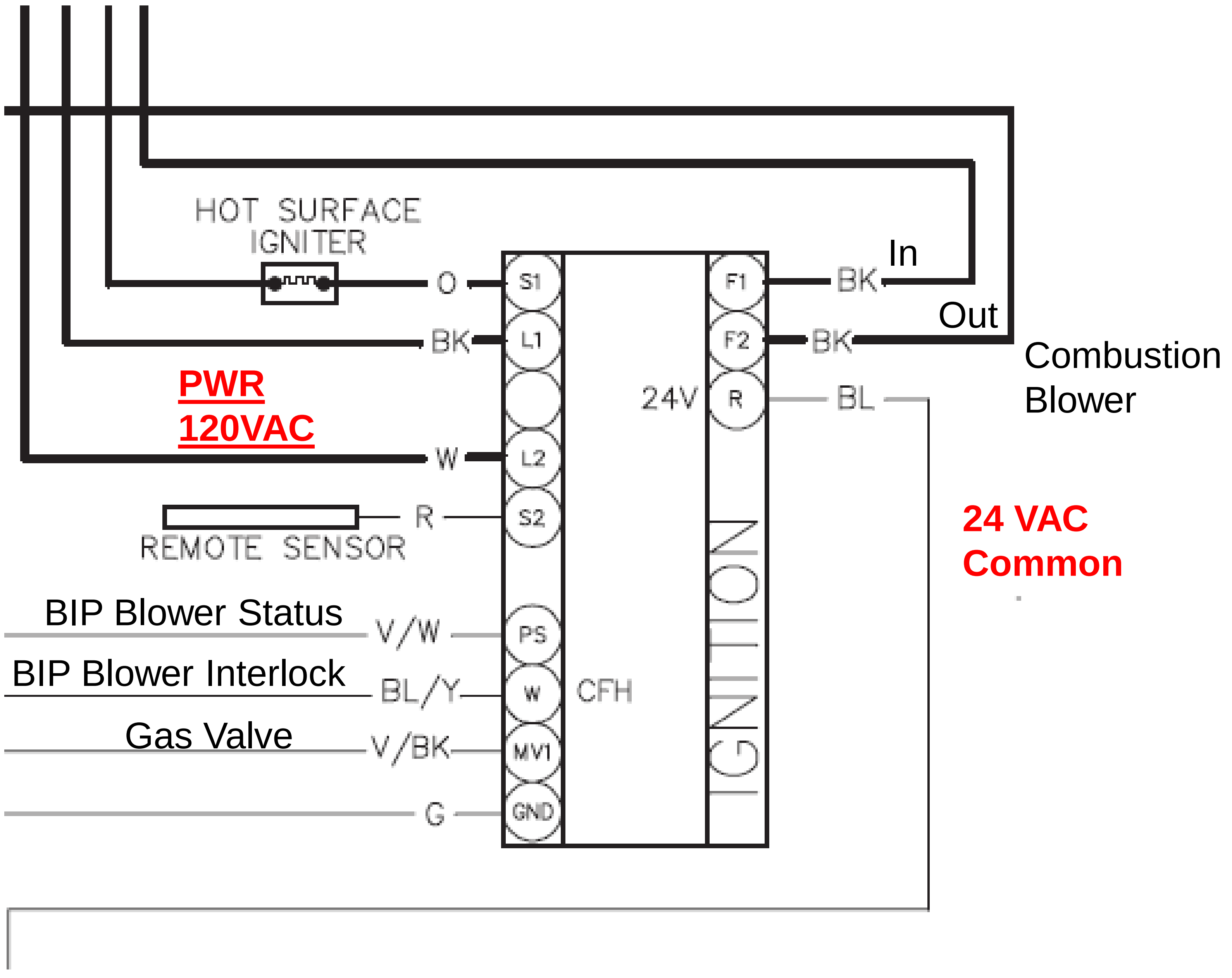
INSERT -H-
TRANSFORMER
24V CONTROLLER



CAUTION: CONNECT APPROPRIATE POWER SUPPLY TO DIGITAL CONTROLLER, OBSERVE PROPER VOLTAGE REQUIREMENT.
FOR 24V USE J10 TRANSFORMER PLUG. SEE INSERT -H-
FOR 120V USE J7 CONTROL POWER PLUG

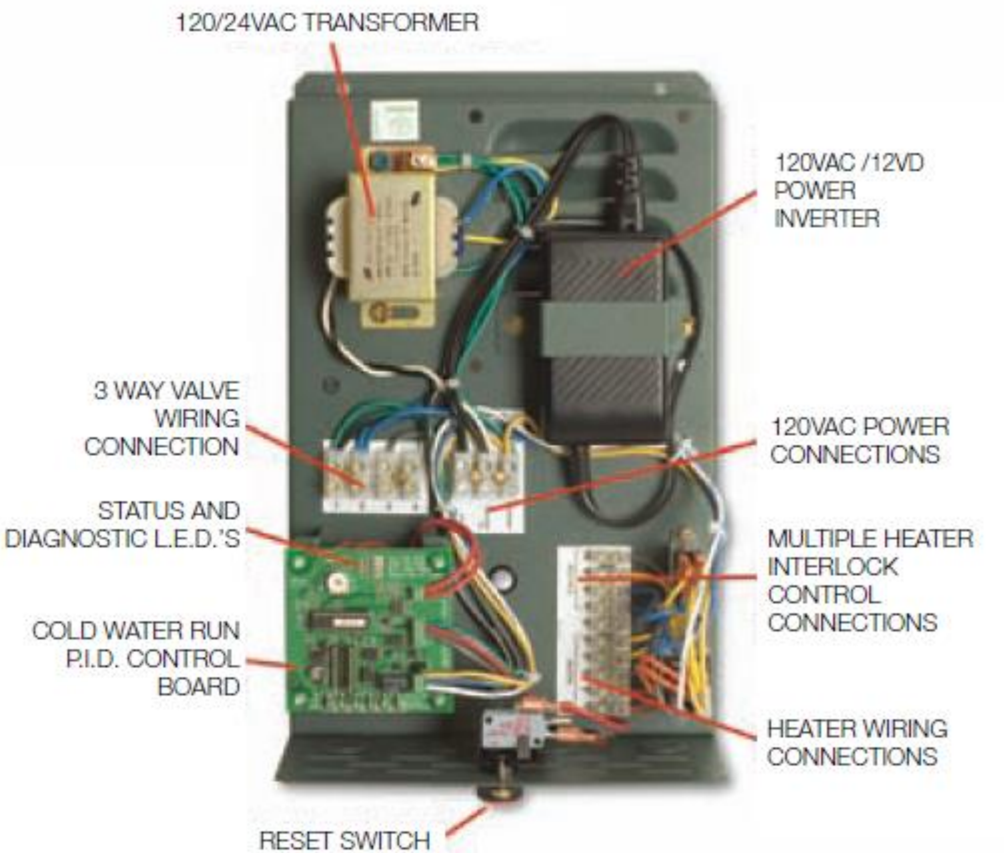


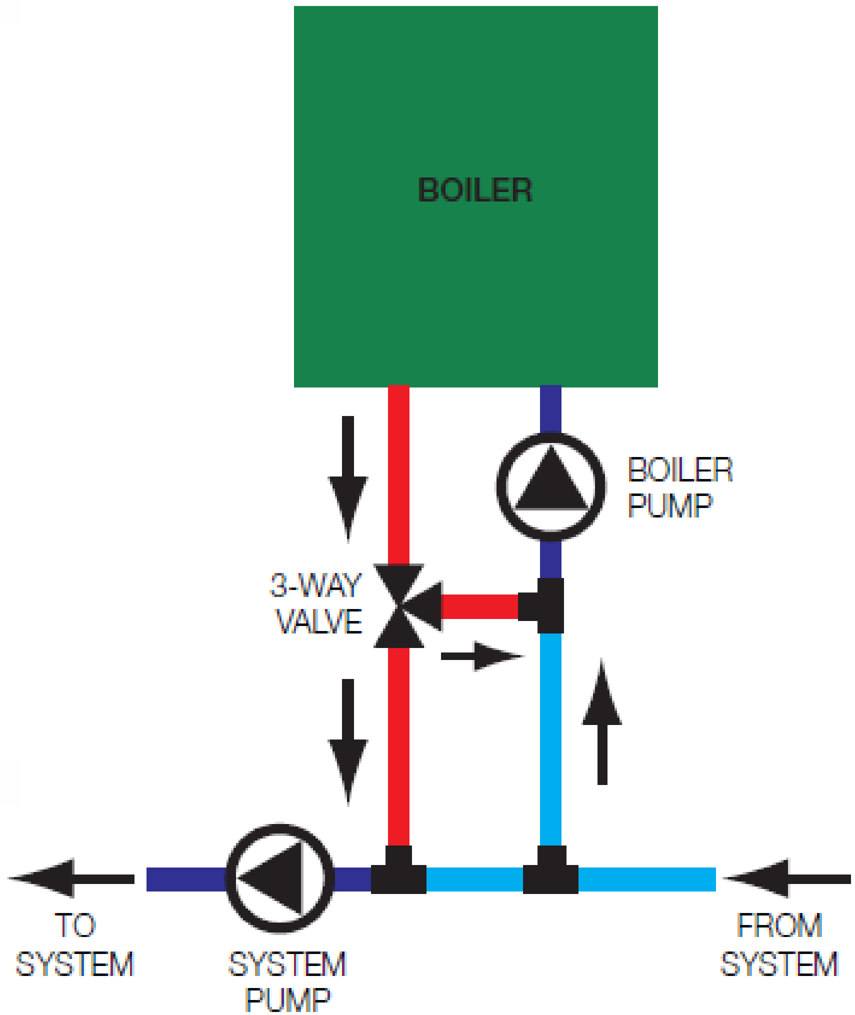
AIR PRESSURE SWITCH 1
992-1262
AIR PRESSURE SWITCH 2
TO UDB F6 (NO)
RESET SWITCH
SILENCING SWITCH
BELL
TO CPW J5 24VR
TO BUILDING MANAGEMENT SYSTEM (NORMALLY JUMPERED)
SEE TABULATION
502-1262 TIME DELAY 1
JUMPER 302-402
SOLID STATE PUMP DELAY
ENABLE/ DISABLE
J20
GAS VALVES
J19
TD3
TD2 TIME DELAY
TD1
J18
ECONOMASTER J17
AIR PRESSURE 1
AIR PRESSURE 2
AIR PRESSURE 3
JUMPER 302-902
FLOW SWITCH
CHX FLOW SWITCH
OPTIONAL FIELD INSTALLED
K1 LY2
K2 LY2
DIAGNOSTICS CABLE
POWER
SAFETY FAULT
CALL FOR HEAT
IGNITION FAULT
STAGE 1
FLOW
STAGE 2
BLOWER 1
STAGE 3
BLOWER 2
STAGE 4
BLOWER 3
SWITCHED 24VAC
SWITCHED 24VAC
24V RETURN
UNIVERSAL DIAGNOSTICS CENTER PCB
PANEL LIGHTS
J15
STAGE 1
STAGE 2
STAGE SELECTOR
STAGE 3
STAGE 4
SEE INSERT -A- THRU -B-
PILOT DUTY
J14
120 VAC PILOT DUTY RELAY (BY OTHERS)
RELAY CONTACT WILL CLOSE TO ENERGIZE FAN/DAMPER. DO NOT POWER FAN MOTOR DIRECTLY! CONNECT FAN/DAMPER PROVE SWITCHES AT J9 INTERLOCK.
FAN AND DAMPER CONNECTIONS IF NECESSARY
PANEL SWITCH
J4 PANEL SWITCH
K4 LY3
SAFETY VALVE
SEE INSERT -L- THRU -N- IF PROVIDED
J13
J5 SAFETY BOARD INTERFACE
J12
HOT SURFACE ELEMENT
J8 BLOWER
#1 #2 #3
SEE INSERT -J-
J9 INTERLOCK
SEE NOTE 6
IGNITION MODULE 1
REMOTE SENSOR
IGNITION 1
J6 LWCO
J7 CONTROL POWER
TB1 POWER INPUT
J10 TRANSFORMER
(CPW) CENTRAL POINT WIRING
24V
TRANS
120V
TERMINAL BLOCK
POWER SWITCH
120V HOT (L1)
BK(10 AWG)
BK (10 AWG)



HOT SURFACE IGNITER
O
S1
BK
L1
PWR 120VAC
W
L2
R
S2
REMOTE SENSOR
24V
F1
F2
R
BK
In
BK
Out
Combustion Blower
BL
24 VAC Common
BIP Blower Status
V/W
PS
BIP Blower Interlock
BL/Y
W
CFH
Gas Valve
V/BK
MV1
G
GND
IGNITION

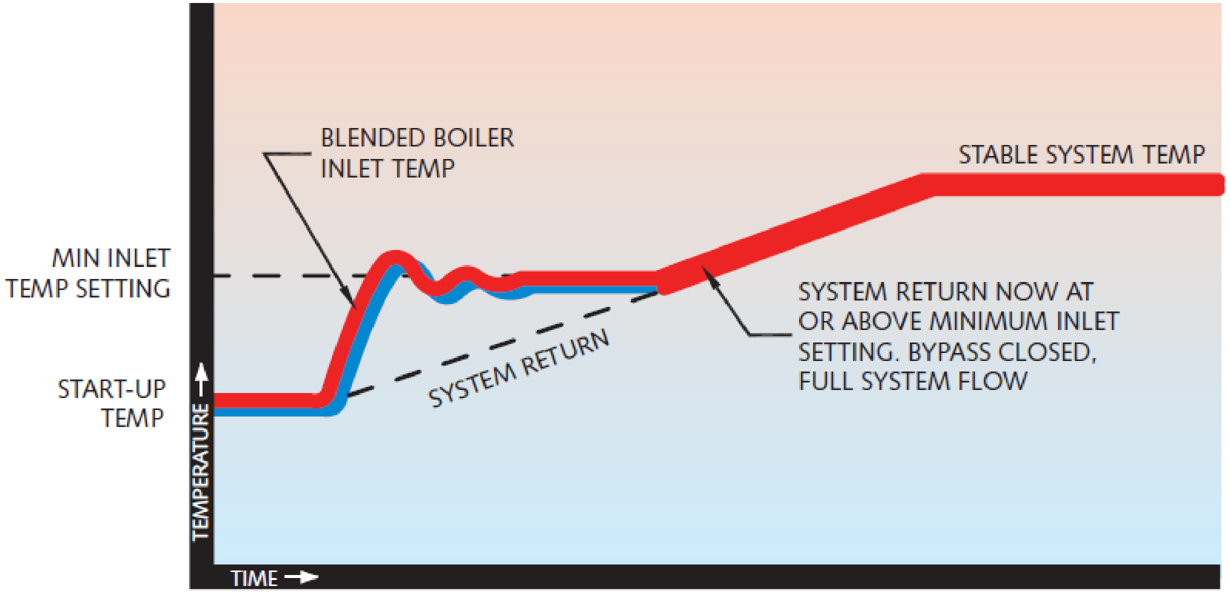
Cold Water Start





Cold Water Start

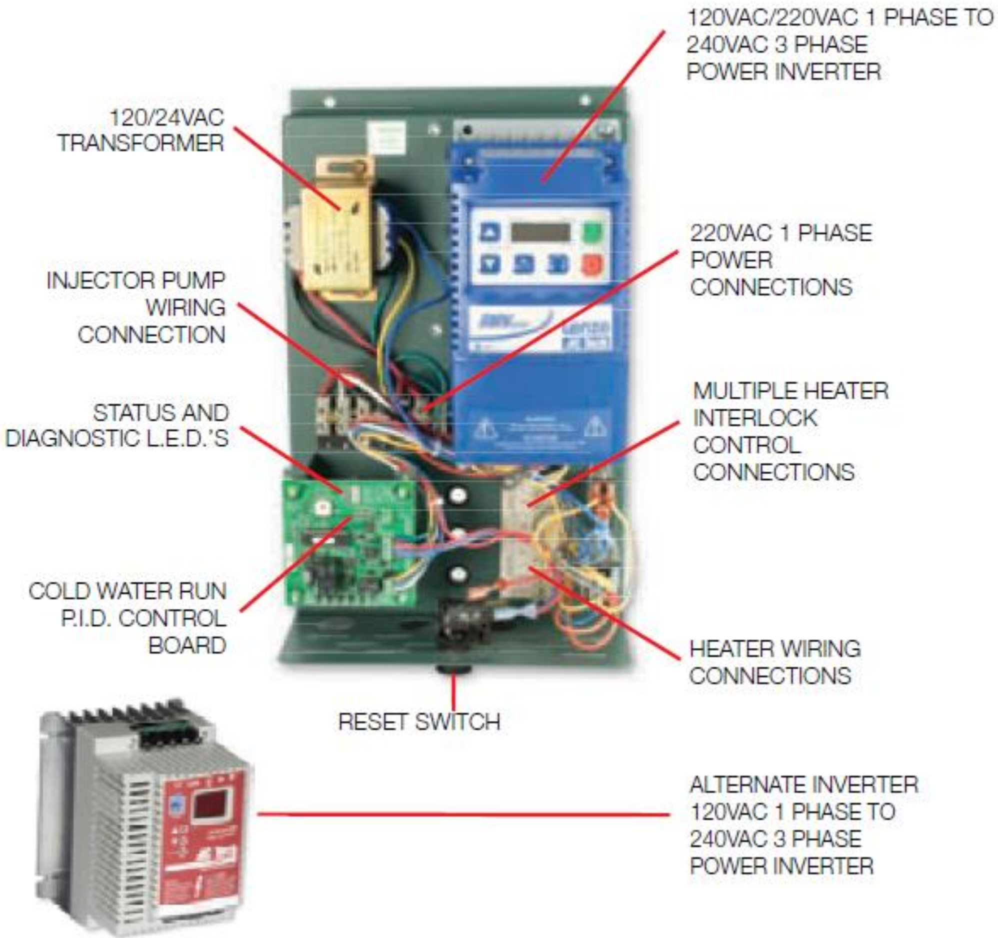
Boiler Start-Up Cycle

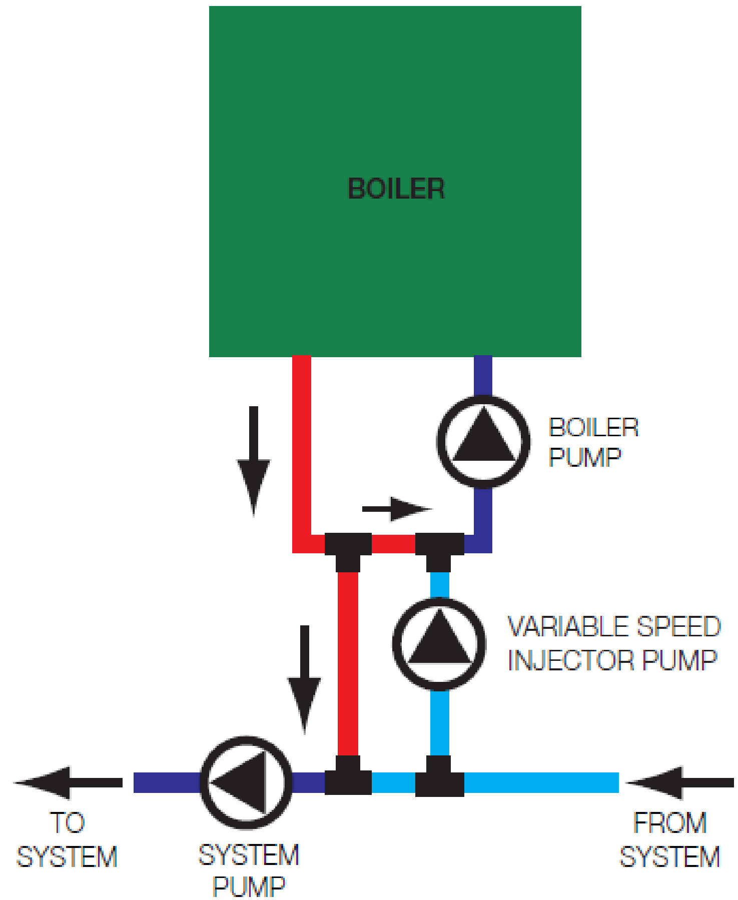


Raypak's Cold Water Start system:

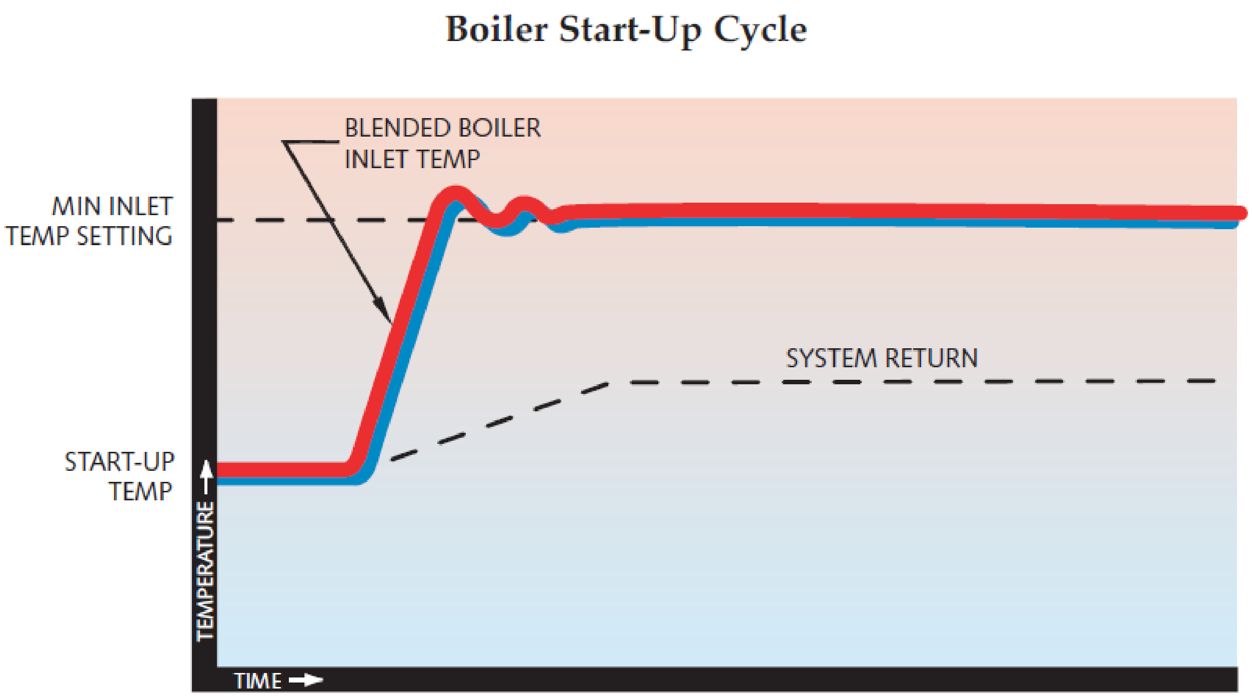
- Continuously monitors and adjusts inlet water temperature to prevent condensation
- Regulates minimum inlet water temperature during system start-up
- Activates alarm and/or shuts down boiler if the minimum inlet water temperature is not achieved
- Eliminates job site set-up with proprietary self-tuning controller and system-matched components
- Utilizes proportional three-way valve to achieve bypass
- Allows high-temperature system operation without cycling on high-limit

Cold Water Run





Cold Water Run

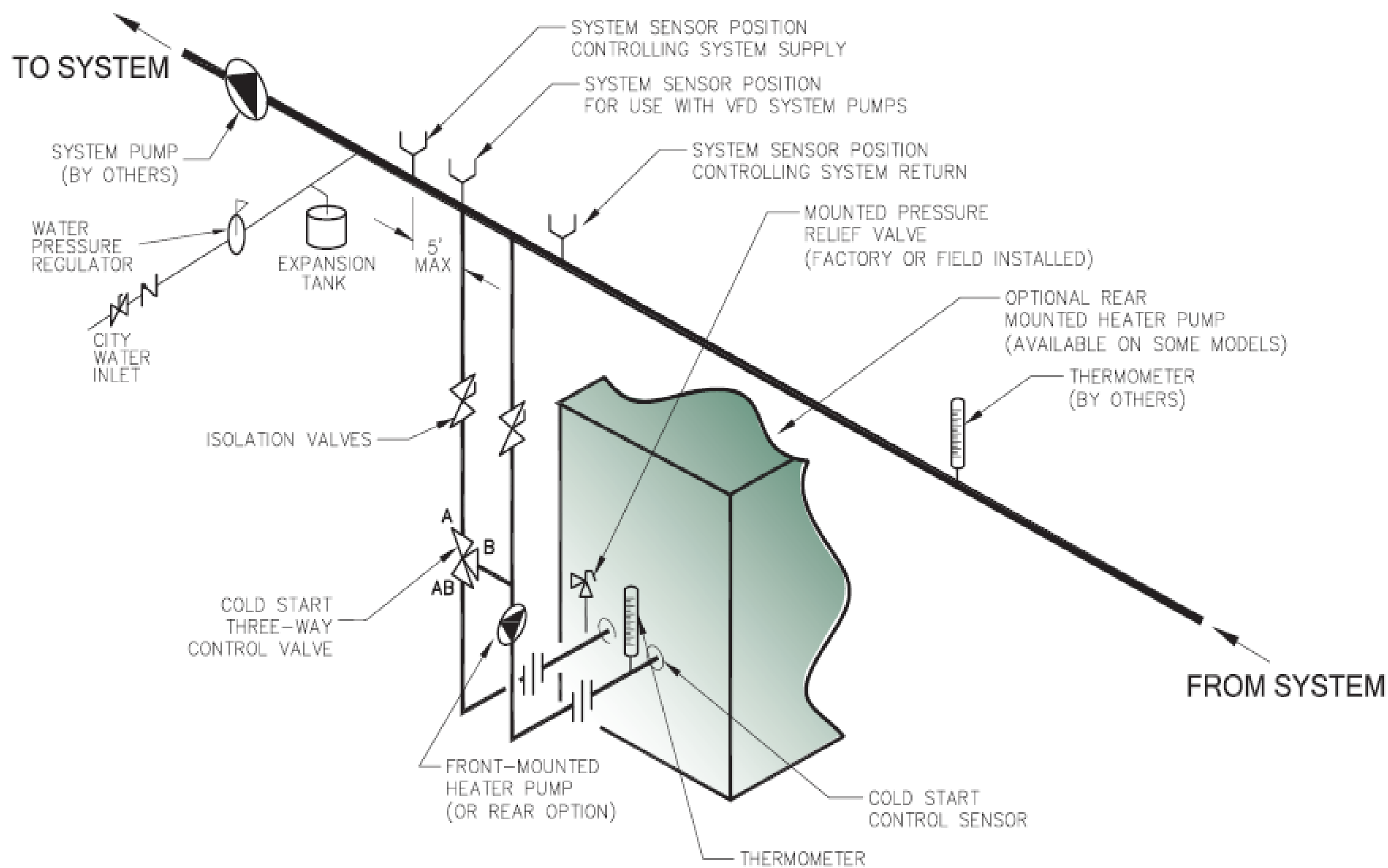


Raypak's Cold Water Run system:

- Continuously monitors and adjusts inlet water temperature to prevent condensation
- Regulates minimum inlet water temperature regardless of system temperature
- Activates alarm and/or shuts down boiler if the minimum inlet water temperature is not achieved
- Protects boiler from constant low return water temperatures with its proprietary self-tuning controller
- Utilizes variable-speed injector pump to control boiler loop temperature

COLD WATER START

TYPICAL BOILER PIPING*

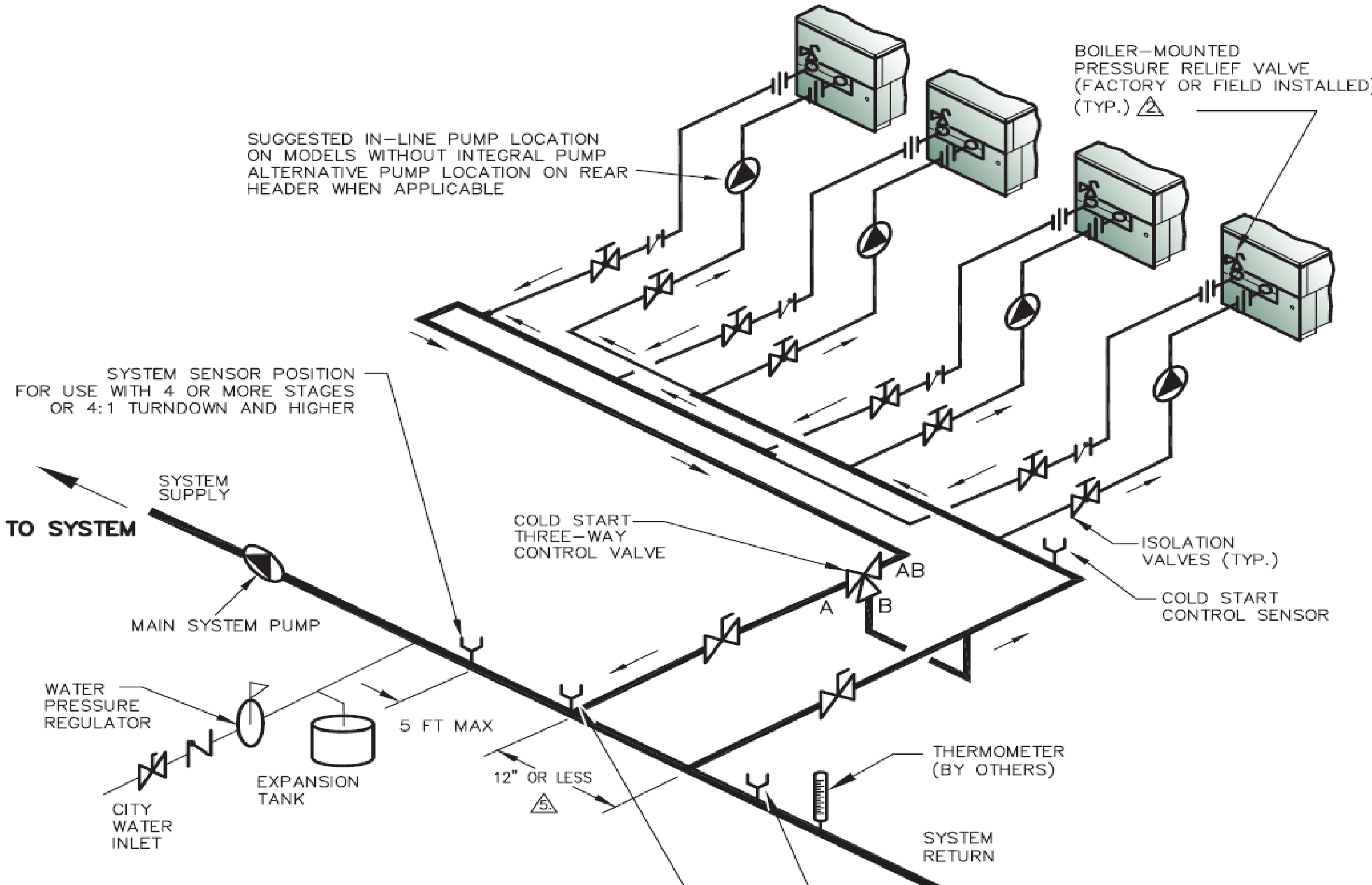


NOTES:

1. LOCATE UNINIONS TO FACILITATE SERVICICING OF PLUMBING SIDE.
2. PLUMB SWING CHECK VALVE IN GRAVITY-CLOSED POSITION.
3. PIPE ALL RELIEF VALVES TO DRAIN, OR AS LOCAL CODES REQUIRE.
4. BUFFER TANK REQUIRED WHEN WATER VOLUME IN BOILER LOOP IS NOT ADEQUATE TO PROVIDE STABLE TEMPERATURE CONTROL. CONSULT FACTORY FOR TANK SIZING.
5. SYSTEM FLOW MUST ECCEED HEATER FLOW AT ALL TIMES.

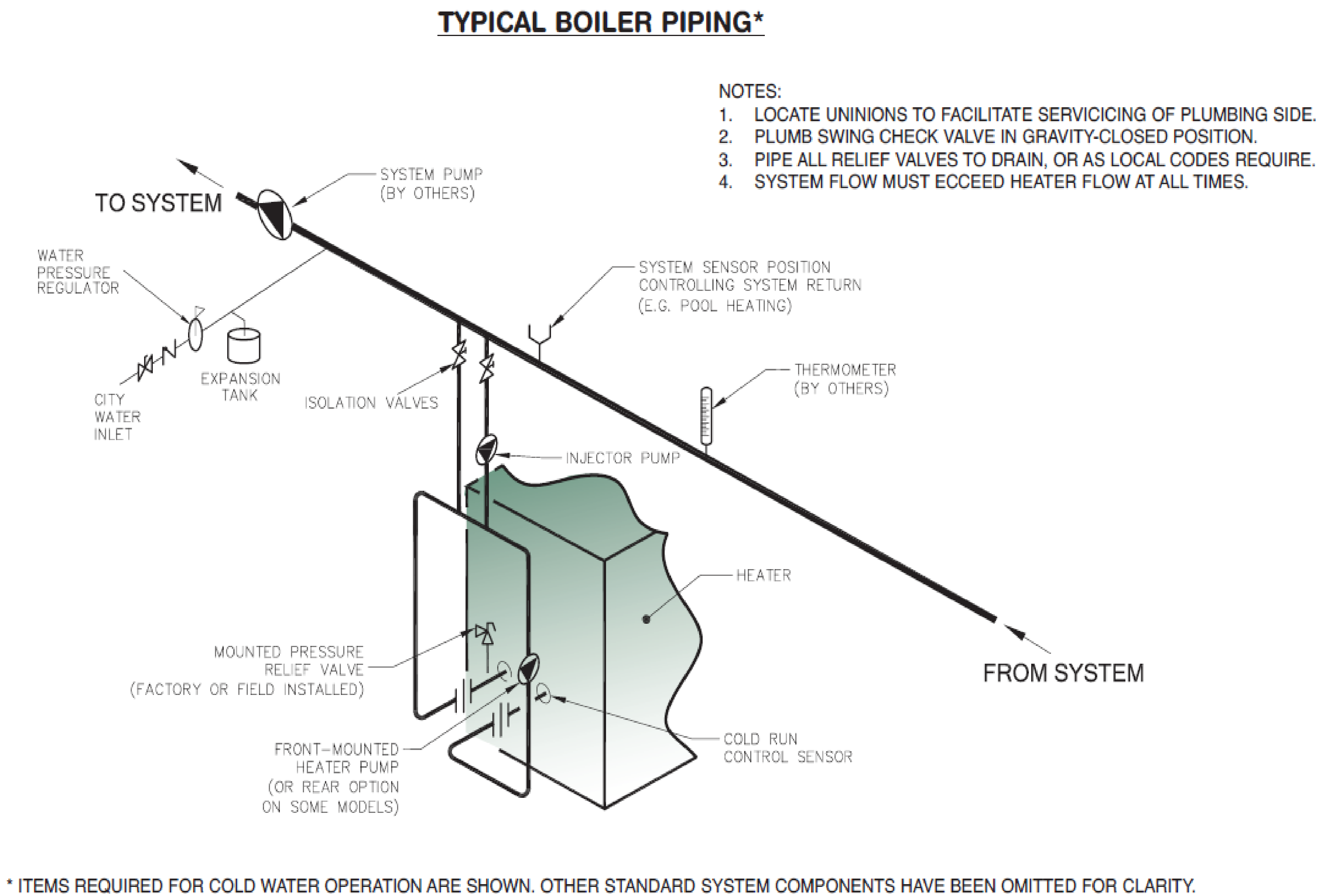
* ITEMS REQUIRED FOR COLD WATER OPERATION ARE SHOWN. OTHER STANDARD SYSTEM COMPONENTS HAVE BEEN OMITTED FOR CLARITY.

MULTIPLE UNIT COLD WATER START



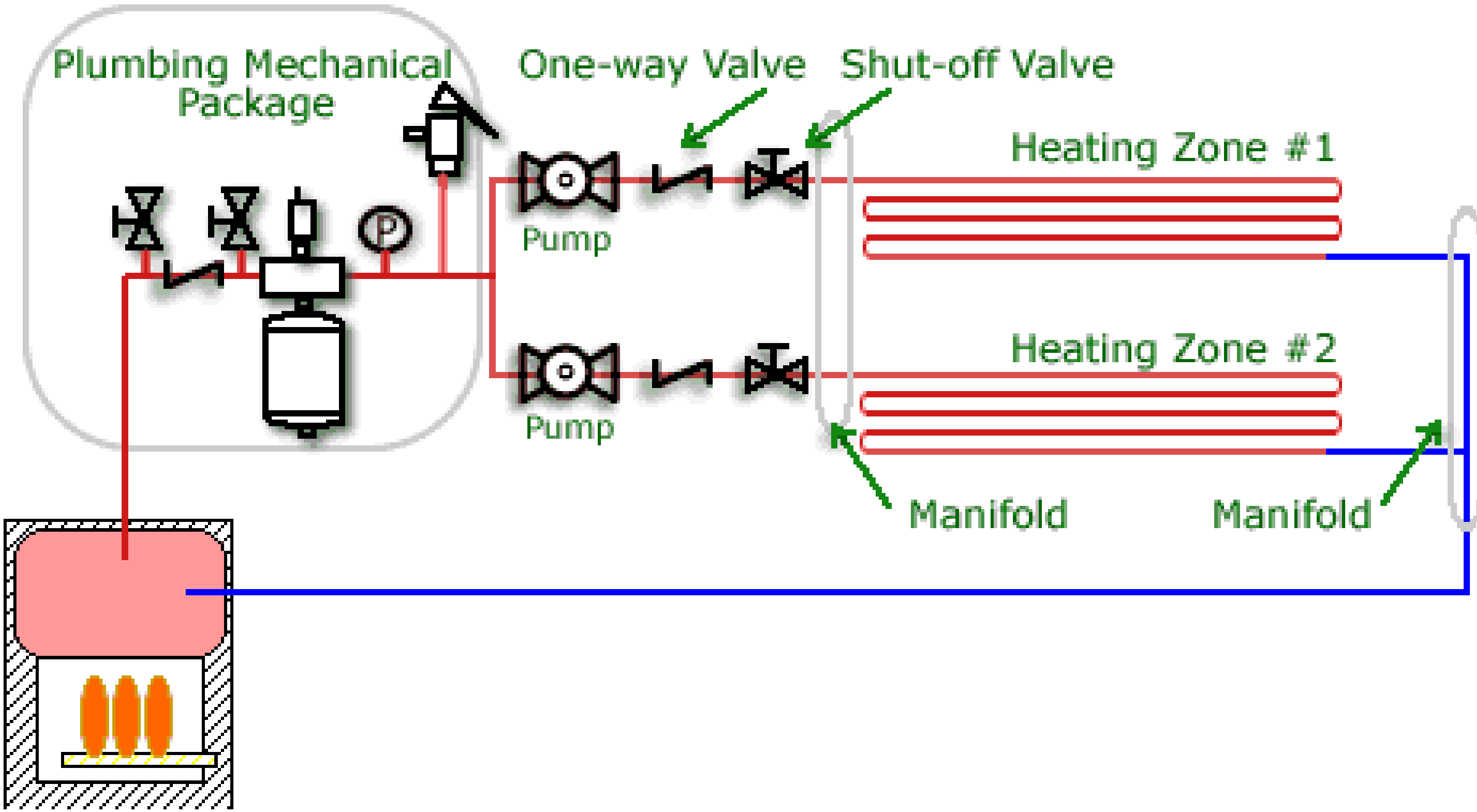
NOTES:
1. PLUMP SWING CHECK VALVE IN GRAVITY-CLOSED POSITION.
2. PIPE ALL RELIEF VALVES TO DRAIN, OR AS LOCAL CODES REQUIRE.
3. LOCATE UNIONS TO FACILITATE SERVICING OF PLUMBING SIDE.
4. BUFFER TANKS MAY BE REQUIRED TO PROVIDE STABLE TEMPERATURE CONTROL ON SYSTEMS WITH VARIABLE FLOW OR LOW WATER VOLUME. CONTACT FACTORY FOR SELECTION CRITERIA
5. NOT TO EXCEED 4 PIPE DIAMETERS.
6. SYTEM FLOW MUST EXCEED TOTAL MINIMUM FLOW RATE OF BOILERS.

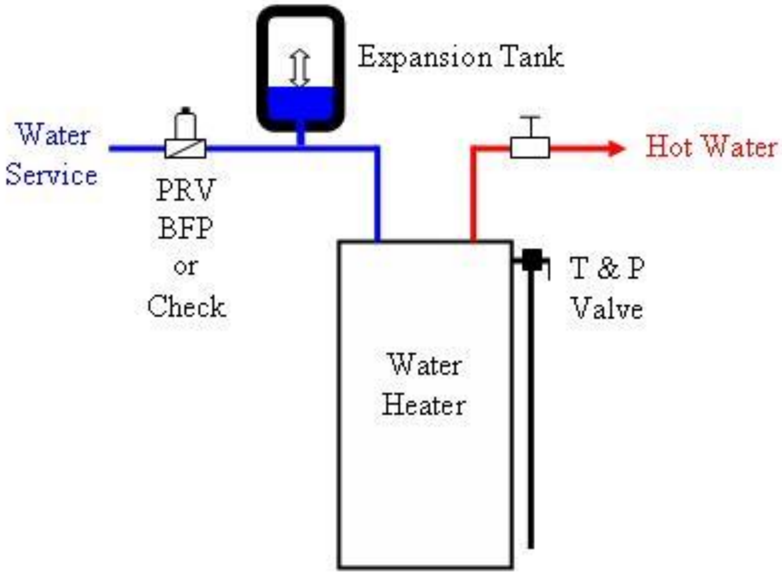
Cold Water Run

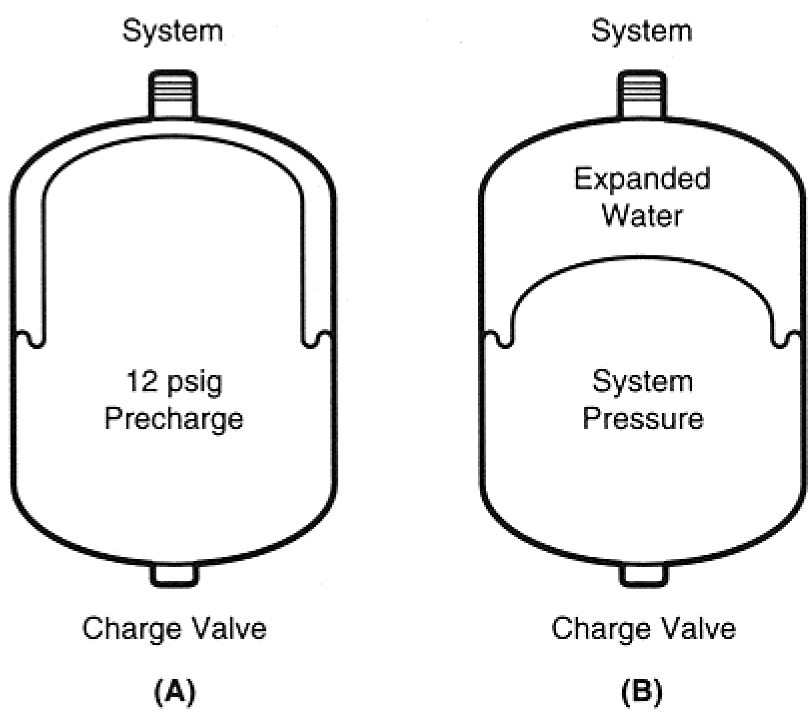


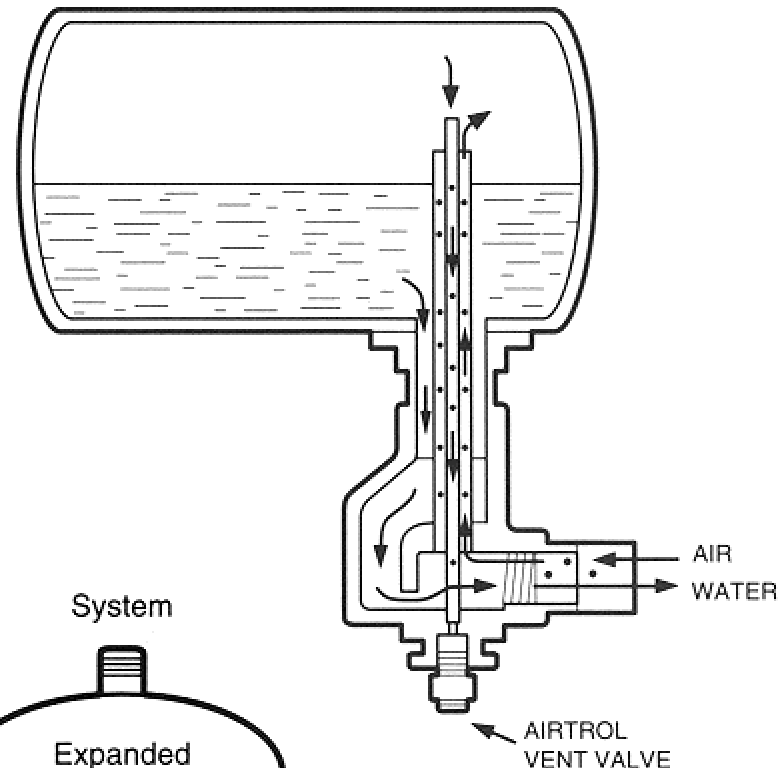
Cold water Start VS Cold Water run

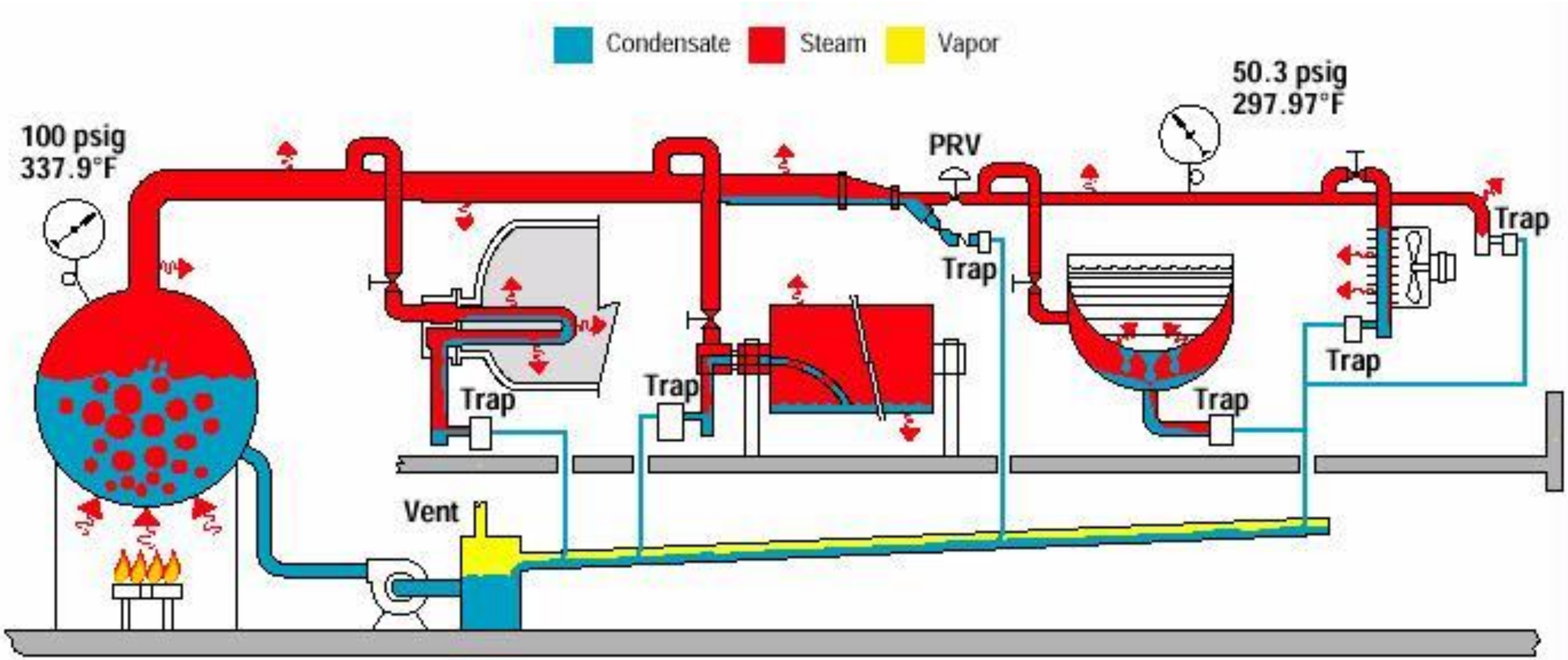
- Cold water start is for transient cold water operation
- Cold water run s for continuous operation below 105deg. F.
- Cold water start maintains design flow rate at system design temperatures but reduces boiler flow rate during heavy bypass operation.
- Cold water run maintains constant design flow rate in the boiler


Plumbing Mechanical Package
One-way Valve
Shut-off Valve
Heating Zone #1
Pump
Heating Zone #2
Pump
Manifold
Manifold


Expansion Tank
Water
Service
PRV
BFP
or
Check
Hot Water
T & P
Valve
Water
Heater


System
12 psig
Precharge
Charge Valve
(A)
System
Expanded
Water
System
Pressure
Charge Valve
(B)

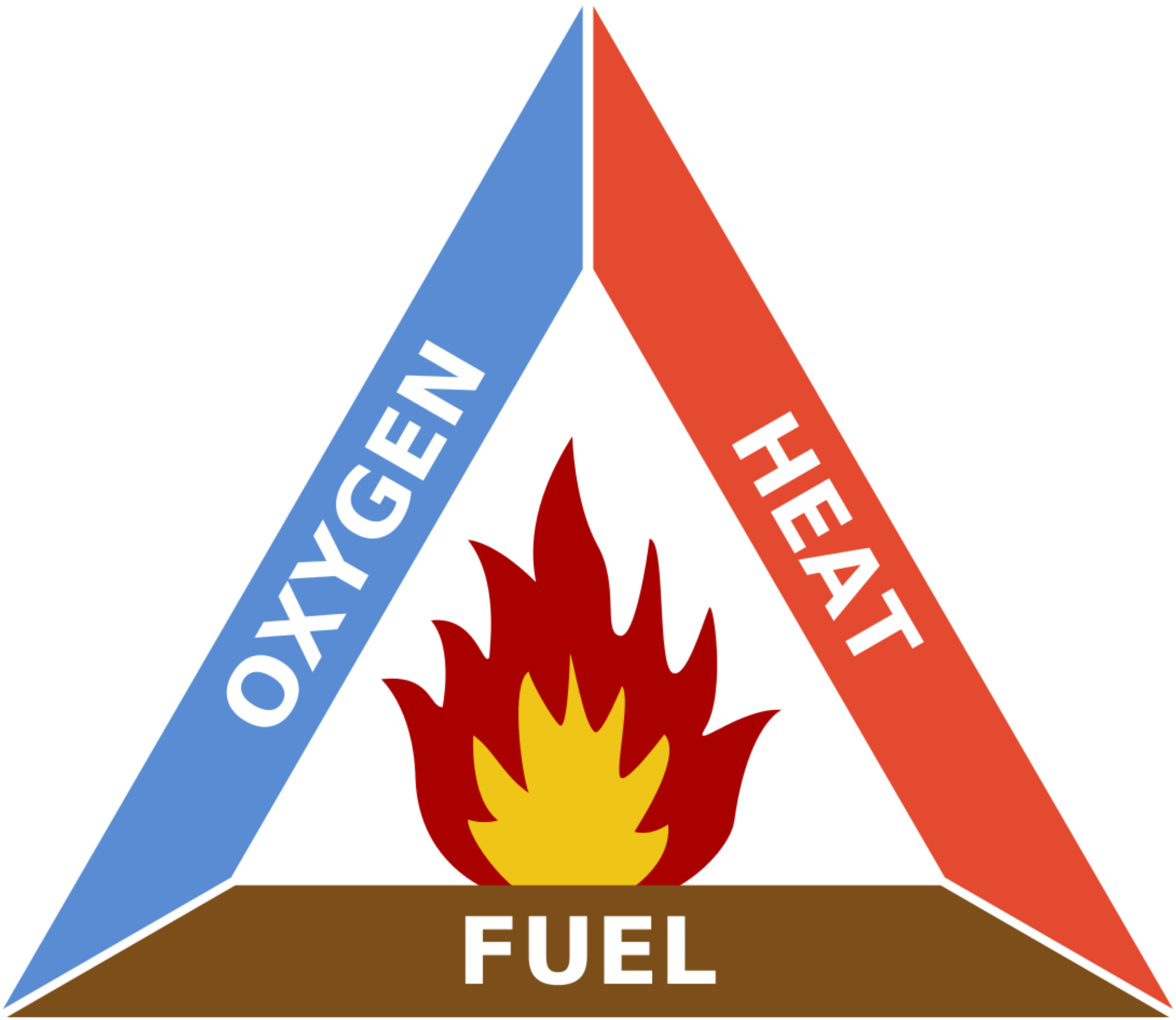

AIR
WATER
AIRTROL
VENT VALVE


Condensate
Steam
Vapor
100 psig
337.9°F
50.3 psig
297.97°F
PRV
Trap
Trap
Trap
Trap
Trap
Trap
Trap
Vent

All heating systems are designed and engineered to operate with very specific ranges of:

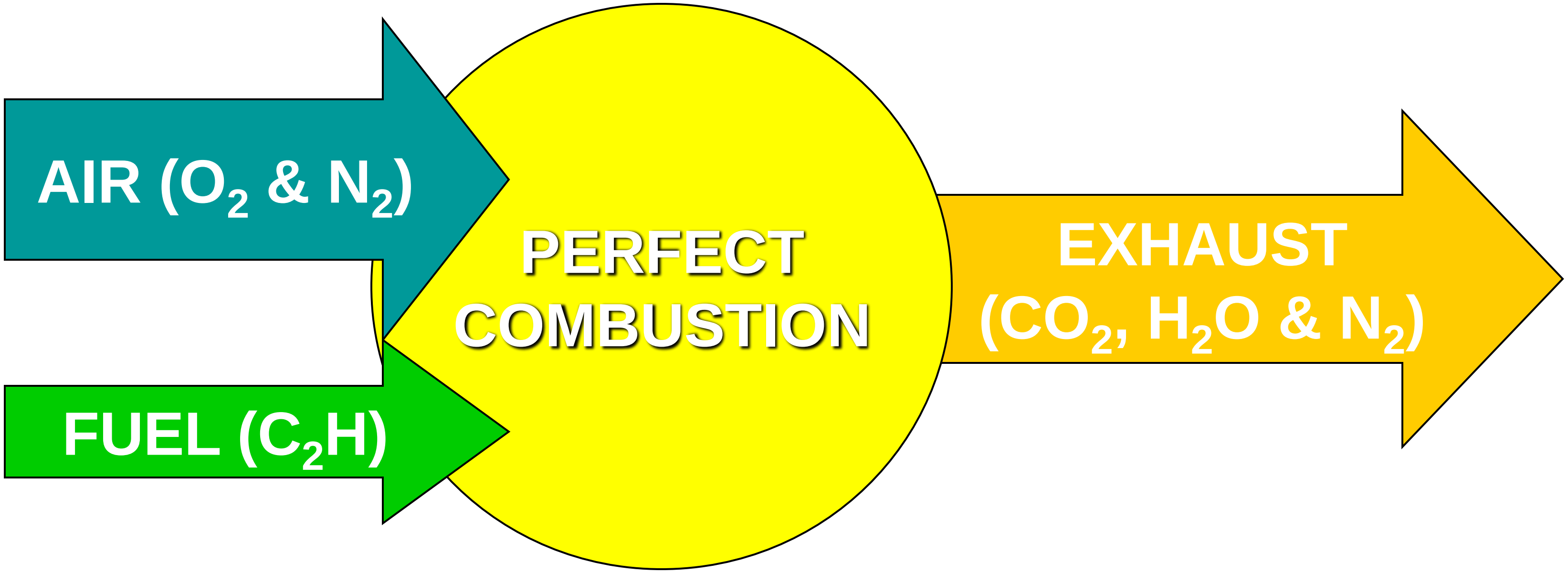
- **Combustion Air**
- **Carbon Monoxide**
- **Stack Temperature**
- **Temperature Rise** across the heat exchanger (air flow)

Combustion



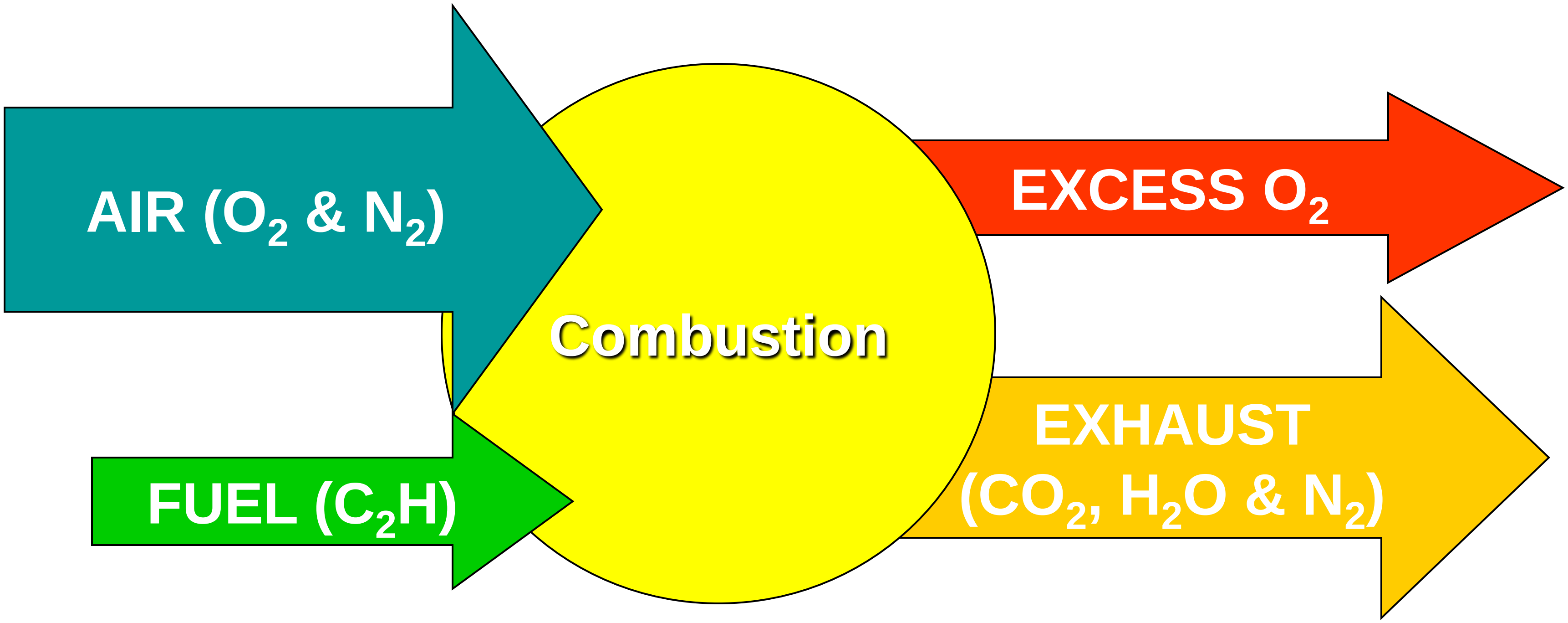
Air/Fuel Ratio – Combustion Efficiency

- In theory . . .

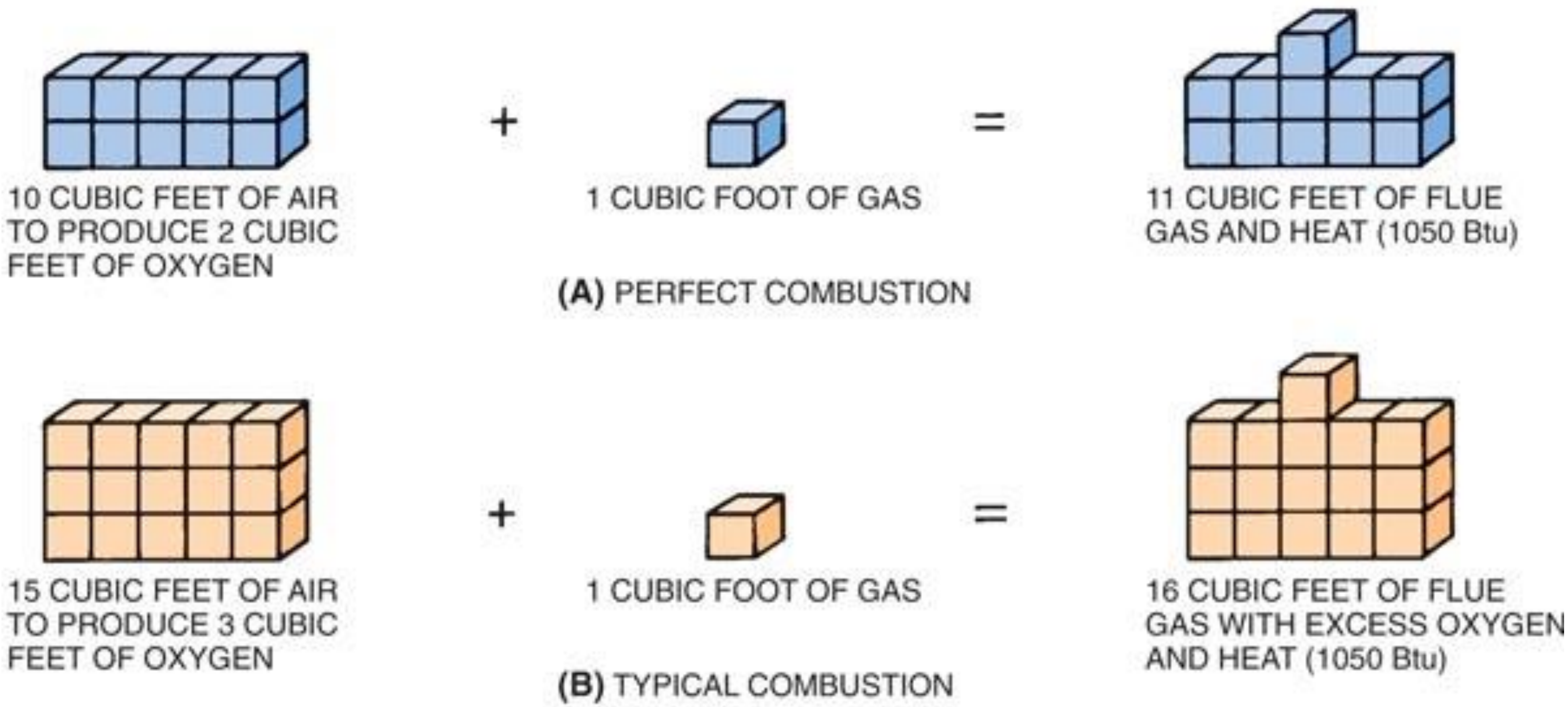


Air/Fuel Ratio – Combustion Efficiency

- In the real world . . .
  - Excess air introduced to prevent incomplete combustion



- ***<u>Left over oxygen carries heat away from boiler</u>***


10 CUBIC FEET OF AIR TO PRODUCE 2 CUBIC FEET OF OXYGEN
+
1 CUBIC FOOT OF GAS
=
11 CUBIC FEET OF FLUE GAS AND HEAT (1050 Btu)
(A) PERFECT COMBUSTION
15 CUBIC FEET OF AIR TO PRODUCE 3 CUBIC FEET OF OXYGEN
+
1 CUBIC FOOT OF GAS
=
16 CUBIC FEET OF FLUE GAS WITH EXCESS OXYGEN AND HEAT (1050 Btu)
(B) TYPICAL COMBUSTION

Standard Air

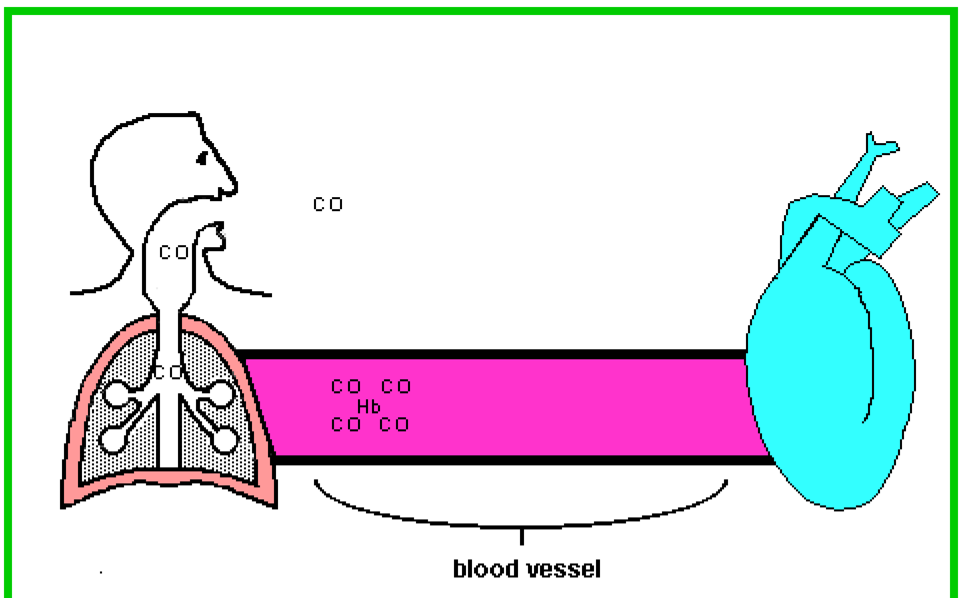
- 20.9% oxygen
- 78% nitrogen
- 1% other gasses

Complete Combustion

- $CH_4 + 3O_2 = \text{Heat} + 2H_2O + CO_2 + O_2$
- Where
  - CH_4 = 1 cubic foot of methane gas (natural gas)
  - $3O_2$ = 3 cubic feet of Oxygen
  - Heat 1027 BTU's of energy produced from the chemical reaction
  - $2H_2O$ = 2 cubic feet of water Vapor
  - CO_2 = 1 cubic feet of carbon dioxide
  - O_2 = 1 cubic foot of excess oxygen

Incomplete Combustion

- $CH_4 + 3O_2 = \text{Heat} + 2H_2O + CO\ (+/-\ O_2)$
  - Where CO = Carbon Monoxide



Courtesy of Bill Spohn, Testo

Combustion Diagram

The ideal operating range is a setting with excess air.

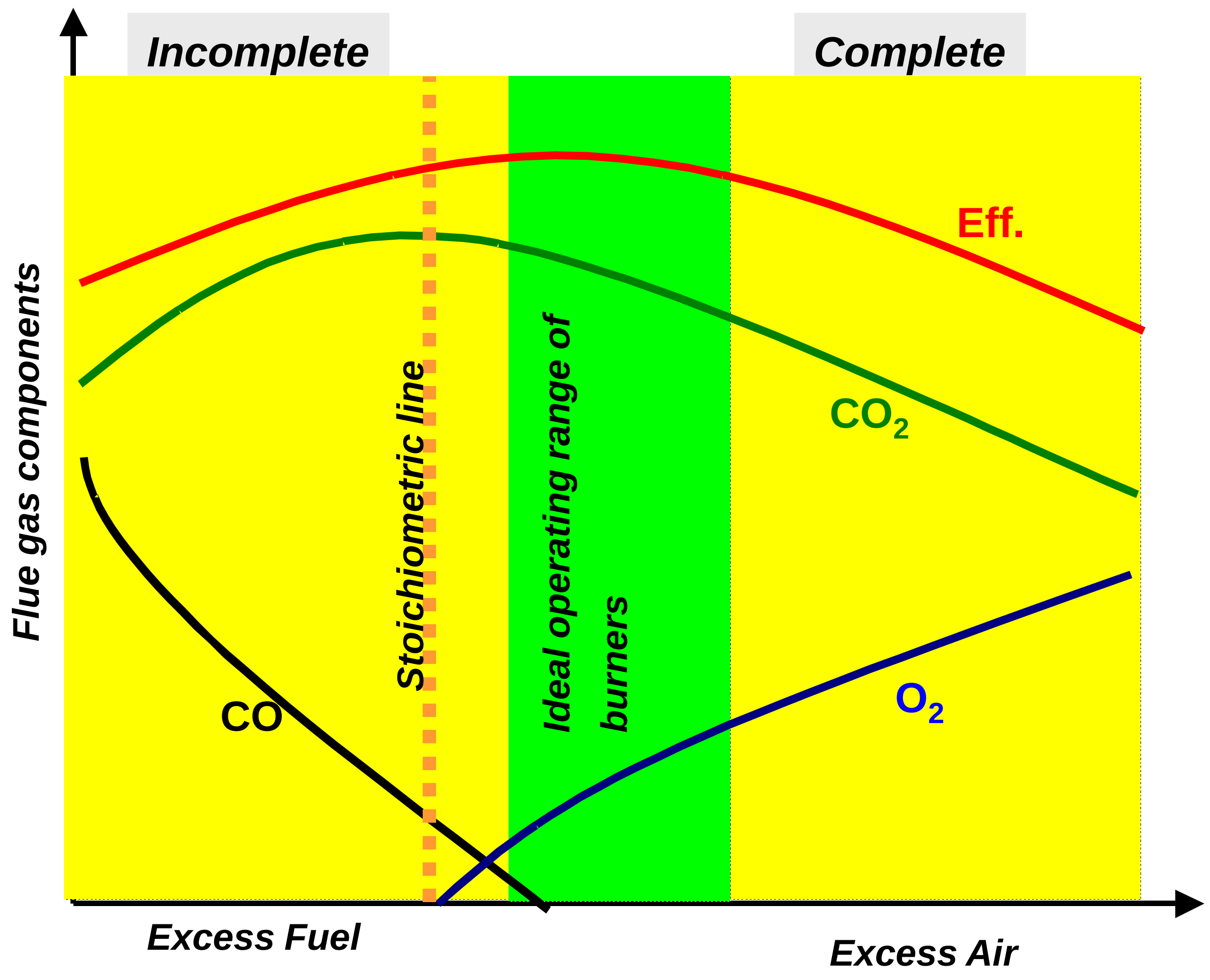


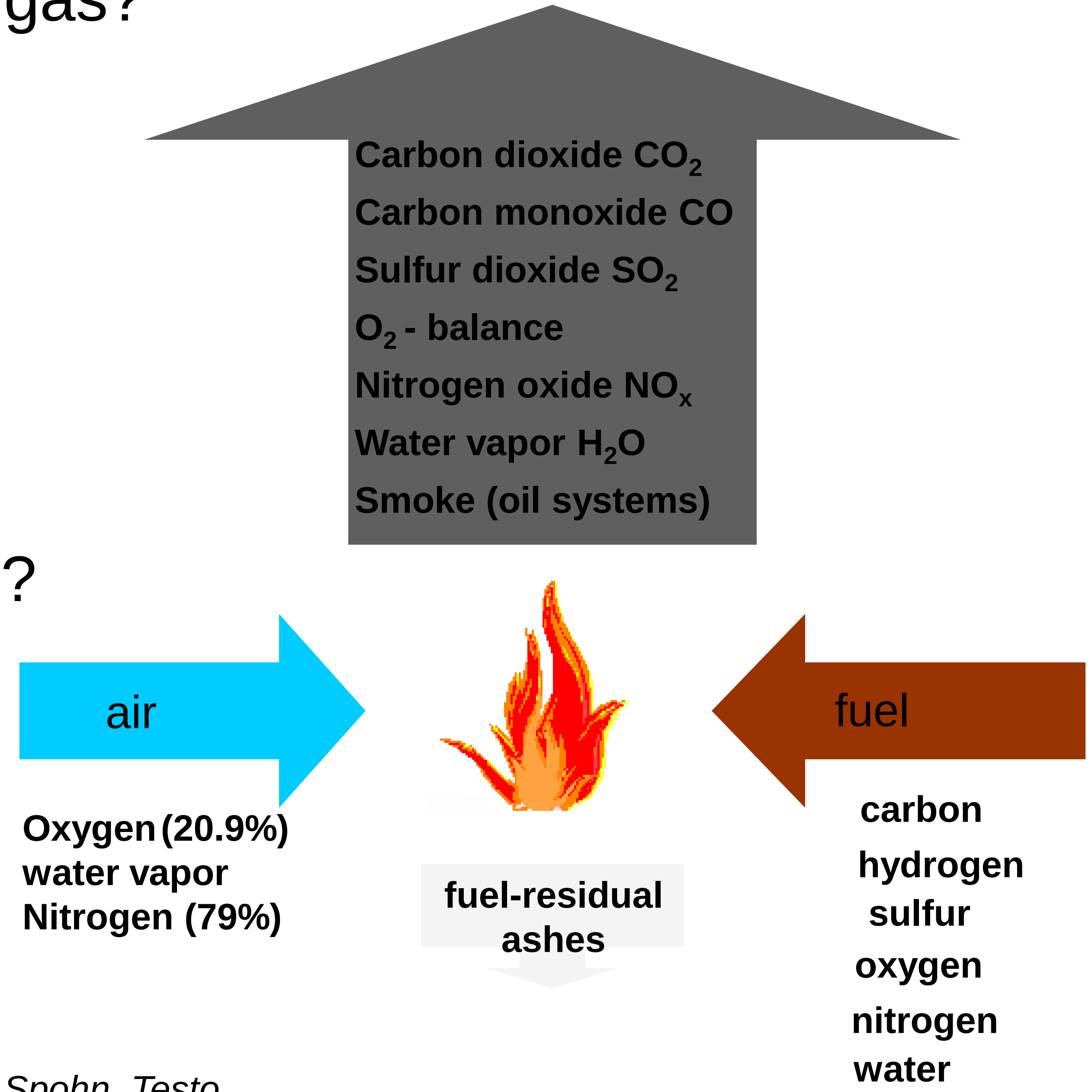
Table 1.1 Combustion ranges for common gases

Fuel	*Stoichiometric Air/Fuel Ratio (air ft.^{3} / fuel ft.^{3})*	*Heat of Combustion (BTU/ft.^{3})*
Methane (CH_4)	9.53	1013
Propane (C_3H_8)	23.82	2590
Natural Gas	9.4-11.0	950-1150
Coke Oven Gas	3.5-5.5	400-600

Table 1.2 Combustion ranges for Oil and Coal

Fuel	*Stoichiometric Air/Fuel Ratio (air ft.^{3} /fuel lb.)*	*Heat of Combustion (BTU/lb.)*
No. 2 Oil	180-195	18,500-19,800
No. 6 Oil	170-185	17,500-19,000
Bituminous Coal	120-140	12,000-14,000

What is flue gas?



How is it formed?

Courtesy of Bill Spohn, Testo

H2O and CO2 are always the products from combustion of hydrocarbons

- H20 Is water
  - What is wrong with water as a product of combustion and where does the water come from.

CO_2 What is it

- Carbon Dioxide
- Emissions of *CO_2* can contribute to climate change
- CO_2 is toxic in higher concentrations: 1% (10,000 ppm)
- The combustion process is two stage, carbon monoxide is formed first and if excess oxygen is present then the carbon monoxide reacts with additional oxygen to form CO_2
- 12 to 14 % by volume, the higher the readings, the better the combustion efficiency. It must be remembered that the CO_2 reading changes with the fuel type/ quality and the level of excess air supplied to the burners
- Of environmental concern

Carbon Dioxide

Ordinary outside air normally contains CO2 at a concentration of about 300 ppm (300 parts of CO2 gas per million parts of air.)

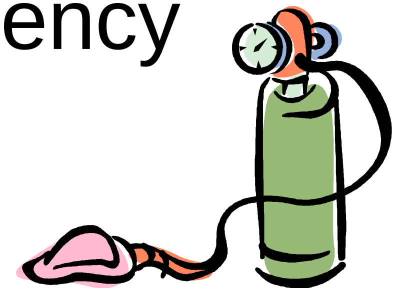
Adults take more than 20,000 breaths a day, and when we breath, we exhale carbon dioxide

It has been observed that CO2 concentrations between 300-600 ppm are adequate, i.e., people don't usually notice whether or not the air is "stale". However, as CO2 concentrations increase beyond these levels, one will notice ill effects. This is especially true if room temperatures rise and/or CO2 levels increase above 800 ppm. As these conditions persist, fresh air will need to be introduced. Several studies have indicate that CO2 does not seriously impact human health until levels reach approximately 15,000 ppm. This level is more than 40 times greater than the normal concentration of atmospheric CO2. At extremely high levels, i.e., 30,000 ppm, (these concentrations are usually never be reached in a standard home) the symptoms can include nausea, dizziness, mental depression, shaking, visual disturbances and vomiting.

Concentrations of 100,000 ppm or more of CO2 can produce unconsciousness or death.

Oxygen

- 3-4 % by volume (for fire tube boiler).
- 0.5-1.5 % by volume (for water tube boiler with high efficiency burners).
- Normally these numbers represent 10% excess air for natural gas
- Generally 1cubic foot of air to 100BTU's of heat value
- Used to analyze combustion efficiency



Excess % Air

- A well designed –natural gas fired system can be run at 10% Excess % Air
- Rule of thumb
  - Boiler efficiency is increased by 1%
    - **For each 15% reduction in excess air**
    - **40^{o}F decrease in stack temperature**

N2

- Nitrogen
- Not of single concern in flue gas analysis

NOX

- Nitrous-oxides
    - NO and NO2 produced from the reaction between nitrogen and oxygen gases during combustion at high temperatures.
- Initiates reactions that result in the production of ozone and acid rain
- < 30 PPMV (parts per million by volume)

  Level requirements change per region and boiler size.

SO2

- Sulfur-Dioxide
- Of environmental concern
- Directly related to sulfur levels in fuel

Incomplete combustion results in

CO


BACHARACH
ENTER
LIGHT
HOLD
I/O
Fyrite Tech Analyzer
03:38
ppm NOx
ppm SO2
MODE
SET
BACHARACH Combustion Analyzer Model 300
CAL
FUEL
RUN
FUEL
TEMP
CO (ppm)
ERROR
SELECT
% O2
% EX AIR
O2 CELL
SELECT
% EFF
% LOSS
% CO2
SELECT

Carbon Monoxide (CO) is a colorless, odorless, tasteless and non-irritating gas resulting from the incomplete combustion of organic matter.

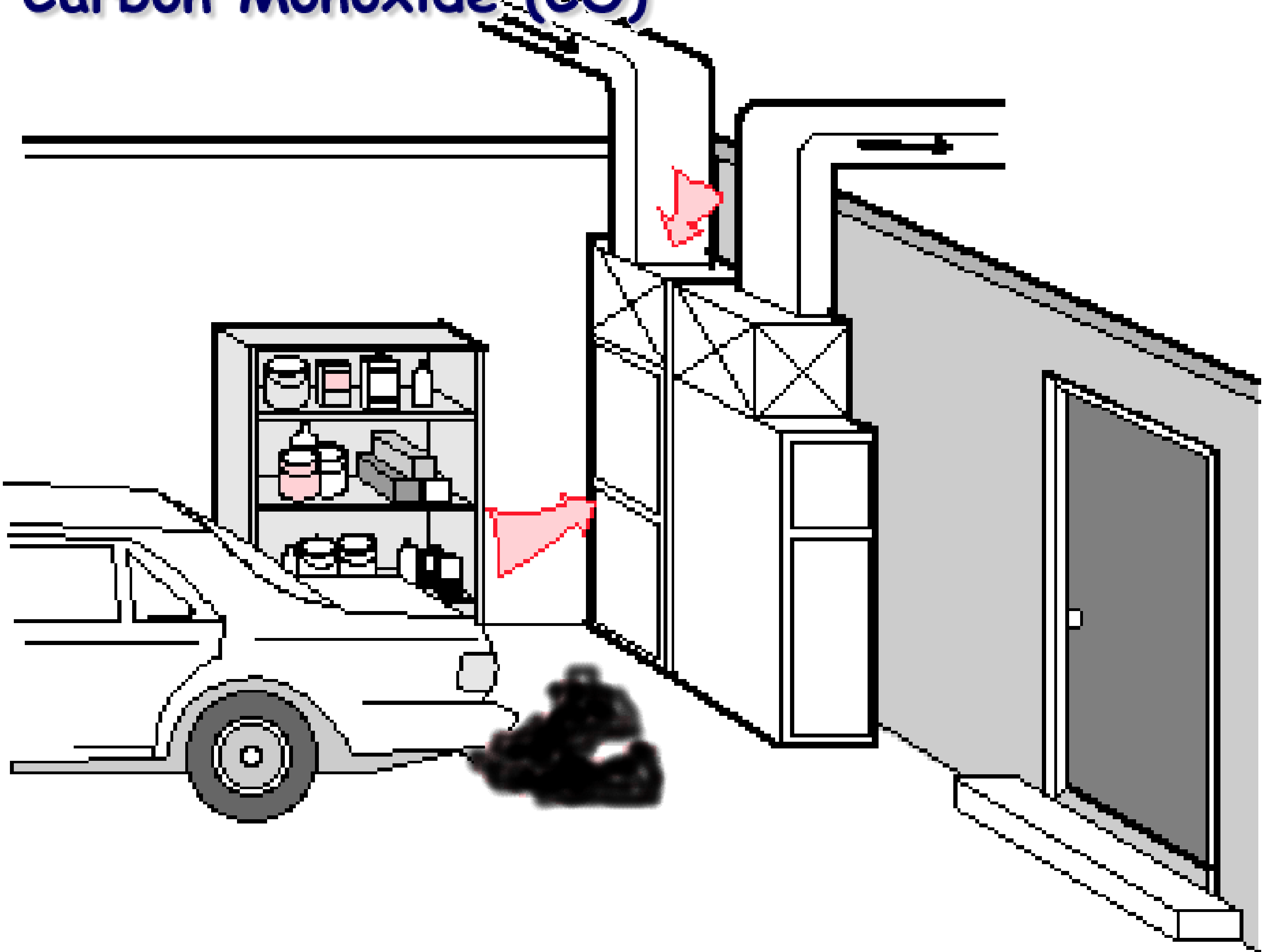
Slightly lighter than air

Sources: Unvented kerosene and gas space heaters; leaking chimneys and furnaces; back-drafting from furnaces, gas water heaters, wood stoves, and fireplaces; gas stoves. Automobile exhaust from attached garages. Environmental tobacco smoke.

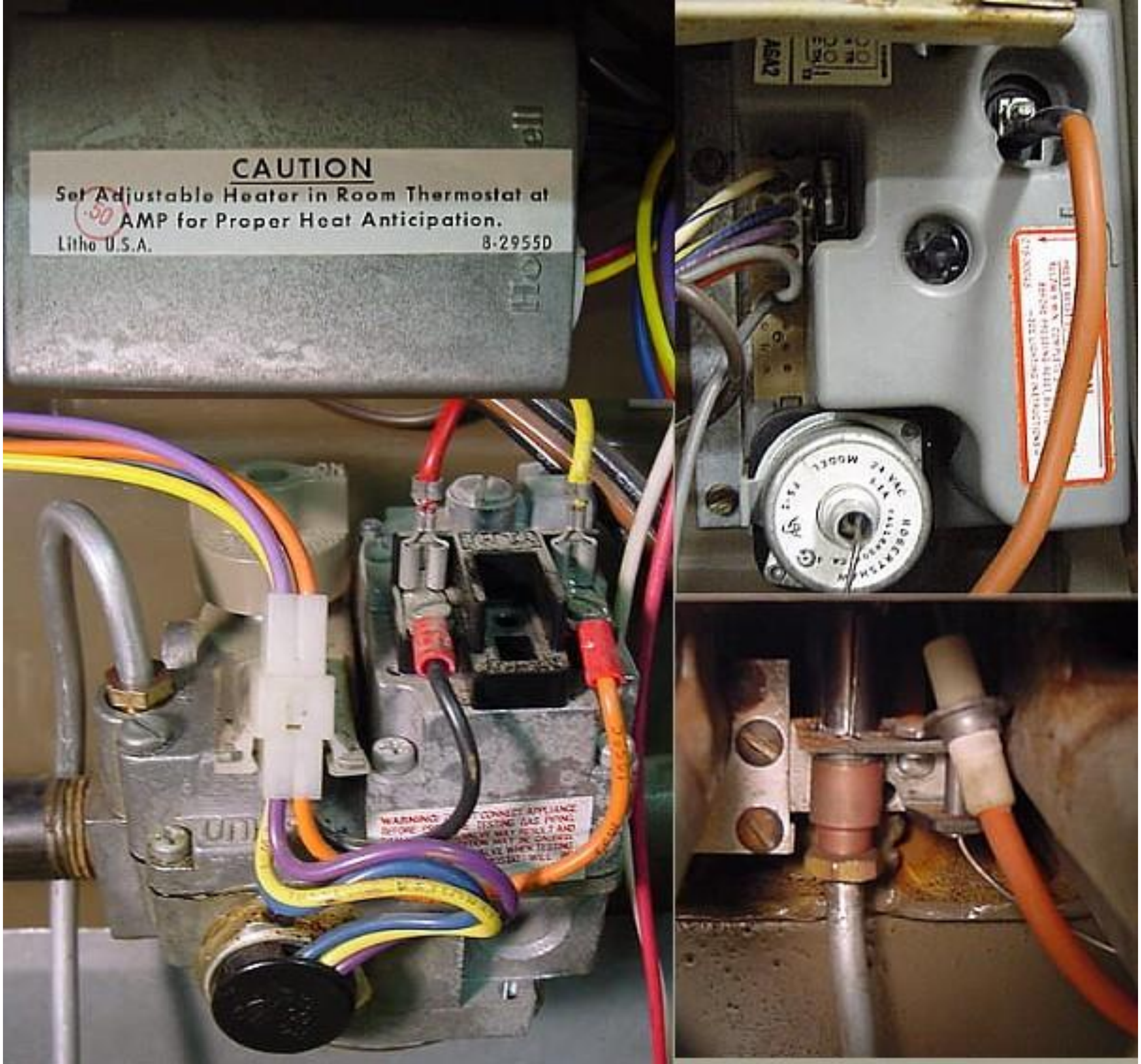
Health Effects: At low concentrations, fatigue in healthy people and chest pain in people with heart disease. At higher concentrations, impaired vision and coordination; headaches; dizziness; confusion; nausea. Can cause flu-like symptoms that clear up after leaving home. Fatal at very high concentrations.

Concentration Of CO In Air (parts per million)	Inhalation / Exposure Time And Toxic Symptoms Developed
9 ppm (0.0009%)	Maximum allowable concentration for short term exposure in a living area according to ASHRAE.
35 ppm (0.0035%)	Maximum allowable concentration for continuous exposure in any 8 - hour period, according to federal law.
200 ppm (0.02%)	Slight headache, tiredness, dizziness, nausea after 2-3 hours. Maximum CO concentration for exposure at any time as prescribed by OSHA.
400 ppm (0.04%)	Frontal headaches within 1-2 hours, life-threatening after 3 hours, also maximum parts per million in flue gas according to EPA and AGA.
800 ppm (0.08%)	Dizziness, nausea and convulsions within 45 minutes. Unconsciousness within 2 hours. Death within 2-3 hours.
1,600 ppm (0.16%)	Headache, dizziness and nausea within 20 minutes. Death within 1 hour.
3,200 ppm (0.32%)	Headache, dizziness and nausea within 5-10 minutes. Death within 30 minutes.
6,400 ppm (0.64%)	Headache, dizziness and nausea within 1-2 minutes. Death within 10-15 minutes.
12,800 ppm (1.28%)	Death within 1-3 minutes

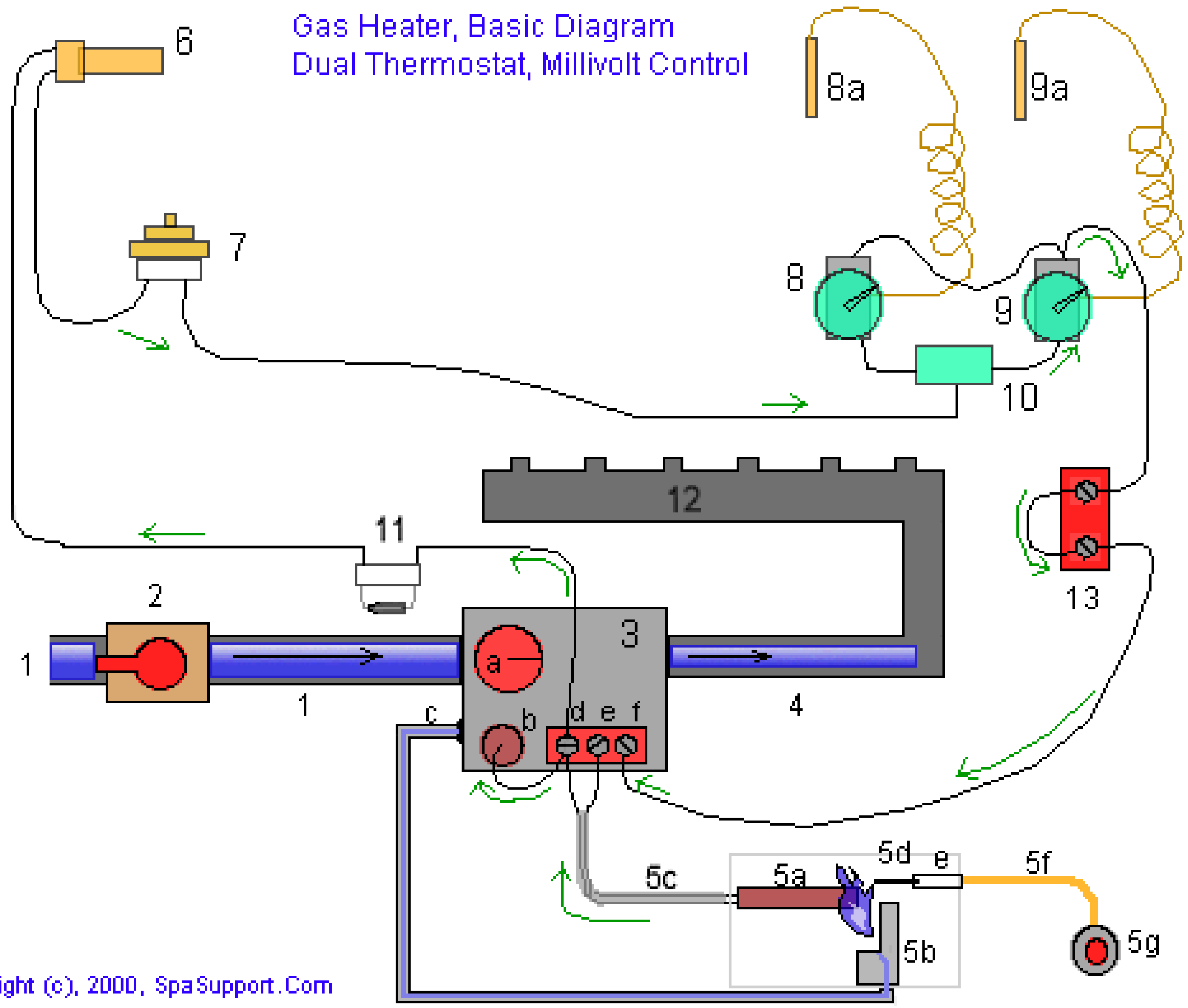
Carbon Monoxide (CO)

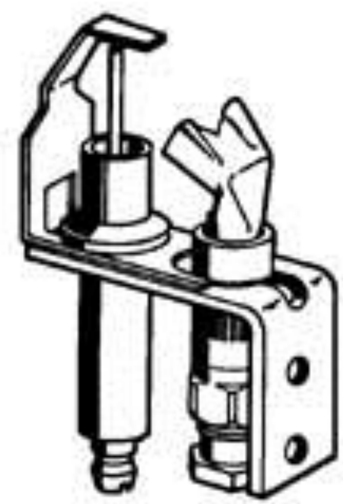


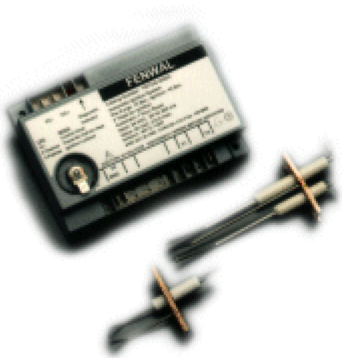
Ignition


CAUTION
Set Adjustable Heater in Room Thermostat at
.50
AMP for Proper Heat Anticipation.
Litho U.S.A.
8-2955D

Gas Heater, Basic Diagram
Dual Thermostat, Millivolt Control






FENWAL


RAM-3
DIRECT SPARK IGNITION CONTROL
Lockout: 15 Sec. Max.
Input: 24 VAC 60Hz
Current Draw: 0.25A
Ambient Temp. Range: 0° to +175°F
Relay Contact Rating: 2.0A MV
Reset Lockout Thru Safety Switch
WARNING

Flame Rectification

Flame Detection Using Flame Conductivity

- If two electrodes are placed in or near the flame and a voltage is applied to the electrodes, a current will flow between the electrodes using the ions and the electrons as charge carriers. A current will flow between the electrodes when a flame is present, but there will be no current when the flame is not present.

Principles of Ionization Flame Monitoring

- An ion is a charged atom that has either gained an electron to become negatively charged (anion) or has lost an electron to become positively charged (cation). The energy released during a combustion process will cause electrons to be knocked loose from an atom, resulting in a positively charged particle and a free electron. This ionization, if monitored properly, can be used to generate a safe and reliable indication of a flame.

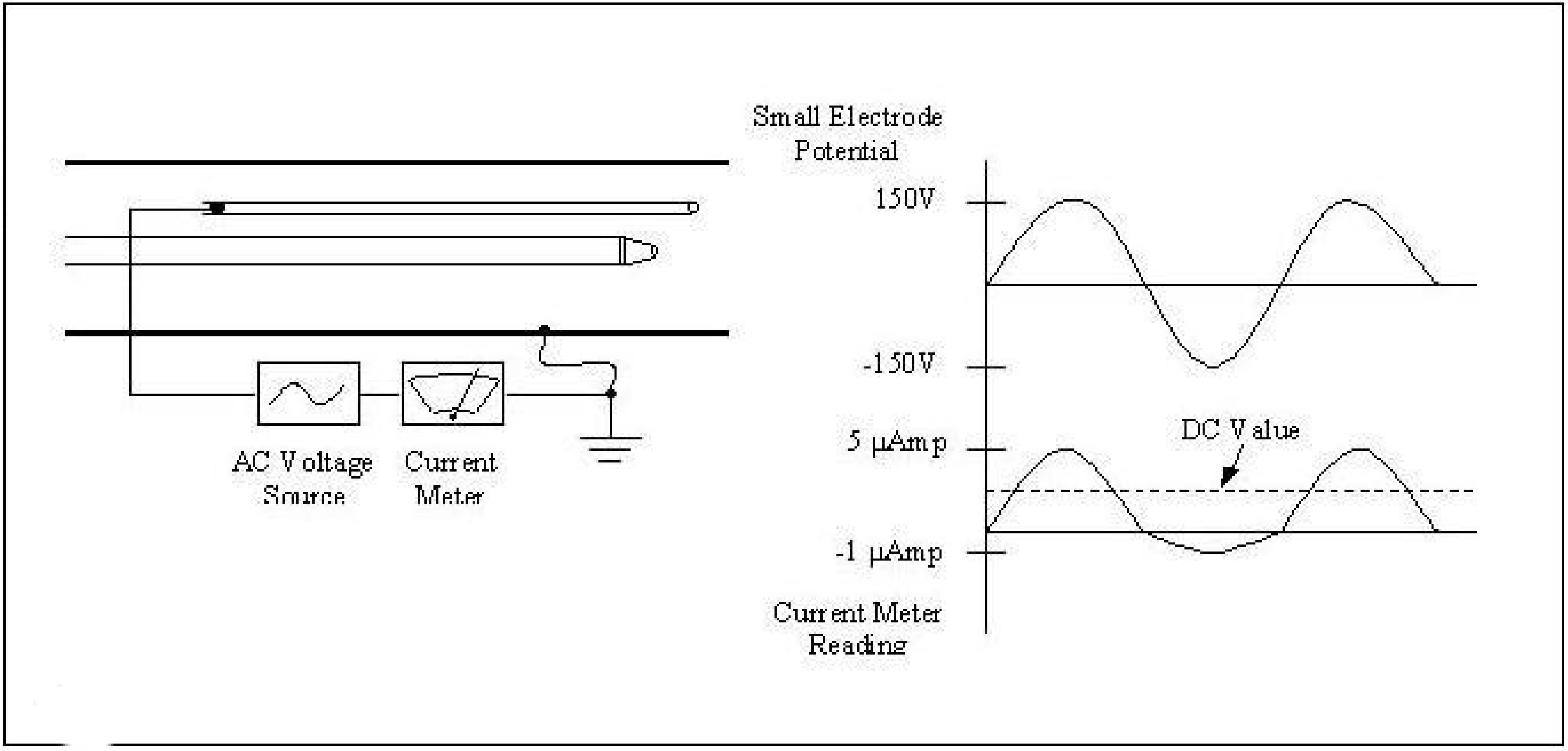
Principles of Ionization Flame Monitoring cont.

- If the air-fuel ratio is optimal, the reaction will be the strongest, and more free ions and electrons will be produced. Since the electrons are so much lighter than the ions, the electrons travel much faster and move away from the burner mouth toward the tip of the flame much more quickly than the heavier ions. This leaves a greater concentration of positively charged ions in the area near the burner mouth than free electrons.

Flame Detection Using Flame Rectification:

- In a rectifying flame ionization detection system, an alternating potential (AC) is supplied to the two electrodes. In addition, one of the electrodes must have a larger surface area compared to the other electrode. To increase the size of one of the electrodes and to simplify construction, one of the electrodes is the burner tube. The small electrode is then electrically isolated from the burner tube (the other electrode) with ceramic insulators.

Flame Detection Using Flame Rectification cont.



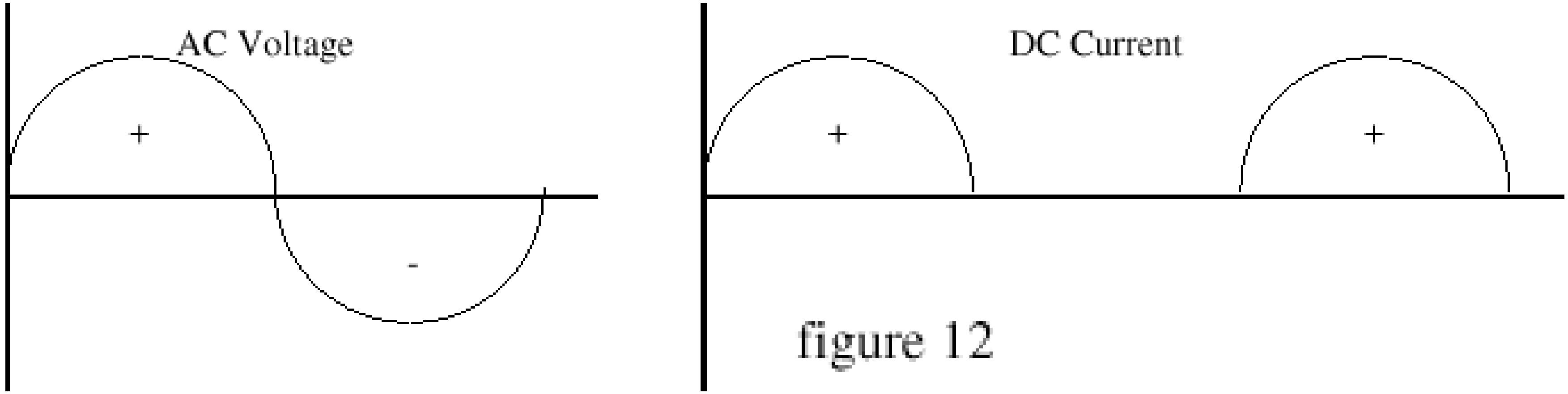


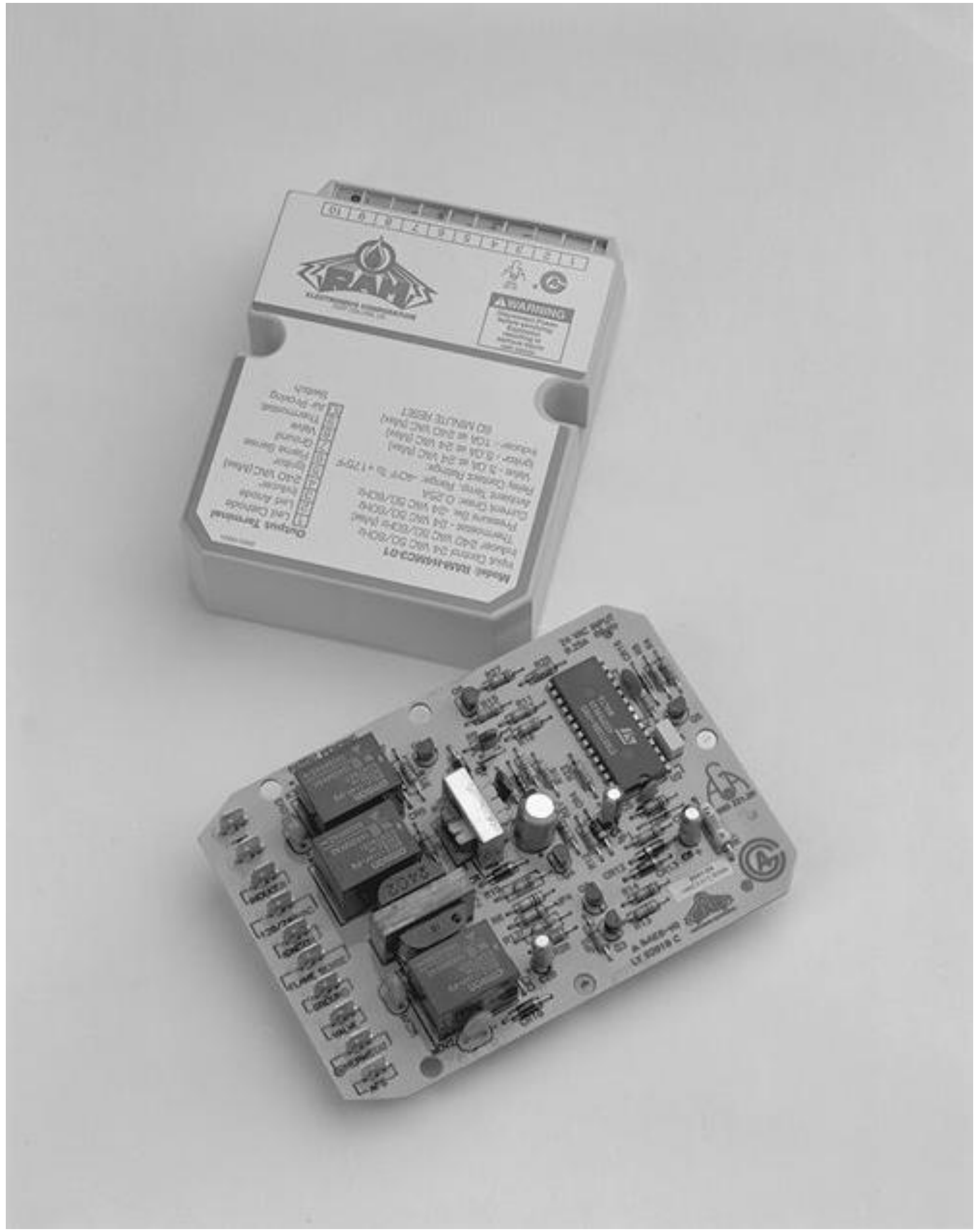
figure 12

The surface with the largest area (the burner) attracts more free electrons, and as a result becomes the negative surface or probe. The direction for the conduction of current through the flame is from the positive surface to the negative surface, the current is conducted to ground potential, and a flame path to ground is established.

As the current is conducted through the flame, the negative portion of the sine wave is chopped off (as illustrated in figure 12) and we are effectively left with DC current.

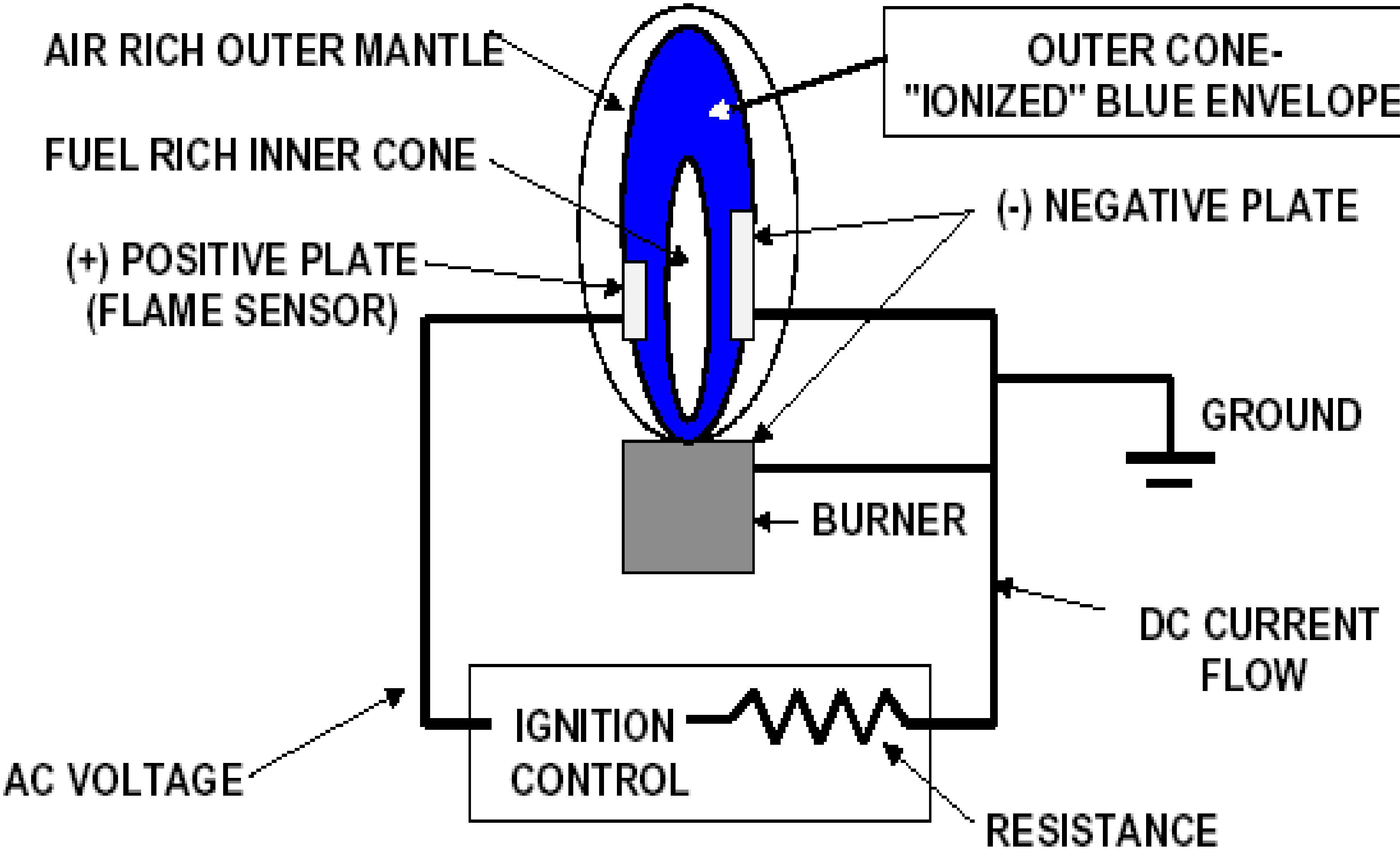
The ignition control module's (IGN's) flame sensing circuit utilizes this DC current flow to effectively energize an internal relay and keep the main gas valve for the burner energized, as long as a flame is present.

Flame rectification based ignition control systems are extremely responsive to loss of flame, these systems respond to loss of flame in less than 0.8 seconds. If flame is lost, the ignition control module (IGN) will recycle and try for ignition again (unless loss of flame occurred during 7 second trial for ignition).

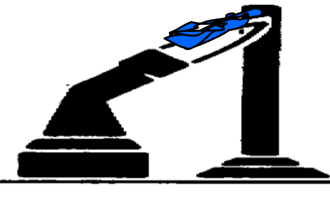


BEFORE PROCEEDING WITH MEASURING FLAME CURRENT THE FOLLOWING CHECKS MUST BE MADE TO THE ELECTRICAL SYSTEM:

- MEASURE THE LINE VOLTAGE INTO THE UNIT. IT MUST BE WITHIN 10% OF THE NAMEPLATE VOLTAGE
- IF THE UNIT IS A SINGLE PHASE APPLIANCE, CHECK FOR PROPER POLARITY. THIS MUST BE DONE BY MEASURING FOR VOLTAGE BETWEEN THE HOT POWER LEAD AND GROUND. IT SHOULD BE WITHIN 10% OF THE NAMEPLATE RATING. NEXT MEASURE BETWEEN THE NEUTRAL POWER WIRE AND GROUND TO BE SURE NO VOLTAGE IS PRESENT.
- IF THE IGNITION CONTROL UTILIZES LOW VOLTAGE FOR THE FLAME SENSING CIRCUIT, MAKE SURE THAT THE LOW VOLTAGE TRANSFORMER IS WIRED PROPERLY AND THAT THE CONTROL VOLTAGE IS WITHIN 10% OF ITS RATING.
- CHECK ALL OF THE GROUND WIRE CONNECTIONS IN THE UNIT TO MAKE SURE THEY ARE CLEAN AND TIGHT.


AIR RICH OUTER MANTLE
OUTER CONE-
"IONIZED" BLUE ENVELOPE
FUEL RICH INNER CONE
(-) NEGATIVE PLATE
(+) POSITIVE PLATE
(FLAME SENSOR)
GROUND
BURNER
DC CURRENT
FLOW
IGNITION
CONTROL
AC VOLTAGE
RESISTANCE

SMALL BLUE FLAME



CHECK FOR

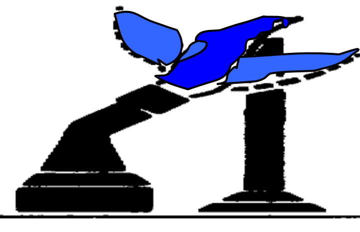
- CLOGGED ORIFICE FILTER
- CLOGGED PILOT FILTER
- LOW GAS SUPPLY PRESSUR

LAZY YELLOW FLAME

LACK OF AIR FROM

- LARGE ORIFICE
- DIRTY LINT SCREEN
- DIRTY PRIMARY AIR OPENING

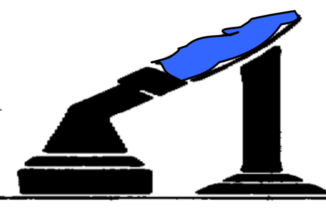
WAVING BLUE FLAME



MEANS:

- EXCESSIVE DRAFT AT PILOT LOCATION
- RECIRCULATING PRODUCTS OF COMBUSTION

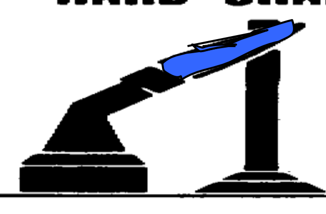
NOISY LIFTING BLOWING FLAME



MEANS

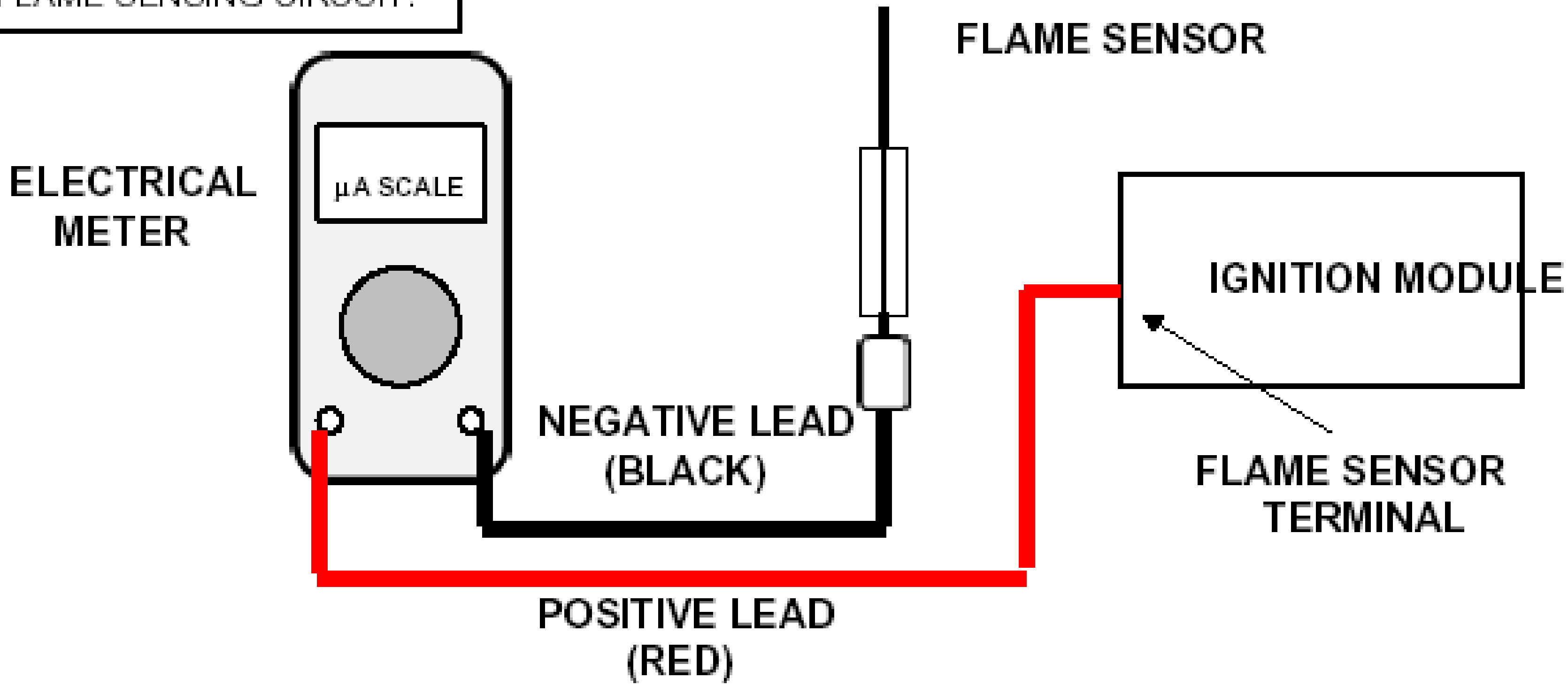
HIGH GAS PRESSURE

HARD SHARP FLAME



- CHARACTERISTIC OF MANUFACTURED GAS.
- HIGH GAS PRESSURE
- ORIFICE TOO SMALL.

THE FOLLOWING DIAGRAM SHOWS HOW TO PROPERLY HOOK UP A DC CURRENT METER TO THE FLAME SENSING CIRCUIT:

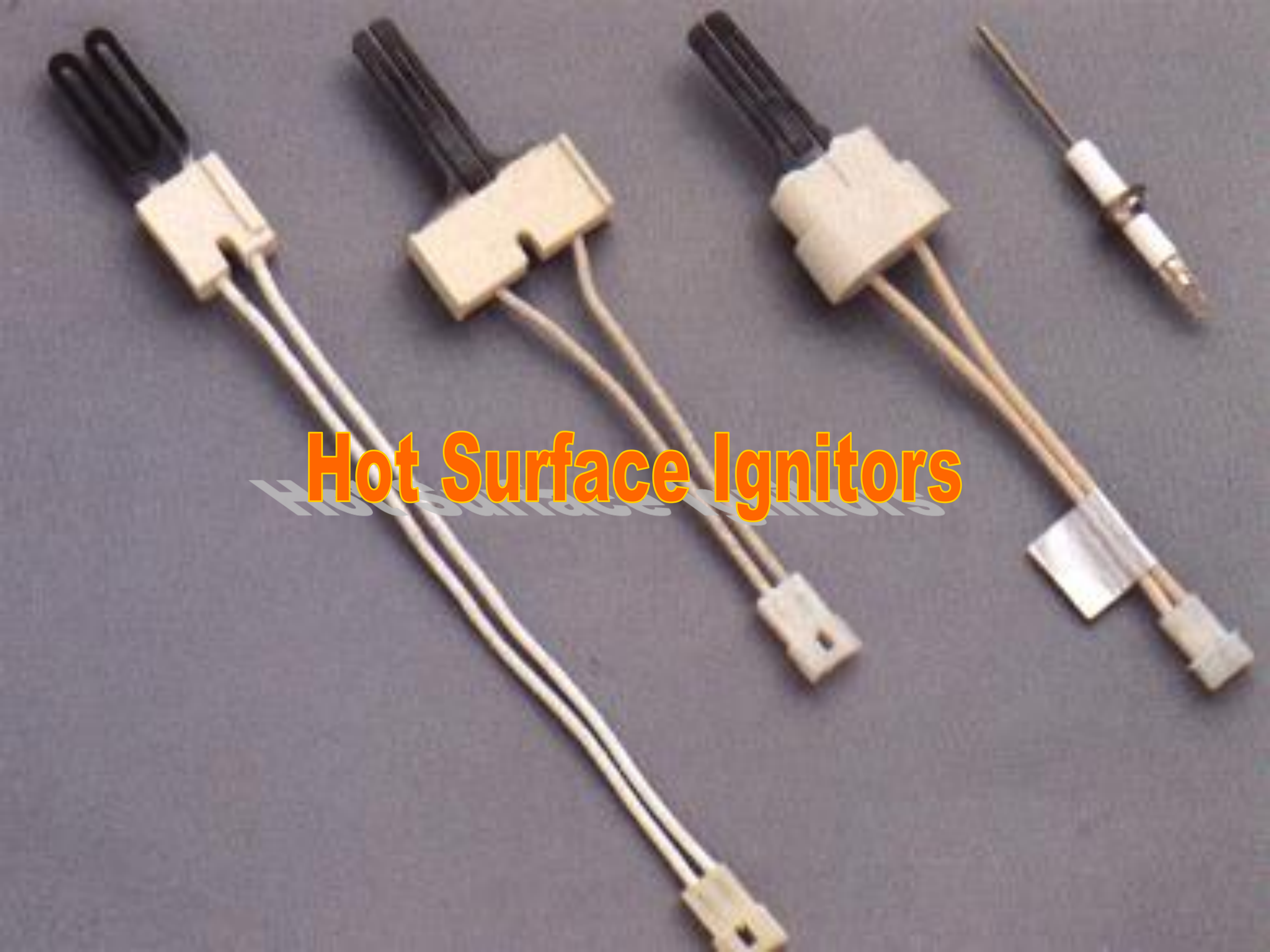


NOTES: 1. THE METER MUST BE CAPABLE OF MEASURING MICRO AMPS (µA). ONE µA IS ONE MILLIONTH OF AN AMP (.000001 AMP). SOME IGNITION MODULES USE MINIMUM FLAME CURRENT SETTINGS AS LOW AS 0.10 µA. A 20 µA SCALE IS RECOMMENDED.

2. WHEN LOW MICRO AMPS (µA) READINGS ARE OBSERVED, CLEAN THE FLAME SENSOR WITH STEEL WOOL. NEVER USE SAND CLOTH. MAKE SURE THAT THE SENSOR IS POSITIONED PROPERLY IN THE FLAME BEFORE RE-TESTING.

3. CONDEMN THE IGNITION MODULE ONLY AFTER FOLLOWING ALL OF THE ABOVE STEPS AND NOTES.

MINIMUM FLAME CURRENT REQUIREMENTS			
MANUFACTURER	MODEL	CONTROL VOLTAGE	MINIMUM CURRENT
FENWALL	05-14*	120 VOLTS	5.0 µA
JOHNSON CONTROLS	G60	120 VOLTS	0.7 µA
JOHNSON CONTROLS	G60	25 VOLTS	0.7 µA
JOHNSON CONTROLS	G65 / G66 / G67	24 VOLTS	0.2 µA
JOHNSON CONTROLS	G770 /G775 / G776	24 VOLTS	0.15 µA
JOHNSON CONTROLS	G951*DB-1401 & 1402	24 VOLTS	0.1 µA
JOHNSON CONTROLS	G951ADB-1403	120 VOLTS	0.2 µA
WHITE-RODGERS	50D47 / 50E47 / 50F47	25 VOLTS	2.0 µA
WHITE-RODGERS	50A50 - 209/230		.30 µA
WHITE-RODGERS	50A50 - 241		.15 µA


Hot Surface Ignitors

What is it made of ?

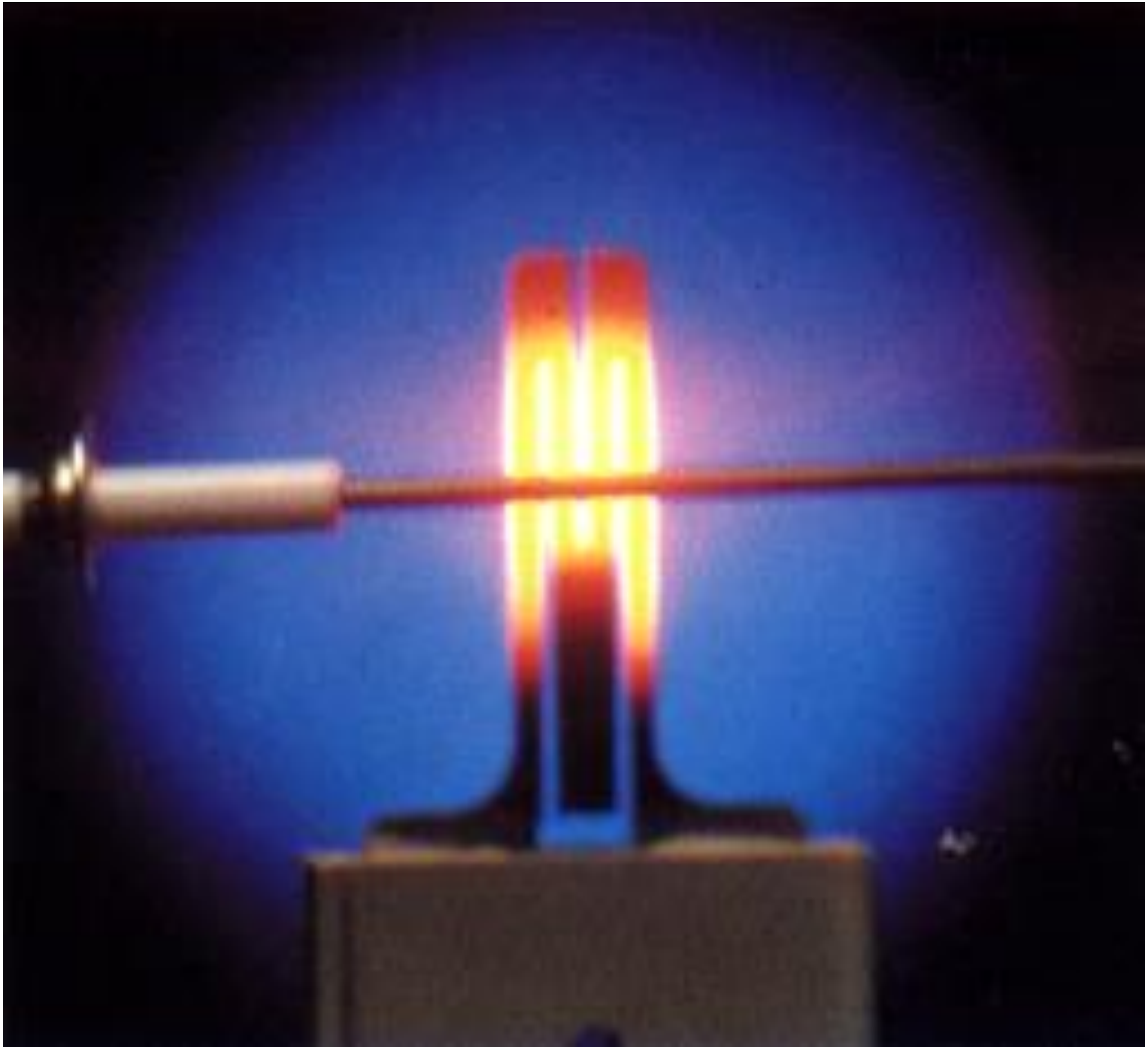
Silicon Carbide

TEMPERATURES

- 1,100 degrees F to 3,000 degrees F

What is the voltage to the HSI ?

- 120 VAC



Gas Leaks

- **Natural gas is lighter than air**, which means it dissipates quickly in well-ventilated areas – unless it becomes trapped in an enclosed space. Given the right concentrations of natural gas and air, natural gas can ignite from sparks from electrical switches or appliances and from open flames such as matches and pilot lights. Fire or explosions can result.

SPECIFICATIONS

Application:	Gas Leak Detection
Composition:	Liquid
Features:	Extreme Sensitivity Consistency Low Temperature Premixed Ready to Use

Leak - SEEK®

Leak-SEEK

Compressed gas leaks result directly from vibration, chemical activity, corrosion, and mechanical flaws.

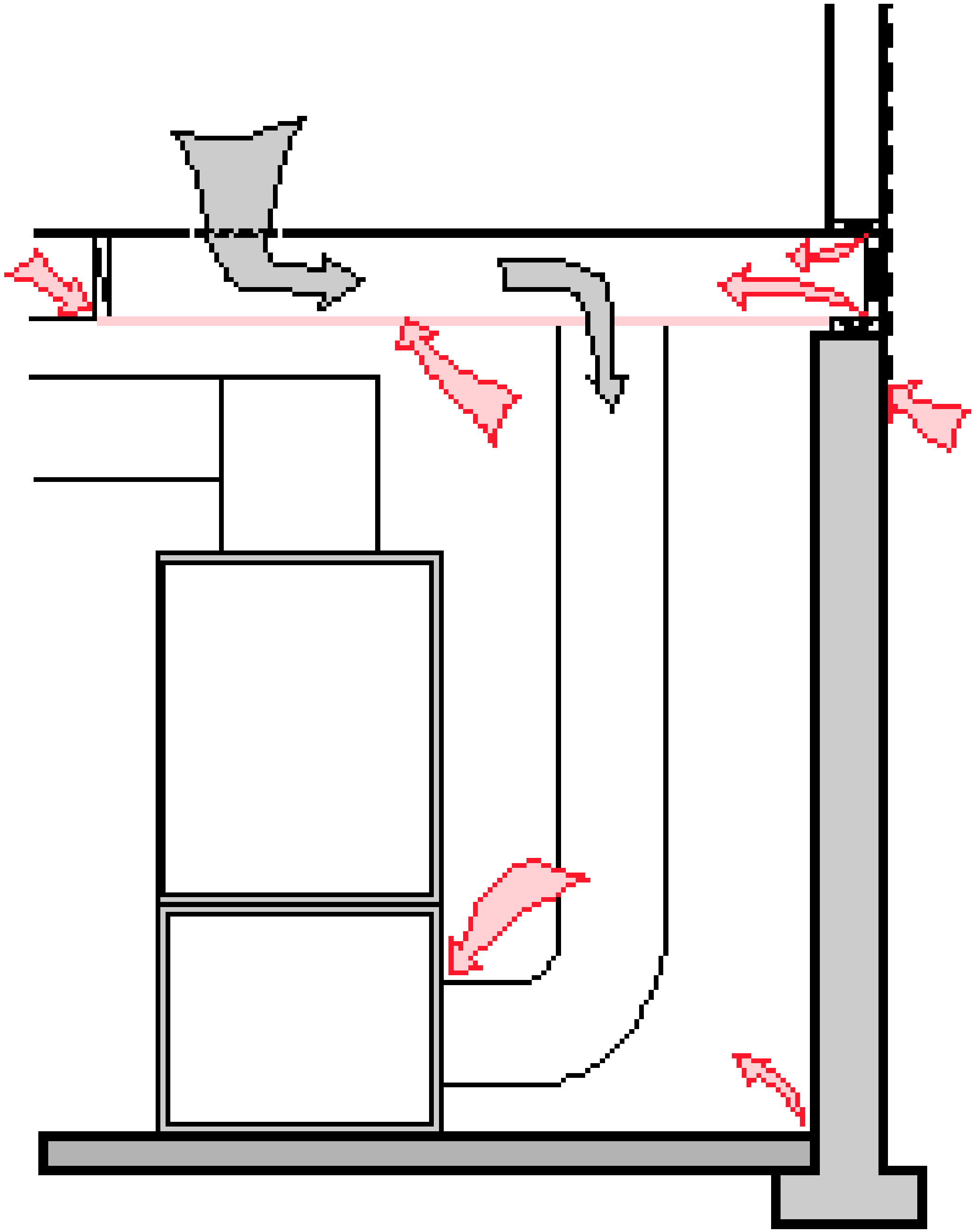
Leak-SEEK finds the smallest pressurized gas leaks; including natural gas, propane, butane, oxygen, and air.

ABBY PRODUCTS

Electronic Detector

Intent is to have the lowest level of Oxygen in percentage and Carbon Monoxide in PPM with carbon monoxide (C) reading less than 250PPM

Cracked heat exchangers ?



Signs of Carbon Monoxide

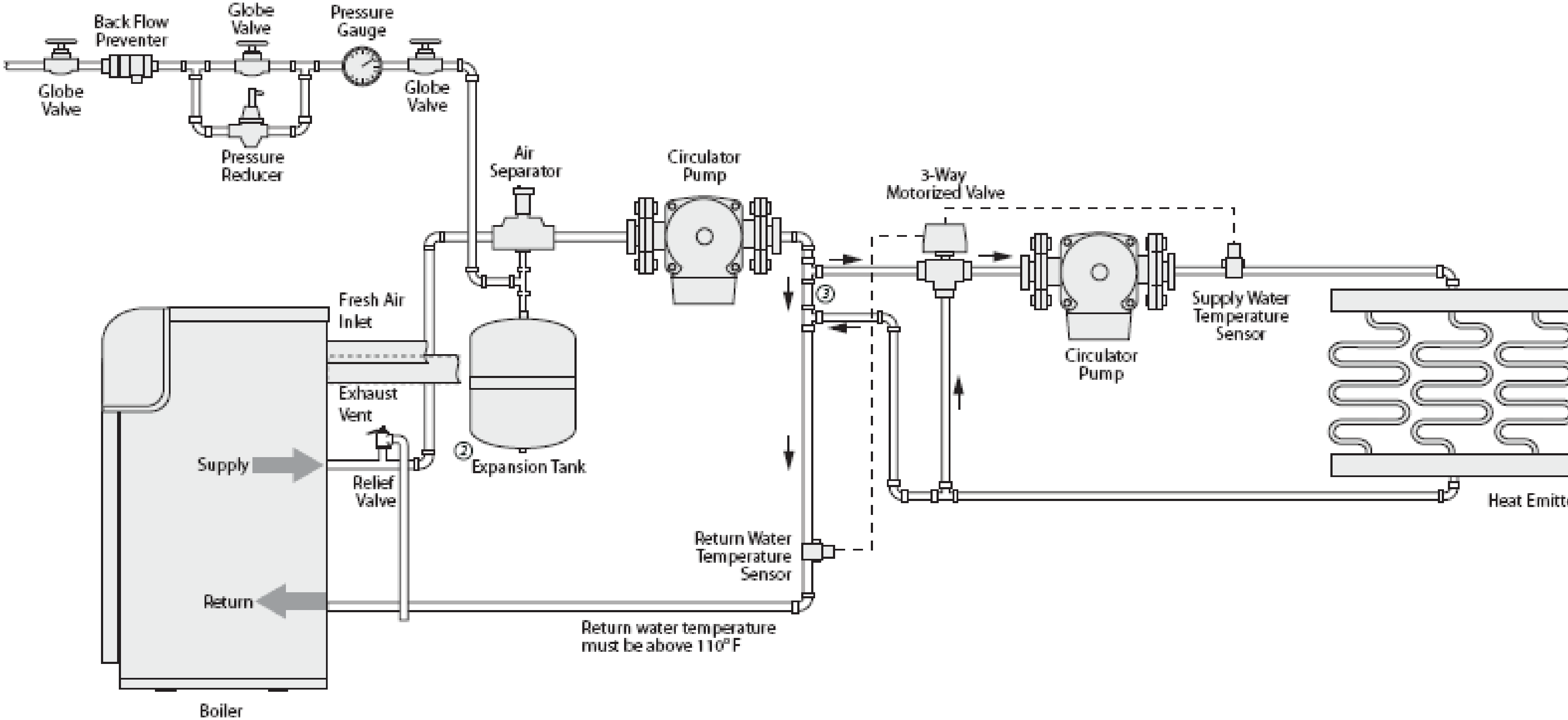
- Stuffy, stale or smelly air
- Dripping water condensation on your windows. (This is a reliable sign if you've already taken steps to reduce moisture production. It could also mean your humidifier is set too high.)
- Backdraft or soot from a fireplace, chimney or other fuel burning equipment. A yellow burner flame, instead of the normal clear blue flame. (This does not apply to natural gas fireplaces.)
- A pilot light that keeps going out, or the smell of unusual gases in your home. Even though carbon monoxide is odorless, it is sometimes accompanied by exhaust gases.

Carbon Monoxide

- A reading of 100-200 ppm normally indicates good combustion efficiency. CO readings are more reliable than CO2 reading.
- Of environmental concern

Boiler Maintenance ?

*Regular service by a qualified service agency and periodic maintenance must be performed to assure maximum boiler operating efficiency and safety



Back Flow
Preventer
Globe
Valve
Pressure
Gauge
Globe
Valve
Globe
Valve
Pressure
Reducer
Air
Separator
Circulator
Pump
3-Way
Motorized Valve
Fresh Air
Inlet
Exhaust
Vent
Supply
Relief
Valve
2 Expansion Tank
3
Circulator
Pump
Supply Water
Temperature
Sensor
Heat Emitter
Return Water
Temperature
Sensor
Return
Return water temperature
must be above 110° F
Boiler

Suggested Minimum Maintenance

- Annual service call by a qualified service agency
- Boiler area is free of combustible materials or vapors
- Check for obstructions to airflow or ventilation air
- Visually check top of vent for soot, check for cracks
- Visually inspect burners, ignitor, flame sensor and wiring
- Visually inspect insulation and/or refractory compound
- Check relief valve (refer to manufacturer's instructions)
- Test operator and safety controls, check settings
- Visually inspect main burner and pilot flames (light blue)
- Check piping and water system for leaks
- Check gas piping and controls for gas leaks

Controls

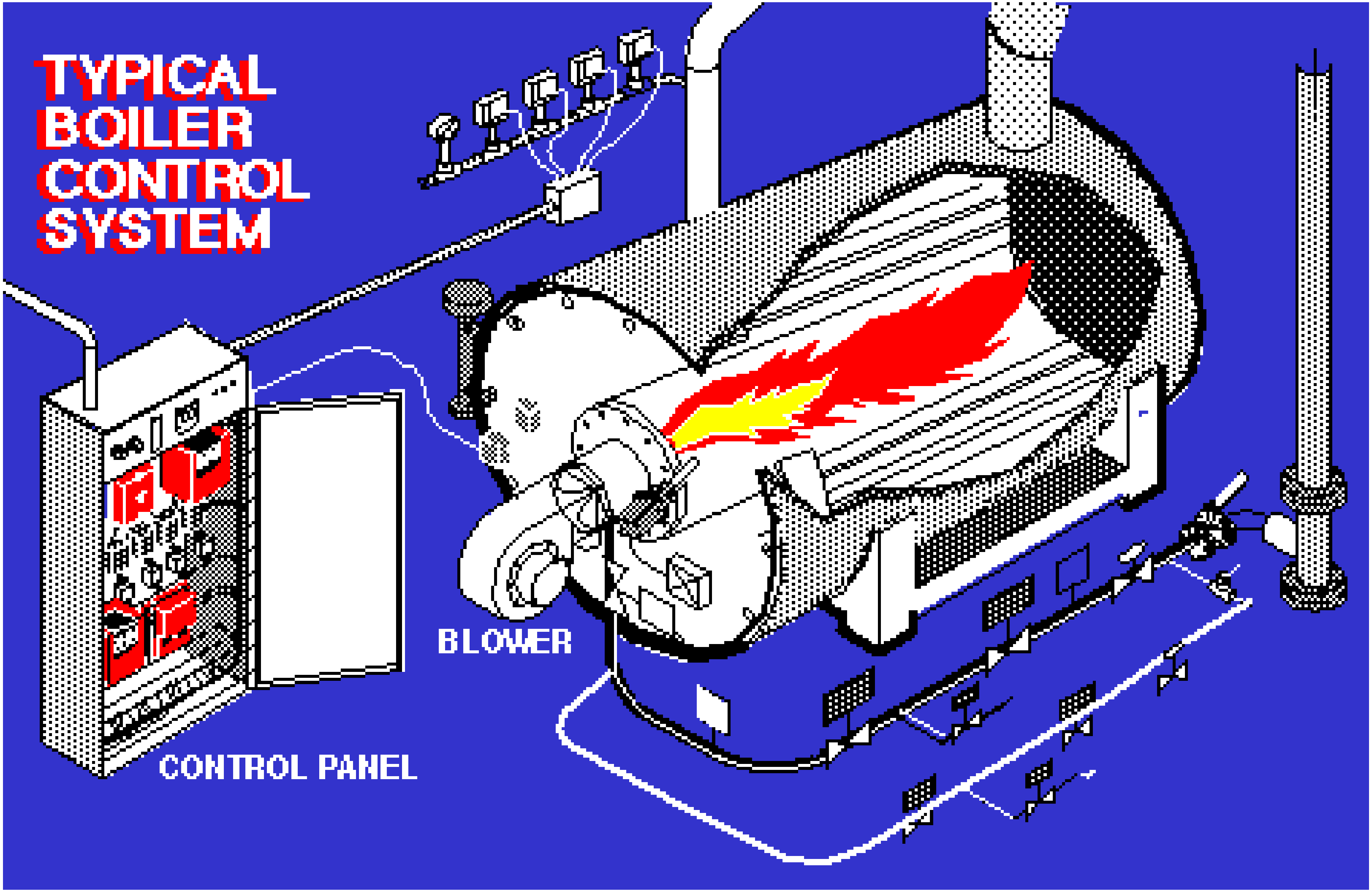
- Operator
  - Sets desired water temperature setpoint
  - *can be leaving or return water control
- Hi-Limit Safety
  - Locks out boiler due to high temp
- Water Flow Switch or Sensors
  - Proves water is actually flowing

Controls

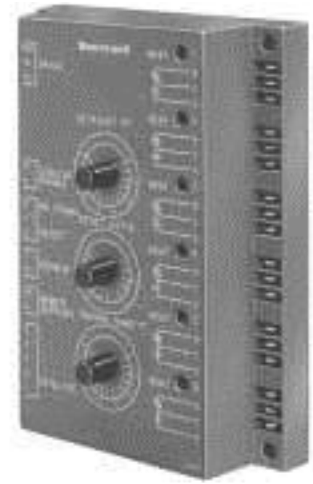
- Pilot Sensor
  - Detects pilot flame (may be visual)
- Flame Sensor
  - Detects main flame (may be visual)
- Airflow Switch
  - Proves combustion airflow

Controls

- Pressure Relief
  - Prevents over-pressurization
- Low Water Cut-off
  - Shuts off burner if water level is too low
- Fuel Pressure Safeties
  - Detects high and/or low gas pressure

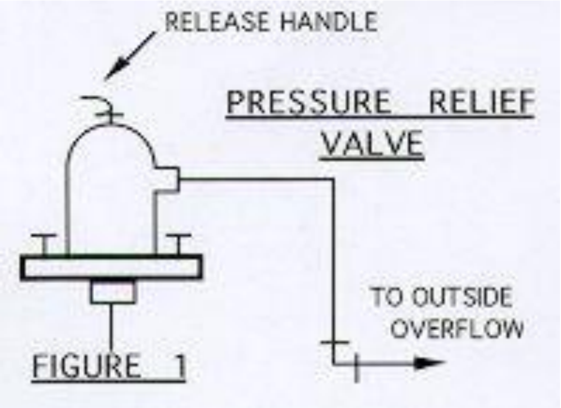

TYPICAL BOILER CONTROL SYSTEM
BLOWER
CONTROL PANEL

Types of Controllers



- **Often considered the primary safety feature on a boiler, the safety valve should really be thought of as the last line of defense. If something goes wrong, the safety valve is designed to relieve all the pressure that can be generated within the boiler. Keep in mind that the same conditions that make other safety devices malfunction can also affect the safety valve. Don't let testing and maintenance schedules slide.**

Pressure Relief



- **Water Level Control and Low Water Fuel Cutoffs**
  - **These devices perform two separate functions, but are often combined into a single unit. This method is economical, providing both a water level control function and the safety feature of a low water fuel cutoff device. It is recommended, however, that both steam and hot water boilers always have two separate devices — a primary and a secondary low water fuel cutoff. Many local jurisdictions <u>require</u> two such devices on steam boilers.**

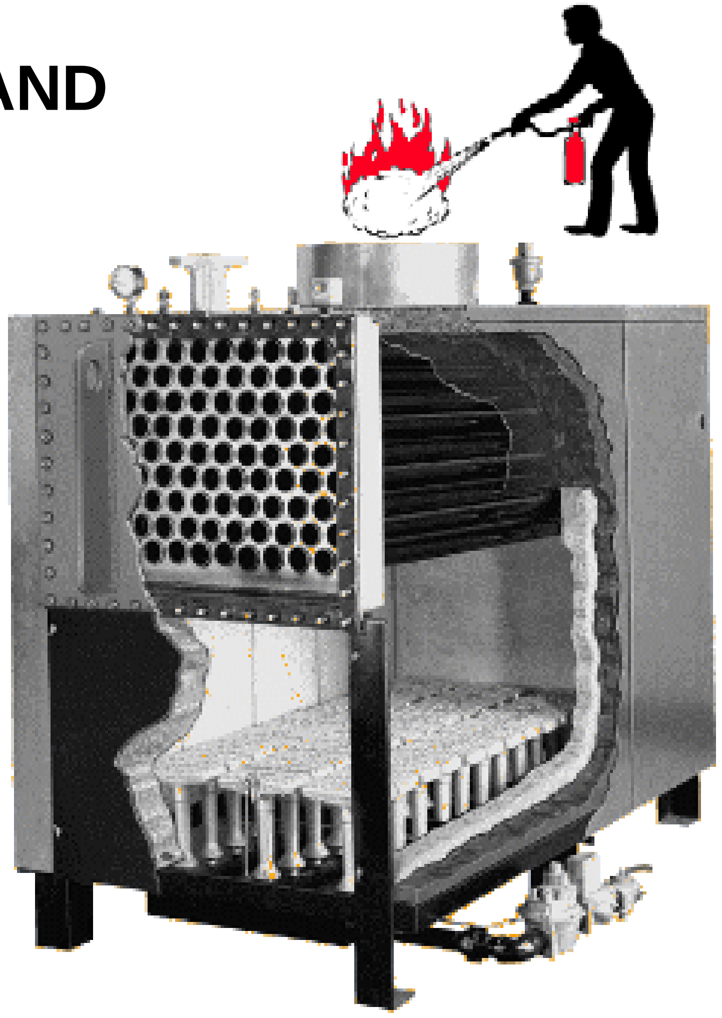
- # The Fuel System

- **Failure to maintain the equipment in good working order could result in higher fuel costs, the loss of heat transfer or even a furnace explosion. Modern fuel systems are very complex assemblies, consisting of both electronic and mechanical components. Over a period of time many things may go wrong. Many users wisely contract with their gas company or oil service company to periodically check and maintain their burner equipment.**

Boiler Logs Are Important

- The majority of boiler accidents can be prevented. One of the most effective tools is the proper use of operating and maintenance logs. Boiler logs are the best method to assure a boiler is receiving the required attention and provide a continuous record of the boiler's operation, maintenance and testing. Because a boiler's operating conditions change slowly over time, a log is the best way to detect significant changes that may otherwise go unnoticed.

A CLOGGED OR WARPED HEAT EXCHANGER
WILL RESULT IN A HAZARDOUS CONDITION DUE
TO OVERHEATING, FIRE AND POSSIBLE
CARBON MONOXIDE POISONING.



Minimum Stack Temp

- Natural Gas: 265 deg F plus ½ deg F for each foot of stack or breeching, including both horizontal or vertical runs.
- #2 Fuel Oil : 240 deg F plus ½ deg F for each foot of stack or breeching, including both horizontal or vertical runs.

Water Quality

- Less than 50 ppm of calcium
- Less than 50 ppm of magnesium
- Less than 100 ppm (5 grains) of total hardness
- Less than 25 ppm of chloride
- Less than 25 ppm of sulfate

Freeze Protection

Concentration by volume	Ethylene Glycol	Propylene Glycol
55%	-50F	-40F
50%	-37F	-28F
40%	-14F	-13F
30%	+2F	+4F
20%	+15F	+17F

Gas Hot Water Boiler PM

1. Vacuum clean boiler and breeching
2. Clean burners and orifices, check for cracks
3. Check and clean pilot, thermocouple and ignitor
4. Check chimney base for dirt or obstructions. Clean as required. Report and unusual conditions (i.e. fallen bricks, etc.)
5. Check gas valves and gas train for closure and external gas leakage
6. Check circulator motors, bearings, and couplers (Lubricate as required)
7. Test fire and adjust burner as required
8. Verify that all safety and operating controls are working properly
9. Check pressure on boiler through firing range and drain or check expansion tank and test auto fill as required

Gas Steam Boiler PM

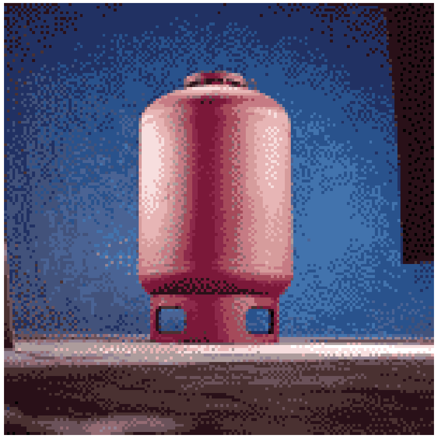
1. Vacuum clean boiler and breeching
2. Clean burner and orifices, check for cracks
3. Check and clean pilot, thermocouple and ignitor
4. Check chimney base for dirt or obstructions. Clean as required. Report any unusual conditions (i.e. fallen bricks, etc.)
5. Check gas valves and gas train for closure and external gas leakage
6. Clean or replace gauge glass as required
7. Flush down boiler and low water cutoffs as required. Verify cutoff operations
8. Pull apart and check or clean all gauge and control siphons and associated piping
9. Test fire and adjust burner as required
10. Verify that all safety and operating controls are working properly
11. Check system traps, air valves, vents, and strainers for proper operation. Report any additional problems
12. Check condensate pumps, floats and traps, if applicable, and auto fill, if required

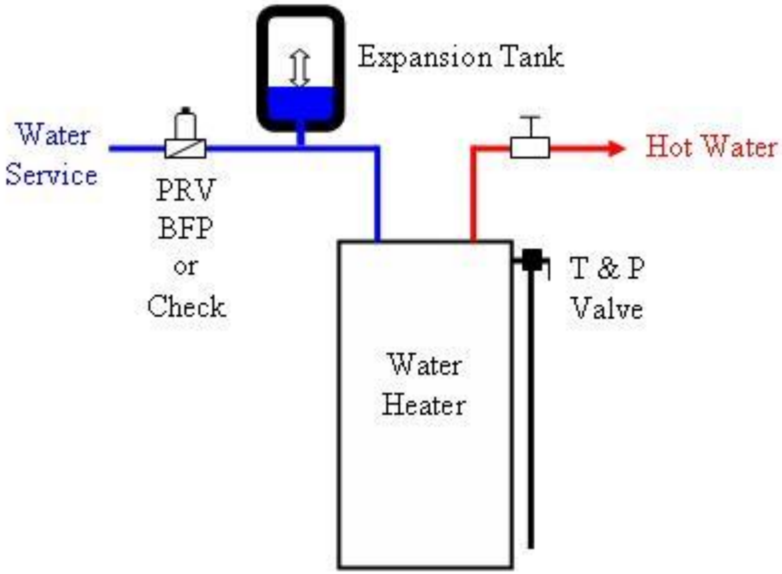
The Advantages of Intermittent Pump Operation

	Boiler A	**Boiler B**
Boiler Input	199,000 BTUH	199,000 BTUH
Circulating Pump	1/7 HP	1/7 HP
Standby Period	18 hrs/day	18 hrs/day
Pump Control	Intermittent	Continuous
Pump Run Time	6 Hours	24 Hours
Watts Used	1224 watts	4896 watts
Daily Electricity Cost (@$.08/kwh)	$.098	$.392
Annual Electricity Cost	$35.74	$142.96

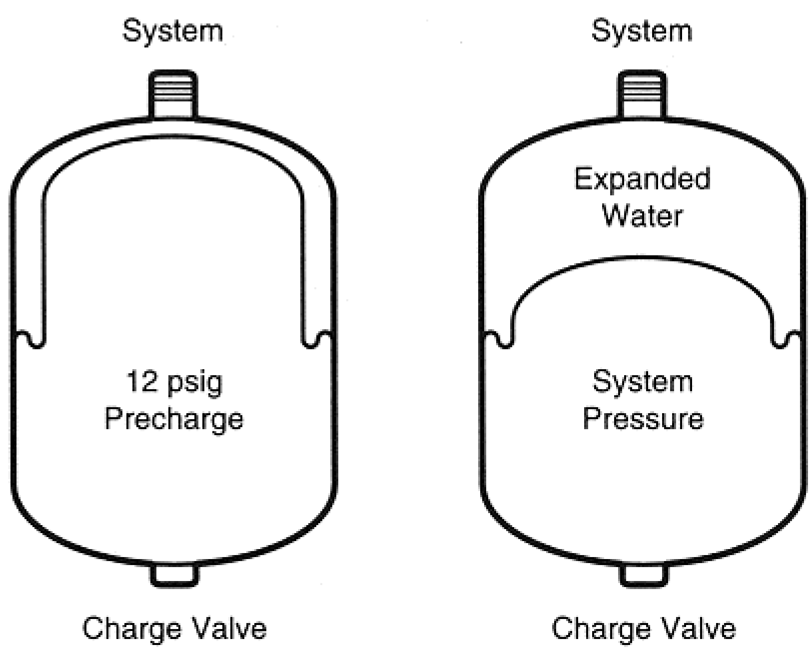
Expansion Tanks

Bladder Type Pre-charged Expansion Tanks



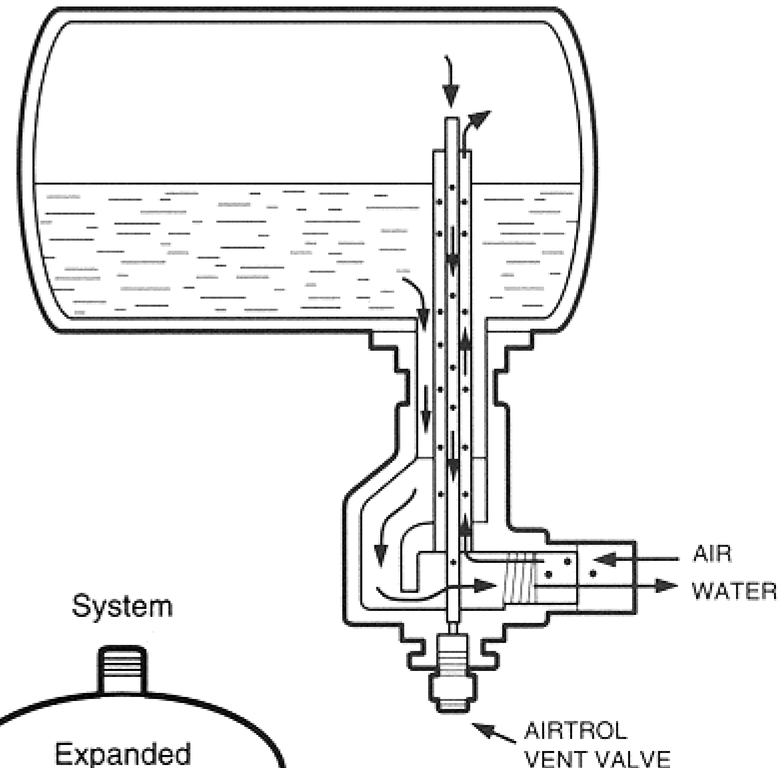


Expansion Tank
Water Service
PRV
BFP
or
Check
Hot Water
T & P Valve
Water Heater

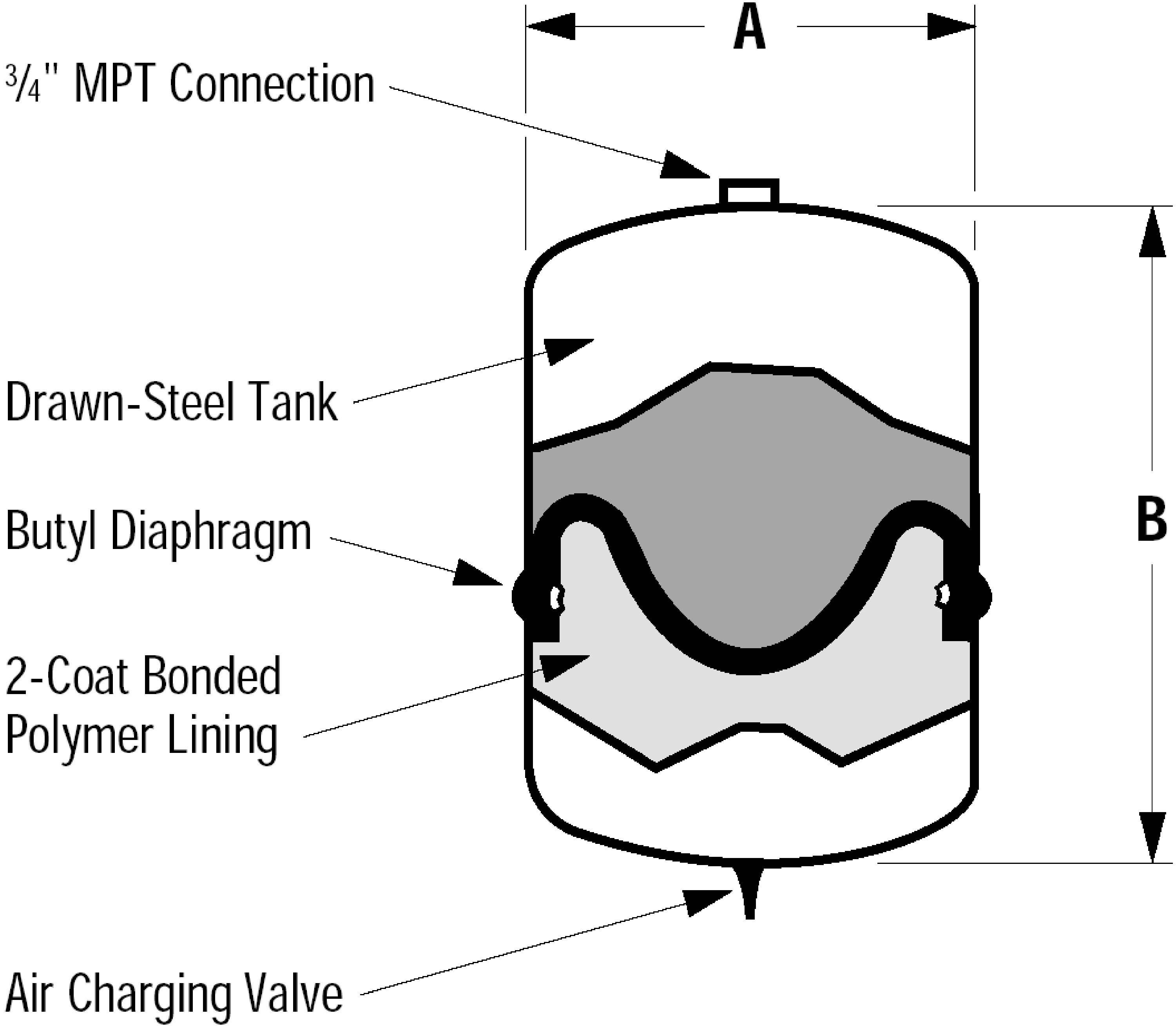


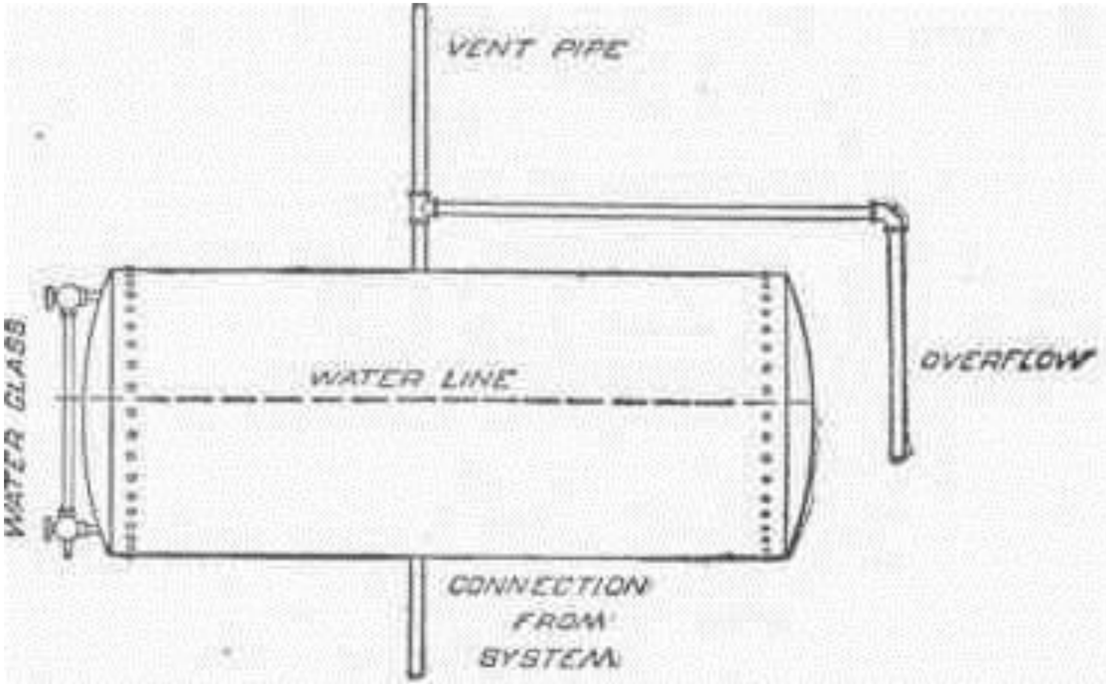
System
12 psig Precharge
Charge Valve
System
Expanded Water
System Pressure
Charge Valve

(A) (B)

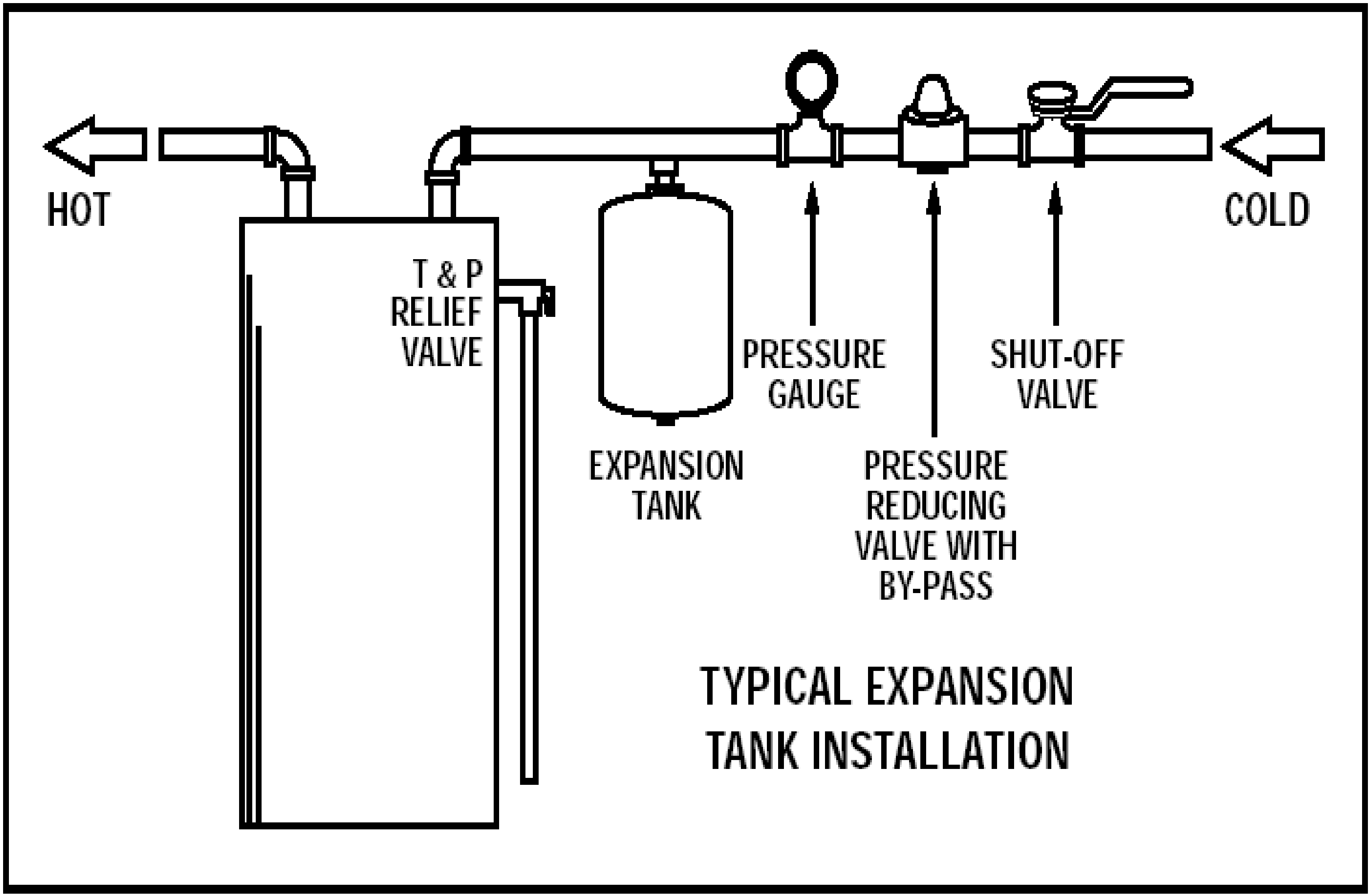


AIR
WATER
AIRTROL VENT VALVE

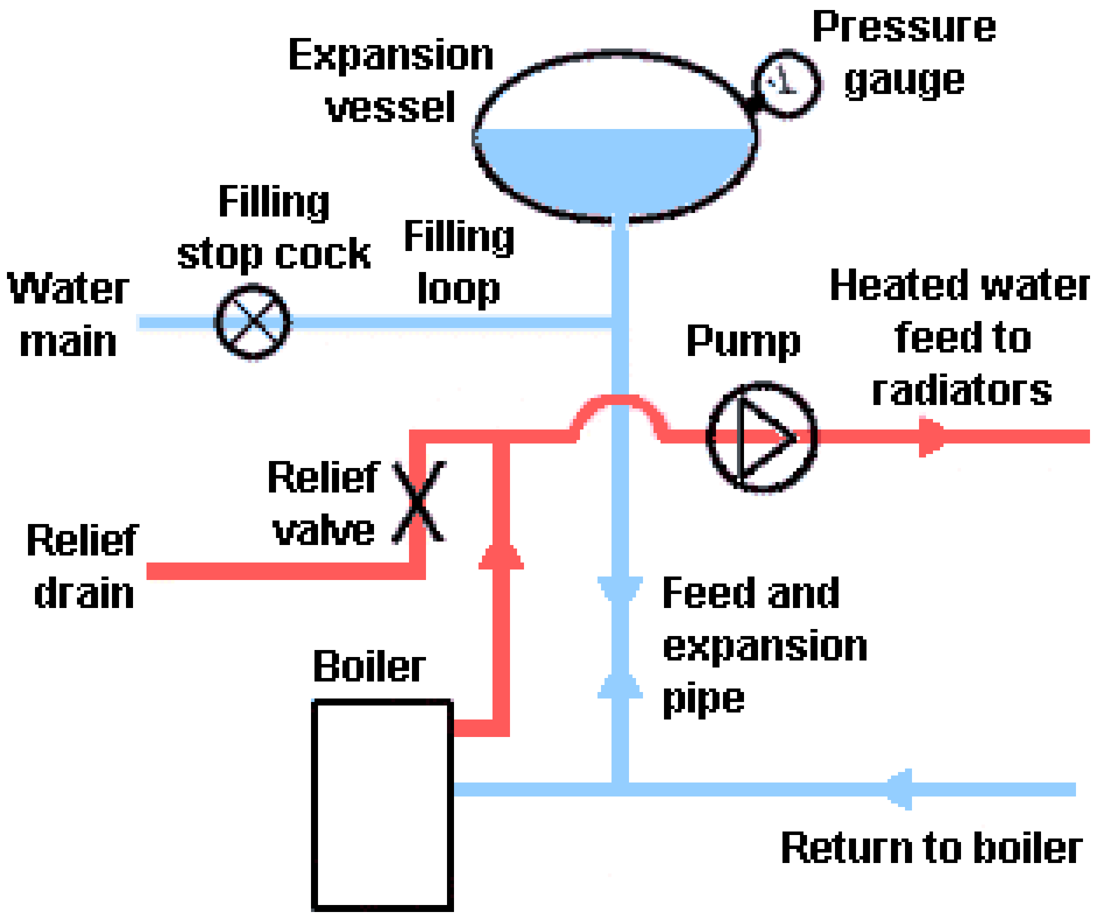

A
¾" MPT Connection
Drawn-Steel Tank
Butyl Diaphragm
2-Coat Bonded
Polymer Lining
B
Air Charging Valve



Old Style Steel Boiler Expansion Tank



TYPICAL EXPANSION
TANK INSTALLATION



Expansion vessel
Pressure gauge
Filling stop cock
Filling loop
Water main
Heated water feed to radiators
Pump
Relief valve
Relief drain
Feed and expansion pipe
Boiler
Return to boiler

$$V_t = \frac{(0.00041T - 0.0466)V_s}{\left(\frac{P_a}{P_f}\right) - \left(\frac{P_a}{P_o}\right)}$$

where:

V_t = Minimum volume of tanks (gallons) (L).

V_s = Volume of system, not including expansion tanks(gallons) (L).

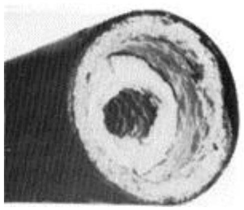
T = Average operating temperature (°F) (°C).

P_a = Atmospheric pressure (psi) (kPa).

P_f = Fill pressure (psi) (kPa).

P_o = Maximum operating pressure (psi) (kPa).

Boiler Water Treatment

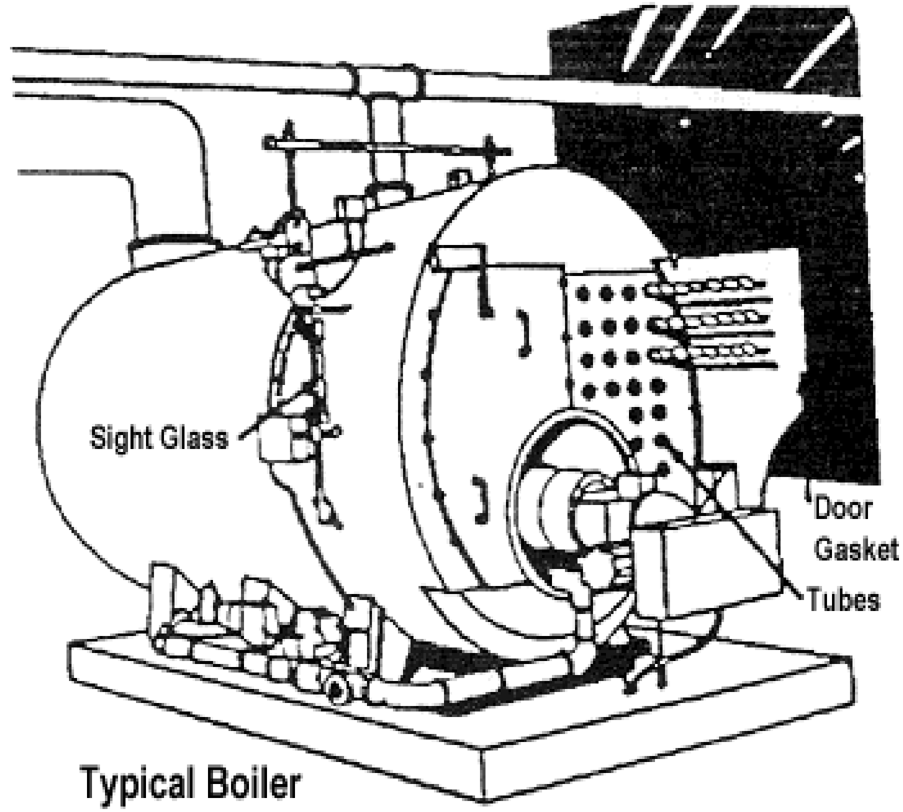


Nu-Calgon Wholesaler, Inc.

Ty-Ion B20

Introduction to Boiler

- Enclosed Pressure Vessel
- Heat generated by Combustion of Fuel i transferred to water t become steam
- Process: Evaporatior
- Steam volume increase to 1,600 times from wate and produces tremendo force
- Boiler to be extremely dangerous equipment. Care is must to avoid explosion.



What is a boiler?

What are the various heating surfaces in a boiler?

Heating surface is expressed in *square feet* or in *square meter*

Classified into :

1 ***Radiant Heating Surfaces*** — (direct or primary) including all water-backed surfaces that are directly exposed to the radiant heat of the combustion flame.

2 ***Convected Heating Surfaces*** — (indirect or secondary) including all those water-backed surfaces exposed only to hot combustion gases.

3 ***Extended Heating Surfaces*** — referring to the surface of economizers and super heaters used in certain types of water tube boilers.

Fuels used in Boiler

S. No	**Solid**	**Liquid**	**Gaseous**	**AgroWaste**
1	**Coal**	HSD	NGas	Baggase
2	**Lignite**	LDO	Bio Gas	Pith
3		Fur.Oil		Rice Husk
4		LSHS		Paddy
5				Coconut shell
6				Groundnutshell

Performance Evaluation of Boilers

- **What are the factors for poor efficiency?**

Efficiency reduces with time, due to poor combustion, heat transfer fouling and poor operation and maintenance.Deterioration of fuel and water quality also leads to poor performance of boiler.

- **How Efficiency testing helps to improve performance?**

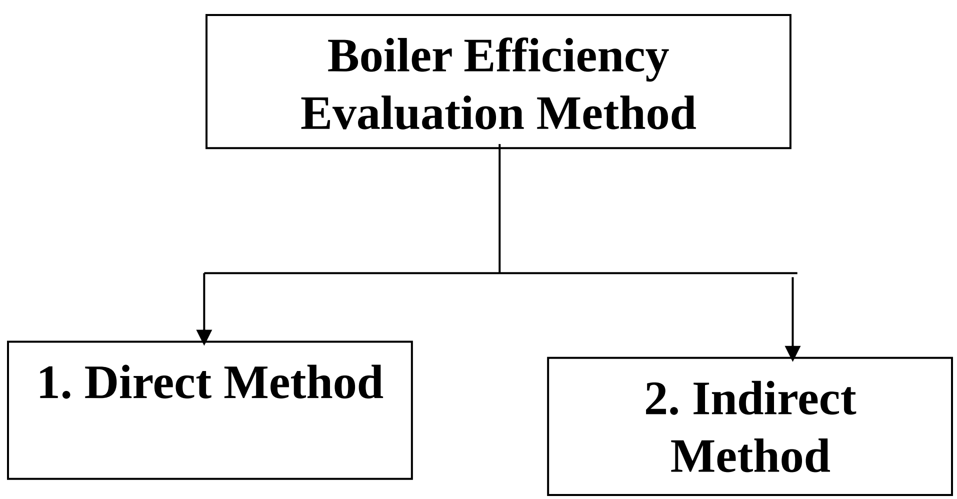
Helps us to find out how far the boiler efficiency drifts away from the best efficiency. Any observed abnormal deviations could therefore be investigated to pinpoint the problem area for necessary corrective action.

Boiler Efficiency

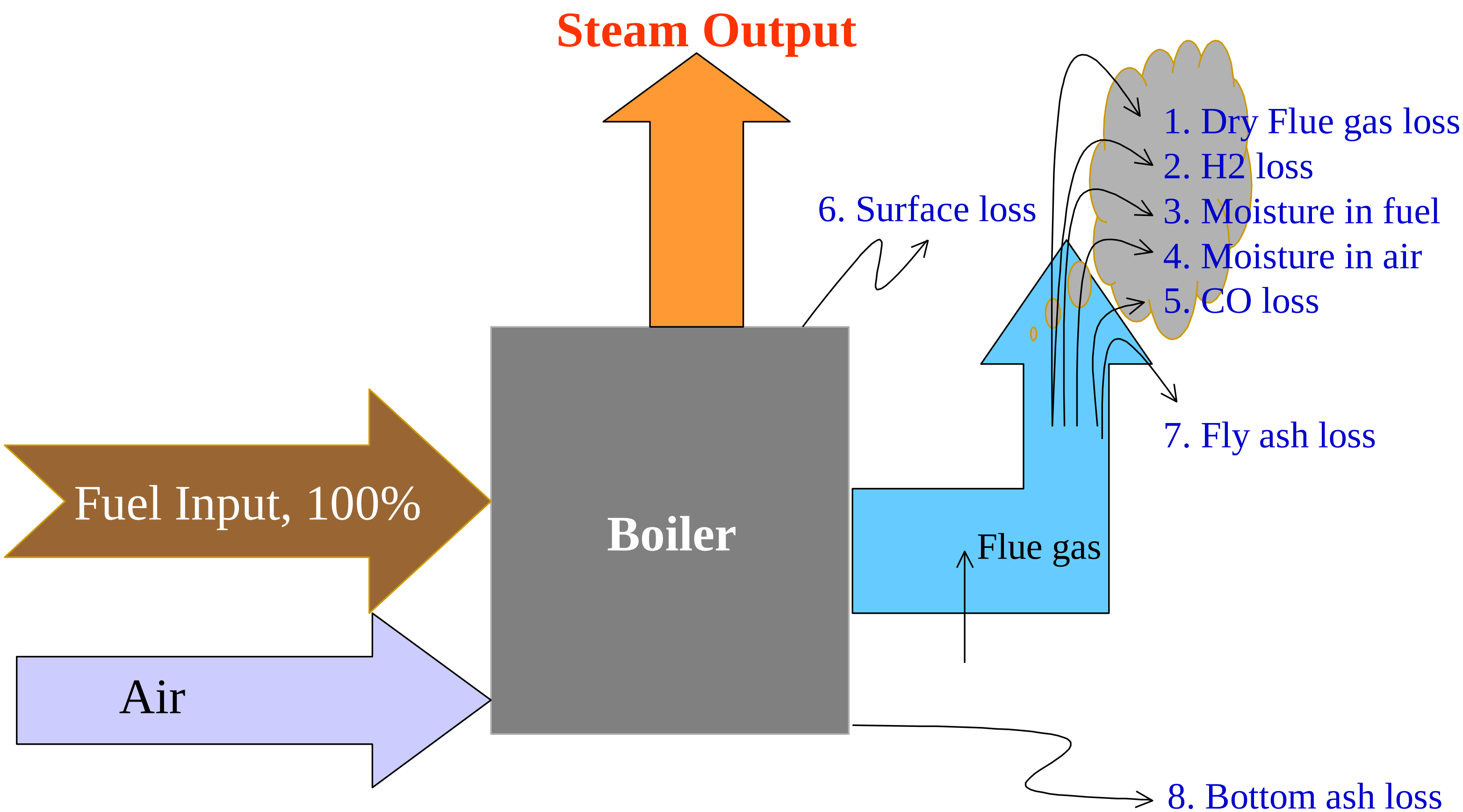
Thermal efficiency of boiler is defined as the percentage of heat input that is effectively utilized to generate steam. There are two methods of assessing boiler efficiency.

1) **The Direct Method:** Where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.

2) **The Indirect Method:** Where the efficiency is the difference between the losses and the energy input.



What are the losses that occur in a boiler?



Efficiency = 100 – (1+2+3+4+5+6+7+8)

(by In Direct Method)

Why Boiler Blow Down ?

<u>When water evaporates</u>

- Dissolved solids gets concentrated
- Solids precipitates
- Coating of tubes
- Reduces the heat transfer rate

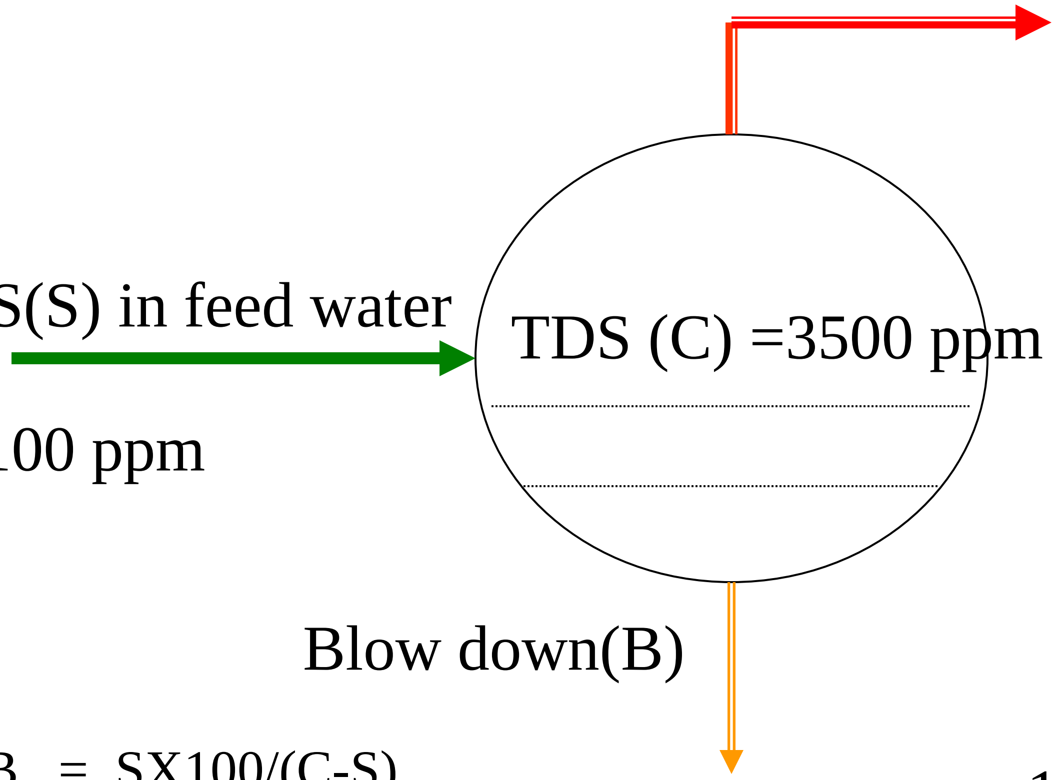
Intermittent Blowdown

- The intermittent blown down is given by manually operating a valve fitted to discharge pipe at the lowest point of boiler shell to reduce parameters (TDS or conductivity, pH, Silica etc) within prescribed limits so that steam quality is not likely to be affected
- TDS level keeps varying
- fluctuations of the water level in the boiler.
- substantial amount of heat energy is lost with intermittent blow down.

Continuous Blowdown

- **A steady and constant dispatch of small stream of concentrated boiler water, and replacement by steady and constant inflow of feed water.**
- **This ensures constant TDS and steam purity.**
- **Once blow down valve is set for a given conditions, there is no need for regular operator intervention.**
- **Even though large quantities of heat are wasted, opportunity exits for recovering this heat by blowing into a flash tank and generating flash steam.**
- **This type of blow down is common in high-pressure boilers.**

The quantity of blowdown required to control boiler water solids concentration is calculated by using the following formula:
(Continuous Blow down)



B = SX100/(C-S)

$$\text{Blowdown \%} = \frac{\text{TDS in FW} \times 100}{\text{TDS in Boiler} - \text{TDS in FW}}$$

= 100 / (3500-100)

= (100/3400)x100

= 2.9 %=3%

Blow down flow rate = 3%x 10,000kg/hr = 300kg/hr

Boiler Water Treatment

- **Method :** It is carried out by adding chemicals to boiler to prevent the formation of scale by converting the scale-forming compounds to free-flowing sludges, which can be removed by blowdown.
- **Limitation :** Applicable to boilers, where feed water is low in hardness salts, to low pressures- high TDS content in boiler water is tolerated, and when only small quantity of water is required to be treated. If these conditions are not applied, then high rates of blowdown are required to dispose off the sludge. They become uneconomical from heat and water loss consideration.
- **Chemicals :** Different waters require different chemicals. Sodium carbonate, sodium aluminate, sodium phosphate, sodium sulphite and compounds of vegetable or inorganic origin are all used for this purpose.
- Internal treatment alone is not recommended.

External Water Treatment

- **Propose:** External treatment is used to remove suspended solids, dissolved solids (particularly the calcium and magnesium ions which are a major cause of scale formation) and dissolved gases (oxygen and carbon dioxide).
- **Different treatment Process :** ion exchange; demineralization; reverse osmosis and de-aeration.
- Before any of these are used, it is necessary to remove suspended solids and colour from the raw water, because these may foul the resins used in the subsequent treatment sections.
- Methods of pre-treatment include simple sedimentation in settling tanks or settling in clarifiers with aid of coagulants and flocculants. Pressure sand filters, with spray aeration to remove carbon dioxide and iron, may be used to remove metal salts from bore well water.
- Removal of only hardness salts is called softening, while total removal of salts from solution is called demineralization.

Ion-exchange Process (Softener Plant)

- In ion-exchange process, hardness is removed as the water passes through bed of natural zeolite or synthetic resin and without the formation of any precipitate. The simplest type is ‘base exchange’ in which calcium and magnesium ions are exchanged for sodium ions. The sodium salts being soluble, do not form scales in boilers. Since base exchanger only replaces the calcium and magnesium with sodium, it does not reduce the TDS content, and blowdown quantity. It also does not reduce the alkalinity.

- Demineralization is the complete removal of all salts. This is achieved by using a “cation” resin, which exchanges the cations in the raw water with hydrogen ions, producing hydrochloric, sulphuric and carbonic acid. Carbonic acid is removed in degassing tower in which air is blown through the acid water. Following this, the water passes through an “anion” resin which exchanges anions with the mineral acid (e.g. sulphuric acid) and forms water. Regeneration of cations and anions is necessary at intervals using, typically, mineral acid and caustic soda respectively. The complete removal of silica can be achieved by correct choice of anion resin. Ion exchange processes can be used for almost total demineralization if required.

De-aeration

- In de-aeration, dissolved gases, such as oxygen and carbon dioxide, are expelled by preheating the feed water before it enters the boiler.
- All natural waters contain dissolved gases in solution. Certain gases, such as carbon dioxide and oxygen, greatly increase corrosion. When heated in boiler systems, carbon dioxide (CO_2) and oxygen (O_2) are released as gases and combine with water (H_2O) to form carbonic acid, (H_2CO_3).
- Removal of oxygen, carbon dioxide and other non-condensable gases from boiler feedwater is vital to boiler equipment longevity as well as safety of operation. Carbonic acid corrodes metal reducing the life of equipment and piping. It also dissolves iron (Fe) which when returned to the boiler precipitates and causes scaling on the boiler and tubes.
- De-aeration can be done by mechanical de-aeration, by chemical de-deration or by both together.

Mechanical de-aeration

Removal of oxygen and carbon dioxide can be accomplished by heating the boiler feed water. They operate at the boiling point of water at the pressure in the de-aerator. They can be of **vacuum or pressure type**.

The vacuum type of de-aerator operates below atmospheric pressure, at about 82^{o}C, can reduce the oxygen content in water to less than 0.02 mg/litre. Vacuum pumps or steam ejectors are required to maintain the vacuum.

- The pressure-type de-aerators operates by allowing steam into the feed water and maintaining temperature of 105^{o}C. The steam raises the water temperature causing the release of O_2 and CO_2 gases that are then vented from the system. This type can reduce the oxygen content to 0.005 mg/litre.
- Steam is preferred for de-aeration because steam is free from O_2 and CO_2, and steam is readily available & economical

Chemical de-aeration

- While the most efficient mechanical de-aerators reduce oxygen to very low levels (0.005 mg/litre), even trace amounts of oxygen may cause corrosion damage to a system. So removal of hat traces of oxygen with a chemical oxygen scavenger such as sodium sulfite or hydrazine is needed.

Reverse Osmosis

- **Reverse osmosis uses the fact that when solutions of differing concentrations are separated by a semi-permeable membrane, water from less concentrated solution passes through the membrane to dilute the liquid of high concentration. If the solution of high concentration is pressurized, the process is reversed and the water from the solution of high concentration flows to the weaker solution. This is known as reverse osmosis.**

- **The quality of water produced depends upon the concentration of the solution on the high-pressure side and pressure differential across the membrane. This process is suitable for waters with very high TDS, such as sea water.**

Recommended Boiler Water Limits

Factor	**Upto20 kg/cm^2**	**21 - 40 kg/cm^2**	**41-60 kg/cm^2**
TDS, ppm	3000-3500	1500-2000	500-750
Total iron dissolved solids ppm	500	200	150
Specific electrical conductivity at 25^{0}C (mho)	1000	400	300
Phosphate residual ppm	20-40	20-40	15-25
pH at 25^{0}C	10-10.5	10-10.5	9.8-10.2
Silica (max) ppm	25	15	10

Energy Conservation Opportunities

in
Boilers

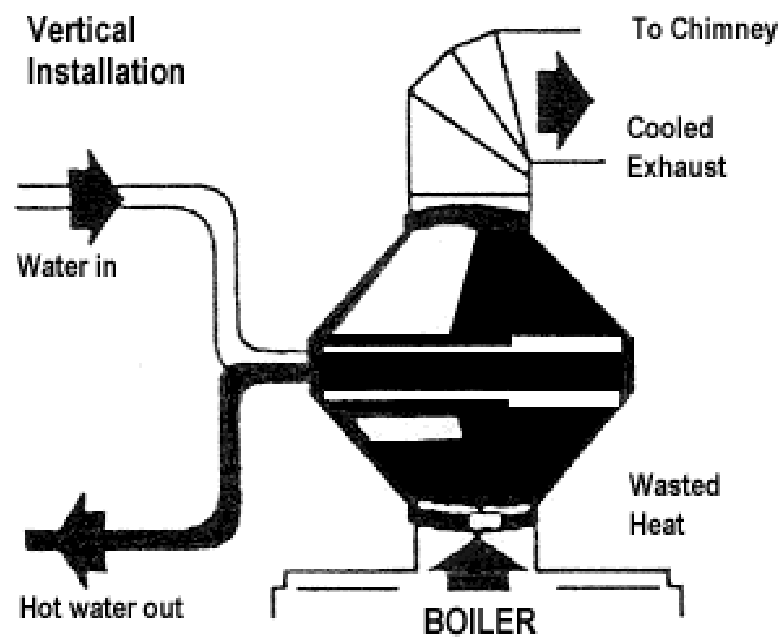
1. Reduce Stack Temperature ↓

- Stack temperatures greater than 200°C indicates potential for recovery of waste heat.
- It also indicate the scaling of heat transfer/recovery equipment and hence the urgency of taking an early shut down for water / flue side cleaning.

22^{o} C reduction in flue gas temperature increases boiler efficiency by 1%

2. Feed Water Preheating using Economizer

- **For an older shell boiler, with a flue gas exit temperature of 260ºC, an economizer could be used to reduce it to 200ºC, Increase in overall thermal efficiency would be in the order of 3%.**
- **Condensing economizer(N.Gas) Flue gas reduction up to 65ºC**



Exhaust Heat Recovery

6ºC raise in feed water temperature, by economiser / condensate recovery, corresponds to a 1% saving in fuel consumption

3. Combustion Air Preheating

- Combustion air preheating is an alternative to feed water heating.

- In order to improve thermal efficiency by 1%, the combustion air temperature must be raised by 20 ^{o}C.

4. Incomplete Combustion

(c c c c c + co co co co)

- Incomplete combustion can arise from a shortage of air or surplus of fuel or poor distribution of fuel.
- **In the case of oil and gas fired systems,** CO or smoke with normal or high excess air indicates burner system problems.

  Example: Poor mixing of fuel and air at the burner. Poor oil fires can result from improper viscosity, worn tips, carbonization on tips and deterioration of diffusers.
- **With coal firing**: Loss occurs as grit carry-over or carbon-in-ash (2% loss).

  Example :In chain grate stokers, large lumps will not burn out completely, while small pieces and fines may block the air passage, thus causing poor air distribution.

  Increase in the fines in pulverized coal also increases carbon loss.

5. Control excess air

for every 1% reduction in excess air ,0.6% rise in efficiency.

The optimum excess air level varies with furnace design, type of burner, fuel and process variables.**Install oxygen trim system**

Table 2.5 Excess air levels for different fuels

Fuel	**Type of Furnace or Burners**	**Excess Air (% by wt)**
Pulverised coal	Completely water-cooled furnace for slag-tap or dry-ash removal	15-20
	Partially water-cooled furnace for dry-ash removal	15-40
Coal	Spreader stoker	30-60
	Water-cooler vibrating-grate stokers	30-60
	Chain-grate and traveling-gate stokers	15-50
	Underfeed stoker	20-50
Fuel oil	Oil burners, register type	5-10
	Multi-fuel burners and flat-flame	10-30
Wood	Dutch over (10-23% through grates) and Hofft type	20-25
Bagasse	All furnaces	25-35
Black liquor	Recovery furnaces for draft and soda-pulping processes	5-7

6. Radiation and Convection Heat Loss

- The surfaces lose heat to the surroundings depending on the surface area and the difference in temperature between the surface and the surroundings.

- The heat loss from the boiler shell is normally a fixed energy loss, irrespective of the boiler output. With modern boiler designs, this may represent only 1.5% on the gross calorific value at full rating, but will increase to around 6%, if the boiler operates at only 25 percent output.

- Repairing or augmenting insulation can reduce heat loss through boiler walls

7. Automatic Blowdown Control

- Uncontrolled continuous blowdown is very wasteful.
- Automatic blowdown controls can be installed that sense and respond to boiler water conductivity and pH.
- A 10% blow down in a 15 kg/cm^2 boiler results in 3% efficiency loss.

BLOWDOWN HEAT LOSS

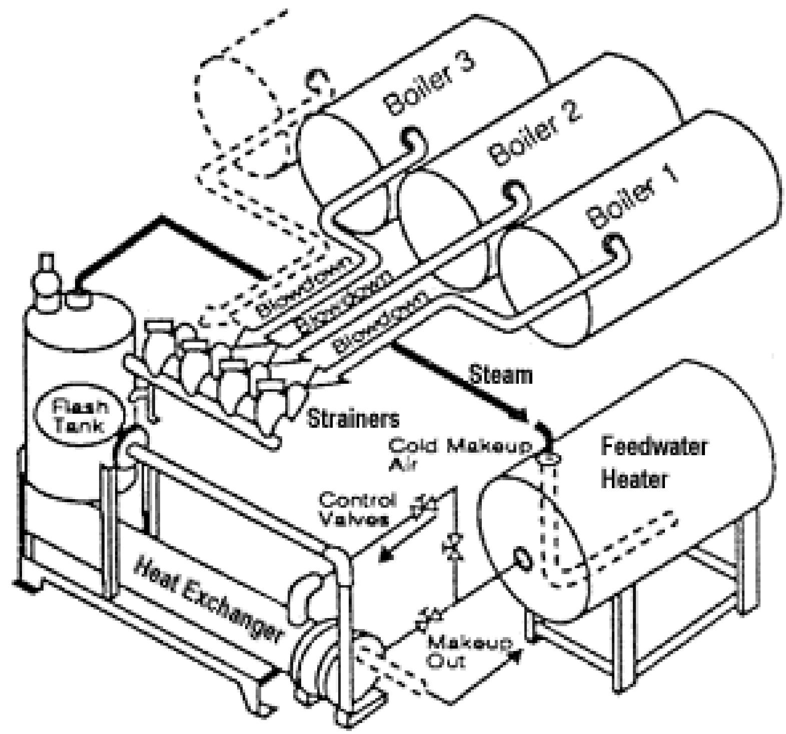
This loss varies between 1% and 6% and depends on a number of factors:

- Total dissolved solids (TDS) allowable in boiler water
- Quality of the make-up water, which depends mainly on the type of water treatment installed

  (e.g. base exchange softener or demineralisation):
- Amount of uncontaminated condensate returned to the boilerhouse
- Boiler load variations.
- Correct checking and maintenance of feedwater and boiler water quality, maximising condensate return and smoothing load swings will minimise the loss.
- **Add a waste heat recovery system to blowdowns**
  - **Flash steam generation**

Blowdown Heat Recovery

- **Efficiency Improvement - Up to 2 percentage points.**
- Blowdown of boilers to reduce the sludge and solid content allows heat to go down the dra
- The amount of blowdown shou be minimized by following a good water treatment program but installing a heat exchanger the blowdown line allows this waste heat to be used in preheating makeup and feedwater.
- Heat recovery is most suitable for continuous blowdown operations which in turn provides the best water treatment program.



Blowdown Heat Recovery System

8. Reduction of Scaling and Soot Losses

- In oil and coal-fired boilers, soot buildup on tubes acts as an insulator against heat transfer. Any such deposits should be removed on a regular basis. Elevated stack temperatures may indicate excessive soot buildup. Also same result will occur due to scaling on the water side.
- High exit gas temperatures at normal excess air indicate poor heat transfer performance. This condition can result from a gradual build-up of gas-side or waterside deposits. Waterside deposits require a review of water treatment procedures and tube cleaning to remove deposits.
- Stack temperature should be checked and recorded regularly as an indicator of soot deposits. When the flue gas temperature rises about 20^{o}C above the temperature for a newly cleaned boiler, it is time to remove the soot deposits

Cleaning

- Incorrect water treatment, poor combustion and poor cleaning schedules can easily reduce overall thermal efficiency
- However, the additional cost of maintenance and cleaning must be taken into consideration when assessing savings.

- Every millimeter thickness of soot coating increases the stack temperature by about 55^{o}C. 3 mm of soot can cause an increase in fuel consumption by 2.5%.

- A 1mm thick scale (deposit) on the water side could increase fuel consumption by 5 to 8%

9. Reduction of Boiler Steam Pressure

- Lower steam pressure gives a lower saturated steam temperature and without stack heat recovery, a similar reduction in the temperature of the flue gas temperature results. Potential 1 to 2% improvement.
- Steam is generated at pressures normally dictated by the highest pressure / temperature requirements for a particular process. In some cases, the process does not operate all the time, and there are periods when the boiler pressure could be reduced.
- Adverse effects, such as an increase in water carryover from the boiler owing to pressure reduction, may negate any potential saving.
- Pressure should be reduced in stages, and no more than a 20 percent reduction should be considered.

10. Variable Speed Control for Fans, Blowers and Pumps

Generally, combustion air control is effected by throttling dampers fitted at forced and induced draft fans. Though dampers are simple means of control, they lack accuracy, giving poor control characteristics at the top and bottom of the operating range.

If the load characteristic of the boiler is variable, the possibility of replacing the dampers by a VSD should be evaluated.

11. Effect of Boiler Loading on Efficiency

- **As the load falls, so does the value of the mass flow rate of the flue gases through the tubes. This reduction in flow rate for the same heat transfer area, reduced the exit flue gas temperatures by a small extent, reducing the sensible heat loss.**
- **Below half load, most combustion appliances need more excess air to burn the fuel completely and increases the sensible heat loss.**
- **Operation of boiler below 25% should be avoided**
- **Optimum efficiency occurs at 65-85% of full loads**

12. Boiler Replacement

if the existing boiler is :

- **Old and inefficient, not capable of firing cheaper substitution fuel, over or under-sized for present requirements, not designed for ideal loading conditions replacement option should be explored.**
- **The feasibility study should examine all implications of long-term fuel availability and company growth plans. All financial and engineering factors should be considered. Since boiler plants traditionally have a useful life of well over 25 years, replacement must be carefully studied.**

Steam System Exercises – Air/Fuel Ratio

- Optimum combustion air = increased efficiency
  - Too much air = excess heat loss in stack
  - Too little air = wasted fuel