

CONDENSER CHARACTERISTICS

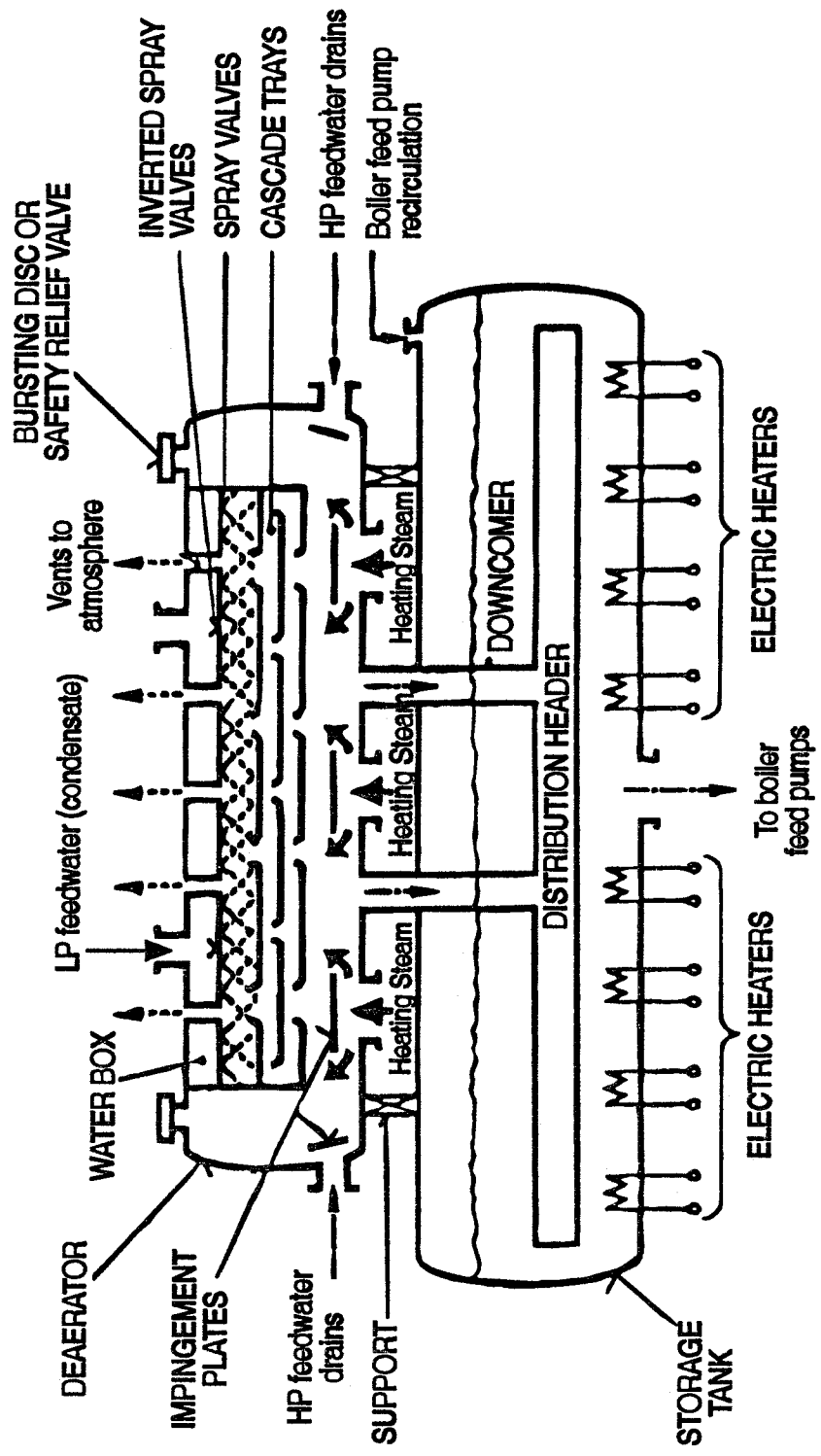


Figure 1 Deaerator and deaerator storage tank (courtesy of NB Power)

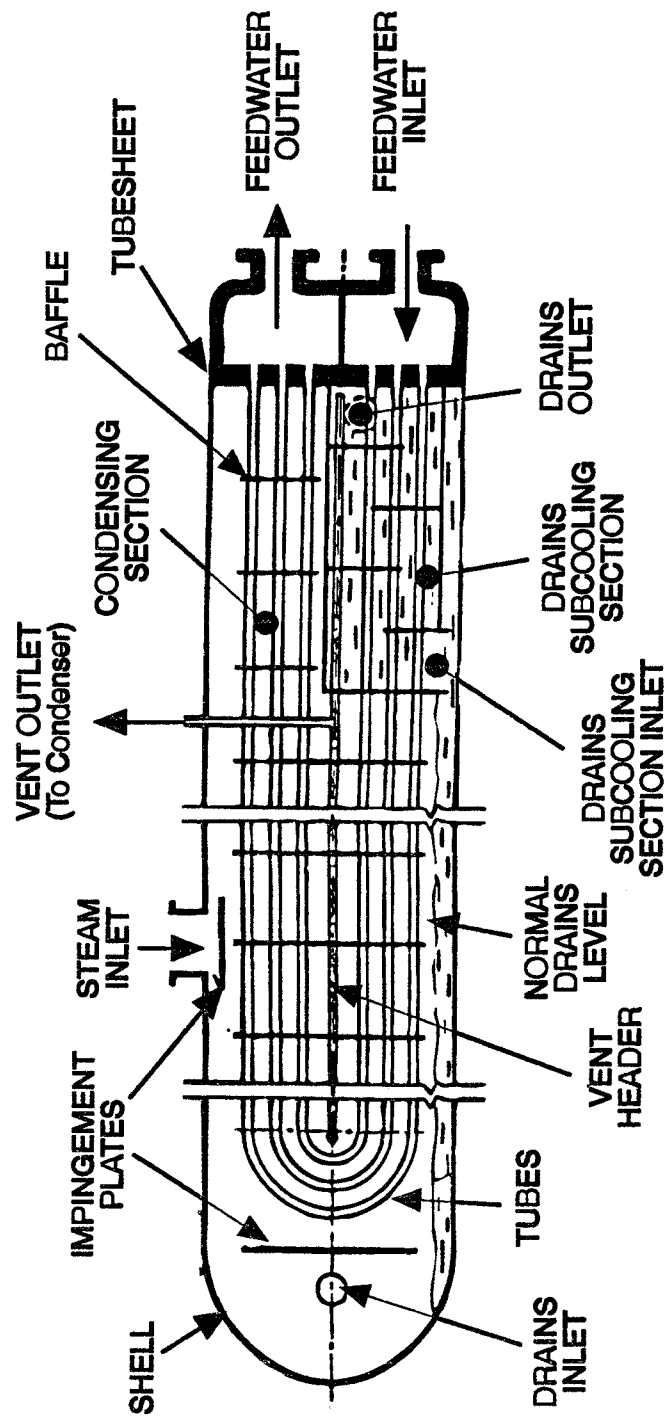


Figure 2 Feedwater heater with integral drains cooler (courtesy of NB Power)

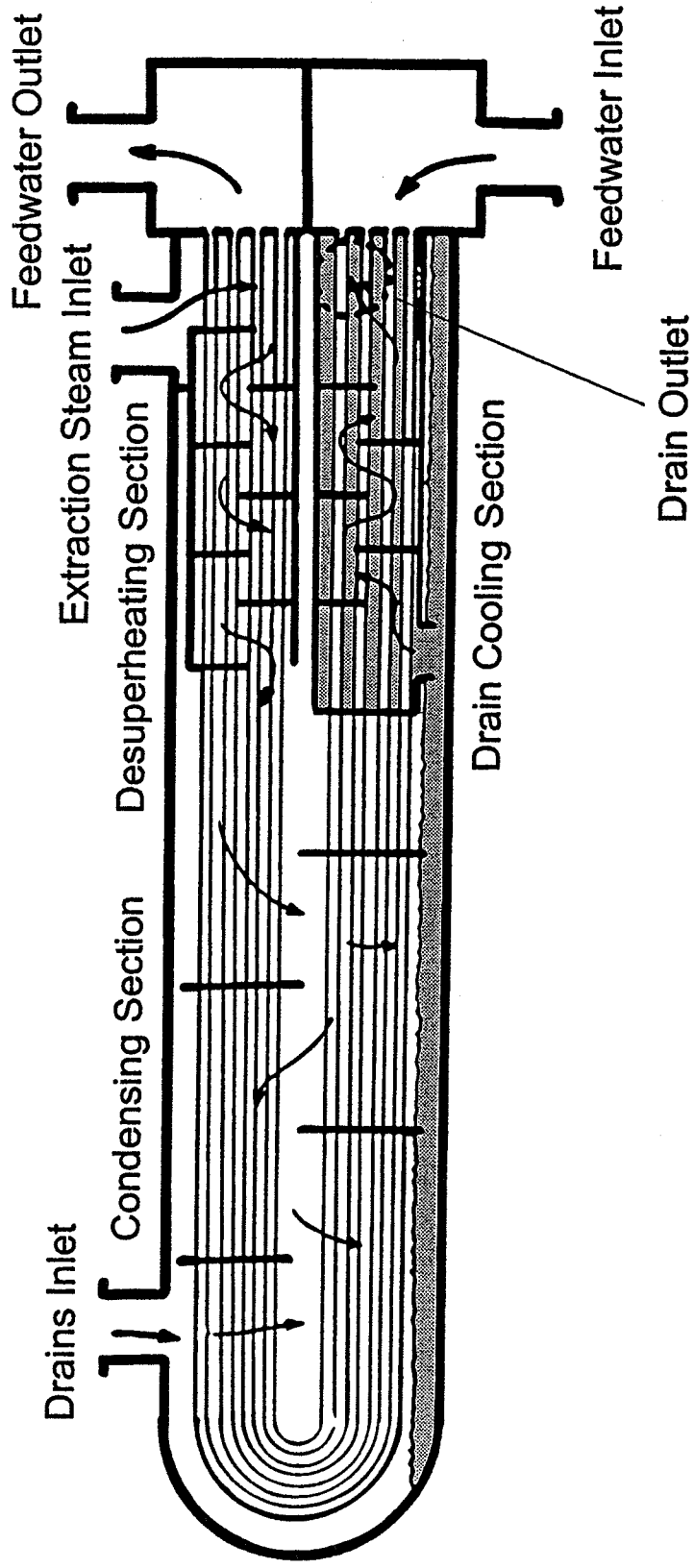


Figure 12 Feedwater heater with desuperheater and drain cooler

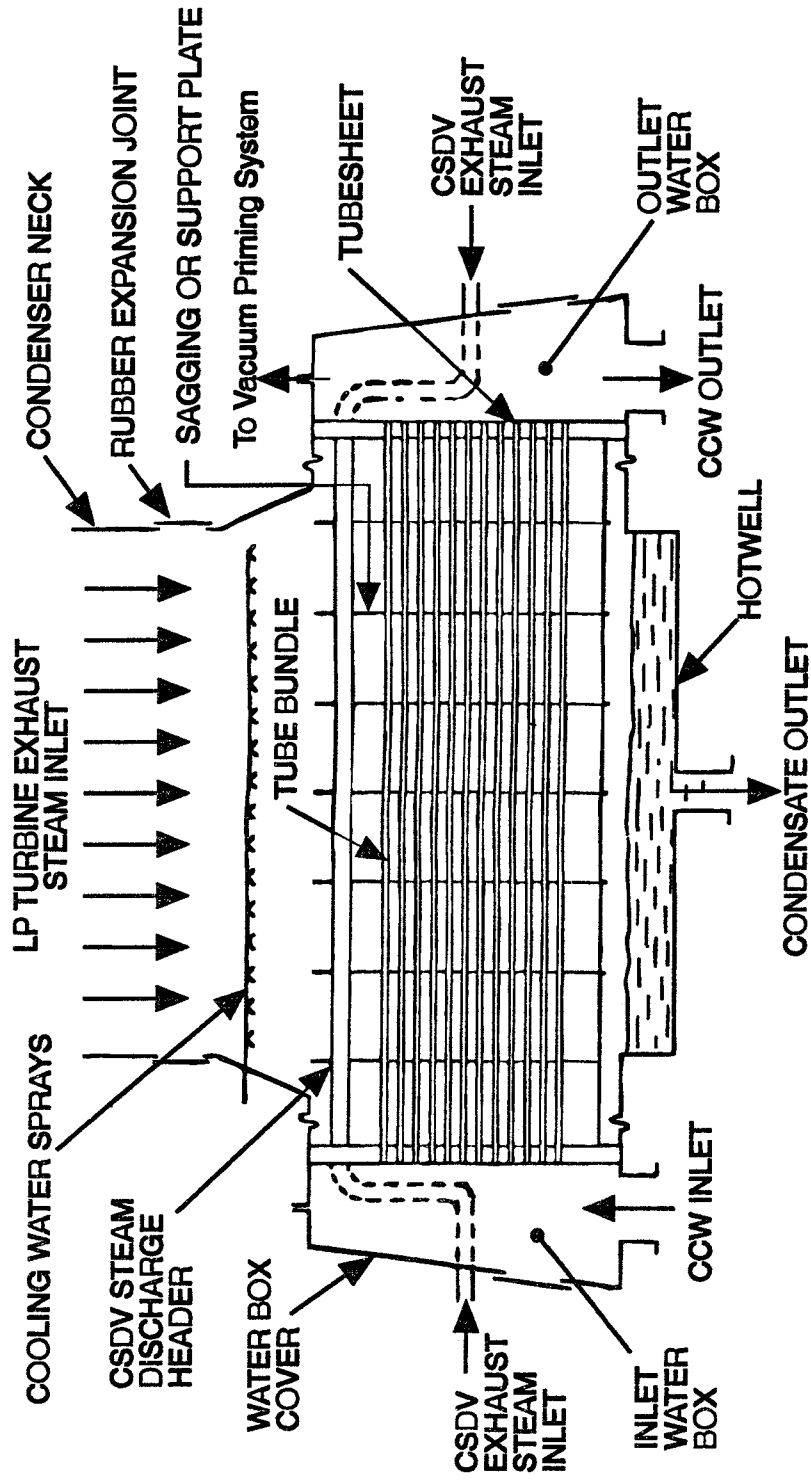


Figure 3 Condenser longitudinal section (courtesy of NB Power)

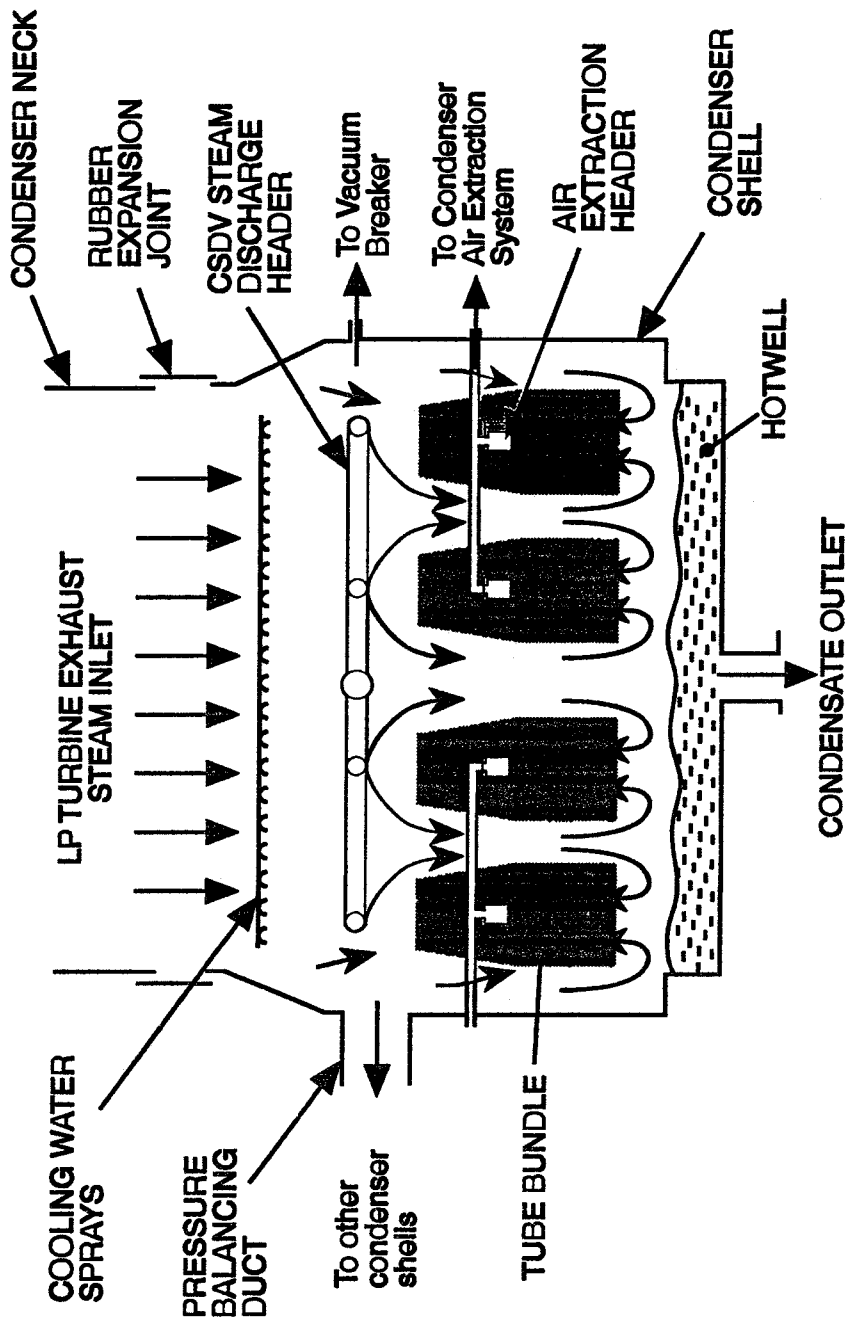


Figure 4 Condenser cross-section (courtesy of NB Power)

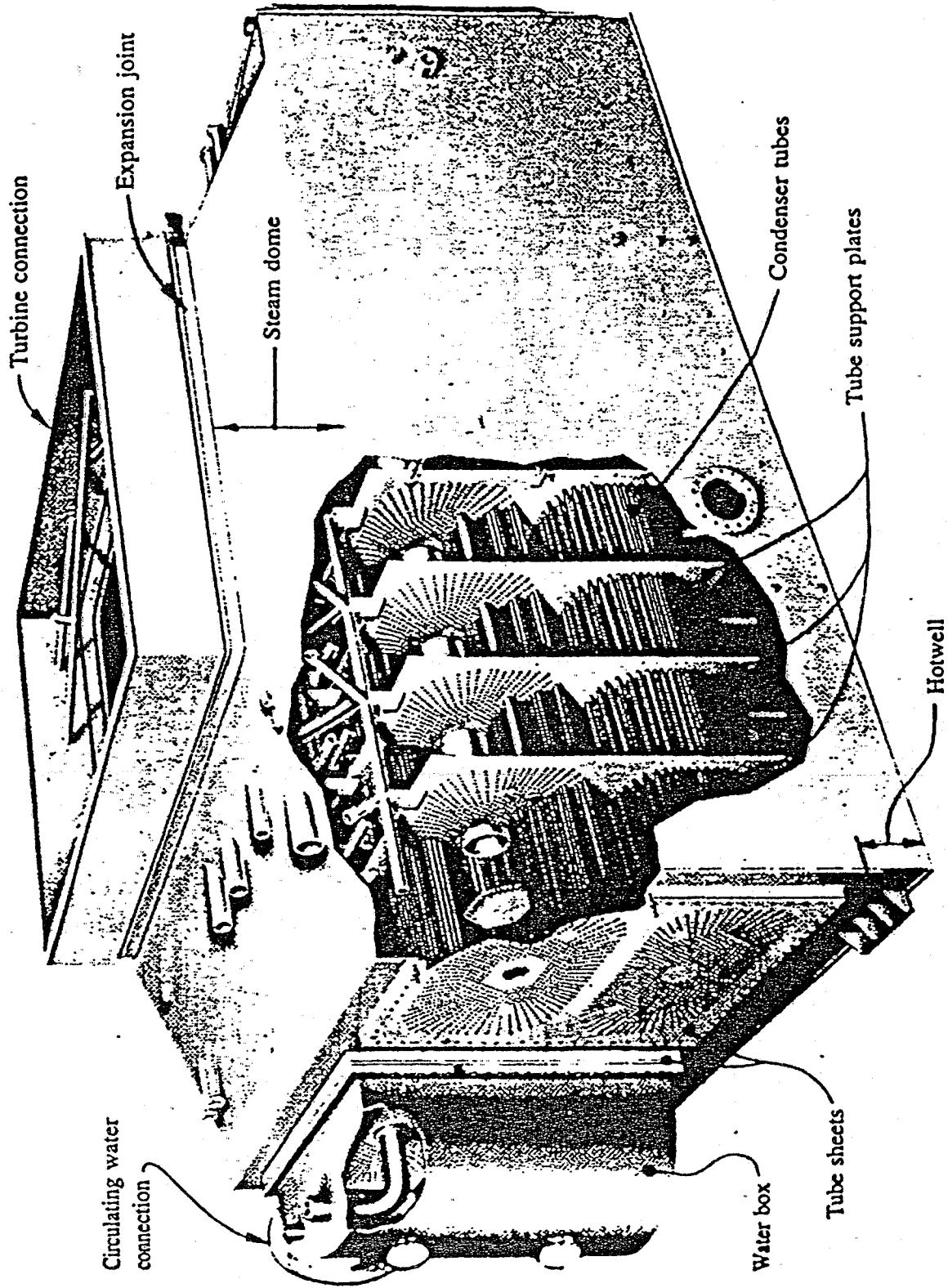


Figure 6-6 A two-pass divided-box surface condenser.

It is evident therefore that, the lower the cycle efficiency, the greater the amount of heat rejected. This effect is actually quite dramatic. If a nuclear plant with a steam cycle efficiency of 0.35 is compared with a fossil fuel fired plant of the same output but with a steam cycle efficiency of 0.45 the values in Table 2 are obtained.

Table 2 Comparison of Heat Rejected in Nuclear and Fossil Plants

Parameter	Nuclear Plant	Fossil Plant
η_{cycle}	0.35	0.45
W_{out}	1000 MW	1000 MW
Q_{in}	2857 MW	2222 MW
Q_{rej}	1857 MW	1222 MW

It is seen that, for the same output of 1000 MW, the nuclear plant, due to its lower steam cycle efficiency, rejects 50 percent more heat than the fossil plant. For this reason nuclear plants are usually located near a large body of water which can serve as a heat sink for the heat rejected.

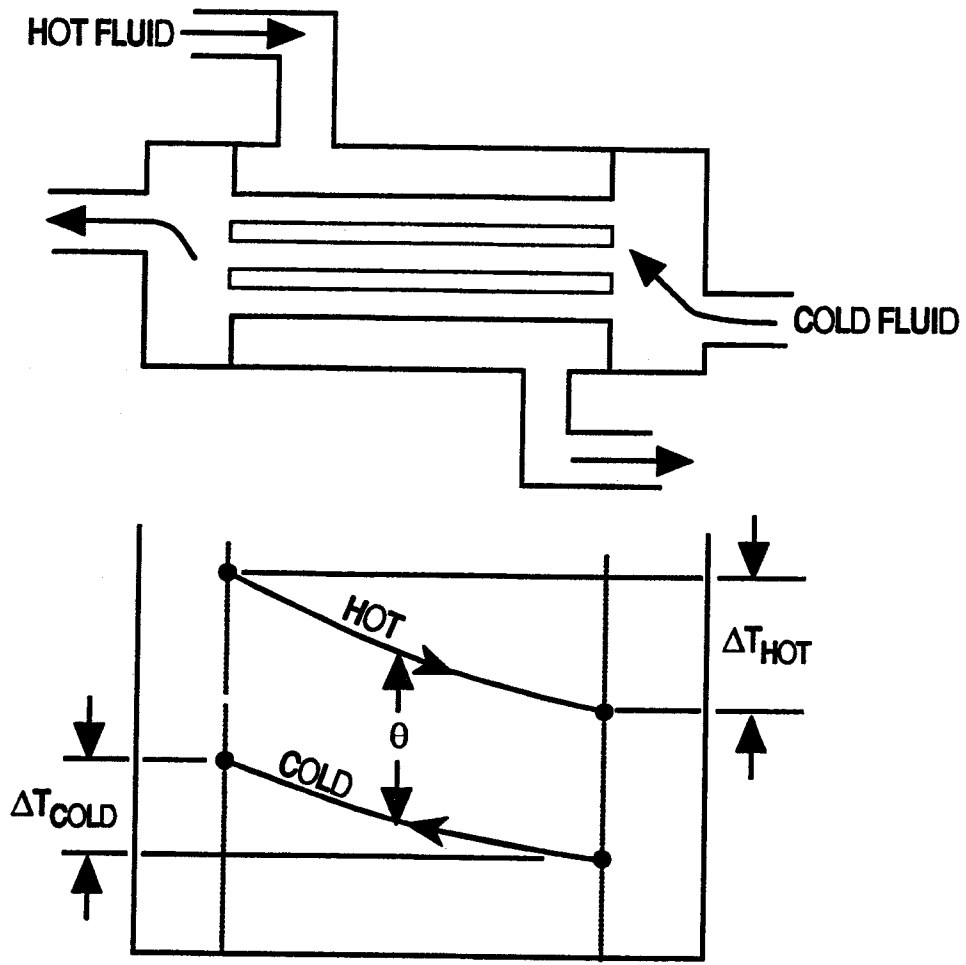
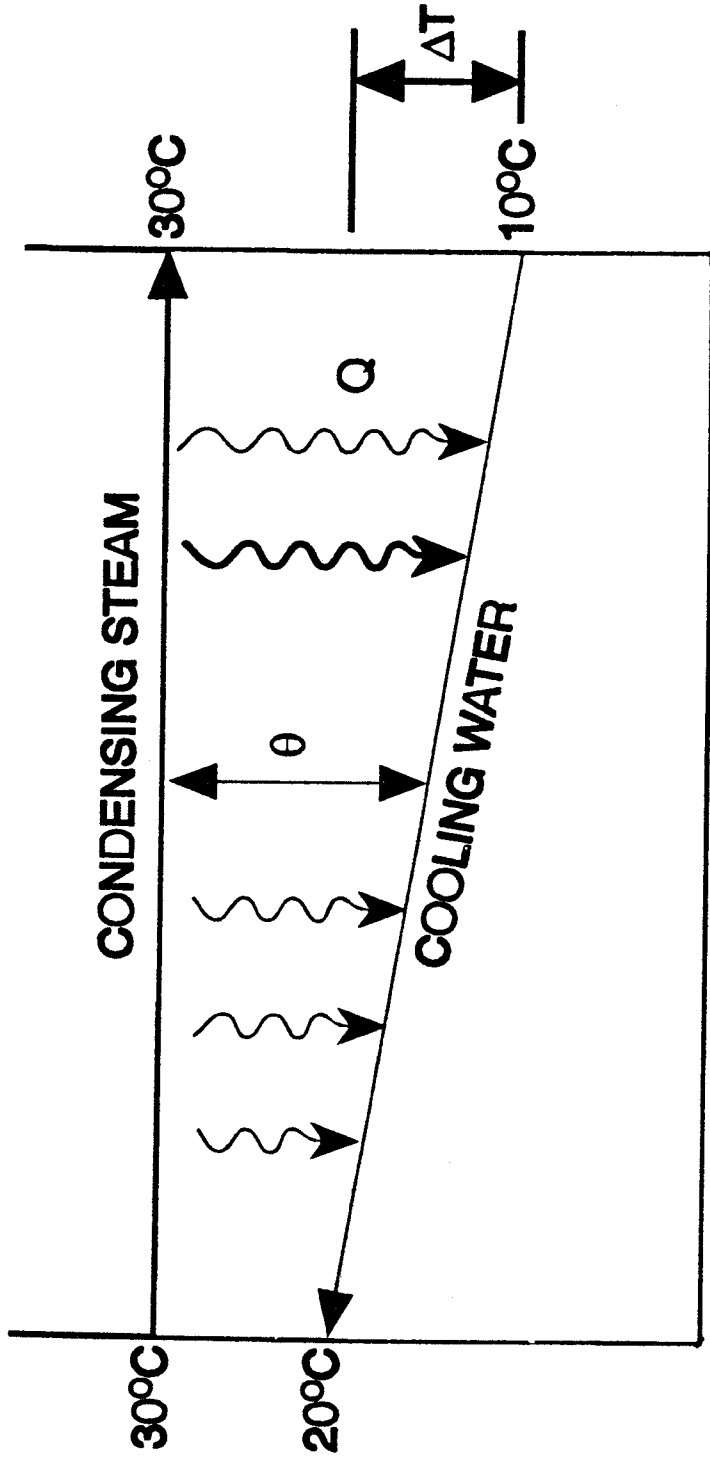


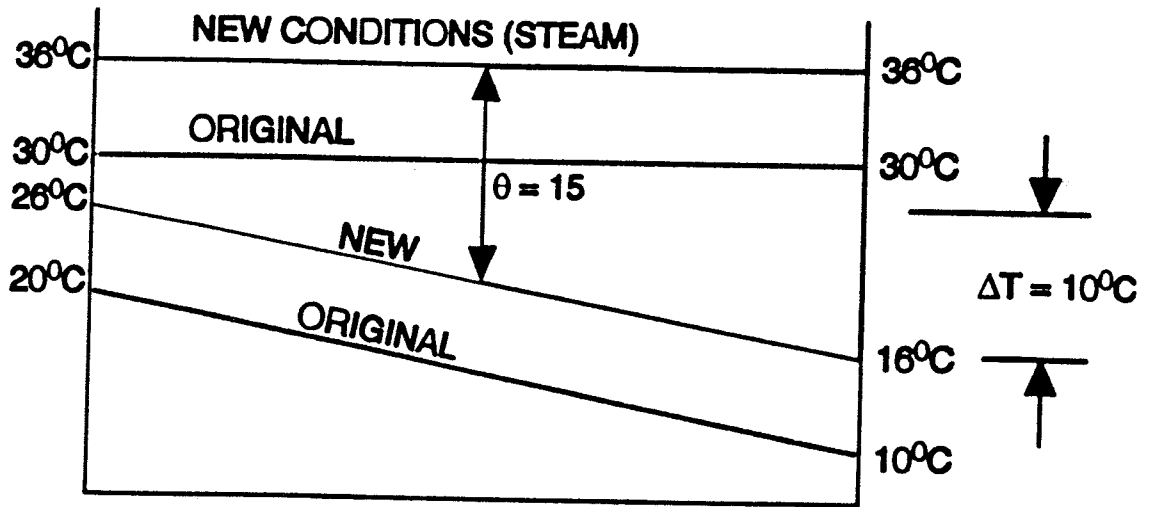
Figure 5 Heat exchanger and temperature profile



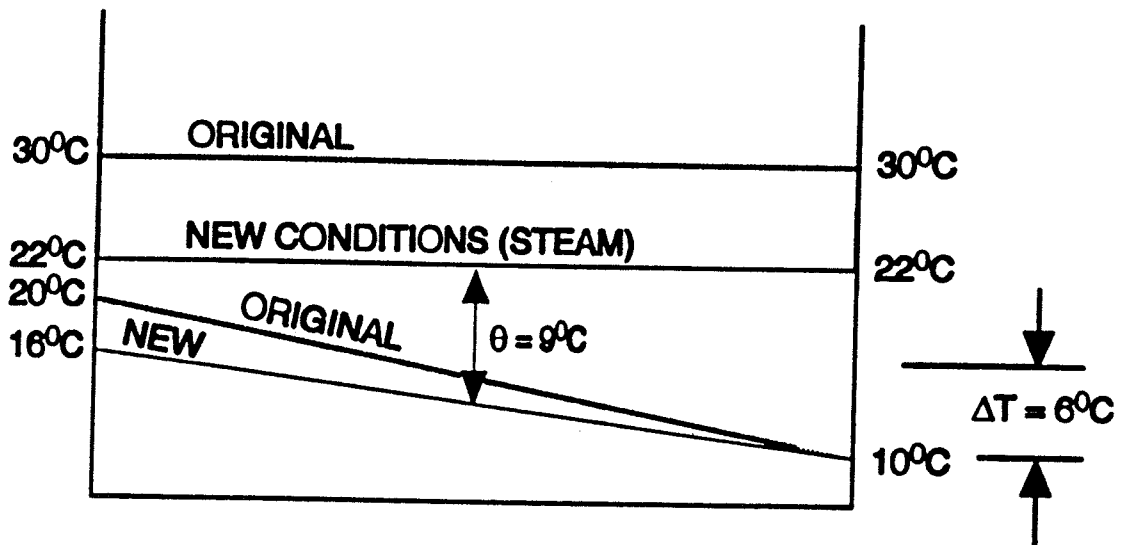
θ = AVERAGE TEMPERATURE DIFFERENCE

ΔT = COOLING WATER TEMPERATURE RISE

Figure 6 Condenser temperature profile



Change in cooling water inlet temperature (increase to 16°C)



Change in load on turbine (decrease to 60%)

Figure 7 Changes in condenser temperature profile

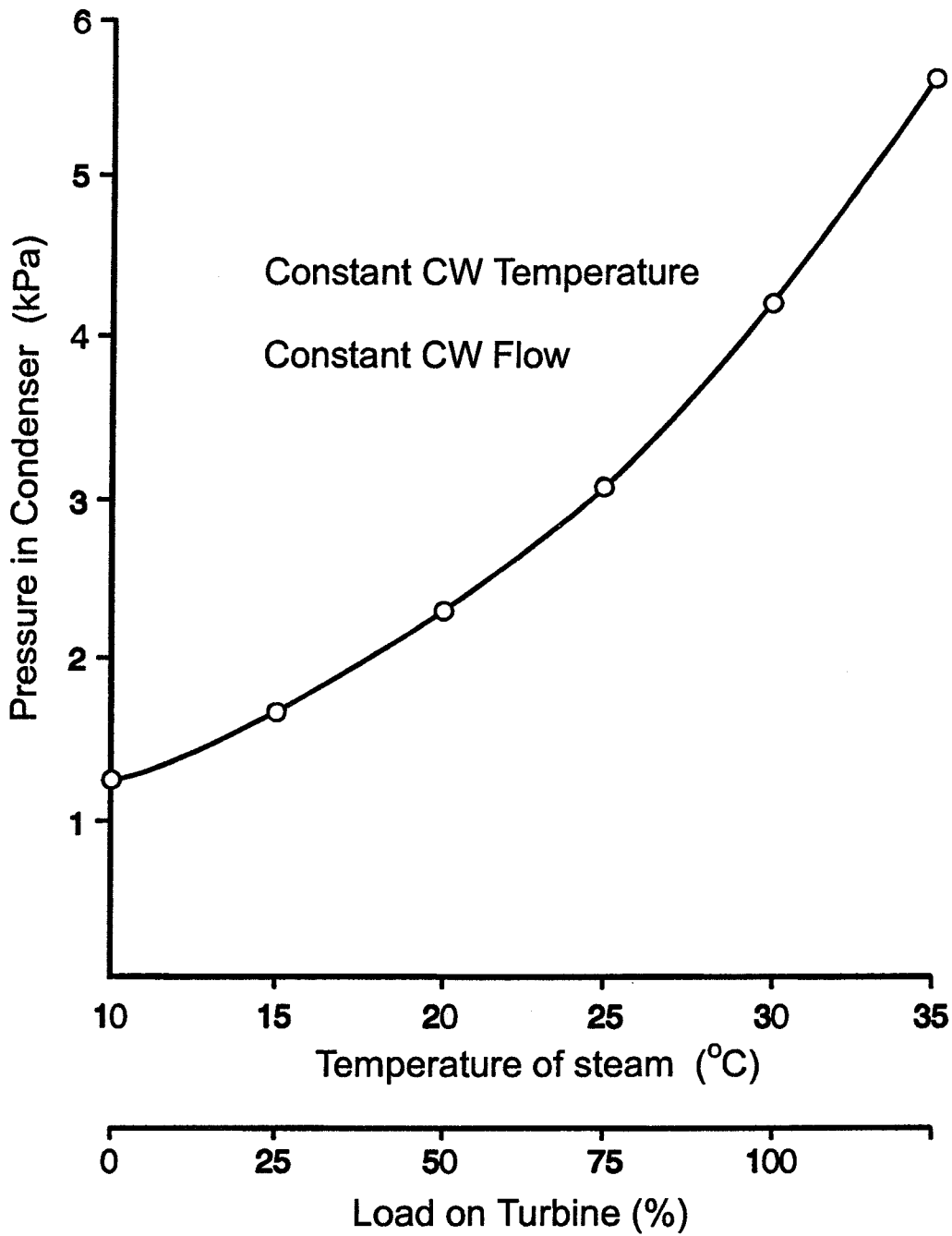


Figure 8 Variation in condenser pressure

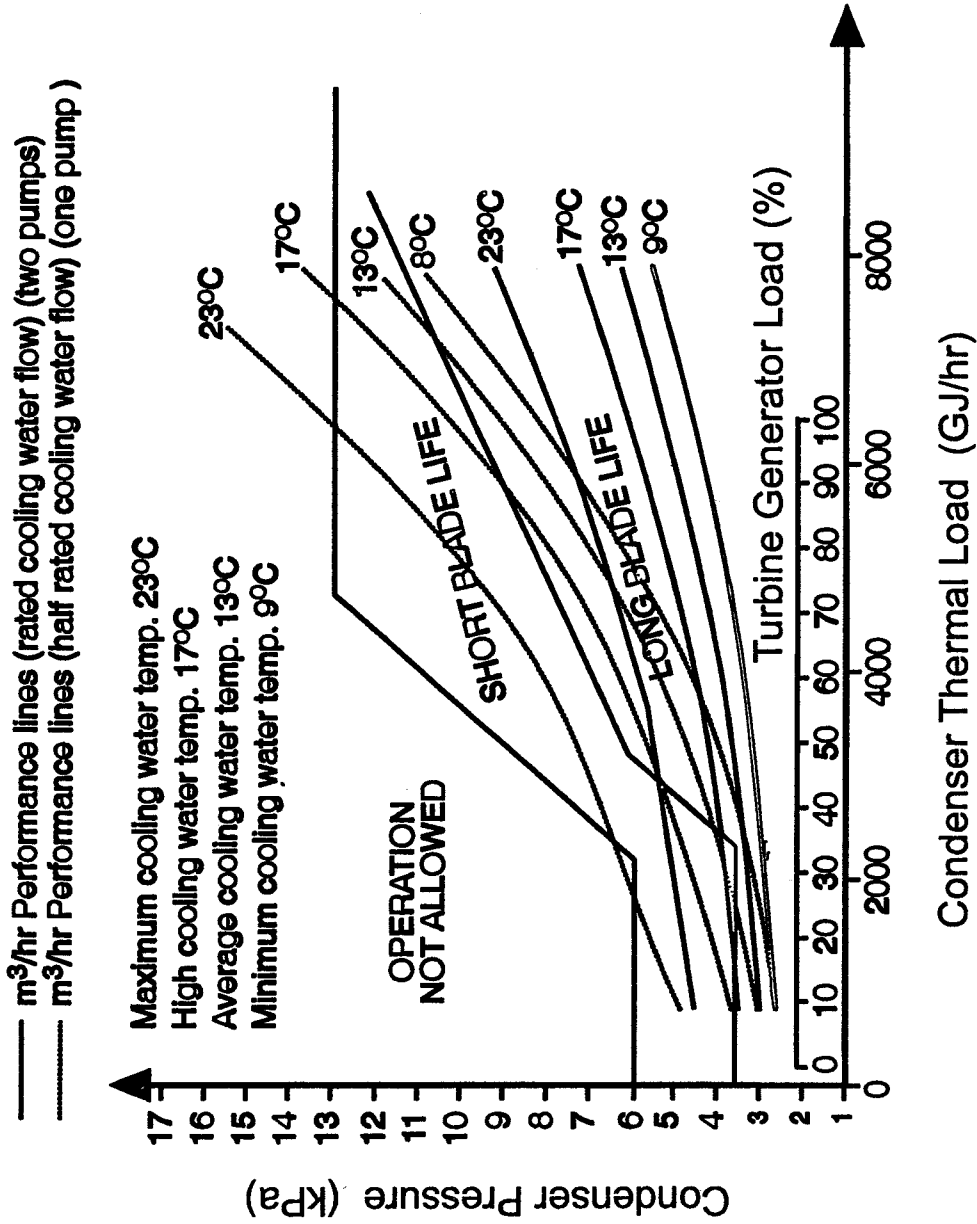


Figure 9 Condenser performance curves (adapted courtesy of Eskom)

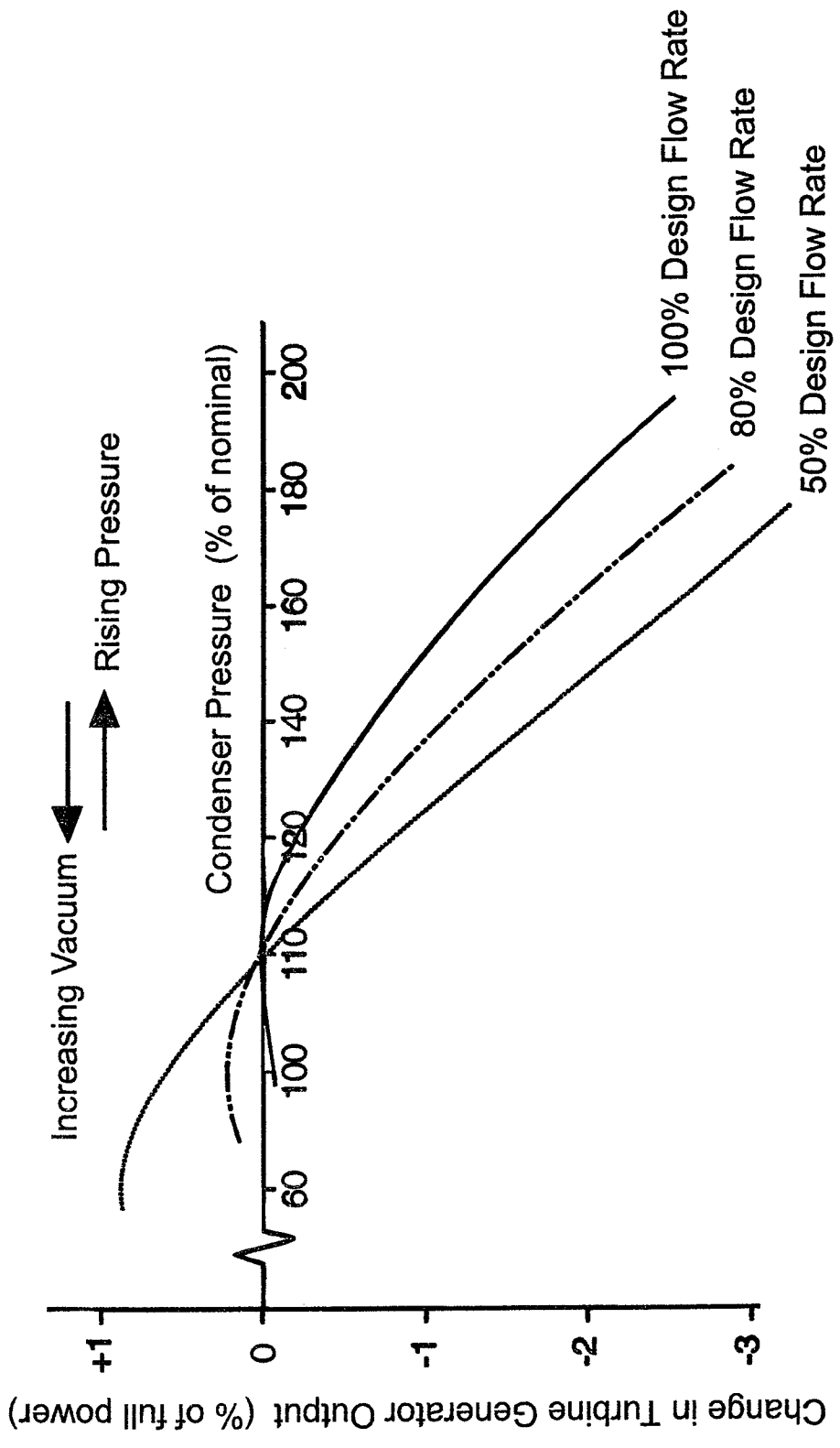


Figure 11 Effect of change in condenser pressure (courtesy of NB Power)

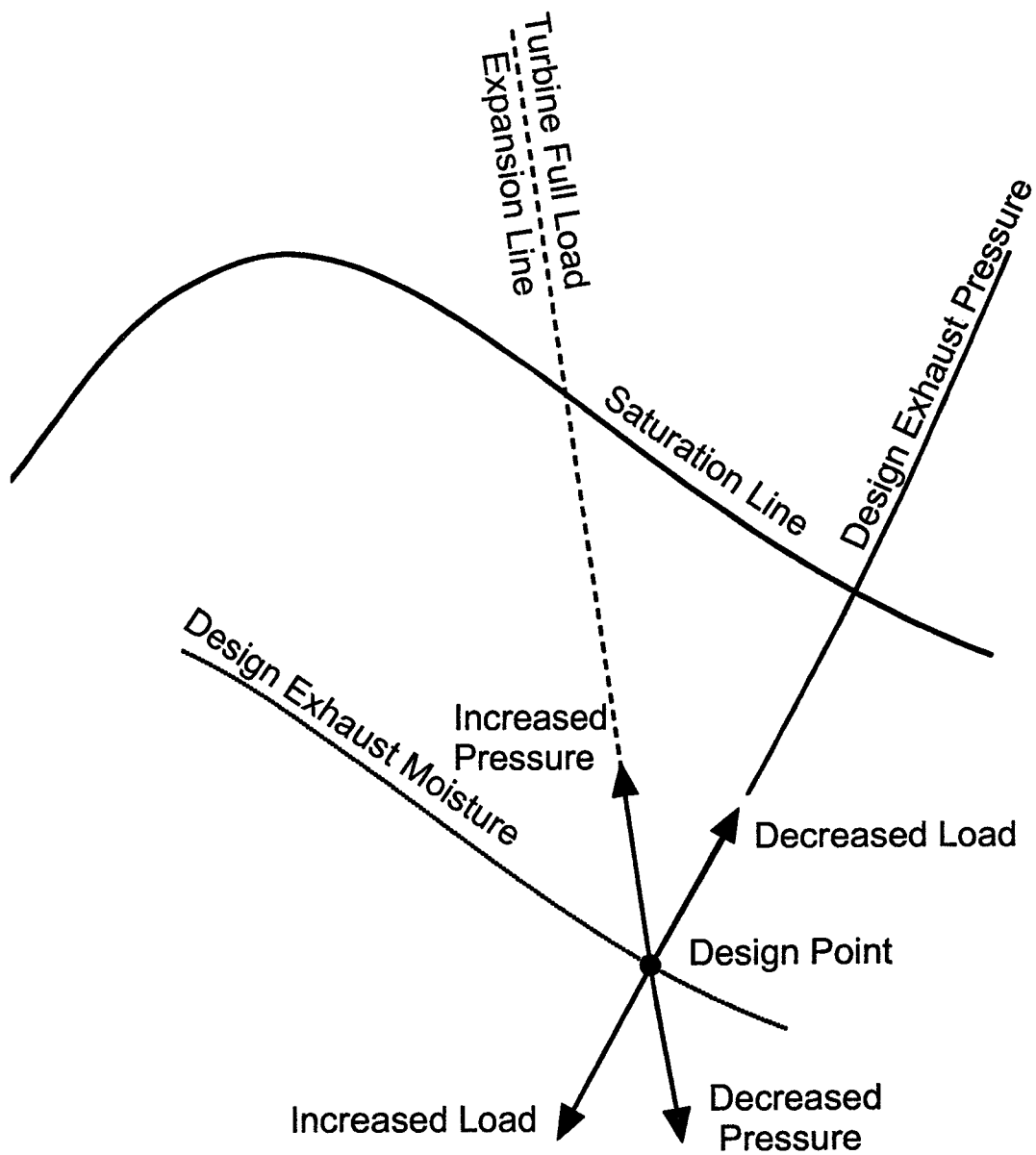


Figure 12 Effect of change in turbine load and condenser pressure

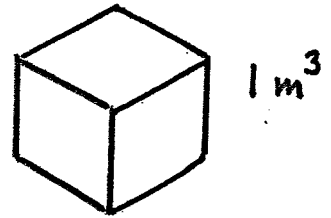
CONDENSER AIR EXTRACTION

ASSUME EXHAUST STEAM SUPPLIED TO CONDENSER AT 35°C
 ASSUME AIR CONTENT IS 1 PART PER MILLION

AT 35°C (308°K)

FOR AIR $R = 0.287 \text{ kJ/kg}^\circ\text{K}$

$$\begin{aligned} p_{\text{STEAM}} &= 5.62 \text{ kPa} \\ v_g &= 25.245 \text{ m}^3/\text{kg} \\ \rho_{\text{STEAM}} &= 0.0396 \text{ kg/m}^3 \\ \rho_{\text{AIR}} &= 0.0396 \times 10^{-6} \text{ kg/m}^3 \end{aligned}$$



$$\begin{aligned} p_{\text{AIR}} &= \rho_{\text{AIR}} RT \\ &= 0.0396 \times 10^{-6} \times 0.287 \times 308 \\ &= 3.50 \times 10^{-6} \text{ kPa} \end{aligned}$$

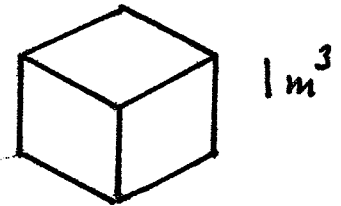
$$pV = RT$$

$$\begin{aligned} p_{\text{TOTAL}} &= p_{\text{STEAM}} + p_{\text{AIR}} \\ &= 5.62 \text{ kPa} \end{aligned}$$

ASSUME AIR COOLING SECTION REDUCES LOCAL TEMPERATURE TO 24°C DUE TO AIR BLANKETING

AT 24°C (297°K)

$$\begin{aligned} p_{\text{STEAM}} &= p_{\text{SATURATION}} \\ &= 2.98 \text{ kPa} \\ v_g &= 45.926 \text{ m}^3/\text{kg} \\ \rho_{\text{STEAM}} &= 0.0218 \text{ kg/m}^3 \end{aligned}$$

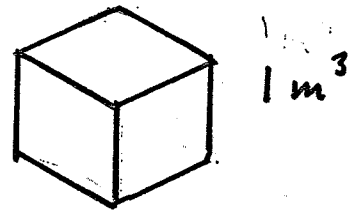


$$\begin{aligned} p_{\text{AIR}} &= p_{\text{TOTAL}} - p_{\text{STEAM}} \\ &= 5.62 - 2.98 \\ &= 2.64 \text{ kPa} \end{aligned}$$

$$\begin{aligned} \rho_{\text{AIR}} &= p_{\text{AIR}} / RT \\ &= 2.64 / (0.287 \times 297) \\ &= 0.0310 \text{ kg/m}^3 \end{aligned}$$

$$p = \rho RT$$

CONSIDER 1m^3 OF MIXTURE



EACH COMPONENT CONTRIBUTES TO PRESSURE AND TO DENSITY

1m^3 OF MIXTURE CONTAINS :

0.0218	kg	OF STEAM	AT	2.98	kPa
0.0310	kg	OF AIR	AT	2.64	kPa
<u>0.0528</u>	kg			<u>5.62</u>	kPa

CONTENT OF STEAM AND AIR

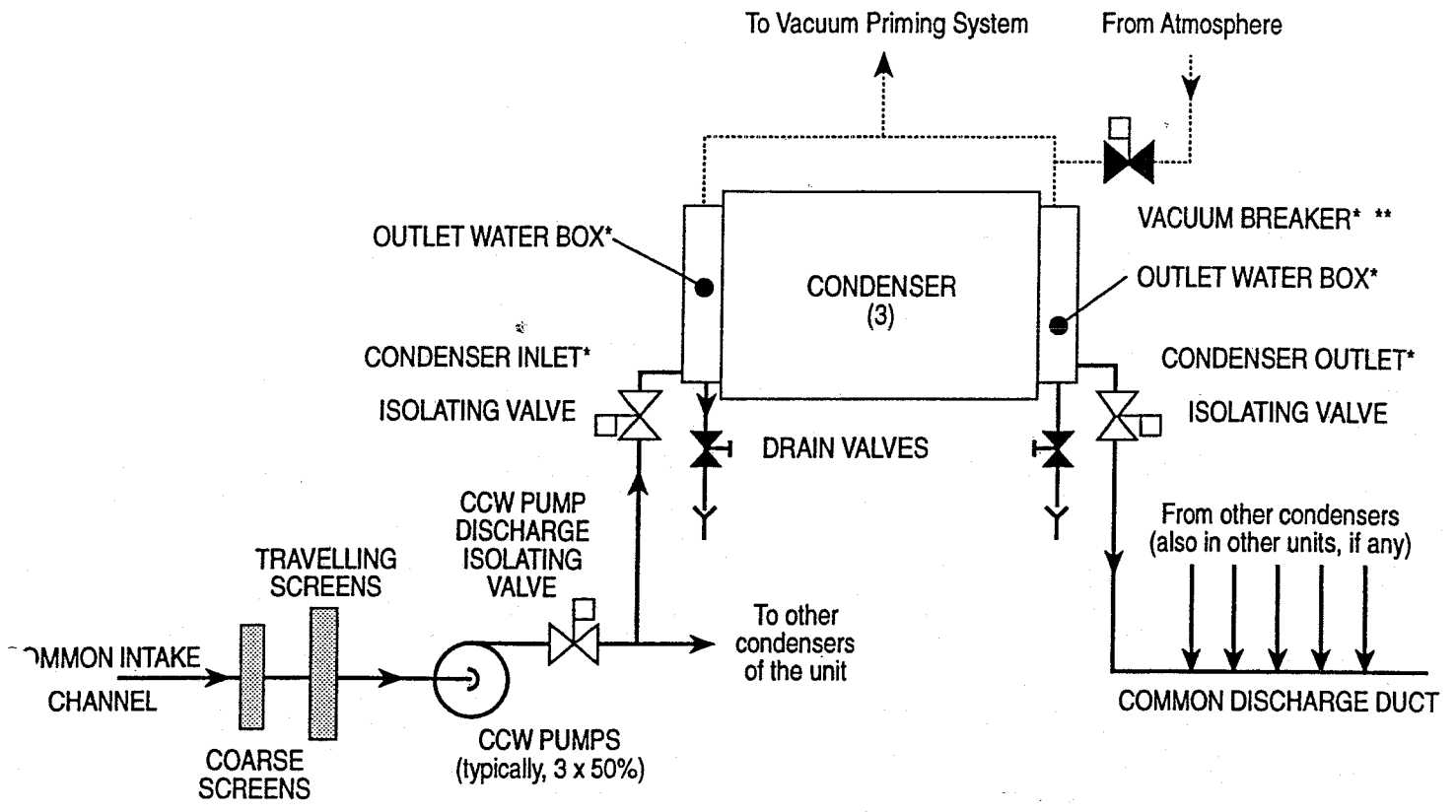
$$\text{STEAM} : 0.0218 / 0.0528 = 41\%$$

$$\text{AIR} : 0.0310 / 0.0528 = 59\%$$

AIR HAS BEEN CONCENTRATED AND CONSEQUENTLY MORE AIR THAN STEAM WILL BE REMOVED THROUGH THE AIR EXTRACTION SYSTEM

WITHOUT AN AIR COOLING SECTION THE MASS OF AIR PER UNIT VOLUME WOULD BE MUCH LESS RESULTING IN EXCESSIVE STEAM REMOVAL.

WHAT WOULD BE THE CONSEQUENCES OF EXCESSIVE STEAM REMOVAL



——— CONDENSER COOLING WATER
 AIR (Mainly)
 * TWO PER EACH CONDENSER;
 ** PART OF THE VACUUM PRIMING SYSTEM.

Figure 5.8
Simplified Condenser Cooling Water System

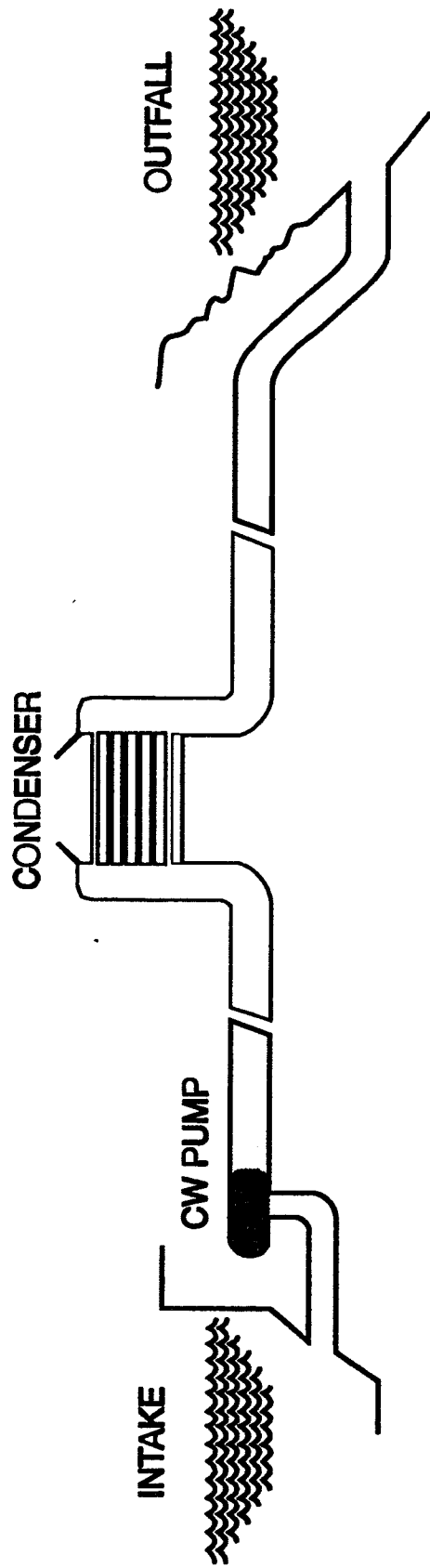


Figure 10 Simplified condenser cooling water system

DIAGNOSIS OF PROBLEMS

HEAT TRANSFER

$$Q = UA \Delta T_m$$

PATRIAL PRESSURE

$$P_{\text{CONDENSER}} = P_{\text{STEAM}} + P_{\text{AIR}}$$

CAUSES OF POOR VACUUM

1. REDUCED CW FLOW RATE
2. INCREASED CW INLET TEMPERATURE
3. TUBE FOULING
4. TUBE FLOODING
5. ACCUMULATION OF GASES
6. EXCESSIVE THERMAL LOAD

CONDENSER VACUUM BREAKING

PURPOSE OF VACUUM BREAKING

TO REDUCE TURBINE SPEED QUICKLY

REASONS FOR QUICK SPEED REDUCTION

- * VERY HIGH ROTOR VIBRATION**
- * LOSS OF LUBRICATING OIL PRESSURE**
- * LOSS OF HYDROGEN SEAL OIL PRESSURE**

NORMAL VACUUM BREAKING

- 1. BREAK VACUUM AT REDUCED SPEED**
- 2. BREAK VACUUM ON TURNING GEAR**

CONDENSER CW LEAKS

ADVERSE CONSEQUENCES

- 1. ACCELERATED CORROSION**
- 2. ACCELERATED BOILER DEPOSITS**
- 3. POSSIBLE BOILER WATER FOAMING**

INDICATIONS

**INSTRUMENTATION IN CONDENSER AND AT
CONDENSATE EXTRACTION PUMPS**

MITIGATING ACTIONS

- 1. LEAK LOCATION (HOW ?)**
- 2. INCREASE BOILER BLOWDOWN
(DISADVANTAGES ?)**

CONDENSER AIR LEAKS

ADVERSE CONSEQUENCES

SEE ABNORMAL CONDENSER PRESSURE

MITIGATING ACTIONS

SEE PREVIOUS ANALYSIS

- 1. PLACE ADDITIONAL VACUUM PUMPS INTO SERVICE**
- 2. ADVISE STATION CHEMISTS**