Condenser Design for the Proposed AM600 NPP

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Introduction

Analysis of global electric markets shows that the electrical grid size of many developing countries (e.g., Bangladesh, Kenya, Vietnam, Egypt) is too small or too distributed to accommodate Nuclear Power Plants (NPP) with large unit sizes (e.g., >1000 MWe).

Thus a modern NPP design with a smaller output (~600 MWe) is of interest. The 'AM600' represents the Balance of Plant (BOP) turbine cycle for such a unit.

The design goals are to make the condenser more robust and compact with a reduced component count.

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General Description of a Surface Condenser

A steam surface condenser is a type of heat exchanger in which vapors are converted into the liquid state by removal of latent heat via condensation on water filled tube surfaces. Such condensers are typically designed with one or two passes.

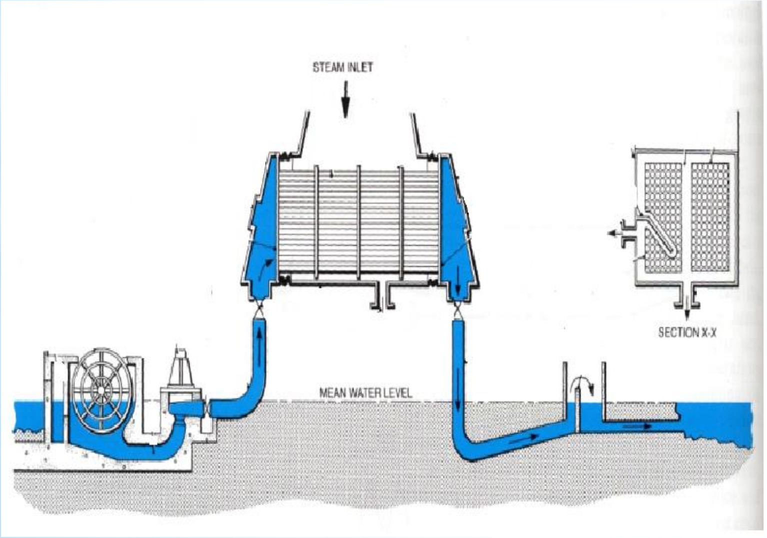

Fig. 1. Steam surface condenser – once through

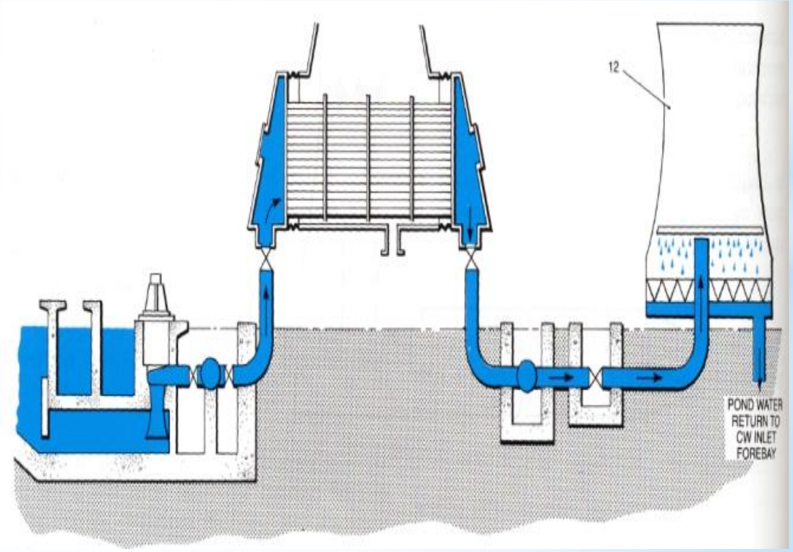

Fig. 2. Steam surface condenser – closed loop

Design Background

The minimum heat sink temperature for potentially emergent nuclear countries is on the order of 21^{o}C or higher (2-3 in HgA).

With these boundary conditions, the AM600 condenser duty can be met with a single pressure zone design with a total of eight titanium tube bundles divided into four isolable sections.

All drains and bypass steam to be fed into an extended flash chamber, reducing hotwell flow and allowing for isolation of individual sections of the condenser in the event of a tube leak.

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Important Design Items

Tube Material Selection and Sizing

Selection of condenser tube material represents a critical design decision.

Material impacts not only heat transfer, fouling, and long term reliability but it also can become a root cause of steam generator degradation.

Failure Mechanism	Admiralty	Aluminm Brass	90-10 Cu-Ni	70-30 Cu-Ni	Stainless Steel	Ti
General Corrosion	2	3	4	4	5	6
Erosion-Corrosion	2	2	4	5	6	6
Pitting (operating)	4	4	6	5	4	6
Pitting (stagnant)	2	2	5	4	1	6
High water velocity	3	3	4	5	6	6
Inlet end erosion	2	2	3	4	6	6
Steam erosion	2	2	3	4	6	6
Stress corrosion	1	1	6	5	1	6
Chloride attack	3	5	6	5	1	6
Ammonia attack	2	2	4	5	6	6

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Standard design tube velocity of 7-ft/sec for Ti tubes and a tube length of 40-ft, for a two-pass condenser.

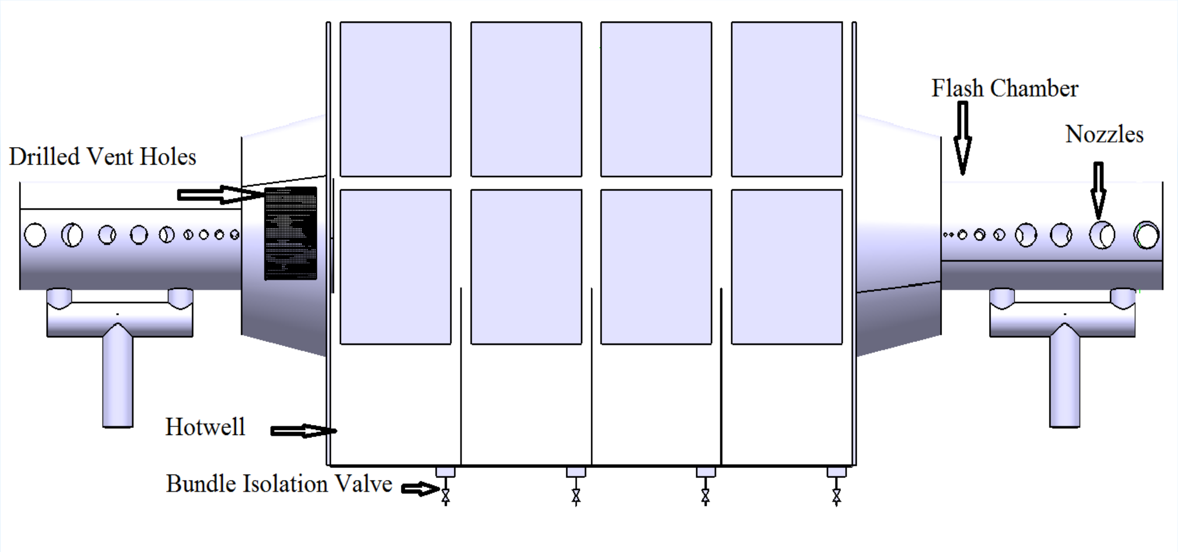
Tube OD (in)	CW Flow (kgpm)	No of Tubes	CW Inlet (˚C)	BP (in-HgA)
1	350	44,500	29	3
1.125	370	37,000	29	3
1.25	400	32,000	29	3

For the AM600 design here, a tube diameter of 1.25-in is selected to minimize upfront capital cost and also to minimize the chances for fouling and plugging of tubes.

Hotwell Design and Leak Detection

The hotwell of a condenser is designed to collect the condensed steam. The AM600 hotwell is divided into four sections.

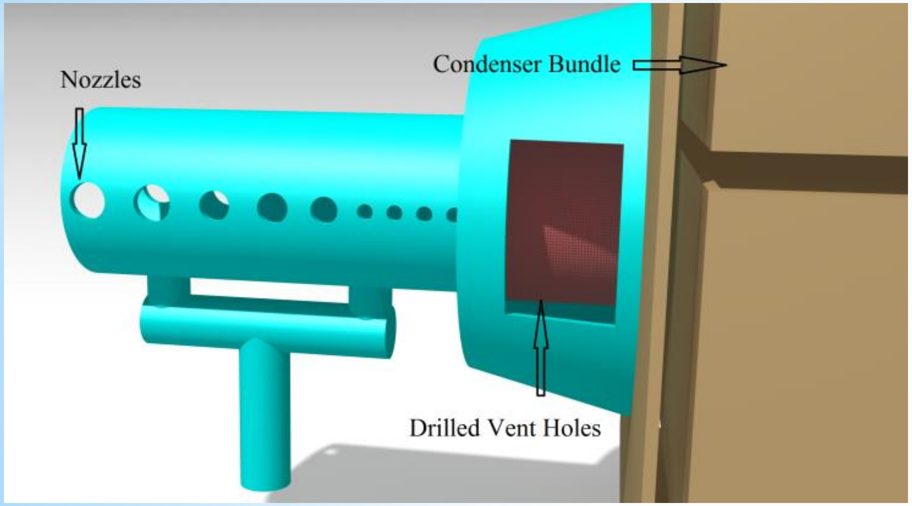
Each section is independently monitored for tube leaks (i.e., chlorides) and can be isolated on such an indication.

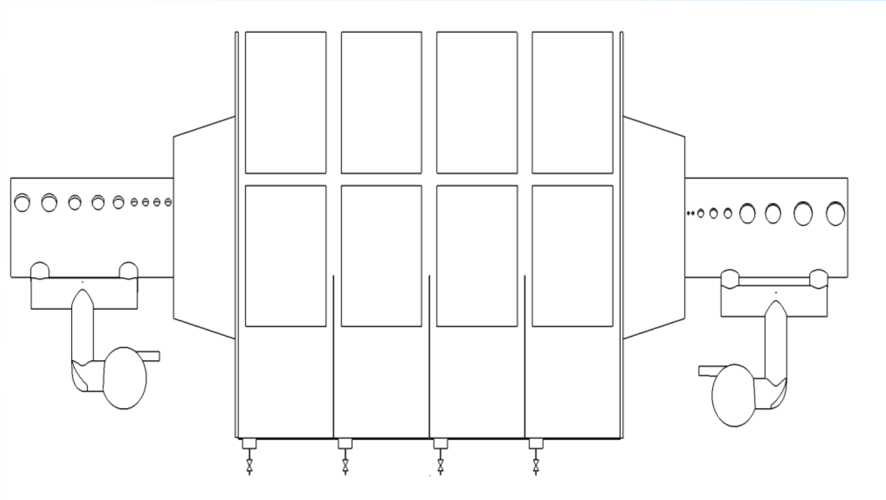


Flash Chamber Design

All the drains, vents, bypasses, and dumps from various services within the turbine cycle are routed to these chambers.

Flashed steam is routed to the condenser bundles through a large sparger and the liquid is then routed directly to the suction header for the CDPs, bypassing the main condenser sections.





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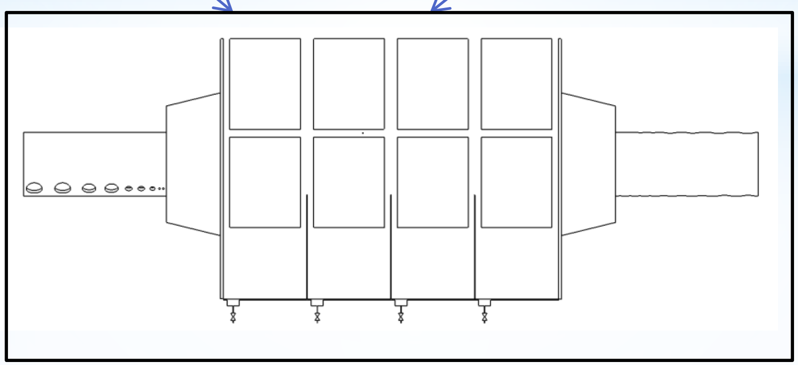
2 shell

3 shell



Single shell

AM 600

This will result in the following advantages:

- simplified fabrication with improved design for nozzle reinforcement
- simplified erection
- reduced component counts, including a reduced number of impingement plates and spargers
- reduced potential for high velocity steam flows due to these sources
- ability to isolate condenser zones in the event of a tube leak
- reduced potential for subcooling (i.e., slight potential for superheat in 1st point heater drains flow to condensate pumps)
- improved flow distribution to condensate pump suction header, and
- simplified access, maintenance, and inspections.

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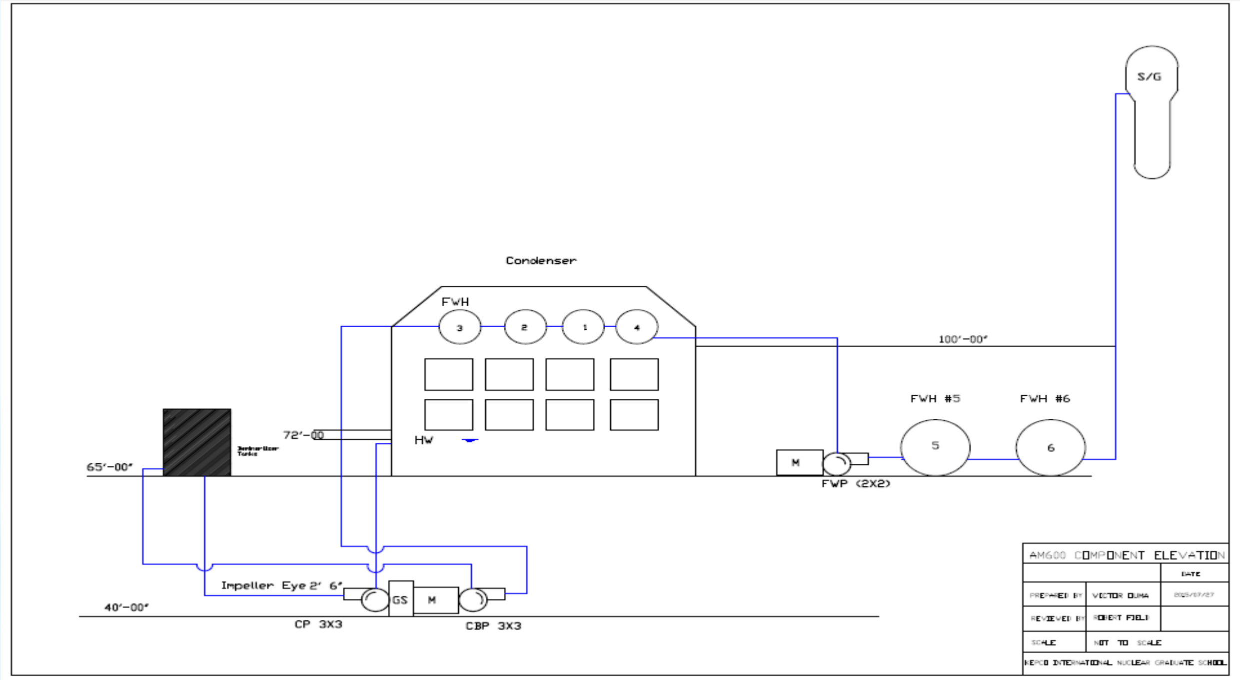
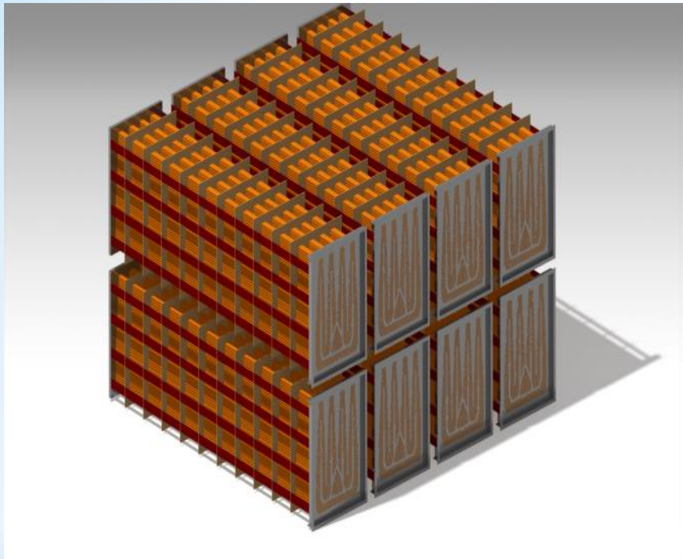
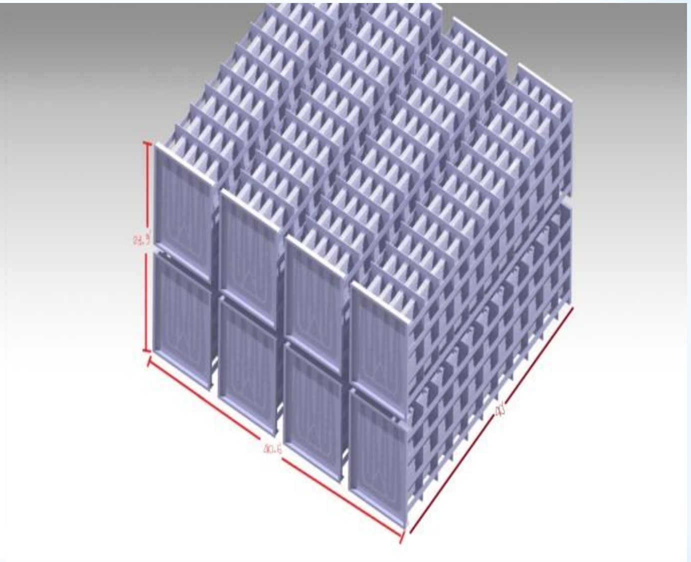
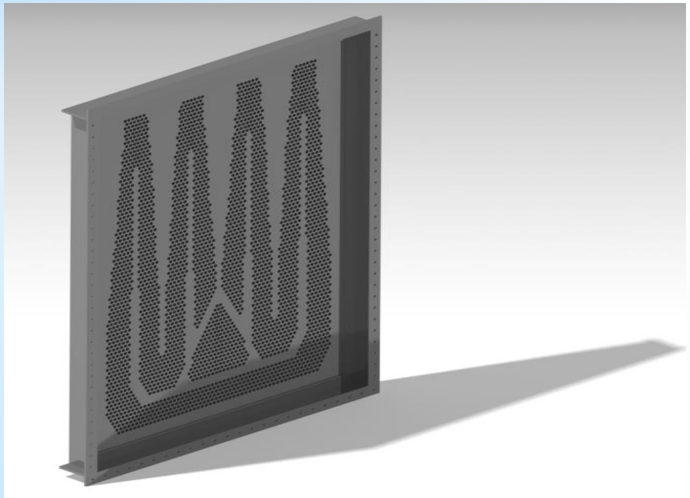
Physical Arrangement

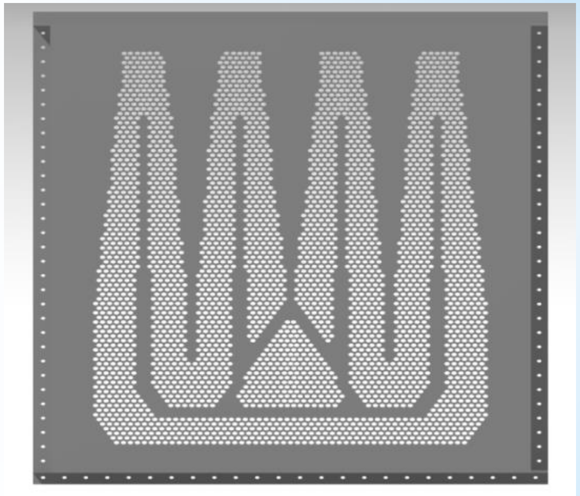


Condenser Tube Bundles and Tube Sheet









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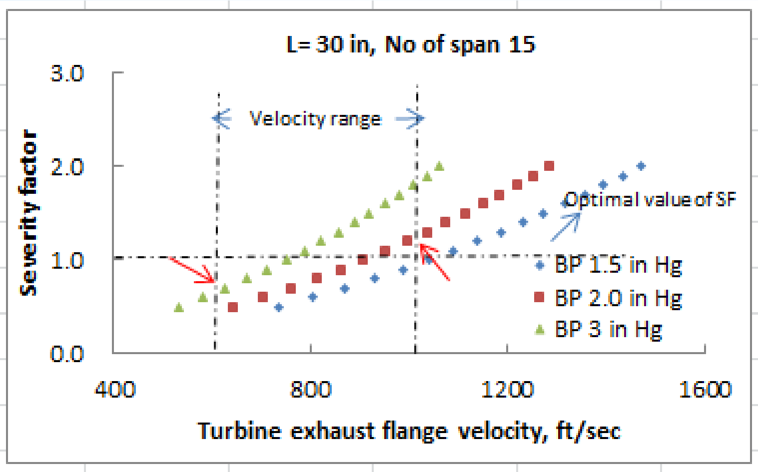
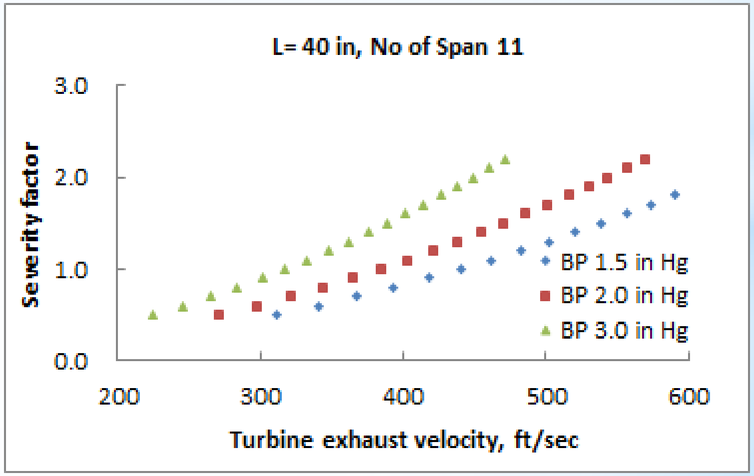
Support Plate Spacing

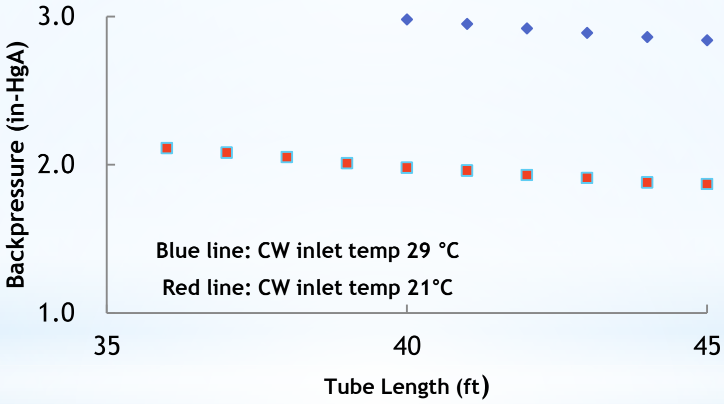
The specification for support plate spacing requires tube vibration analysis. Support plate spacing is based on an enveloping value from analysis using several distinct methodologies.

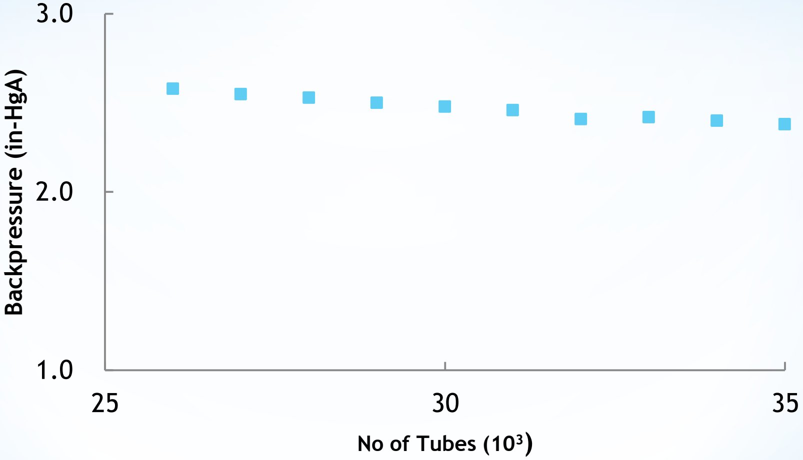




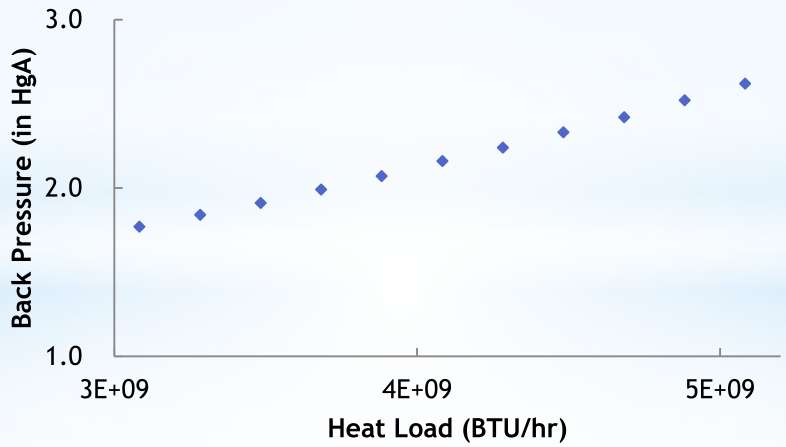
Back Pressure Analysis

Condenser backpressure plays a key important role in determining the efficiency of the plant





Following figure illustrate the functional dependence of backpressure for a variation in heat load.



AM600 Condenser Design Parameters

Parameters	Unit	Value	
No of Passes	(-)	Two	
Backpressure Ranges	(in-HgA)	1.5 - 3.0	
Circulating Water (CW) Inlet Temp Range1	(^{o}F / ^{o}C)	70 - 86	21 - 30
CW Volumetric Flow Rate	(kgpm / m^3/hr)	400	90.8
Tube Material	(-)	Ti	
Tube OD	(in)	1.250	
Tube Wall	BWG	24	
Tube Wall Thickness	(in)	0.022	
Total Number of Tubes - All Passes	(-)	32,000	
Active Tube Length	(ft / m)	40	12.2
Total Surface Area	(ft^2 / m^2)	418,880	38,915
Tube Velocity	(ft/s / m/s)	7.02	2.14
Uncorrected Heat Transfer Coefficient	(BTU/ft^{2}-^{o}F-hr)	695.4	
Inlet Water Correction Factor	(-)	1.034	
Tube Material and Gauge Correction Factor	(-)	0.85	
Cleanliness Factor	(-)	0.55	
Overall Heat Transfer Coefficient	(BTU/ft^{2}-^{o}F-hr)	517.0	
Condenser Heat Load (Summer)	(BTU/hr)	4.083×10^9	
Span Length for S=1 and Velocity 1039	in	30 (Peake et.al)	
Span Length for S=1 and Velocity 1039	in	28.3 (Coit. et.al)	

Conclusion

A smaller size NPP may be more suitable to meet growing demands for electricity in developing countries.

From analysis of heat sink temperatures for target countries along with other factors, the AM600 condenser is designed with a single cell, two pass with 8 bundles.

The single shell design of this condenser then allows for an innovative design feature, namely the extended flash chambers. This permits the routing of dump, drain, vent, and bypass flows directly to these chambers, bypassing the condenser shell.

Within the condenser shell, this design eliminates impingement plates, impingement boxes, and spargers.

The extended flash chamber approach also has a number of other advantages as delineated above. These relate to cost, simplicity, reduced inspections, and robust design.

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Thank You