SECTION DA

HEAT TRANSFER WITH PHASE CHANGE (CONDENSERS)

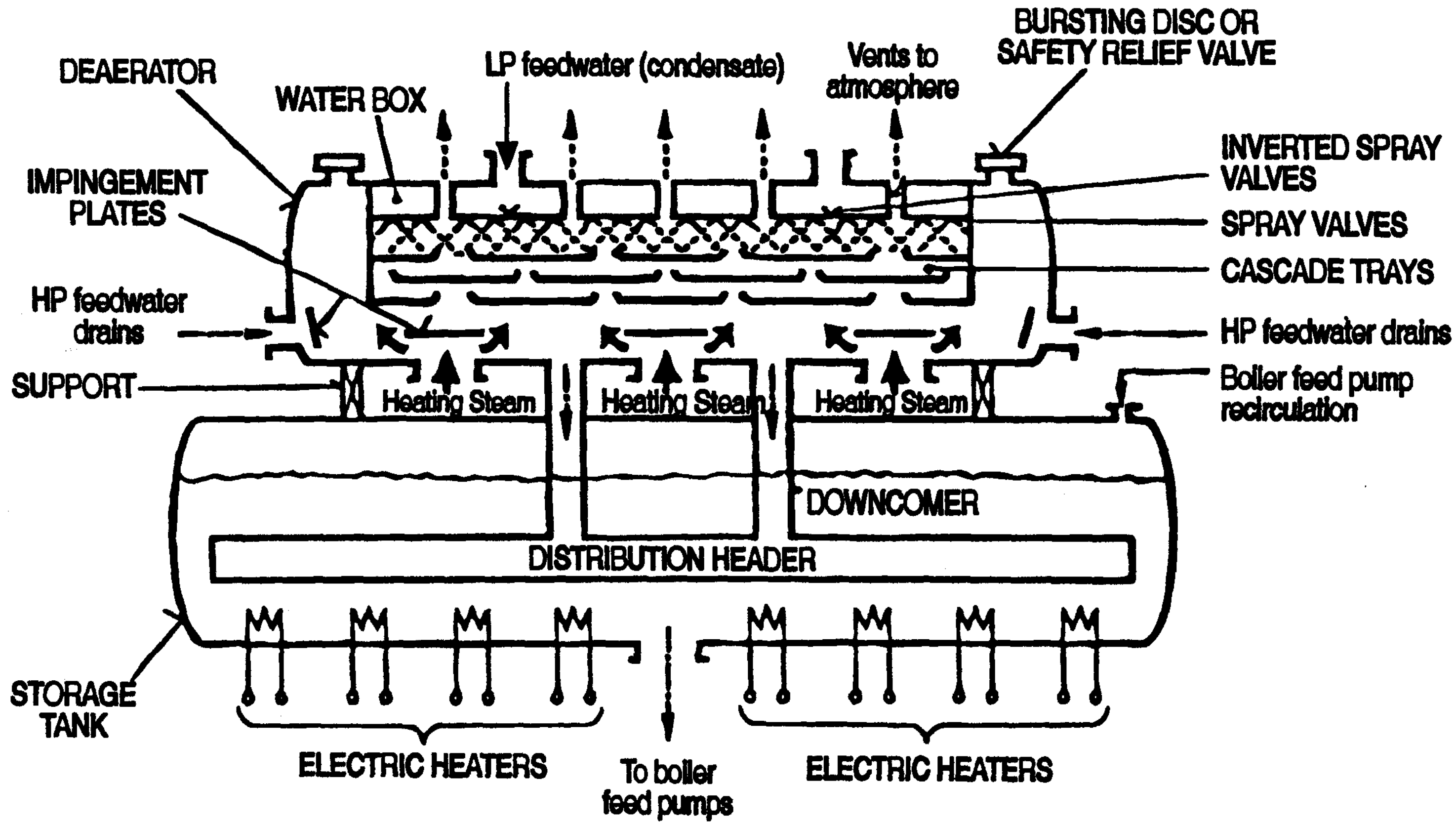


Figure 1 Deaerator and deaerator storage tank (courtesy of NB Power)

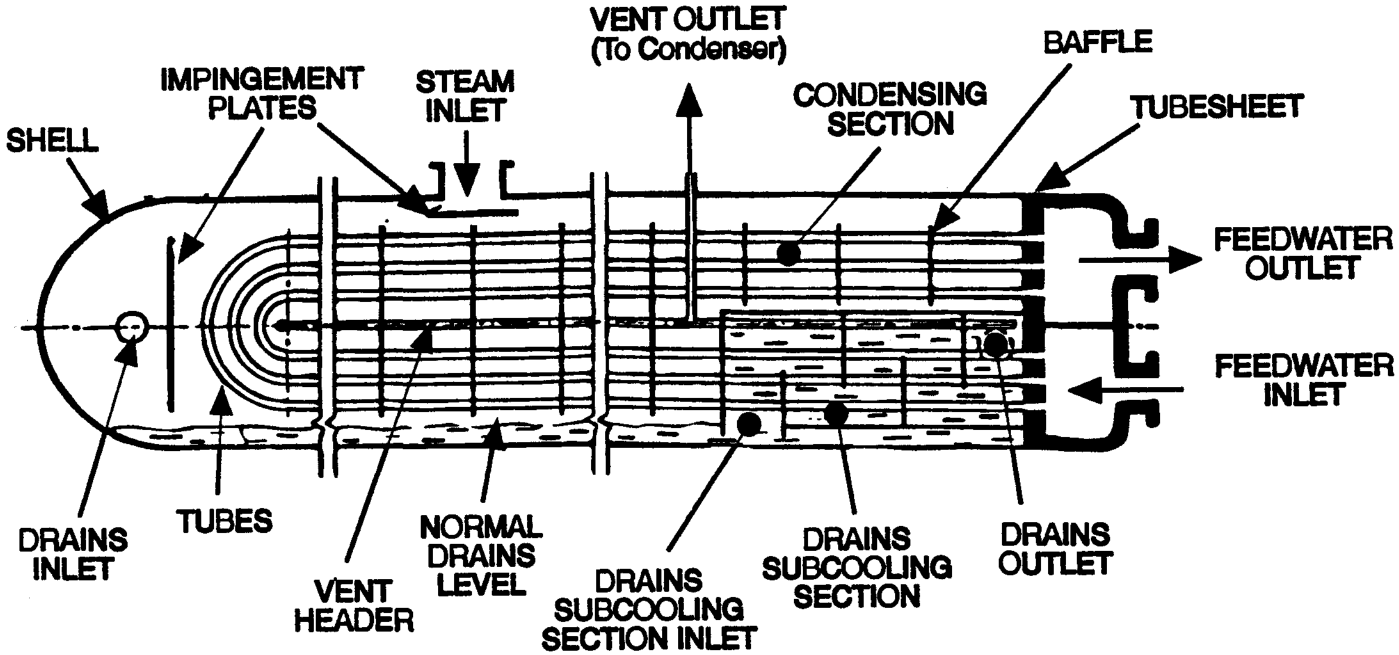


Figure 2 Feedwater heater with integral drains cooler (courtesy of NB Power)

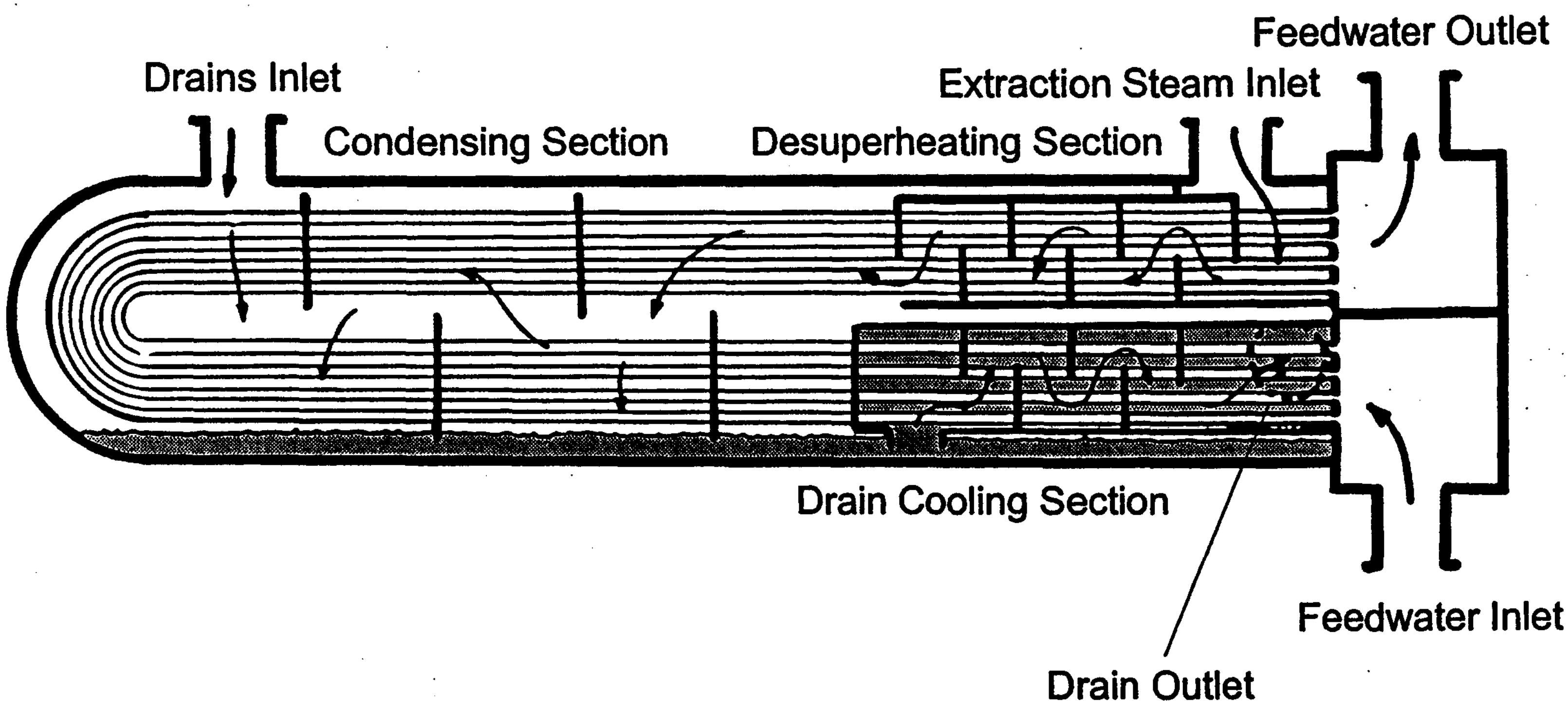


Figure 12 Feedwater heater with desuperheater and drain cooler

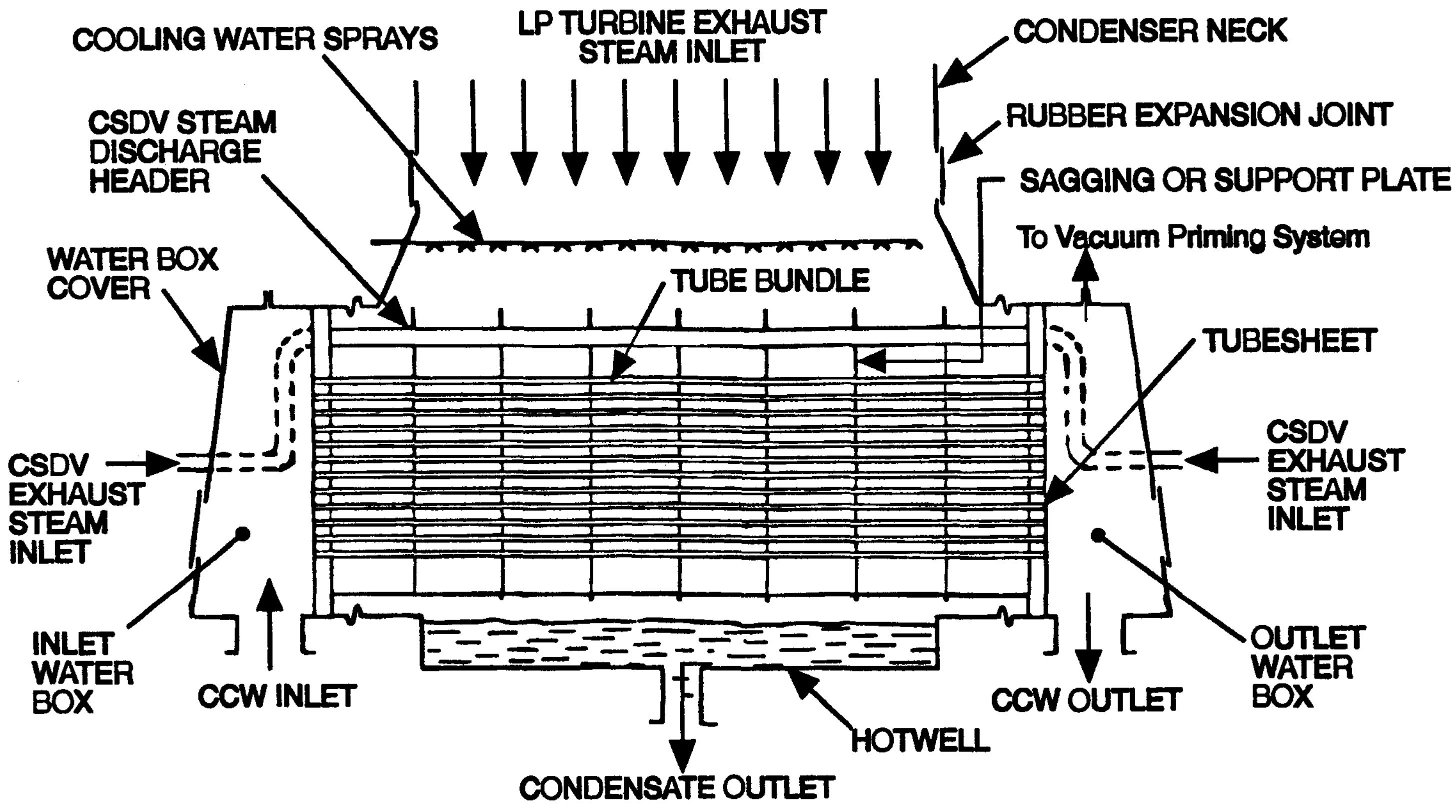


Figure 3 Condenser longitudinal section (courtesy of NB Power)

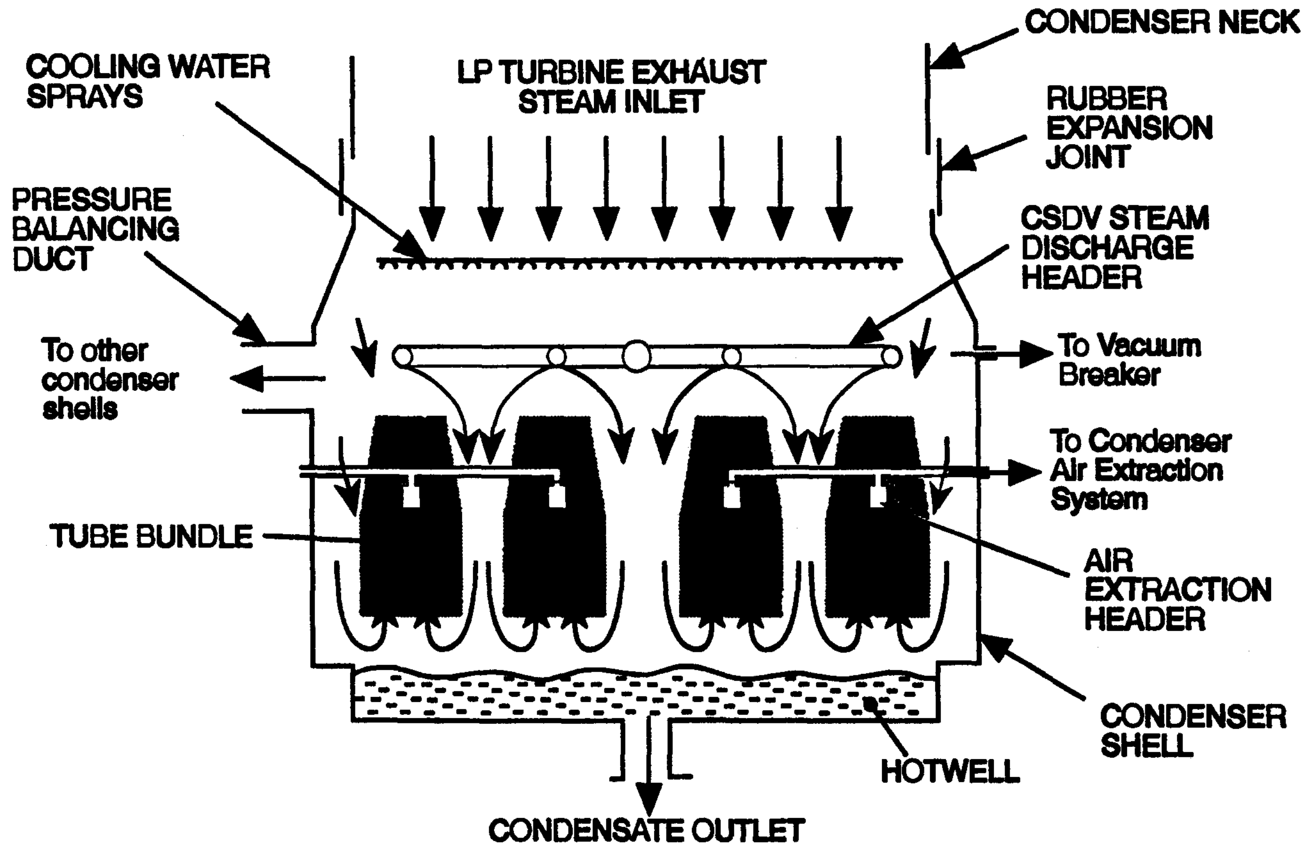


Figure 4 Condenser cross-section (courtesy of NB Power)

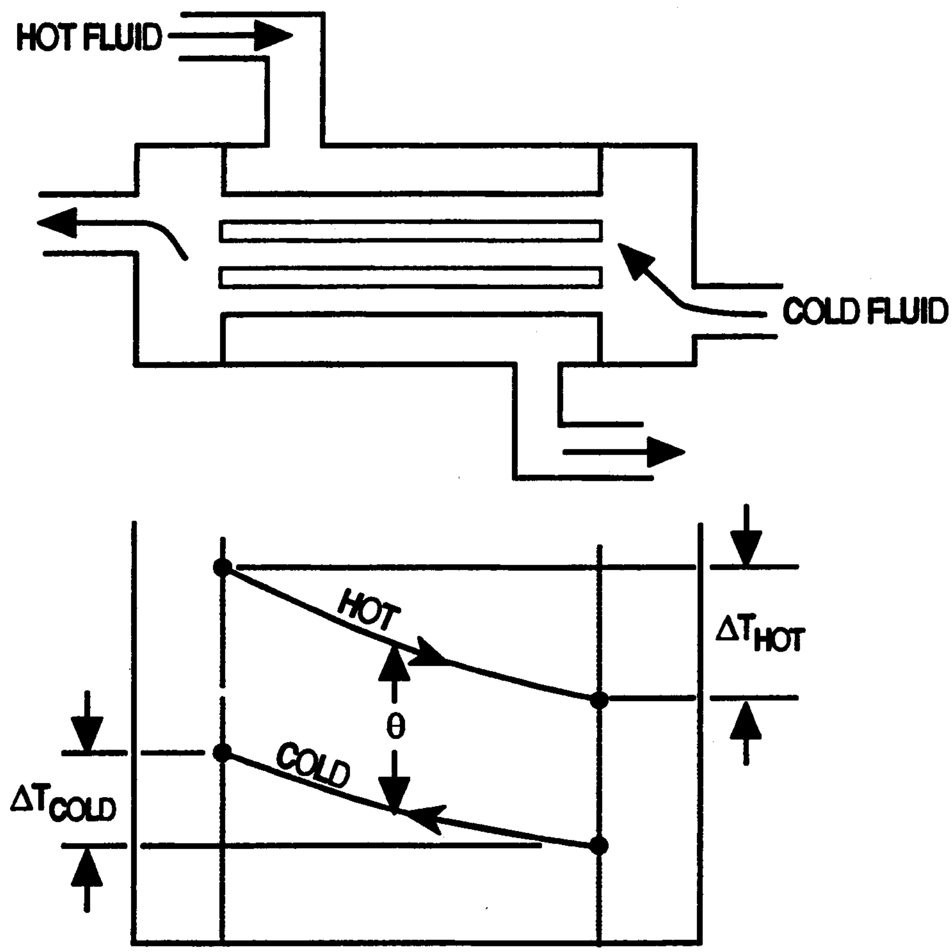
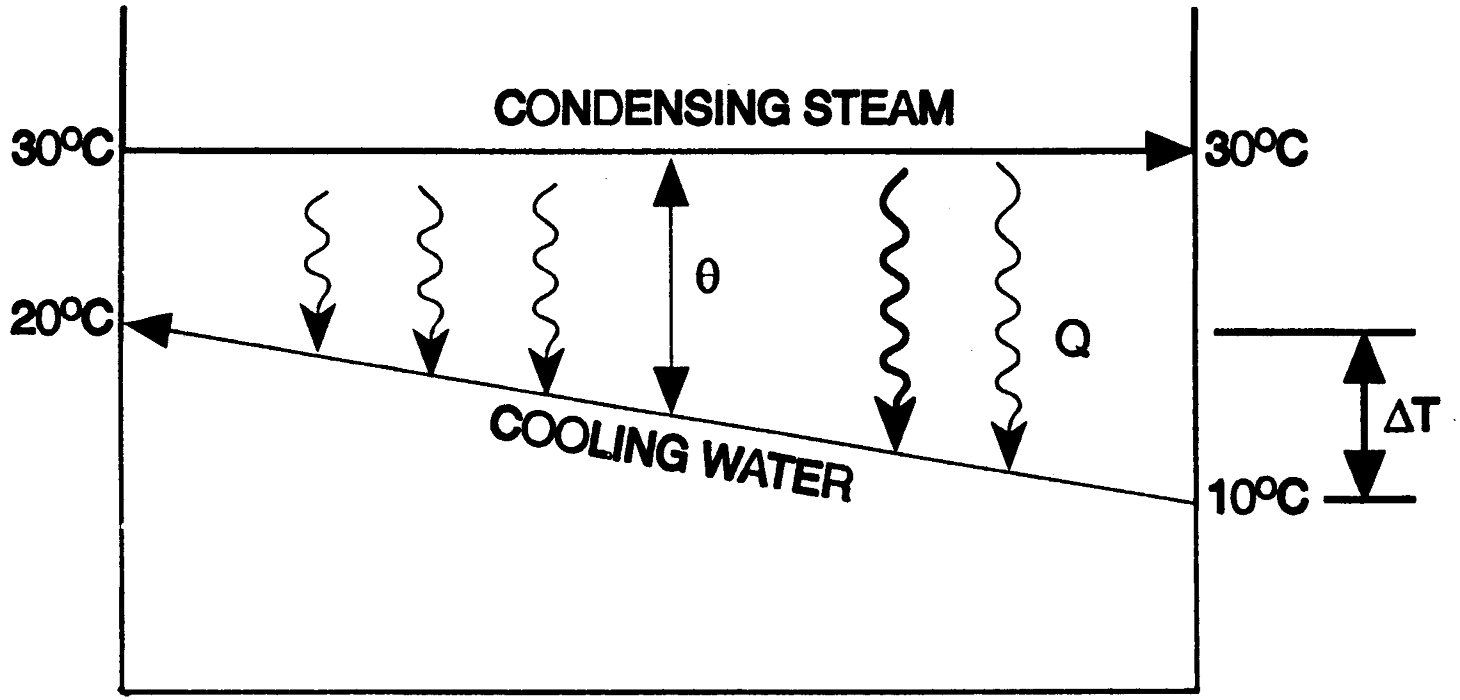


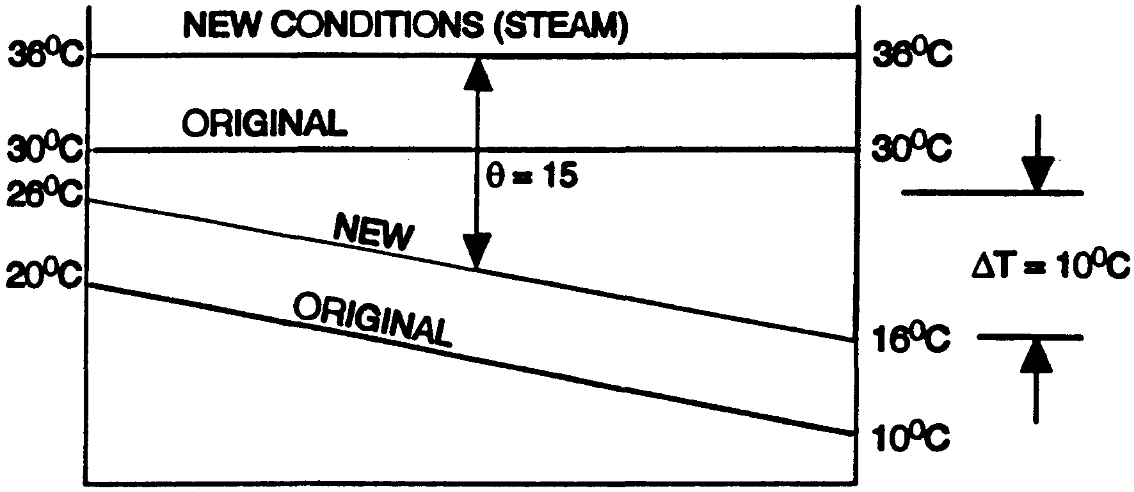
Figure 5 Heat exchanger and temperature profile



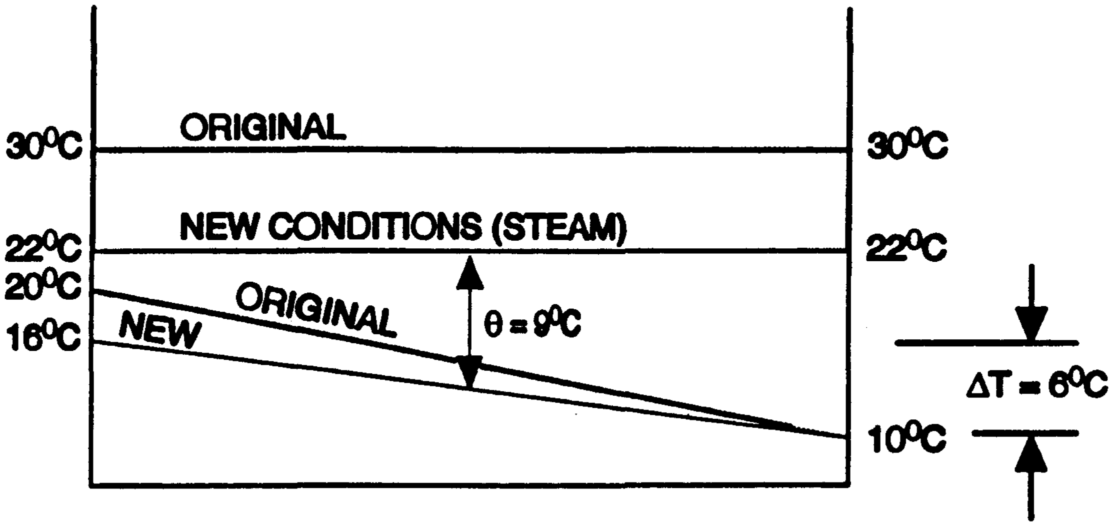
θ = AVERAGE TEMPERATURE DIFFERENCE

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

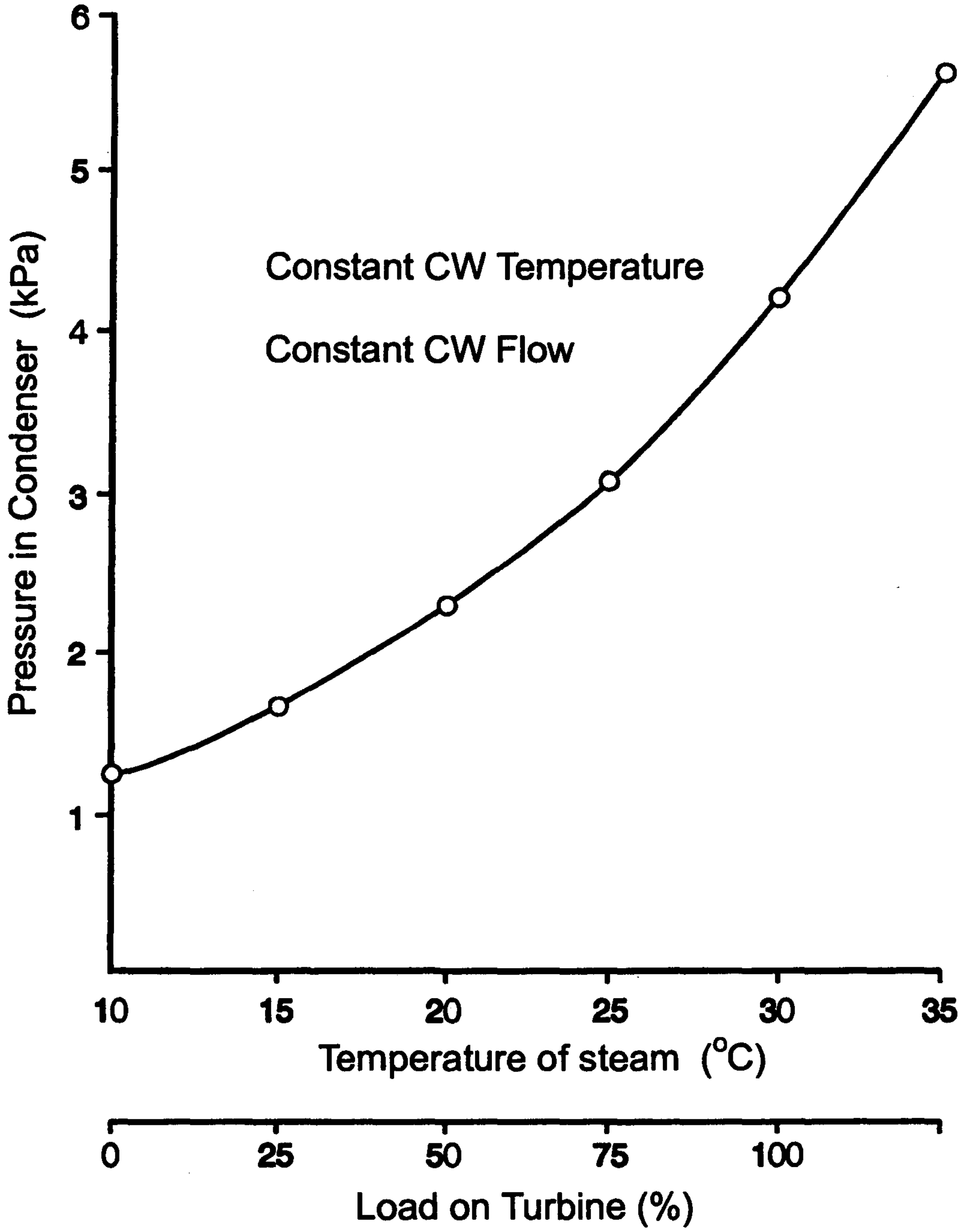


Figure 8 Variation in condenser pressure

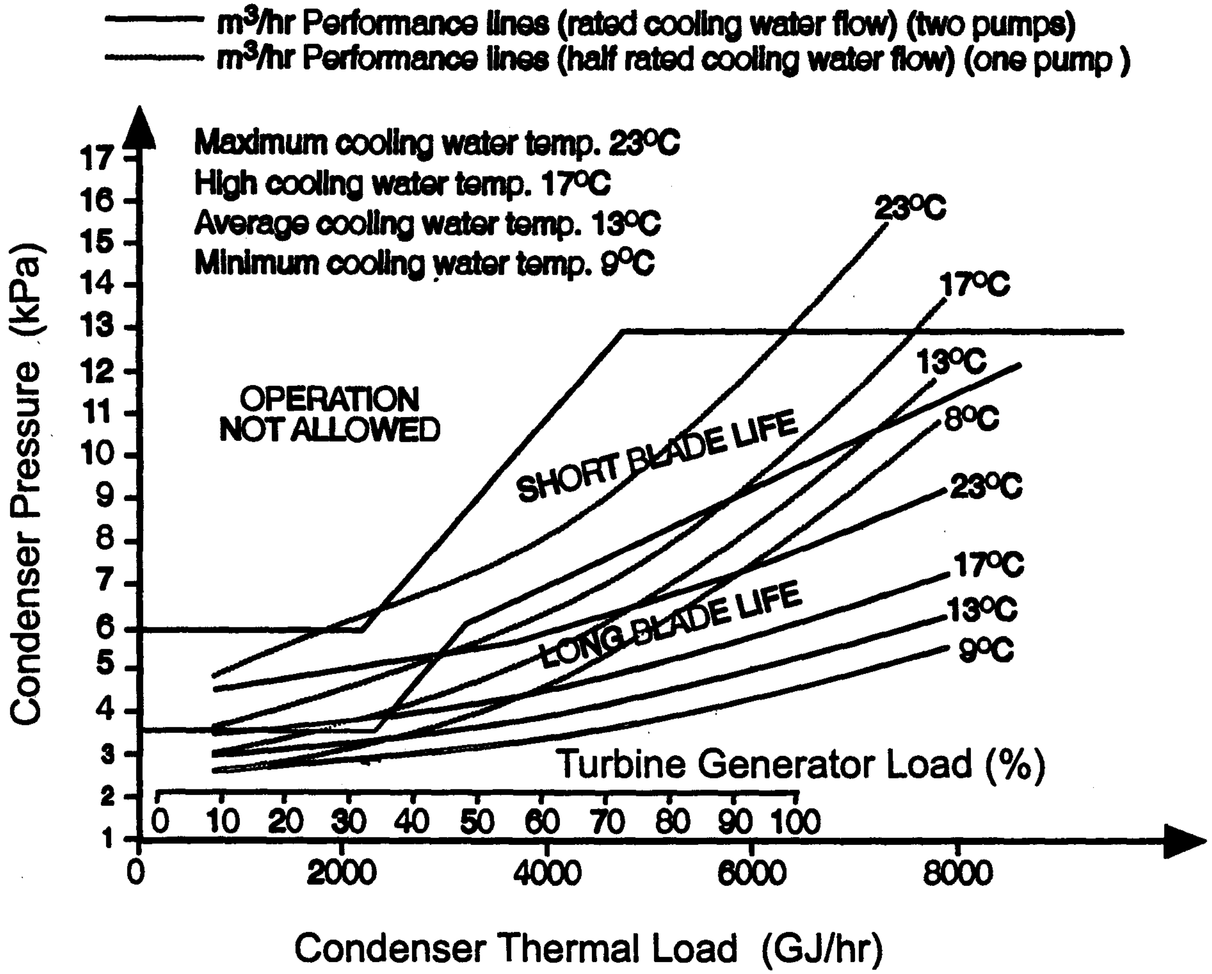


Figure 9 Condenser performance curves (adapted courtesy of Eskom)

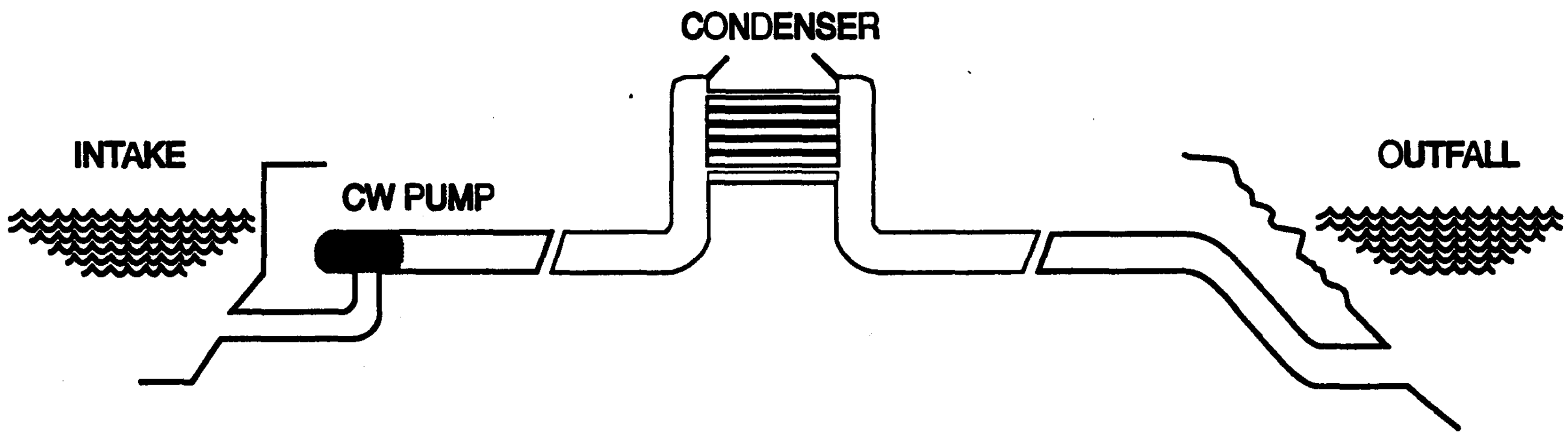


Figure 10 Simplified condenser cooling water system

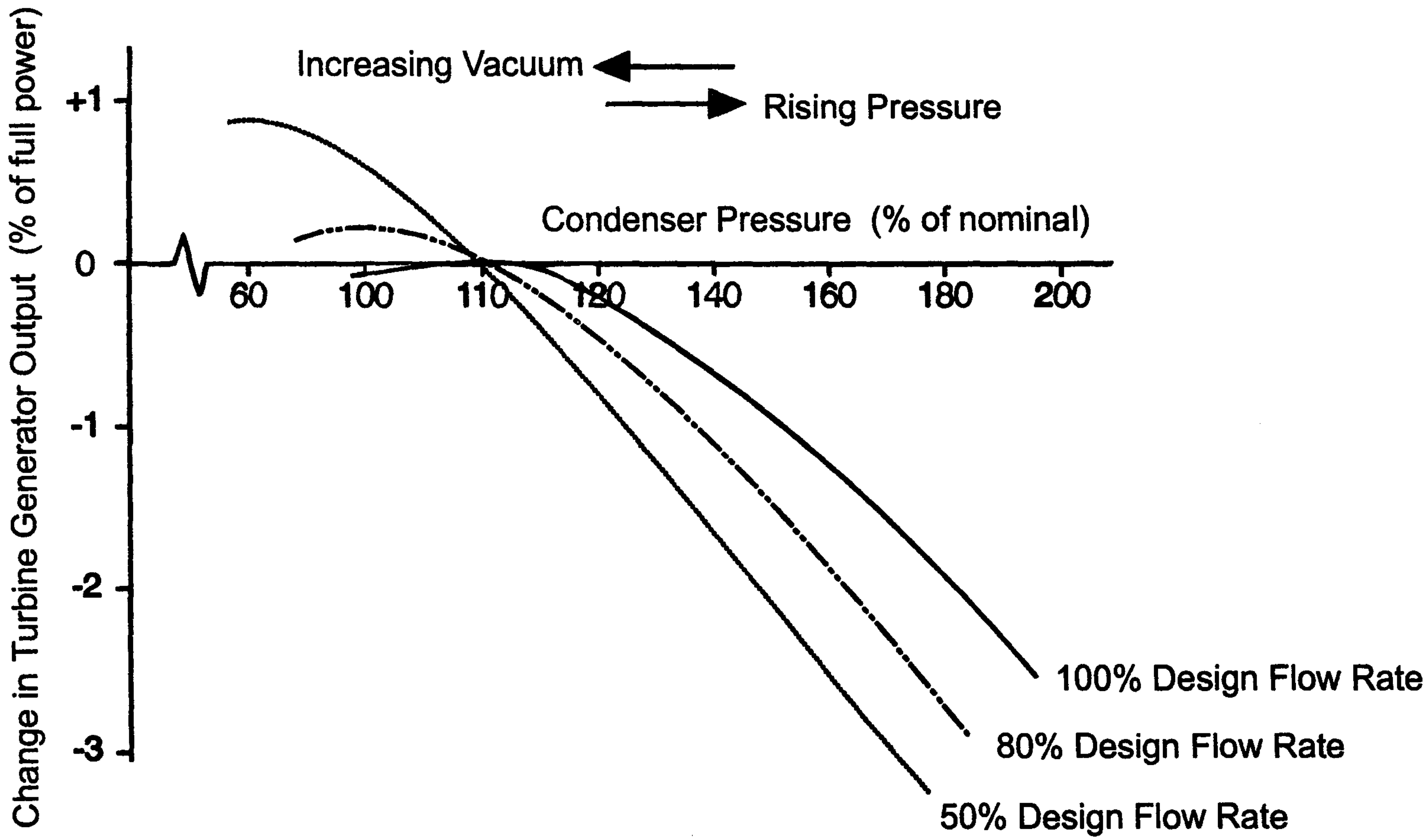


Figure 11 Effect of change in condenser pressure (courtesy of NB Power)

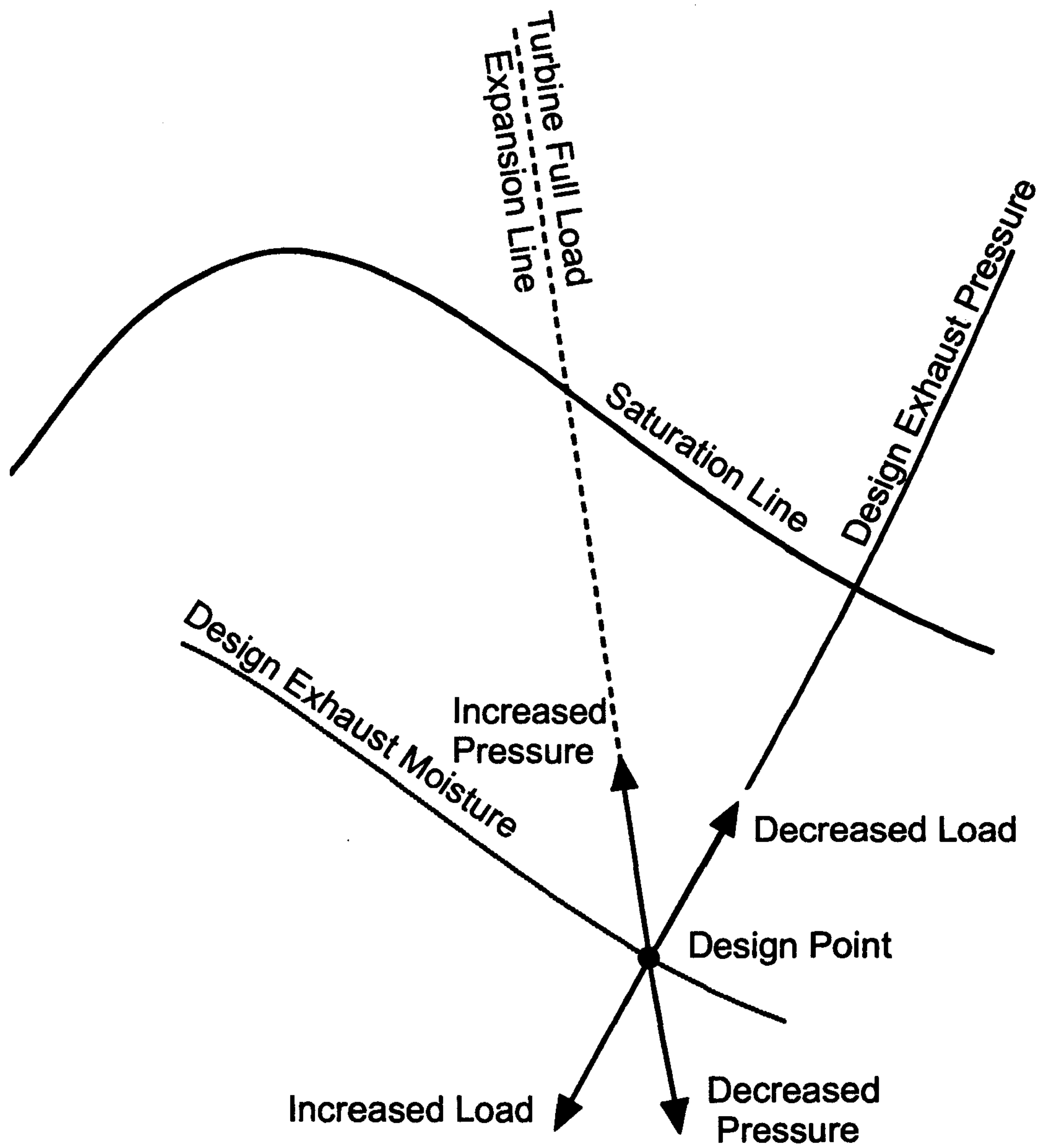


Figure 12 Effect of change in turbine load and condenser pressure

STEAM DISCHARGE VALVES

(CSDV's)

POTENTIAL PROBLEMS

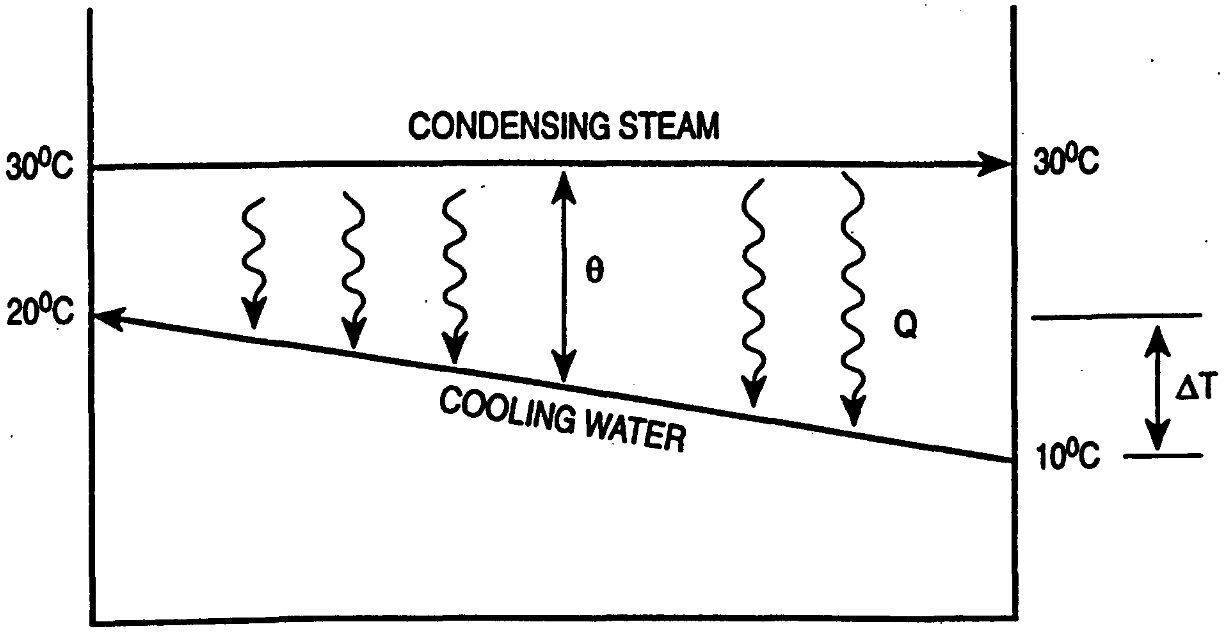
* DAMAGE BY STEAM JETS
* DAMAGE BY WATER INDUCTION
* EXCESSIVE TEMPERATURE GRADIENTS
* OVERHEATING OF EXPANSION JOINT

OPERATIONAL LIMITS

1. CONDENSER VACUUM
2. TURBINE LOAD

CSDV TRIP (INHIBITS OPENING)

1. POOR CONDENSER VACUUM
2. UNAVAILABILITY OF COOLING SPRAYS
3. VERY HIGH BOILER LEVEL



θ = AVERAGE TEMPERATURE DIFFERENCE

ΔT = COOLING WATER TEMPERATURE RISE

HEAT LOST: $Q = M_{STEAM}(h_{STEAM} - h_{CONDENSATE})$

HEAT TRANSFERRED: $Q = UA\theta$

HEAT GAINED: $Q = M_{WATER}C_{pWATER}\Delta T$

Figure 5.3
Heat Exchanger Equations

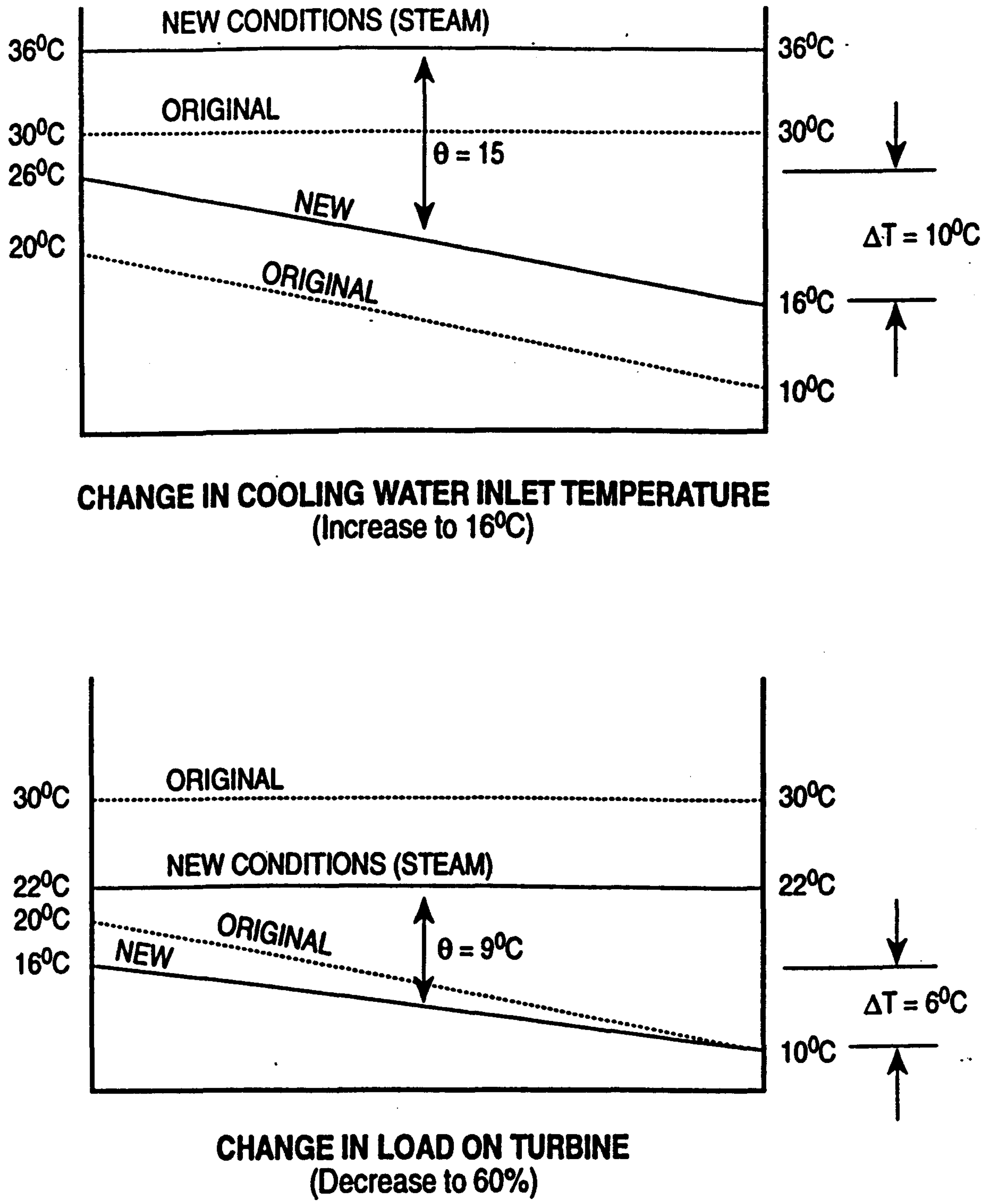


Figure 5.4: Changes in Condenser Conditions

DIAGNOSIS OF PROBLEMS

HEAT TRANSFER

$$Q = UA \Delta T_m$$

PATRIAL PRESSURE

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

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

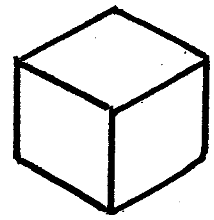
CONDENSER AIR EXTRACTION

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

AT 35°C (308°K)

FOR AIR $R = 0.287$ kJ/kg°K

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



1 m^3

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

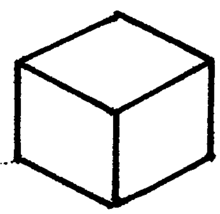
$$pv = RT$$

$$p_{TOTAL} = p_{STEAM} + p_{AIR} = 5.62 \text{ kPa}$$

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

AT 24°C (297°K)

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



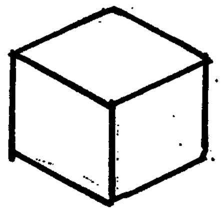
1 m^3

$$p_{AIR} = p_{TOTAL} - p_{STEAM} = 5.62 - 2.98 = 2.64 \text{ kPa}$$

$$\rho_{AIR} = p_{AIR}/RT = 2.64/0.287 \times 297 = 0.0310 \text{ kg/m}^3$$

$$p = \rho RT$$

CONSIDER $1 m^3$ OF MIXTURE



EACH COMPONENT CONTRIBUTES
TO PRESSURE AND TO DENSITY

$1 m^3$ OF MIXTURE CONTAINS :

0.0218	kg	OF STEAM	AT	2.98 kPa
0.0310	kg	OF AIR	AT	2.64 kPa
0.0528	kg			5.62 kPa

CONTENT OF STEAM AND AIR

STEAM : 0.0218 / 0.0528 = 41 %

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 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