APPENDIX D BOILER WATER CALCULATIONS

D-1. BOILER BLOWDOWN CALCULATIONS

The rate of blowdown from a boiler is a critical operating control on total dissolved solids (paragraph 4-4c).

a. The water added to the boiler must equal water lost from the boiler

$$F = E + B$$

Where: F = Feedwater, pounds/hour
E = Steam generation, pounds/hour
B = Blowdown, pounds/hour

b. The blowdown can be related to the feedwater using the cycles of concentration:

$$C + \frac{F}{B} \text{ or } F = B \times C$$

Where: C = Cycles of concentration, no units
F = Feedwater, pound/hour
B = Blowdown, pound/hour
It is common to express blowdown as a present.

$$\%B = \frac{100}{C}$$

c. The relationship between feedwater,blowdown, steam generation, and cycles is represented as:

$$B = \frac{E}{(C\text{-}1)}$$

This is derived as follows:
(1) F = B x C (paragraph C-1b)
(2) F = E + B (paragraph C-1a)
(3) B x C = E + B (Replacing F in Equation 2 with Equation 1)
(4) B x C - B = E (Rearranging Equation (3))
(5) B x (C-1) = E (Rearranging Equation (4))
(6) $B = \frac{E}{(C\text{-}1)}$ (Rearranging Equation (5))

b. Blowdown is never metered, but it can be calculated if any two of the feedwater, cycles,or steam generation quantities are known. Steam is usually metered. The cycles of concentration can be determined by comparing the concentration of dissolved solids in the boiler water to the concentration in the feedwater. Cycles can than be calculated (note that the blowdown concentration is the same as the boiler concentration):

$$C = \frac{Bs}{Fs} \text{ or } C = \frac{B \text{ mmho}}{F \text{ mmho}}$$

Where: C = Cycles of concentration, no unit
Bs = Blowdown TDS, ppm
Fs = Feedwater TDS, ppm
B mmho = Blowdown conductivity, micromho
F mmho = Feedwater conductivity, micromho

D-2. DETERMINING FEEDWATER REQUIREMENTS

The blowdown calculations in paragraph D-1 can be used to determine feedwater requirements. Note that feedwater means the water that is fed to the boiler from the deaerator and includes makeup plus condensate return.

a. Example D-1. A 250 psig boiler operates at a conductivity level of 5500 mmho (see paragraph 4-5**a** for guidance on the maximum allowable level). The boiler feedwater has a conductivity of 275 mmho. The cycles of concentration is calculated as follows:

$$C = \frac{B}{F} = \frac{5500}{275} = 20$$

b. The percent blowdown is:

$$\%LB = \frac{100}{C} = \frac{100}{20} = 5\%$$

D-3. DETERMINING MAKEUP REQUIREMENTS

Makeup is the water from the external water treatment system provided to the deaerator. The criteria for treating makeup is covered in section 4-II.

a. Makeup is the difference between the condensate return and the feedwater.

$$M = F\text{-}R$$

Where: M = Makeukp, pounds/hour
F = Feedwater, pounds/hour
R = Condensate return, pounds/hour

b. The condensate will not contain any appreciable level of dissolved solids (or conductivity) unless there is a source of contamination within the system. This allows the determination of percent makeup using the equation:

$$\%M = \frac{F}{M} \times 100$$

Where: %M = Percent makeup
F mmho = Feedwater conductivity, micromho
F mmho = Makeup conductivity, micromho

c. Example D-2. Makeup conductivity is 610 mmho for the boiler in example 4-1. The percent makeup is calculated:

$$\%M = \frac{F}{M} \times 100 = \frac{275}{610} = \frac{275}{610} \times 100 = 45\%$$

(1) This means that the makeup is 45% of the feedwater. The condensate return percent is calculated:

$$\%R = 100 - \%M = 100 - 45 = 55\%$$

(2) The quantity of makeup is calculated:

$$M = \frac{\%M}{100} \times F = \frac{45}{100} \times 42,105 = 18,947 \text{ pounds/hour}$$

(3) The condensate return quantity is calculated:

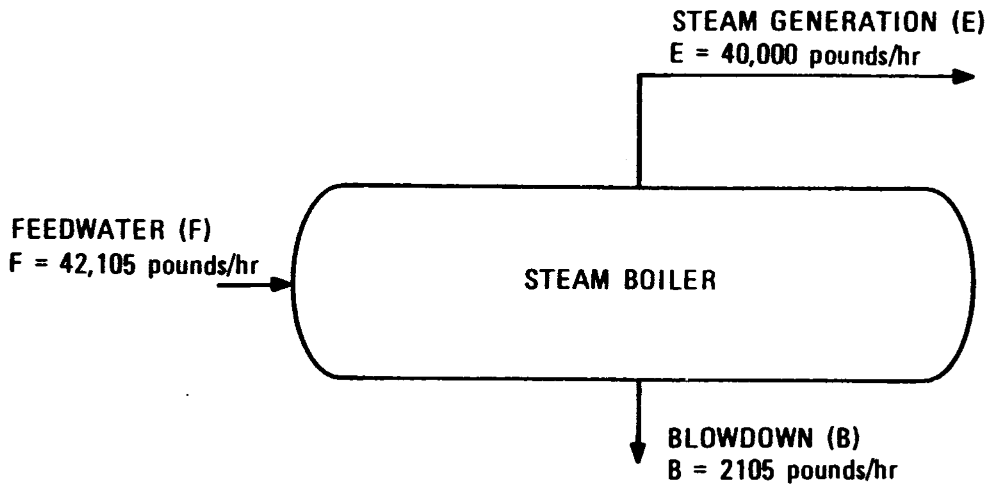

FIGURE D-1. EXAMPLE OF BOILER FEEDWATER, STEAM GENERATION AND BLOWDOWN RELATIONSHIPS

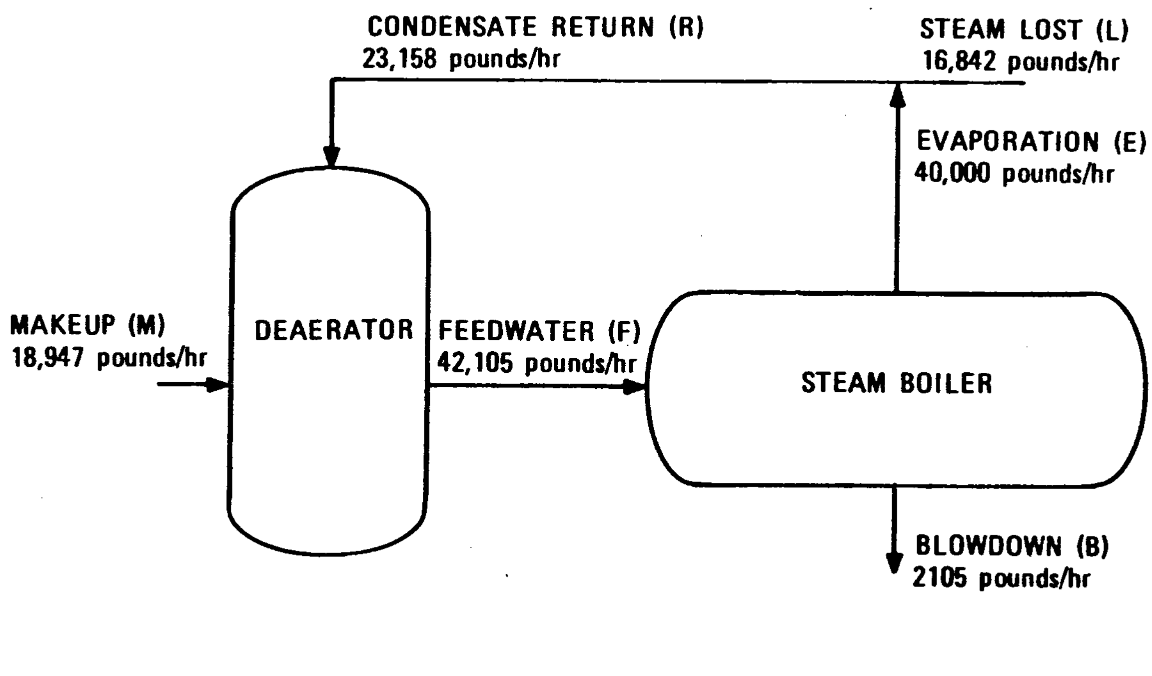

FIGURE D-2. EXAMPLE OF BOILER CALCULATIONS

R = F - M = 42,105 - 18,947 = 23,158 pounds/ hour

d. The difference between steam produced and the condensate returned is due to steam or condensate lost in the system. These losses may include leaks or consumption of steam by the process equipment. The losses can be calculated as follows:

L = E - R

Where: L = Steam or condensate losses, pounds/hour
E = Steam generated, pounds/hour
R = Condensate return, pounds/hour

e. Example D-3. The steam and condensate losses for the boiler described in Examples D-1 and D-2 can be calculated:

L = E - R = 40,000 - 23,158 = 16,842 pounds/ hour

(1) This relationship and the information from the previous examples are presented in figure D-1 and figure D-2.

f. Monitoring the system for steam generated and dissolved solids, and performing these calculations on a regular interval will give a basis for evaluating boiler system performance. An increase in steam and condensate loss may indicate the development of a new leak or an increase in existing leaks. These calculations can provide a good basis for estimating steam savings from maintenance efforts.

D-4. DETERMINING CHEMICAL TREATMENT REQUIRED

Chemical treatment programs involve selecting the type of chemical to be used and establishing a treatment level. These factors are discussed in paragraph 4-7. Blowdown calculations can be used to determine the amount of chemical that needs to be added to meet the treatment objectives.

a. Example D-4. The boiler in examples D-1, D-2, and D-3 is to be operated with a phosphate level of 60 pm in the boiler water. The blowdown has been determined to be 2,105 pounds per hour. The required phosphate addition on a daily basis must equal the phosphate that is discharged with the blowdown. This is calculated as follows:

Phosphate Loss = B x Level

$$= \frac{(2{,}105 \text{ lb/day} \times 24 \text{ hr/day} \times 60 \text{ ppm}}{1{,}000{,}000}$$

= 3.03 pounds phosphate/day

The treatment chemical contains 40% phosphate, which means there is 0.4 pounds phosphate per pound of chemical:

Chemical Required = Phosphate Loss divided by 0.4

$$= \frac{3.03}{0.4} = 7.58 \text{ pounds/day}$$