to the boiler. For the most satisfactory performance, especially in large steam distribution systems, it is recommended that both morpholine and cyclohexylamine be used in a 75/25 or 50/50 ratio of morpholine/cyclohexylamine. When using a mixture of amines, the minimum pH point must be determined locally through on-site chemical analysis of the condensate throughout the system.

(5) **Procedure.**

(a) Rinse three of the combination mixing tubes with the sample to be tested. Fill them to the first mark (5 ml) with the sample, wipe dry, and place in the holes back of the three slots in the Taylor base. The two outside tubes act as blanks to eliminate the effect of color and turbidity on the sample.

(b) To the middle tube add 0.5 ml of Cresol Red. (Taylor #R-1003K-D).

(c) Remove the tube from the base and mix thoroughly, using a clean stirring rod. Replace the tube in the middle hole.

(d) Place the Cresol Red pH slide comparator (pH 7.2 to 8.8) on the base so that one of the white lines on the slide is directly above the line on the base.

(e) Make comparison with the standards by holding the comparator toward a window or, perferably, placing it on the shelf in front of the Taylor Dalite lamp. Do not use fluorescent light.

(f) If the color of the middle tube does not match the color of either of the standards, or lies between the colors of the two standards, move the slide to the right or left, as required, until the next line on the slide is directly above the line on the base.

(g) If the color of the middle tube exactly matches one of the standards, read the pH value directly from the slide. If, however, the color of the sample lies between the colors of two consecutive standards, the pH is taken as an average of the two.

(h) Never consider a match with the lowest or highest standard as an accurate determination. The actual pH may be beyond the range of the indicator.

(i) Should a match appear to be likely with the lowest or highest pH color standard on the slide, repeat the test using a fresh sample and using Bromthymol Blue (Taylor #R-1003H-D) indicator and Bromthymol Blue pH slide (pH range 6.0 to 7.6) **or** Thymol Blue (Taylor #R-1003M-D) indicator and Thymol Blue pH slide (pH range 8.0 to 9.6).

(6) NOTE: Do not filter any samples for pH test. If the sample is too cloudy or turbid, allow it to stand in a closed bottle until the liquid is clear. Decant required amount of sample carefully.

APPENDIX C HEAT BALANCE CALCULATIONS

C-1. 100PSIG STEAM HEAT BALANCE

Reference figure C-1. (Note that this figure is a duplicate of figure 1-1.) The following assumptions have been made:

—100 lb of steam at 100 psig saturated conditions will heat water from 50° F to 140° F.

—Percent energy is based on the energy in the steam input to the heat exchanger.

—Negligible heat is lost from the insulated piping, heat exchanger, vent condenser, or condensate tank.

—The vent condenser condenses 91% of the flash steam and cools the condensate to 100° F.

—The amount of flash steam released is not effected by the water returned from the vent condenser. With this assumption our example serves to establish flash steam losses for systems without vent condensers.

a. The following steam table enthalpies in Btu/lb have been utilized:

For 100 psig steam hg100 = 1189.7 and hf100 = 309.0
For 0 psig steam hg0 = 1150.4 and hf0 = 180.0
For water at 50° F hf50 = 18.0
For water at 100° F h100 = 68.0
For water at 140° F hf140 = 107.9
For water at 198° F hf198 = 166.0

b. Percent energy in saturated water at the heat exchanger outlet is calculated as follows:

Base Energy = M x hg100 = 100 lb x 1189.7 Btu

Energy at heater exchanger outlet = M x hf100 = 100 lb x 309.0 Btu/lb = 309,000 Btu

Percent energy at heat exchanger out = (energy at heat exchanger outlet divided by base energy) x 100 = (30,900 divided by 118,970) x 100 = 26%

c. Energy from the 100 psig saturated water at 309 Btu/lb and 338° F reaches a new equilibrium after it exits the steam trap at 0 psig, 180 Btu/lb, and 212° F by flashing a portion of its mass to steam at 0 psig. The pounds of flash steam Fs released is calculated as follows:

M x hf100 = Fs x hg0 + (M-Fs) x hfo

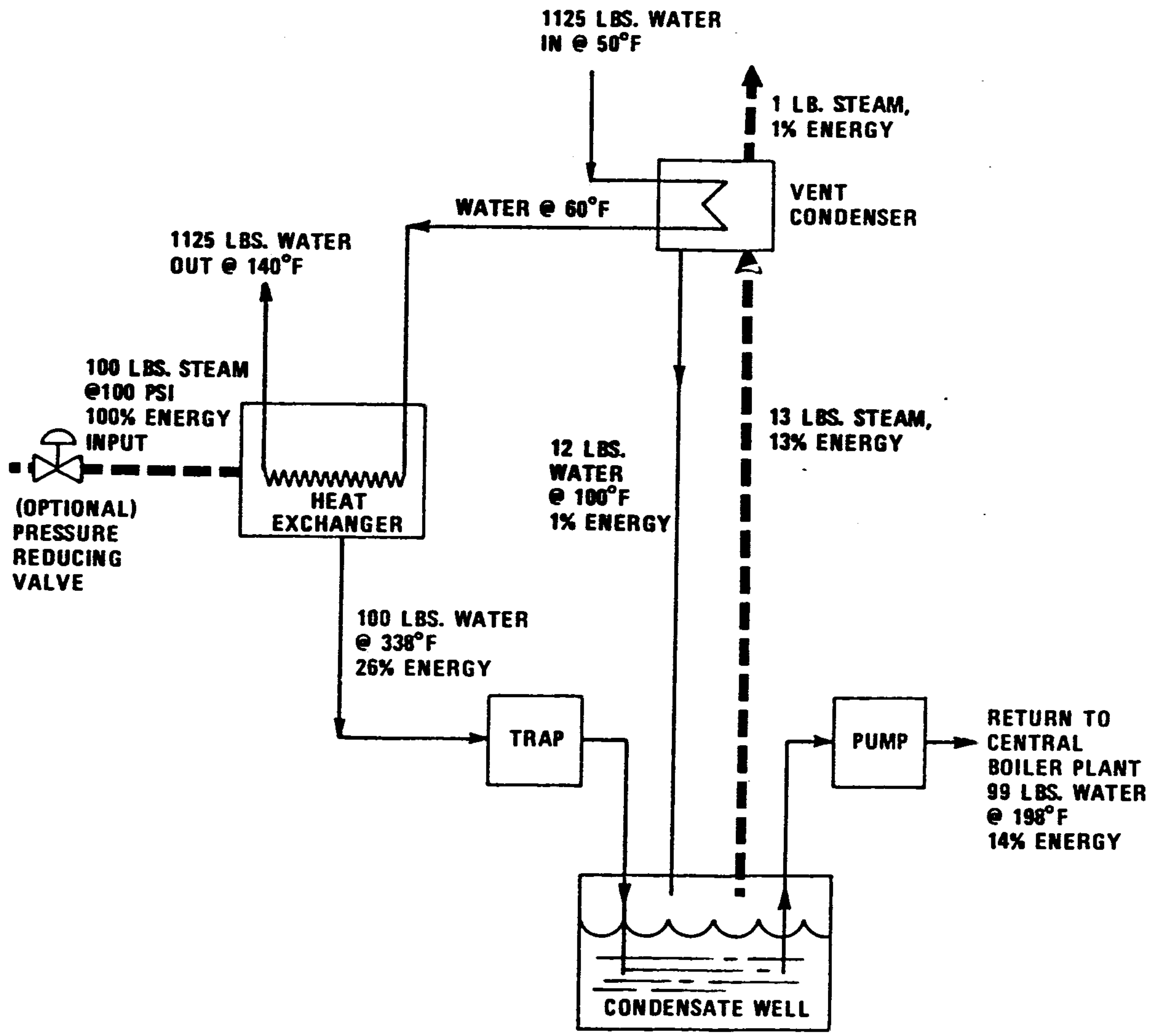

FIGURE C-1. 100 PSIG STEAM HEAT BALANCE

100 lb x 309.0 Btu/lb = Fs = (100 lb-Fs 1150 Btu/lb = (100 lb-Fs) x 180 Btu/lb

30,900 Btu = 1150 Btu/lb x fs + 18,000 Btu + 180 Btu/lb x Fs

12,900 Btu = 970 Btu/lb x fs

13.3 lb = Fs Use Fs = 13 lb for Figure C-1.

d. Percent energy in flash steam is calculated as follows:

Energy in flash steam = MF x hg0 = 13.3 lb x 1150 Btu/lb = 15, 295 Btu

Percent energy in flash steam = (energy in flash steam divided by base energy) x 100 = (15,295 Btu divided by 118,970 Btu) x 100 = 12.86%

Use 13% in Figure C-1.

e. Pounds of flash steam lost = .09 x 13.3 lb = 1.2 lb. Use 1 lb.

f. Percent energy in flash steam lost = (MFlost x hg0 divided by base energy) x 100 = (1.2 lb x 1150 Btu/lb divided by 118970 Btu) x 100 = 1.16%. Use 1%.

g. Pound of condensate returned from vent condenser = .91 x 13.3 lb = 12.1 lb. Use 12 lb.

h. Percent energy in condensate return from vent condenser = (MCR x hf100 divided by base energy) x 100 = 12.1 lb x 68 Btu/lb divided by 118,970 Btu) x 100 = .69%. Use 1%.

i. Condensate return to the Central Boiler Plant will nave characteristics calculated as follows:

—The mass flow to the plant will equal (water in — flash steam out = condensate returned from the vent condenser) = 100 lb — 13.3 lb = 12.1 lb = 98.8 lb. Use 99 lb.

—The energy in the condensate well will equal the energy in the 86.7 lb of condensate from the heat exchanger at 180 Btu/lb and 212°F = 12.1 lb of condensate from the vent condenser at 68 Btu/lb and 100°F = (86.7 lb x 180 Btu/lb = 12.1 lb x 68 Btu/lb) = (15,606 + 823) = 16,428 Btu.

—The temperature of the condensate can be calculated from the energy of the condensate and the steam tables. Energy in condensate divided by lb of condensate = (16,428 Btu divided by 98.8 lb) = 166.3 Btu/lb. This corresponds to 198°F.

—Percent energy in the condensate return is (energy in condensate divided by base energy) x 100 = (16,428 Btu divided by 118970 Btu) x 100 = 13.8%. Use 14%.

j. The amount of water heated from 50°F to 140°F in the heat exchanger and vent condenser is calculated as follows:

The energy available for heating the water equals the energy in the incoming steam (base energy) minus the energy lost by vented steam (paragraph f) minus energy return (paragraph i) = (118,970 Btu — 1,380 Btu — 16,428 Btu) = 101,162 Btu.

The energy required to heat water from 50° F to 140° F is (hf140-hf50) =)107.9 Btu/lb) — 18 Btu/lb = 89.9 Btu/lb.

The pounds of water heated is (101,162 Btu divided by 89.9 Btu/lb) = 1,125 lb.

k. The temperature at the outlet of the vent condenser is calculated:

MFcond. x (hg0-hf0) divided by Mw = 12.1 lb x (1150.4 Btu/lb-180 Btu/lb) divided by 1125 lb = 10.44 Btu/lb

h50 + 10.44 = 18 Btu/lb + 10.44 Btu/lb = 28.44 Btu/lb. From the steam tables this coresponds to a temperature of 60° F.

C-2. 15 PSIG STEAM HEAT BALANCE

Reference figure C-2. (This figure is a duplicate of figure 1-2.) This heat balance is based on the same assumptions listed in paragraph C-1 except now 15 psig saturated steam is utilized for heating the water.

a. The following steam table enthalpies in Btu/lb have been utilized:

For 15 psig steam hg15 = 1164.0 and hf15 = 219.0

For water at 50° F hf50 = 18.0

For water at 140° F hf140 = 107.9

For water at 208° F mf208 = 176.0

b. Percent energy in saturated water at the heat exchanger outlet is calculated as follows:

Base Energy = M x hg15 = (100 lb x 1164.0 Btu/lb = 116,400 Btu

Energy at heat exchanger outlet = M x hf15 = (100 lb x 219.0 Btu/lb) = 21,900 Btu

Percent energy at heat exchanger outlet = (Energy at heat exchanger outlet divided by base energy) x 100 = (21,900 divided by 116,400) x 100 = 18.8%

use 19%.

c. Energy from the 15 psig saturated water at 219 Btu/lb and 250° F reaches a new equilibrium after it exits the steam trap at 0 psig, 180 Btu/lb, and 212° F by flashing a portion of its mass to steam at 0 psig. The pounds of flash steam F_s released is calculated as follows.

M x hf15 = F_s x hg0 + (M-F_s) x hf0

100 lb x 219.0 Btu/lb = F_s x 1150 Btu/lb = (100 lb-F_s) x 180 Btu/lb

21,900 Btu = 1150 Btu/lb x F_s + 18,000 Btu-180 Btu/lb x F

3,900 Btu = 970 Btu lb x F_s

4.0 lb = F_s

d. Percent energy in flash steam is calculated as follows:

Energy in flash steam = M_F x hg0 = 4.0 lb x 1150 Btu/lb = 4,600 Btu

Percent energy in flash steam = (energy in flash steam divided by base energy) x 100 = (4,600 Btu divided by 116,400 Btu) x 100 = 4.0%.

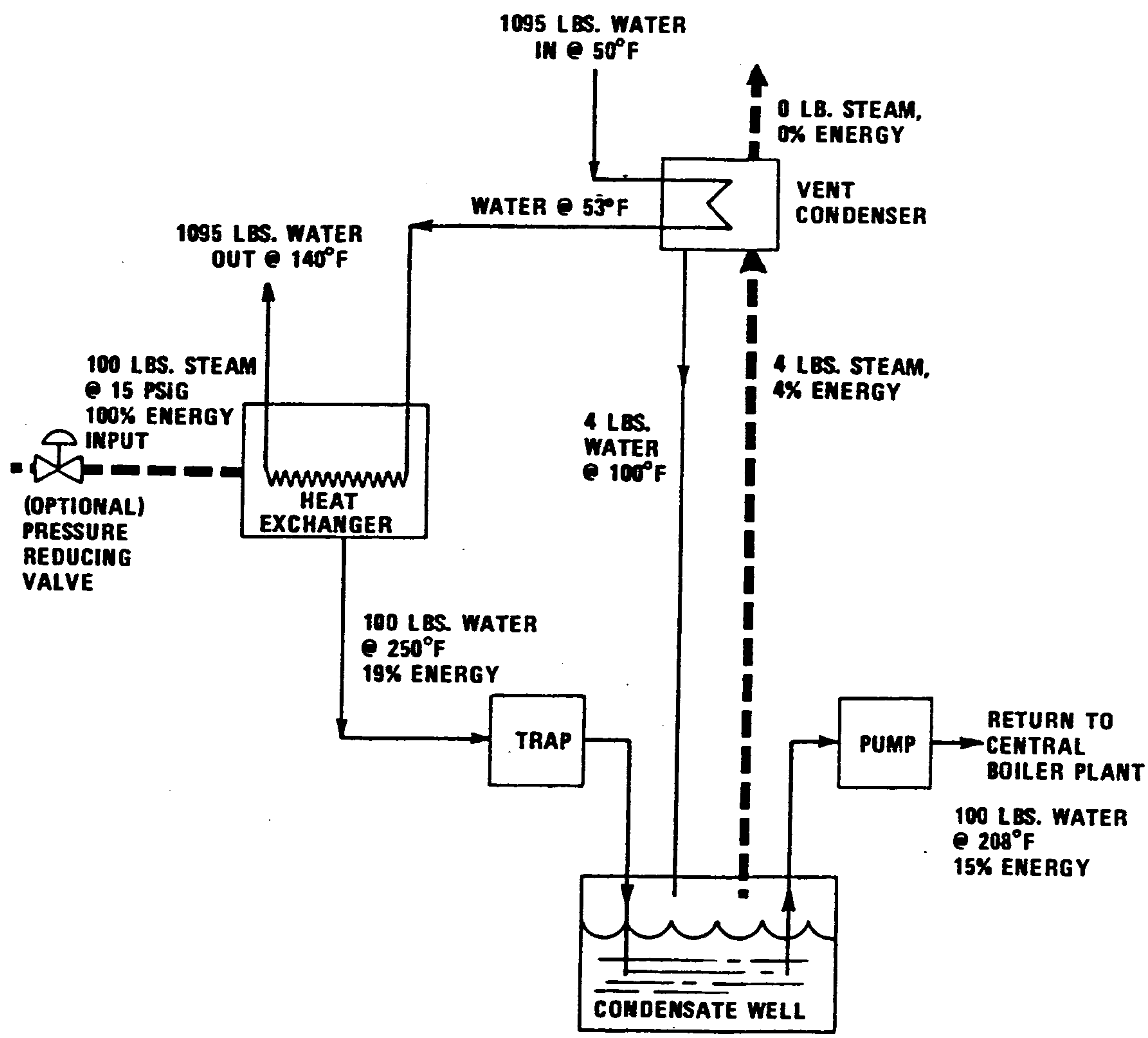

FIGURE C-2. 15 PSIG STEAM HEAT BALANCE

e. Pounds of flash steam lost = .09 x 4.0 lb = .36 lb.

f. Percent energy in flash steam lost = (Flost x h_g0 divided by base energy) x 100 = (.36 lb x 1150 Btu/lb divided by 116,400 Btu) x 100 = .36%.

g. Pound of condensate returned from vent condenser = .91 x 4.0 lb = 3.64 lb. Use 3.6 lb.

h. Percent energy in condensate return from vent condenser = (MMCR x $_h$f100 divided by base energy) x 100 = 3.64 lb x 68 Btu/lb divided by 116,400 Btu) x 100 = .21%

i. Condensate return to the Central Boiler Plant will have characteristics calculated as follows:

The mass flow to the plant will equal (water in — flash steam out = condensate returned from the vent condenser) = 100 lb — 4.0 lb + 3.6 lb = 99.6 lb. Use 100 lb.

The energy in the condensate well will equal the energy in the 96.0 lb of condensate from the heat exchanger at 180 Btu/lb and 212° F + 3.6 lb of condensate from the vent condenser at 68 Btu/lb and 100° F = (96.0 lb x 180 Btu/lb + 3.6 lb x 68 Btu/lb) + (17,280 + 245) = 17,525 Btu.

The temperature of the condensate can be calculated from the energy of the condensate and the steam tables. Energy in condensate divided by pounds of condensate = (17,525 Btu divided by 99.6 lb) = 176 Btu/lb. This corresponds to 208° F.

Percent energy in the condensate return is (energy in condensate divided by base energy) x 100 = (17,525 Btu divided by 116,400 Btu) x 100 = 15%.

j. The amount of water heated from 50° F to 140° F in the heat exchanger and vent condenser is calculated as follows:

The energy available for heating the water equals the energy in the incoming steam (base energy) minus the energy lost by vented steam (paragraph f) minus energy return (paragraph i) = (116,400 Btu — 414 Btu — 17,525 Btu) = 98,461 Btu.

The energy required to heat water from 50° F to 140° F is (hf140°-hf50) = (107.9 Btu//lb-18 Btu/lb) = 89.9 Btu/lb.

The pounds of water heated is (98,461 Btu divided by 89.9 Btu/lb) = 1,095 lb. Use 1,100 lb.

k. The temperature at the outlet of the vent condenser is calculated:

MFcond. x (hg0-hf0) divided by Mw = 3.64 lb x (1150.4 Btu/lb-180 Btu/lb) divided by 1,095 lb = 3.22 Btu/lb

hf50 + 3.22 = 18 Btu/lb + 3.22 Btu/lb = 21.22 Btu/lb. From the steam tables this corresponds to a temperature of 53° F.

C-3. HIGH TEMPERATURE WATER HEAT BALANCE

Reference figure C-3 (identical to figure 1-3). The following assumptions are made so we can compare the high temperature water system with the 100 psig steam system:

—1125 lb of water will be heated from 50° F to 140° F.

—The heat exchanger will be designed to heat the water with a 400° F inlet and 240° F outlet high temperature water.

—Negligible heat is lost from the insulated piping and heat exchanger.

a. The following steam table enthalpies in Btu/lb have been utilized:

Water at 50° F hf50 = 18.0
Water at 140° h140 = 107.9
Water at 240° F h240 = 208.3
Water at 400° F hf400 ° 375.0

b. Energy added to water is calculated: M_w x (hf140-hf50) = 1125 lb x (107.9 Btu/lb-18.0 Btu/lb) = 101,138 Btu.

c. High temperature water (HTW) flow rate is calculated by the following energy balance:

Energy added = Energy released by HTW

101,138 Btu = MHTW x (hf400 - (hf240) = MHTW x (375.0 Btu/lb-208.3 Btu/lb)

MHTW = 606.7 lb. Use 607 lb.

d. Percent energy in water returned to the central boiler plant is calculated as follows:

(Energy in water returned divided by energy in water supplied) x 100 = (MHTW x hf400) x 100 = 606.7 lb x 208.3

Btu/lb divided by 606.7 lb x 375 Btu/lb) x 100 = 55.5%. Use 56%.

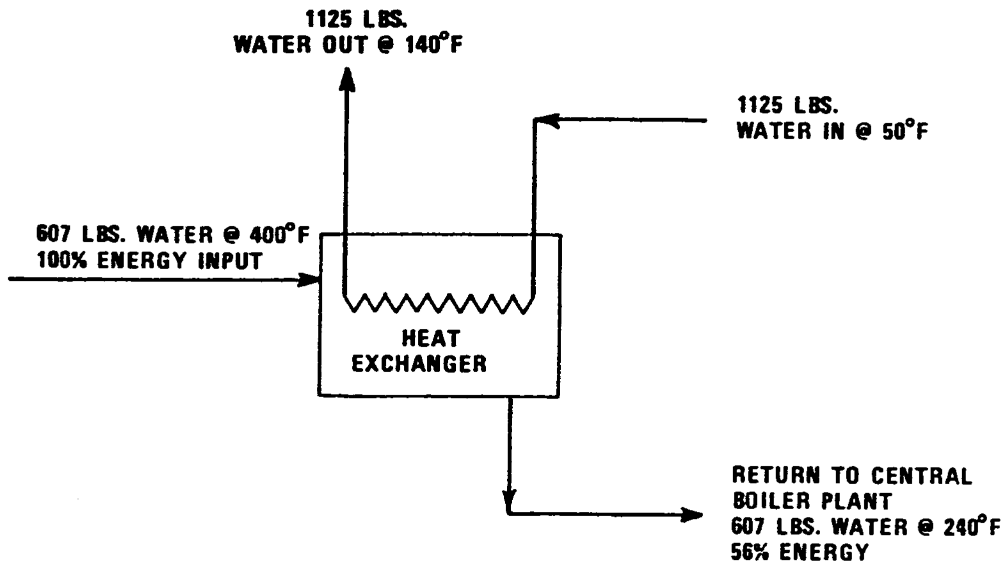

FIGURE C-3. HIGH TEMPERATURE WATER HEAT BALANCE