CHAPTER 3
OPERATION

SECTION I. PRELIMINARY OPRATING PROCEDURES

3-1. PLANT OPERATION CONSIDERATIONS

Plant operation is considered to be satisfactory if the needed energy is produced safely with minimum operating expenses. Operating expenses include manpower, fuel, utilities, supplies, and maintenance of the plant and equipment. Proper daily operation requires inspection and preventive maintenance, discussed in chapter 5. Maximizing efficiency of operation requires an understanding of the basic principles of combustion, steam or hot water generation, and equipment operation. Good operation makes the best use of facilities provided, while avoiding practices which waste fuel, steam, utilities, supplies, or manpower.

3-2. STANDING OPERATING PROCEDURES

Standing operating procedures (SOP) should be prepared and posted in the boiler room. The SOP should clearly indicate the sequence of actions to be performed for each unusual condition which could create a hazard or operational interruption. Examples of such unusual conditions include flame failure, loss of water, tube failure, sudden loss of load, steam line failure, loss of electric power, or control malfunction. The exact order in which each valve, control, and piece of equipment should be operated for a particular type of failure should be stated in the SOP. Valves and equipment should be marked for easy identification. The SOP may also be used to describe normal actions necessary to maximize boiler and plant efficiency.

3-3. DAILY AND MONTHLY BOILER PLANT OPERATING LOGS

The Daily Boiler Plant Operating Log, DA Form 3995 (figure 3-1), provides a means of recording continuous data on boiler plant performance. The data on this form can be used to analyze plant operation. It is arranged for use over a 24-hour period consisting of three 8-hour shifts. Entries are made in columns, with the explanation of each column provided on the back of the form. A monthly operating log must also be kept at each boiler plant in addition to the daily log. DA Form 3967, shown in figure 3-2, is the standard form for reporting monthly boiler plant operations. Data contained on the Daily Log is compiled at the end of each month and reported on the Monthly Log.

3-4. INSPECTION

A boiler is subject to damage and must be periodically inspected by a qualified inspector to ensure that it is in safe operating condition. All boilers must be inspected as required by AR 420-49. Details are included in chapter 5. Daily operation requires the operator to be aware of normal operation and to perform daily inspections to ensure that equipment is operating properly and safely. Abnormal operation should be logged and reported.

3-5. APPLICABLE CODES

The following codes provide rules and practical guidance for the safe and effective opration of boilers and boiler accessories:

- ASME Boiler and Pressure Vessel Code Section VI, "Recommended Rules for Care and Operation of Heating Boilers."
- ASME Boiler and Pressure Vessel Code Section VII, "Recommended Rules for Care of Power Boilers."
- NFPA National Fire Codes, NFPA 85A, "Standard for Prevention of Furnace Explosions in Fuel Oil- and Natural Gas-Fired Single Burner Boiler-Furnaces."
- NFPA National Fire Codes, NFPA 85B, "Standard for Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler-Furnaces."
- NFPA National Fire Codes, NFPA 85D, "Standard for Prevention of Furnace Explosions in Oil-Fired Multiple Burner Boiler-Furnances."
- NFPA National Fire Codes, NFPA 85E, "Standard for Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces."
- INFPA National Fire Codes, NFPA 85F, "Standard for Installation and Operation of Pulverized Fuel Systems."

3-6. BASIS FOR COMMENTS

Chapter 3 discusses the operation of equipment that has been described in chapter 2. Operational recommendations are made for steam andhot water boilers with capacities less than 200,000 pounds per hour of steam or less than 250 million Btu per hour output. Comments are generally

DAILY BOILER PLANT OPERATING LOG
For use of this form, see AR 420-49, the proponent agency is Office of the Chief of Engineers.

BOILER PLANT NUMBER: 1520 | STATION: FT GOOD | DATE: APRIL 1, 1988

Time (24 hr)	Steam Pressure	Steam Flow per Hour Chart	Feedwater Heater Pres.	Feedwater Heater Temp.	Feed Pump Pres.	Draft 1 Force	Draft 1 Furnace	Draft 1 Last Pass	CO_2 % of Flue Gas No. 2	Flue Gas Temperatures No. 1	Outside Temperature	Makeup Water (Daily Gallons)	Water Pressure	Water Softeners No. 1 Meter Ending	No. 1 Meter Start	No. 1 Meter Total
1st shift	100	22000	4	224	150	3.9	1.2	0.2		480	55		60	225070	223140	1930
0100	100	23000	4	224	150	3.7	1.2	0.2		460	54		60			
0200	100	23000	4	224	150	4.0	1.2	0.2		480	52		60			
0300	100	22000	4	224	150	3.9	1.2	0.2		470	52		60			
0400	100	25000	4	224	150	3.9	1.2	0.2		470	47		60			
0500	100	25000	4	224	150	4.1	1.3	0.2		460	48		60			
0600	100	28000	4	224	150	4.4	1.4	0.3		500	49		60			
0700	100	29000	4	224	150	4.5	1.4	0.3		520	52		60			
0800	100	30000	4	224	150	4.6	1.4	0.3		530	53		60			
Total												1930				
Average			4	224						490	52					
2d shift	100	30000	4	224	150	4.6	1.4	0.3		520	53		60	227700	225670	2630
0900	100	30000	4	224	150	4.6	1.4	0.3		520	56		60			
1000	100	26000	4	224	150	4.1	1.2	0.2		510	60		60			
1100	100	25000	4	224	150	4.0	1.2	0.2	4.3	510	63		60			
1200	100	26000	4	224	150	4.0	1.2	0.2		510	66		60			
1300	100	25000	4	224	150	4.0	1.2	0.2		500	67		60			
1400	100	27000	4	224	150	4.1	1.2	0.2		470	68		60			
1500	100	26000	4	224	150	4.0	1.3	0.4		470	70		60			
1600	100	26000	4	224	150	4.0	1.2	0.2		480	70		60			
Total												2230				
Average			4	224					4.3	500	64					
3d shift	100	21000	4	224	150	4.0	1.2	0.2		480	70		60	229900	227700	2200
1700	100	20000	4	224	150	3.4	1.0	0.1		470	68		60			
1800	100	19000	4	224	150	3.3	0.9	0.1		470	66		60			
1900	100	18000	4	224	150	3.2	0.9	0.1		470	64		60			
2000	100	20000	4	224	150	3.4	1.0	0.1		480	64		60			
2100	100	21000	4	224	150	3.5	1.0	0.1		490	63		60			
2200	100	20000	4	224	150	3.4	1.0	0.1		470	61		60			
2300	100	19000	4	224	150	3.4	1.0	0.1		470	58		60			
2400	100	20000	4	224	150	3.4	1.0	0.1		480	55		60			
Total												2200				
Average			4	224						475	63					
Total												[illegible]				
Average			4	224							60					

	Shift Number One	Shift Number Two	Shift Number Three	Total
Steam flow stop (integrator) X 1000	170840	170840	191267	
Steam flow start X 1000	190643	171095	191095	
Total steam flow X 1000	177	255	172	624
Pounds of steam per unit of fuel				
Boiler feed pump in service				
Soot blown - time	0430	1330	2130	
Blow down - time / gage		1100 / 30 sec		
Phosphate added	SEE WATER LOG			
Soda ash added				
Tannin added				
Operator				
Fireman	S Tanner	C Jones	I. Clark	

REMARKS:
PM Check — ok CJ
Continuous Blowdown set at Position 4.

SIGNATURE (Chief Operating Engineer)

DA FORM 1 DEC 72 3995 REPLACES DA FORM ..., WHICH WILL BE USED.

FIGURE 3-1. DAILY BOILER PLANT OPERATING LOG

FACILITIES ENGINEERING OPERATING LOG (*Boiler Plant*) For use of this form, see AR 420-49; the proponent agency is the Corps of Engineers.	INSTALLATION FT GOOD	PLANT CENTRAL	BLDG. NO. 1520	MONTH APRIL, 1988

DATE	STEAM PRODUCED: STEAM PRESSURE LB. (1)	STEAM PRODUCED: BOILER 1, 1,000 LB. (2)	BOILER 2, 1,000 LB. (3)	BOILER 3, 1,000 LB. (4)	TOTAL 1,000 LB. (5)	FEED-WATER TO BOILER 1,000 LB. (6)	FUEL USED ~~...~~ GAL. #6 (7)	EVAP. LB. PER UNIT (gal) (8)	OUTSIDE TEMP. AV. °F. (9)	FEEDWATER HEATER: PRESS. LB. (10)	FEEDWATER HEATER: TEMP. °F. (11)	FEEDWATER HEATER: MAKEUP GAL. (12)	% O_2 BOILER 1 (13)	% O_2 BOILER 2 (14)	% O_2 BOILER 3 (15)	FLUE GAS TEMPERATURE BOILER 1 °F. (16)	FLUE GAS TEMPERATURE BOILER 2 °F. (17)	FLUE GAS TEMPERATURE BOILER 3 °F. (18)	TEMP. H.W. SUPPLY °F. (19)	TUBES CLEANED NUMBER OF TIMES (20)	PREVENT MAINT. CHECK (21)	(22)	(23)
1	100	624			624		5010	125	60	4	224	6760	4			490				3	CJ		
2	100	540			540		4340	124	64	4	224	5900	5			455				3	ST		
3	100	532			532		4270	125	61	4	224	5760	5			455				3	ST		
4	100	600			600		4820	124	65	4	224	6500	4			480				3	CJ		
5	100	621			621		4990	124	58	4	224	6590	4			485				3	CJ		
6	100	628			628		5000	126	57	4	224	6600	4			490				3	CJ		
7	100	635			635		5050	126	58	4	224	6710	4			500				3	CJ		
8	100	607			607		4800	126	60	4	224	6640	4			480				3	RG		
9	100	511			511		4100	125	63	4	224	5540	4			460				3	ST		
10	100	491			491		4050	121	67	4	224	5440	5			450				3	ST		
11	100	588			588		4720	125	68	4	224	6600	5			475				3	LC		
12	100	597			597		4750	126	65	4	224	6510	4			480				3	LC		
13	100	567			567		4630	122	70	4	224	6400	5			470				3	LC		
14	100	575			575		4700	122	67	4	224	6450	5			470				3	LC		
15	50	560			560		4500	124	70	4	224	6390	5			430				3	RG		
16	50	482			482		3780	128	66	4	224	5200	5			410				1	ST		
17	50	470			470		3720	126	72	4	224	5010	5			410				1	ST		
18	50	545			545		4120	127	71	4	224	5300	5			415				1	CJ		
19	50	500			500		3920	128	71	4	224	5150	5			405				1	CJ		
20	50	425			425		3330	128	68	4	224	4310	7			380				1	CJ		
21	50	410			410		3250	126	72	4	224	4200	7			375				1	CJ		
22	50	400			400		3200	125	70	4	224	4150	7			375				1	RG		
23	50	390			390		3060	127	74	4	224	4010	7			370				1	LC		
24	50	382			382		3040	126	70	4	224	4050	7			364				1	LC		
25	50	405			405		3180	127	72	4	224	4100	7			370				1	ST		
26	50	401			401		3180	126	71	4	224	4070	7			370				1	ST		
27	50	403			403		3170	127	67	4	224	4050	7			370				1	ST		
28	50	410			410		3250	126	70	4	224	4090	7			370				1	ST		
29	50	380			380		2980	128	75	4	224	3830	7			360				1	RG		
30	50	363			363		2850	127	72	4	224	3710	8			360				1	LC		
31	—																						
TOTAL		15042			15042		119760					[illegible]											
MAXIMUM	100	635			635		5050	128	75	4	224	6760	[illegible]			500							
MINIMUM	50	363			363		2850	121	57	4	224	3710	4			360							
AVERAGE	73	501			501		3992	125.6	66	4	224	5334	5.5			426							

EVAPORATION LB. STEAM PER ~~...~~ GALLON	FUEL USED DURING MONTH (STANDARD TONS)	REMARKS		
125.6	119760 gal. (719 STD TNS)	START SUMMER OPERATION 4/16 CLOSE SOUTH HDR 4/19		
SEE REVERSE SIDE FOR INSTRUCTIONS	PREPARED BY Charles A Jones	DATE 5/2/88	APPROVED BY Robert L Green — DATE 5/3/88	POST ENGINEER James R. [illegible] — DATE 5/6/88

DA FORM 3967, 1 NOV 72 REPLACES DA FORM 5-98, 1 JUN 55, WHICH WILL BE USED.

FIGURE 3-2. MONTHLY BOILER PLANT OPERATING LOG based upon steam boilers producing saturated steam, although in some cases, specific differences are noted for hot water boilers. ASME Code Sections VI or VII, NFPA 85 series standards, and manufacturers operating and maintenance instructions should be carefully considered in addition to the following text. Safe and reliable operation is dependent to a large extent upon the skill and attentiveness of the operation and maintenance personnel. Operating skill requires knowledge of fundamentals, familiarity with equipment, and a suitable background of training and experience.

3-7. PREPARATION FOR STARTUP

Specific plant SOPs should be prepared and followed in preparing for boiler startup. In general, before lighting a fire in a boiler the following steps should be taken.

a. Instrumentation. Check all instrumentation. If possible, operate control devices to prove operation, freedom of movement, and function of limit switches. Check that the boiler pressure gage cock is open.

b. Internal Inspection. Check that all personnel and tools have been removed from the boiler. Inspect furnace walls, boiler tubes, and flues to confirm that they have been cleared of slag, soot, and deposits which could act as insulation, reducing heat transfer and boiler efficiency. Slag, soot, and ash should be removed as discussed in paragraphs 3-16 and 5-1. Check that all doors and openings are closed.

c. Combustion Equipment. Inspect and test operation of the combustion equipment without lighting a fire. Careful inspection of a stoker or burner and their accessories helps to prevent forced outages.

d. Fuel Supply. Check the fuel storage system to ensure that there is enough fuel to meet the boiler requirements. For solid fuels, check the fuel level in the hopper, as well as its size and moisture content. For oil, measure the quantity of fuel oil by stick or gage. Ensure that the valves are properly aligned, and that necessary pumps and regulating valves are in operation. Check that fuel oil is available at the required pressure and temperature. If atomizing air or steam is required, confirm its availability. For gas fuel, check for correct gas pressure and valve positions, and for any signs of gas leakage from piping or valves.

e. Water Supply. Ensure that an adequate supply of treated feedwater is available at the proper temperature. Check the level and temperature of the water storage tanks or deaerator. Check valve alignments and boiler feedwater pump availability.

g. Water Column and Gage Glass. Check operation and close blowoff valves, water column, gage glass drains, and gage cocks. Ensure that the gage glass is clean and well lighted. Open drum vent and drain valve between header and nonreturn valves. Open feedwater valves and admit water to boiler slowly until water level is just below center line of gage glass. Blow down water column and operate try cock as a further check of water level and to ensure that these appliances are in good working condition. If provided, check the operability of the low-water fuel cutoff. On forced circulation hot water boilers, start the circulating pump and, if a proof of water flow switch is provided, prove switch operating by shutting off and then restarting the pump.

h. Boiler Safety Control. Clean the flame scanner lens when provided. Check limit switches to prove operation.

i. Furnace Purge. The furnace, boiler bank, economizer, air heater, ducts, and pollution equipment must be adequately purged before starting a fire.

CAUTION

MANY DISASTROUS EXPLOSIONS ARE CAUSED BY FAILURE TO VENT THE FURNACE AND SETTING COMPLETELY BEFORE ATTEMPTING TO START A FIRE. EXPLOSIVE MIXTURES OF AIR AND GASES MAY ACCUMULATE AND IGNITE IF A FIRE IS STARTED WITHOUT FIRST VENTING THE FURNACE AND SETTING. TO AVOID THIS DANGER, OPEN THE STACK DAMPER AND OPERATE NECESSARY FANS AND DAMPERS TO PURGE THE FURNACE AND ATTACHED EQUIPMENT.

The purge air should be at a sufficient rate to provide adequate velocity to clear dead spots or inactive pockets and sweep the entire unit. Purge air flow rates of 25% to 75% and purge time of 3 to 5 minutes, or 8 air changes are considered adequate. A boiler must also be purged after an accidental loss of ignition.

3-8. STARTING FIRE

After completing the preparatory steps outlined above, combustion equipment may be started. Manufacturers' recommendations for equipment startup should be reviewed and carefully followed for each type of equipment and fuel. General recommendations are provided below.

a. Hand Firing Coal. Ensure that ashes and clinkers are removed from grates. If lump coal is available, spread a layer three to six inches thick on grates to prevent fines from sifting through. When ash content of coal is low (under about 7%), spread about an inch of ashes on grate before introducing coal. Spread dry wood, shavings, or live coals from an adjacent boiler on top of coal. Gasoline, naphtha, or other highly flammable liquids should never be used as kindling. Partly open the stack damper and ash-pit doors to induce air flow through the furnace. Light the kindling, leaving the fire door partly open to admit air over the fire and reduce smoke. After the fire is started, regulate the damper and ash-pit doors to maintain a draft and accelerate combustion. Supply additional coal as required and control the rate of combustion by regulating air flow through the fuel bed.

b. Stoker Firing Coal. To start a fire on a mechanical stoker, supply coal to furnace by operating the feed mechanism or shoveling coal into the furnace. Place enough coal into the furnace to cover all the tuyeres of an underfeed stoker to a depth of about six inches, or the grates of a spreader stoker to about two inches. Place wood, shavings, or kindling on top of the coal, and open the stack damper or operate the induced-draft fan. Maintain a slightly negative furnace pressure to remove the products of combustion. Light shavings and regulate the draft as required to keep fire burning. In some plants, fires may also be started with live coals from another furnace. As soon as the coal burns freely, operate forced-draft fan and regulate air flow to the furnace with the blast gate or damper to control the rate of combustion. If the boiler heats up too rapidly, operate fans at lower ratings or stop them for a short time. Do not add more coal to furnance until the fire burns freely. When neither steam nor electric power is available to operate the fan and stoker, feed the coal by hand and use natural draft until steam pressure is high enough to operate the auxiliary equipment.

c. Pulverized Coal Firing. When firing pulverized coal follow the procedures outlined in NFPA Standards 85E and 85F, and reference the plant's specific SOPs. For additional information, reference the Navy Manual MO-205 and the ASME Code Section VII.

d. Oil Firing. Oil firing procedures vary with the type of burner, controls, and fuel oil. Some plants use No. 2 fuel oil with pressure or steam atomizing burners, automatic controls and electric-spark ignition. Most army installations use No. 4, 5, or 6 fuel oils with either manual, semi-automatic or automatic ignition procedures. In every procedure an important step is the purging of the boiler-furnace. If ignition is delayed, immediately determine the cause and correct the problems.

(1) **Preheating the Fuel Oil.** Heavy oils (Nos. 5 and 6, and sometimes 4) require heating to reduce the oil viscosity to a point where pumping is practical. Additional heating may also be required to optimize atomization. Pump and burner manufacturer viscosity recommendations should be followed. Steam or electric tank heaters are used to heat oil to a temperature of 90° to 110° F, with oil preheaters supplying the additional heat as needed. To determine the amount of preheat temperature necessary for a given oil, consult the burner manufacturer for an initial recommendation. Experimentation is often necessary to determine the temperature that works best for the particular installation. 100 to 300 saybolt seconds universal (SSU) viscosity is usually desirable for No. 5 and 6 fuel oils. No. 4 may also need some preheating depending on the type of atomizer/burner and the particular oil. No. 2 oil rarely needs preheating, but outside storage in cold climates may necessitate preheating to room temperature.

(2) **Lighting Burners.** Before lighting off a burner, always check for proper oil pressure, temperature, and atomizing air or steam pressure. Purge the unit and establish air flow suitable for light-off. To manually light an oil burner insert a lighted torch adjacent to the oil atomizer and admit oil and atomizing steam at their low fire rates. The trial for ignition of the main flame should not be longer than 15 seconds. If the trial for ignition fails, remove the torch and repurge the furnance before trying again. A torch for safe lighting of oil burners can be made from an iron rod of ¼-inch pipe of suitable length. Wrap 10 inches of the rod end closely with cloth and secure the cloth with wire. Store the torch in an oil container made from a 2- or 3-foot length of 3-inch pipe so that it is saturated with oil and ready for instant use. To light the torch, remove it from the container and ignite the oil-saturated rag. After the burner has been lit, extinguish the torch by immersing it in the oil container. Leave the torch in this position for future use.

(a) Gas igniters or pilots are usually used to light off modern light oil burners. These igniters typically use an electric spark to ignite the gas. If the igniter flame is seen by the flame scanner within a 10-second trial for ignition, the oil safety shut-off valve is opened, either manually or automatically. The oil control valve should be at its low fire position and is often interlocked in this position. Fifteen seconds after the oil shut-off valve is opened, the igniter is shut off. If the flame scanner still sees flame, the burner will continue to operate. If no main flame is seen at this time, the shut-off valve is closed. The boiler should be repurged before a second trial for ignition is made. Loss of main flame or other safety interlock limits as shown on figure 2-48 and figure 2-49 will result in the safety shutdown of a burner.

(b) High energy spark igniters are now being applied to some oil-fired burners. These igniters eliminate the use of gas igniters by directly igniting the oil with a low voltage, high amperage spark. Operational sequence is similar to the above, except that the igniter trial for ignition period is eliminated.

(c) Maintain a small, stable flame by adjusting the combustion air flow, oil flow, and furnace draft. Insufficient air is likely to cause smoke, while too much air can cause the flame to blow away from the burner. By experimentation, the proper fuel/air ratio for light-off of a cold furnance should be determined for each individual boiler.

(d) The burner and control manufacturer's recommended lighting off procedure for semi-automatic operation should be rigidly followed. Step by step instructions should be posted in a convenient place near the burners.

e. Gas Firing. The ignition of a gas burner is always accomplished with the use of a gas igniter, flame scanner, and flame safeguard control. Purging the boiler is required before a trial for ignition. Proper gas pressure should be available to both the igniter and main burner, and the gas control valve should be in its low fire position. The semi-automatic or automatic light-off sequence is identical to that for oil burners except the trial for ignition of main flame is only 10 seconds. Loss of flame or boiler and burner limits shown on figure 2-49 or figure 2-50 will result in the shutdown of a burner. The boiler-furnace must be repurged before a new trial for ignition may be attempted.

3-9. WARM-UP TIME

The time required to bring a boiler up to line pressure or temperature is dependent on many things including the size and type of boiler, its operating pressure or temperature, the combustion equipment, and whether or not it is equipped with a superheater. Manufacturer's detailed instructions should be followed to minimize thermal stresses as the boiler heats up and expands. In general, boilers out of service long enough to cool down to room temperature require ½ to 2½ hours to reach line pressure. If a new boiler or one with extensive repairs to the furnace or setting is being placed in service, sufficient time must be allowed for the brickwork to dry out. Operate the boiler on low fire for several days before it is actually placed into service. If the boiler is equipped with a superheater, take extra precautions to prevent it from overheating by firing at a low rate during the warm-up period, and by allowing a small amount of steam to flow through the superheater. Leave the outlet drain from the superheater open so that some steam flows through the tubes as pressure builds up. This steam will help to cool the superheater metal, and prevent tube damage.

3-10. PLACING A HIGH PRESSURE STEAM BOILER IN SERVICE

When water in the drum begins to boil, steam is discharged from the drum vent. When the boiler pressure reaches about 25 psig, all air will have been removed, and the vent should be closed. If the boiler does not have a vent, use the gage cocks to allow air to escape. Carefully observe the fire while the pressure is increased, and maintain minimum stable firing conditions. If the firing rate is too high on multiple burner boilers, shut off some of the burners. Rotate operation of the burners to promote uniform heating. If the firing rate is too high on a stoker fired boiler, shut off the forced draft fan for a period and operate on natural or induced draft only.

a. Control of Water Level. Observe water level frequently during the warmup period. Increasing temperature and the formation of steam causes the boiler water to expand. To avoid high water levels, start the boiler with the water level just above the lowest safe level. If necessary, open the blowdown valves and remove water to prevent high level conditions.

b. Checking Safety Valves. The safety valves should be tested periodically by hand lifting them. Do this when the steam pressure in the boiler is at least 75 percent of the set pressure of the lowest safety valve. Care should be taken to hold the valve open wide and release the hand lever briskly, so that the valve closes with a snap. At intervals, as required by the Authorized Inspector, the safety valves must be tested by raising the boiler pressure to the set pressure of the safety valve to ensure that it pops and reseats correctly. When a safety valve fails to operate, do not attempt to free it by striking the body or other parts of the valve. If a saftey valve leaks or fails to operate properly remove the boiler from service immediatley and repair or replace the valve. Checking of safety valves by raising pressure on the boiler must b under direct supervision of a designated, qualifie employee.

c. Operation of Header Valves. When placing a boiler inter service, care must be taken to avoid water hammer and expansion stresses associated with large temperature differentials. When other boilers on a header are already operating, the steam line from the boiler being started must be brought up to temperature by operating the bypass and drain valves to create a flow of steam from the header. When the line is up to temperature and pressure, the header gate valve may be opened wide and the bypass closed. The nonreturn valve should be opened to a 25 percent position until the boiler starts to supply steam to the header, after which it may be fully opened. In the absence of a nonreturn valve, the boiler stop valve should be opened slowly when the pressure in the boiler land header are approximately equal. If a boiler is being put into service on a header which is not under pressure, it is desirable to warm up both the boiler and steam line/header together. In this case, open both the stop and nonreturn valves and make sure the steam header drain valves are open to remove any condensate formed.

d. Activate Controls. When the boiler is producing steam and properly coinnected to the header, place the feedwater and combustion controls into automatic operation, i accordance with the manufacturer's recommendations and instructions.

3-11. PLACING A HOT WATER BOILER IN SERVICE

The following general procedures should be followed for placing a single LTW or HTW boiler into service. Procedures are also included for placing additional boilers into service on multiple boiler installations.

a. Procedure for a Single Boiler. When starting a boiler after layup, proceed as follows.

(1) Review manufacturer's recommendations for startup of burner and boiler.

(2) Fill boiler and system; vent air at high point in system.

(3) Check altitude gage and expansion tank to assure system is properly filled.

(4) Set control switch in "OFF" position.

(5) Make sure fresh air to boiler room is unobstructed and manual dampers are open.

(6) Check availability of fuel.

(7) Vent combustion chamber to remove unburned gases.

(8) Clean glass on flame scanner, if provided.

(9) Observe proper functioning of water pressure regulator and turn circulator pumps on electrically.

(10) Check temperature control(s) for proper setting.

(11) Check manual reset button on low-water fuel cutoff and high-limit temperature control.

(12) Set manual fuel oil supply or manual gas valve in"OPEN" position.

(13) Place circuit breaker or fuse disconnect in "ON" position.

(14) Place all boiler emergency switches on "ON" position.

(15) Place boiler control starting switch in "ON" or "START" position. (Do not stand in front of boiler doors or breeching.)

(16) Do not leave boiler unattended until it reaches the established cutout point to ensure that controls shut off the burner.

(17) During the temperature and pressure buildup period, walk around the boiler frequently to observe that all associated equipment and piping is functioning properly. Visually check burner for proper combustion.

(18) Immediately after burner shuts off, inspect water pressure and open the highest vent to determine that system is completely full of water.

(19) Enter in log book:

(a) date and time of startup

(b) any irregularities observed and corrective action taken

(c) time when controls shut off burner at established temperature, tests performed etc.

(d) ignature of operator

(20) Check safety relief valve for evidence of leaking. Perform try lever test. (Reference Exhibit C in ASME Code Section VI, "Recommended Rules for Care and Operation of Heating Boilers.")

b. Action in Case of Abnormal Conditions. If any abnormal conditions occur during light off or temperature buildup, immediately open emergency switch. Do not attempt to restart the unit until difficulties have been identified and corrected.

c. Placing Additional Boilers into Service. When placing a boiler on the line with other boilers which are already in service, start the boiler using the above procedures, but have its supply and return stop valves closed. Bring the second boiler to the same temperature as the operating boiler and partially open the supply valve(s). If there is no unusual disturbance, such as noise, vibration, etc., continue to open the valve slowly until it is fully open. Open the valve in the return line.

CAUTION

When the stop valve at the boiler outlet is closed, the stop valve in the return line of that boiler must also be closed.

SECTION II. OPERATING ADJUSTMENTS AND PROCEDURES

3-12. BOILER OPERATION

Basic boiler operation consists of supplying fuel to generate steam (or hot water) as required by system demand, and supplying air in the correct proportion to efficiently burn the fuel. The rate of fuel feed used to maintain steam pressure or water temperature may be controlled either manually or automatically. In supplying air to the burner or furnace, both the quantity and its point of application for optimum combustion must be considered. Other facets of boiler operation include feedwater supply, which must be introduced in proportion to the quantity of steam discharged, and the operation of pumps, fans, dampers, valves, controllers and fuel-handling equipment, all of which are used to maintain proper flow of materials to and from boiler.

3-13. MAINTAINING PRESSURE OR TEMPERATURE

Pressure gages indicate the difference between pressure inside boiler and atmospheric pressure. Pressure on each square inch of internal surface is expressed as pounds per square inch gage (psig). For steam boilers the pressure gage indicates if the firing rate is properly adjusted. If the rate of steam flow from a boiler increases, the pressure drops because heat is carried away faster than it is being supplied, and the firing rate must be increased. If steam flow decreases, the pressure increases and the firing rate must be decreased. For hot water boilers, the temperature gage is used to indicate proper firing rate. If the boiler outlet temperature falls below the setpoint, the firing rate needs to be increased. If the outlet temperature rises above the setpoint, the firing rate must be decreased. If manual control is being used, the operator notes changes to pressure or temperature and adjusts the fuel and air supply accordingly. Automatic combustion controls, as discussed in paragraph 2-26, sense pressure or temperature changes and automatically adjust fuel and air supplies. Automatic systems relieve the operator of the tedious and continuous adjustment necesssary with each change in demand.

3-14. FEEDWATER AND BOILER WATER TREATMENT

Feedwater must be supplied to the boiler at an acceptable temperature to avoid thermal shock and excessive stresses on the boiler pressure parts. The water must also be treated to minimize corrosion and scale formation in the boiler and the distribution system and optimize heat transfer and boiler efficiency. Reference chapter 4, which discusses feedwater treatment, boiler water treatment principles, equipment, chemicals, operating procedures, tests, and records.

3-15. CONTROLLING FEEDWATER

Hot water boilers operate with constant water flow rates and do not require feedwater controls. Water flow to steam boilers must be regulated so that one pound of water replaces each pound of steam generated. The gage glass, try cocks, and other water level indicators are used as guides in controlling water flow to a boiler. Visible water level is not always a true indication of the amount of water in a boiler because steam bubbles, as well as water, are contained in the water space and cause the water to swell. If the steaming rate decreases, the amount of steam bubbles decreases, the water shrinks, and the water level drops. The tendency of water level to vary with steaming rate is known as "swell" and "shrink." Swell and shrink must be taken into consideration in controlling water flow so that the flow varies properly with steam output. The types of feedwater controls available are discussed in paragraph 2-25. Most feedwater controls on Army boilers are of the single element type, and sense only water level. Although they do a very good job on most boilers, they cannot compensate for swell and shrink. Where swell and shrink become a problem, two and three element feedwater controls are available to provide improved control.

3-16. BOILER ACCESSORIES

Operating procedures for water columns, gage glasses, safety valves, blowoff lines, and sootblowers are outlined below.

a. Water Column and Gage Glass. If water level is too low, the boiler may be severely damaged by overheating. If water level is too high, water may be carried out with steam, resulting in damage to engines and turbines and causing deposits to form in piping, valves, and other equipment. A gage glass, try cocks, high- and low-level alarms, and various other indicating and recording devices are used as guides in maintaining proper water level. The gage glass and try cocks are the most reliable and should be used as the final check when the various devices disagree.

(1) Removing Sediment. Sediment collects in the water column and, in time, will obstruct the connection so the gage glass and try cocks do not show correct level. To ensure correcte indication, the water column and gage glass must be blown down regularly. Once per shift is the recommended interval. The lines from the boiler drum to the indicating and recording devices should be blown uown daily.

(2) Leaks. Promptly repair leaks in pipes, valves, or gage glasses to avoid false water-level indication.

(3) **Valves.** Gage glasses have valves at both top and bottom. Hand-operated valves are usually supplied with chain operators so that if the glass breaks, the operator can close valves and void danger of burns from escaping steam and hot water. Some gage-glass valves are automatically closed by the rush of steam and water if the glass breaks. Determine the type of valves employed on all gage glasses and decide in advance what to do in case of breakage.

(4) **Replacement of Gage Glass.** To replace a broken gage glass, remove all packing nuts, packing, and broken pieces of glass. Insert new glass and packing. Tighten packing nuts carefully.Turn on upper steam valve first to heat the new glass uniformly. Goggles and wire mesh or canvas screen should be provided with first putting pressure on gage glass.

(5) **Valves in Water-Column Line.** If valves are supplied in lines from drum to water column they must be sealed or locked open.

b. Safety Valves. Safety valves are designed to remain closed under normal operating conditions. If load drops ‡ fuel supply is not readjusted quickly enough, the safety ‹ve opens to relieve the increased pressure. Opening of safety valves causes discharge of steam or hot water into the atmosphere and results in a loss of heat. Although it may be assumed that the original safety valves were of sufficient capacity, large capacity is required when a coal fired boiler is converted to oil or gas firing.

(1) **Adjustment.** A safety valve normally requires two adjustments, popping pressure and blowdown. For boilers operating at pressures of 250 psig or below, the popping pressure can be adjusted over a range of ten percent above or below the pressure for which the valve is designed, by varying the compression of the valve spring. A new spring must be installed if the desired adjustment exceeds ten percent. Blowdown is varied by means of an adjusting ring. The Boiler and Pressure Vessel Code requires that safety valves be adjusted to close after blowing down not more than four percent of the set pressure but not less than two psi. It also requires that the blowdown be not less than two percent for pressures between 100 and 300 psig. Lifting levers are provided to lift the valve manually to check its action and blow any dirt away from the seat. When using the lift lever, the boiler pressure should be at least 75 percent of the set pressure. Use these levers to test safety valves at 30-day intervals to ensure that the valve disc does not stick to the seat. Once a year, a test ɔuld be made by actually raising the boiler pressure to ‿ıeck the valve setting and blowdown. When the lifting lever is used, raise the valve disc sufficiently to ensure that all foreign matter is blown from around the seat. This will help to prevent leakage after the valve is closed. Adjustment and sealing of safety valves should be performed only by properly trained and authorized personnel, such as qualified boiler inspectors and factory representatives. In case of emergency, the Director of Engineering and Housing may authorize installation personnel who are thoroughly familiar with safety valves to make adjustments.

(2) **Hydrostatic Test Caution.** Testing clamps or gags are often used to hold the valve discs on their seats during hydrostatic tests. When this is done, ensure that the clamps are not over tightened, as damage to the valve stem may occur. ALSO TAKE EVERY PRECAUTION TO ENSURE THAT THE CLAMPS ARE REMOVED AS SOON AS THE TEST IS COMPLETED. NEVER USE A TEST CLAMP TO GAG A VALVE THAT IS LEAKING.

(3) **Capacity.** The capacity of the safety valve(s) must be sufficient to discharge all the steam generated by the boiler without allowing the pressure to rise more than six percent above the maximum allowable working pressure. This capacity may be checked by closing the steam outlets and forcing the fire to the maximum. If the pressure builds up more than six percent, additional valve capacity is needed. The safety valve capacity for each boiler must not be less than the minimum ASME Boiler and Pressure Vessel Code requirements shown in table 2-1. When changing from coal to oil gas firing, do not overlook the increased safety valve requirements. Capacity checks must be authorized by the facilities' engineer and made under the direct supervision of a designated qualified employee, an authorized insurance inspector, or a factory representative.

c. Blowoff Lines. All boilers are equipped with blowoff lines at the lowest point in the water system. These lines are necessary for draining and also to help control concentration of solids and sludge. This concentration is determined by an analysis of the boiler water and should be a routine part of operating procedure. Blow down a specific quantity of water each time, usually a few inches as measured on gage glass. Frequency of blowdown is based on results of water analysis.

(1) **Blowdown Procedure.** Open the quick-opening valve or cock first. Then open the slow-opening valve fully until the required quantity of water is discharged. Do not open the valves too rapidly, as undue stress or damage to blowoff piping and connections may result. Blowdown when the boiler is banked or steaming at low rate is most effective in removing sludge and solids. Bottom blowoff connections must be used to remove sludge.

(2) **Continuous Blowdown.** Surface type blowoff connection are also provided on most steam boilers and, when used on a continuous basis, are the most effective

and economical means of controlling dissolved solids. Recovery of some of the heat from the blowdown water can be accomplished by use of a heat exchanger. If continuous blowdown is used, the bottom blowdown valves should still be used at intervals to prevent them from becoming stuck or otherwise inoperative, and to remove sludge. The quantity and frequency of manual blowdowns is determined by the degree to which sludge accumulates in mud drums and headers. A more complete discussion of bottom blowdown and continuous blowdown is given in paragraphs 4-4c and 4-8.

d. Sootblowers. Flue gases carry ash and soot which act as insulators and, when deposited on boiler heating surfaces, reduce the rate of heat transfer. The extent of soot deposit depends upon the fuel burned, completeness of combustion, and rating at which boiler is operated. When coal-fired boilers are operated at high rating, ash and slag may deposit on tubes to such an extent that gas flow is restricted and draft loss through the boiler increases. Oil-fired boilers seldom build up enough ash to restrict gas flow, but heat transfer efficiency can be affected. Several cleaning methods are discussed below.

(1) **Swinging-Pipe Sootblower.** Fire-tube boilers may be cleaned while in operation by means of steam jets operated from outside the boiler setting. Steam is applied to the pipe of a swinging-pipe sootblower with steam jets directed into the boiler tubes. The sootblower is rotated to direct the jets into each tube. After completing the blowing operation, the sootblower is moved to a position where it is protected from heat or gases. Fire-tube boiler tubes should be cleaned daily.

(2) **Long-Handled Brush.** Swinging-pipe sootblowers for fire-tube boilers are convenient but are not satisfactory when boiler tubes are long. Soot can be effectively removed from the tubes of fire-tube boilers with a long-handled brush. The brush should be just large enough to pass through the tubes. Frequency of cleaning depends upon operating conditions. Goggles and respiratory protection equipment should be used when cleaning boiler tubes.

(3) **Mechanical Sootblowers.** Many water tube boilers are supplied with mechanical sootblowers. These should be operated once very eight hours, or an internal dictated by operating experience. To operate a sootblowing system,open the piping system drains first, then slowly open the steam valve to admit steam. Completely preheat and drain the piping system before admitting steam to the sootblower elements, as a small quantity of water introduced into a hot sootblower element can cause serious damage. Drain valves may be throttled but not closed while the elements are being operated. Increase the draft in the boiler and furnace during sootblowing periods to prevent smoke and to carry away material removed from tubes. Sootblower elements are operated by a handwheel or chain or in some cases by an electric motor. As the element is rotated, an automatic valve opens and admit steam. Two rotations of the element are usually sufficient; more rotations only result in wasted steam. Rotate the element slowly for maximum effect. Start the sootblowing sequence near the furnace and progress toward the boiler outlet.

(4) **Hand Lancing.** If mechanical sootblowers are not available or cannot be used, hand lancing must be employed. A practical hand lance can be made from a section of ½-inch pipe of suitable length attached to a hose and supplied with 100 psig air pressure. When using a hand lance, care must be exercised to prevent damage to furnance walls and baffles.

3-17. COAL FIRING PROCEDURES

Procedures for firing coal by hand firing, underfeed stoker, spreader stoker, and traveling grate stoker follow. Procedures for pulverized coal firing may be found in manufacturer's instructions and Navy Manual MO-205 Volume One, Chapter 3, Sections 19 and 20. Fluidized bed firing procedures may be found in manufacturer's instructions.

a. Hand Firing. Methods of firing by hand are as follows:

(1) **Coking.** Coking allows time for escape of volat gases before coal is placed directly on the fuel bed. Fi place coal on the dead plate where radiant heat causes the gases to be distilled off. These gases mix with secondary air coming through the damper in the fire door and burn as they pass over the hot fuel bed. Coked coal is later distributed over the fuel bed. Disadvantages of this method are that smoke is produced and the introduction of air causes ash and burning coke to mix and create clinkers, wasting both time and fuel. However, this method of firing may be successfully applied to small furnaces operating at low rating.

(2) **Alternate Method.** Satisfactory combustion can be obtained by use of an alternate method of firing. A layer of green coal is applied to one side of the furnace. Heat generated by combustion on the opposite side causes volatile gases to be distilled off and accelerates combustion. The ash-pit door should be closed during and immediately after firing to reduce smoke. Keep the fire door open about one inch for one to three minutes to supply sufficient secondary air to allow the volatile gases to burn off. Despite these precautions, gases may still be distilled off more rapidly than they can be burned due to the large surface of green coal exposed.

(3) **Spreader Method.** Spreader firing consists of distributing coal over the entire fire bed. Thin spots ar observed by their bright appearance and additional fı applied to keep the fuel bed uniformly thick. Whe correctly used, this method permits operation at high

ratings. Be sure to supply sufficient overfire air, as volatile gases are quickly liberated. Agitation of the fuel bed causes ash to come into contact with the hot portion of fire, forming clinkers. If coal is properly placed, firing proceeds without resorting to agitation of fuel bed.

(4) **Cleaning Hand-Fired Furnaces.** Coarse pieces of ash and clinkers which do not fall through the grates must be removed at sufficiently short intervals, or the air passages can become restricted and the rate of combustion reduced. One method of cleaning grates consists of poushing burning coal against the bridge wall, after which ash and clinkers can be removed from the front. This method has the advantage of being quick, but does not remove all ash, as some always remains at the bridge wall. A more complete cleaning is accomplished by the "side" method, which consists of pushing good coal to one side of furnace and exposing ash and clinkers, which are then readily removed. All burning coal is then moved to the side which has been cleaned and the remaining ash and clinkers are removed. When shaking grates are employed, a greater percent of ash can be discharged to the ash pit and the work of cleaning fires is materially reduced.

(5) **Combustion-Rate Regulation in Hand-Fired Furnaces.** Rate of combustion is controlled by the quantity of air passing through the fuel bed, while efficiency of combustion is controlled by the quantity and distribution of overfire air.To regulate the rate of combustion, change the furnace draft by controlling the stack damper. The fuel bed must be kept light (six to eight inches) so that air flow is not retarded. If holes develop in the fuel bed, air will follow the path of least resistance and pass through the holes rather than the active portion of fuel.

b. **Underfeed Stoker Firing.** Underfeed stokers admit coal from underneath the burning fuel bed. Gases distilled from the fuel pass up through the bed to accelerate combustion. Single-retort underfeed stokers are horizontal, with coal being moved into the furnace and distributed by mechanical motion. Multiple-retort underfeed stokers are inclined and coal movement is caused by mechanical motion and force of gravity.

(1) **Adjusting Feed.** Adjust the stoker feeding mechanism (screw or ram)so that coal is fed to meet consumption requirements. If the stoker has an off-and-on control, adjust the fuel and air feed so that the stoker operates most of the time. Adjust the coal-distributing mechanism (secondary arm) as necessary to maintain sufficient coal to fill the retort. If the fire burns back, it will damage the stoker. After dumping ashes, cover the ends of grate bars adjacent to the dump grates with coal. The depth of fuel bed above the tuyeres of single-retort stokers varies from 8 to 14 inches, and from 12 to 24 inches on high-rating multiple-retort stokers. If the fuel bed is too thin, increase coal feed without increasing air until normal conditions are restored. If the fuel bed is irregular, adjust the secondary feeding mechanism or air distributor. Many stokers have dampers which vary the supply of air to different zones. If a hole appears in the fire, the condition may be corrected by reducing the airflow to that area. If the fuel bed is of correct thickness, the rating is changed by varying both air and fuel supply.

(2) **Ash Removal.** Procedure for removing ash depends on whether stationary grates, dumping grates, or clinker grinders are used. In all cases, burn coke thoroughly before dumping refuse into the ash pit. Air must be passed through the coke and ash for some time before discharging. Do not introduce too much air as fuel losses may result. In cleaning the fires, do not remove ashes from the grate bars, instead, let them move down by stoker action for removal at the next cleaning.

(3) Agitation and Clinker Formation. Underfeed stokers vary in the amount of agitation given the fuel bed. In some designs, coal is forced into the furnace and passed over stationary tuyeres and grate; in others these parts move and agitate the burning fuel bed. Stokers which supply agitation are best suited for burning coals having extreme coking tendencies as the movement tends to retard coke formation. Burning coal of low ash fusion temperature on these stokers causes clinkers when the ash is pushed into the high temperature zone. Clinkering is greatly accelerated when the stoker is operated at high ratings. Work the fire as little as possible to reduce clinker formation, and remove clinkers which adhere to grates or side walls at once with the least possible agitation of the fuel bed.

(4) **Air Supply.** Underfeed stokers are operated with relatively thick fuel beds and require a forced draft fan to supply air. The windbox pressure varies from one to seven inches of water. Best results are usually obtained by operating with a slight draft in the furnace. Regulate windbox pressure to supply the required quantity of combustion air and regulate the induced-draft fan or stack damper to produce the necessary draft to overcome resistance of the boiler. This draft regulation is often accomplished automatically.

(5) **Operation.** Lubricate all moving parts according to manufacturer's instructions. Keep sufficient coal in the retort to prevent fire from reaching this section of stoker. Do not permit ashes to fill the ash pit. Inspect windboxes each operating shift and remove any accumulation of siftings. When banking the boiler, feed sufficient coal and renew coal supply as required during long banking periods. Make frequent inspection of stoker and brickwork and report unusual conditions so that repairs can be made before equipment is seriously damaged.

c. **Spreader Stoker Firing.** Spreader stokers permit burning of fine coal particles in suspension and the remainder of the coal on grates. This permits faster load response and reduces clinker formation since the fuel bed on the grates is quite thin. Coal inventory in the furnace lasts only a few minutes. Check the thickness of the fuel bed by stopping the coal feed and noting the rate at which fuel on the grates is burned. If ashes are ready to dump after three to five minutes, the thickness of the fuel bed is correct.

(1) **Adjusting Spreading Mechanism.** Adjust spreading mechanism for a uniform thickness of fuel over the grates to optimize mixing of fuel and air. At the same time, adjust the rate of fuel and air feed in correct proportions for efficient combustion.

(2) **Effect of Coal Size on Operation.** Spreader type stokers are not suitable for burning coal particles larger than 1½ inches, as they hinder operation of the feeding mechanism. The most efficient size of coal is ¾ inches by zero with not more than 40 percent passing through a ¼-inch screen. Satisfactory results can be obtained with sizes up to 1½ inches. The fine coal burns in suspension with the larger particles falling to the grates where combustion is completed. Too much coal overloads the grates. In passing through bunkers or chutes, coal sometimes segregates into coarse and fine particles. If this occurs, the stoker will burn practically all "fines" at one time and all coarse at another, resulting in variable and inefficient operation.

(3) **Ash Removal.** Clean the fires at regular intervals, usually twice each operating shift or when ashes are from three to six inches deep on grates. If the grates are divided, clean one zone at a time. Shut off the coal feed and wait three to five minutes with the forced draft fan on for the remaining coal to burn. Do not allow the bed to become too thick or clinkers will form. Remove the ash deposit promptly from ash pit to prevent fires.

(4) **Banking Procedures.** Allow some accumulation of ash on the grates before banking a spreader stoker. Reduce the air supply and adjust the feeder mechanism to deliver coal to the front of the stoker in order to build up the fuel bed in that area. Maintain a slight draft in the furnace during the time the furnace is banked.

(5) **Overfire Draft.** The best operating results are usually obtained with an overfire draft from .03 to .07 inches of water. This reduces air leakage to a minimum without causing overheating of the furnace walls, doors, or other parts subjected to heat. Adjust the air supply so that it is just sufficient to prevent smoking. This should result in approximately 11 to 14 percent carbon dioxide in flue gas. Examine the furnace frequently to ensure that it is not overheated. Low carbon dioxide and inability to secure proper draft through the boiler are often due to air leakage through the boiler setting. Maintain the flue gas temperature at the minimum level consistent with good operation. Some packaged type boilers are operated with positive pressure in the furnace. These boilers should be operated in accordance with the manufacturer's operating instructions.

(6) **Operation.** Examine the windbox periodically and keep it clean. Check the operation of feeding mechanisms to ensure equal distribution. If wet coal sticks in the hopper, push it into the feeder with a rod. Lubricate bearings frequently in accordance with manufacturer's requirements.

d. Traveling-Grate Stoker Firing. Traveling-grate stokers provide a means of burning very fine coal or coal having a low ash fusion temperature. They are not generally suitable for burning caking or coking coal. Control is obtained by varying the rate of feed either by changing the thickness of coal-feed ribbon to the stoker or by changing the rate of grate movement. The method employed is determined by trial to suit the skill of the individual operator. Adjustment of grate speed must be done with care.The usual speed varies from 2½ to 3½ feet per minute. The fuel must be completely burned before it reaches the end of the grate to prevent excess carbon loss to the ash pit. Excessive burning of link ends is an indication that an appreciable amount of burning combustible is passing over the refuse end of the stoker However, if the fuel is burned too far before the end the grate, too much air will be admitted through the uncovered grate and an excessive quantity of heat carried away of flue gases. This condition can be determined by observation and flue gas analysis. Additional regulation of the fuel-bed level is obtained by use of section-air-control dampers under the stoker. Use these dampers to reduce the supply of air to thin sections. Note that if the ash has a low fusion temperature, excessive agitation of fuel bed can result in clinker formation.

(1) **Air Control.** Traveling-grate stokers are used with either natural or forced draft boilers, with modern units being almost all forced draft type. Forced draft is necessary when the use of fine coal increases the resistance of the fuel bed or when the grate openings are small in size. Greater control and high rates of combustion are also obtained with the use of forced draft. Operation, in either case, remains essentially the same. Draft loss through the fuel bed varies from 0.25 to 0.60 inch of water with natural draft and from one to four inches with forced draft.

(2) **Draft Control.** An overfire draft of .03 to .07 inches of water should be maintained. This minimizes air leakage, overheating of furnace walls, doors and other parts exposed to heat.

(3) **Storing Coal.** Do not segregate coarse and fine coal in bunkers or hoppers, as this will result in irregular burning and holes in the fuel bed.

(4) **Adjusting Grate Tension.** Adjust tension on the grate with tension screws at the back sprocket bearing.

Adjust the screws on both sides until chain or grate bars are tight, then loosen the screws slightly.

(5) **Ledge-Plate Clearance.** Many stokers are supplied with ledge plates on the sides to prevent excessive air leakage. Ensure that ledge plates have approximately ⅛-inch clearance. If proper clearance is not maintained, excess air levels increase and boiler efficiency is reduced.

(6) **Banking Procedures.** To bank fire on a traveling-grate stoker, allow the fire to burn down, reducing draft as much as possible. Introduce a bed of coal approximately one foot thick. The stoker should be run ahead at hourly intervals during the banked period. Frequency of this operation depends upon the rate of burning. In starting from bank, break up any coke which has formed, introduce air, allow the coke to burn, and wait until the furnace walls are heated before resuming normal operation.

3-18. OIL FIRING PROCEDURES

Efficient operation of oil fired burners requires careful oil storage, oil preparation, and burner adjustment.

a. Sludge Control. Good bunkering practices greatly reduce sludge accumulation in storage tanks. However, occasional cleaning is necessary. When sludge reaches the level that it may enter the pump suction line, the tank must be emptied and the sludge removed. The most practical method of reducing sludge formation to a minimum is controlled bunkering. This consists basically of extending the fill, suction, and return lines to within one to two pipe diameters of the tank bottom. Keep the fill line on the opposite end of the tank from the suction and return lines. This piping arrangement helps to prevent heavy sludge deposits by sweeping the bottom of the storage tank. Sludge conditions in storage tanks are aggravated by the following:

(1) Return to the tank of overheated oil.

(2) Maintaining the oil temperature too high in the storage tank, causing separation of the light and heavy fractions.

(3) Leakage of ground water into the tank.

(4) Storing oil in tanks for excessively long periods.

b. Air Leakage. A small air leak in a pump suction line can cause a great deal of trouble. Such leaks can occur around valve stems, screwed or flanged fittings, and strainer gaskets. Test for such leakage by applying a small quantity of light oil to the joint or part in question. The oil is drawn into the suction line if leakage is present. If air does get into lines, it should be released from bleed points. If bleed points are not available, check burner operation closely until air is completely cleared. Air coming through the burner may cause fires to go out. If oil flow is then resumed, explosive ignition can occur from the hot furnace walls. Do not allow oil-storage tanks to be emptied to the level where the suction line may draw air, except when necessary for annual cleaning.

c. Oil Strainers. Strainers are provided in oil suction and distribution piping to protect pumps and burner atomizers from being damaged or clogged. These strainers remove particulate and sludge from the oil. All strainer baskets should be checked and cleaned on at least a weekly basis, while daily cleaning may be required for heavy oils.

d. Oil Heating. When heating oil in a storage tank or suction line before transfer or supply pumps, do not heat the oil to a temperature at which vapors are given off, as vapor locking of pumps and unpredictable burner operation can result. Day tanks may be effectively used if significant quantities of heated oil are circulated through a distribution header with only a portion of that oil used. When a pumping and heating set is part of an installation, it is important to adjust the pressure control valve to maintain a constant oil supply pressure and recirculate oil to the tank ahead of the heaters. Oil temperature control can often be improved by reducing the steam pressure or water temperature to the oil heater. This is particularly important if oil flows through the heater are less than the design conditions.

e. Oil Temperature at Burner. The best oil temperature for atomization is dependent upon the type of oil and the burner manufacturer's recommendation. The burner manufacturer will recommend a viscosity range in which to operate. Typically a range of 35 to 150 SSU is recommended for pressure type atomizers, 35 to 250 SSU for steam or air atomizers, and 35 to 300 SSU for rotary atomizers. An atomizer for a low excess air burner may require an 80 to 120 SSU RANGE FOR No. 4, No. 5, or No. 6 oil. Reference paragraph 1-4b, table 1-2, and table 1-3 for further information. Figure 3-3 illustrates typical viscosity limits for various oils as a function of temperature. This chart can be used to plot a viscosity curve for a particular oil. Semi-logarithmic graph paper must be used. If the viscosity at one temperature is known, a curve can be plotted by assuming that the slope of the line is the same as the standard slopes. An example is shown on figure 3-3. However, with the blended oils common today, it is best to know the viscosity at two different temperatures and draw a straight line through those two points. When the viscosity-temperature curve is known, the proper operating temperature range can be read from the chart. Maintaining a constant and stable viscosity to the oil control valve is also important if accurate control of oil flow over the burner control range is to be maintained. Most control systems do not compensate for viscosity changes, and fuel-air ratio control becomes difficult if viscosity is not held constant.

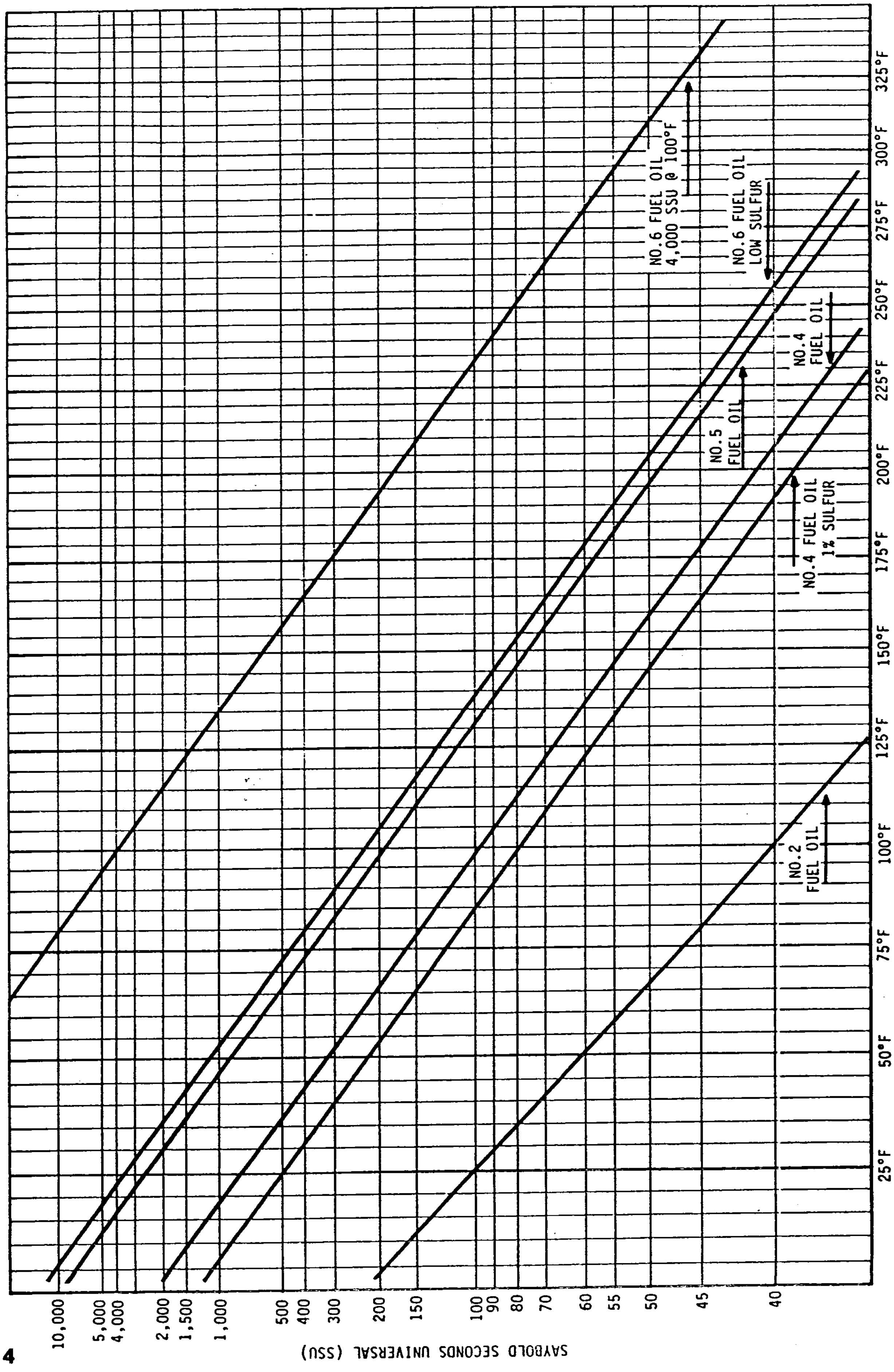

FIGURE 3-3. OIL VISCOSITY VERSUS TEMPERATURE

f. Oil, Atomizing Steam, and Combustion Air at Burner. Oil, atomizing steam (or atomizing air), and combustion air must be supplied to the burner at the pressures recommended by the manufacturer. Oil atomizers using steam or air for atomization normally maintain a differential pressure with the pressure of the steam or air being above the oil pressure throughout the firing range. Atomizing steam lines should be well drained and trapped to ensure that no water is delivered with the steam. Combustion air also must be controlled at the pressures and quantities necessary for complete and efficient combustion. The energy in the oil pressure, atomizing steam or air, and combustion air are all used to mix the fuel and air for efficient combustion.

g. Burner Adjustments. Burner adjustments are necessary to ensure that the atomized fuel and combustion air mix completely and efficiently. Position of the atomizer, diffuser, and register baffles are adjusted to optimize burner performance. Some control systems change the register positions automaticlly throughout the firing range to maintain low excess air levels. If automatic adjustment is not part of your system and boiler load varies significantly over the year, optimum burner adjustment for the low and high load ranges should be determined and the burners and controls adjust accordingly.

h. Daily Operation. Oil burners should be inspected daily. The atomizer should be removed and cleaned per manufacturer's recommendations. For No. 6 oil firing, this may be a daily procedure, while for No. 2 oil, a weekly cleaning is usually sufficient. A visual inspection of the burner flame and furnace condition should be made. The flame should be clean, smokeless, and steady with a yellow to yellow- orange color. There should be minimal or no flame impingement on the furnace walls, no smoke or sparklers in the fire, no slanting or laziness in the flame, and no brilliant color. If any of these conditions exist, check the excess air levels, oil pressure and temperature, water in oil, atomizing steam or air differential pressure, burner adjustments, and the atomizer for wear. Take corrective action or request assistance. Fuel/air ratio control is discussed in paragraph 3-20.

3-19. GAS FIRING PROCEDURES

Efficient operation of gas fired burners requires proper gas handling and burner adjustment.

a. Pressure Regulation. Gas is supplied under pressure. A strainer, pressure regulating valve, and gas meter are commonly supplied at the inlet of gas service to reduce line pressure and meter the gas. A second gas pressure regulating valve is then supplied to maintain a constant pressure in the distribution piping to the burners. Accurate gas pressure regulation is important for the proper functioning of the gas control valve and for maintaining the proper fuel/air ratio. Gas distribution pressure should be checked each shift. A higher than normal gas pressure reduces the amount of excess air, while a lower pressure increases the excess air.

b. Burner Adjustments. Burner adjustments are required to ensure that the gas and combustion air mix completely and efficiently. Gas burner position, if movable, diffuser position, and register/baffle positions must be adjustsed to optimize burner performance in that specific furnace. Some control systems automatically change the register positions throughout the burner firing range to maintain low excess air levels. If automatic adjustment is not part of your system and boiler load varies significantly over the year, optimum burner adjustment for the low and high load ranges should be determined and the burners and controls adjusted accordingly.

c. Daily Operation. Gas burners should be inspected daily. A visual inspection of the flame and furnace conditions should be made. Traditionally, gas flames have been blue in color with yellow tips. However, modern burners, designed for low excess air and/or NOx control, may vary in color from almost invisible to luminescent yellow. The burner flame should be clean and steady, with minimal impingement on the furnace walls, and no smoke, flaring, instability, brilliance, shortness, or flashback. If any of these conditions exist, check the excess air levels, ga pressure, burner adjustments, and furnace pressure. Take corrective action or request assistance, as required. Fuel/air ratio control is discussed in paragraph 3-20.

3-20. COMBUSTION CONTROLS

Operate combustion controls in the fully automatic mode whenever possible. Review manufacturer's operating instructions to fully understand the operating characteristics of your particular control system. Inspect all control drives and linkages daily for smooth operation and tight connections.

a. Fuel/Air Ratio Adjustment. When the amount of excess air observed in the flue gas exceeds the amount determined as proper for your system, the fuel/air ratio should be adjusted. To determine the proper fuel/air ratio, the boiler should be operated at four different loads; approximately 20 percent, 40 percent, 70 percent, and full load. Data should be taken at each load, after adjusting the burner for optimum operation. The data should include steam flow or Btu output, fuel flow, fuel valve position, fuel pressure, fuel temperature, and atomizing steam or air pressure (of oil), overfire air pressure (if coal), Bacharach or Ringleman smoke desnity, combustion air pressure, combustion air flow if available, fan damper position(s), furnace pressure, percent oxygen or carbon dioxide in the flue gas, and flue gas temperature. At each load, a curve of smoke density versus percent oxygen or carbon dioxide should be developed. Figure 3-4 illustrates such a curve. When the desired operating positions are known for the four loads, the controllers and linkages should be adjusted to duplicate the settings. When compromise is necessary due to control limitations, the system should be arranged for best control throughout the normal operating range of the boiler.

b. Standing Operating Procedures. Simple biasing of the fuel/air ratio is often possible to allow the operator to compensate for changes in fuel, air, or other operating characteristics. This involves increasing or decreasing the amount of air flow by a fixed amount. Biasing of air flow does not change the basic fuel/air ratio. Figure 3-5 illustrates fuel/air ratio biasing. When simple biasing of the fuel/air ratio is possible, a Standing Operating Procedure should be developed to detail and authorize actions to be taken by the operator. Each time corrective action is taken, it should be noted in the boiler log. Any other adjustment to the combustion control settings must be authorized by the Director of Engineering and Housing or chief operator.

3-21. BOILER SAFETY CONTROLS

The water column discussed in paragraph 3-16a is often equipped with a low water cutout switch interlocked to shut down the fuel to the boiler. Historically, this is the most important boiler safety control. Tube rupture failure due to low water level is one of the most common and most dangerous types of failure. The water column must be blown down each shift to prove operation and ensure that sediment does not prevent normal operation. High steam pressure or high water temperature switches, flame scanner function, and other safety switches as shown in figures 2-48, 2-49, or 2-50, must also be tested periodically. Tests can best be performed during the normal start-up shutdown procedures.

3-22. CENTRIFUGAL PUMPS

Centrifugal pumps are widely used in heating plants and require a minimum of attention. Small, electrically driven centrifugal pumps are started by closing the motor-starting switch. Discharge valves of large pumps should be closed before the pump is started to reduce power required for starting. After the pump has started, slowly open the discharge valve. Pumps can be safely operated for a few minutes with the discharge valve closed, but continued operation without water circulation will cause the pump to overheat. Open casing vents to remove air or gases trapped in the casing. Some centrifugal pumps are driven at constant speed with output controlled by throttling a discharge valve either manually or automatically. When centrifugal boiler feed pumps are used, pump control may consist of the boiler feedwater control valve. In all cases where automatic regulation is employed, be sure to prevent the discharge valve from closing off completely, as this would result in overheating of the pumps. Large hot water distribution pumps are often equipped with variable speed drives to economically control water flow. Centrifugal pumps are built to operate against a given head or discharge pressure for a specified speed. If there is stoppage, or if for any reason discharge pressure becomes higher than the rated value, the pump will stall and a no-flow condition will exist. Immediately investigte and correct the cause of the increased pressure.

a. Operating Centrifugal Pumps in Parallel. If centrifugal pumps are operated in parallel, each pump must have the same characteristic, otherwise the pump with the greatest head will pump all or most of the water. This results in overheating of the low head pump. Exercise care in selecting the required number of pumps to meet load conditions.

b. Controlling Leakage. For a pump not using mechanical seal, pack the pump shaft with the recommended packing material to minimize leakage. In tightening the packing, be sure to take it up evenly, but not so tight as to produce excessive friction and cause overheating.

c. Lubrication. If centrifugal pump bearings are lubricated by oil rings, ensure that the oil level is maintained high enough to come up to the rings. Check the rings to see that they are turning. Drain the oil occasionally, flush out the bearings, and add new oil. Centrifugal pumps have roller bearings packed with grease require infrequent attention. Do not overgrease the bearings as this may result in overheating. In adding grease to a roller bearing, remove the drain plug or use a safety fitting to prevent overgreasing. Inspect pumps daily for proper operation and bearing temperatures.

3-23. DIRECT-ACTING PUMPS

Direct-acting pumps (duplex and simplex) may be used where steam of 60 psig or more is available and where the exhaust steam may be utilized for heating. These pumps are not economical when exhaust is discharged to atmosphere. Neglecting leakage, direct-acting pumps deliver a given amount of water per stroke. The maximum pressure which a given pump develops depends on the steam pressure supplied, and it is necessary to regulate the speed of the pump to control output. Regulation is accomplished by controlling the rate of steam flow to the pump with a hand-operated globe valve or a regulating valve actuated by pump discharge pressure. This control varies the pump speed and thereby maintains consta'

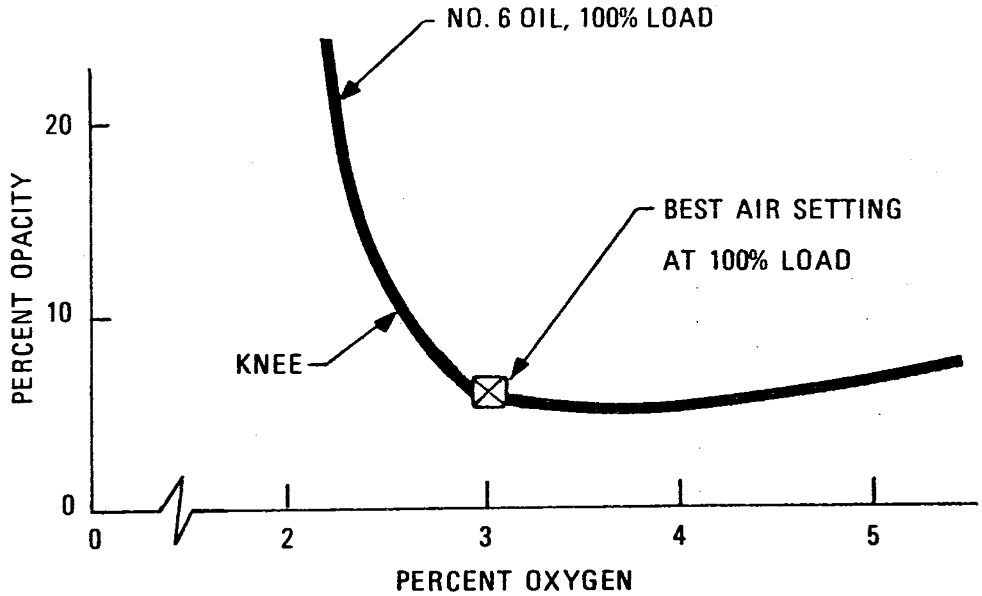

FIGURE 3-4. SMOKE DENSITY VERSUS PERCENT OXYGEN

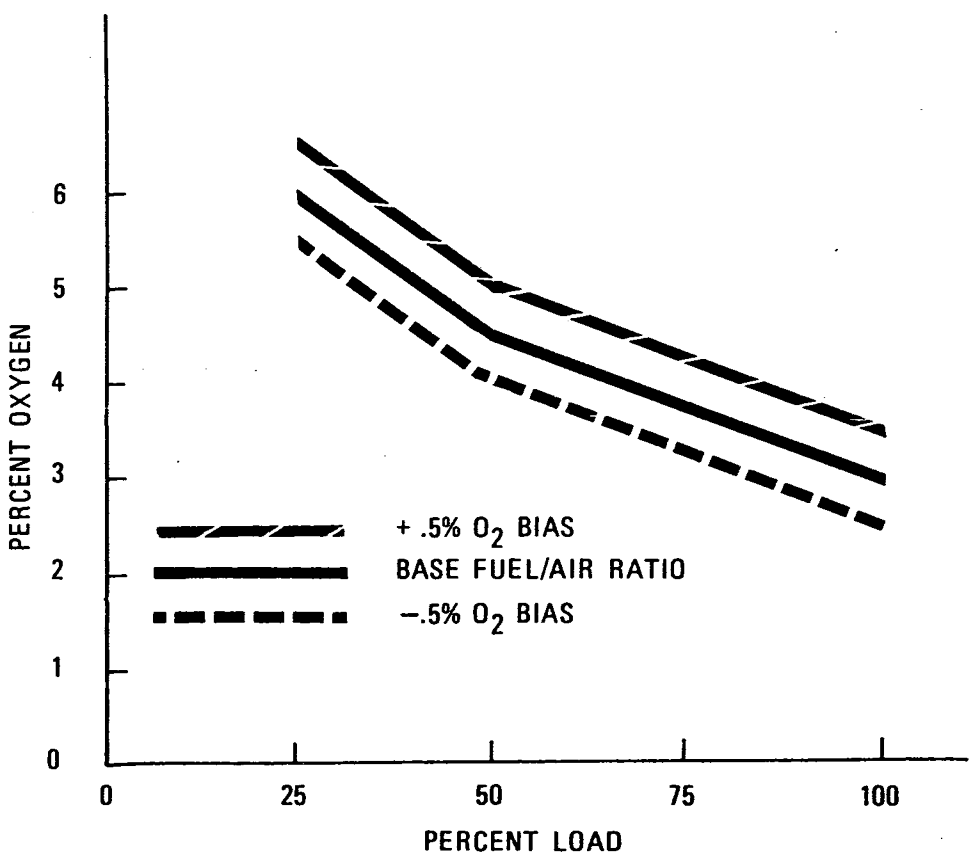

FIGURE 3-5. FUEL/AIR RATIO BIASING

discharge pressure. Some duplex pumps are supplied with cushion valves to regulate the length of stroke; when the pump begins to short-stroke the cushion valve is opened to compensate. If cushion valves are not supplied, the length of stroke is regulated by adjusting the valve-gear lost motion; this adjustment cannot be made during pump operation.

a. Operation. To start a direct-acting steam pump, drain the steam line and ensure that no water is present. Open the drain cocks on steam cylinders. Ensure that valves on the inlet and outlet water lines and exhaust steam lines are open. Admit steam to the pump and allow the cylinder drain cocks to remain open until the pump operates. Adjust cylinder lubricators to feed the required amount of cylinder oil.

b. Lubrication. There are two principal types of lubricators: hydrostatic and mechanical. Hydrostatic lubricators depend upon pressure created by a column of water to force oil into the cylinder against steam pressure. A mechanical lubricator consists of a small plunger pump operated by the reciprocating motion of the pump. Avoid excessive lubrication so that oil does not find its way into the boiler by mixing with the condensate.

c. Duplex Pump Adjustment. A duplex pump will strike its heads if there is too much lost motion in the valve gear and will short stroke if there is too little. If the crosshead of a duplex pump slips, the pump may strike the head on one end and short stroke on the other end. Reference figures 2-105, 2-106, and 2-107. To adjust the steam valves of a duplex pump, proceed as follows:

(1) Remove steam-chest cover.

(2) Locate midposition of one piston by moving it to alternate ends of its stroke and marking the rod at same edge of the same stuffing box. Locate and mark the center of the distance between the two previous marks and move the piston until this third mark is in line with the indicated outside edge of the stuffing box. The piston is now in its midposition. Note: Use a very light marking to prevent scoring the rod during operation. A very light scratch with a sharp pointed tool is best.

(3) Check position of rocker arm. Correct position is at a right angle; relocate spool on the rocker arm operating rod to achieve this position.

(4) Repeat steps (2) and (3) on the other piston.

(5) Locate valves in their midposition.

(6) Adjust the effective length of the valve rod to obtain the same amount of lost motion on either side. With an arrangement as shown in Figure 2-106A, this is done by disconnecting the valve and pusher rods and turning the valve rod until the lost motion is equally divided, then reconnecting the valve and pusher rods. With an arrangement as shown in figure 2-106B, the nuts on the valve stem may be relocated. Care must be taken not to change the amount of lost motion while relocating these nuts.

(7) Move one valve off midposition before the steam chest is covered. The pump will not start unless this is done and it will be necessary to pry one side of the pump off dead center by hand.

d. Leakage. Leakage of packing and valves results in decreased capacity of displacement pumps. Valve leakage is usually accompanied by irregular operation. Replace the packing or repair valves as necessary.

e. Steam or Air Binding. Steam or air binding is a common cause for failure of displacement pumps to deliver water. When suction lift is too great or water too hot, flashing takes place within the suction pipe and pump cylinder, and the steam expands and contracts as the piston or plunger operates. To correct this condition, decrease suction lift, or cool the water. If air leaks into the suction line past the packing, the cylinder will become filled with air instead of water. Since air is a compressible gas, its presence prevents the pump from operating. When the pump has a suction line, ensure that the suction pipe is absolutely tight.

3-24. INJECTORS

Injectors used in stationary practice are usually of the self-starting automotive type. To operate, open the water and steam supply valves. Water is first discharged through an overflow. When the injector starts to deliver water, the overflow valve is automatically closed by the vacuum produced. Rate of flow is then controlled by means of either water- or steam-supply valves. Some of the common difficulties encountered in operation of injectors are:

a. Water too hot.
b. Suction lift too great.
c. Leaks in suction piping.
d. Scale deposits in injector nozzles and body.
e. Worn nozzles caused by impurities in water.
f. Clogged foot valve, strainer, or suction piping.
g. Fluctuating steam pressure.

3-25 FANS

In many older plants, natural draft created by a stack was used to move air through the boiler. The need for more positive control and safety resulted in the use of forced and induced draft fans.

a. Lubrication. Sleeve bearings are lubricated by oil rings. Oil rings are larger in diameter than the shaft and dip into an oil well under the bearing. Rotation of the shaft causes the rings to turn and carry oil to the bearing. It is important that proper oil levell in the well be maintained. If the ring fails to touch oil, the bearing will not be lubricated. Roller bearings require less attention than sleeve bearings. Pack roller bearings with grease every six months to one year, depending on service. Use of manufacturer's recommended grease only and use care to prevent overgreasing.

b. Water-Cooled Bearings. For fans handling high-temperature air or gases, water-cooled bearings may be required. Ensure that cooling water is maintained on the bearings. Bearing operating temperature of 130° F or less is considered satisfactory.

c. Regulation. Output of a fan can be regulated either by changing its speed or by adjusting inlet or outlet dampers. Damper adjustment is usually employed to avoid the expense of supplying a variable-speed drive for the fan. The dampers may be manually or automatically controlled. In either case, means are provided to regulate air flow to meet system requirements.

d. Common Difficulties. Some common difficulties encountered in fan operation are:

(1) Vibration caused by unbalanced rotor.
(2) Misalignment resulting in vibration, overheating of bearings and wear of couplings.
(3) Incorrect or insufficient lubrication resulting in failure or overheating of bearings.
(4) Improper regulation due to fouled or worn control vanes, dampers, and control mechanisms.
(5) Reduced fan efficiency and capacity due to blades fouled with dust, dirt, or grease.
(6) Fan rotor and casing erosion due to handling air or gases laden with fly ash and other abrasive material.

3-26. FEEDWATER HEATING AND TREATMENT

In the simplest of systems a closed feedwater heater may be used to heat the feedwater to an acceptable temperature, usually 180° F to 220° F. More involved systems for feedwater heating, deaerating, and treatment are discussed in chapter 4. Reference chapter 4, Section III for operating recommendations.

3-27. ECONOMIZERS, AIR HEATERS, AND POLLUTION CONTROL EQUIPMENT

This equipment is located between the boiler outlet and the stack. Gas pressure and temperature through this equipment should be closely monitored, as they are good indicators of performance, both for the individual items of equipment and for the overall boiler installation. When sootblowers or other cleaning devices are provided they should be operated once a shift or as recommended by the manufacturer. Moving parts such as dampers, linkages or air heater drives should be lubricated as recommended by the manufacturers. Ash hoppers should be emptied daily or more frequently, if required. Care must be taken to maintain gas temperature above the acid dew point (reference figure 2-18) to minimize corrosion. Daily inspection is required. Manufacturer's shutdown instructions should be incorporated into the boiler shutdown procedure. When an economizer or air heater will not be operated for more than two days, clean the fire side to minmize corrosion problems.

3-28. EMERGENCY PROCEDURE — ABNORMAL WATER LEVEL

Correct water level is maintained either manually or automatically. Automatic control is an aid but cannot always replace the operator for reliability. Low water level can result in burned tubes and boiler plates with the possibility of destructive explosion. High water level causes water to be carried out with the steam and causes damage or destruction to engines, turbines, valves, or piping. Abnormal water level (high or low) can be caused by operator carelessness, failure of a regulator or pumps, broken piping, boiler leaks, failure of an indicating device, or failures in the water circulating system.

a. Low Water Level. If the water level is below the visible range of the gage glass, shut off fuel flow, purge the boiler, and shut off all fans. Continue to feed water slowly until normal level is restored. If there is any possibility that the boiler has been damaged, it should be cooled and thoroughly inspected before being put back into service. The underlying cause of the low water condition should be determined and appropriate corrective action taken before attempting to resume normal operation. Water level should be controlled manually until the automatic control is known to be functioning correctly.

b. High Water Level (Steam Boilers). If water is above the visible range of the gage glass, shut off feedwater and fuel, purge the boiler, and shut off combustion air. For hand-fired boilers, smother the fire by covering the grate with green coal or wet ashes. For stoker-fired boilers, shut down the stoker, cut off the air supply, and open the furnace doors. If the water level does not recede into the visible range of the gage glass within two minutes, operate the main blowdown valves as required. The underlying cause of the high water should be determined and appropriate corrective action taken before attempting to resume normal operation. Water level should be controlled manually until the automatic control is known to be functioning correctly.

3-29. EMERGENCY PROCEDURE — BOILER TUBE FAILURE

If relatively cold water is introduced into the empty drum of a hot boiler, the drum and tube joints are subjected to severe thermal strains which may result in cracks or loosened tubes. Should the water get too low while heat is still applied, serious damage to tubes and boiler structures may result. Leakage may become so great that available water is not sufficient to maintain the required level. If a feedwater regulator is used, it will open wide when the level drops. This results in a large flow of water to that boiler and may cause other boilers on the same header system to develop low water conditions. The correct remedial procedure varies, depending on rapidity with which the fire can be extinguished.

a. Procedure for Gas- or Oil-Fired Boilers. If the leak is so serious that immediate removal of the boiler is necessary, proceed as follows for gas-or oil-fired boilers.

(1) Shut off fuel.

(2) Close the steam outlet valves if only one boiler is in operation. Do this quickly to prevent a sudden pressure drop and corresponding temperature drop. For a multiple boiler installation when more than one is in service, the header pressure and the non-return valve will automatically isolate the disabled boiler from the header.

(3) Shut off the supply of feedwater to the boiler, provided there is not enough hot refractory to cause overheating. In the case of boilers with refractory furnaces, adjust the feedwater flow to the maximum consistent with the protection of supply to other operating boilers. Attempt to maintain a normal water level until the overheating hazard is past, then shut off the feedwater.

(4) Maintain minimum air flow through the boiler setting to carry away steam discharged from the leak.

(5) After 15 or 20 minutes, shut down the forced-draft fans.

(6) Proceed with the normal method of cooling the boiler. Do not drain the unit until the furnace is cool enough to enter.

(7) Inspect the boiler and all pressure parts completely. Repair the boiler, as required. Be sure the boiler is hydrostatically tested and approved by an Authorized Inspector before returning to service.

b. Procedure for Stoker-Fired Boilers. For stoker-fired units, the following procedure is recommended if tube failure occurs:

(1) Shut off the fuel feed and gradually reduce air flow as the fuel bed decreases. Also, use whatever means have been predetermined or are available to smother the fire effectively without danger of explosion.

(2) Close the steam outlet valves.

(3) Adjust the feedwater flow to the maximum permissible and attempt to maintain normal water level. Shut off the feedwater after the setting has cooled to a point where no danger of overheating exists.

(4) Adjust air flow to minimum safe level consistent with preventing water or steam from flowing into the boiler room and minimizing the rate of cooling.

(5) Inspect the boiler completely and make the necessary repairs. Be sure the boiler is hydrostatically tested and approved by an Authorized Inspector before returning to service.

3-30. EMERGENCY PROCEDURE — FAN FAILURE

The flow of air and gases through the boiler depends upon the action of the forced and induced draft fans. The greatest difficulty occurs when induced draft fans stop for any reason. If the combustion system continues to operate when the induced draft fan fails, smoke, combustion gases, or fire are discharged into the boiler room. The forced draft fan and fuel feed should be immediately stopped when the ID fan trips. Most boilers are equipped with safety interlocks which do this automatically. Safety interlocks are also normally provided to stop the fuel feed if the forced draft fan fails. If such interlocks are not provided, the operator must take these actions manually. If the induced draft fans have tripped for any reason, slowly open all dampers in the air and flue gas passages to their wide open position in order to create as much natural draft as possible to ventilate the setting. Opening the dampers should be timed or controlled to avoid excessive pressure transients during fan coast-down. Maintain this condition for a period that will result in not less than five volume changes, but in any case not less than fifteen minutes. At the end of this period, close the flow control dampers and immediately start the fan(s). Gradually increase the air flow to at least 25 percent of full load flow and purge the setting for five minutes. These general recommendations should be adhered to unless adequate tests on a specific boiler demonstrate that different values should be used.

3-31. EMERGENCY PROCEDURE — ELECTRIC SYSTEM FAILURE

Auxiliary equipment in some plants is equipped with both steam and electric drives. In case of failure of one, the other can be quickly put into service. If all auxiliary equipment is electrically driven and there is no gasoline or steam engine backup, or emergency source of auxiliary power, electrical failure causes a complete outage. While power is being restored, prepare the boiler equipment so that operation may be immediately resumed when power is available. Prepare and follow a schedule for testing operation of all standby equipment. Some boilers may be operated at reduced rating with natural draft. Steam driven pumps may be used to supply feedwater. If this is possible, some of the steam service may be able to be maintained. Arrange a schedule so that the least important service is shut off during an emergency. Study the plant and determine how, in case of electric power failure, the following services may be continued:

a. Water supply tc the boilers.

b. Operation of induced draft fan.

c. Fuel supply to the furnace.

d. Combustion sir supply.

e. Operation of automatic controls.

f. Operation of valves and safety devices.

3-32. EMERGENCY PROCEDURE — FLAME FAILURE

Oil- and gas-burners are provided with flame scanners and safety controls which will safely shut down a burner within two to four seconds of flame failure, and post purge the furnace before shutting off the fans. Manual systems require that the operator take these actions. If the fans are operating after a safety shutdown, continue the operation. Do not immediately increase the air flow. If the air flow is above 25 percent of full load flow, it should be gradually decreased to this value for a post-firing purge of at least five minutes. If the flow is below 25 percent at the time of the shutdown, it should be continued at that rate for five minutes, then increased to the 25 percent level, and held there for an additional five minutes. Reference NFPA 85 standard series for additional information.

3-33. REMOVING A BOILER FROM SERVICE

When removing a boiler from service, care must be taken to prevent rapid temperature changes and resulting thermal stress. This helps to decrease the possibility of future forced outages and reduces maintenance costs. The procedure for removal is as follows:

a. Reduce the load on the boiler to the minimum stable firing rate.

b. Open the bottom blowdown connection for a sufficient time to remove sludge from the mud drum.

c. With oil- or gas-firing, the fuel shutoff valve should be tripped at the appropriate time and all manual valves at burners closed immediately. With stoker- fired boilers, the stoker hoppers should be emptied and the fuel bed burned out.

d. The setting and boiler should be cooled down without exceeding the maximum rate prescribed by the manufacturer. As a general guide it is advisable to wait until furnace refractory is black before using higher rates of air flow for cooling. Exercise care when using the ID fan for cooling. The ID fan and motor are designed to handle hot gases, and cooler gases, if not controlled, can cause the motor to overload.

e. On high pressure steam boilers, after the feedwater flow ceases and the nonreturn valve has closed, close the feedwater valves and main steam stop valve. Run down the stem on the nonreturn valve to hold the disc on its seat. Where two stop valves are used, open the drain between them to ensure that it is clear and bleeds off any pressure in the line.

f. When steam pressure falls below 25 psig, open the drum vent(s) to prevent formation of vacuum which might cause subsequent leakage of gasketed joints.

g. On hot water boilers, maintain water circulation until the boiler is sufficiently cooled, then stop circulation, close the inlet and outlet water valves, and open a vent valve.

h. The boiler should be inspected and cleaned per instructions in paragraphs 5-11 and 4-12. If storage is planned, follow the instructions in paragraph 4- 18 to protect the water side.

Procedures for removing low pressure steam and low temperature water heating boilers from service can be found in ASME Code Section VI.

SECTION III. OPTIMIZING CENTRAL PLANT EFFICIENCY

3-34. OPTIMIZING COMBUSTION EFFICIENCY

With the cost of fuel continuously increasing, the need to operate central boiler plants efficiently becomes more important all the time. Procedures for optimizing operating efficiencies are discussed in this section. An operator should review the Elementary Combustion Principles and Principles of Steam and Hot Water Generation found in chapter 1. To optimize boiler efficiency the combustion efficiency must first be optimized. We have seen in paragraph 1-11 and tables 1-4, 1-5, 1-6, 1-7, and 1-8 that combustion efficiency is a function of the type of fuel burned, the flue gas temperature, and the amount of excess air in the flue gas. For a given fuel, the operator must take action to optimize combustion efficiency by maintaining as low a flue gas temperature and excess air level as is possible.

a. Sootblowing/Cleaning to Reduce Flue Gas Temperatures. On all boilers equipped with sootblowers, they should be operated as needed to maintain clean heat transfer surfaces. Once a shift is the recommended internal when oil or coal is being fired although experience may dictate a different interval for a particular unit. Note the flue gas temperature before and after scootblowing. A reduction in temperature of 35° F to 40° F corresponds to an efficiency improvement of one percent. Reference tables 1-5 through 1-8 for the specific improvement at the actual temperatures and excess air levels at which you are operating. For fire tube boilers not equipped with sootblowers, a record of flue gas temperatures at the normal firing rate of the boiler should be kept. When the flue gas temperature exceeds the clean boiler flue gas temperature by more than 70° F, the boiler should be taken out of service and cleaned. Fire-tube boilers should, as a minimum, be cleaned during the quarterly inspection.

b. Water Side Cleaning. Maintaining the water side of a boiler is equally as important as maintaining the fire side. Scale on the water side reduces heat transfer just as soot does, and thereby increases flue gas temperature and reduces efficiency. Maintain aproper water treatment program as described in chapter 4. Quarterly inspection and mechanical cleaning may be required. Chemical cleaning may be required occasionally. The operator should know the flue gas temperature of the boiler at its normal firing rate and excess air level, with the gas and water side clean. Any major change in temperature at those firing conditions indicates a problem, typically dirty gas or water side heat transfer surfaces.

c. Setting Leaks. Air leakage into the boiler system increases excess air levels and reduces efficiency. Any air drawn into the boiler through leaks in the furnace setting, casing, or flues must be heated from room temperature to the flue gas temperature, using heat that could otherwise be transferred to the steam. Normal maintenance should greatly reduce the number and size of leaks. Reference paragraph 5-11. The operator should ensure that all doors, ports, and openings into the furnace are closed tightly. The furnace draft should be maintained at a slightly negative level of -0.03s to -0.10 inches of water. This practice helps to minimize air leaks. When the draft is increased for sootblowing, take care to return it to its normal level after sootblowing is complete. The use of a continuous oxygen analyzer to traverse the stack or flue can sometimes help to locate an air leak by showing a higher than normal excess air level.

d. Baffles. To obtain maximum heat absorption, baffles are often used to help direct the hot gases over the tubes. Arrangements vary widely, depending upon tube arrangement. The baffles restrict the flow of gases and affect draft flow required by the boiler. Defective baffles allow gases to short-circuit so they do not pass over the entire heating surface. Leaking baffles result in high outlet gas temperature, and decreased efficiency. Leaking baffles ca usually be distinguished from fouled heat transfer surfac by their effect on draft loss: leaking baffles decrease gas loss, while fouled surfaces increase draft loss. Always investigate and report a change in flue gas temperature or draft loss.

e. Fuel/Air Ratio Optimization. Reference paragraph 3-20a, Combustion Controls-Fuel/Air Ratio Adjustment. Know the proper excess air levels for each firing rate. When proper levels are known, corrective action can be taken if the fuel/air ratio is out of adjustment. Some corrective actions, such as returning the oil header pressure or temperature to the correct operating point, adjusting the stoker feed, returning the furnace draft to the operating point, or biasing the fuel/air ratio may be taken by the operator. If additional corrective action is required, note this in the boiler log and inform the responsible personnel. The optimum fuel/air ratio for a winter load is probably not optimum for a summer load. Determine the optimum ratio over the full load range of the boiler, and post a chart where it can be readily accessed by the operators. Table 3-1 gives recommended oxygen, carbon dioxide, and excess air levels at full load, 50 percent load, and 25 percent load for typical equipment. All boilers will not be able to operate at these levels, but this level of performance is possible with modern, correctly adjusted equipment. Plant modifications to reach these levels may b economically justified based on fuel savings resulting from improved combustion efficiency.

Table 3-1. Flue Gas Analysis at 25%, 50%, and 100% Load
For Natural Gas, No. 2 Oil, No. 6 Oil, and Stoker Coal

	FUEL											
	Natural Gas			No. 2 Oil			No. 6 Oil			Stoker Coal		
Load, Percent	25	50	100	25	50	100	25	50	100	25	50	100
O_2, Percent	4.0	3.0	2.0	5.0	4.0	2.5	5.5	4.5	3.0	7.0	6.0	5.0
CO_2, Percent	9.6	10.1	10.7	11.9	12.6	13.8	12.2	13.0	14.1	12.4	13.3	14.2
Excess Air, Percent	21.1	15.1	9.5	29.2	22.0	12.6	33.6	25.8	15.8	48.5	38.8	30.3

3-35. OPTIMIZING BOILER EFFICIENCY

Boiler efficiency accounts for the energy loss included in combustion efficiency plus the energy losses associated with heat radiated from the boiler casing, heat removed with blowdown, and heat lost due to incomplete combustion. Boiler efficiency is affected by the stability of the combustion controls. Boiler efficiency is always less than combustion efficiency.

a. Reduce Radiation Losses. Inspect, maintain, and improve boiler, flue, and pipe insulation. Improved insulation is often available and economically justified. Radiation losses can be minimized by the proper selection of operating and standby boilers, and the temperture at which standby boilers are maintained. For some plants operating with non-critical load, a standby boiler need not be maintained in hot condition. Close the inlet and outlet dampers of any standby boilers. This will help to minimize the natural draft air flow which will cool the boiler.

b. Reduce Blowdown Losses. Blowdown is necessary to control steam boiler water quality and minimize scale formation. Reduced scale formation helps to maintain combustion efficiency near clean boiler levels and reduces side maintenance. Blowdown is a form of preventive maintenance that should be carefully controlled (reference paragraph 4-8). Continuous blowdown is recommended for steam boilers because blowdown heat exchangers can be used to recover much of the heat in the blowdown water by preheating make-up water. Automatic control of continuous blowdown is also recommended to improve the accuracy of the blowdown procedure and help minimize losses.

c. Reduce Unburned Carbon Losses. Unburned carbon losses from oil- and gas- fired boilers are usually negligible because the fuels burn easily and excess air levels and smoke are easily controlled. Unburned carbon losses for stoker fired boilers, however, can be significant. Stokers should be carefully maintained and operated to minimize unburned carbon losses. Ash reinjection systems are an important part of a spreader stoker system which must be maintained in good operative condition. Overfire air is also very important on any stoker system to obtain proper mixing of air and combustion gases. Reference operation procedures in paragraph 3-17.

d. Stabilize Combustion Controls. The combustion control system must accurately establish the correct fuel/air ration to optimize combustion efficiency. Combustion controls are designed to regulate fuel and air flows to satisfy load demand, establish correct fuel/air ratio, and minimize the time spent at inefficient firing conditions. Combustion controls are stabilized by making the proper adjustments to the proportional band, integral, and rate settings to best respond to the load conditions. It is common that the best settings for winter load conditions are not best for summer conditions. The assistance of the control manufacturer may be required to determine the best settings. Settings should be changed only by trained and authorized personnel.

3-36. OPTIMIZING CENTRAL BOILER PLANT EFFICIENCY

Overall plant efficiency is always less than boiler efficiency. Reference paragraph 1-13 for an initial discussion of Central Boiler Plant efficiency. After individual boiler efficiency is optimized, then consideration must be given to proper boiler selection, deaerator control, use of steam driven auxiliaries, building energy conservation, and modifications or additions to plant equipment.

a. Boiler Selection. The best use of available boilers is necessary to optimize plant efficiency. A curve of efficiency versus load should be developed for each boiler based upon the data obtained when the fuel/air ratios were developed. Figure 3-6 illustrates such a curve. With this information it is possible to select which boiler or group of boilers is best suited to operate at a given load. For a steam demand of 30,000 PPH, operation of boilers #1 and #2 would be most economical. If efficiency of particular boiler is good over a very small range, it ma be best to baseload that boiler in that range and allow the other boiler(s) to handle load swings. Two boilers operating at partial load may be more efficient than one boiler operating near its design capacity. A Standing Operating Procedure should be developed establishing which boilers should operate for a given load.

b. Deaerator Control. Reference paragraphs 4-6g and 4-16c. Deaerators consume a significant amount of steam to heat and deaerate feedwater. Some of the steam is vented to atmosphere and lost. The amount vented ranges from one-tenth percent to one percent of the plant load and is dependent upon both the original design of the deaerator and vent condenser and their proper operation. With poor operation or design, 5 percent or more of the plant load can be vented through the deaerator. If operation alone does not resolve excessive venting, equipment modification or replacement should be considered.

c. Steam Driven Auxiliaries. Steam driven fans and pumps may be useful in providing a plant that can be operated in case of electric failure. Care must be taken, however, in utilizing such drives, because they can have a significant effect on plant efficiency. The efficiency of a non-condensing steam turbine is only about 20 percent. Suitable uses for the exhaust steam must, therefore, be developed if steam turbines are to be used effectively Operate steam drives only when a use for the low pressure exhaust steam is available.

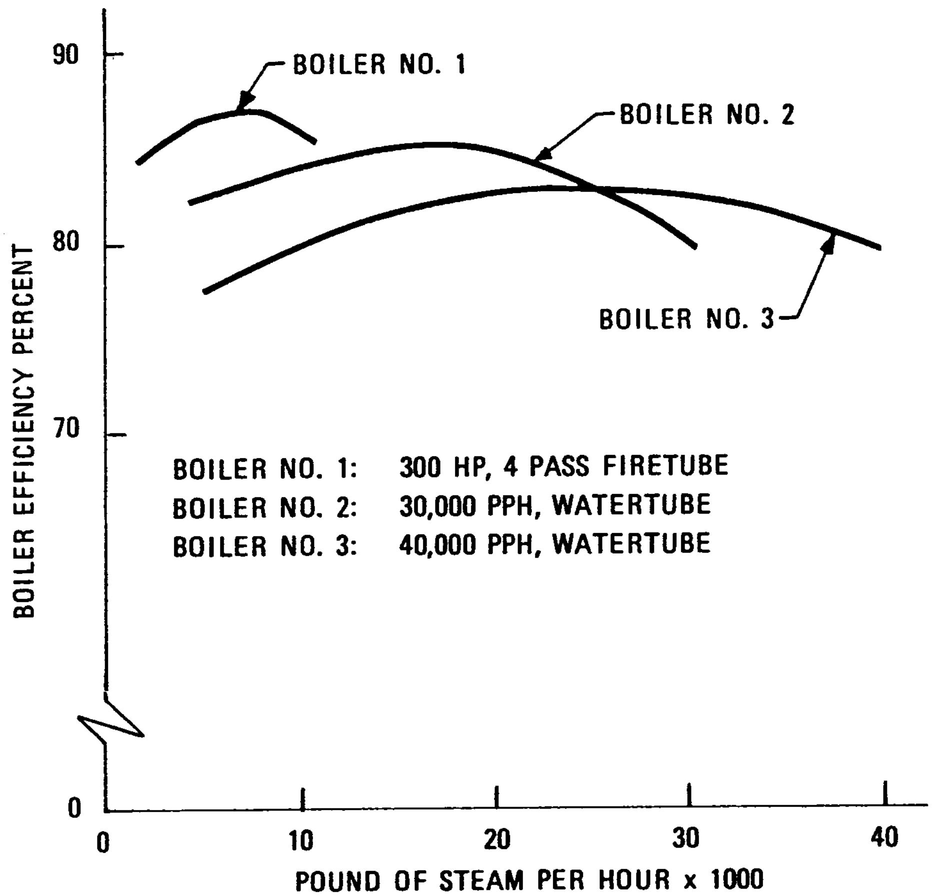

FIGURE 3-6. BOILER EFFICIENCY VERSUS LOAD

d. Plant Building Conservation. Overall plant efficiency can be improved by minimizing the use of plant generated energy for building heating. Use waste heat from condensate return, blowdown water, or boiler radiation whenever possible. Insulate the building. Maintain building steam traps and repair all water or steam leaks immediately. Provide vent condensers on condensate wells, deaerators or deaerating heaters, and use the minimum steam pressure practical in heat exchangers. Reference paragraph 1-2b(1) Energy Losses.

e. Equipment Modifications or Additions. Existing equipment which does not operate efficiently should be modified or replaced if economically justified. Economizers or air heaters should be considered for boilers that normally operate with flue gas temperatures above 500° F, if these boilers operate for significant periods of the year. Five percent improvement in boiler efficiency is common and can often economically justify the addition of such equipment. Improvements to external water treatment may be justified if significant reductions in blowdown quantities can be realized. The addition of a blowdown heat recovery system should be considered. The use of vent condensers, condensate heat recovery systems, improved steam traps, and upgraded boiler combustion controls should also be considered. The economics of such modifications should be carefully reviewed, but it will often be found that the potential energy savings will quickly pay back the capital investment required.

f. Distribution System Effects on Plant Efficiency. If less water is returned to the central plant than was supplied in the form of steam or hot water, plant efficiency is reduced. Make-up water must be heated from its supply temperature, usually about 60° F, while condensate return water needs only to be heated from its already elevated temperature of 150 to 180° F. It is important to monitor supply and return flows as well as makeup flow and determine if excessive losses occur. Note that temperature compensation is required for accurate flow comparison. If losses are determined to be excessive or other problems develop, appropriate personnel should be alerted so repairs to the distribution system can be made. Distribution system losses should not exceed five to ten percent of supplied flow in a steam system and one percent in a hot water system.