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District Cooling Heat Rejection – the Arabian Gulf

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Once-through Sea Water or Cooling Towers with polished Treated Sewerage Effluent (TSE) make-up, will be considered for large District Cooling Plants (Western Shore of the Arabian Gulf)

- Why the Discussion
- The Chillers
- Cost of Resource
- Materials and Equipment
- Environmental Case Study

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Why the Discussion?

The future of potable water use in the region as the *normal* source for DC heat rejection make up water is being phased out

- Potable water use for heat rejection in the region is a significant strain on potable water systems
- In at least 2 GCC countries the use of potable water for the *normal* source of heat rejection for cooling systems is no longer allowed
- Many potable water providers are strongly discouraging the use of potable water for DC even when it is still allowed

Two possible alternatives are TSE and Sea Water

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The Chillers

Chiller Efficiency

- Entering Condenser Water Temperature (ECWT)
- Fouling

Materials

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Chiller Performance ECWT

Average Coastal Sea Water Temperature							Dhahran Average WB (F)
	Western Arabian Gulf Sampling						
Month	Sta 1	Sta 2	Sta 3	Sta 4	(C) Avg	(F)	
Jan	20.5	20.5	19.0	19.5	19.9	67.8	59.1
Feb	21.0	20.5	21.5	21.5	21.1	70.0	55.1
Mar	28.0	26.5	26.5	26.0	26.8	80.2	58.9
Apr	26.0	29.0	27.0	27.0	27.3	81.1	64.1
May	31.0	31.5	30.0	30.0	30.6	87.1	68.4
Jun	32.0	37.0	28.0	28.0	31.3	88.3	69.4
Jul	37.0	38.0	30.0	28.0	33.3	91.9	72.3
Aug	34.0	34.0	32.0	31.0	32.8	91.0	74.0
Sep	38.0	36.0	31.0	31.0	34.0	93.2	74.4
Oct	34.0	34.0	29.0	32.0	32.3	90.1	69.8
Nov	24.0	22.0	19.0	24.0	22.3	72.1	63.4
Dec	26.0	24.5	23.0	23.5	24.3	75.7	56.6

[1] [2]

…when it comes to chiller efficiency…

TSE out-performs Sea Water

1. *Mangrove Investigations Vol. IV*
2. *BIN data Dhahran (MIL) SD, WMO No. 404160*

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Chiller Performance

Fouling

- Fouling for sea water is far greater than polished TSE even when occasional sand storms are taken into account
- Sea water requires more frequent cleaning and maintenance to keep heat exchangers clean and chiller performance high

Materials

- Sea water requires titanium or other expensive heat exchange surfaces
- No special materials required for TSE once polished

…when it comes to chiller fouling and materials…

TSE Cooling Towers out performs Sea Water

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Cost of the Resource

TSE

- Cost of operating the RO polishing system
- TSE costs $1.363 per 1,000 gals (AED1.32/m^3) in Dubai as of 2012, about one fifth the price of potable water[3]
- Other GCC countries are following Dubai's lead as TSE use grows

Sea Water

- It's still free

…as a commodity…

Sea Water out performs TSE

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Materials and Equipment

Piping Size

- Once though Sea Water will require a greater diameter
- TSE piping will typically be supplied by the TSE utility
- Similar piping materials required (GRP, HDPE, et al.)

Cooling Towers vs Sea Water Intakes

- Cooling towers less expensive than sea water intakes
- Sea Water intake pumps will consume more power than CT fans

…for initial investment and power use…

TSE is less expensive than Sea Water

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Environmental Case Study

Once-through Sea Water heat rejection for District Cooling

- Western coast of the Arabian Gulf
- TR DC plant located on an ~ 2km x 1 km bay
- 40,000 TR and 70,000 TR plants at opposites sides of bay

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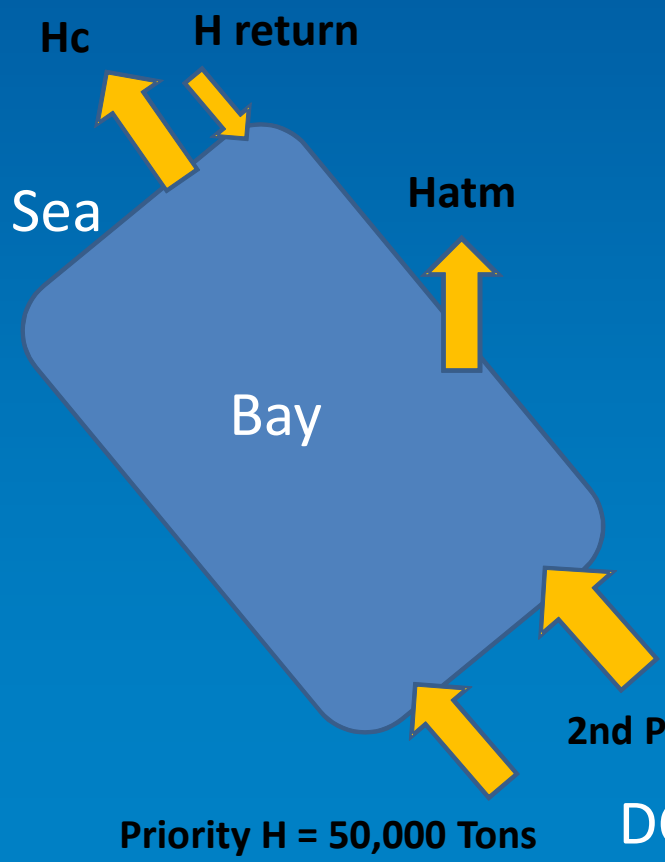
- Schematic heat Budget



Can heated seawater from once-through district cooling be safely discharged back to the bay? Local regulations state:

- Bay temperature cannot increase more than 2 C
- Outfall cannot be 10 C greater than intake

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X = distance from the SE end of the bay

T(X) = Temperature of the Bay at any X

T = Discharge Temperature of DCP

Ta = Ambient Gulf Temperature

Upstream Boundary Condition

At the SE end of the Bay, where heated water would be discharged:

$$(T - Ta)_{se} > 15 \text{ F degrees} = 8.33 \text{ C degrees}$$

(Use as "$(T - Ta)_{se}$ = 8.33 C degrees", realizing the actual (T – Ta) will be greater than thus predicted.)

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Downstream Boundary Condition

R*B*Xc = delta volume of Bay per tide cycle x (Cp)

Where R = tide range, B = Bay width, Xc = Bay length

At the NW end of the Bay (channels to the sea), the tidal heat export rate is

$$Hc < (T - Ta)*R*B*Xc$$

(Use as "Hc = (T – Ta)*R*B*Xc", again realizing that the actual (T – Ta) will be greater than thus predicted.)

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A pair of diffusion equations in difference form were integrated numerically from the sea (X = Xc) back to the discharge points (X = 1):

$$\Delta(T - Ta)/\Delta X = -H(X)/(Ko*X*B*D)$$ *[tidal flushing]*

and

$$\Delta H(X)/\Delta X = -k*B*(T - Ta)$$ *[heat to atmosphere]*

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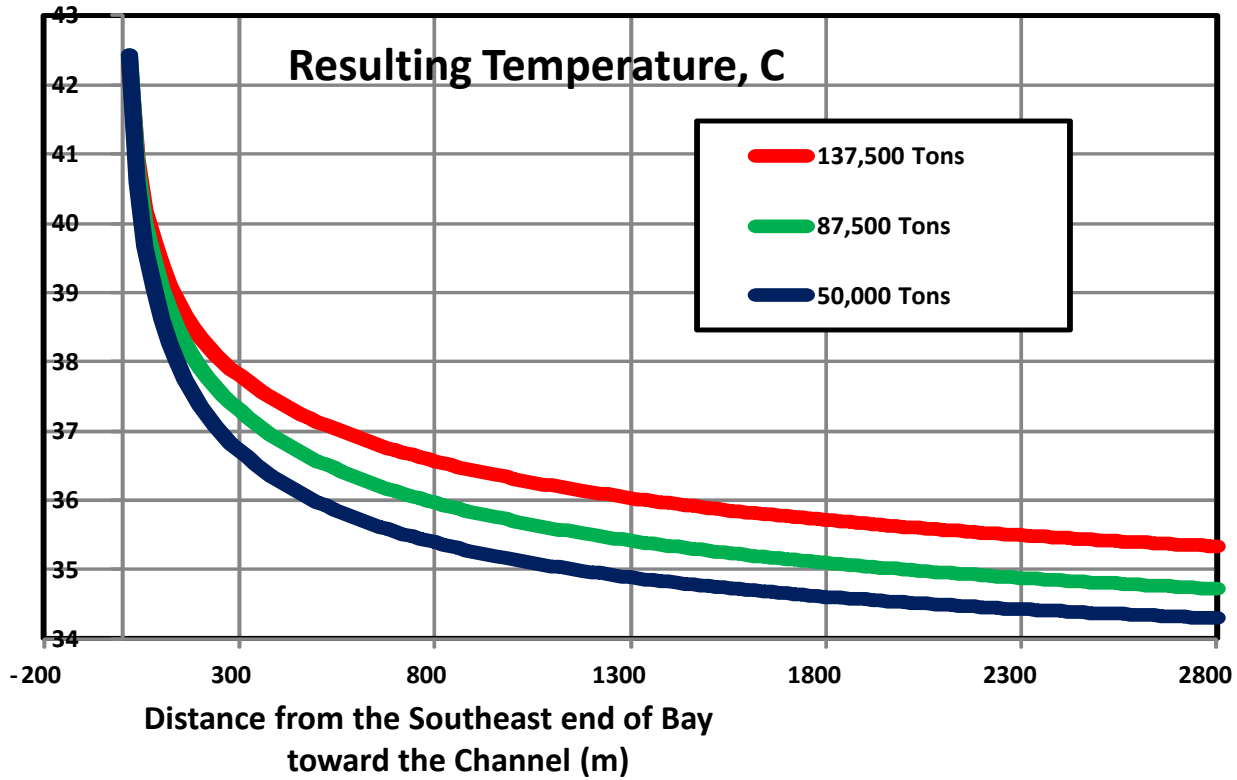
Resulting Temperature, C, if the ambient temperature in the Gulf is 34 C (mean for July)



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Assumption No. 1

- Tidal export of heat to sea via the channel will be “perfect”, i.e.; no water warmer than background will return on the flood tide
- *Yet realistically, export will be imperfect, water warmer than Ta will enter on the flood*
- Thus temperature curves would be somewhat higher than shown

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Assumption No. 2

- The maximum temperature at the discharge points will be 15 F degrees = 8.33 C degrees warmer than the ambient sea temperature, Ta
- *This will be true only if water is taken in directly from the sea, at temperature Ta*
- Water taken in from the Bay will be warmer than Ta, thus discharge temperature will be greater than Ta + 8.33 C
- *Again the curves would be higher than shown*

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Simplifying assumptions mask realities that would raise the figure's curves to higher values than shown. Therefore we may infer that in July, water temperature will:

- Not meet the regulatory requirement of no more than 2 C rise in bay temp
- Accelerate algal blooms due to elevated biochemical reaction rates
- Depress DO due to the algal blooms
- Depress the DO saturation concentration
- Exceed human body temperature

For this project, once-through Sea Water heat rejection was not feasible for environmental reasons

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Thank You