Workshop Internacional

A TERMOELETRICIDADE NO CONTEXTO DO SETOR ELÉTRICO
A importância da Avaliação de Impactos Ambientais

Cooling Technologies & Project Evaluation for TPPs

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Treinamento

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Topics

I. Cooling Tower Technology
II. Air Cooled Condenser Technology
III. Hybrid Cooling Technology
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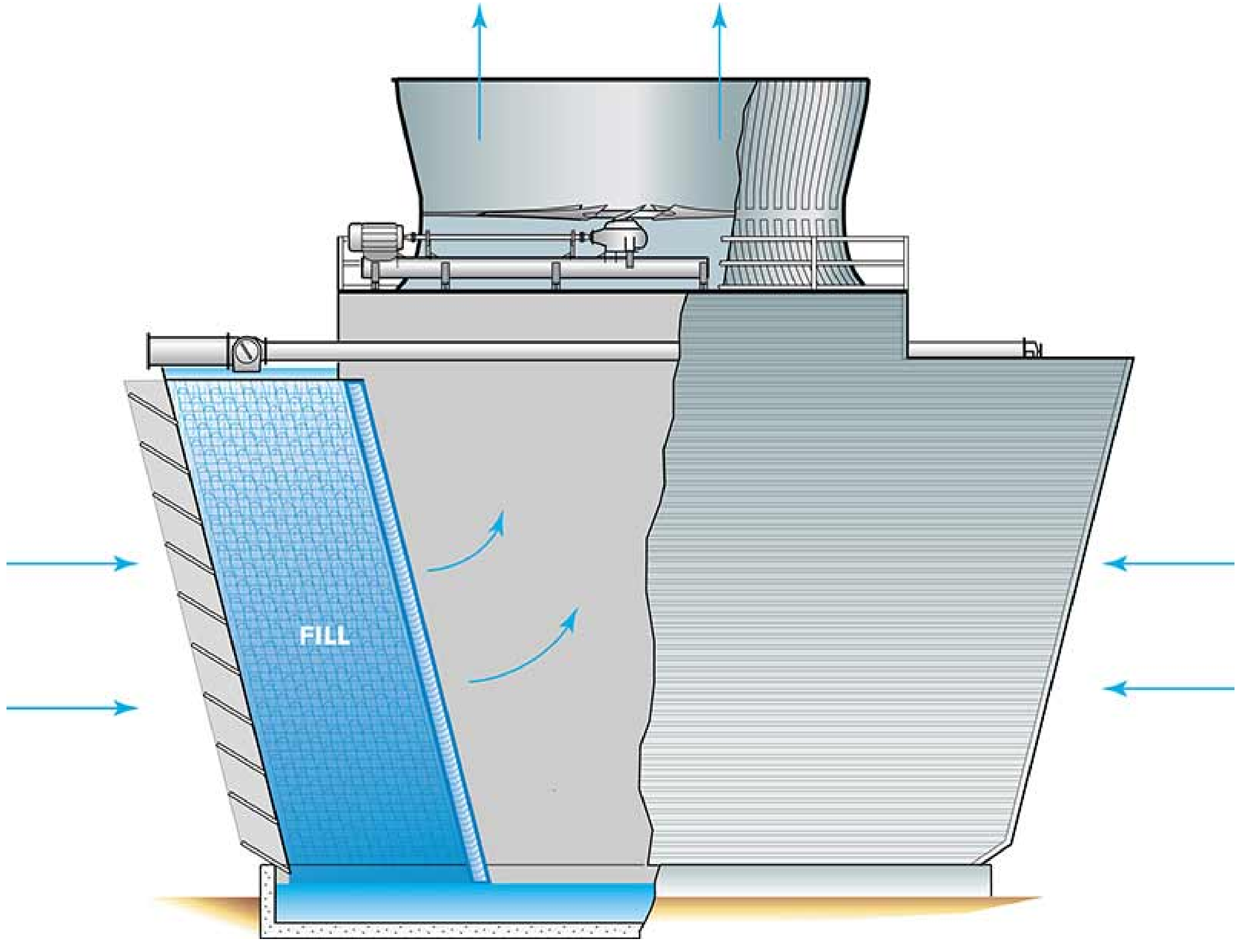
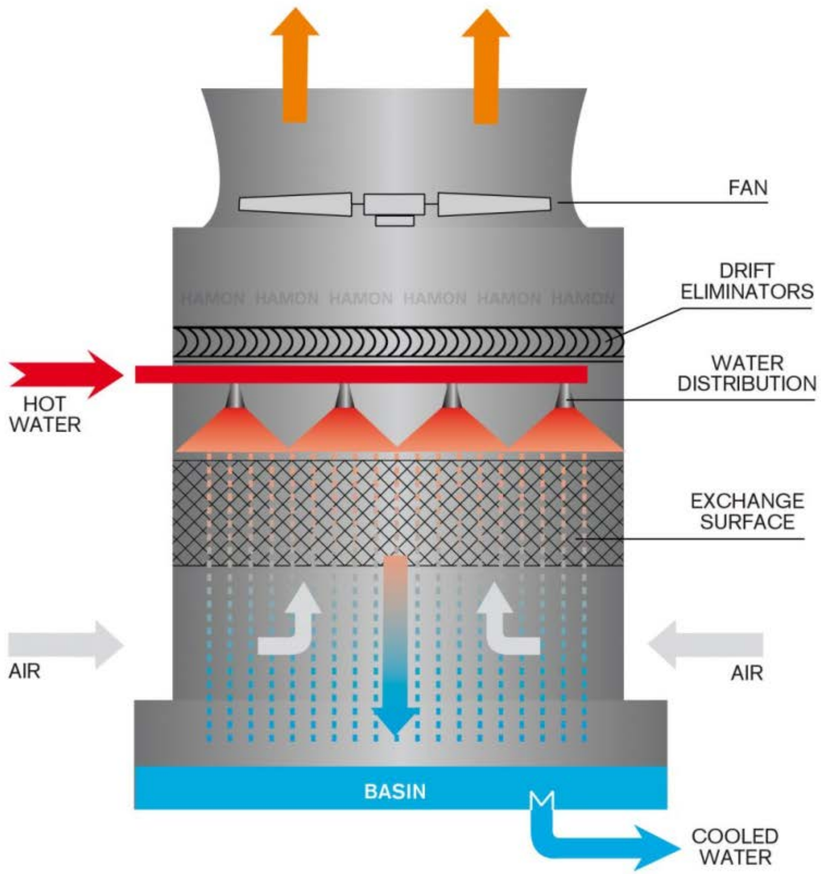
VI. Questions & Answers

Cooling Tower Technology

Cooling Tower Technology
Crossflow vs Counterflow



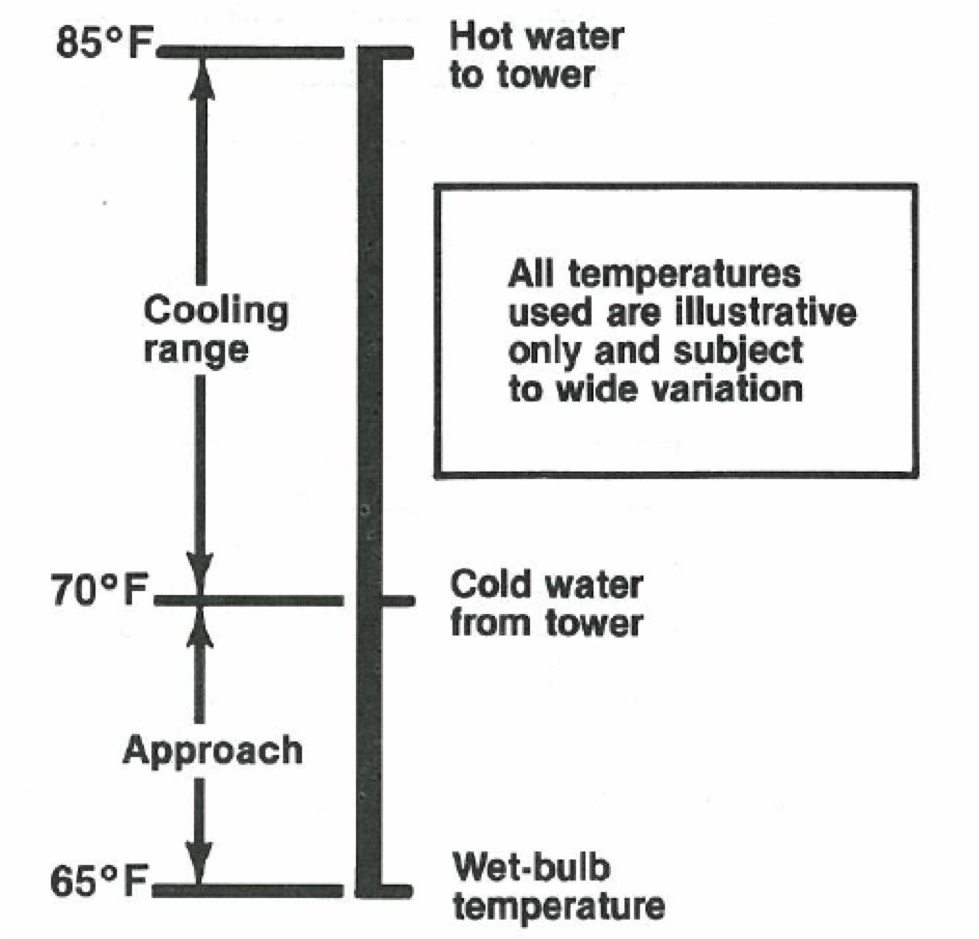
Induced Draft Counter Flow



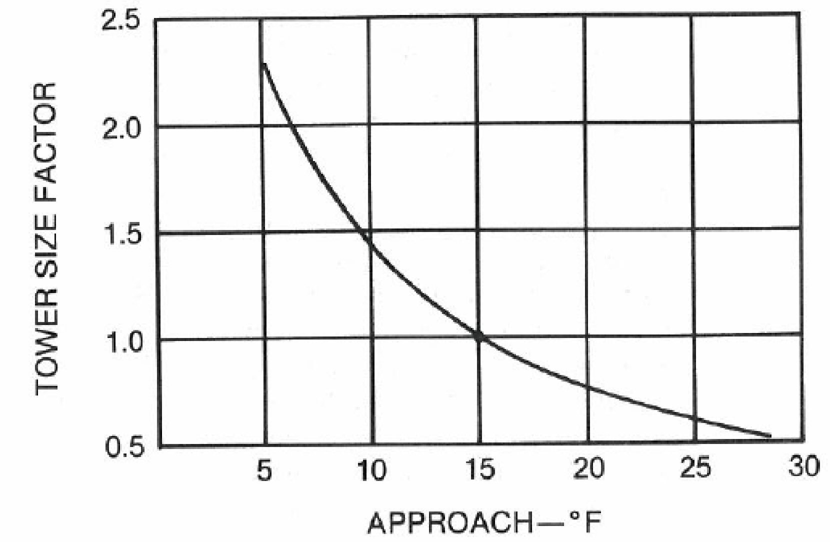
CT Technology
Crossflow vs Counterflow

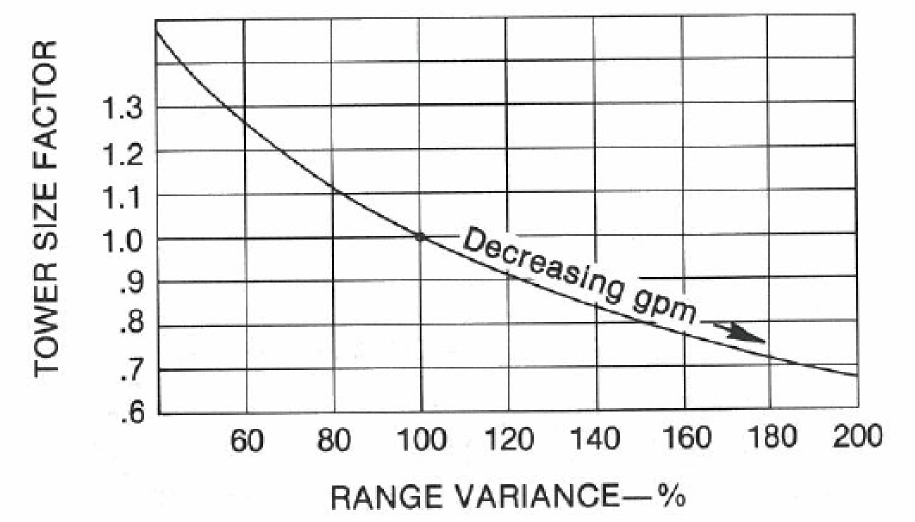
Crossflow Cooling Towers Features	Counterflow Cooling Towers Features
• Older technology	• Modern technology
• **Splash fill**	• **Film or splash fill**
• Higher pump head	• Less power consumption
• **More common in process plants**	• **More common in power plants**
• More efficient in smaller cells	• More efficient in larger cells
• **Easier access and maintenance**	• **Easier construction**

CT Technology
Design Parameters



Heat Load in BTU/hr = *GPM x* ***500*** *x Range in °F*
Heat Load in kW = *m³/h x* ***1.16*** *x Range in °C*





CT Technology
Water Losses & Makeup

$$C = \frac{E + D + B}{D + B}$$

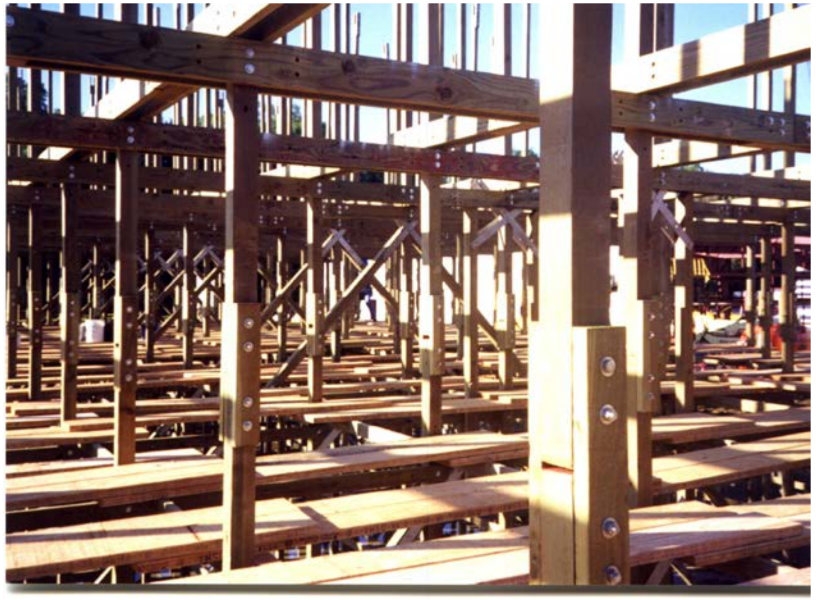
$$B = \frac{E - [(C - 1) \times D]}{(C - 1)}$$

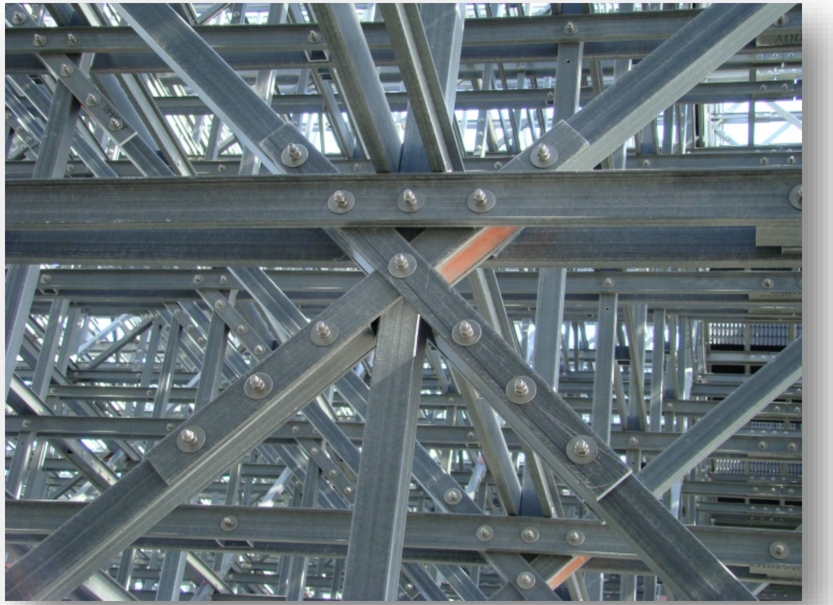
$$B \approx \frac{E + D}{(C - 1)}$$

- Evaporation = **10,000 gpm** flowrate x 25°F Range x **0.08%** = **200 gpm**
  E = 2,271.23 m^3/h x 13.89°C x **0.144%** = 45.42 m^3/h
- Drift (droplets) = 10,000 gpm x **0.005%** = **0.5 gpm**
  D = 2,271.23 m^3/h x 0.005% = 0.1136 m^3/h
- Cycles of Concentration (TDS) = 750ppm max chlorides circulating water/ 250ppm chlorides in makeup water = **3 cycles < 5 cycles (normal operation)**

- Blowdown (discharge) = {200 – [(3-1) x 0.5]}/(3-1) = **99.5 gpm**
  B = {45.42 – [(3-1) x 0.1136]}/(3-1) = 22.60 m^3/h
- Makeup water = E + D + B = 200 gpm + 0.5 gpm + 99.5 gpm = **300 gpm or 3%**
  M = 45.42 m^3/h + 0.1136 m^3/h + 22.60 m^3/h = 68.13 m^3/h

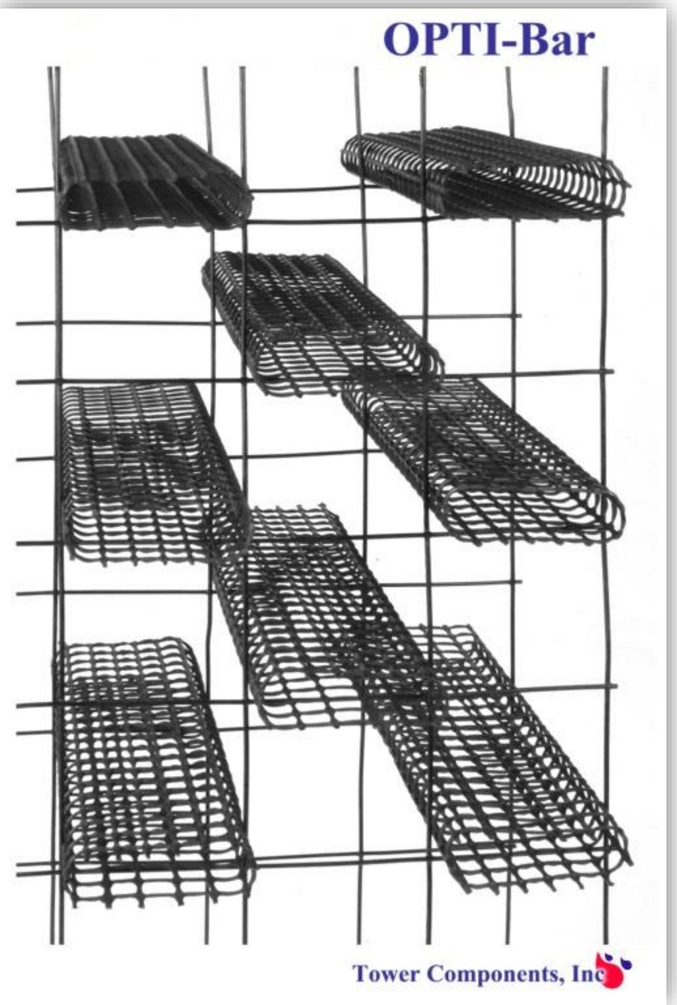
CT Technology
Components - Structure

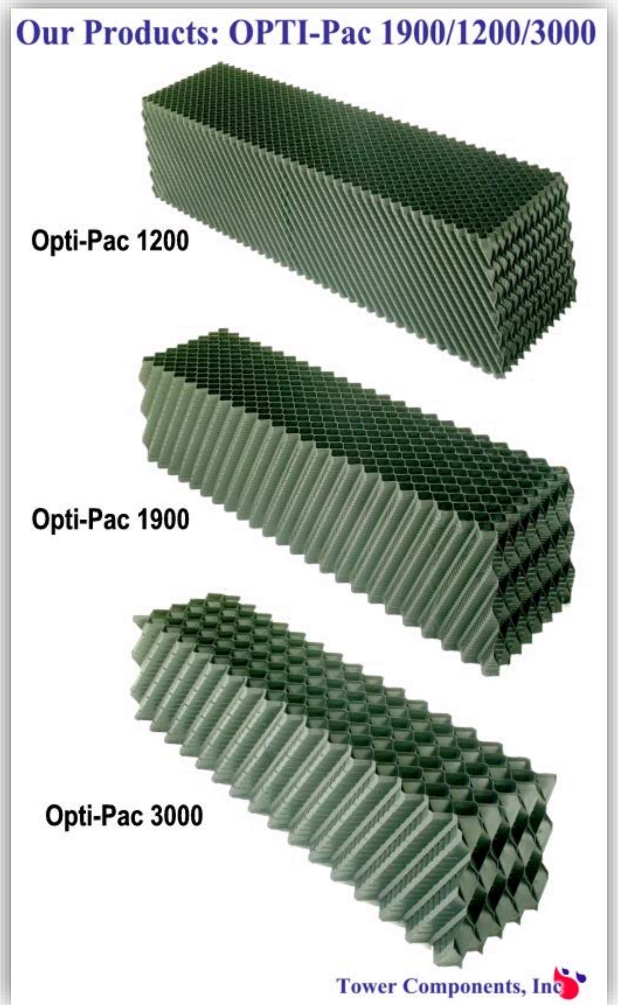


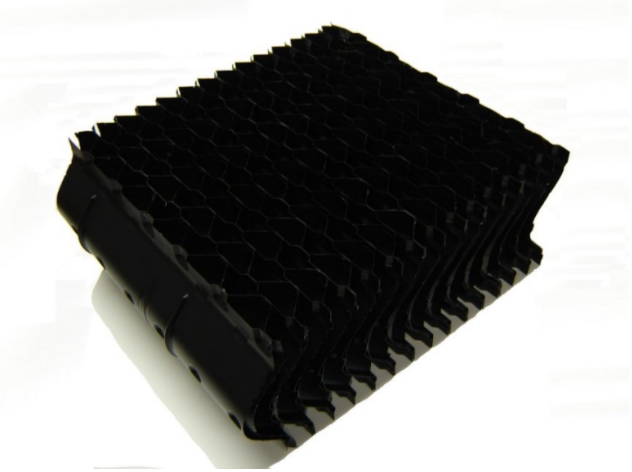


CT Technology
Components – Distribution System

CT Technology
Components - Fill & Drift Eliminators







evapco POWER

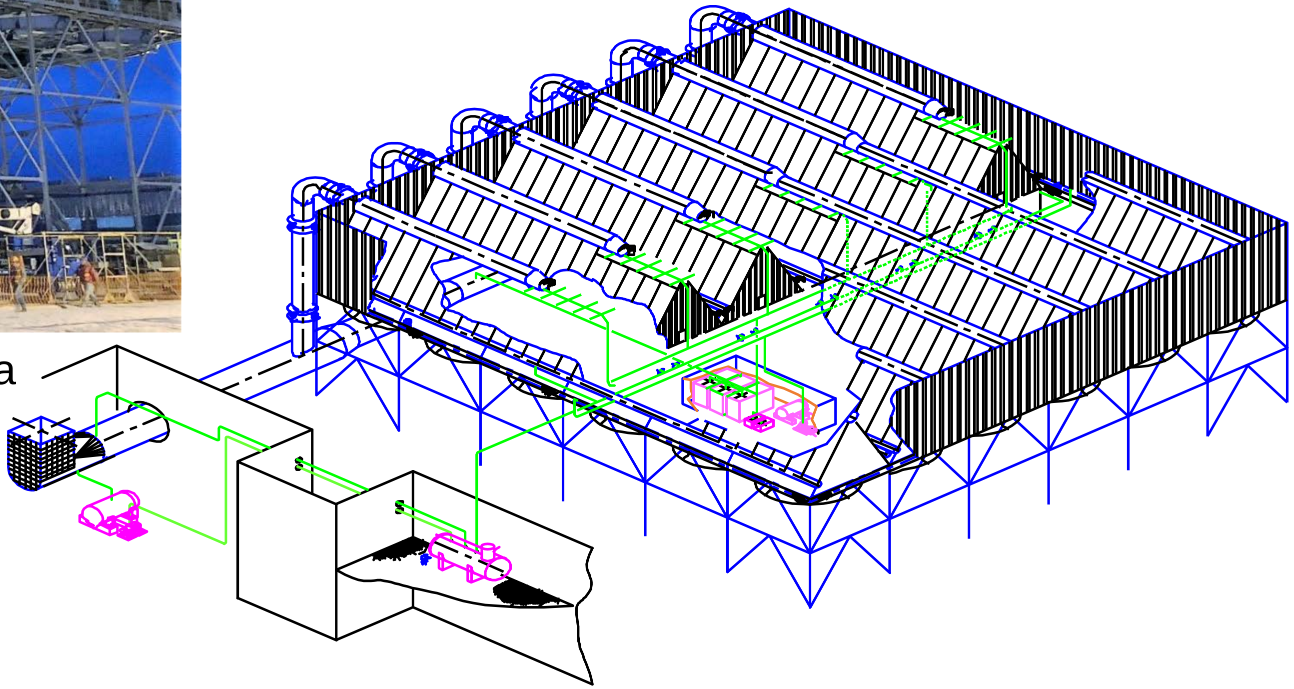
CT Technology
Components – Mechanical Equipment

iema Instituto de Energia e Meio Ambiente

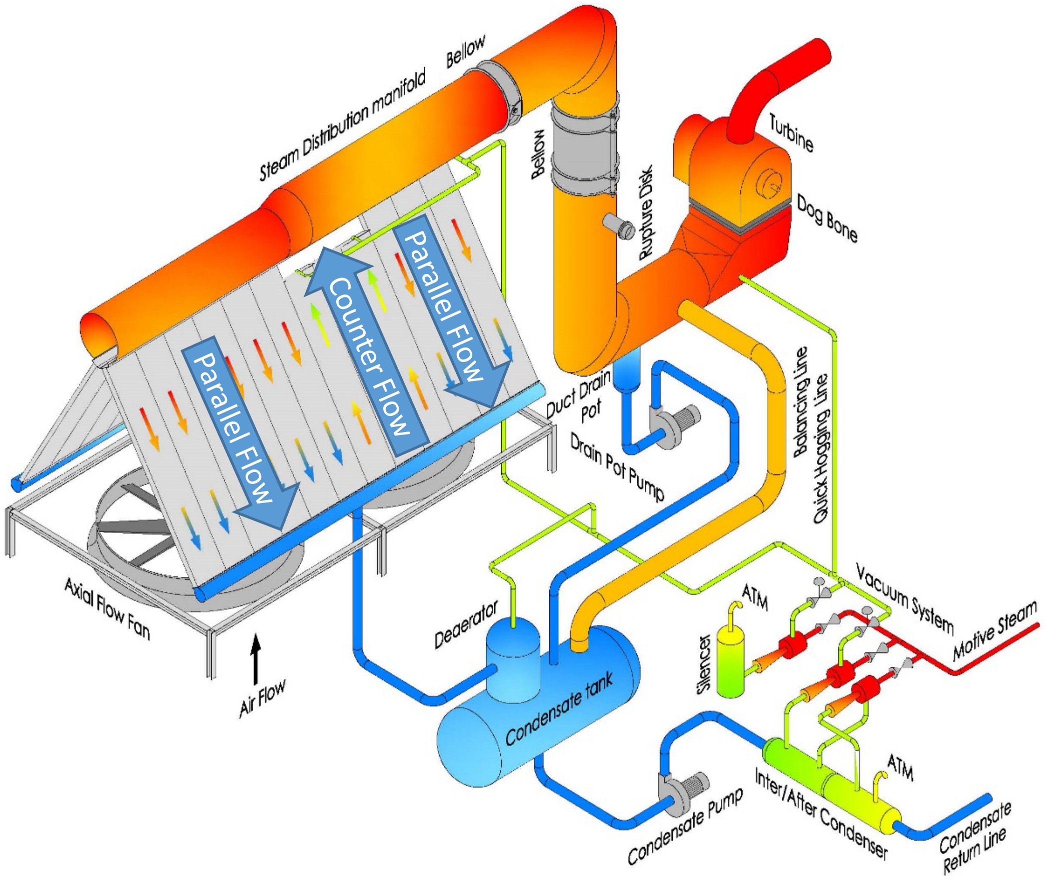
IBAMA MMA

Air Cooled Condenser Technology

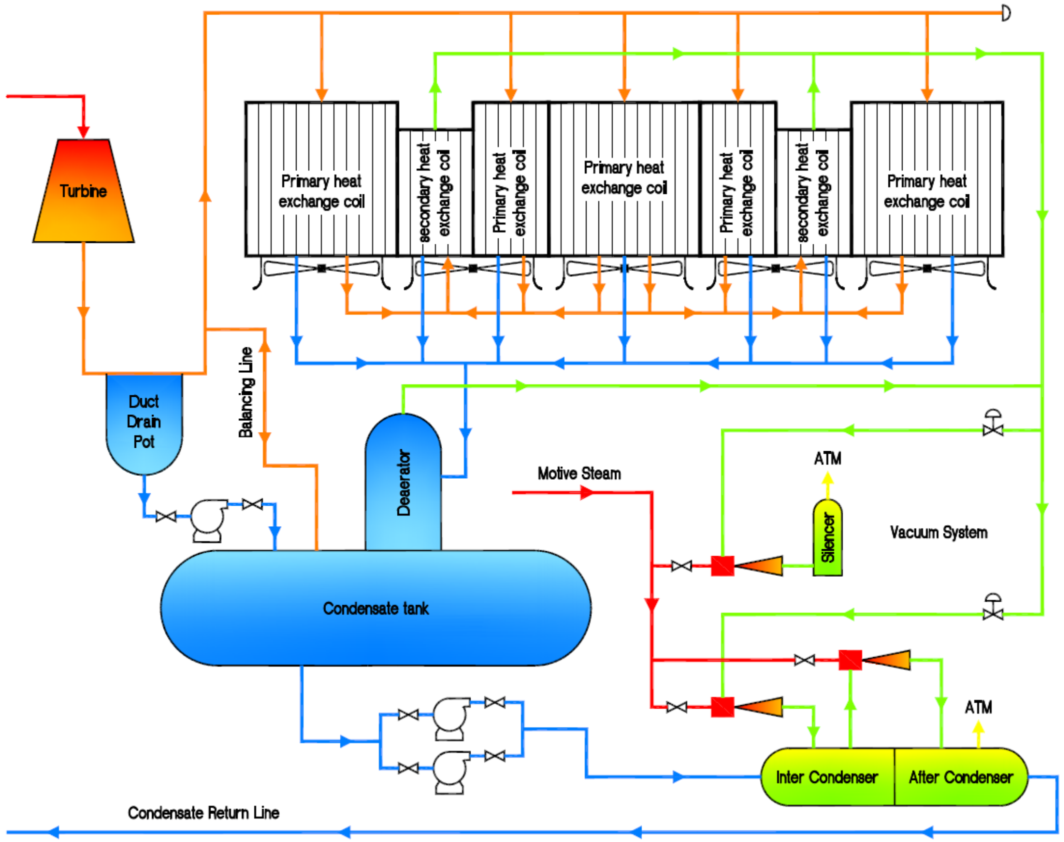
Escobedo, México. Largest ACC in Latin America
56 cells: 105m L x 96m W x 35m H



ACC Technology Basics



ACC Schematic



Process Flow Diagram

ACC Technology
Design Parameters

Minimum Design Requirements

- Steam flow rate (kg/s)
- Steam enthalpy or quality (kJ/kg, %)
- Turbine back pressure (mbara)
- Inlet dry bulb temperature (°C)
- Site altitude (masl) or
- Atmospheric Pressure (mbara)

Additional Cost Impacts

- Guaranteed wind speed (3 or 5m/s typ)
- Design Noise Level (dBA @ ___m)
- Height Restrictions
- ACC Layout (T-piece, elbows, butterfly)
- Delivery Location
- Delivery Schedule
- Construction (union or non-union)

ACC Technology
Design Parameters

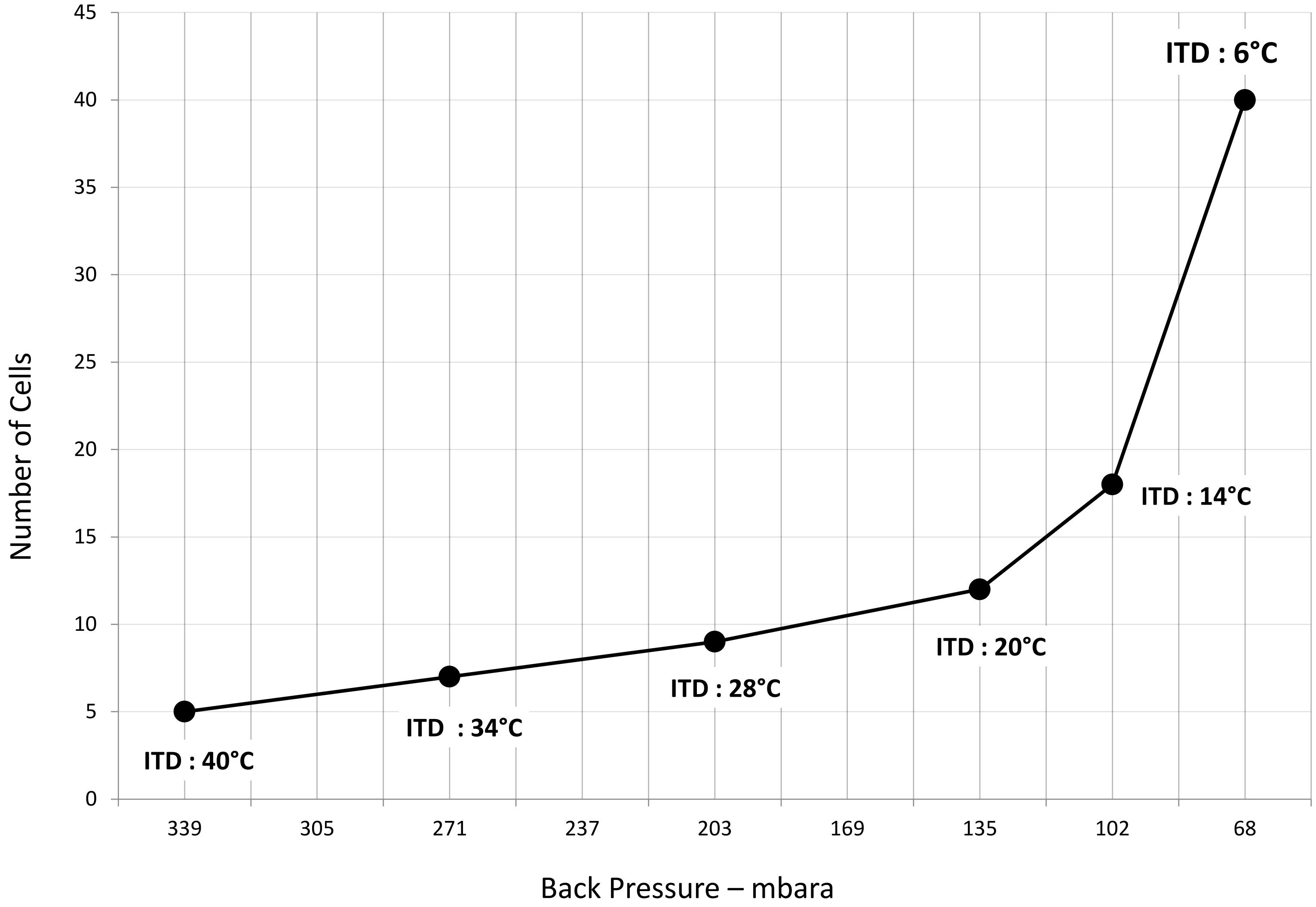
Initial Temperature Difference (ITD) is equal to the temperature of saturated steam $T_{(sat)}$ minus the dry bulb temperature of the ACC inlet air $T_{(air)}$

- ITD = T(sat) – T(air)

The specified ITD is the key driving factor in the sizing of an Air Cooled Condenser

ITD ↑ ACC Size ↓   ITD ↓ ACC Size ↑

ACC Technology
Design Parameters – 100MW Steam Cycle

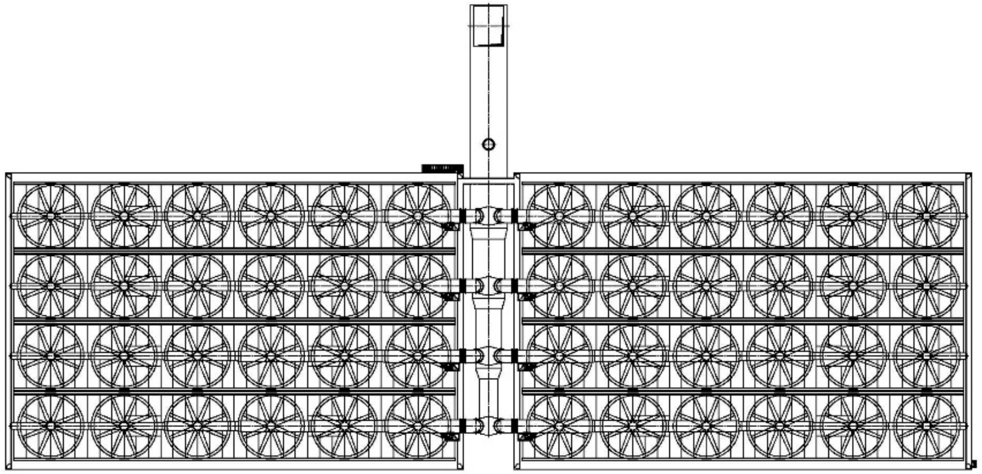


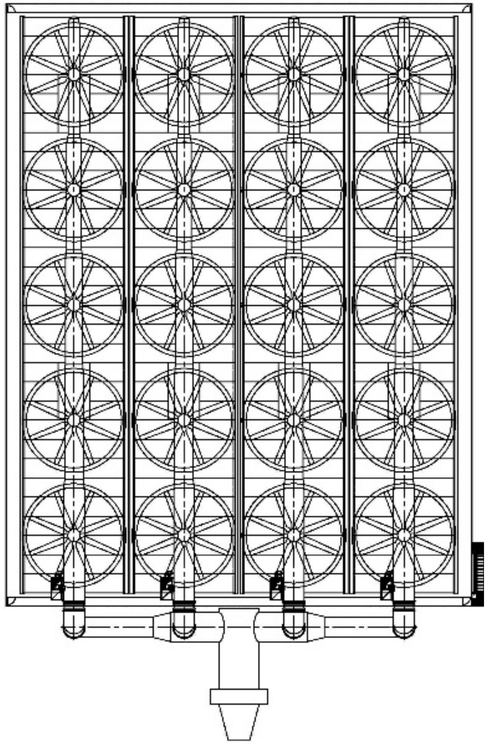
Design Conditions:

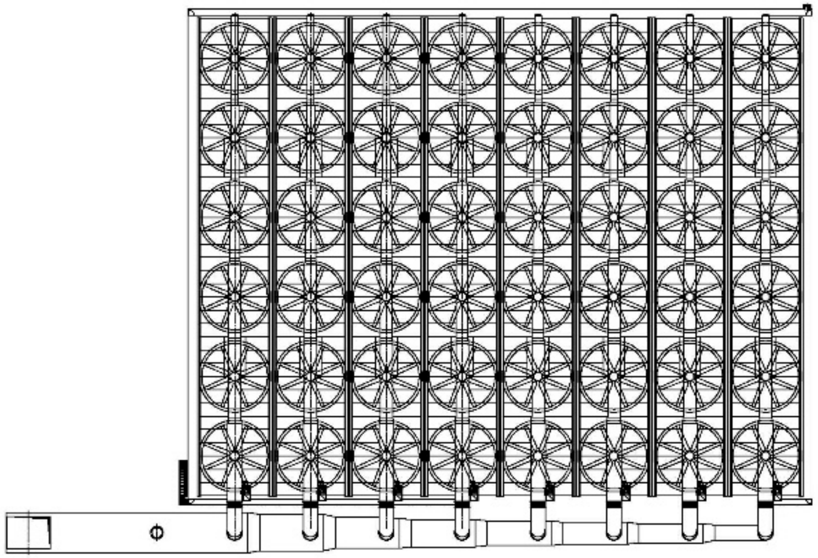
- Flow = 63 kg/s
- DBT = 32.2C
- RH = 50%
- Quality = 96%
- Elev. = sea level

ACC Technology Layouts

- Steam duct costs millions ($$$) and adds pressure losses
- “Butterfly” designs have lower capital and construction costs for large units
- Avoid elbows and ‘T’ pieces if possible; lateral ducting is better and cheaper.



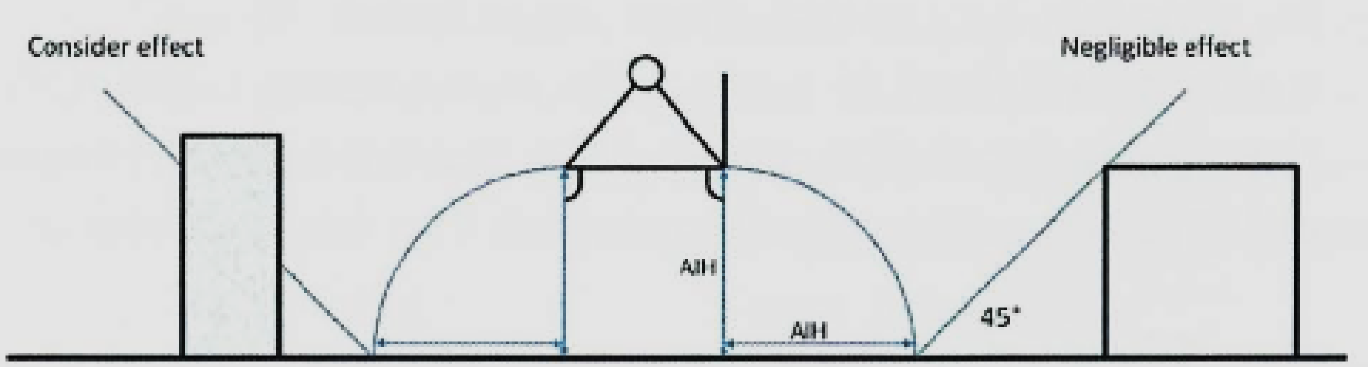


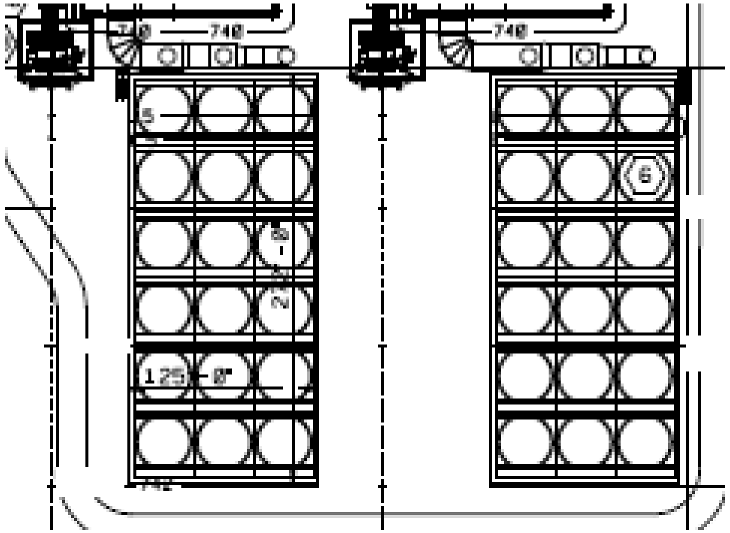


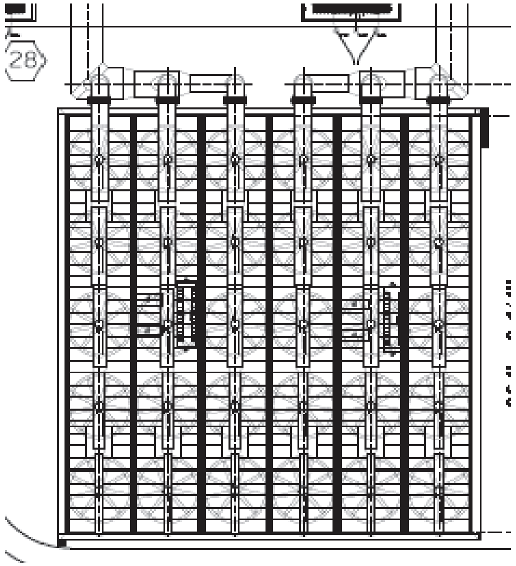
ACC Technology Layouts

Interference

- None if underneath 45° line from a distance of one AIH from air inlet
- If interference is another ACC this should be considered for each ACC, effectively doubling the distance
- In many cases it makes more sense to combine two adjacent ACCs onto one common structure

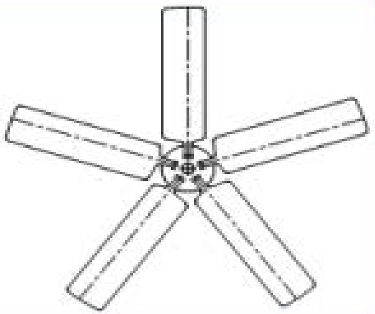
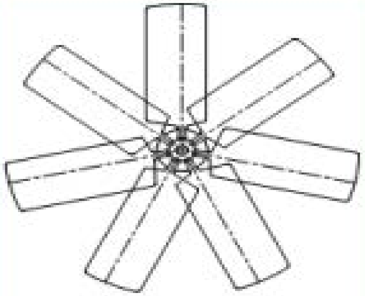
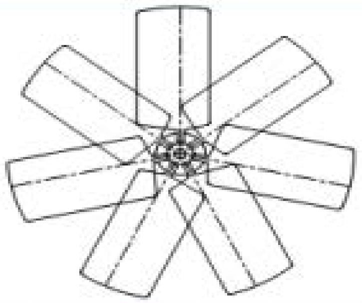
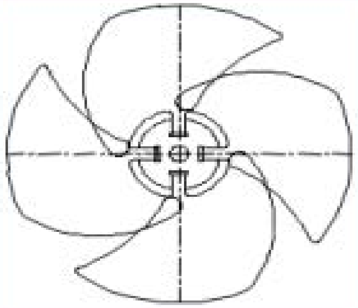






ACC Technology
Noise

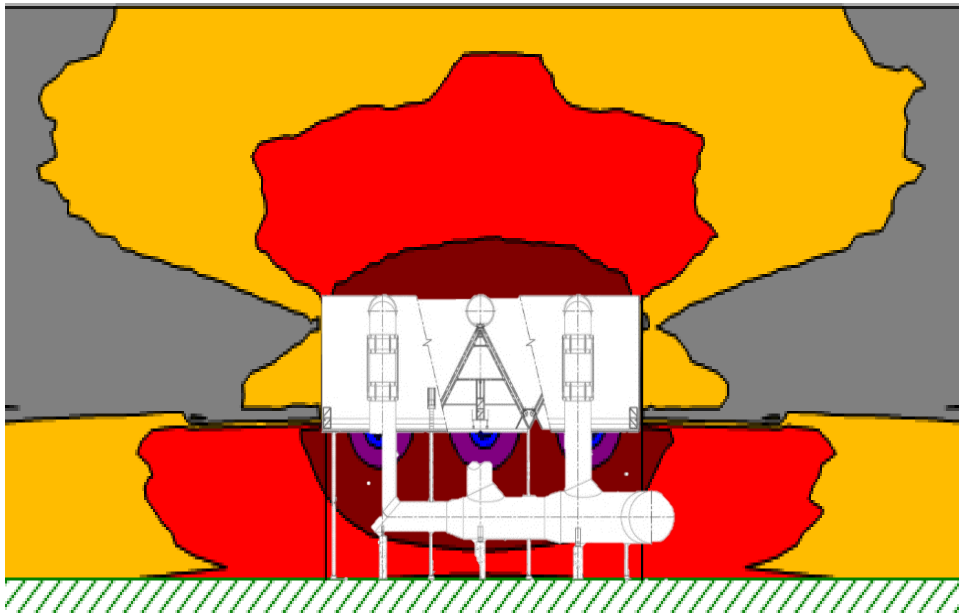
- Noise generated by the mechanical equipment at 1m:
    - Fans - 90- 110 dB(A)
    - Motors - 85-95 dB(A)
    - Gearboxes - 90 dB(A)

Shape				
Noise Classification	 Standard	 Low-noise	 Very low-noise	 Ultra low-noise
Static Efficiency	65-70%	60-65%	55-60%	50-55%
Cost	100%	130%	175%	300%

ACC Technology
Noise

Noise leaves the ACC through the air outlet and air inlet

40% Air Outlet, 60% Air Inlet



Methods of Noise Abatement:

Baffles - Intermediate Noise Abatement

- $$$
- 👍ΔP

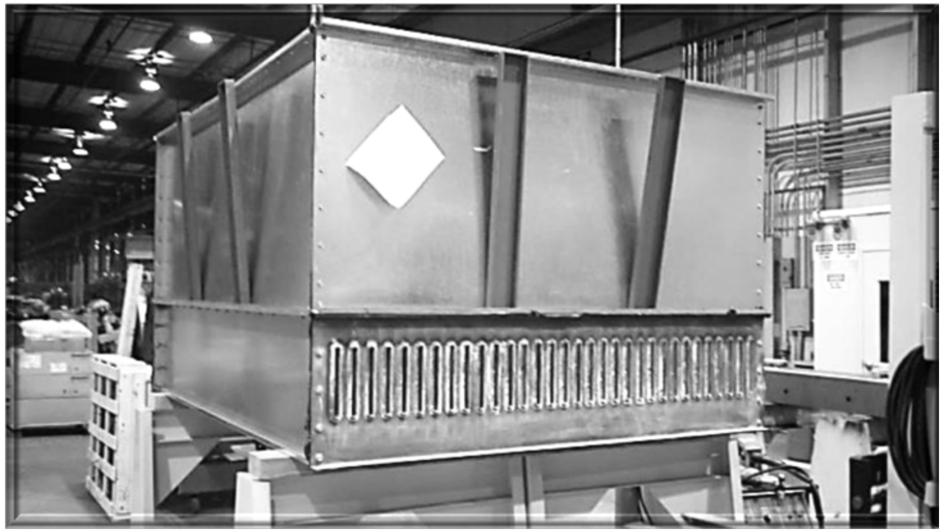
Louvers - Maximum Noise Abatement

- $$$$
- 👎ΔP

ACC Technology Research & Development

Small Scale Thermal Testing

- Heat transfer, air & steam side pressure drop, fouling factor all calculated, using 4’ x 4’ test rig
- Water used as process fluid, not saturated steam under vacuum



Full Scale Steam Laboratory

- Testing full sized 11.5 m long bundles at the installed angle
- Actual effects of 2 phase steam flow under vacuum in parallel and counter flow.

ACC Technology - Components Structure

A-Frame & Partition Walls

Motor Bridge

ACC Technology - Components
Steam Ducting

Turbine Exhaust Duct

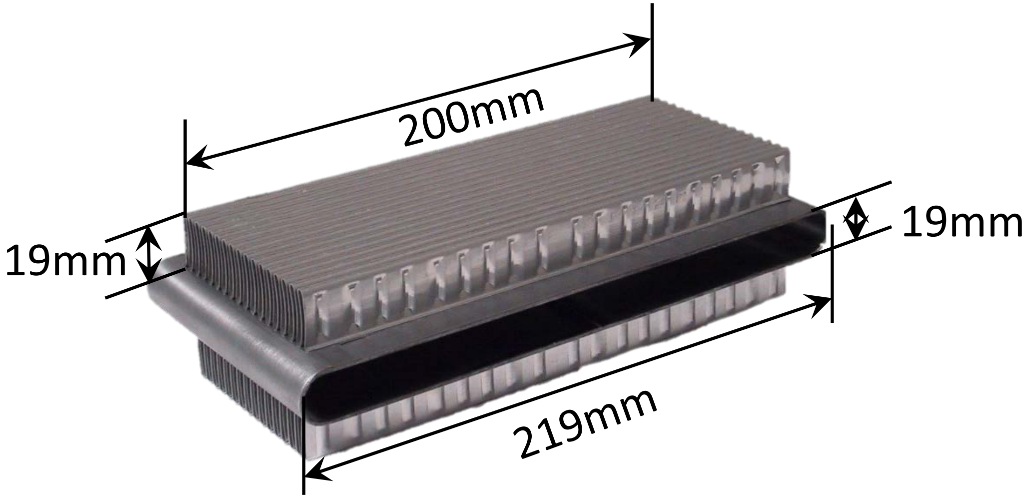
Risers

ACC Technology - Components Steam Ducting

Steam Distribution Manifold (SDM)

Condensate Collection Manifold (CCM)

ACC Technology - Components
Heat Exchanger Cores ("Tube Bundles")



Finned Tubes

HEC Lift up to A-Frame

ACC Technology - Components Mechanical Equipment

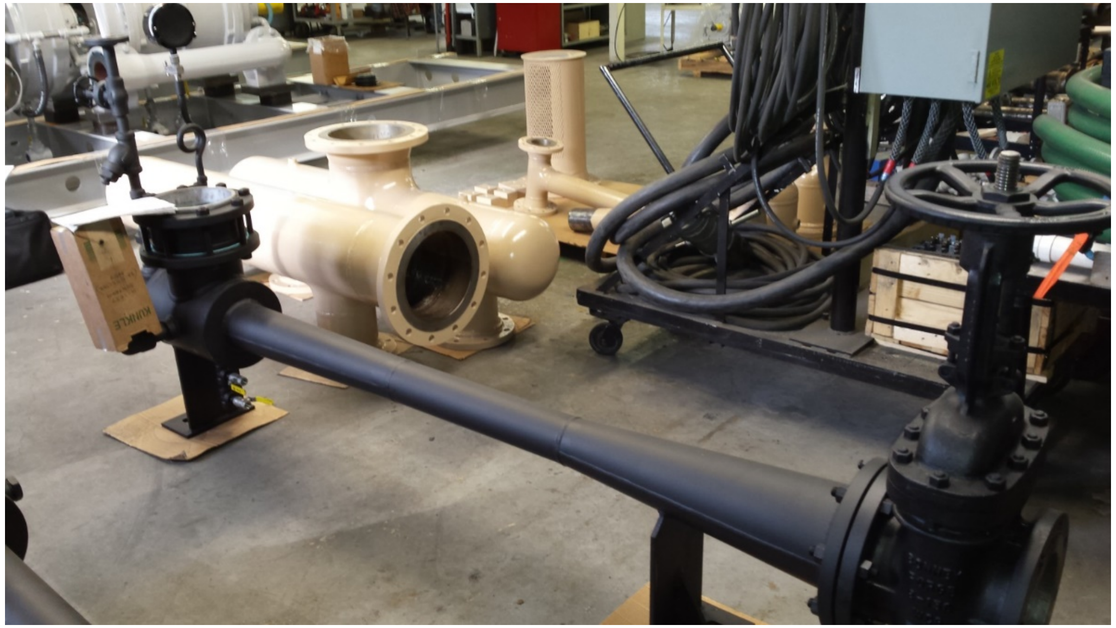
Vertical Motor & Gearbox

Fan, Fan Ring & Fan Screen

ACC Technology - Components
Condensate Tank & Deaerator

ACC Technology - Components
Vacuum System

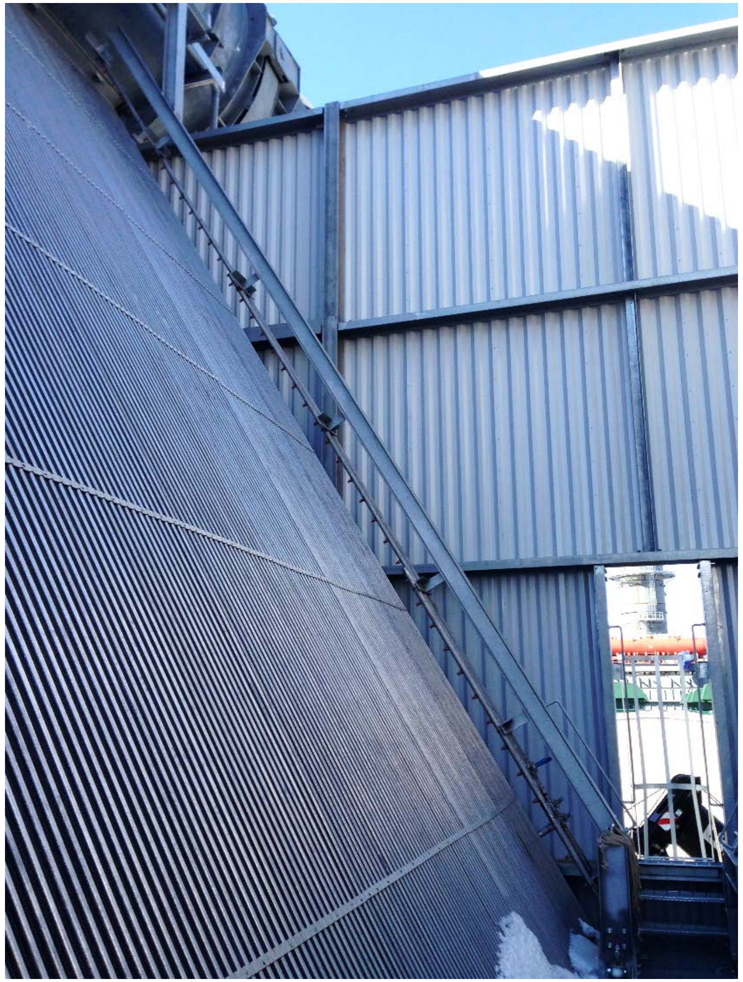
Vacuum Pumps



Steam Jet Air Ejector

ACC Technology - Components
Fin Tube Cleaning System

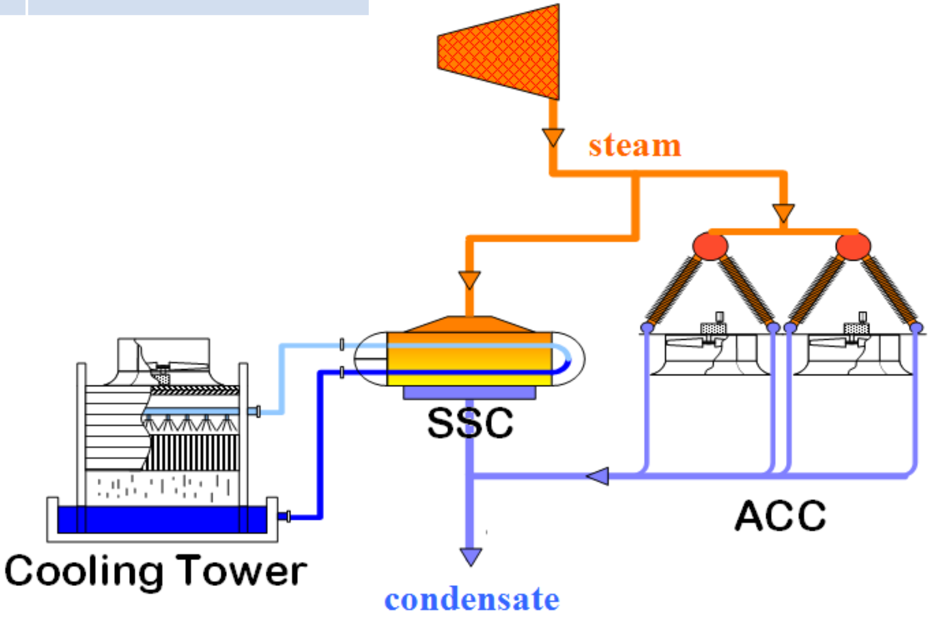
Pump Skid



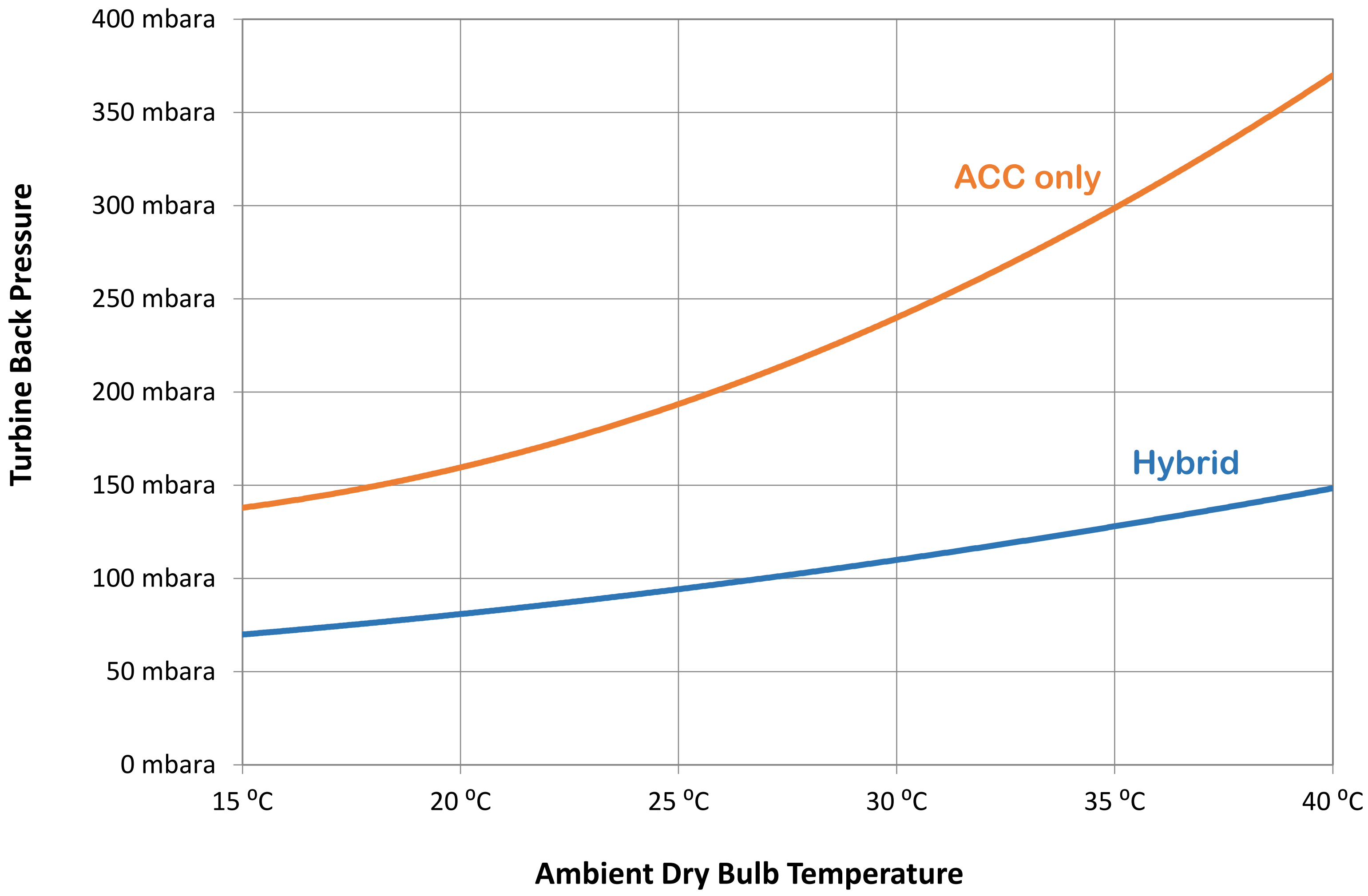
Cleaning Ladder

Hybrid Cooling Technology

Cooling System	Water Use	Cost
Dry Cooling	Zero	Higher
Wet Cooling	High	Lower
Hybrid	H_2O Available	Optimized



Hybrid Cooling Technology Performance

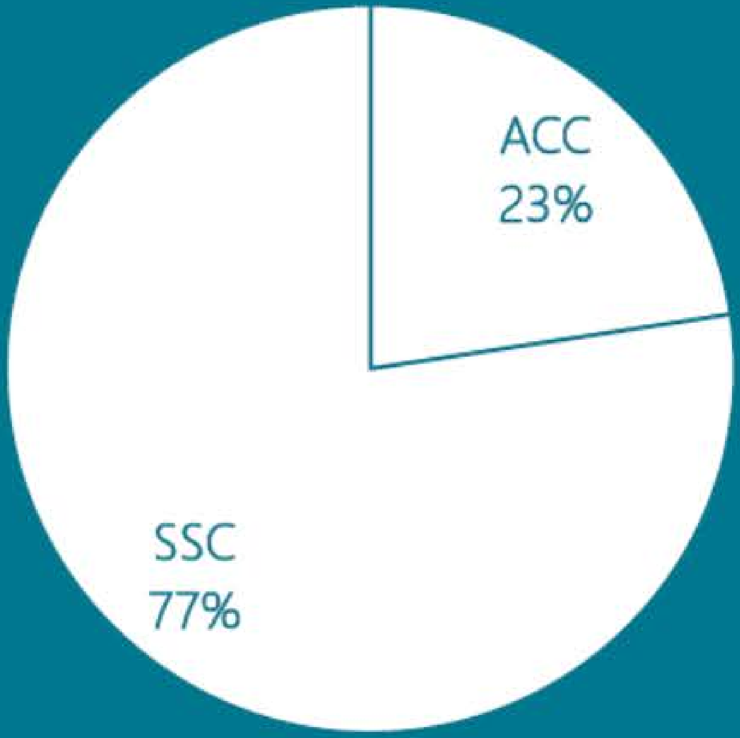


Hybrid Cooling Technology Design Parameters

- Total steam turbine exhaust Steam Flow
- Steam Enthalpy or steam quality at turbine exhaust
- Steam Turbine Exhaust Pressure
- Plant Site Elevation (or atmospheric pressure)
- Design Inlet Air Dry Bulb and Wet Bulb Temperatures
- Annual or instantaneous Makeup Water Usage limits
- Auxiliary cooling duty (& flow) to be handled by cooling tower
- Climatic data for the site (DBT and WBT)

Hybrid Cooling Technology Optimization

	ACC	SSC	MDCT	Unit
Steam or Water Flow rate	102,415	350,598	15,210,755	[pph]
Pressure	0.75	0.75	NA	[psia]
Tsat	92.35	92.354	NA	[°F]
Heat Load	26,002	89,013	89,013	[kW]
DBT	59.0	59.0	59.0	[°F]
WBT	49.7	49.7	49.7	[°F]
TTD (Tsat - Tw,Out)	NA	10.69	NA	[°F]
HWT	NA	81.66	81.66	[°F]
CWT	NA	61.66	61.66	[°F]
Approach	NA	NA	12.0	[°F]
Range	NA	NA	20.00	[°F]
Evaporation Loss	0	0	450	[gpm]
Total Water Required (make u|	0	0	563	[gpm]
			*5 cycles of concentration	



Alternative Cooling Technologies Economic Comparison (USA)

530 MWe Gas-Fired, Combined-Cycle Plant (200 MW Steam Cycle)			
Item	**Wet System**	**Dry System**	**Hybrid System**
ACC, number of cells	—	20	10
Wet tower, number of cells	8	—	5
Condenser tube area	6,800 m^2 (73,350 ft^2)	—	2,800 m^2 (30,000 ft^2)
Water consumed per year	2.5×10^7 m^3 (~2,700 ac ft)	–	1.6×10^7 m^3 (~1,700 ac ft)
Installed cost	~US$7,000,000	~US$24,000,000	~US$17,000,000

Source: EPRI

Alternative Cooling Technologies Economic Comparison (Chile)

Total Investment Cost Analysis for Cooling Systems					
Cooling System for 260 MW Coal Plant		**Once through Cooling**	**Cooling Tower**	**Cooling Pond**	**Air Cooled Condenser**
Cost of Water Intake or Withdrawal System	**Overhead Siphon**	k US$ 160- 267 per meter	k US$ 160- 267 per meter	k US$ 160- 267 per meter	$0
	Submarine System	k US$ 67 -133 per meter	k US$ 67 -133 per meter	k US$ 67 -133 per meter	$0
Installed Cooling Component Cost	**Mejillones**	N/A	M US$ 5,6 – 6,5	M US$ 7,2 - 8,7	M US$ 45,6 - 50,9
	Quintero	N/A	M US$ 5,7 – 6,7	M US$ 7,9 - 9,4	M US$ 45,6 - 50,9
	Quillota	N/A	M US$ 5,7 – 6,7	M US$ 8,7- 10,2	M US$ 58,3 - 62.2
	Coronel	N/A	M US$ 5,7 – 6,7	M US$ 6,3 - 7,8	M US$ 46,1 -51,4
Condenser Cost		18– 44 US$/m3 hr (*)	18– 44 US$/m3 hr (*)	18– 44 US$/m3 hr (*)	
Cost of pumping system		Cost of pumping system			$0
Other Significant Costs to Consider		Intake Protection System cost Water Use Permit cost, Development & Engineering Costs, Piping costs	Intake Protection System cost Water Use Permit cost, Development & Engineering Costs, Piping costs	Intake Protection System cost Water Use Permit cost, Development & Engineering Costs, Land Costs	Land Costs, Development & Engineering Costs

Source: inodú Chile

References

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- Antecedentes Técnicos, Económicos, Normativos y Ambientales de Tecnologías de Centrales Termoeléctricas y sus Sistemas de Refrigeración, Inodú Chile, 2014

Questions & Answers

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