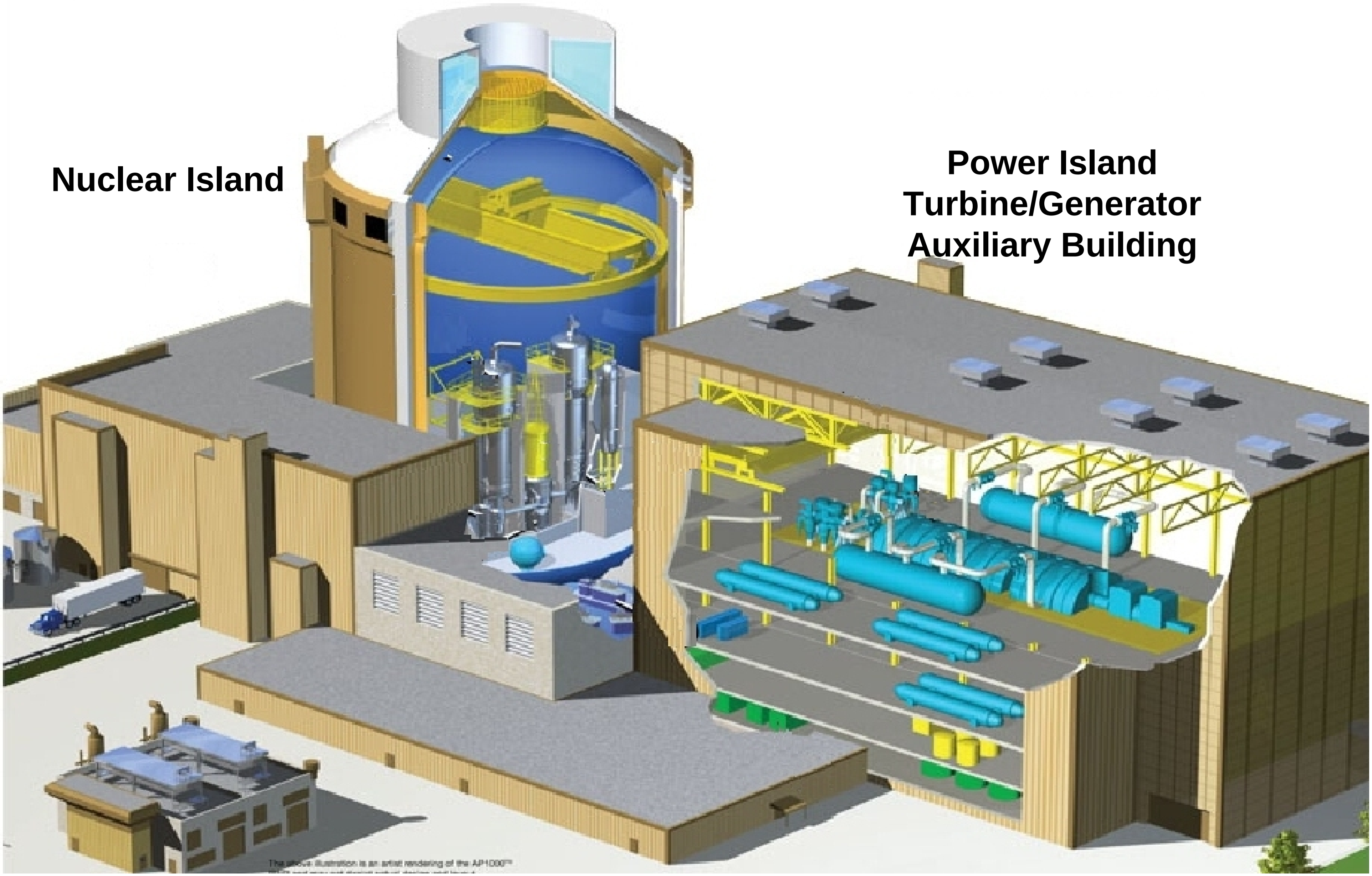
SNC000026

Dry Cooling Presentation

by James W. Cuchens

AP1000™ Standardized Nuclear Plant Concept (Westinghouse AP1000)

Westinghouse
Westinghouse Electric Company LLC



at a Glance

The AP1000 is a standardized unit design that has a net electrical output of 1117 megawatt electric (MWe). The AP1000 received Final Design Approval from the U.S. NRC in September 2004, and Design Certification in December 2005. The AP1000 is the first and only Generation III+ reactor to receive such certification from the NRC.

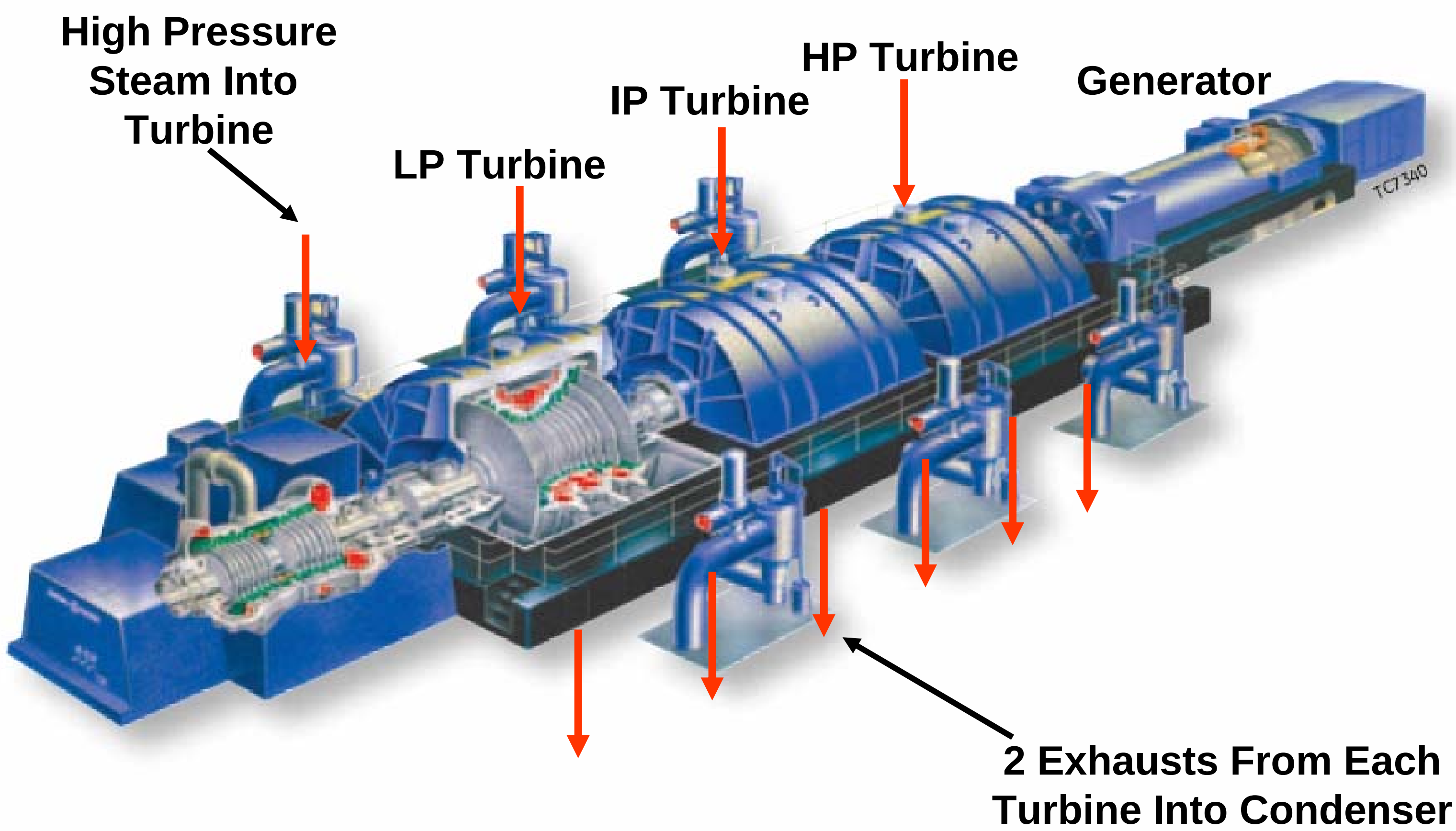
Simplified Plant Design

Simplification of the AP1000 unit design include safety systems, normal operating systems, control room, construction techniques, and instrumentation and control systems which will be easier and less expensive to build, operate, and maintain. Plant simplifications yield fewer components, cable, and seismic building volume, all of which contribute to considerable savings in capital investment, and lower operation and maintenance costs.

The Technology

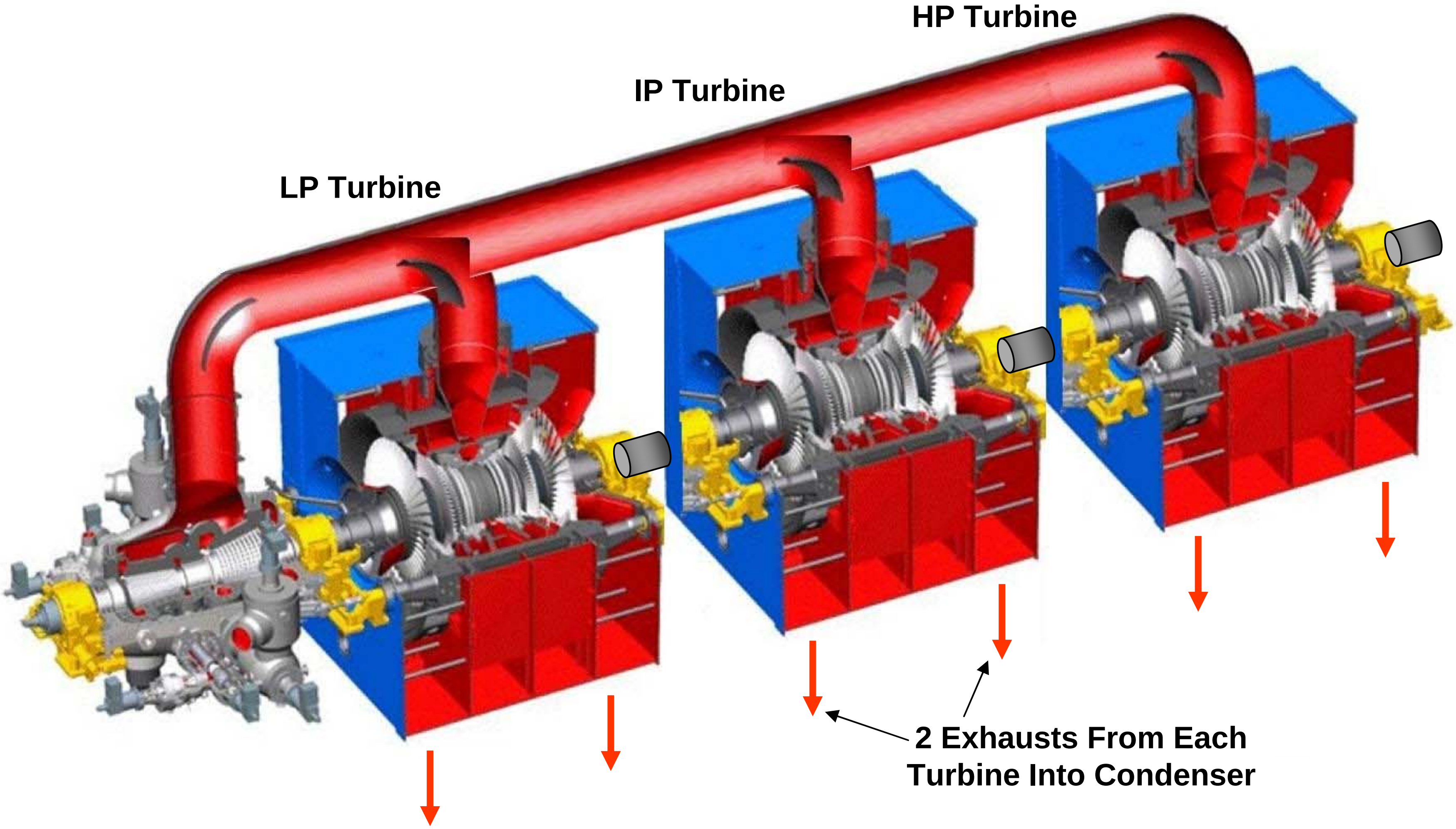
The AP1000 is comprised of components (Nuclear Island and Power Island) that incorporate design improvements distilled from 50 years of successful operating nuclear power plant experience. As such, the turbine generator design represents the most efficient plant based on current technology.

6-Flow Turbine Configuration
GE Series N or Westinghouse TC6F Turbine

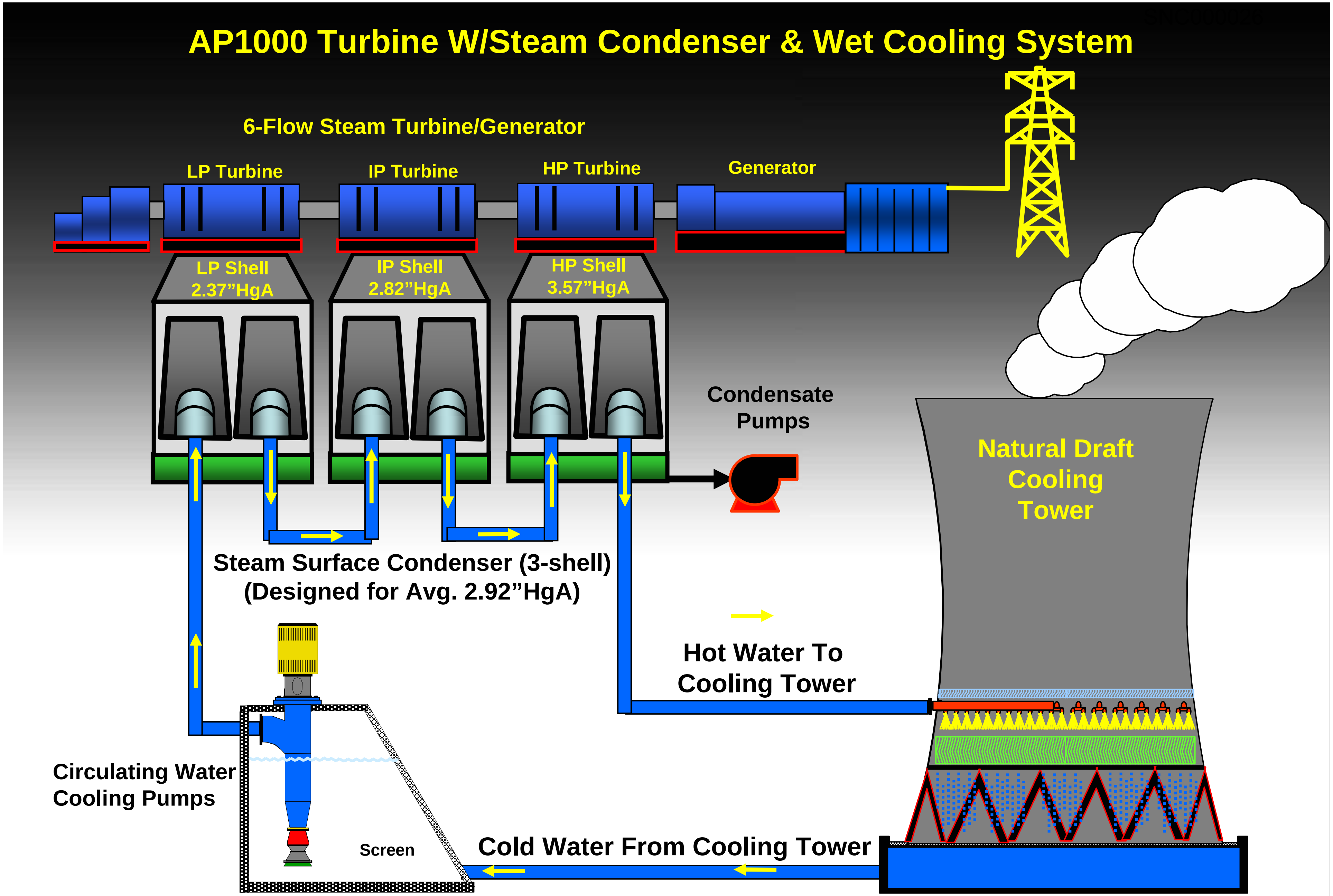


Note: All current standardized Westinghouse or GE employ 6-flow turbines
Viable Operating Range = 0.0 to 5.0 “HgA (+,-) Vacuum/Backpressure

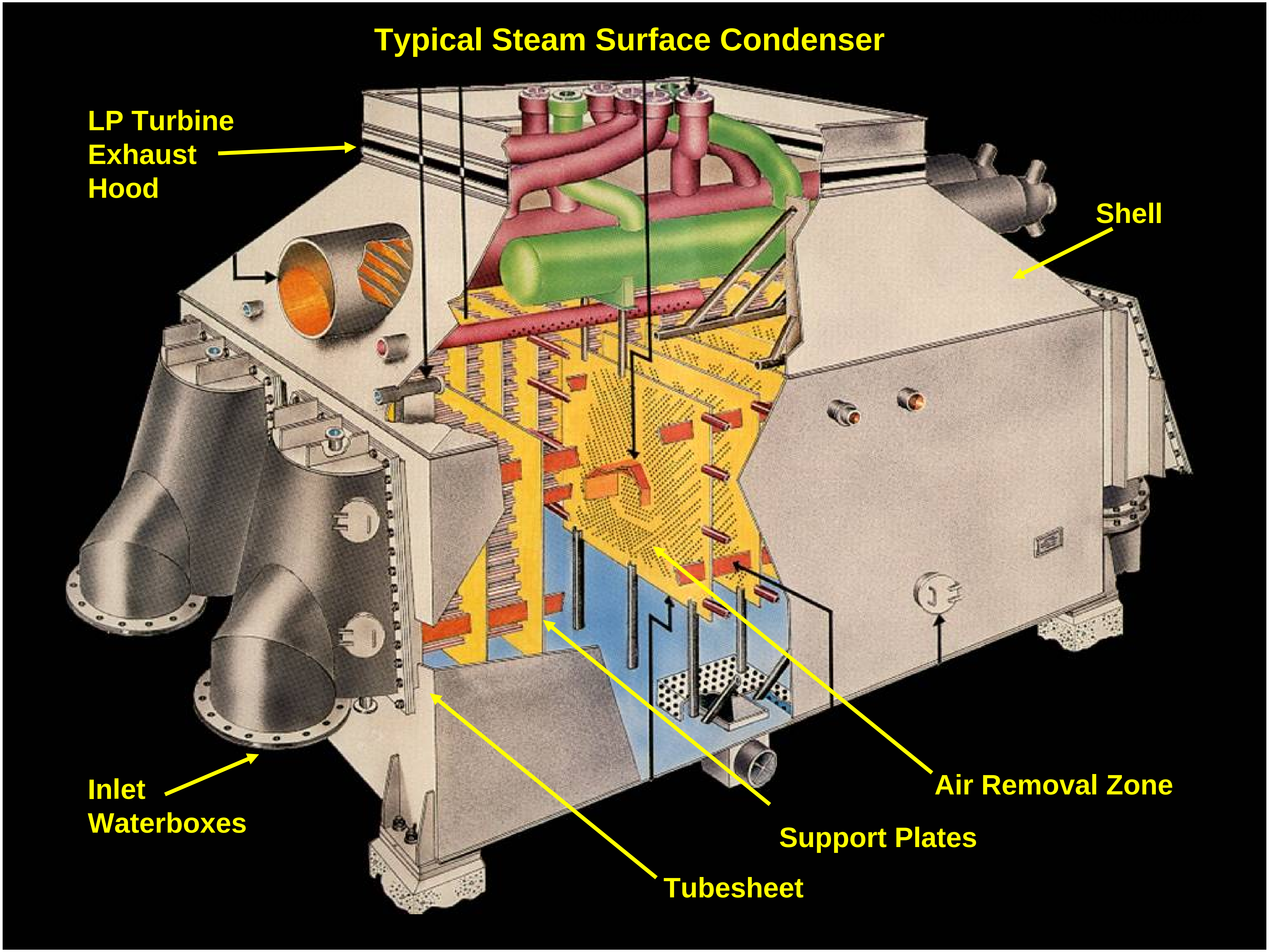
6-Flow Turbine Configuration
GE Series N or Westinghouse TC6F Turbine



Note: All current standardized Westinghouse or GE employ 6-flow turbines
Viable Operating Range = 0.0 to 5.0 "HgA (+,-) Vacuum/Backpressure


AP1000 Turbine W/Steam Condenser & Wet Cooling System
6-Flow Steam Turbine/Generator
LP Turbine
IP Turbine
HP Turbine
Generator
LP Shell
2.37”HgA
IP Shell
2.82”HgA
HP Shell
3.57”HgA
Condensate
Pumps
Natural Draft
Cooling
Tower
Steam Surface Condenser (3-shell)
(Designed for Avg. 2.92”HgA)
Hot Water To
Cooling Tower
Circulating Water
Cooling Pumps
Screen
Cold Water From Cooling Tower

Typical Steam Surface Condenser



What Happens Inside A Steam Surface Condenser

Steam Condensation & Resultant Backpressure

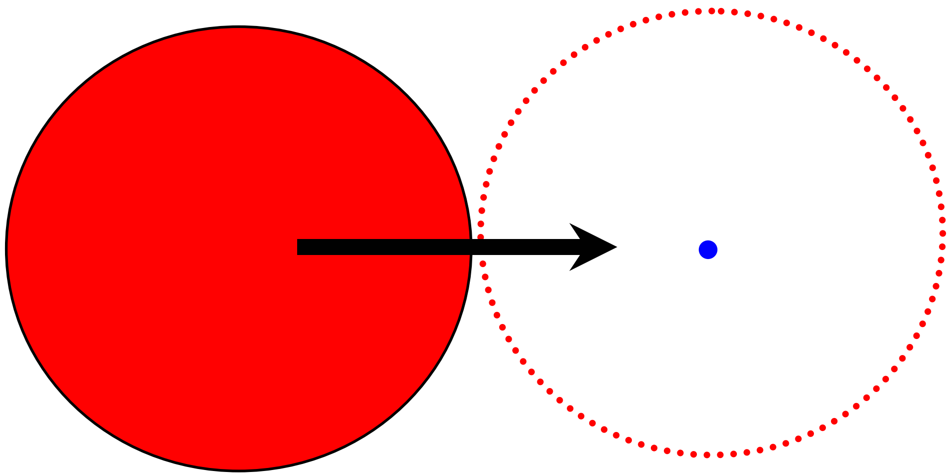
Water flowing inside the condenser tubes condenses steam flowing across the outside surface of the tubes. When steam is condensed to become a liquid, it requires a significantly less amount of space and/or volume. In doing so, it creates a vacuum which is often referred to as backpressure inside a steam condenser and turbine exhaust. Typically, the lower the backpressure (or vacuum), the better turbine performance will be (similar to a car's performance when you remove tennis balls stuck in the car's exhaust pipes).

The Vacuum Effect

- Imagine 1 lb of saturated **steam** at 2"HgA. Its occupied volume is 339 ft^3.
- Now imagine this steam is condensed in to 1 lb of **condensate** (saturated liquid) that occupies a volume of 0.016 ft^3.
- The occupied volume reduces more than 21,000 times!
- Condensing itself Creates Vacuum!

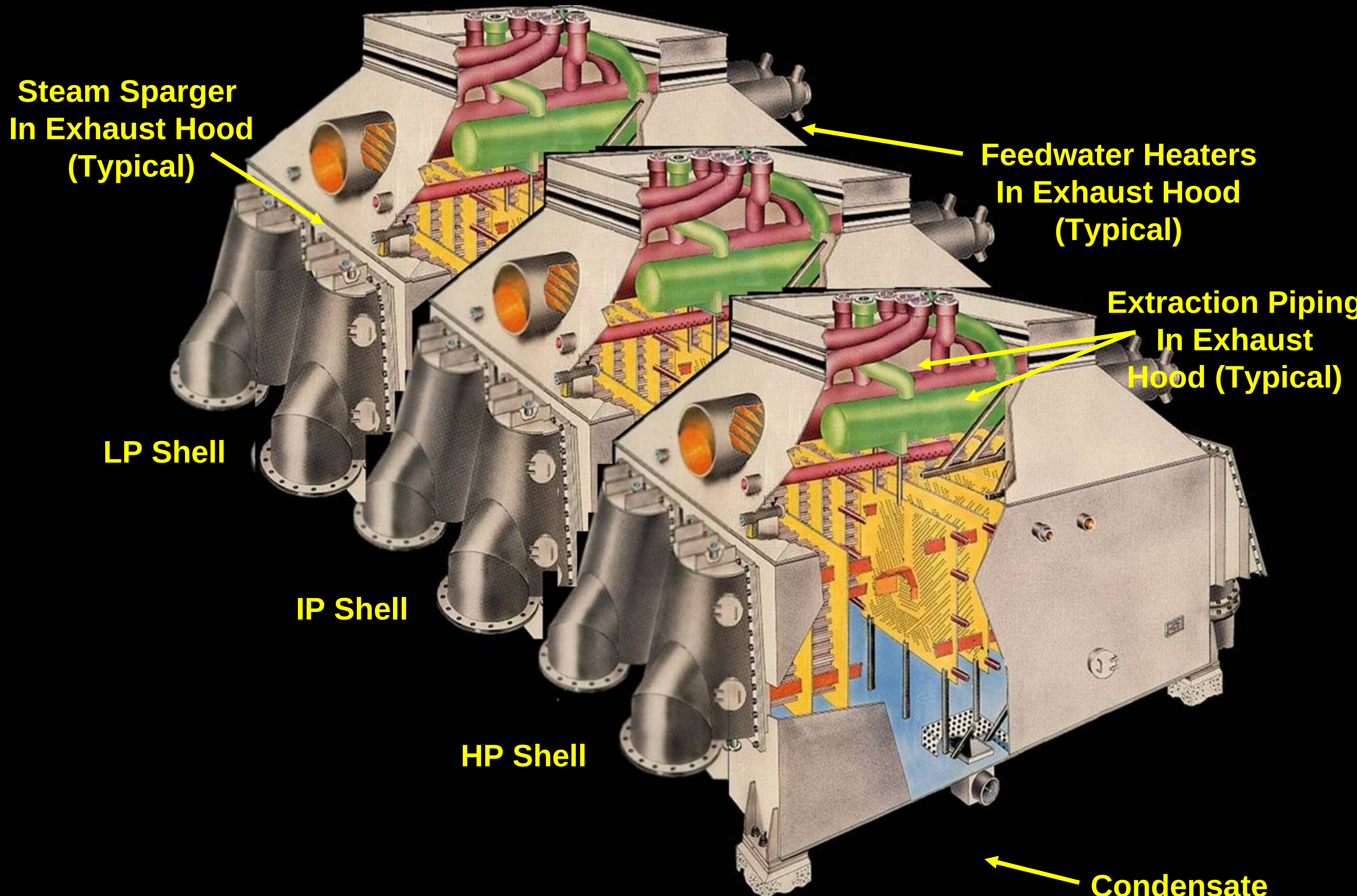
Phase Change

(Steam/Gas to Liquid/Condensate)

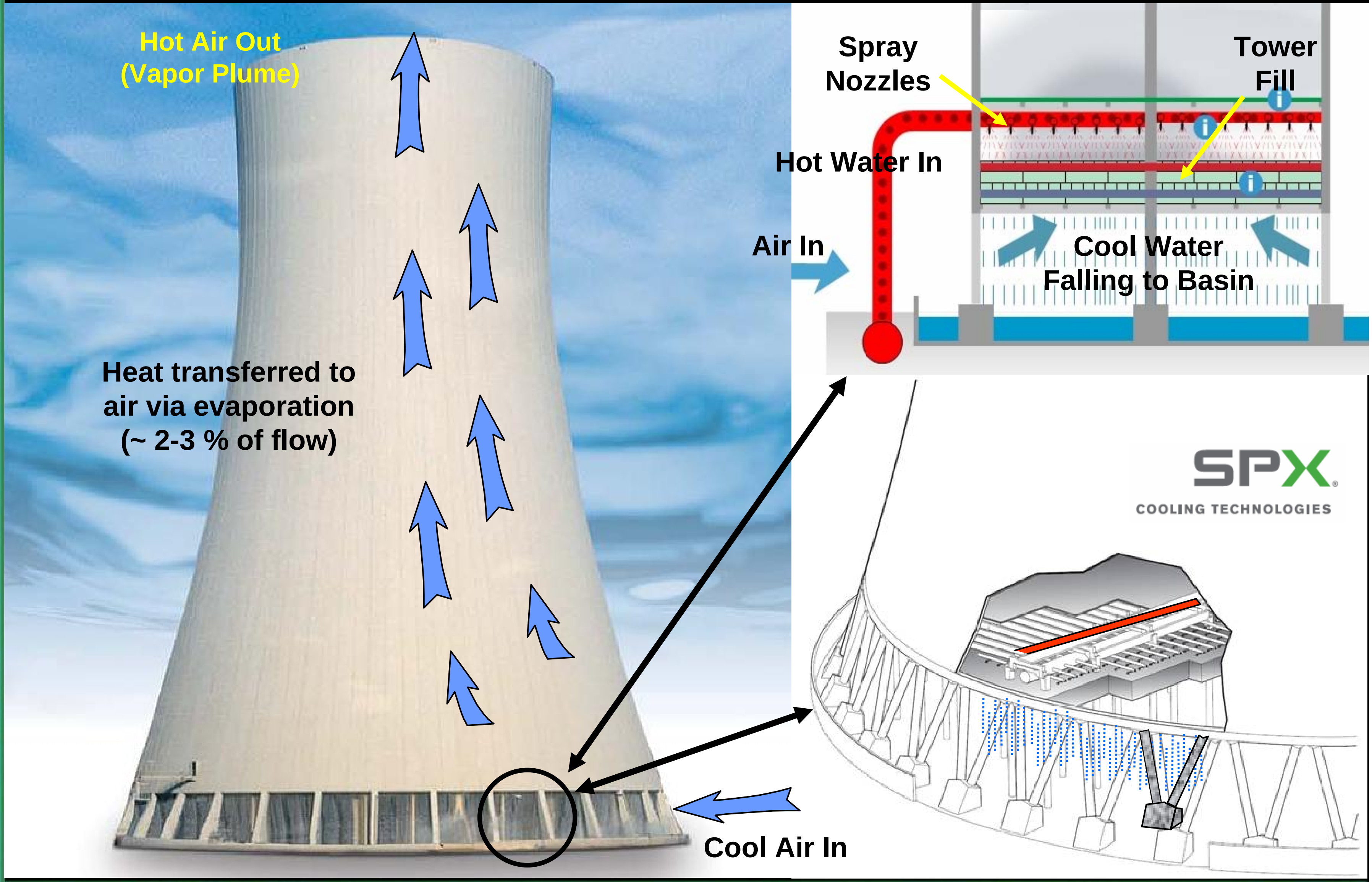


Steam **Condensate**

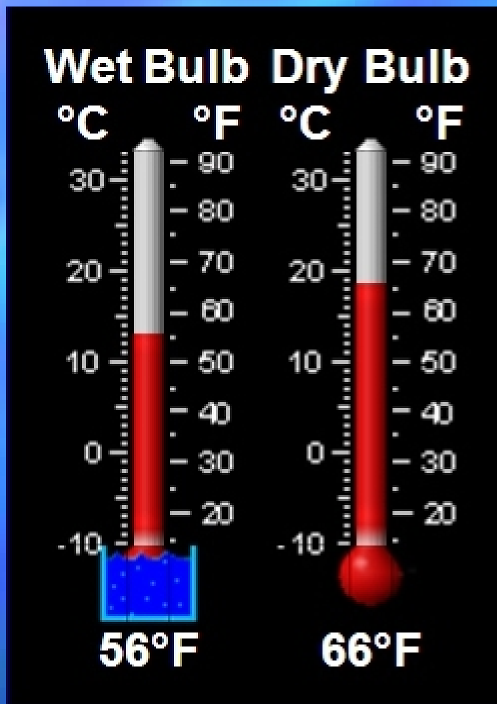
Steam Surface Condenser (Triple Pressure -3 Shell for AP1000)



Natural Draft Cooling Tower Design

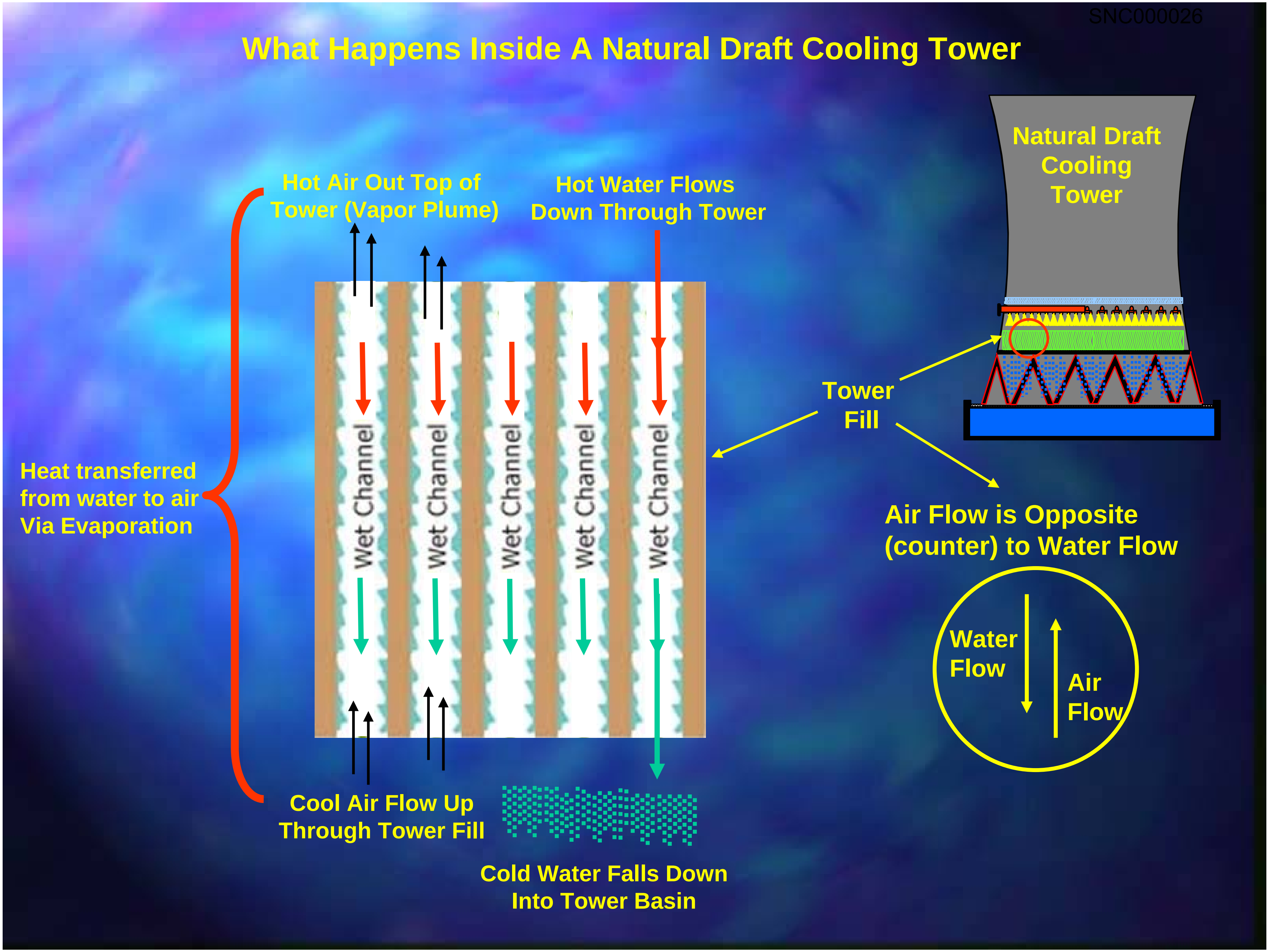


Fundamentals of Evaporative Cooling (Natural Draft Cooling Tower)

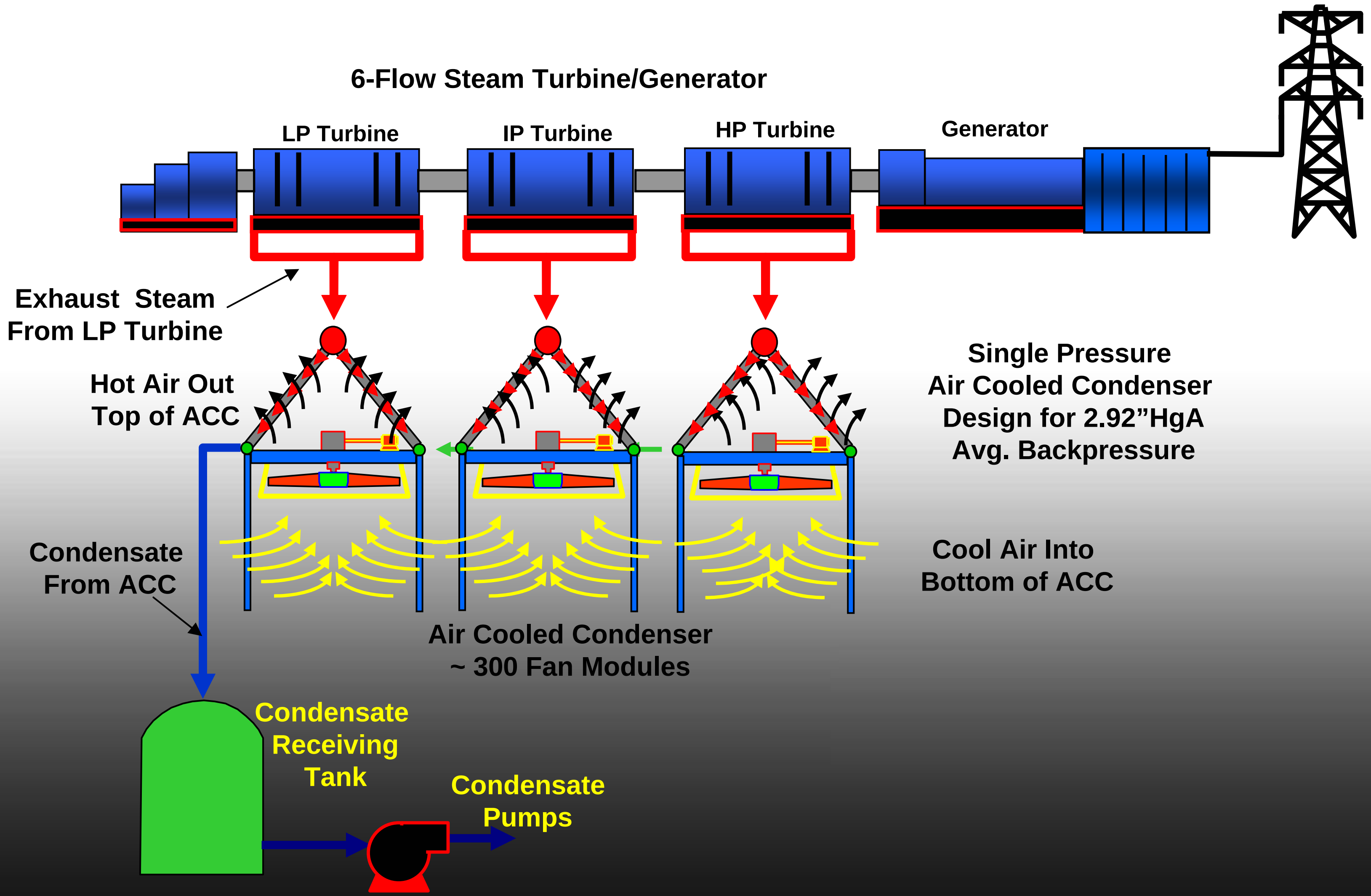


Wet-bulb Temperature = Temperature at which evaporation occurs
Wet-bulb Temperature Typically Less Than Dry-bulb (ambient) temperature
i.e. @ 95.0 Deg.F Ambient Dry-bulb & 50 % Humidity, Wetbulb ~ 78.0 Deg.F

The human body maintains a basic minimum rate of heat production at about 250 Btu/hr during sleep, the heat equivalent of about 75 watts, and about 400 Btu/hr (120 watts) when awake but sedentary. As bodily activity increases, the rate of oxidation of food, with its attendant release of energy, must increase. The level of heat production for light work will be about 650 Btu/hr (190 watts), the extreme value for heavy work, about 2400 Btu/hr (700 watts).

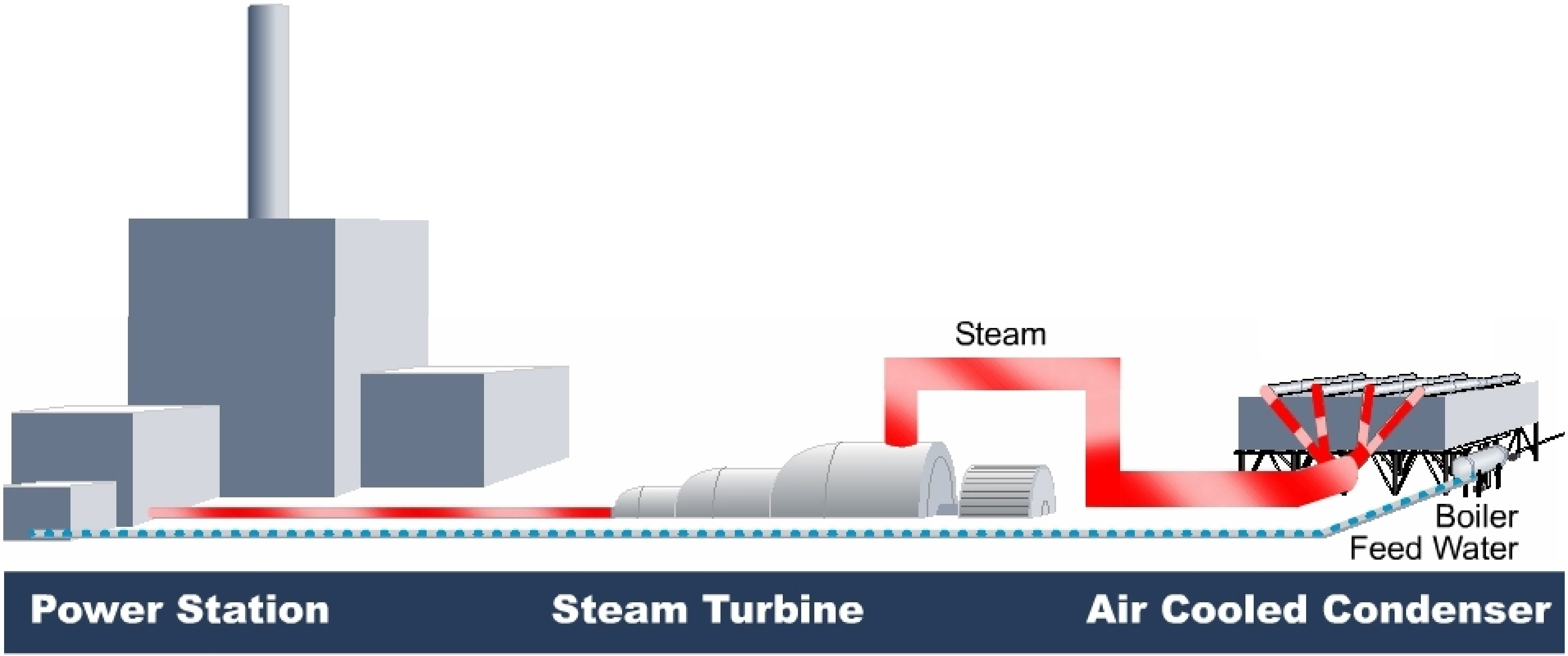

SNC000026
What Happens Inside A Natural Draft Cooling Tower
Natural Draft Cooling Tower
Hot Air Out Top of Tower (Vapor Plume)
Hot Water Flows Down Through Tower
Wet Channel
Wet Channel
Wet Channel
Wet Channel
Wet Channel
Tower Fill
Heat transferred from water to air Via Evaporation
Air Flow is Opposite (counter) to Water Flow
Water Flow
Air Flow
Cool Air Flow Up Through Tower Fill
Cold Water Falls Down Into Tower Basin

AP1000 Turbine Cycle W/Air Cooled Condenser



Air Cooled Condenser (Single Pressure) Configuration

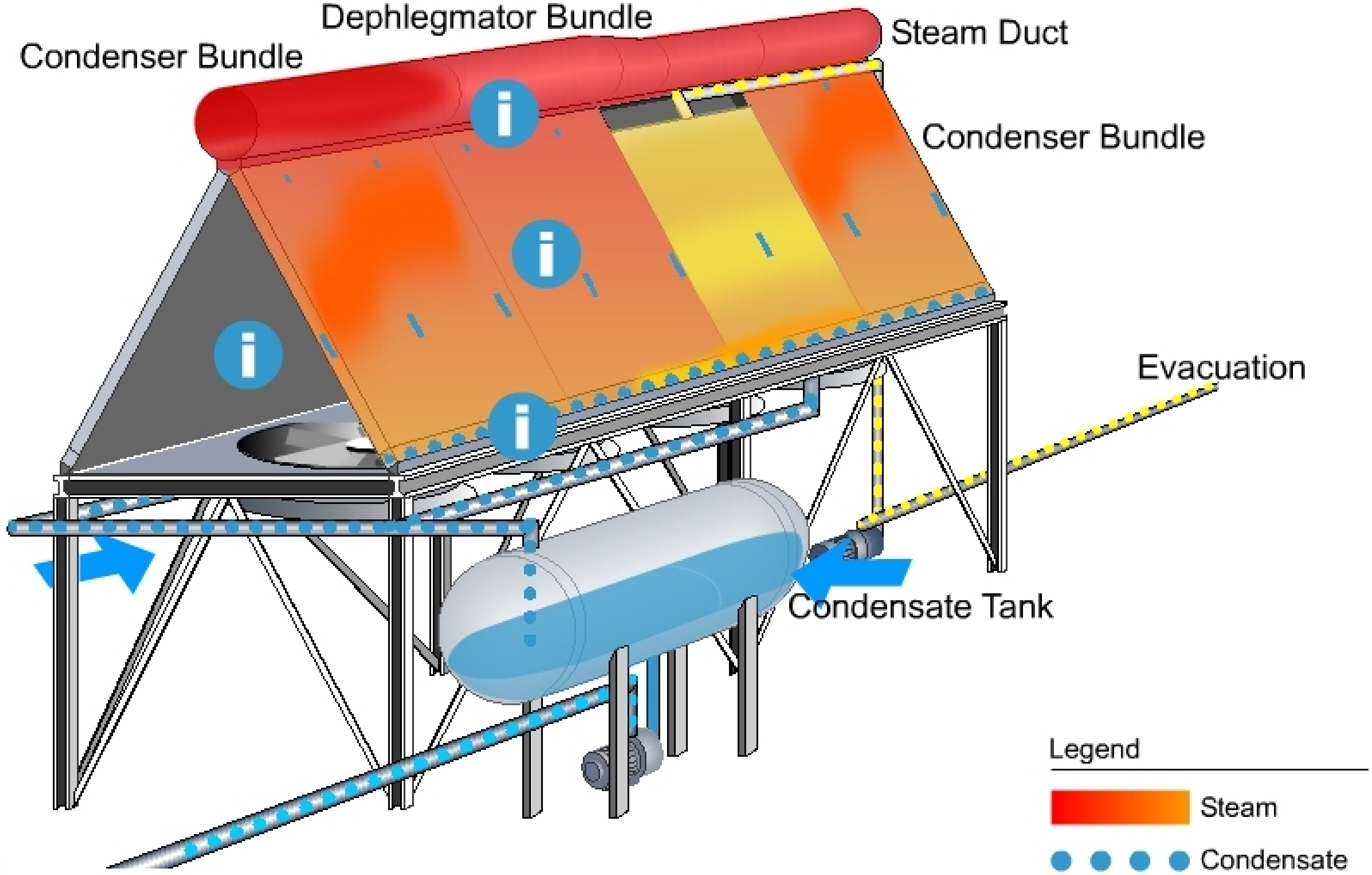
Power Station W/ Air-Cooled Condenser



GEA Energy Technology Division

SNC000026

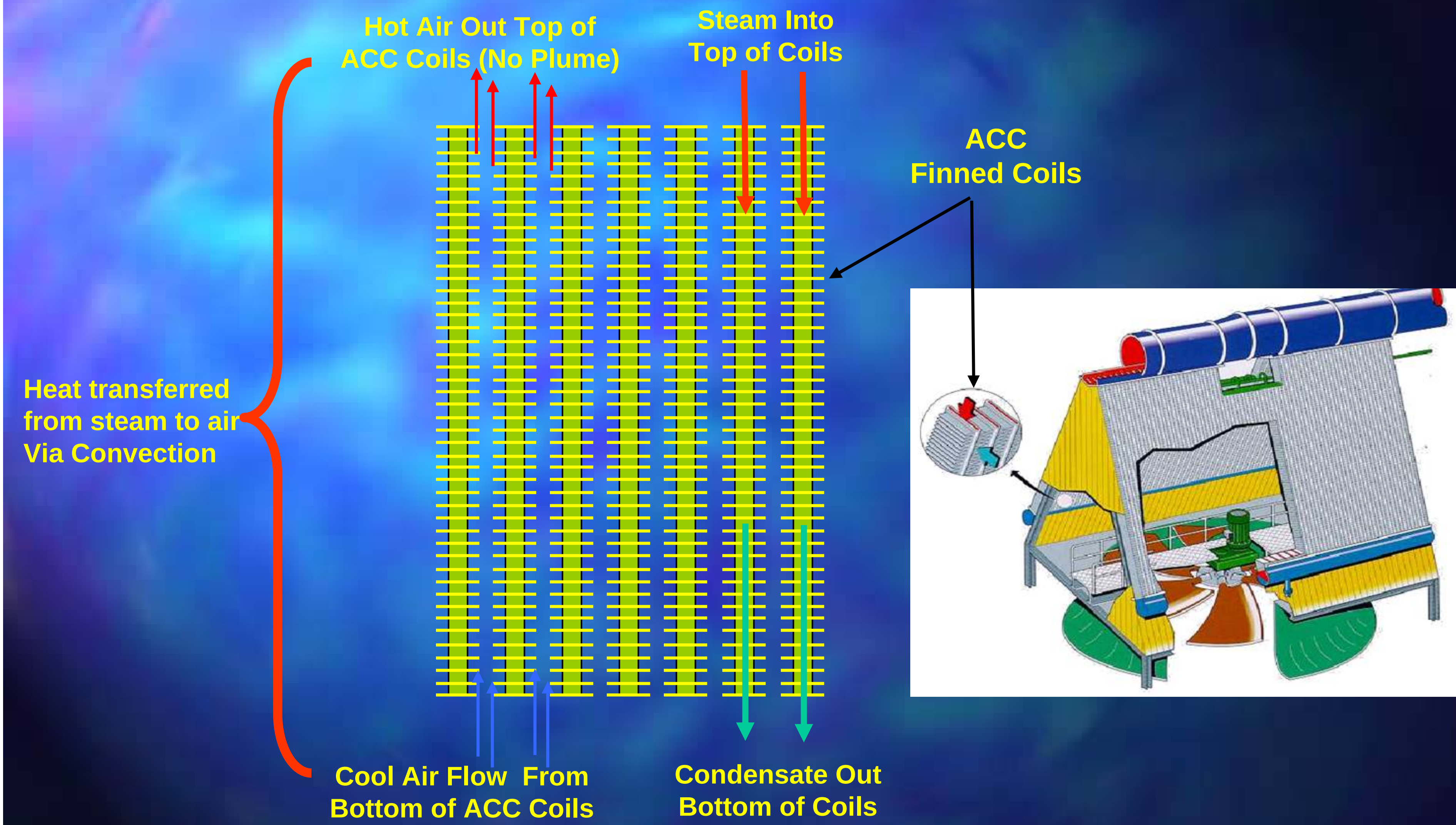
Air-Cooled Condenser



GEA Energy Technology Division

Back

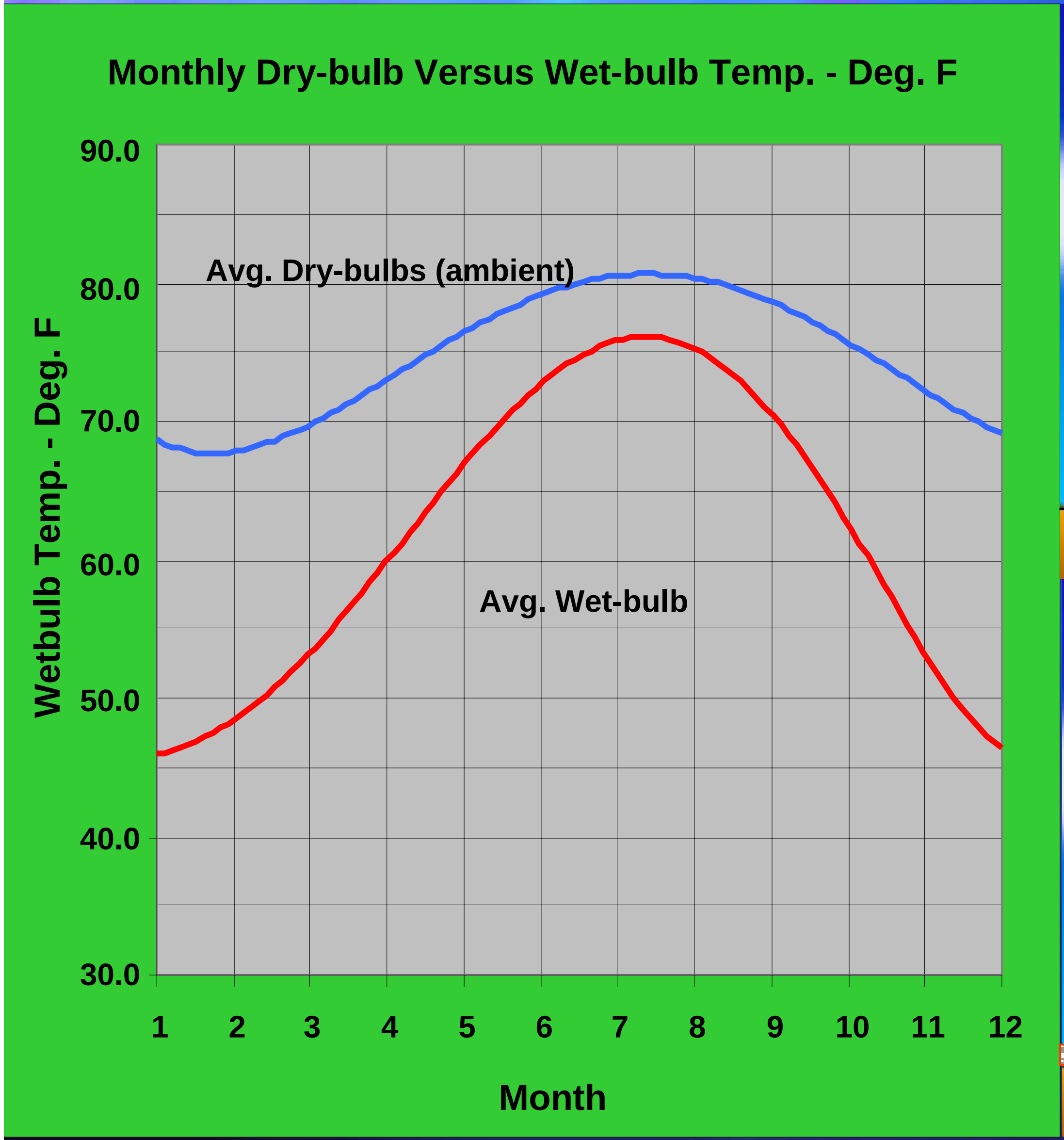
What Happens Inside An Air-Cooled Condenser

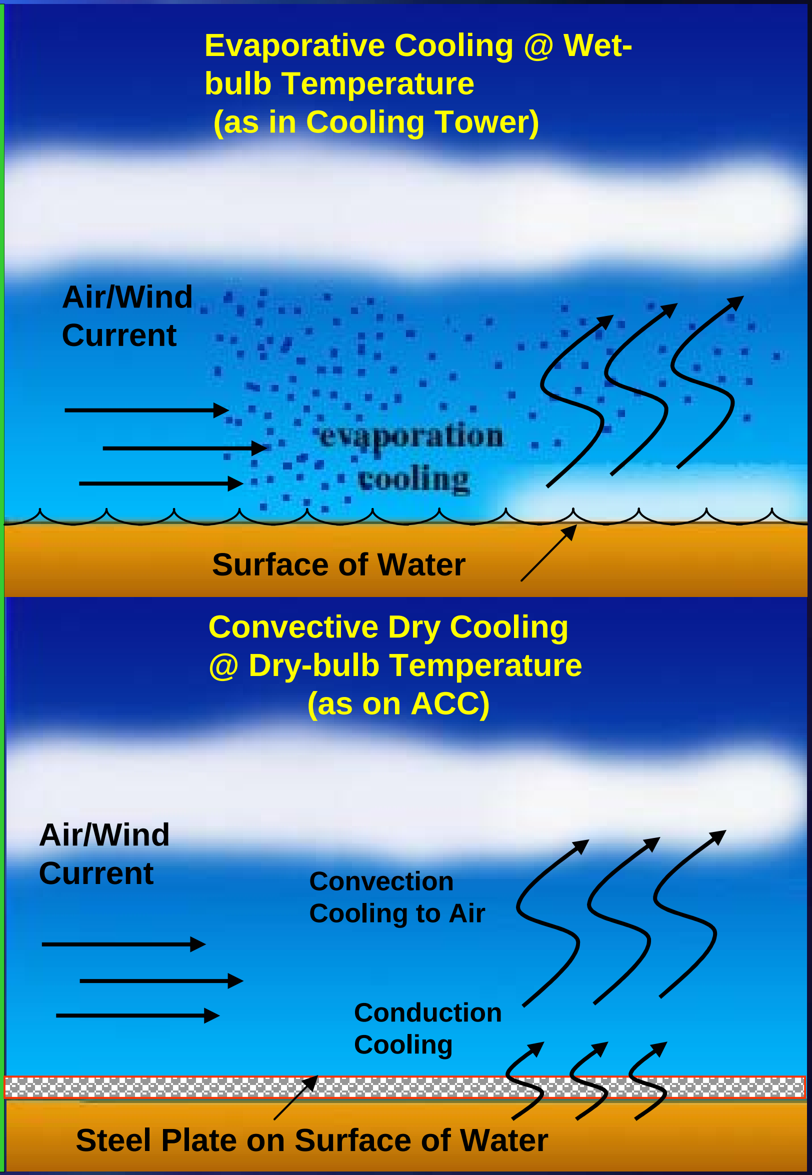


Steam Condensation & Resultant Backpressure = *f* (drybulb & ACC surface area)

Metal-to-Air Heat Transfer (Forced Convection)

Performance Drivers for Evaporative Cooling (W/Cooling Tower) Versus Dry Cooling (Air Cooled Condenser)

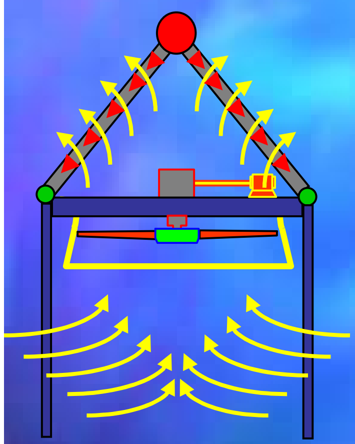




Typical 500 Mw Combined Cycle ACC Installation
(240 Mw Steam Turbine)

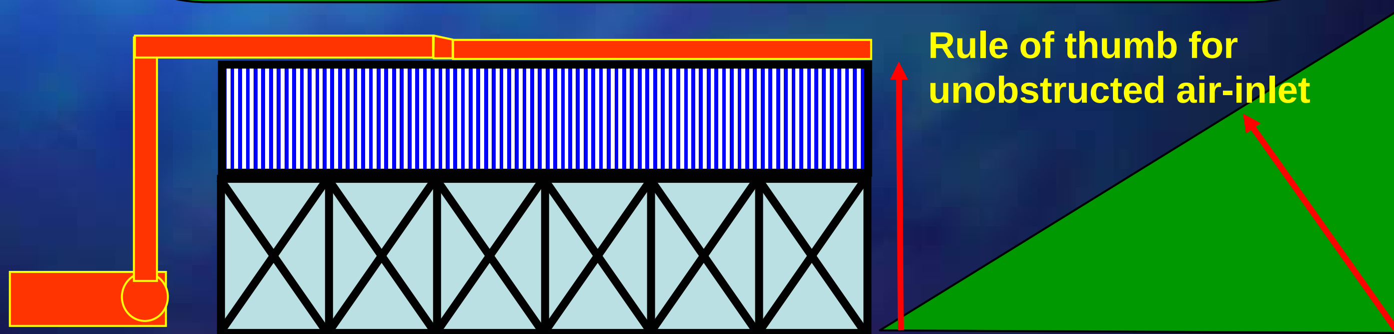
Note: Turbine/Condenser Design backpressure ~ 10.0"Hga @ 112 Deg.F Ambient

Proximity Issues – Restricted Perimeter Air-Inlet Zones



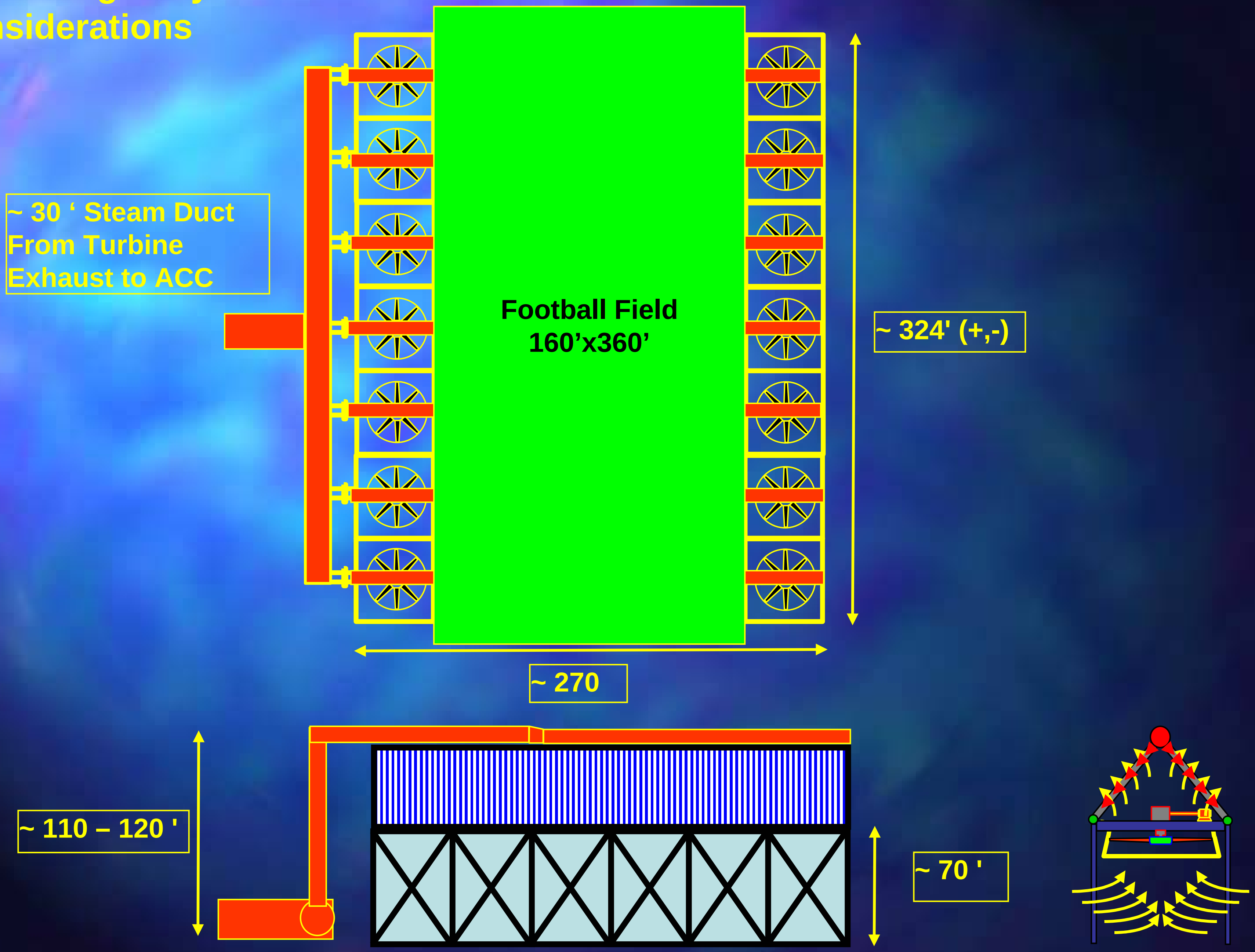
Comparative Height
(ACC Vs Cooling Tower)

RESTRICTED PERIMETER
1. No-build zones to avoid air-inlet interference
2. To provide maintenance access



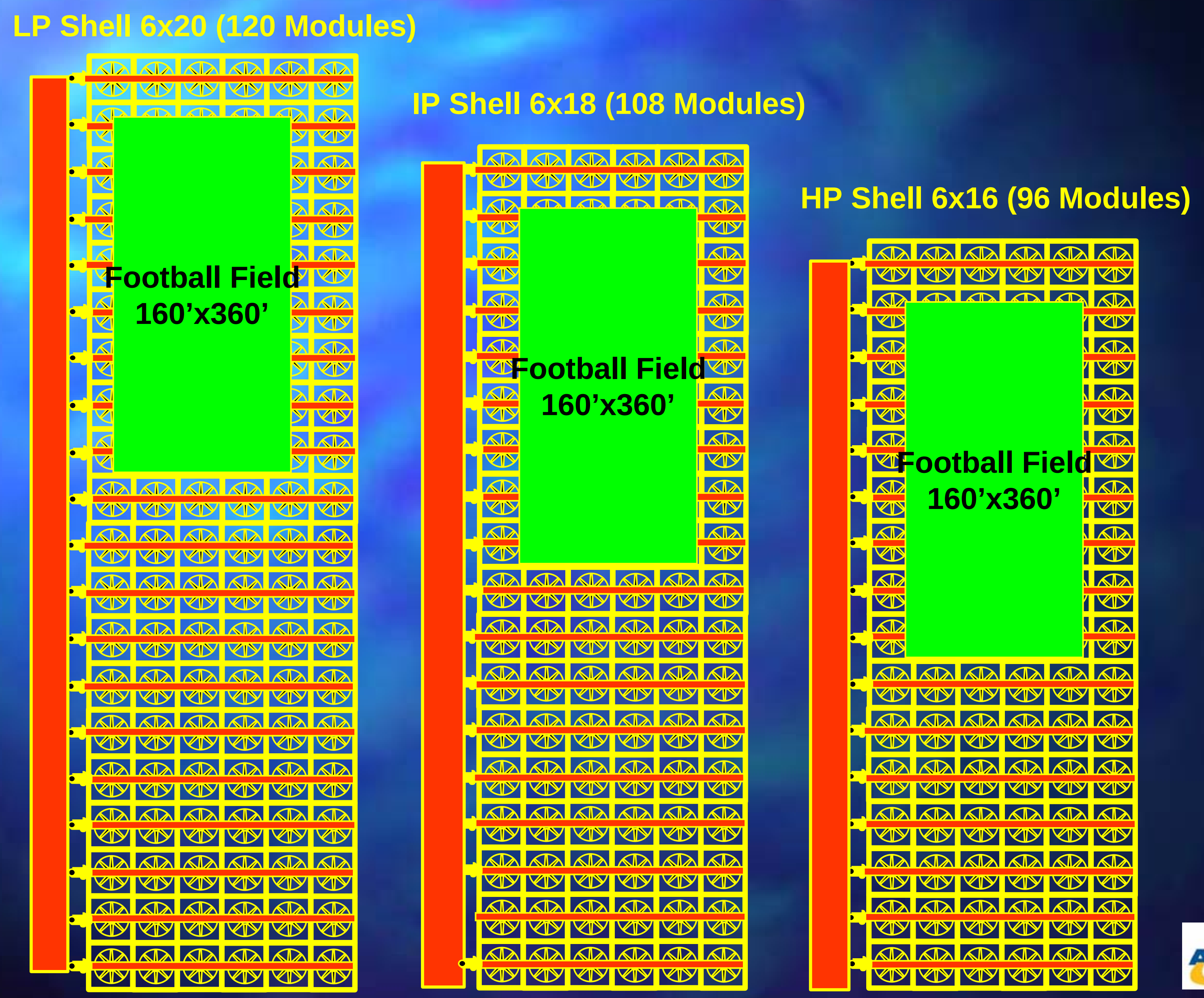
Rule of thumb for unobstructed air-inlet

ACC Design/Layout Considerations



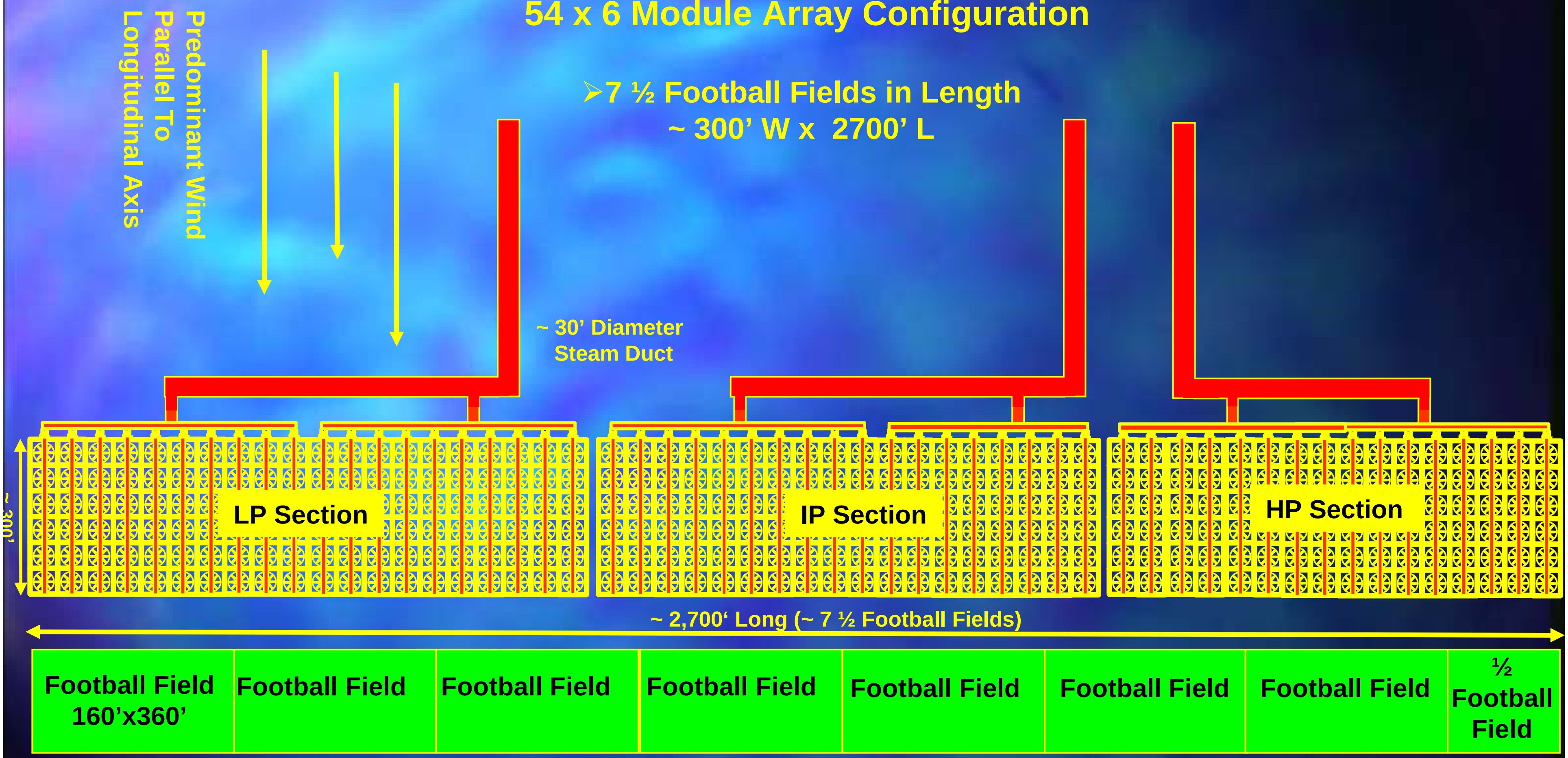
SNC000026

AP1000 Plant - ACC Size & Layout Requirements
Designed For 2.92"HgA @ 95 Deg. Ambient
324 Modules (54 x 6 Module Array Configuration)



AP1000™

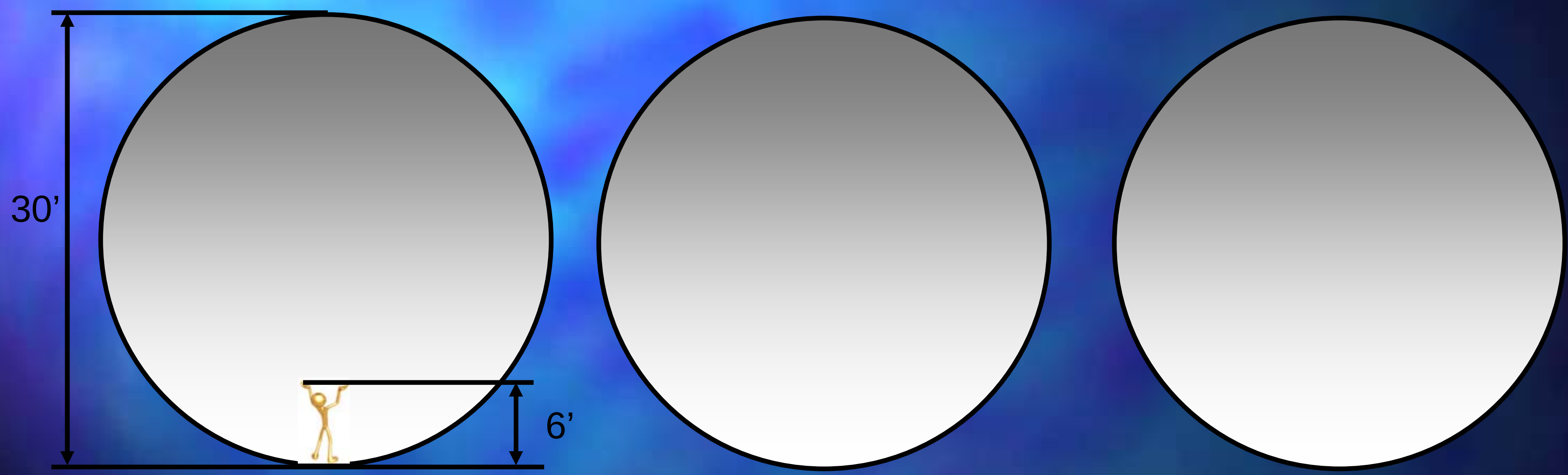
AP1000 ACC CONDENSER
DESIGNED FOR 2.92"HgA @ 95 Deg. Ambient
324 Modules
54 x 6 Module Array Configuration



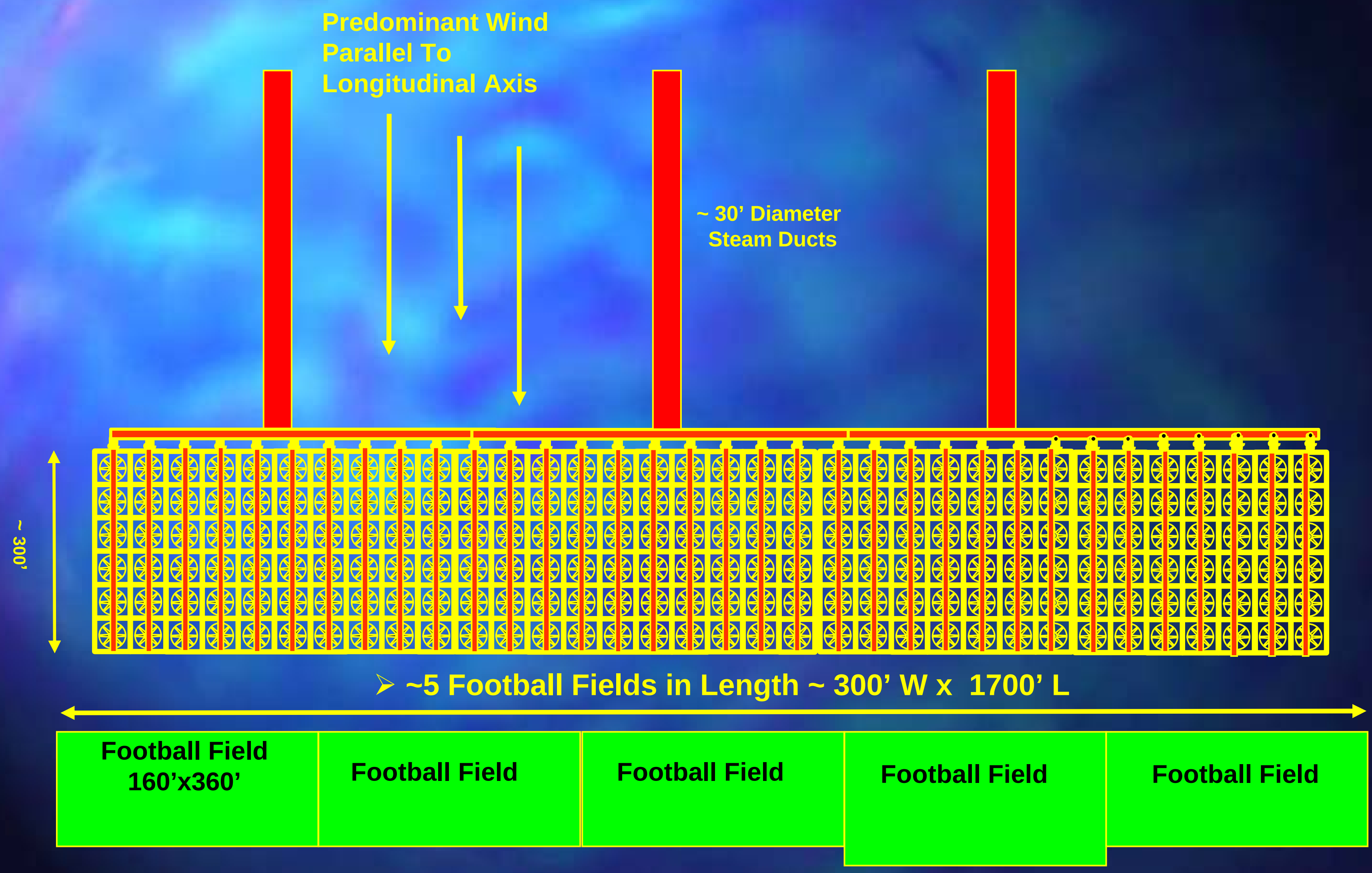
Design Backpressure @ ACC (steam turbine backpressure = ACC + Duct Losses)
ACC Backpressure Design Not Recommended due to performance limitations and reliability)

Required Size for ACC Steam Ducts for an AP1000 Unit

(Average Height Man Shown for Scale)



AP1000 ACC CONDENSER
DESIGNED FOR 4.5"HgA @ 95 Deg. Ambient
204 Modules (34 x 6 Module Array Configuration)



Design Backpressure @ ACC (steam turbine backpressure = ACC + Duct Losses)
ACC Backpressure Design Not Recommended due to performance limitations and reliability)

ACC Designed For 2.92"HgA @ 95 Deg. Ambient
Modules (54 x 6 Module Array Configuration)

AP1000 ACC Designed for 4.5"HgA @ 95 Deg. Ambient
204 Modules (34 x 6 Module Array Configuration)

7 ½ Football Fields in Length (~ 300' W x 2700' L)

➢ ~5 Football Fields in Length ~ 300' W x 1700' L

SNC000026

ACC Impact on AP1000

Standardized Unit Design