CONFERENCE ON WATER OPTIMISATION IN THERMAL POWER PLANTS

OPTIMISATION OF WATER USAGES IN THERMAL POWER PLANTS AND A STUDY ON DRY COOLING SYSTEM

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WATER AVAILABILITY ASPECTS

- **WATER IS A KEY INPUT REQUIREMENT FOR THERMAL POWER GENERATION.**
- **AVAIALBLE WATER RESOURCES ARE FIXED AND WATER REQUIREMENT IS INCREASING.**
- **WATER HAS PRIORITY FOR DRINKING AND IRRIGATION OVER THAT FOR POWER GENERATION.**
- **AVAILABILITY AND ALLOCATION OF WATER FOR THERMAL POWER PLANTS HAS BEEN REDUCING.**
- **LOW GRADE WATER IS ALSO BEING SUPPLIED AS INPUT RAW WATER TO THE THERMAL PLANTS.**

NEED FOR OPTIMISING/ MINIMISING WATER CONSUMPTION IN THERMAL PLANTS

- **THERMAL CAPACITY ADDITION PROJECTED AT ABOUT 15000 MW/ANNUM FOR NEXT TWO DECADES.**
- **LARGE NUMBER OF SITES REQUIRED WITH AVAILABILTY OF ADEQUATE WATER.**
- **DIFFICULTIES BEING FACED IN SELECTION OF NEW SITES IN DIFFERENT STATES DUE TO WATER SCARCITY.**
- **CONSTRAINTS IN AVAILABILITY OF SWEET WATER FOR COASTAL SITES.**

WATER OPTIMISATION/ MINIMISATION IS NECESSARY TO ENHANCE PLANT SITING OPTIONS

TYPICAL WATER USES IN COAL BASED THERMAL POWER PLANTS

- **COOLING OF CONDENSER AND SECONDARY COOLING OF PHEs IN ECW SYSTEM.**
- **POWER CYCLE MAKE UP.**
- **WET ASH DISPOSAL.**
- **COAL DUST SUPPRESSION.**
- **AIR CONDITIONING AND VENTILATION.**
- **OTHER USES VIZ. POTABLE USE, PLANT WASHING, GARDENING.**

COOLING WATER SYSTEM

- **Once through system:**

  Permissible for coastal sites with temperature rise of 7^0C over temperature of receiving water body.

- **Closed cycle open recirculation system using cooling towers:**

  Requires make up water to compensate for loss of water due to evaporation, drift and blow down.

  Blow down is required to maintain a desired level of COC in CW system.

CT MAKE-UP & BLOWDOWN

- CT make-up water, $M = \frac{E \cdot C}{(C-1)}$

- Blow down water, $B = \frac{E}{(C-1)} - D$

Where E = Evaporation,
D = Drift,
C = COC of CW system

VARIATION OF CT MAKE UP WITH COC (500 MW UNIT)

Description	Cycle of Concentration (C)				
	1.6	2.0	3.0	4.0	5.0
Evaporation, m^3/h (%)	1020 (1.7)	1020 (1.7)	1020 (1.7)	1020 (1.7)	1020 (1.7)
Drift, m^3/h (%)	30 (0.05)	30 (0.05)	30 (0.05)	30 (0.05)	30 (0.05)
Blow down, m^3/h (%)	1670 (2.783)	990 (1.65)	480 (0.8)	310 (0.517)	225 (0.375)
Make up, m^3/h (%)	2720 (4.533)	2040 (3.4)	1530 (2.55)	1360 (2.267)	1275 (2.125)

BROAD FEATURES GOVERNING PLANT WATER REQUIREMENT

- **Source/ quality of raw water.**
- **Type of CW system.**
- **Quality of coal.**
- **Plant design aspects.**
- **Use of dry fly ash.**
- **Treatment/ reuse of waste water.**

WATER REQUIREMENT TRENDS

- **Earlier water was taken as an assured input.**
- **Plant used to have liberal considerations and high design margins.**
- **Plant consumptive water with cooling tower used to be about 7 m^3/h/MW without ash water recirculation and 5 m^3/h/MW with ash water recirculation.**
- **In recent past, consumptive water requirement used to be taken as 3.5- 4m^3/h per MW.**

CONSIDERATIONS FOR REDUCTION OF PLANT WATER REQUIREMENT

- New plants to progressively achieve 100% utilisation of fly ash by 4th year of plant operation.
- COC of 5 for CW system operation
- Clarifier sludge water and filter backwash to be recycled.
- Boiler blowdown to be used as part of CT make up.
- Power cycle make up as 2% of BMCR flow.
- Waste water to be used for coal dust suppression and gardening.
- Dry cooling system as per constraint in availability of raw water.

PLANT OPERATION CONSIDERATIONS

- **Fly ash disposal in wet slurry mode or HCSD mode during initial period of plant operation.**
- **Bottom ash disposal in wet slurry mode.**
- **70% recovery of ash pond water.**
- **Ash pond water recovery expected to be available within one year of plant operation.**

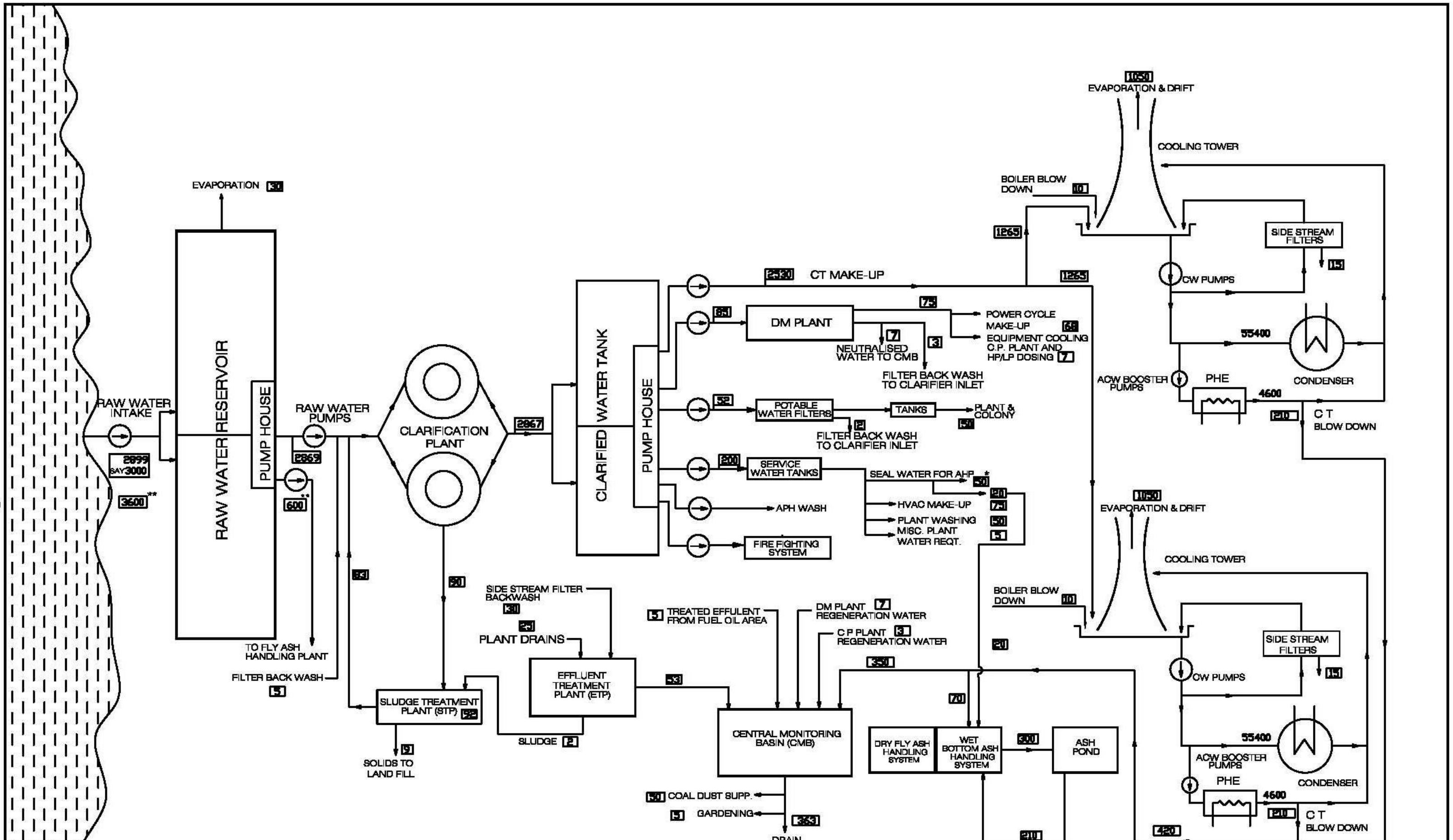
CONSIDERATIONS WITH DRY COOLING SYSTEM

- **Condenser cooling by dry cooling system.**
- **ACW system to be based on wet cooling tower.**
- **Fly ash disposal in dry mode/ HCSD mode.**
- **Bottom ash disposal in wet mode.**

CASES CONSIDERED

- Inland power plant with wet cooling tower.
- Inland power plant with dry cooling system.
- Coastal power plant based on sea water.

WATER BALANCE DIAGRAM 2 X 500 MW COAL BASED WITH WET COOLING TOWER



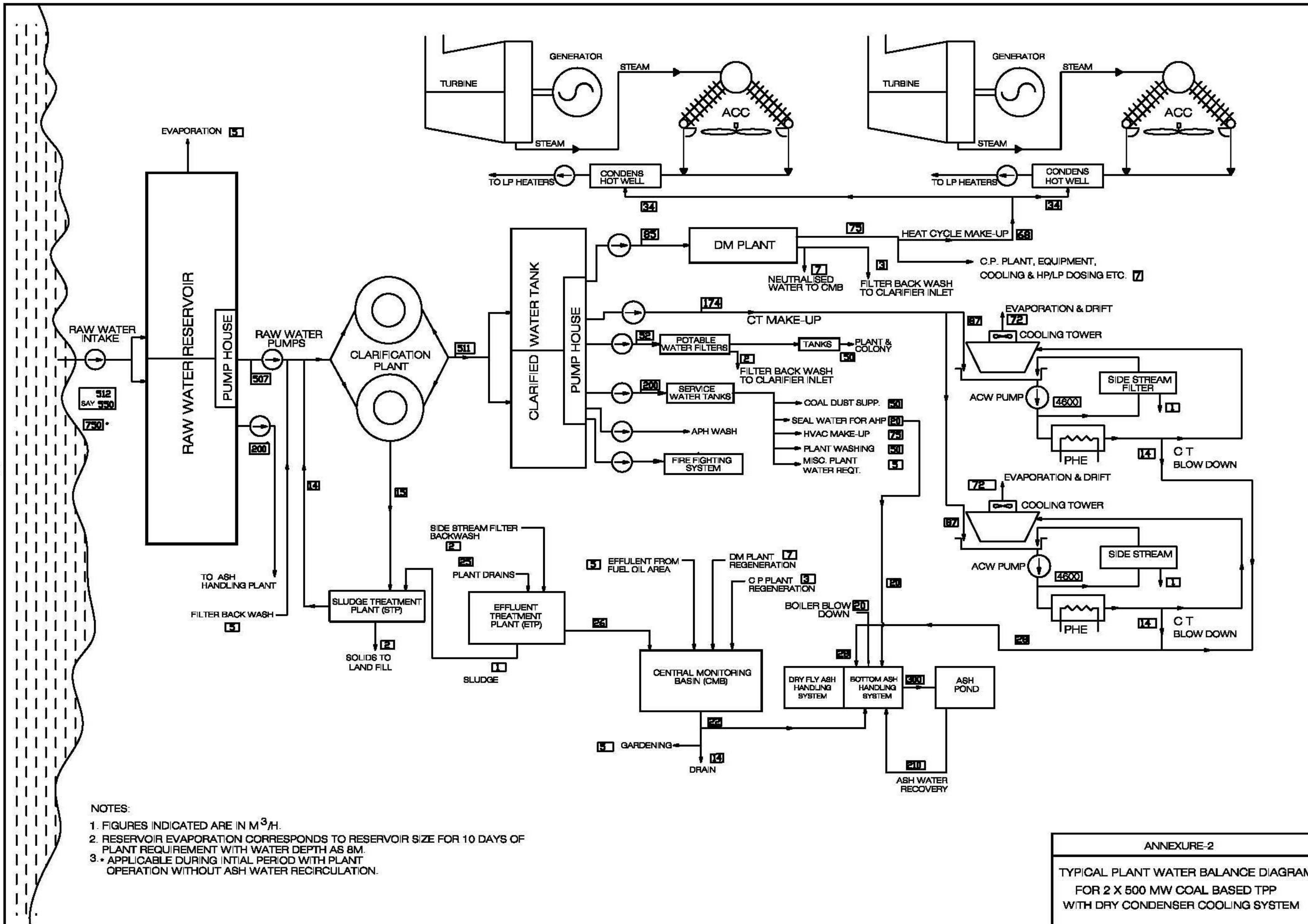
NOTES:

1. FIGURES INDICATED ARE IN M^3/H.
2. RESERVOIR EVAPORATION CORRESPONDS TO RESERVOIR SIZE FOR 10 DAYS OF PLANT REQUIREMENT WITH WATER DEPTH AS 8M.
3. * APPLICABLE FOR FLY ASH DISPOSAL IN WET SLURRY MODE.
4. **APPLICABLE DURING INITIAL PERIOD OF PLANT OPERATION WITH FLY ASH DISPOSAL IN WET SLURRY MODE WITHOUT ASH WATER RECOVERY.

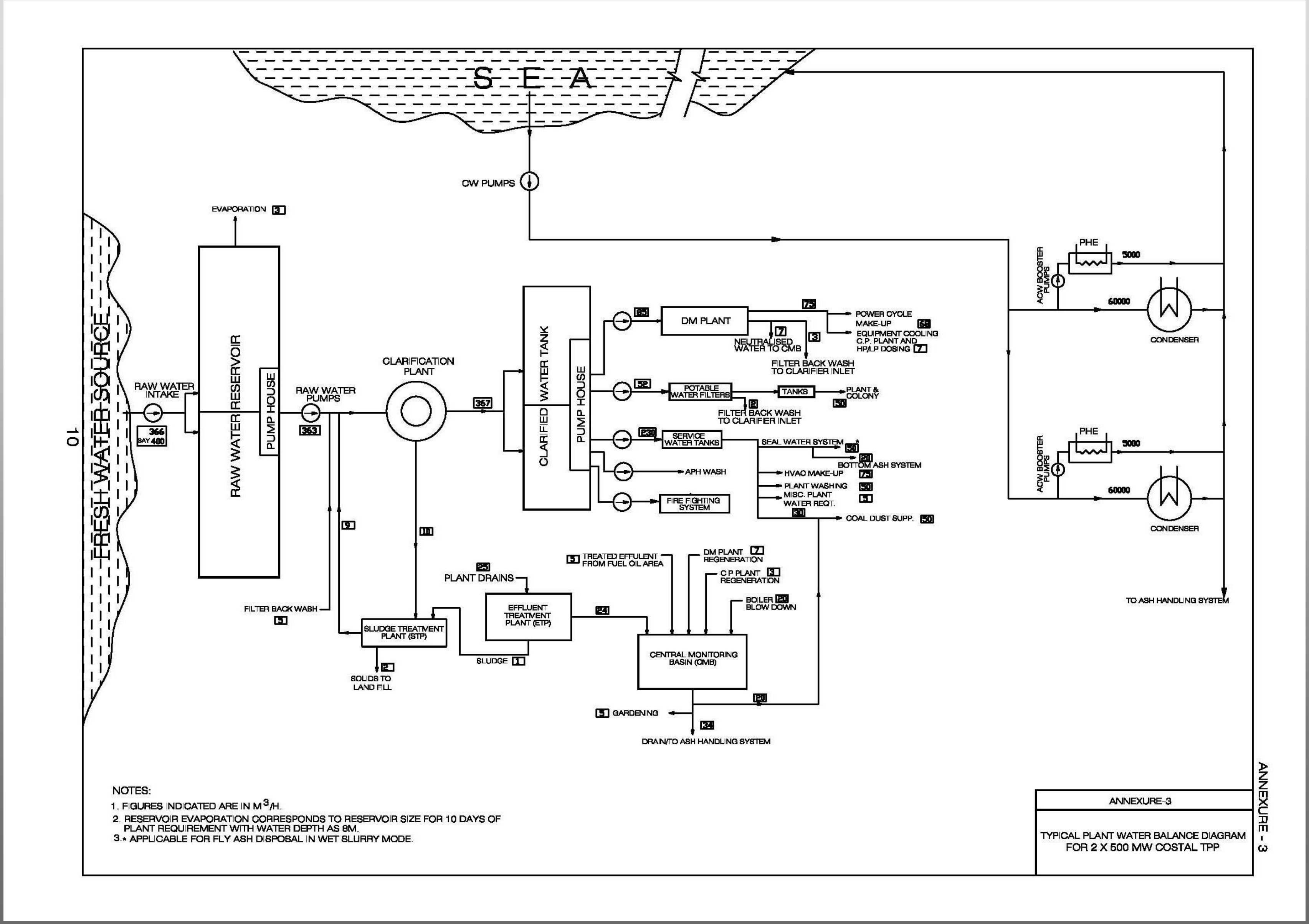
ANNEXURE-1
TYPICAL PLANT WATER BALANCE DIAGRAM FOR 2 X 500 MW COAL BASED TPP WITH WET COOLING TOWER

ANNEXURE - 1

WATER BALANCE DIAGRAM 2 X 500 MW COAL BASED TPP WITH DRY COOLING SYSTEM



WATER BALANCE DIAGRAM 2 X 500 MW COASTAL TPP



MINIMISED PLANT WATER REQUIREMENT FOR 2 x 500MW PLANT (M^3/H)

		Wet cooling	**Dry cooling**	**Coastal plant**
1.	CT make up	2550*	174	-
2.	Bottom ash handling	90**	90**	-
3.	DM plant input	85	85	85
4.	Service & potable water	252	252	282
5.	Clarifier sludge	90	15	10
6.	Reservoir evaporation	30	5	3
7.	Recovered sludge water & filter backwash	(-) 88	(-)19	(-)14
8.	Boiler blow down used as CT make up	(-) 20	-	-
9.	Total (1+3+4+5+6+7+8)	2899	512	366
10.	Say	**3000**	**550**	**400**
11.	Additional requirement during initial period	600	200	-

* Includes $450m^3/h$ CT blow down.
**To be met from available CT blow down and other waste waters.

WASTE WATER GENERATION IN 2 x 500MW PLANT (M^3/H)

		Wet cooling	Dry cooling	Coastal plant
1.	Unused CT blow down/ boiler blow down	350	-	20
2.	DM plant & CPU regeneration	10	10	10
3.	Treated effluent of plant drains etc.	58	31	29
4.	Waste water utilized for coal dust suppression/ ash disposal	(-)50 (coal dust suppres sion)	(-)22 (ash disposal)	(-)20 (coal dust suppres sion)
5.	Waste water utilized for gardening	(-)5	(-)5	(-)5
6.	Waste water to be disposed from CMB (1+2+3+4+5)	**363**	**14**	**34**

SUMMARY ON PLANT WATER REQUIREMENT:
WET COOLING SYSTEM

- **3.6m^3/h per MW during initial period of plant operation with fly ash disposal in wet mode (without ash water recovery).**

- **3 m^3/h per MW after recovery of ash pond water, expected to begin within one year of plant operation.**

- **If fly ash is disposed in dry mode/ HCSD mode, 3m^3/h per MW will be adequate for plant operation right from beginning.**

SUMMARY ON PLANT WATER REQUIREMENT:
DRY COOLING SYSTEM

- **Fly ash disposal in dry mode**:

  0.75 m^3/h per MW during initial period of plant operation without recovery of bottom ash water.

  0.55 m^3/h per MW after recovery of bottom ash water, expected to begin within one year of plant operation.

- **Fly ash disposal in HCSD mode:**

  0.9 m^3/h per MW during first year of plant operation.

  0.7 m^3/h per MW in subsequent period.

About 80% reduction in plant water requirement when using dry cooling system.

SUMMARY ON PLANT WATER REQUIREMENT:
COASTAL PLANTS

- **Fresh water requirement 0.4 m^3/h per MW.**
- **Sea water to be used for process cooling and ash disposal.**
- **In case, desalination plant is installed, required fresh water shall be generated from sea water.**

STUDY ON DRY CONDENSER COOLING SYSTEM

KEY FEATURES OF DRY COOLING SYSTEM

- Operate on the basis of sensible cooling with ambient dry bulb temperature as reference temperature.
- Steam condensation temperature = ambient dbt + initial temperature difference (ITD), governed by size of cooling equipment.
- Turbine back pressure achieved is higher and power output of the unit is reduced.

TYPES OF DRY COOLING SYSTEM

Cont'd 2

Direct dry cooling: Air cooled condenser

- LP turbine exhaust steam is directly cooled inside a system of finned tube bundles by ambient air using forced draft fans.
- No Terminal temperature difference (TTD) is involved.

TYPES OF DRY COOLING SYSTEM

Cont'd 3

Indirect dry cooling: Surface condenser

- Steam is cooled in a surface condenser by circulating water which in turn, inside a system of finned tube bundles, is cooled by ambient air using fans or a natural draft tower.

- Terminal temperature difference (TTD) is involved.

TYPES OF DRY COOLING SYSTEM

Cont'd 4

Indirect dry cooling: Jet condenser

- Steam is cooled by direct mixing with DM water in a jet condenser. A part of mixed hot DM water is sent to power cycle and rest is pumped to a system of finned tube bundles for cooling by ambient air using a natural draft tower.
- Negligible TTD is involved.
- Hydraulic turbine can be used to recover pressure head of circulating water.

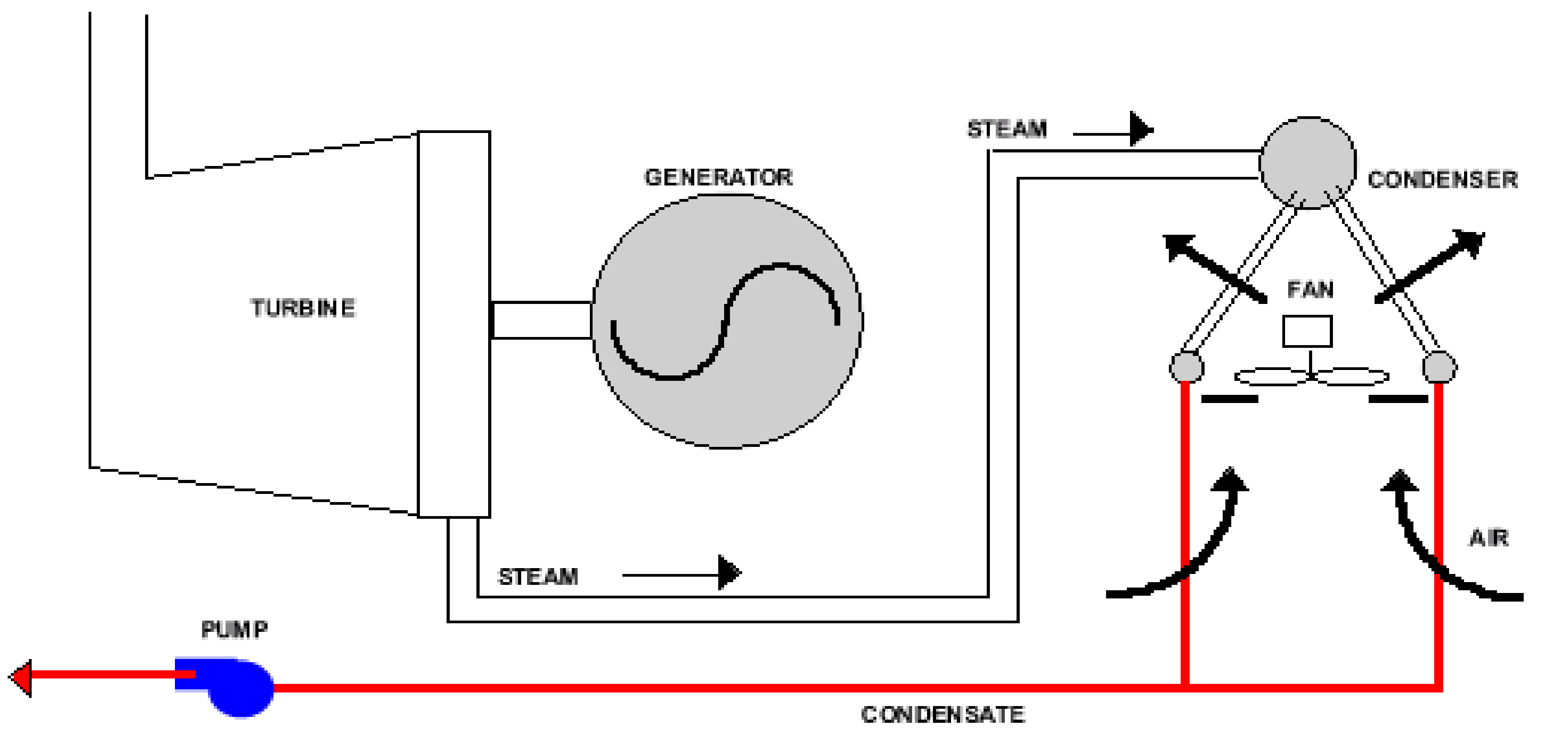
TYPES OF DRY COOLING SYSTEM

Hybrid system

Employs both wet cooling and dry cooling system provisions:

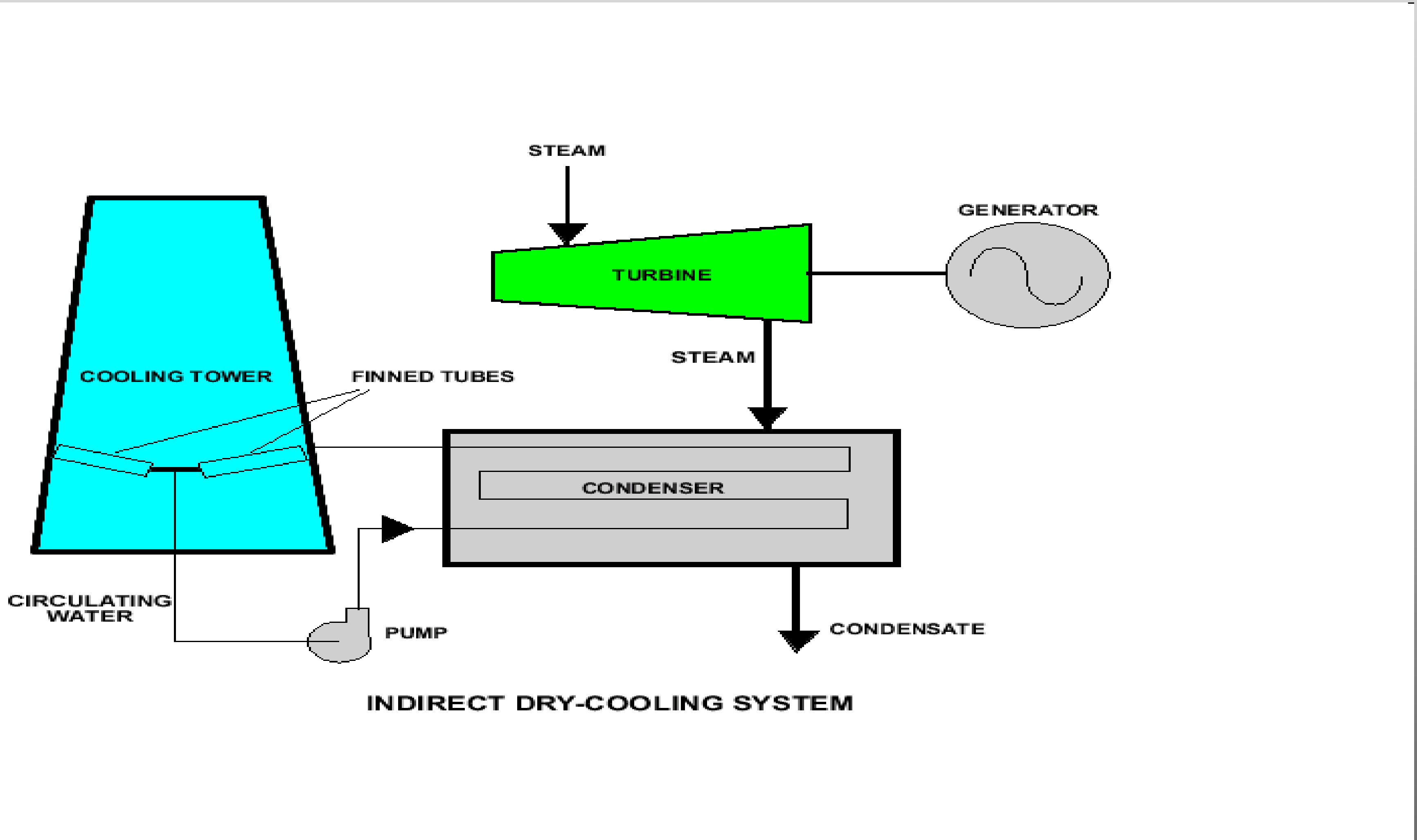
- When water is not available, plant is operated with dry cooling system.
- When water is available, cooling system is switched over to wet cooling system.

AIR COOLED CONDENSER WITH FANS

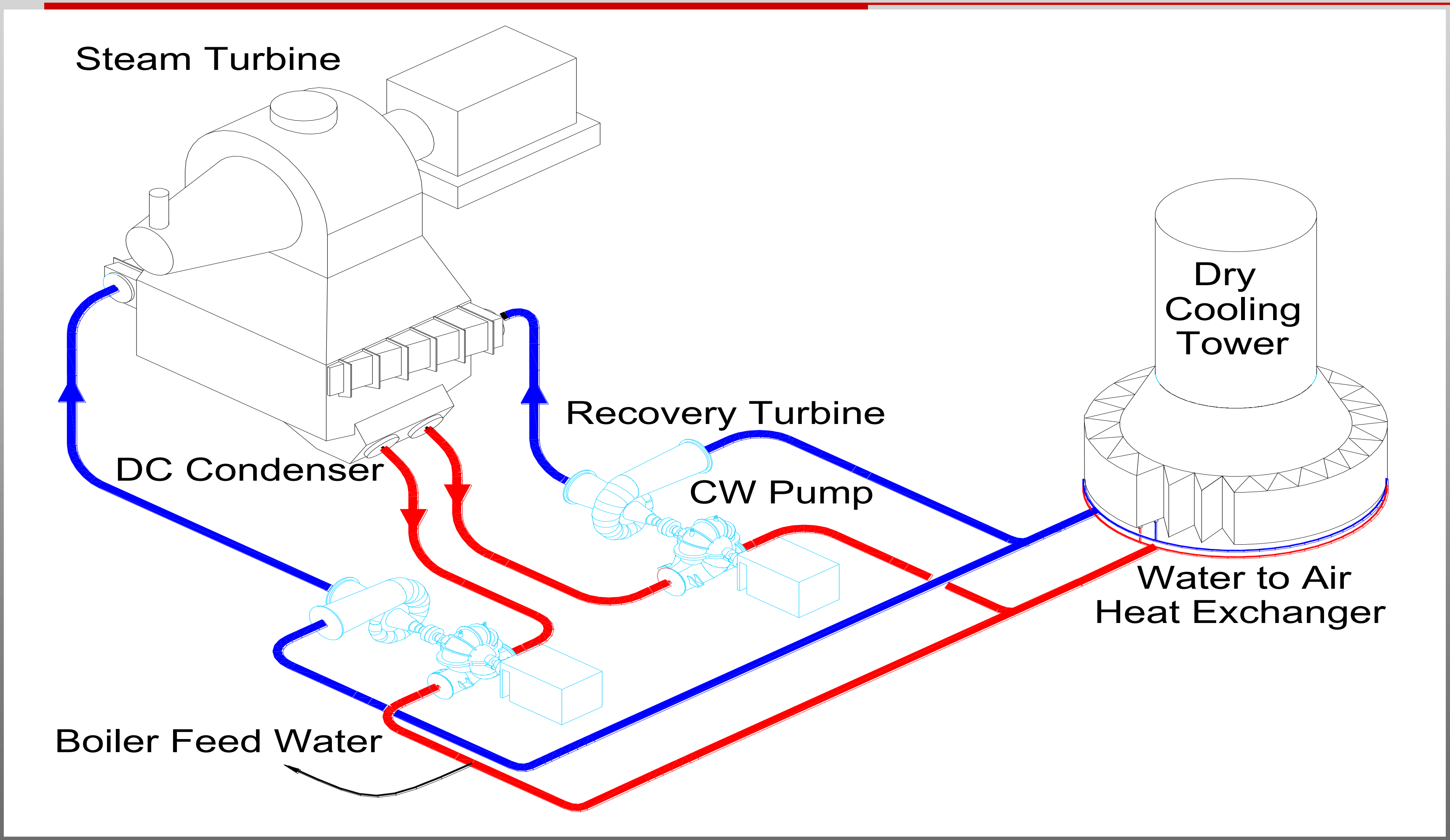


DIRECT AIR-COOLED SYSTEM

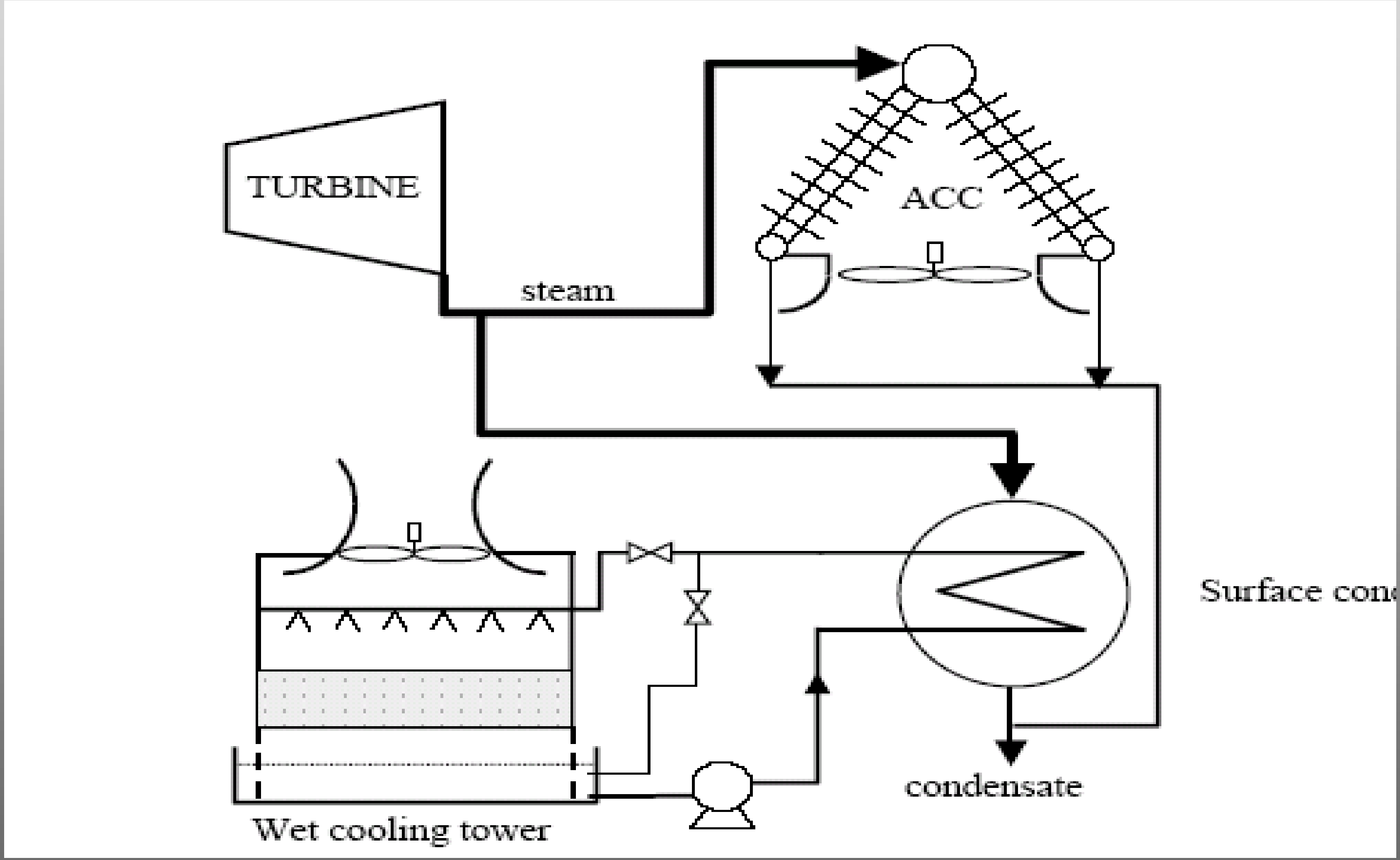
INDIRECT DRY COOLING WITH SURFACE CONDENSER



INDIRECT DRY COOLING WITH JET CONDENSER- HELLER SYSTEM



HYBRID (DRY/WET) COOLING SYSTEM



DRY COOLING SYSTEM ANALYSIS METHODOLOGIES

- Same unit output with higher size BTG plant.
- Same size BTG plant with lower unit output for dry cooling system plant.

CASE STUDY

- Study has been carried out for a 500 MW size unit plant considering same size BTG plant for wet cooling and dry cooling.
- Inputs for wet cooling system obtained from M/s NTPC.
- Inputs for dry cooling system obtained from:

  M/s SPX/Thermax for ACC and

  M/s GEA-EGI/Energo for Heller system
- Inputs on BTG system obtained from M/s BHEL.

DESIGN INPUT DATA FOR DRY COOLING SYSTEM

Size of BTG: 500 MW with wet cooling; 0.1 ata(a) back pressure

Design ambient dbt, ^oC	38			
ITD, ^oC	20	22	24	26
Steam condensation temp. ^oC	58	60	62	64
Condenser pressure, ata (a)	0.18	0.2	0.22	0.24
Unit output, MW	464.6	463.7	462.8	461.9
% short fall	7.1	7.3	7.4	7.6
Design condenser heat load, million Kcal/h (MWt)	581.7 (676.5)	582.1 (677)	582.7 (677.7)	583.6 (678.7)

INPUT DATA- Reference Values

Water requirement	3m^3/h/MW (wet cooling) 0.55m^3/h/MW(dry cooling)
Distance of water source from plant	18 km
Water storage	45 days
Auxiliary power consumption for wet cooling	6.5% for IDCT based plant 6% for NDCT based plant
Unit heat rate for wet cooling	2425 kcal/kWh
Capital cost with wet cooling system	Rs. 5 crore/MW
O&M expenses for plant with wet cooling system	Rs. 13 lakh/MW/year

INPUT DATA- Tariff Calculations

Debt/ equity ratio	70 : 30
Interest rate	11%
Return on equity	15.5%
Plant PLF	85%
Fuel escalation	6 %
O&M escalation	5%
Discount rate	9.35%
Depreciation rate	5.28%

OPTIONS CONSIDERED

1. Load centre station with coal GCV of 4000 kcal/kg and coal cost of Rs. 2200 per ton.
2. Pit head station with coal GCV of 3600 kcal/kg and coal cost of Rs. 1000 per ton.

Wet cooling: NDCT IDCT	Dry cooling: ACC Hellar system

RESULTS OF THE STUDY

- Reduction in plant output by about 7%.
- Increase in capital cost per MW of the plant by about 10 to 14%.
- Increase in specific fuel consumption and specific CO_2 emission by about 7%.
- Auxiliary power consumption for plant with ACC about 6.8% as compared to 6.5% for reference plant with IDCT.
- O&M expenses marginally lower at about Rs. 12 lakh/year per MW over reference of 13 lakh/year per MW for wet cooling plant.

IMPACT ON LEVELISED TARIFF

Description	Differential Levelised Tariff (Rs/kWh)						
	Wet cooling tower	ACC				Heller system	
		0.18 ata (a)	0.20 ata (a)	0.22 ata (a)	0.24 ata (a)	0.22 ata (a)	0.24 ata (a)
Plant at load centre	**Base (NDCT)**	**0.31**	**0.30**	**0.31**	**0.30**	**0.34**	**0.33**
	Base (IDCT)	**0.32**	**0.31**	**0.31**	**0.30**	**0.34**	**0.34**
Plant at pit-head	**Base (NDCT)**	**0.21**	**0.20**	**0.20**	**0.19**	**0.23**	**0.23**
	Base (IDCT)	**0.21**	**0.20**	**0.20**	**0.20**	**0.24**	**0.23**

Base levelised tariff : Rs.4/KWh at load centre, Rs.2.6/kWh at pit head

KEY FINDINGS

- **Plant with dry condenser cooling requires only about 20% of the water that required for the plant with wet cooling.**
- **Dry cooling system result in unit heat rate increase by about 7% and accordingly specific CO_2 emission increases by about 7%.**
- **Levelised tariff is increased by 8-9% over base levelised tariff for the plant with wet cooling.**
- **Dry cooling systems are costly technologies and are not comparable to wet cooling systems on techno- economic considerations. These need to be considered only in case adequate water is just not available for power generation using wet cooling.**

THANK YOU