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Engineering Encyclopedia

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BOILER WATERSIDE OPERATION and CONTROL

Note: The source of the technical material in this volume is the Professional Engineering Development Program (PEDP) of Engineering Services.

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INFORMATION

MAJOR BOILER OPERATING VARIABLES - MONITORING AND CONTROL

The major boiler operating variables are:

- Steam drum level/BFW rate
- Boiler blowdown
- Steam drum pressure/steam production rate
- Fuel flow/Pressure
- Maximum metal temperatures
- Minimum metal temperature

Steam Drum Level/BFW Rate

The objective of the steam drum level control is to:

1. Control the drum level to the set point
2. Minimize the interaction with the combustion control system
3. Make smooth changes in boiler water inventory as boiler load changes (shrink/swell)
4. Properly balance the BFW input with boiler steam output
5. Compensate for BFW pressure variation without process upset

Level Measurement

SAES-J-602 (Boiler Safety Systems for Water Tube Boilers) specifies that the water level in the steam drum shall be measured by 3 independent differential pressure type transmitters. Each transmitter is to have separate tap points. Two transmitters will be connected to the same end of the steam drum. One will be used for control and the other will be used for local and control room indication. The third transmitter located on the other end of the steam drum will be used for control room indication of low and high level alarms. In addition, two externally mounted level switches directly connected to the drum with their own taps are required for high and low drum level shutdown functions. The level switches are mounted on the same end of the drum, just like the control transmitter. Level switches are dedicated to shutdown functions only. Level gage glasses, with their own taps are also provided on each end of the steam drum.

While the level gage glass is the basic level measurement, the indication it provides is usually in error. The reason for the error is that the level gage acts like a condenser/cooler for the boiler steam, thus causing circulation of condensate through the gage glass. This cooling also cools the condensate to a lower temperature than the water in the steam drum. The greater density of the cool water in the gage glass results in a level reading that is often 1 to 3 inches lower than the actual level in the steam drum. These errors can be corrected by installation and calibration of the gage glass to show the proper level at operating conditions, but the level will be in error at atmospheric conditions.

Control Valves

Two parallel control valves are provided for BFW supply to the steam drum. Only one valve is in service at one time as per SAES-J-602. A motor operated valve (MOV) located upstream of each control valve selects which control valve is in service. Indication is provided for the position of the MOVs. The BFW control valves remain in their last position on air failure.

Shrink and Swell

When the steam load is increased more steam bubbles are generated in the riser tubes. This results in some water being displaced in the tubes and results in an initial sudden rise in water level. This swell effect that results in an increased water level normally would decrease the BFW rate but the steam load indicates that the BFW rate should be increased.

When the steam load is decreased fewer bubbles are generated in the riser tubes. Water then replaces the space formerly occupied by steam bubbles and results in an initial sudden decrease in water level. The shrink effect, which results in a decreased water level will increase BFW rate when the steam load indicates that the BFW rate should be decreased.

The increase in pressure on a load decrease can enhance shrink because the steam bubbles get smaller due to the pressure change. Likewise, a decrease in pressure on a load increase can enhance swell because the bubbles get larger due to the pressure decrease.

The amount of water in the boiler in any one time is called the water inventory. Increasing boiler loads cause an apparent swell of this inventory. The increase in BFW rate to supply increased steam production must be delayed due to the swell to maintain level at its setpoint. The level effect of shrink and swell will decrease with larger steam drums (less % volume change) and higher boiler operating pressure (the density difference between water and steam is less).

Control

The proper control action will balance the effect of swell and shrink with steam production to minimize major swings in steam drum level and BFW rate. A high-high steam drum level can result in boiler water being carried over into the steam system with associated problems downstream especially in turbines. A low-low steam drum level will result in inadequate water supply to some tubes, which can result in tube overheating and possible rupture. Shutdown switches at high-high and low-low level shutdown the boiler, when the level control system cannot adequately control the steam drum level.

The three-element control system takes into account the drum level and steam flow to adjust the BFW rate as shown in the control schematic of Figure 1. The steam drum pressure may also be used to avoid conflict with the firing control system. The control system in Figure 1 can be described as a combination feedforward plus feedback cascade control. When boiler load increases the level control will delay a BFW rate increase required by the steam rate increase until the level swell has been reduced by boiling due to the load change. A similar control is initiated on a reduced load change except the BFW continues at the original rate until the shrink has been reduced and then the BFW is reduced to be proportional to the steam rate. Proper tuning of the control system results in a desired response so that the control system meets all control objectives.

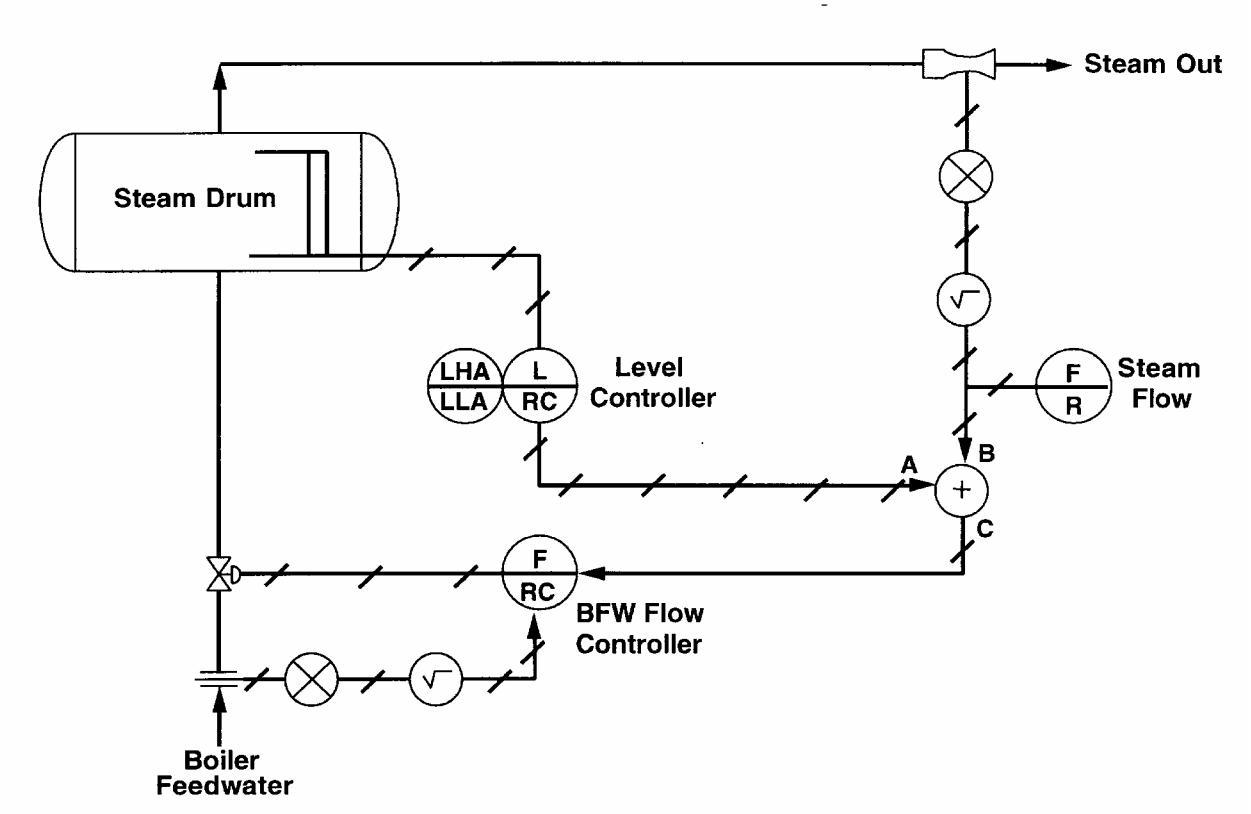


Figure 1. Three-Element Feedwater Control System

Boiler Blowdown

The boiler blowdown rate from the steam drum is continuous to control the circulating boiler water quality. The continuous blowdown may be controlled by an on-line conductivity analyzer. Conductivity is proportional to the total dissolved solids in the boiler water but can be calibrated for any impurity.

Mud drum blowdown is intermittent based on experience for the required removal of sediment.

Large rapid changes in the steam or mud drum blowdown rate can adversely affect the steam drum level control.

Steam Drum Pressure/Steam Production Rate

The overall steam production rate is set by user demand. The steam production rate is proportional to the firing rate. The steam pressure is the primary control of firing. As user demand increases, there is a slight decrease in pressure until firing rate can be increased so that steam production will match steam demand. The reverse holds true for a decrease in steam demand. In a single boiler installation, the steam pressure controls the firing directly.

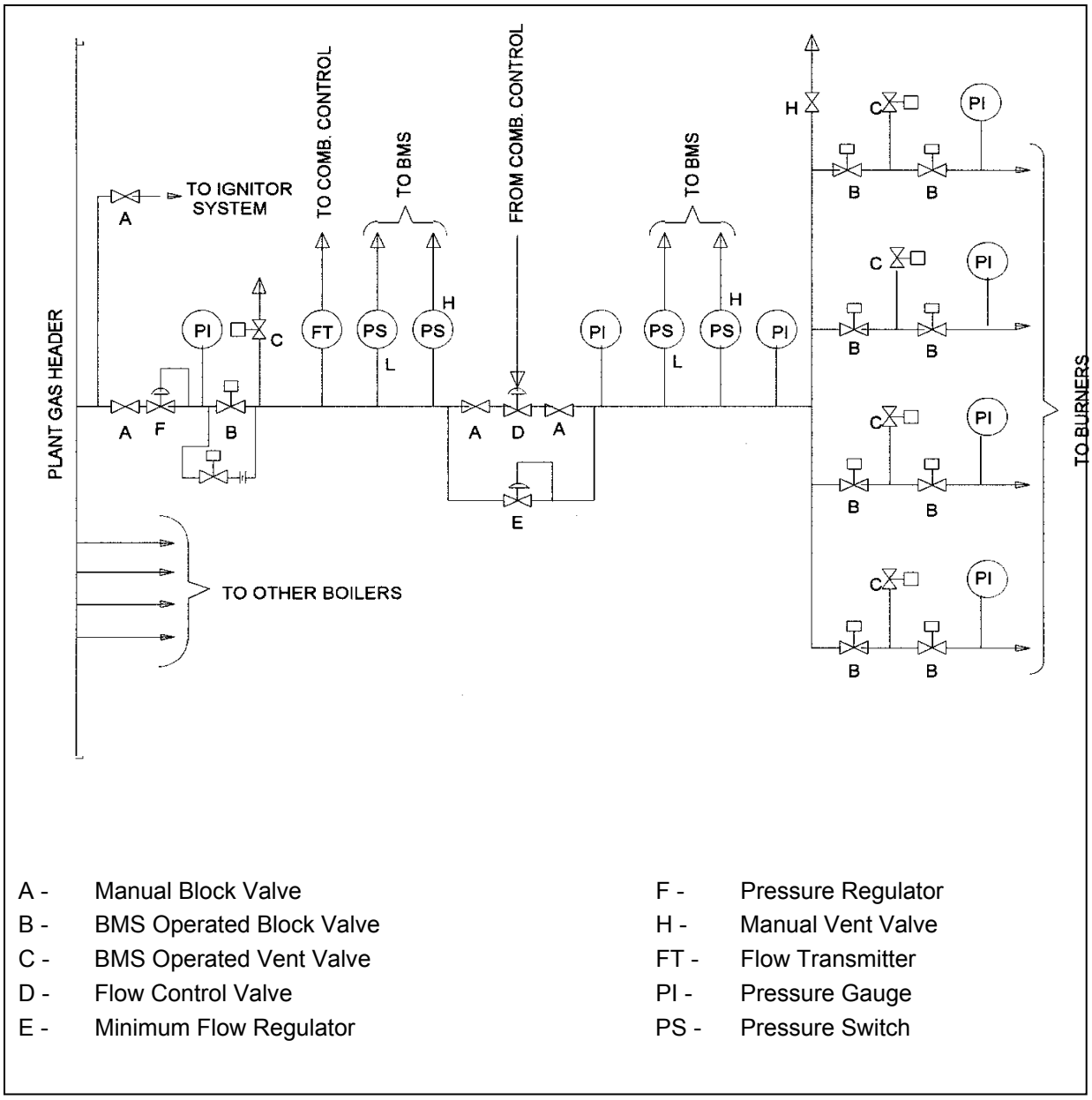
In multiple boiler installations a master firing rate pressure controller resets the set point for the steam rate on individual boilers. The steam rate controls the firing rate on each boiler. The master controller can allocate steam rate to individual boilers based on the boiler size or on a least cost basis. Individual boilers may be base loaded by placing them on a constant steam flow control with no adjustment by the master controller.

Steam production can drop off if the heating value of the fuel decreases. The reduced steam flow will correct the boiler firing in a multiple boiler installation. In a single boiler installation, the reduced steam flow will result in decreased steam pressure, which will correct the firing If there are frequent fluctuations in fuel quality, firing controls can be made more responsive by adding a fuel heating value feed-forward control component.

32-SAMSS-021 calls for smooth operation with demand changes in either direction of 20% maximum rated capacity (MCR) without actuating shutdown due to high-high or low-low level in the steam drum. Smooth operation includes a stable flame over the complete operating range of 20% to 110% MCR rating.

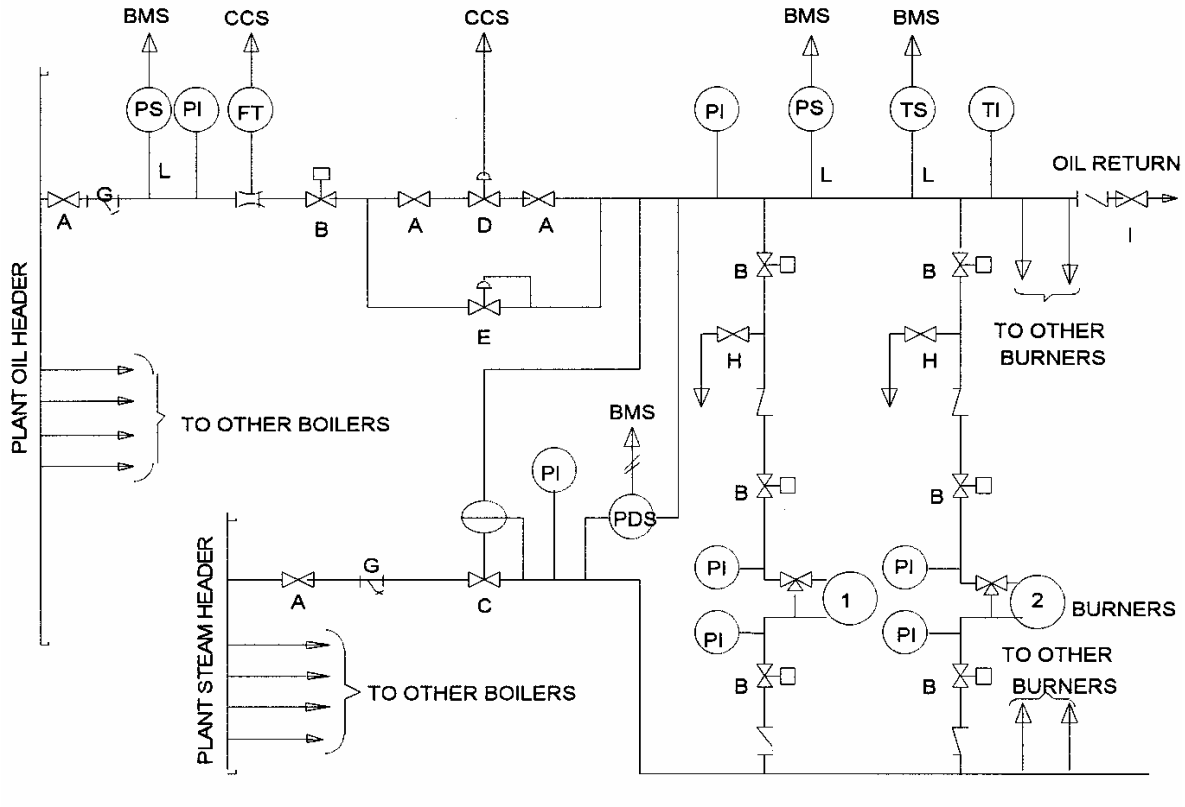
Fuel Flow/Pressure

Fuel flow is controlled to meet a boiler demand by the firing control signal through the combustion control system. Fuel flow can change due to boiler load changes and from heating value changes in the fuel. Fuel flow should not be a function of fuel supply pressure. Supply pressure to the control valve should have an independent control as shown in the typical gas and fuel oil installation flow schematics shown in Figure 2 and Figure 3 which are the minimum fuel system specified by SAES-J-602 for automatic startup of water tube boilers. Addendum C contains all fuel supply figures from SAES-J-602. The oil supply system also controls the differential pressure between oil and steam for proper atomization of the oil.



A - Manual Block Valve
B - BMS Operated Block Valve
C - BMS Operated Vent Valve
D - Flow Control Valve
E - Minimum Flow Regulator
F - Pressure Regulator
H - Manual Vent Valve
FT - Flow Transmitter
PI - Pressure Gauge
PS - Pressure Switch

Figure 2. Gas Burner System (Automatic Startup)



A - Manual Block Valve
B - BMS Operated Block Valve
C - Steam/Oil Pressure Regulator
D - Flow Control Valve
E - Minimum Flow Regulator
G - Strainer
H - Manual Bleed Valve
BMS - Burner Management System
CCS - Combustion Control System
PDS - Differential Pressure Switch
TS - Temperature Switch

Figure 3. Oil Burner System (Automatic Startup)

Fuel flow will be shut off in a boiler shutdown event by BMS block valve (B). One shutdown event that has been discussed is a high high or a low low level in the steam drum. The fuel flow will also be shutoff on air failure in a forced draft system.

On boilers with the ability to burn both gas and oil fuels the combustion control system can control the rate of either fuel but not both. When both fuels are fired, the oil rate is usually controlled by the number of oil burners in service and the gas rate is controlled by the combustion control system.

Maximum Metal Temperatures

The metal temperature can drastically affect the strength of a material. If design metal temperatures are exceeded the tubes can creep which can result in bending and bulging. The tube metal temperatures are monitored by tubeskin thermocouples. 32-SAMMS-021 calls for a minimum of 4 tubeskin thermocouples on superheater tubes.

Minimum Metal Temperature

When fuel is burned, water and carbon dioxide are the major products. When the fuel contains sulfur, SO_2 and SO_3 are formed. If the flue gases encounter metal, cool the flue gas to its dew point. At this point, SO_2 and SO_3 will combine with water to form sulfurous and sulfuric acids. The dew point of flue gas mixtures is given in Figure 4 as a function of SO_3 in the flue gas and water content of the flue gas. 32-SAMSS-021 specifies that 5% of the sulfur in the fuel should be calculated as SO_3 in the flue gas. You will notice that the guideline of avoiding metal temperatures below 300ºF is fairly safe.

Minimum metal temperatures are experienced in the economizer and in the stack. Economizers are designed to avoid the minimum metal temperature problem. The coolest economizer tube metal temperature may be monitored. The top part of the stack is usually an alloy to prevent sulfur acid corrosion if the flue gas permeates in back of the refractory.

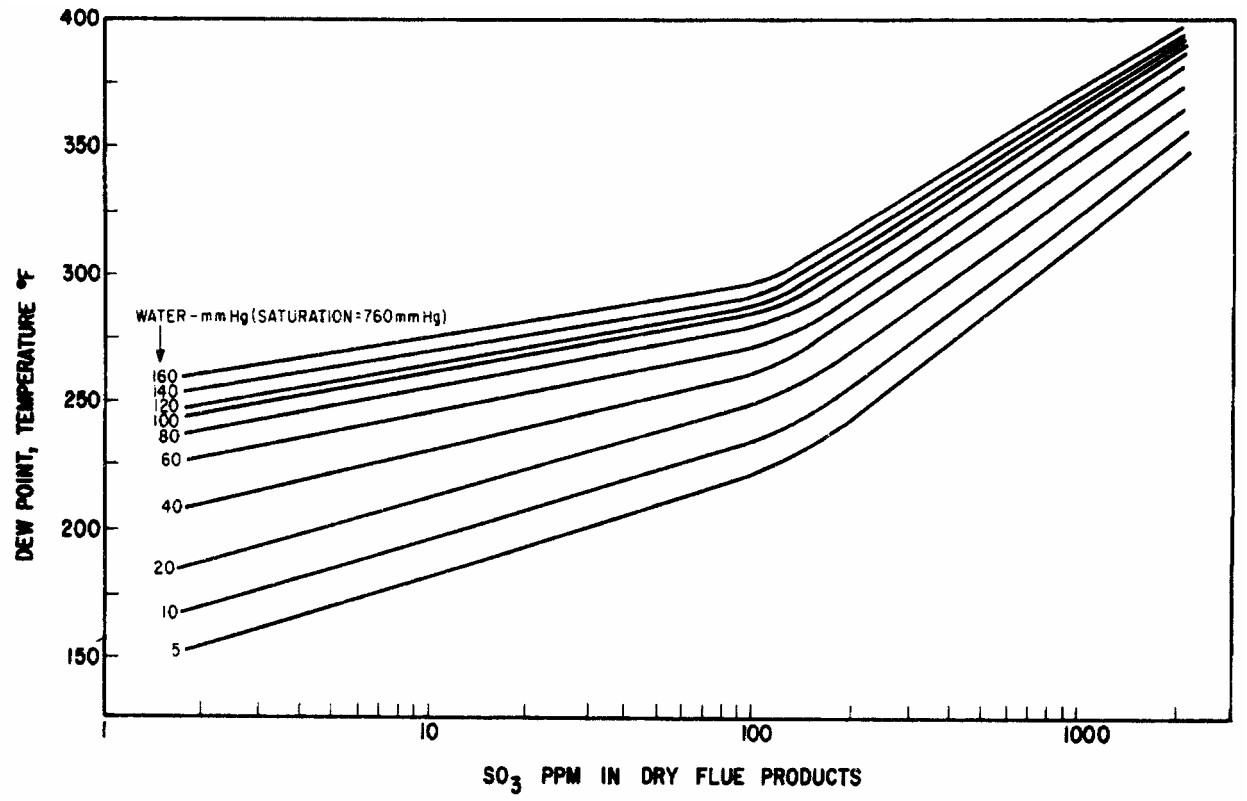


Figure 4. Flue Gas Dew Point

"Total System" Interaction of Variables

Tuning of the control system is very important to prevent unwanted system interaction. For example the level control can affect the firing rate by swings of the cold BFW rate into the steam drum. If the system is not properly tuned, swings in the BFW rate can result in firing rate swings which will then affect the level control because of the changes in shrink and swell and cause further swings in the BFW rate. This swinging could be started by a change in steam demand. Interactions can also occur in other systems such as the draft control and the firing system, blowdown and steam drum level control, etc.

Consequences of Inadequate Control

Inadequate control can result in overheating of tubes with the results shown in Figure 5 and Figure 6. Other consequences of inadequate control include carryover of boiler water into the steam system, boiler explosions, lifting safety valves, etc.

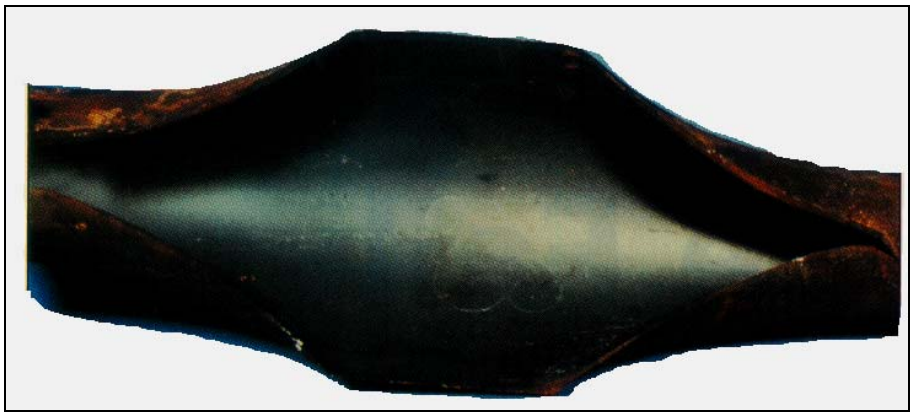


Figure 5. Short Term Overheating

Figure 6. Extreme Short Term Overheating

BOILER SAFETY SYSTEMS

Boiler safety systems include:

- Alarm systems
- Emergency shutdown systems
- Flame detectors
- Startup interlocks
- Safety valves (PZV)
- Non-return valve

Alarm Systems

Alarms on a boiler typically include the following recommended by SAES-J-602:

1. A high boiler firebox pressure could indicate a ruptured tube. A low boiler firebox pressure could indicate a failure of combustion air supply.
2. High and low steam drum level.

   A high steam drum level can result in carryover of boiler water into the steam system and a low steam drum level can result in inadequate supply of water to the tubes, which could result in a ruptured tube.
3. Flame failure detection.

   Flame failure can result in a hazardous explosive mixture in the boiler. Each burner has two flame detectors and each will alarm a flame failure.
4. Low gas or oil fuel pressure to burners.
5. Low combustion airflow.
6. Combustion air fan trip.

   A combustion air fan trip requires shutdown unless the spare fan has successfully started up.
7. Low steam to oil differential.

   A low steam to oil differential will result in improper combustion of the oil with a poor flame pattern.

8. Low instrument air header pressure.

   Low instrument air pressure could result in shutdown of all control systems.

Additional alarms may include:

1. High steam temperature.

   A high steam temperature could result in a ruptured tube in the superheater or possible damage to downstream equipment.

2. High and low stack oxygen.

   High stack oxygen is indicative of poor operation (high excess air) and a low stack oxygen can be indicative of inadequate air supply, which could result in flame failure.

3. High gas or oil fuel pressure to burners.

   High fuel pressure could indicate over firing the burners and/or plugging of the burners.

4. Low oil temperature can also result in flame failure.

   A low oil temperature causes a high viscosity of the oil. A high viscosity will result in improper combustion of the oil with a poor flame pattern and oil drip.

Emergency Shutdown (ESD) Systems

An automatic emergency shutdown of the boiler can result from the following as specified in SAES-J-602 and 34-SAMSS-619:

1. Flame failure on both flame detectors for primary fuel.
2. Low-low gas or oil fuel burner header pressure after firing control valve.
3. Low-low gas or oil fuel burner header pressure.
4. Low-low steam to oil fuel differential.
5. High-high or low-low steam drum level.
6. Furnace pressure high-high.
7. Low-low combustion airflow.
8. Fan(s) tripped.
9. Low-low instrument air header pressure.
10. Local or remote manual ESD push-button enabled.

The shutdowns above are simply extremes of alarms already discussed. The purpose of the alarm is to give warning of a situation that can lead to a shutdown.

The following sequence will be initiated by Emergency Shutdown System (ESD):

1. Close fuel gas and oil header shut off valves and open vent valves
2. Close fuel gas and oil burner shut off valves and open vent valves
3. Close pilot gas header shut off valves and open vent valves
4. Turn on appropriate shutdown lights and alarms
5. Return system to pre-purge state
6. De-energize all ignitors

Flame Detectors

SAES-J-602 specifies there should be a minimum of two flame detectors for each burner for main flame detection. On multiple fuel burners, two detectors are required for the primary fuel and at least one detector is required for the secondary fuel if the secondary fuel.

Where burner front space is limited and will not allow a third flame detector to be fitted, single-element dual sensitivity or dual-element flame detectors are acceptable. Single element flame detectors shall have automatically selected dual-sensitivity adjustments. There should be two separate sensitivity adjustments for gas and oil firing.

Startup Interlocks

The primary purpose of startup interlocks is to prevent a boiler explosion. Introducing a flame into a boiler that contains fuel can result in an explosion if the fuel concentration is within the explosive (flammable) limits. These interlocks should not be bypassed for normal operation. Bypassing these interlocks will be required to perform system maintenance. Interlock details are discussed under boiler startup.

Safety Valves (PZVs)

A typical safety relief valve (PZV) is shown in Figure 7.

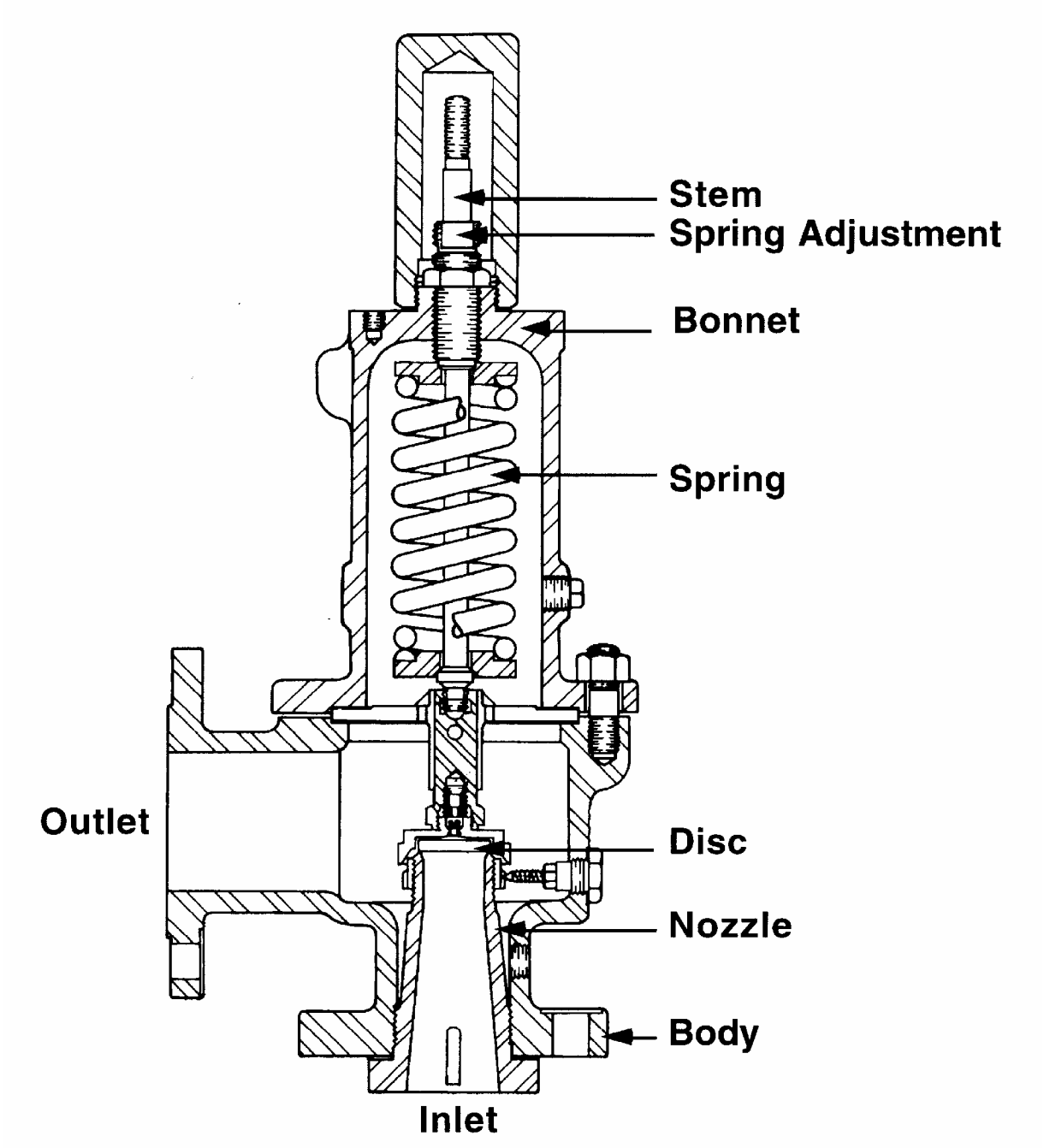


Figure 7. Typical Safety Valve

Safety valves are provided on the steam drum and after the superheater as noted in Figure 7. A separate PZV is also provided for the economizer if it can be valved off from the steam drum.

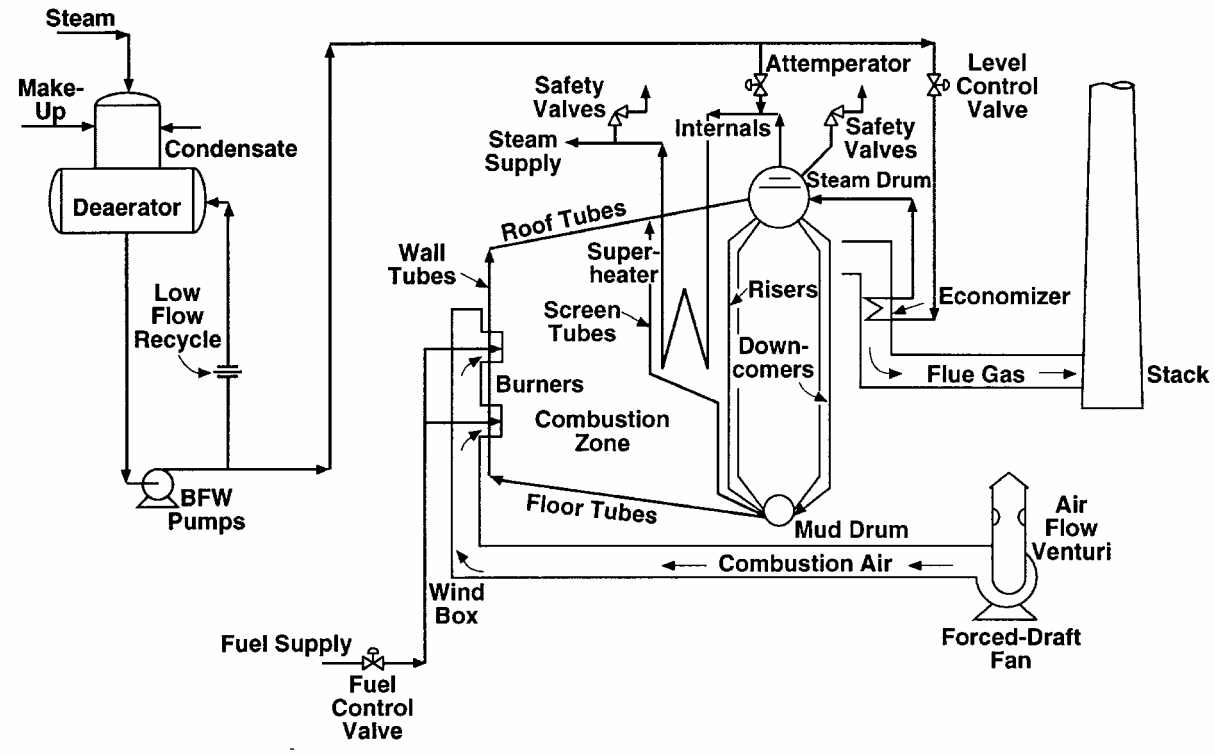


Figure 8. Typical Steam Generation System

At least two PZVs (one spare) are required per SAES on the steam drum, on almost all boilers. Each PZV must be capable of relieving at least 75% of the steam the boiler can generate without the pressure in the boiler rising more than 16% above the lower PZV setting. The pressure of the first PZV can be set at or below the design pressure (maximum allowable working pressure) and the maximum setpoint for the other PZV is 3% above the design pressure. The maximum range of set points is 10% of the highest set point.

At least one PZV is required by ASME code to protect the superheater and is located between the superheater and the first block valve downstream of the boiler. The superheater PZV should be set to open first so that flow through the superheater is ensured. Without adequate flow, the temperature of the superheater tubes may exceed design temperature and could burst at a lower pressure than design. The superheater PZV setting is commonly 97% of the lowest boiler drum PZV setting minus the superheater pressure drop at full flow.

For PZVs operating between 300 and 1000 psig, the popping tolerance is plus or minus 10 psi. PZVs should close at no less than 96% of set pressure (blowdown adjustment).

The total required design capacity for steam drum and superheater PZVs is the greater of the boiler's maximum rated capacity or a capacity factor times the heat transfer area. The capacity factors are 16 lb/ft^2 of heat transfer surface for watertube boilers, 14 lb/ft^2 of heat transfer surface for fire tube boilers and 3.5 lb/ft^2 of heat transfer surface for electric boilers. The capacity of the superheater PZV may contribute to the boilers total PZV capacity but the steam drum PZV capacity must be at least 75% of the total required.

The ASME code requires that no valves be installed between the PZVs and the boiler or between the PZV and it discharges to atmosphere. Discharge piping should be as short and straight as possible and located away from any platform or walkway. Discharge piping should also be supported.

Sizing a Safety Valve

Figure 9 is a diagram of pressure and flow through a boiler. The pressure at the inlet of the boiler is much greater than the pressure on the outlet. Each major piece of equipment in this flow pattern has a different design pressure due to pressure drop through the system. For example, the design pressure of the economizer is greater than the design pressure of the steam drum and tubes. The design pressure of the steam drum and tubes is greater than the design pressure of the superheater. The safety valve for the steam drum maximum setting will be set at the design or MAWP for the steam drum. The safety valve for the superheater maximum setting will be set at the design or AWP for the supeheater.

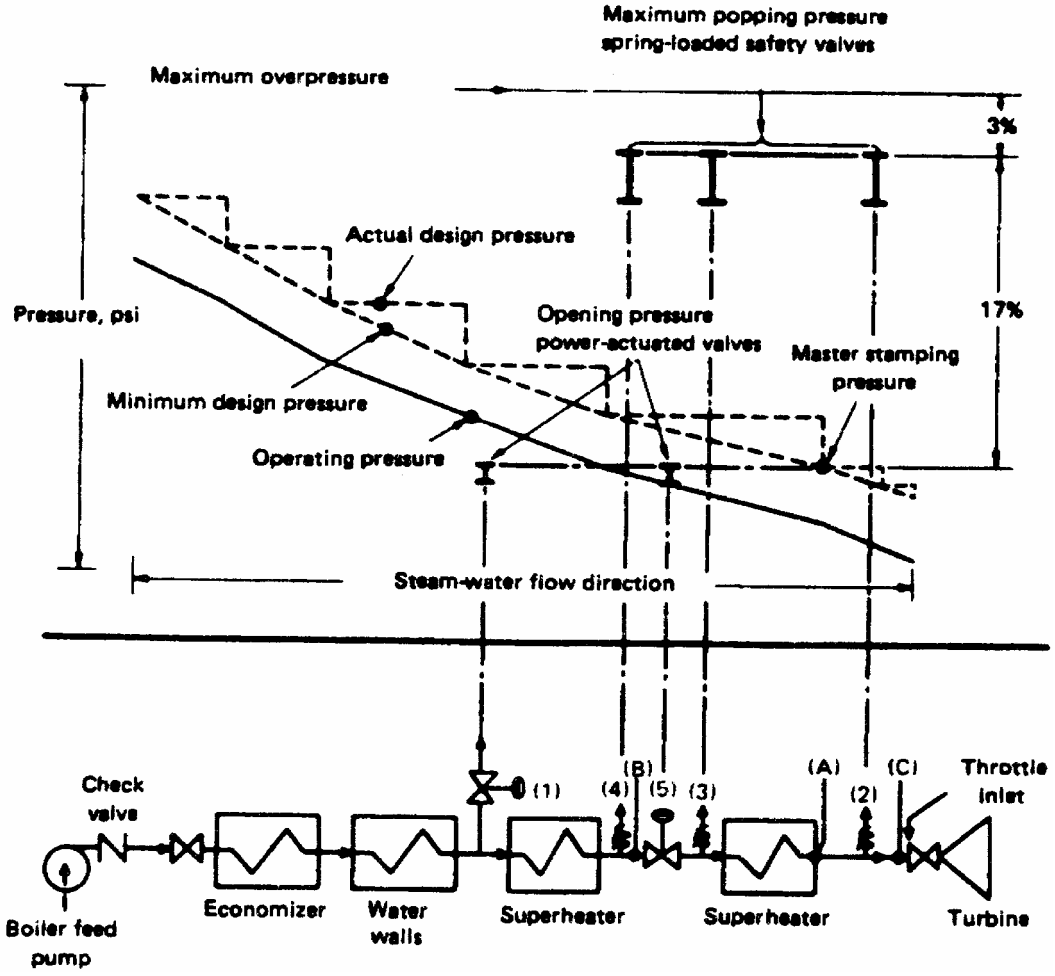


Figure 9. Design Pressure For A Boiler

A safety valve is a spring-loaded device. It will start to open at the set pressure. It will not be fully open and attain full capacity until the pressure has increased above the set pressure by an amount called accumulation. Boiler safety valves are sized with an accumulation of 10% of the set pressure for a single valve and 16% for multiple valves as shown in Figure 10.

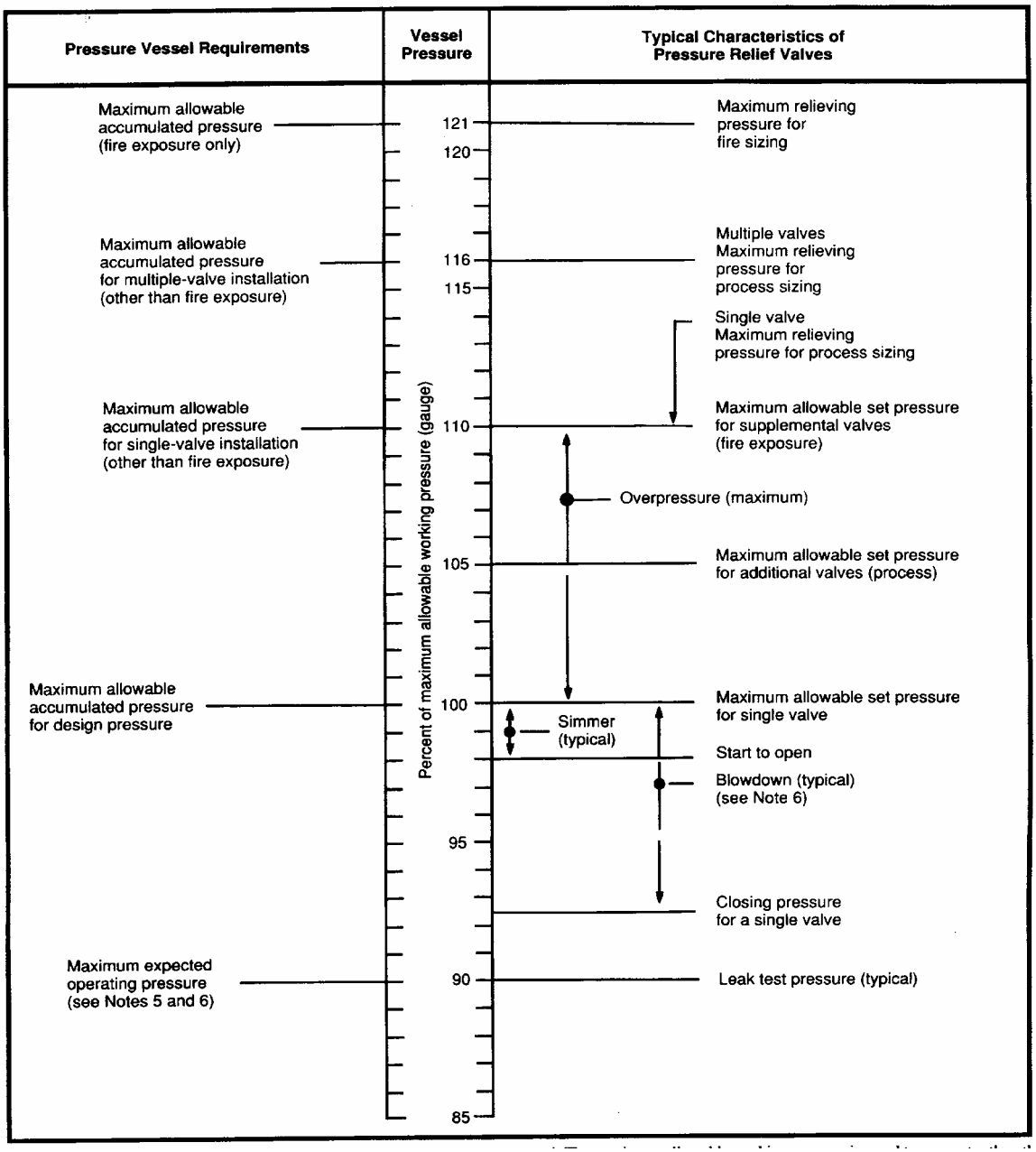


Figure 10. Safety Valve Pressure Level Relationship

The flow capacity of the steam drum safety valve will be based on the MCR and/or 14 pounds of steam per square foot of surface which ever is greater. The superheater safety valve flow capacity will be based on the MCR and/or 6 pounds per square foot of surface which ever is greater. The code gives the following Table 1 for minimum area for connection of safety valves for fire tube boilers.

Boiler Heating Surface, sq ft (H)

Gauge Pressure, psi	100	200	300	400	500	600	800	1000
16	3.174	6.348	9.522	12.696	15.869	19.043	25.392	31.739
25	2.500	5.000	7.499	10.000	12.498	15.000	20.000	24.996
50	1.584	3.168	4.752	6.338	7.920	9.504	12.677	15.839
75	1.166	2.331	3.497	4.663	5.828	6.995	9.326	11.657
100	0.924	1.849	2.773	3.697	4.621	5.546	7.394	9.243
125	0.767	1.533	2.300	3.067	3.834	4.600	6.134	7.667
150	0.655	1.311	1.966	2.621	3.276	3.932	5.242	6.553
175	0.572	1.145	1.718	2.289	2.862	3.435	4.579	5.725
200	0.508	1.016	1.525	2.033	2.541	3.049	4.066	5.082
225	0.457	0.913	1.370	1.827	2.284	2.740	3.654	4.567
250	0.415	0.830	1.244	1.659	2.074	2.489	3.318	4.148

Boiler Heating Surface, sq ft (H)

Gauge Pressure, psi	1200	1400	1600	1800	2000	2500	3000	v
16	38.086	44.435	50.783	57.130	63.478	79.347	95.216	13.330
25	30.000	35.000	40.000	44.992	49.992	62.489	74.987	10.498
50	19.007	22.175	25.354	28.510	31.678	39.599	47.517	6.655
75	13.989	16.320	18.652	20.983	23.314	29.143	34.972	4.896
100	11.092	12.940	14.789	16.637	18.486	23.106	27.729	3.882
125	9.201	10.734	12.267	13.800	15.334	19.166	23.000	3.220
150	7.863	9.174	10.484	11.795	13.106	16.382	19.658	2.752
175	6.870	8.015	9.158	10.305	11.450	14.312	17.175	2.404
200	6.099	7.115	8.132	9.148	10.164	12.706	15.247	2.1345
225	5.481	6.394	7.308	8.221	9.134	11.417	13.702	1.9183
250	4.978	5.807	6.637	7.466	8.296	10.370	12.444	1.7422

A = HV/420

Table 1. Minimum Safety Valve Connection Flow Area

The area for a safety valve nozzle can be calculated from the following equation that assumes sonic flow through the nozzle.

$$A = \frac{W}{C\,(P)\,(K_{sh})}$$

where:

A = required flow nozzle area, in^2

C = 45 for ASME Section VIII

50 for ASME Section I

K_{sh} = superheat correction factor (Refer to Table 12)

1.0 value for saturated steam

P = upstream relieving pressure, psia

(set + accumulation + 14.7)

W = flow, lb/hr

Set Pressure Psig	Saturation Temperature ºF	Correction Factor K_{sh}											
		0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88
		Total Temperature, ºF											
10	240	269	305	335	368	400	428	460	492	520	545	570	595
20	259	286	315	343	375	405	433	463	492	518	542	565	590
40	287	310	335	357	382	410	440	467	493	515	540	561	585
60	308	330	350	370	390	422	450	472	495	515	537	560	580
80	324	345	365	385	405	432	460	478	497	515	535	556	580
100	338	360	375	395	415	440	466	485	500	515	535	555	580
120	350	370	388	405	425	450	475	490	505	520	537	557	581
140	361	–	395	415	435	455	480	497	510	525	540	560	585
160	370	–	405	425	443	463	487	502	516	530	545	565	586
180	379	–	415	432	450	470	492	508	523	535	550	570	590
200	388	–	420	440	456	475	497	513	527	540	555	575	592
220	396	–	430	445	463	480	502	517	532	546	560	577	596
240	403	–	435	452	470	485	507	522	537	550	565	583	600
260	409	–	440	460	475	490	512	526	541	555	569	586	603
280	416	–	447	465	480	495	516	531	545	558	573	590	606
300	422	–	452	470	485	500	520	535	550	562	577	593	610
350	433	–	465	480	496	512	530	545	558	572	586	602	618
400	448	–	475	492	508	523	540	553	566	580	595	610	626
500	470	–	495	513	526	543	557	568	582	597	610	625	646
600	489	–	512	530	543	556	570	585	596	610	625	638	655
800	520	–	545	558	570	585	597	610	625	635	650	665	680
1,000	546	–	567	582	595	608	620	633	645	660	675	688	705
1,250	574	–	593	605	620	630	640	655	688	681	696	710	725
1,500	597	–	–	630	642	653	664	676	688	702	715	728	744
1,750	619	–	–	647	660	670	680	692	704	717	730	743	759
2,000	637	–	–	665	675	685	696	708	719	732	745	757	773
2,500	760	–	–	690	702	712	723	733	742	755	766	780	795`
3,000	697	–	–	713	723	733	742	751	762	773	785	795	812

Courtesy American Petroleum Institute

Table 2. Superheat Correction Factor K_{sh}

Example Problem 1

Size steam drum safety valves for a capacity of 200,000 lb/hr. The MAWP pressure is 600 psig. There are two safety valves set for 600 and 615 psig. The accumulation will be 16%. Each will have a minimum capability of 75% capacity.

Answer:

For safety valve with 600 psig setting

$$P = 600 + 0.16(600) + 14.7 = 710.7 \text{ psia}$$

Each valve must be sized a minimum of 75% capacity.

$$W = 0.75\ (200{,}000) = 150{,}000 \text{ lb/hr}$$

$$A = \frac{W}{C\ (P)\ (K_{sh})} = \frac{150{,}000}{50\ (710.7)\ (1)} = 4.22 \text{ in}^2$$

This is the minimum size nozzle area required.

Table 2 is a standard orifice letter area table. The standard letter chosen must be equal or greater than the required orifice area. An “N” orifice size which has 4.34 in^2 will meet this application. 100% capacity sizing would require an area of 5.63 in^2 or a P orifice.

Orifice Letter	Orifice Area Square inch	Orifice Letter	Orifice Area Square inch
D	0.110	P	6.38
E	0.196	Q	11.05
F	0.307	R	16.0
G	0.503	T	26.0
H	0.785	W	57.26
J	1.287	W_2	93.6
K	1.838	X	101.8
L	2.853	Y	128.8
M	3.60	Z	159.0
N	4.34		

Table 2. Standard Orifice Letter/Area

Non-Return Valve

Each boiler is equipped with a non-return (check) valve in accordance with ASME code to prevent the whole steam system from being depressured by venting through a ruptured tube in a boiler. Two check valves in series are usually used for a non-return valve function.

MAJOR STEPS FOR SAFE BOILER STARTUPS

Both automatic and manual startups must follow the same sequence of events to prevent boiler explosions. Natural draft boilers will use steam to purge the boiler instead of air used on forced draft boilers. Burners are always lit one at a time for both manual and automatic startup. The automatic startup will be discussed in detail because most boilers have an automatic startup.

Addendum A is the detailed startup for Ras Tanura Refinery high-pressure steam plant, which is an example of a typical boiler startup. This startup instruction contains additional safe guards beyond the minimal acceptable startup sequence in 34-SAMSS-619.

Safe boiler startups are necessary to avoid boiler explosion damage shown Figure 11.

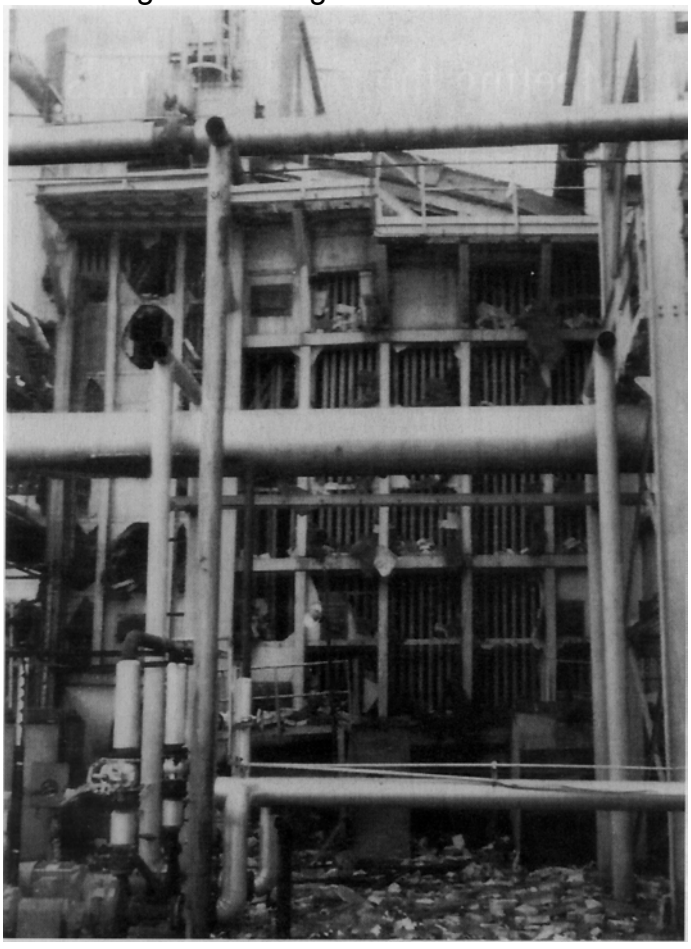


Figure 11. Boiler Explosion Damage

Startup Sequence

The boiler startup sequence as specified in 34-SAMSS-619 includes the following:

1. Pre-purge permissives
2. Purge
3. Light-off pilot and first burner
4. Light-off subsequent pilot and burner

The pre-purge permissives require that the following be in place:

1. Drum level satisfactory (BFW level control established)
2. Instrument air pressure satisfactory
3. Fan running
4. Combustion air (purge air) flow satisfactory
5. No flame in the furnace (flame detectors)
6. All burner fuel gas and fuel oil block valves closed
7. Main fuel gas header block valves closed and vent is open
8. Main fuel oil header block valve and recirculating valve closed
9. Main pilot gas header block valves closed and vent valve open
10. All burner air registers at predetermined open position
11. Atomizing steam/ oil differential pressure satisfactory
12. Fuel gas header pressure upstream of block valves is satisfactory
13. Fuel oil header pressure upstream of block valve is satisfactory
14. Pilot gas header pressure is satisfactory

If the status of the above is satisfactory, then the indicating lamp “Purge Available” will be turned on, and the purge can begin.

The purge sequence includes starting the purge timer for a minimum of 5 minutes, turning on “Purge in Progress” light and turning off “Purge Available” light.

1. Turning off “Purge in Progress” light and turning on “Purge Complete” light,
2. Enabling the pilot gas header push-button circuit, and
3. Start ignitor/burner light off period timer set for about 10 minutes.
4. The “Burner Available” light will be turned on if the permissives are still satisfactory which enables the pilot start push-button at the local panel only.

Operation of the first pilot or burner start push-button will initiate the following sequence:

1. If selected register predetermined position is satisfactory
2. If remaining air registers are in their predetermined open position
3. Start the pilot flame establishing period timer, open the pilot solenoid valves, and energize pilot ignitor.

The pilot flame will be proven (flame detected) within 10 seconds (pilot flame establishing period). Failure to detect the pilot flame shall result in closing the pilot solenoid valves and the pilot start being inhibited for 2 minutes.

When the pilot flame is proven, the burner sequence can be started resulting in the following:

1. Enabling the main fuel gas or oil header valve push-button circuit.
2. Opening of selected burner fuel block valves and closing vent valves.
3. First burner must be proven within 10-minute light off period.

The main flame detectors will prove the flame present within 3 - 5 seconds. Failure to prove the first main burner flame present or a system malfunction will result in the pilot solenoids closing, the burner fuel block valves closing and vent valve opening and return to “Purge Required” state.

Satisfactory completion of the first burner light-off will enable the burner start circuits on the remaining burners. Light off of the remaining burners is possible from either the local panel or the control room. Failure to ignite a subsequent burner within its light-off period shall close fuel and pilot gas block valves and open vents on that burner only.

Once all burners are lit, the system is then in the normal run condition. Combustion is controlled by the combustion (firing) control system, which controls steam production. Any ESD event shall command the logic to initiate a boiler shutdown.

MAJOR STEPS FOR SAFE BOILER SHUTDOWNS

There are five types of boiler shutdown. They are as follows:

1. Standby
2. Normal shutdown
3. Shutdown for maintenance
4. Emergency shutdowns
5. Boiler layup

Standby

In standby, the boiler remains at system pressure but all burners and pilots are turned off and blocked in. The non-return valve will have to be bypassed to maintain pressure if standby is to be maintained for a long period of time. Standby can be returned to service quicker than other shutdowns.

Normal Shutdowns

In a normal shutdown, the burners and pilots are blocked in and the boiler is depressured but water level is maintained in the boiler. See layup if the boiler will be wet and idle for one week or more.

Shutdown for Maintenance

In a shutdown for maintenance, the boiler is completely shutdown. All water is drained and the fireside is purged. The fireside of tubes may be water washed. See procedure for water washing tubes in Addendum B.

When shutting down a boiler, care should be taken to avoid a vacuum being formed by condensing of steam. Boilers are usually vented to atmosphere once the pressure reaches about 15 psig.

Addendum B is a detailed shutdown procedure for Ras Tanura Refinery high pressure steam plant which is an example of a typical boiler shutdown.

Emergency Shutdowns

In an emergency shutdown, the burners and pilots are shutdown and blocked in so that the boiler is in a standby condition.

The following sequence will be initiated by an Emergency Shutdown Device:

1. Close all fuel gas/oil header shut off valves and open vent valves
2. Close all fuel gas/oil burner shut off valves and open vent valves
3. Close all pilot gas header shut off valves and open vent valves
4. Turn on appropriate shutdown lights and alarms
5. Return system to pre-purge state
6. De-energize all ignitors

Note that the air fan continues to operate purging the boiler and cooling the boiler.

Boiler Layup

Boiler layup procedures are specified in GI 403.001. The layup procedures minimize boiler corrosion during layup. Layup should be considered for time periods of greater than one week. The two principle methods used for boiler layup are:

1. Wet layup in which the boiler is drained and then completely filled with boiler feed water that contains additional corrosion inhibitors. All vapor space is filled.
2. Steam layup in which 15 - 60 psig steam pressure is maintained in the boiler. All boiler water is drained. Steam connections are made to the superheater outlet and steam traps are installed on the mud drum and superheater drains. Corrosion inhibitors may be added to the steam.

WORK AIDS

WORK AID 1: RESOURCES USED TO SIZE A PZV

Size steam drum safety valves for a capacity of 200,000 lb/hr. The MAWP pressure is 600 psig. There are two safety valves set for 600 and 615 psig. The accumulation will be 16%. Each will have a minimum capability of 75% capacity.

Answer:

For safety valve with 600 psig setting

P = 600 + 0.16(600) +14.7 = 710.7 psia

Each valve must be sized a minimum of 75% capacity.

W = 0.75 (200,000) = 150,000 lb/hr

$$A = \frac{W}{C(P)(K_{sh})} = \frac{150{,}000}{50(710.7)(1)} = 4.22 \text{ in}^2$$

This is the minimum size nozzle area required.

Table 3 is a standard orifice letter area table. The standard letter chosen must be equal or greater than the required orifice area. An “N” orifice size that has 4.34 in2 will meet this application.

Orifice Letter	Orifice Area Square Inch	Orifice Letter	Orifice Area Square Inch
D	0.110	P	6.38
E	0.196	Q	11.05
F	0.307	R	16.0
G	0.503	T	26.0
H	0.785	W	57.26
J	1.287	W_2	93.6
K	1.838	X	101.8
L	2.853	Y	128.8
M	3.60	Z	159.0
N	4.34		

Table 3. Standard Orifice Letter/Area

GLOSSARY

alloy steel	el that owes its distinctive properties to elements other than carbon, or jointly to these elements and carbon. Chromium, nickel, and molybdenum are the most common alloying elements.
austenitic steel	o known as stainless steel.
BFW	er feed water
buckstay	ictural beams that encircle the water walls of a boiler, increasing the boiler's structural strength.
carbon steel	el that owes its distinctive properties to the carbon it contains.
compensation	erial added to a base wall thickness to compensate for openings in the wall.
corroded condition	geometry of a component (for example, diameter, radius, thickness), assuming that any corrosion allowance has been completely removed.
corrosion allowance	part of a wall thickness that is included to provide for future metal loss due to corrosion or erosion.
draft	ft is the amount of negative pressure in the boiler. A negative draft is a positive pressure
ferritic steel	o known as low alloy steel.
inside radius	inside radius of a cylindrical component, in the corroded condition.
interlock	eans of preventing further action until certain criteria have been satisfied
ligament efficiency	relative strength of a component in which a number of openings have been made compared to the same component with no openings.
maximum allowable stress	allowable stress of the metal to be used in stress calculations.
maximum allow-able working pressure	pressure used for design. This is the maximum pressure at which the boiler is allowed to operate.
minimum required thickness	minimum required wall thickness of a new component, taking into account all allowances.
MOV	or operated valve
non-return valve	heck valve(s) to prevent depressuring the entire steam system through a burst tube in a boiler.
operating temperature	temperature used for design. This is the maximum temperature the component is expected to experience under normal operating conditions.
outside diameter	actual outside diameter of a new cylindrical component.
pitch	center-to-center spacing of adjacent holes in a vessel wall.

PZV	ety relief valve
ratio control	ow rate is controlled so that it is in a constant ratio with another flow rate.
safety relief valve	pring loaded valve that will release gas at a specified pressure with a poppet action.
shrink	nk takes place when the firing of the boiler is reduced and less boiling occurs in the riser tubes which results in the water level dropping
steel	alleable alloy of iron and carbon, usually also containing trace elements.
swell	ell occurs when the firing in the boiler is increased and more vaporization occurs in the riser tubes causing the water level to increase
transition	tapered section in a vessel wall joining two sections of the wall having unequal thicknesses.

ADDENDUM

ADDENDUM A: HP BOILER STARTUP INSTRUCTIONS, RT REFINERY

Table 4. HP Boiler Startup Instructions

CONTENT:

This Instruction outlines the procedure to be followed for firing a boiler at the Ras Tanura Steam Plant. The text includes:

1. Description Of Boilers
2. Responsibilities
3. Qualified Firemen Only To Fire Boilers
4. Safety Regulations
5. Preparation For Firing
6. Firing Boiler
7. Checking During Operation

1. DESCRIPTION OF BOILERS

Main Boilers at the Ras Tanura Steam Plant, designed by the Combustion Engineering Corp., New York, are water tube, vertical (VU50) two drum bent tube type, combination oil and gas fired, 3 pass boilers. The capacity of each boiler is rated at 220,000 pounds (lbs) of steam per hour with 625 lbs at superheater outlet, superheat temperature of 725 °F and saturated temperature of 498 °F at boiler pressure. The manufacturer's working pressure limitation on each boiler is 655 psig in the boiler drum.

2. RESPONSIBILITIES

2.1 The Foreman is responsible for the correct and safe operation of the Steam Plant Boilers, their associated auxiliaries and systems. He must take the necessary action to ensure maximum availability of equipment for the safe and efficient generation of steam.

2.2 The Supervising Operator shall be responsible for enforcing the Safety Regulations outlined in paragraph 4 and operating procedures outlined in paragraphs 5 & 6 of this Instruction and for such actions as may be deemed necessary for the safe and efficient generation of steam during the duration of his shift.

2.3 The Operators shall be responsible for observing the Safety Regulations outlined in paragraph 4 and performing the procedures outlined in paragraphs 5 & 6 of this Instruction and all instruction received from their superiors. The Operators shall be certified to fire boilers SAFELY on Crude Oil/ Fuel Oil and Fuel Gas System.

Table 5. HP Boiler Startup Instructions, (cont'd)

3. **QUALIFIED FIREMEN ONLY TO FIRE BOILERS**

Only Firemen who have been issued certificates as shown in Supplement -2 of this Instruction shall be authorized to fire the furnaces covered by this Instruction.

3.1 Certificates signed by the Foreman and the Superintendent shall be issued to Operators who have been trained in firing these boilers and have been examined and found to be qualified.

3.2 Certificates shall be valid for ONE YEAR ONLY, from the date of the qualifying examination. Certificates must be renewed, or new certificates issued, when the Foreman and the Superintendent fully satisfied that the Fireman is still qualified.

3.3 A list of certified Firemen shall be maintained in the boiler control room, this list shall include the date of qualification or re-qualification as is applicable.

4. **SAFETY REGULATIONS**

The regulations in this paragraph are designed to ensure safety of personnel and equipment and shall be observed at all times.

4.1 Before starting firing procedure, check and ensure that Crude/Fuel Oil, Gas fuel and Pilot gas supply valves are closed and blinded.

4.2 The fire box shall be inspected before firing to ensure that it is clean, free of personnel, and free of flammable material.

4.3 Immediately before lighting or relighting a boiler, the fireside of the boiler must be purged by forced air draft fan for ten minutes. Purging shall be continued until the boiler is free of explosive gases, As indicated by the Purging Cycle Completion Green Light at the Local Panel.

4.4 If the water level in the gauge glass of the steam drum is not visible, fires must be stopped, feed water secured, and Supervising Operator informed immediately.

4.5 When a boiler is in operation the Operators shall check the fires once each hour and shall report any unusual condition such as Flame Impingement on the boiler tubes to the Supervising Operator.

4.6 Extreme care shall be taken to keep liquids in the fuel gas from entering boilers.

4.7 Water column gauge glasses shall be blown down each shift.

4.8 All emergency chain operated cutout valves to water column gauge glasses shall be checked by Operator at least once per shift.

4.9 The Video Spec Operator at the start of each shift shall check and ensure that steam drum high-low water level alarms to individual boiler are in good operating condition as indicated on the Video Spec.

STEAM PLANT - START UP BOILERS NOs. 5 & 6 **Page 3 of 11**

Table 5. HP Boiler Startup Instructions, (cont'd)

4.10 When boilers are fired below 66,000 pounds per hour, main gas fires shall be cut out and the number of oil burners firing shall be reduced rather than to attempt turning down at burners below the minimum firing stable pressure.

5. **PREPARATION FOR FIRING**

5.1 The Operators assigned to fire a boiler shall carefully review this Instruction and shall initial the boiler firing check list shown in Supplement -1 of this Instruction.

5.1.1 This check list will be used during a boiler firing and as each item is performed, the Operators will enter the time and his initials in the spaces provided.

5.2 No boiler shall be started up after a T&I or after steam or mud drums have been opened for repairs or cleaning until:

5.2.1 The boiler has been inspected and accepted by the operation, ROED/Engineer and RESD/Inspector.

5.2.2 All blinds listed in Boiler Blinds Check List, Supplement -3, have been removed and the check list certified by the Supervising Operator.

5.3 Set up the feed water system as follows:

5.3.1 Ensure that north and south steam drum angle valves are closed and feed water block valves before regulators are closed on the main and auxiliary feed water headers and feed water regulators are closed (zero loading pressure).

5.3.2 Ensure that block valves on main feed water header after feed water regulators are closed (all boilers) and block valves on auxiliary feed water header after feed water regulators are closed on boiler No. 5 and block valve on auxiliary feed water header after feed water regulator is opened on #6 boiler only during filling of the boiler.

5.3.3 Open the upper and lower valves on the condensate filling line to the boiler slowly.

5.3.4 Crack open the auxiliary feed water regulator by setting control pressure at 10 psig on #6 boiler only, and on #5 boiler by cracking open the south angle valve.

5.3.5 Crack open the south steam drum angle valve.

5.3.6 Open boiler vents and make sure that all superheater vents and drains are open. Close condensate filling valves and (auxiliary feed water regulator on #6 boiler only zero loading pressure).

5.3.7 Close feed water angle valve and drain the boiler to half (50%) gauge glass.

5.3.8 Open feed water hand and motor operated block valves before and after regulator on main and auxiliary feed water headers to boiler.

STEAM PLANT - START UP BOILERS NOs. 5 & 6 **Page 4 of 11**

Table 5. HP Boiler Startup Instructions, (cont'd)

**5.3.9 The Water Lab Operators shall be responsible for ensuring that the boiler feed water quality is within the required ranges prior to a boiler start up and after a boiler start up.

5.3.9.1 **Before start up of a boiler, check the following:

**5.3.9.1.1 Check Iron level in B/Down, should be (< or = 0.3 ppm).

**5.3.9.1.2 Remove all hold tags, chain and open all valves from chemical pumps to steam drum.

**5.3.9.1.3 Ensure the chemical pumps and lines are in good condition.

5.3.9.2 **After start up of a boiler, check the following:

**5.3.9.2.1 Immediately start up the chemical pumps with 10% stroke for TR+ and caustic.

**5.3.9.2.2 Open the overhead SBD valve (near steam drum) and keep the regular SBD (near mud drum) valve closed.

**5.3.9.2.3 Open the sample point valve.

**5.3.9.2.4 When the boiler pressure is increased to 300 psig in HPBs or 50 psig in LPBs, take samples (every one hour) to check for TR+ (250-350 ppm), Caustic (20-40 ppm) , pH (10.5-11.3), Chloride (max 50 ppm) & TDS (upto 400 ppm in HPB or 450 ppm in LPB), Cycles (60-80 in HPB & 80-100 in LPB).

**5.3.9.2.5 Adjust the pumps stroke accordingly until the results are within the limits.

**5.3.9.2.6 Samples to be taken regularly as per the Lab Schedule.

**5.3.9.2.7 Crack open the SBD (surface B/Down) valve.

5.4 Check and ensure that:

5.4.1 Individual atomizing steam valve, all gas and oil burner fuel valves are closed.

5.4.2 Bypass block valves around atomizing steam and fuel oil regulators are closed and fuel oil/crude oil regulator is off the jack.

5.4.3 Crude/fuel oil and atomizing steam hoses are connected up to oil burner barrels.

5.4.4 All fuel gas and pilot gas flanges and threaded joints are tight.

5.4.5 Blinds are in boiler high and low pressure gas header, vent line block valves before and after the gas blinds are closed, and unions in vent lines are disconnected.

STEAM PLANT - START UP BOILERS NOs. 5 & 6 **Page 5 of 11**

Table 5. HP Boiler Startup Instructions, (cont'd)

5.4.6 Front draft doors, burner air register, and stack dampers are operative.

5.5 Open atomizing steam supply valve and valves before and after steam regulator to boiler atomizing steam header.

5.6 Open fuel oil/crude oil supply valves before and after the fuel oil regulator.

5.7 Open fuel oil/crude oil header recirculation ZV and manual valve approximately 2-4 turns.

5.8 Open fuel oil/crude oil ZV and regulate oil pressure at 25 - 30 psig by oil controller.

5.9 Open steam drum air vent cock.

5.10 Open superheater steam circulating valve to the blowdown drum wide open and leave it open until boiler is on the line.

5.11 Start the boiler fan and open fully the dampers and vanes for purging.

6. **FIRING BOILER**

6.1 Fire boiler as detailed in Refinery Instruction No. 13.613, H.P. Boilers Nos. 5 and 6 Fuel Burning And Fuel Safety Equipment Operation.

**6.1.1 Temporarily, put the fuel gas to burner pressure low low, ESD on bypass just to allow for boiler start up until the fuel gas pressure reaches 5 psig. Then, immediately reactivate the fuel gas pressure ESD.

6.2 Close steam drum air vent when boiler pressure reaches 15 psig.

6.3 Open boiler lead line drain valves and crack open the bypass valve around the 600 psig steam motor operated valve.

6.4 During startup, hold the water level in the steam drum at 50% of the gauge glass and control with angle valve until boiler is on line.

6.5 Observe fire and regulate as required to obtain the most efficient combustion.

6.6 Open the 600 psig boiler lead line main valve to 600 psig common steam header and close the bypass valve around the 600 psig main valve.

6.7 Open 600 psig boiler main steam non-return stop valve to boiler lead line.

6.8 Place the boiler on the line at very low steam flow. Close the superheater circulation line valve to blowdown drum.

6.9 The maximum allowable steam drum pressure during relief valve setting is 720 psig.

6.10 Install 1,500 lb test gauge with 10 psig divisions and pigtail fitting on steam drum air vent valve.

Table 5. HP Boiler Startup Instructions, (cont'd)

6.11 Supervising Operator, Operator, RESD/Inspector and relief valve Machinist shall be present during relief valve settings.

6.12 After the boiler is on the line:

6.12.1 Check that water gauge glass level reads 50% of the gauge glass.

6.12.2 Transfer feed water control to instruments.

6.12.3 Open north and south steam drum feed water angle valves wide open.

6.12.4 Switch feed water instrument control from manual to automatic control, at the video spec.

6.13 Light off the two remaining fuel/crude oil or fuel gas burners and bring the unit to half load of 110,000 lbs/hr.

6.13.1 Control the fuel/crude oil supply to burners manually by remote control on the video spec.

6.13.2 Maintain 120,000 lbs steam per hour for four hours, then 140,000 lbs per hour for two hours, then 160,000 lbs for two hours. After this time the boiler unit may be fired to load demand.

6.13.3 The liquid fuel burners should remain in place for burning of liquid fuel.

6.14 The Supervising Operator and the Instrument Man shall check out the fuel oil, fuel gas, atomizing steam, feed water, and boiler draft systems for operation on manual and full automatic controls.

6.15 All threaded or flange pipe and valve connections on low pressure and high pressure gas systems of the boiler shall be checked for leaks.

7. CHECKING DURING OPERATION

Once a week check the instrument air supply pressure to the board mounted instruments. This pressure is regulated to 30 psig.

CAUTION: If the pressure is allowed to exceed beyond 45 psig, it will damage the instruments and result in unsafe conditions.

Table 5. HP Boiler Startup Instructions, (cont'd)

Date: _____

Approved By: _____ 9/27/95

A.A. Al Najjar, Manager
RT Refinery Operations Dept.

INITIALS	DATE
QSG	9/17
AMJ	9/18

BOILER FIRING LIST **Page 8 of 11**

Table 5. HP Boiler Startup Instructions, (cont'd)

	DATE	TIME	BOILER OPERATOR	STEAM PLT. CONTROLMAN
1. Reviewed and understand Instructions No. 13.6711 and No. 13.613				
2 Boiler drain valves closed				
3. Feed water system set up (see paragraph 5.3)				
4. Water columns and gauge glasses in service				
5. Boiler water level normal (50% of gauge glass)				
6. Steam drum vent (air cock) opened				
7. Relief valves checked (gags off)				
8. Superheater circulation valve to K.O. drum opened. Vents and drains opened				
9. Wind box inspected for oil and air leakage				
10. Fuel gas line to boiler blinded				
11. Fire box inspected. Boiler fuel oil & gas cocks closed				
12. Dampers, registers & fan speed set to maintain -.15 inches water				
13. Furnace purged				
14. Purge completed				
15. Fires regulated to raise temperature 100 ºF per hour 16. Hold flue gas temperature of 420 ºF for one hour				
16. Boiler drum pressure 15 psig air vent cock closed and test gauge installed				
*18.600 psig boiler lead line MOV bypass valve and vent valves open				
19. High-low water level alarms and water columns tested				

BOILER FIRING LIST **Page 9 of 11**

Table 5. HP Boiler Startup Instructions, (cont'd)

	DATE	TIME	BOILER OPERATOR	STEAM PLT. CONTROLMAN
20. Superheater outlet relief valve manually lifted				
21. Relief valves set to popping pressure				
22. Boiler main steam stop manual valve opened				
23. Motor operated valve (boiler lead line) opened				
24. Boiler on the line via 600 psig main steam stop valve				
25. Superheater circulation valve to K.O. drum closed. Vents and drains closed				
26. All oil burners lighted off				
27. Boiler fuel gas & pilot gas blind removed				
28. Gas burners lighted off				
29. Check gas fires				

WHEN COMPLETE RETURN THIS CHECK LIST TO THE PLANT FOREMAN

SUPERVISING OPERATOR

Table 5. HP Boiler Startup Instructions, (cont'd)

RAS TANURA, SAUDI ARABIA

CERTIFICATE NO._____ _____19_____

This certificate is issued to_____Badge No_____signifying that he has been examined and found to be qualified to fire the Main Boilers at the Ras Tanura Steam Plant. This certificate is valid for one year from date of issue and shall thereafter be renewed or automatically canceled.

_____ _____
(FOREMAN) (SUPERINTENDENT)

RENEWED:_____19_____ RENEWED:_____19_____ RENEWED:_____19_____

_____ _____ _____
(FOREMAN) (FOREMAN) (FOREMAN)

CERTIFICATE OF ACKNOWLEDGMENT

This is to acknowledge receipt of a copy of Boiler Fireman Certificate No._____and a copy of Refinery Instruction No. 13.611. I understand that the certificate issued to me covers no furnaces except those specifically named in the certificate. I will faithfully observe all the regulations and procedures outlined in Refinery Instruction No. 13.611 at all times during furnace firing operations.

_____DATE:_____
(FIREMAN'S SIGNATURE)

BOILER BLINDS CHECK LIST **Page 11 of 11**

Table 5. HP Boiler Startup Instructions, (cont'd)

EQUIPMENT AND LOCATION OF BLINDS	OPERATOR
North End Of Steam Drum 1. Superheater outlet – drum flange before non-return valve	
2. Soot blower – blind insertion flange after drum block valve	
3. Superheater bleeder – blind insertion flange after drum block valve	
4. Feed water angle valve – before check valve	
5. Upper water column – after drum valve	
6. Lower water column – after drum valve	
7. Upper level meter – break union	
8. Lower level meter – break union	
North End Of Mud Drum: 1. Bottom blowdown blind insertion flanges between block valves	
South End Of Mud Drum: 1. Bottom blowdown blind insertion flanges between block valves	
South End Of Steam Drum: 1. Upper water column – after drum valve	
2. Lower water column – after drum valve	
3. Upper level meter – disconnect after block	
4. Lower level meter – disconnect after block	
5. Surface blowdown – drum flange	
6. Chemical feed – break union	
7. Steam sample – break union at #2 boiler	
8. Superheater drain line – break union	
9. Drum pressure gauge – open drain	
10. Feed water angle valve – before check valve	

All blinds above have been removed.

CHECKED BY: _____

OPR. OPER. (DATE & TIME)

ADDENDUM B: HP BOILER SHUTDOWN INSTRUCTIONS, RT REFINERY

HP STEAM PLANT

Table 5. HP Boiler Startup Instructions

CONTENT:

This Instruction outlines the procedure to be followed for taking a boiler out of service at the Ras Tanura Refinery High Pressure Steam Plant. The text includes:

1. Responsibilities
2. Taking A Boiler Out Of Service When It Is Being Fired On Fuel Gas
3. Preparation For Taking A Boiler Out Of Service When Safety Valves Are To Be Tested
4. Taking A Boiler Out Of Service When It Is Being Fired On Fuel Oil
*5. Water Washing The Fireside of the Boiler Tubes.

1. **RESPONSIBILITIES**

1.1 The Foreman is responsible for the operation of the boilers and their auxiliaries. He will take such action as is deemed necessary to ensure the maximum availability of equipment for steam generation.

1.2 In the absence of the Foreman the Supervising Operator will assume his responsibilities.

1.3 The Supervising Operator on shift will provide adequate supervision to ensure that the procedures outlined in this Instruction are followed correctly.

1.4 The Operators will be responsible for ensuring that this Instruction is correctly followed.

2. **TAKING A BOILER OUT OF SERVICE WHEN IT IS BEING FIRED ON FUEL GAS**

2.1 Place the boiler being removed from service on manual control.

2.2 Reduce steam load on boiler slowly. Transfer load to other boilers evenly.

2.3 When steam flow recorder indicates a flow rate of 20%, open superheater circulating valve to knockout drum; open superheater drains.

2.4 Operate "SHUTDOWN PUSH BUTTON" in the H.P boiler control room, BOILERS No. 5 through No. 10.

2.5 Close Boiler Main Steam Stop Valve.

2.5.1 When boiler is not to be drained refer to paragraph 2.13.2.

2.6 Check fuel and pilot gas vents to atmosphere are open and that fuel gas valves are in the correct positions. Close all hand operated valves on fuel gas and fuel oil to burners and pilot burners. Check atomizing steam valves are shut.

HP BOILER - TAKING OUT OF SERVICE Page 2 of 11

Table 6. HP Boiler Shutdown Instructions, (cont'd)

2.6.1 Install blinds in pilot, fuel gas and fuel oil system of the boiler.

2.7 Close chemical injection valve.

2.8 Close continuous blowdown valve (surface blow).

2.9 Close motor operated valve on boiler lead line.

2.10 Open all drain valves and drain boiler lead line.

2.11 When the boiler pressure is at 200 psig to 150 psig, bottom blow the boiler. Each of the following valves is to be opened for ten (10) seconds: Each mud drum bottom blowdown valve, and each of the water wall header drain valves (only on H.P. Boilers Nos. 7, 8, 9 and 10). These valves must be opened in a sequence (e.g., north mud drum, south mud drum, all of the south water wall headers, then all of the north water wall headers). Continue blowing down the boiler in the sequence initiated until the water level gauge glass indicates a TWO INCH (2") level. Do not return the water level to normal when it is known that the boiler is to be drained, but maintain sufficient water in the boiler to cover the tubes i.e., level should be observed at lowest point of the level gauge glass.

NOTE 1: To obtain the maximum benefit from blow down of a boiler which is shut down, the feed water MOVs must be shut before starting to blow down the boiler.

NOTE 2: The boiler will not be damaged by allowing the boiler water level to fall to the lowest visible level as seen at the level gauge glass (inch) when there is no fire in the furnace and the boiler pressure is at 200 psig or less.

2.12 When the boiler pressure is between (10-15 PSIG), open the steam drum and superheater vent valves to atmosphere. This is essential to prevent a vacuum being created in the boiler.

2.12.1 When a boiler is to be drained, open the mud drum blowdown valves wide. When the boiler pressure at zero ('0') psig, open all mud drum and water wall header drains.

2.12.2 When a boiler is not required to be drained, and item 2.6 is completed, fill the boiler with deaerated boiler feed water through the feed water until the level in the steam drum is at the high level trip point.

2.12.3 When there is no pressure in the boiler, close the superheater steam circulating valve.

2.13 Secure feed water system as follows:

2.13.1 Close feed water angle valves at steam drum.

2.13.2 Close main and auxiliary block valves.

2.13.3 Open bleed valves on main and auxiliary feed lines.

Table 6. HP Boiler Shutdown Instructions, (cont'd)

**2.14 The boilers forced draft fans should be kept running throughout the entire cooling period.

**2.14.1 For the High Pressure Boilers No. 5 and 6, the boiler forced draft fan should be kept running throughout the entire cooling period of the boiler. The boiler should be left to cool down for 16 hours. At the end of the cooling period, shut down the forced draft fan motor.

**2.14.2 For the High Pressure Boilers No. 7, 8, 9 and 10, stop the forced draft fan as soon as fuel gas and pilot gas blinds have been turned to close position.

**2.15 The boiler should be left to cool down for 16 hours. At the end of the cooling period, shut down the forced draft fan motor (for H.P. Boilers 5 & 6 Forced Draft and Induced Draft Fans).

2.16 If the boiler has been removed from service for T&I, maintenance, or other repairs, blinds must be installed as directed in Supplement -1 of this Instruction before any work is started.

2.17 As each blind is installed the Supervising Operator will put the date and his initials in Supplement -1 of this Instruction. The completed check list will be given to the Foreman.

NOTE: IF THE SITUATION AND TIME PERMITS instructions are to be given to test a selected shut down device fitted to the boiler when it is to be removed from service.

3. **PREPARATION FOR TAKING A BOILER OUT OF SERVICE WHEN SAFETY VALVES ARE TO BE TESTED**

3.1 Place boiler being removed from service on Manual Control.

3.2 Reduce steam load on boiler slowly. Transfer load to other boilers evenly.

3.3 When load on boiler is at 50% stop reducing load.

3.4 When firing fuel gas.

3.4.1 Adjust fuel gas pressure. Shut off burners as may be necessary. Maintain correct burner operating sequence to prevent boiler trip due to incorrect burner sequence (operation).

3.4.2 Continue reducing steam load on the boiler and evenly transferring it to other boilers.

3.4.3 Shut off additional burners as necessary (see paragraph 3.4.1).

3.4.4 Continue reducing steam load on boiler by reducing fuel gas pressure. Take care that the pressure remains above the low fuel gas trip pressure.

3.4.5 Change to manual control the boiler feed water. Station an Operator at the boiler to monitor and control feed water as it becomes necessary.

3.4.6 Continue as described in paragraph 3.6.

Table 6. HP Boiler Shutdown Instructions, (cont'd)

3.5 When firing liquid fuel. (fuel oil or crude oil)

3.5.1 Continue to reduce load on the boiler slowly. Transfer load to other boilers evenly.

3.5.2 Adjust fuel/crude oil pressure. Shut off burners as may be necessary. Maintain correct burner operating sequence to prevent boiler trip due to incorrect burner sequence (operation).

3.5.3 Continue reducing steam load on the boiler and evenly transferring it to the other boilers.

3.5.4 Shut off additional burners as necessary (see paragraph 3.5.2).

3.5.5 Continue reducing steam load on boiler by reducing fuel/crude oil pressure. Take care that the pressure remains above the low fuel/crude oil trip pressure.

3.5.6 Change to manual control of the boiler feed water. Station an Operator at the boiler to monitor and control feed water as it becomes necessary.

3.6 When the steam flow recorder indicates a flow rate of 20%, fully open superheater outlet and inlet header drain valves if applicable, open superheater steam circulation valve to knock-out drum.

3.6.1 When the steam flow recorder indicates a flow rate of 5%, open superheater circulation valve.

3.6.2 Shut the Boiler Main Steam Stop Valve.

3.6.3 Pressure increases in the steam drum is accomplished by closing the superheater circulating valve.

3.6.4 As the steam drum pressure increases and the safety valve lifts, open the superheater circulating valve to knockout drum.

3.6.5 After completion of the test, secure burners that were in use for the test. Shut off atomizing steam.

3.6.6 Close 600 psig motor operated valve (MOV) in boiler lead line.

3.6.7 Proceed to secure the boiler as detailed in paragraphs 2.12 through 2.16 when the boiler is to be shut down.

4. TAKING A BOILER OUT OF SERVICE WHEN IT IS BEING FIRED ON LIQUID FUEL

4.1 Place boiler being removed from service on Manual Control.

4.2 Reduce steam load on boiler slowly. Transfer load to other boilers evenly.

4.3 When load on boiler is at 50% stop reducing load.

HP BOILER - TAKING OUT OF SERVICE

Table 6. HP Boiler Shutdown Instructions, (cont'd)

4.4 Shut off burners as ordered by the Foreman; usually this will be:
No. 5 & 6 TWO (2) burners, No. 7 and No. 8 THREE (3) burners, and No. 9 and No. 10 FOUR (4) burners.

4.5 Proceed as outlined in paragraphs 3.5 through 3.6.2.

4.6 Proceed as outlined in paragraphs 2.7 through 2.16 to secure the boiler.

*5. **WATER WASHING THE FIRESIDE OF THE BOILER TUBES**

When the furnace is opened for T&Is, water wash the tubes externally as per Supplement No. 13.604-2 when deemed necessary by Inspection.

HP BOILER - TAKING OUT OF SERVICE **Page 6 of 11**

Table 6. HP Boiler Shutdown Instructions, (cont'd)

Date: _____

Approved By: 4-25-95
G.L. Pocock, Manager
RT Refinery Operations Dept.

INITIALS	DATE
G.L.P	4-23-95
AAA	4/26-95

HP BOILER - TAKING OUT OF SERVICE

Table 6. HP Boiler Shutdown Instructions, (cont'd)

NO.	BLIND SIZE	LOCATION OF BLINDS	DATE INSTALLED	IINITIALS
1	10"	Superheater outlet – flange before non-return valve or stop valve		
1	2"	Sootblower – blind insertion flange after drum block valve		
1	2"	Superheater bleeder – blind insertion flange after block valve		
1	4"	Feed water angle valve – before check valve on Boilers 5 & 6 - after block valve on Boilers 7, 8, and 9		
1	2"	Upper block valve to water column – before drum block valve		
1	2"	Lower block valve to water column – before drum block valve		
1	½"	Upper block valve to Tru scale – break union		
1	½"	Lower block valve to Tru scale – break union		
1	2"	Bottom blowdown of mud drum – insert blind between block valves		
SOUTH END OF STEAM DRUM				
1	2"	Bottom blowdown of mud drum – insert blind between block valves		
1	2"	Upper block valve to water column – before drum block valve		
1	2"	Lower block valve to water column – before drum block valve		
1	½"	Upper block valve to level meter – disconnect after block valve		
1	8"	Feed water bypass line on No. 10 HP Boiler – before the bypass line		

T & I BLIND & SAFETY VALVE CHECK LIST

Table 6. HP Boiler Shutdown Instructions, (cont'd)

NO.	BLIND SIZE	LOCATION OF BLINDS	DATE INSTALLED	IINITIALS
SOUTH END OF STEAM DRUM (Cont'd)				
1	½"	Lower block valve to level meter – disconnect after block valve		
1	½"	Surface blowdown – blind insertion before drum block valve		
1	¾"	Chemical feed – insert union before block valve		
1	1"	Sample station – break union		
1	¾"	Superheater drain line – break union		
1	1"	Drum pressure gauge – disconnect union at block valve		
1	4"	Feed water angle valve – insert blind before check valve		

SAFETY VALVE TEST PRESSURES
Lift Pressure
Blowdown Pressure

BOILERS	SUPERHEATER OUTLET	NORTH	SOUTH	DATE OF TEST	INITIALS OF OPERATIONS WITNESS
No. 5 & 6	1. _____ 2. _____	1. _____ 2._____	1. _____ 2._____	1. _____ 2. _____	1. _____ 2. _____
No. 7 and No. 8	1. _____ 2. _____	1. _____ 2._____	1. _____ 2._____	1. _____ 2. _____	1. _____ 2. _____
No. 9 and No. 10	1. _____ 2. _____	1. _____ 2._____	1. _____ 2._____	1. _____ 2. _____	1. _____ 2. _____

WATER WASHING OF THE FIRESIDE OF BOILERS Page 9 of 11

Table 6. HP Boiler Shutdown Instructions, (cont'd)

1. **PREPARATION**

1.1 All refractory repairs must be completed.

1.2 Furnace must have been swept clean.

1.3 All furnace and other fire side drainage systems must be proved open and clear. Remove all furnace refractory drain plugs and prove the drainage system is clear.

1.4 Scaffolding must be erected in accordance with Aramco Construction Safety Manual, Section 13 to enable those engaged in the cleaning to reach all parts of the furnace and generating bank, including superheaters.

1.5 All refractory should be sealed with a bitumen refractory (AMS #32-180-460) which is very easily burned off of all surfaces, including tubes, where required. This coating is to protect the refractory.

1.6 Mix approximately 0.5% Soda Ash with condensate water. Wash water pH should not fall below 8.5 at any time during the water washing. (As sampled at the water washing drain).

1.7 a. Suitable storage must be provided at the boiler. This should include a suitable pumping and distribution system.

b. Condensate pressure may be used, this should be connected to a manifold (1.7a) and the cleaning solution injection mixed.

c. All cleaning hoses should be 12.7 mm (1/2") to 19 mm (3/4") suitably fitted with jets.

2. **METHOD**

2.1 Pressure should be 810 kPa (116 psig) at 48 deg C (120 deg F) at the manifold, in the furnace. Refer to Supplement -3 of this Instruction.

2.2 Each cleaning hose should be tended by one operator.

2.3 Cleaning (washing) should start at the highest point of each part to be cleaned.

2.4 Special attention must be given to those areas where an accumulation of combustion deposits are prone to gather, e.g., tube roots (top and bottom). Effluent must be monitored and maintained in an alkaline condition.

2.5 Care must be taken not to direct jet directly at refractory, or persons.

2.6 Water should not be allowed to build up a level in the furnace.

2.7 On completion of the water wash, the furnace refractory drain plugs must be replaced, scaffolding and all equipment removed.

WATER WASHING OF THE FIRESIDE OF BOILERS Page 10 of 11

Table 6. HP Boiler Shutdown Instructions, (cont'd)

2.8 The furnace should then be closed up and the boiler fired on low flame to dry out the furnace and burn off the protective coating from the refractory.

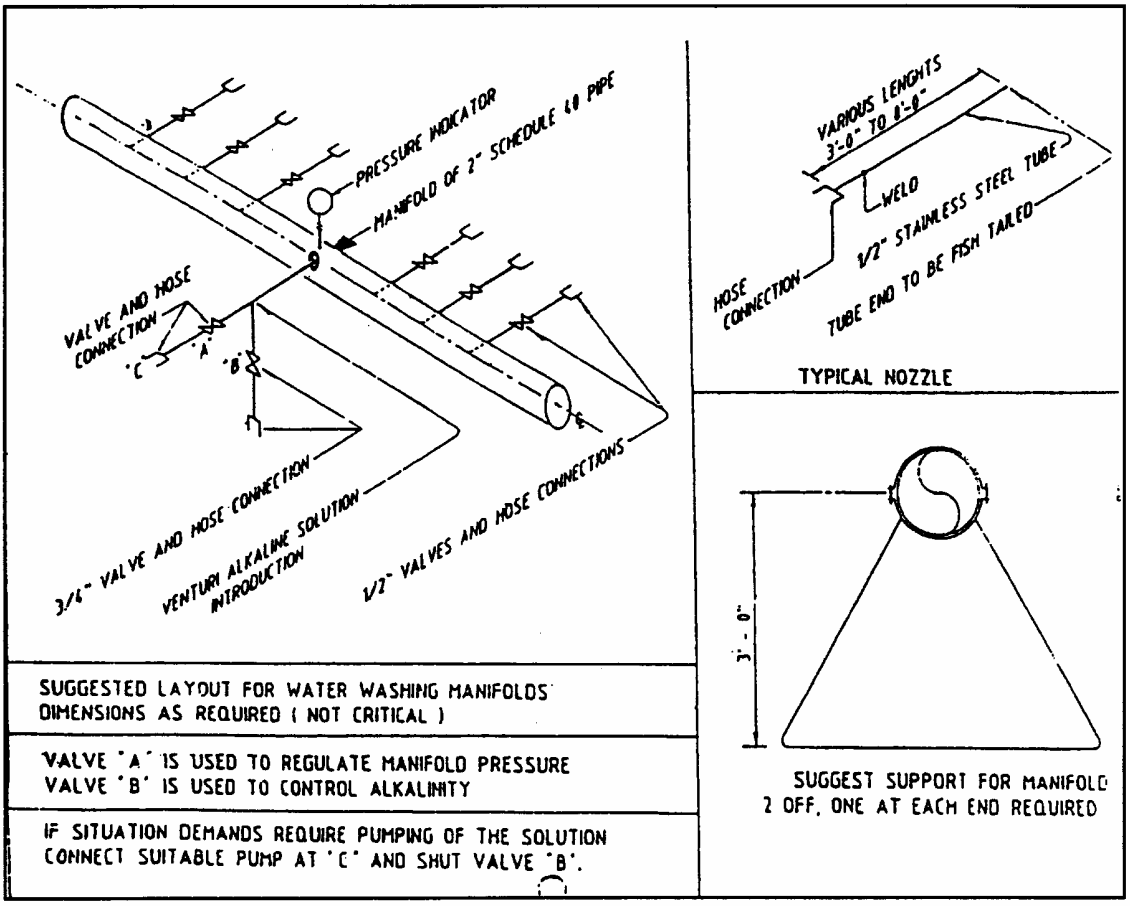
2.9 Shut all drains when boiler is on line.

NOTE:

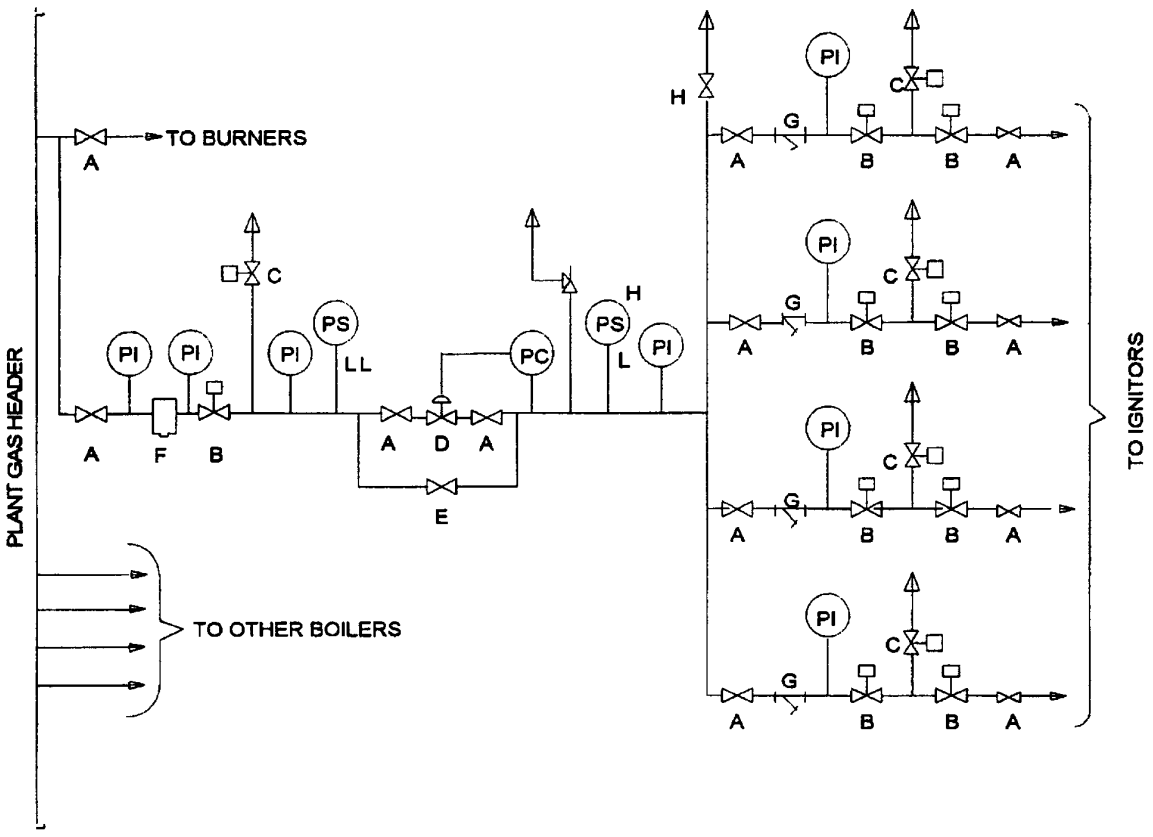
1. General practice and industrial standards require that water washing (when necessary) is the last operation to be carried out. Immediate firing for drying out is mandatory. (Except when steam lay-up procedure is used.)
2. Under no circumstances is salt or raw water to be used, no matter how dirty the boiler.
3. If condensate is not available, do not use another source of water, remove as much deposit manually as possible.
4. During water washing, excessive water pressure must not be used, to prevent any damage to refractory.
5. Hard deposits should be removed manually rather than increasing pressure.
6. The boiler or a part to be entered must be tested for the presence of oxygen, combustible gases and toxic gases (e.g., hydrogen sulphide, carbon monoxide), and certified on the work permit as being safe for entry.

WATER WASHING MANIFOLDS

Table 6. HP Boiler Shutdown Instructions, (cont'd)



ADDENDUM C: BOILER SAFETY SYSTEMS FOR WATERTUBE TYPES



A - Manual Block Valve

B - BMS Operated Safety Shutoff Valve

C - BMS Operated Vent Valve

D - Pressure Control Valve

E - Bypass Valve

F - Filter

G - Strainer

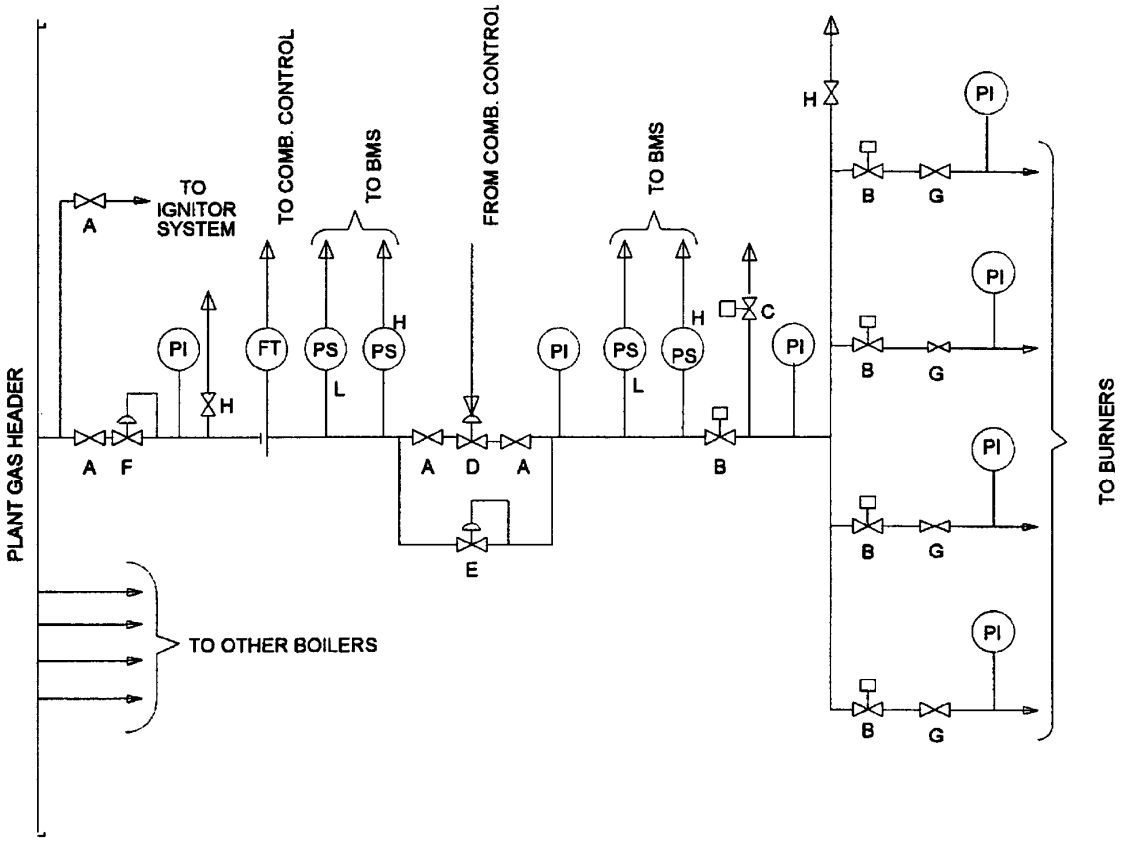
H - Manual Vent Valve

PI - Pressure Indicator (Gauge)

PC - Pressure Controller

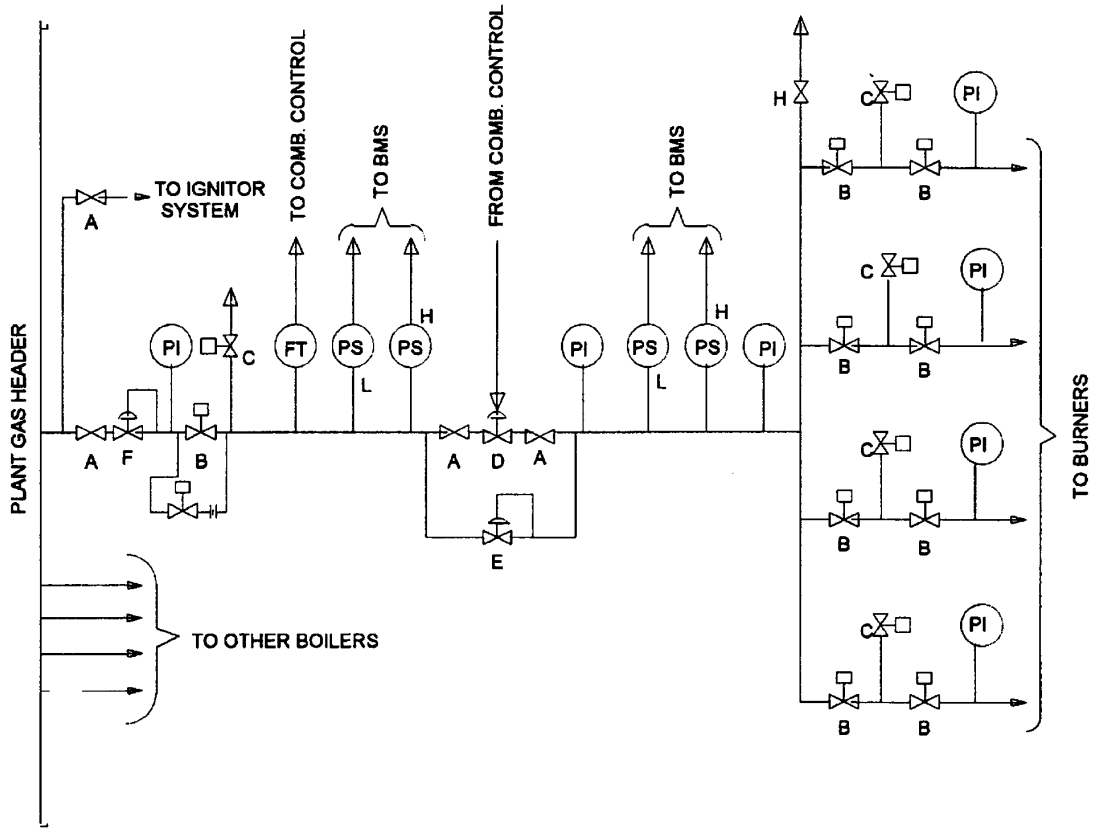
PS - Pressure Switch (or Transmitter)

Figure 12. Ignitor Gas System



A -	Manual Block Valve	G -	Manual Supervisory Shutoff Valve
B -	BMS Operated Safety Shutoff Valve	H -	Manual Vent Valve
C -	BMS Operated Vent Valve	FT -	Flow Transmitter
D -	Flow Control Valve	PI -	Pressure Indicator (Gauge)
E -	Minimum Flow Regulator	PS -	Pressure Switch (or Transmitter)
F -	Pressure Regulator		

Figure 13. Gas Burner System (Supervised Manual)



A - Manual Block Valve

B - BMS Operated Block Valve

C - BMS Operated Vent Valve

D - Flow Control Valve

E - Minimum Flow Regulator

F - Pressure Regulator

G - Charging Valve (Optional-Must be Self Closing)

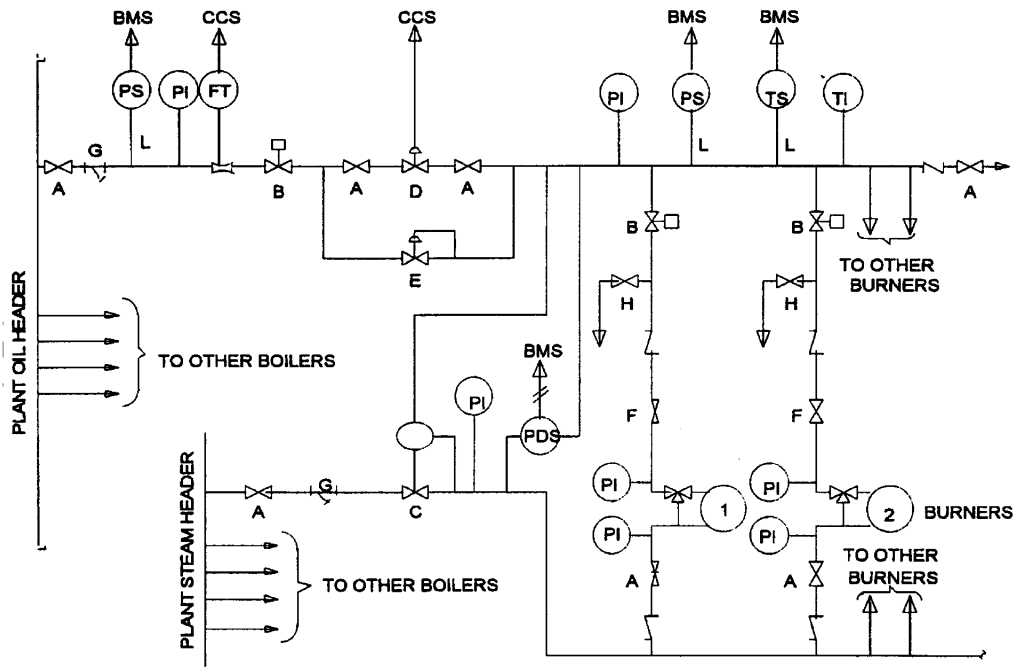
H - Manual Vent Valve

FT - Flow Transmitter

PI - Pressure Indicator (Gauge)

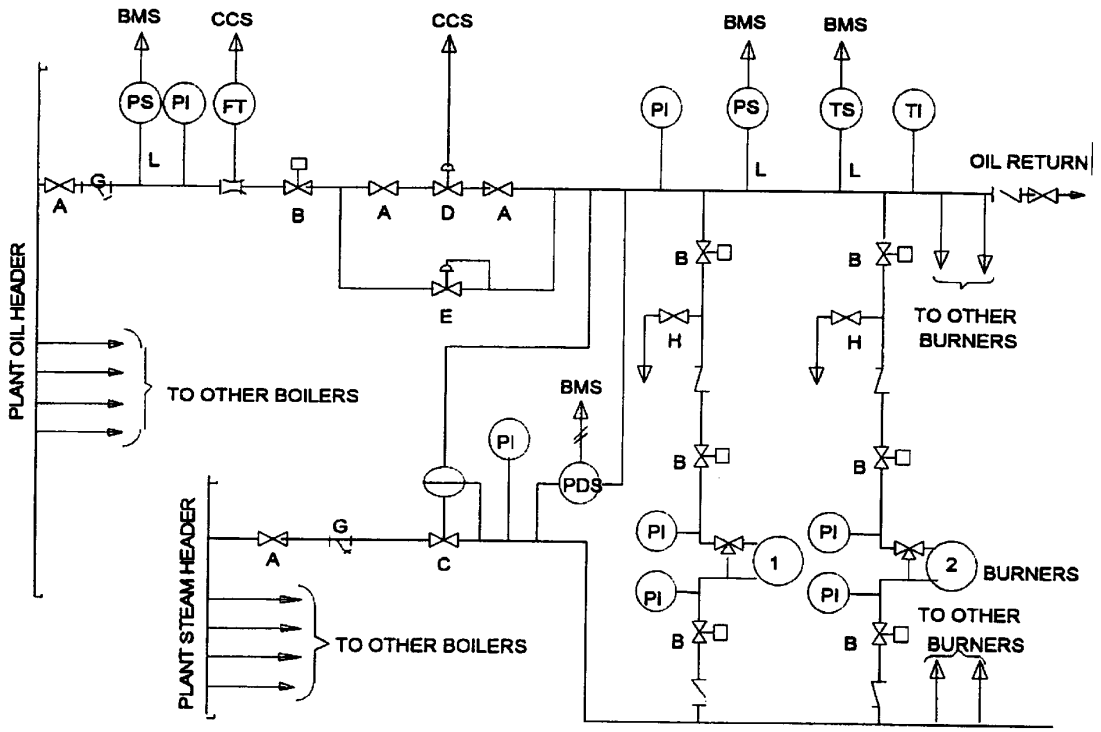
PS - Pressure Switch (or Transmitter)

Figure 14. Gas Burner System (Automatic)



A -	Manual Block Valve	H -	Manual Bleed Valve
B -	BMS Operated Block Valve	I -	Recirculating Valve (Optional for Unheated Oils)
C -	Steam/Oil Pressure Regulator	BMS -	Burner Management System
D -	Flow Control Valve	CCS -	Combustion Control System
E -	Minimum Flow Regulator	PDS -	Differential Pressure Switch (or Transmitter)
F -	Manual Supervisor Shutoff Valve	PS -	Pressure Switch (or Transmitter)
G -	Strainer	TS -	Temperature Switch (or Transmitter)

Figure 15. Oil Burner System (Supervised Manual)



A -	Manual Block Valve	I -	Recirculating Valve (Optional for Unheated Oils)
B -	BMS Operated Safety Shutoff Valve	BMS -	Burner Management System
C -	Steam/Oil Pressure Regulator	CCS -	Combustion Control System
D -	Flow Control Valve	PDS -	Differential Pressure Switch (or Transmitter)
E -	Minimum Flow Regulator	PS -	Pressure Switch (or Transmitter)
G -	Strainer	TS -	Temperature Switch (or Transmitter)
H -	Manual Bleed Valve		

Figure 16. Oil Burner System (Automatic)

REFERENCES

Saudi Aramco Standards

SAES-J-602	Boiler Safety Systems for Watertube Boilers
32-SAMSS-021	Watertube Boilers
34-SAMSS-619	Flame Monitoring and Burner Management Systems for Boilers

ASME Standards

ASME Boiler and Pressure Vessel Code	Section I Power Boilers