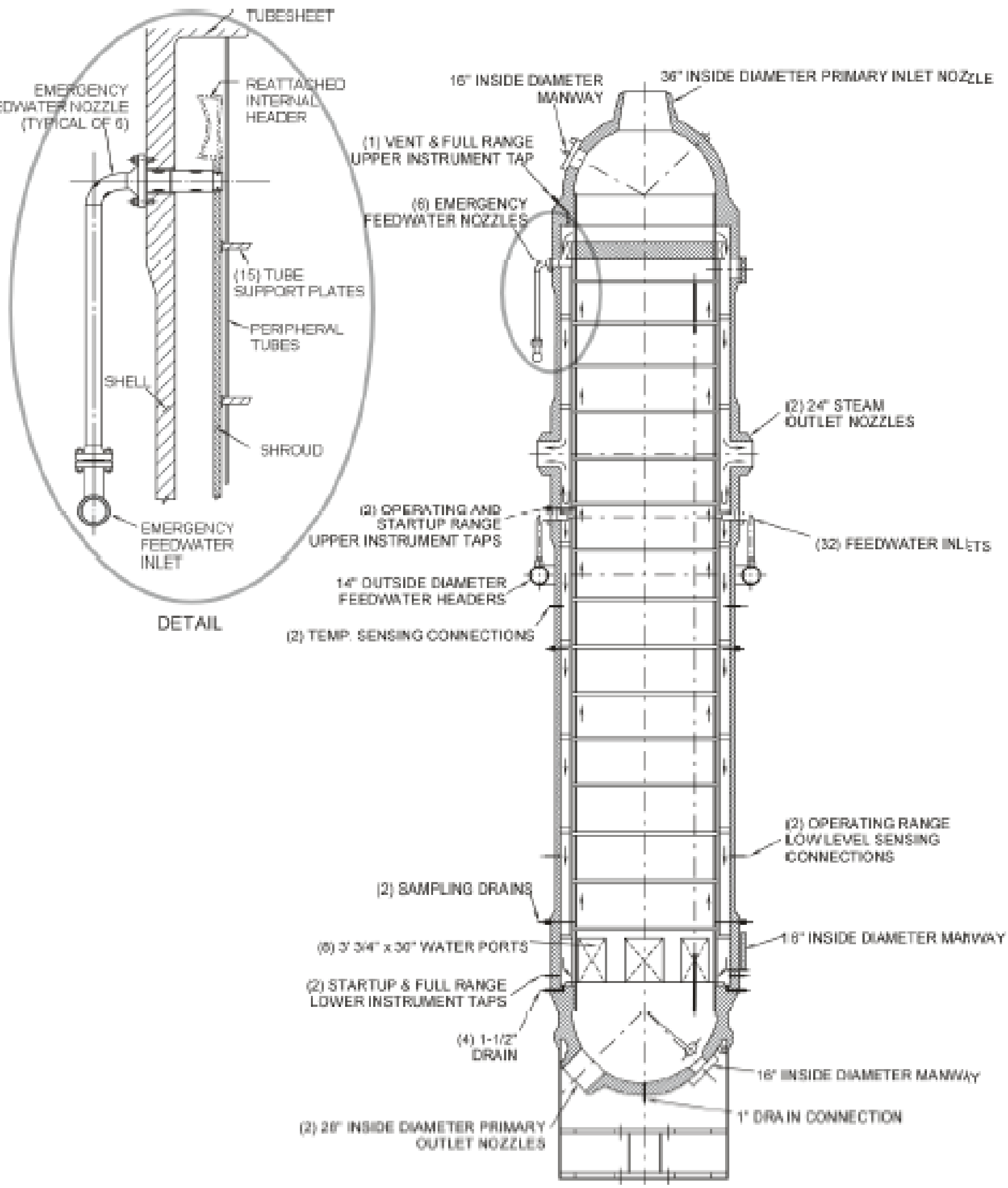
Once-Through Steam Generators

Chapter 2.4
B&W Cross-training Course
R-326C

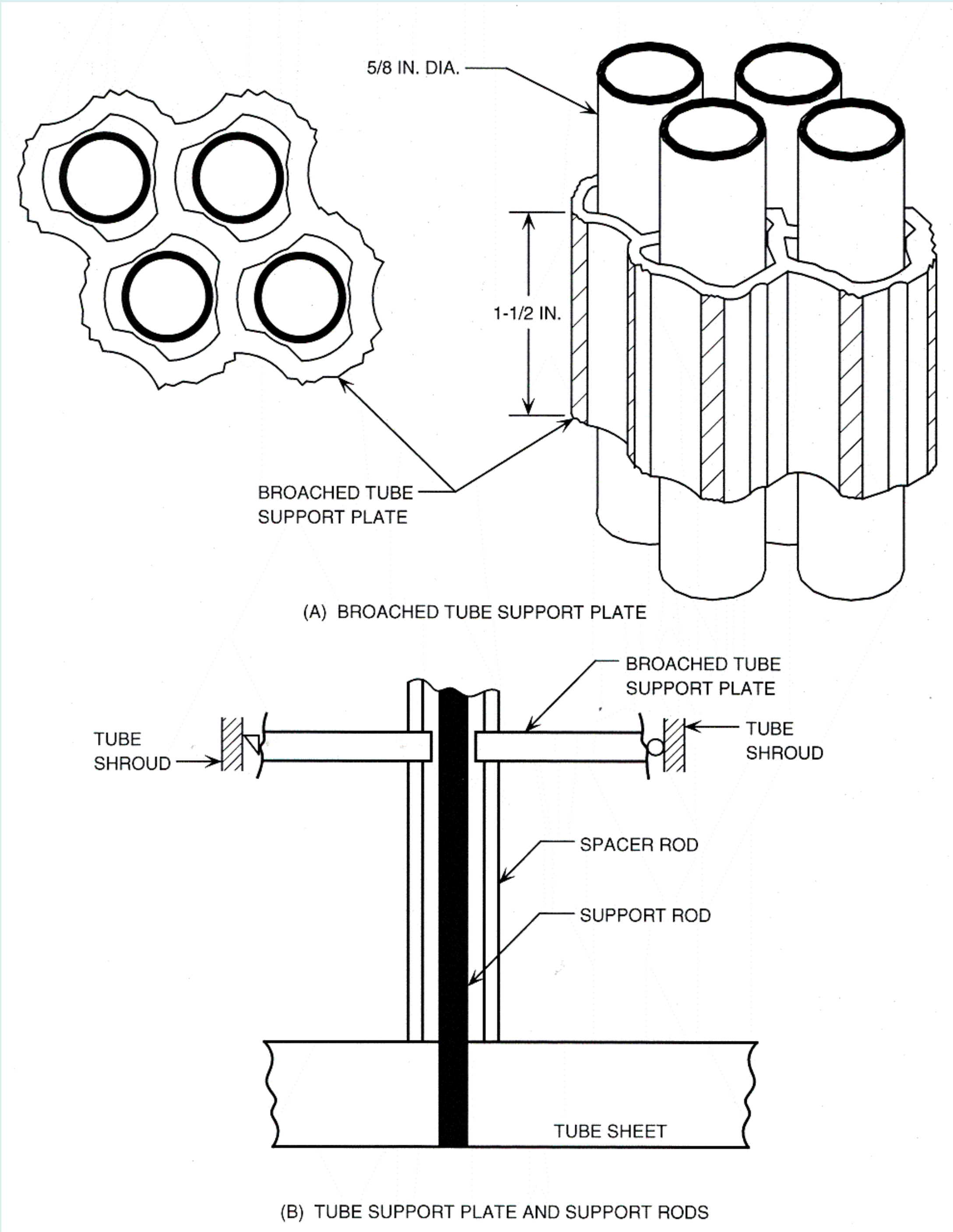
OBJECTIVES

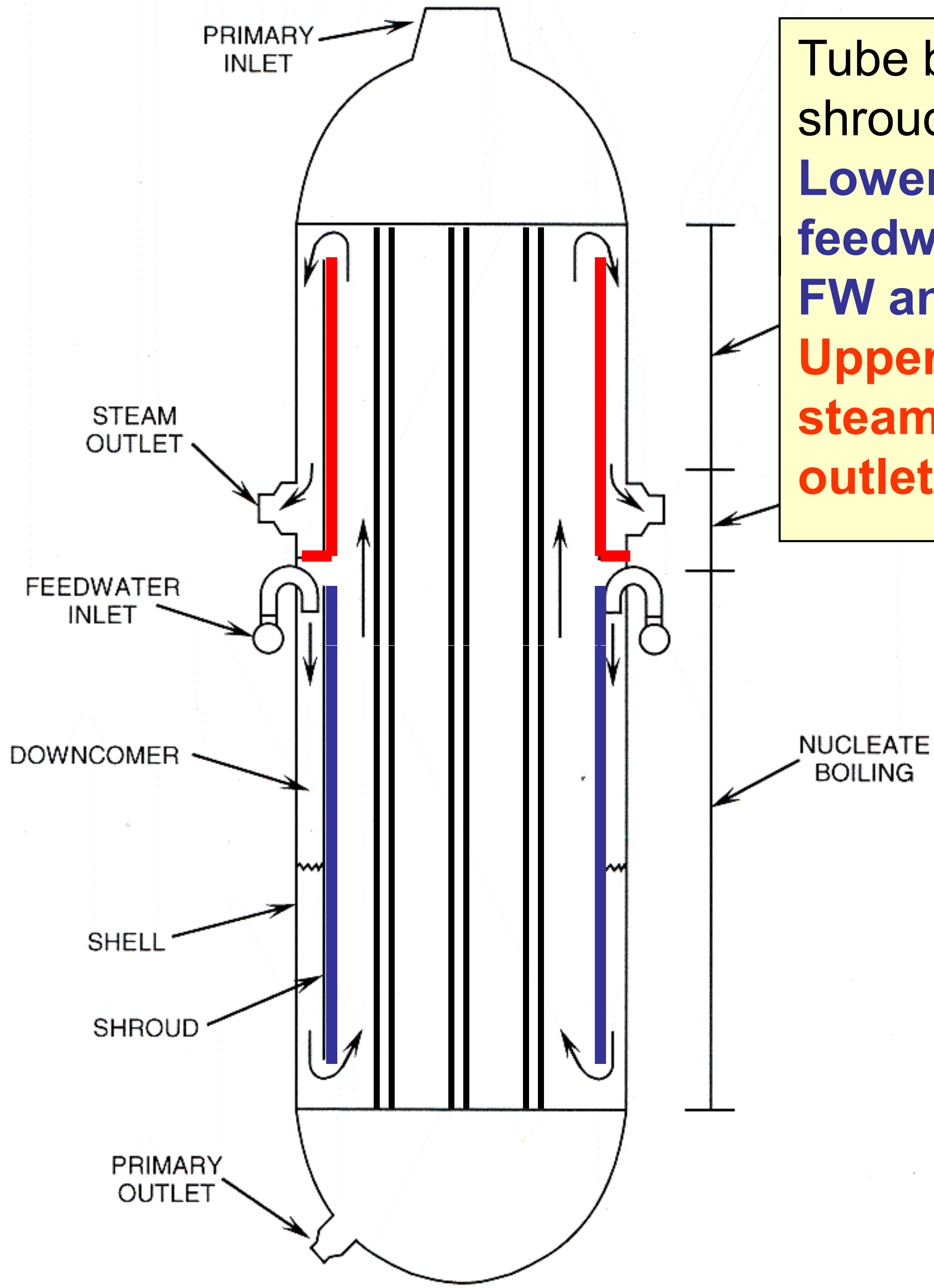
1. State the function of the once-through steam generator (OTSG).
2. List the three heat transfer regions of the OTSG.
3. Describe <u>How</u> & <u>Why</u> the areas associated with the 3 heat transfer regions change with an increase or decrease in plant load.
4. Explain why the differential temperature between the tubes & shell of the OTSG is critical, and explain how it is maintained below the critical value.


TUBESHEET
EMERGENCY FEEDWATER NOZZLE (TYPICAL OF 6)
REATTACHED INTERNAL HEADER
(15) TUBE SUPPORT PLATES
PERIPHERAL TUBES
SHELL
SHROUD
EMERGENCY FEEDWATER INLET
DETAIL
16" INSIDE DIAMETER MANWAY
36" INSIDE DIAMETER PRIMARY INLET NOZZLE
(1) VENT & FULL RANGE UPPER INSTRUMENT TAP
(6) EMERGENCY FEEDWATER NOZZLES
(2) 24" STEAM OUTLET NOZZLES
(2) OPERATING AND STARTUP RANGE UPPER INSTRUMENT TAPS
(32) FEEDWATER INLETS
14" OUTSIDE DIAMETER FEEDWATER HEADERS
(2) TEMP. SENSING CONNECTIONS
(2) OPERATING RANGE LOW LEVEL SENSING CONNECTIONS
(2) SAMPLING DRAINS
(8) 3' 3/4" x 30" WATER PORTS
16" INSIDE DIAMETER MANWAY
(2) STARTUP & FULL RANGE LOWER INSTRUMENT TAPS
(4) 1-1/2" DRAIN
16" INSIDE DIAMETER MANWAY
1" DRAIN CONNECTION
(2) 28" INSIDE DIAMETER PRIMARY OUTLET NOZZLES

OTSG
Fig. 2.4-1

Tube Support
Plate and
Support Rods
Fig. 2.4-2





Tube bundle is wrapped by two cylindrical shrouds.

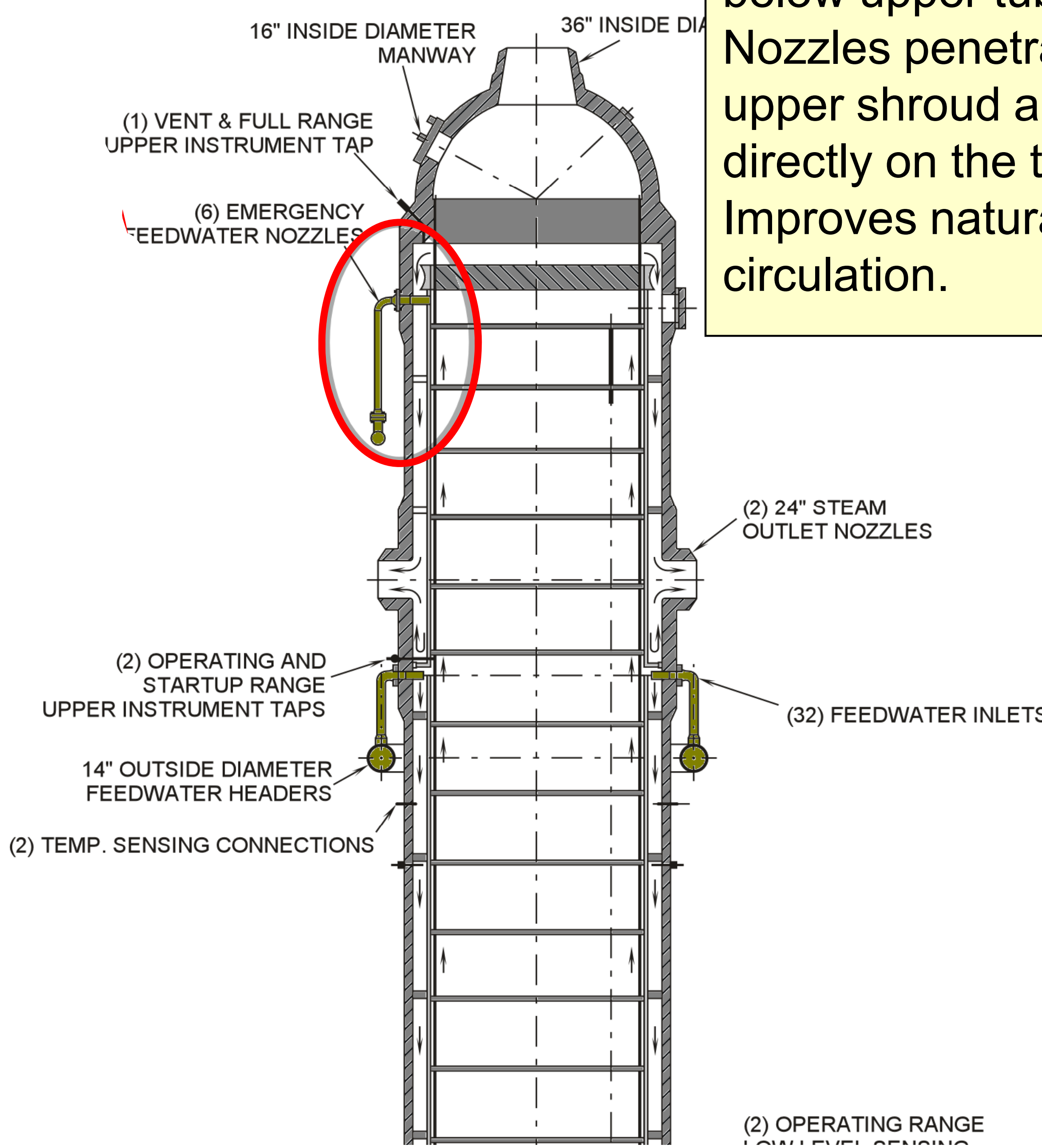
Lower shroud (FW shroud) directs feedwater from the 32 nozzles through FW annulus to tube bundle.

Upper shroud (steam shroud) directs steam through steam annulus to steam outlet nozzles.

Heat Transfer Regions
Fig. 2.4-3

AFW enters OTSG just below upper tube sheet. Nozzles penetrate the upper shroud and spray directly on the tubes. Improves natural circulation.

OTSG
Fig. 2.4-1

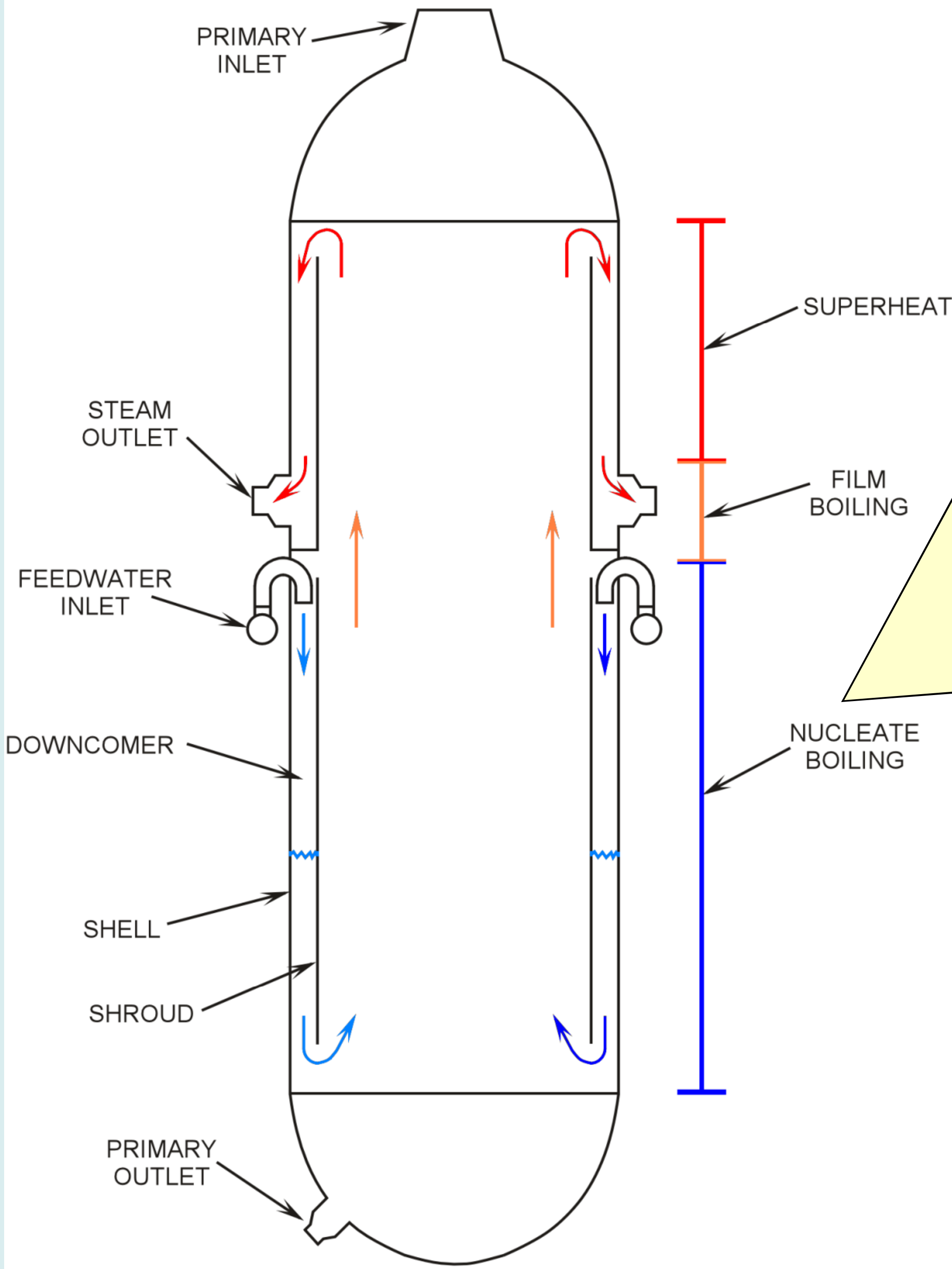


Secondary Flow Path

- FW sprayed in FW annulus. Nozzles approx. midpoint of the shell.
- FW is preheated in annulus by steam from tube bundle region through aspirating ports.
- Aspirating ports are gaps between the steam shroud & FW shroud.
- FW is at saturation when it flows from annulus to tube bundle region.
- FW is transformed into saturated, then superheated steam by the time it reaches upper tube sheet.
- Superheated steam directed down the steam annulus & exits the OTSG through one of two steam nozzles.
- Steam nozzles located just above FW nozzles.

Heat Transfer Regions

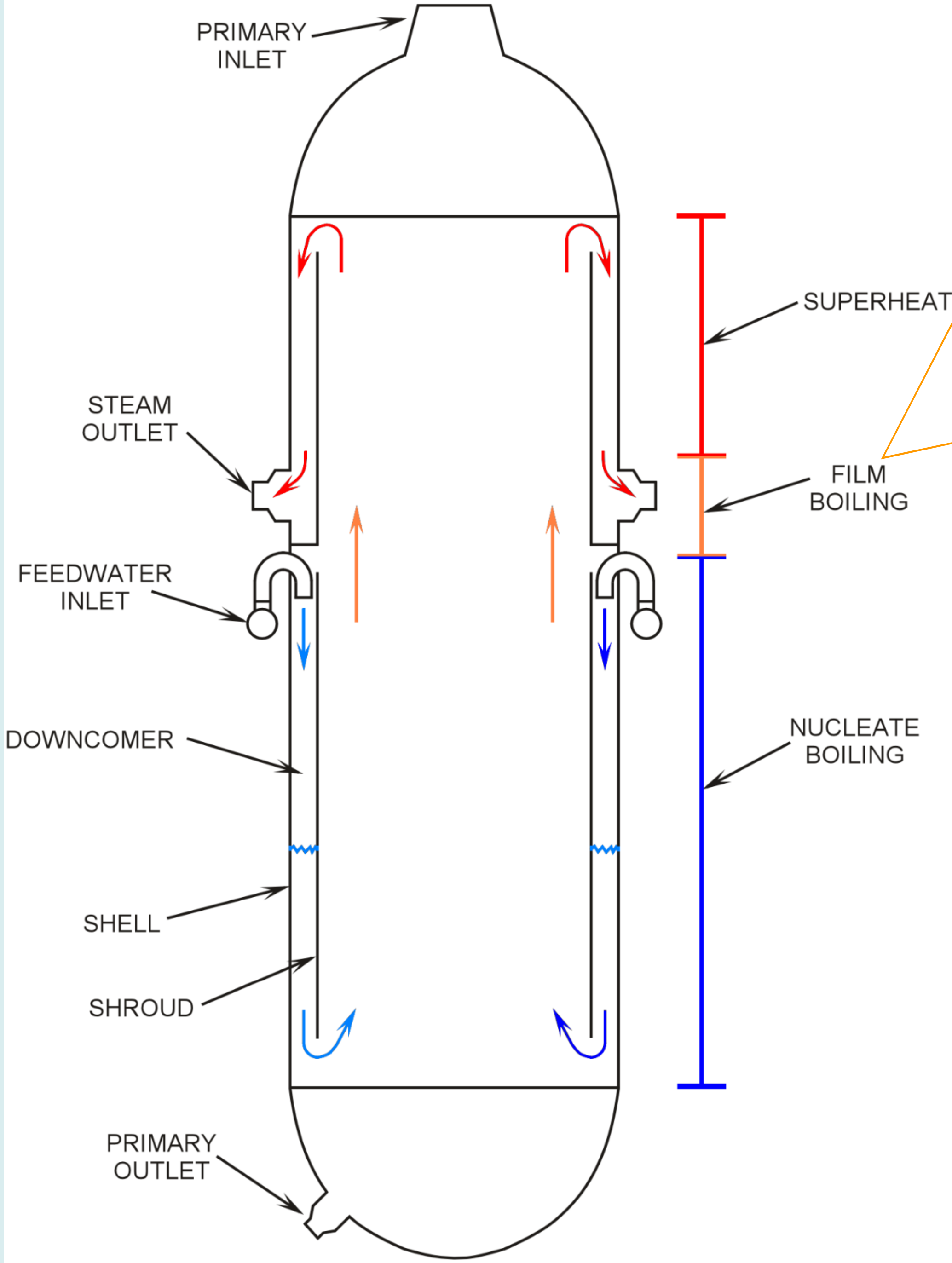
- Unlike U-tube S/Gs, the OTSG produces superheated steam.
- This is accomplished in 3 separate regions of the tube bundle:
  - Nucleate boiling region.
  - Film boiling region.
  - Superheating region.



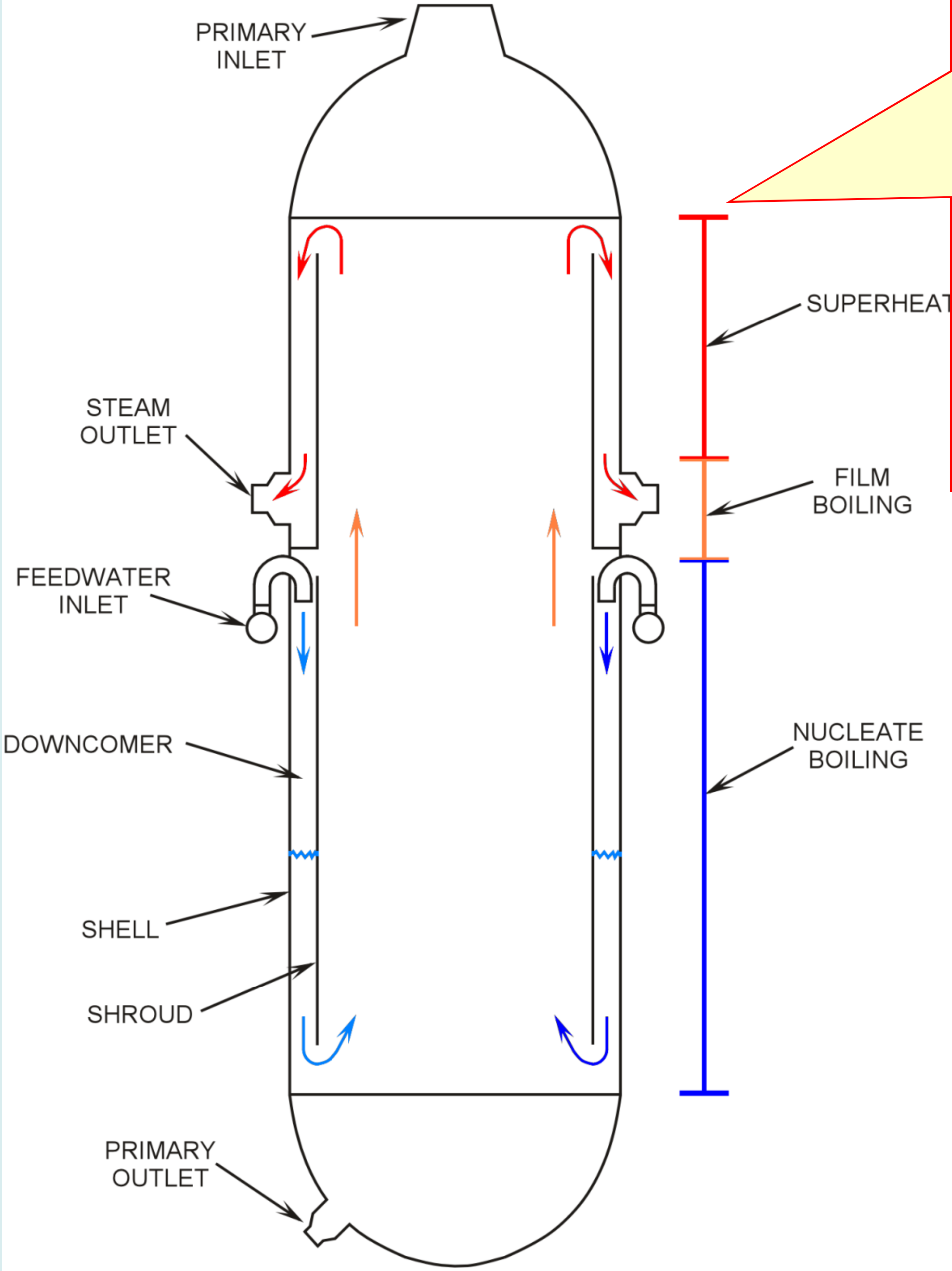
Nucleate Boiling Region:
Saturated FW becomes saturated steam in this region.
Tubes remain wet & small steam bubbles break away from tube surfaces.
Most of the heat transfer from RCS occurs in this region (due to turbulence).
Steam quality ~ 90% at top of region.
Size of region increases with power level as power increases from 15 to 100%.

Heat Transfer Regions
Fig. 2.4-3

Film Boiling Region:
Steam blanket gradually forms on tubes.
Phenomenon fully develops in a very short axial distance.
Steam quality ~ 100% at top of region.
Size of region stays relatively constant as power increases.



Heat Transfer Regions
Fig. 2.4-3

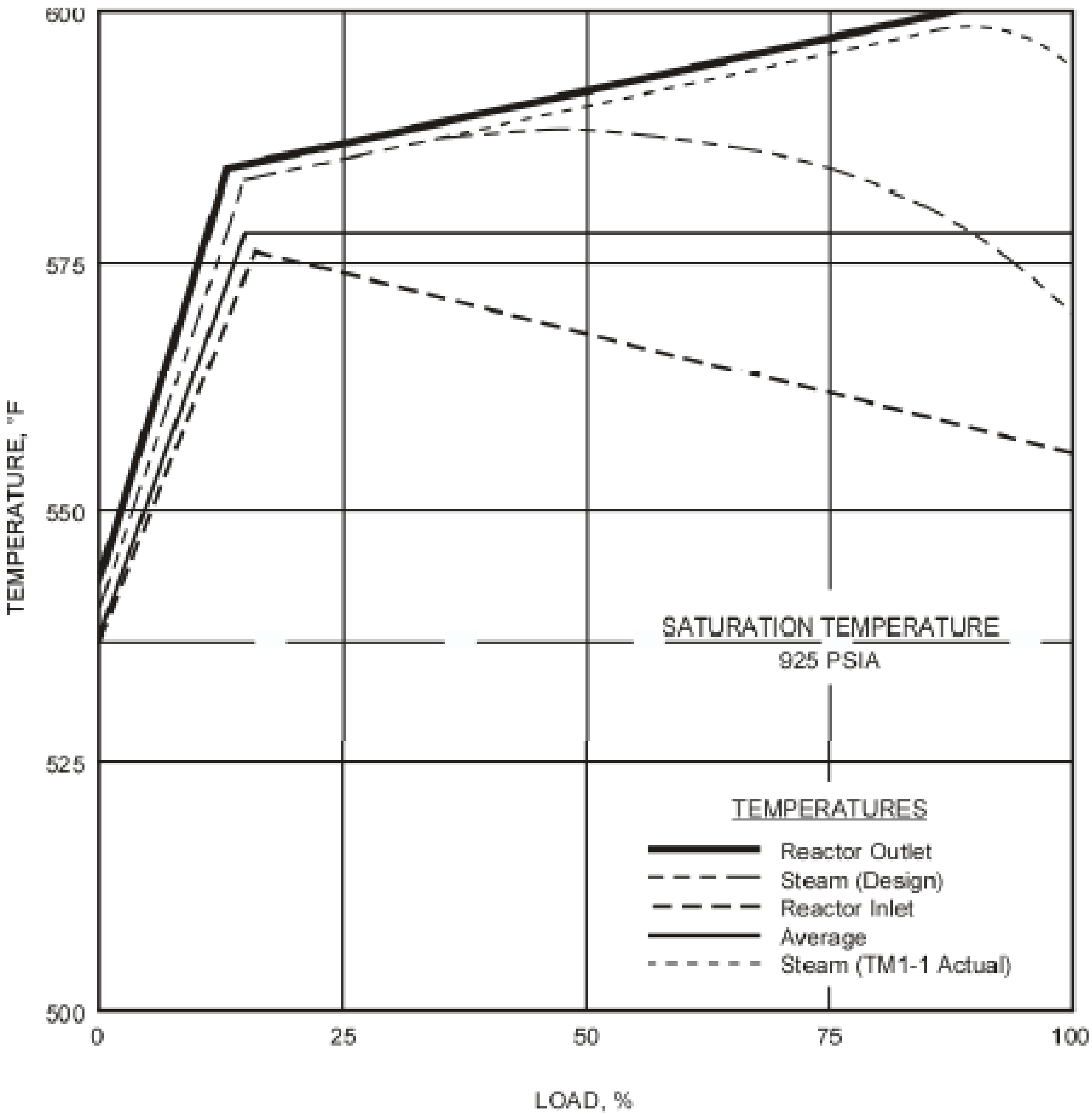


Superheating Region:
Steam is superheated a minimum of 35°F.
Size of region decreases as power increases.
At higher loads, less surface area available to add superheat.

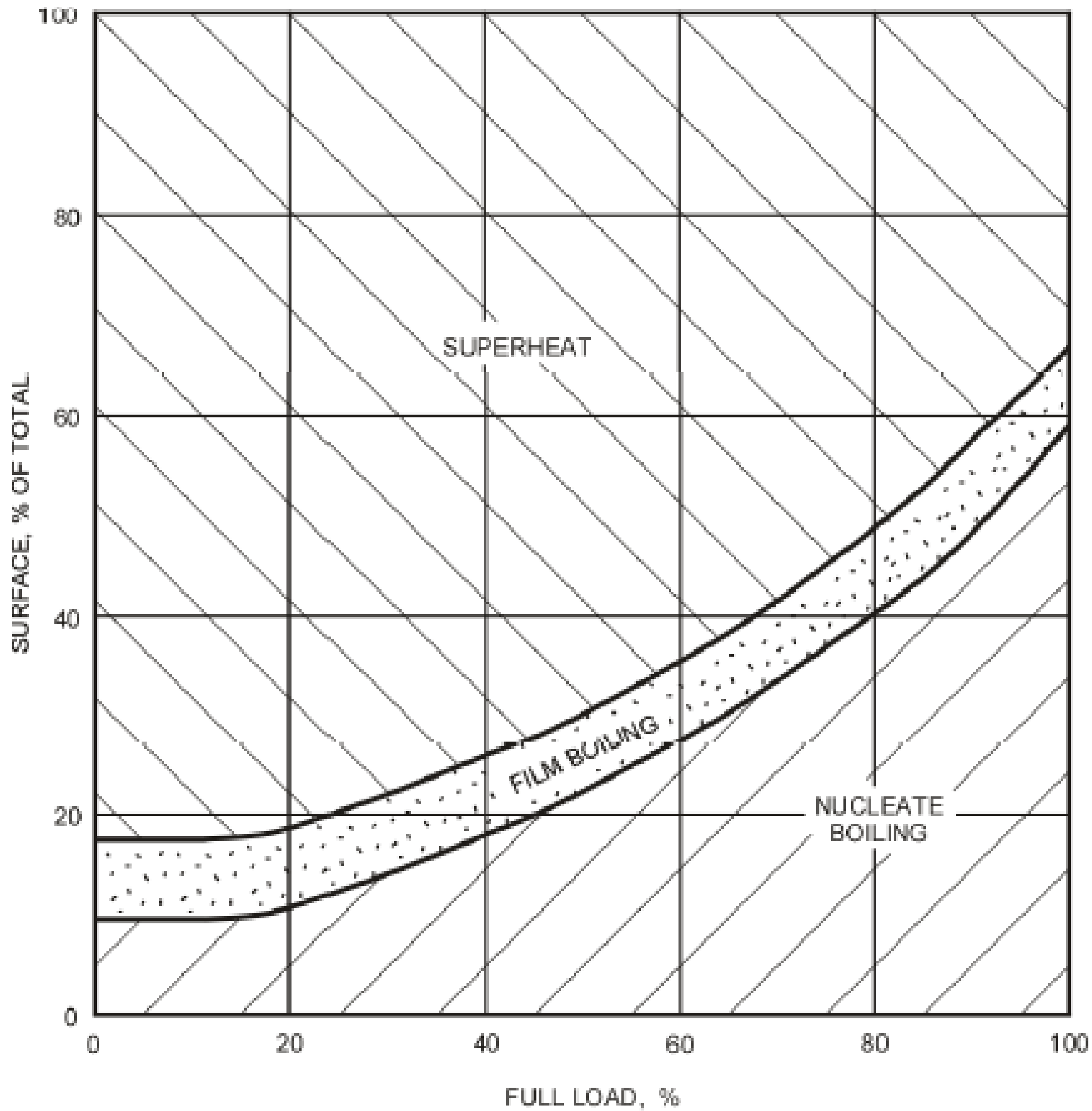
Heat Transfer Regions
Fig. 2.4-3

OTSG Operations > 15%

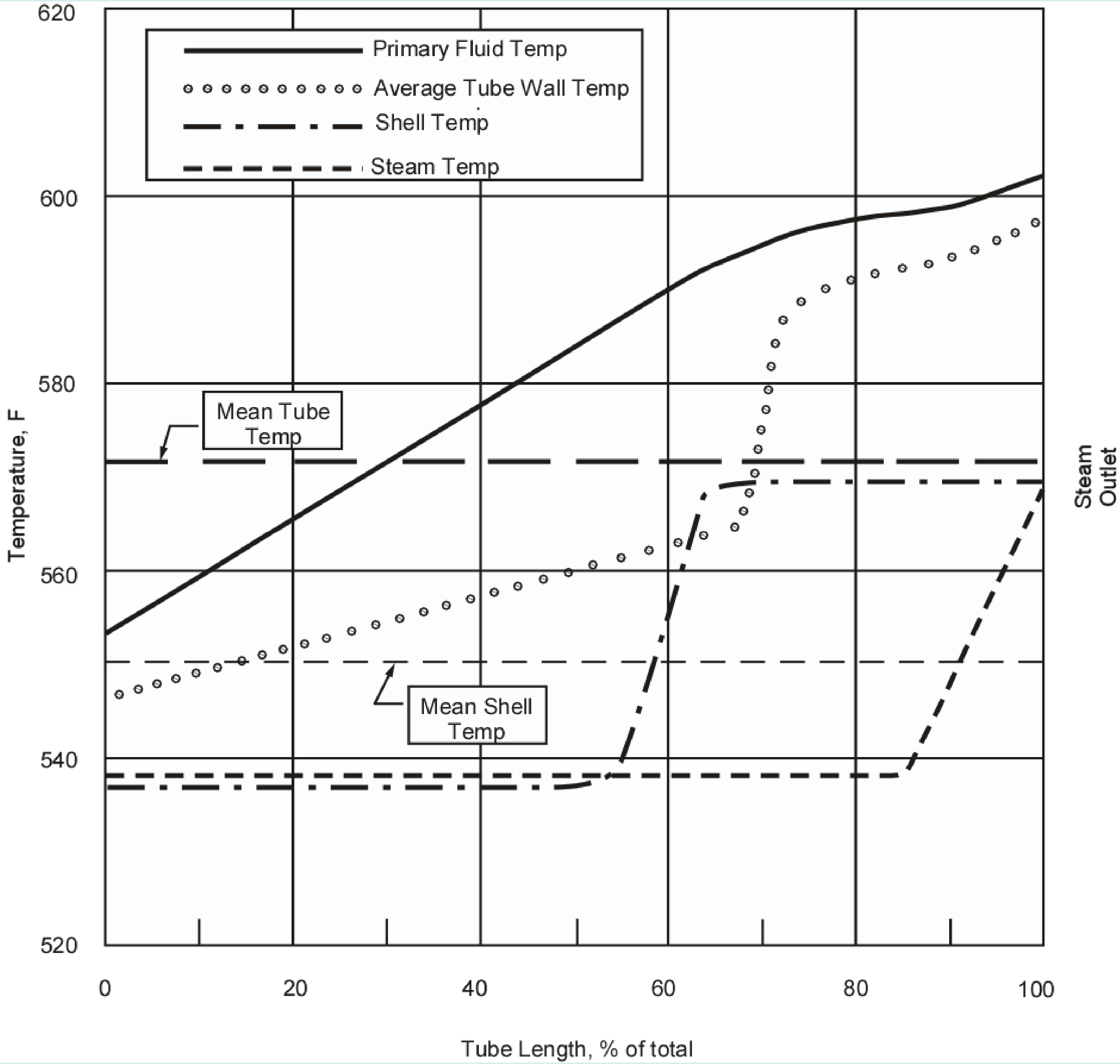
- $\dot{Q} = UA\,(T_{ave} - T_{sat})$
- T_{ave} & T_{sat} held constant by ICS.
- For power increase, the OTSG relies on change in size of nucleate boiling region.
- As power increases, more FW, more tubes covered (larger nucleate boiling region), more heat transfer.
- **The amount of superheat added increases until load ~ 50%.**
- **Above 50%, size of superheat region decreases & amount of superheat added decreases.**
- **Always a minimum superheat of 35°F.**



Reactor Coolant and Steam Temperature vs. Load
Fig. 2.4-4



Steam Generator
Heating Surface
vs. Load
Fig. 2.4-5



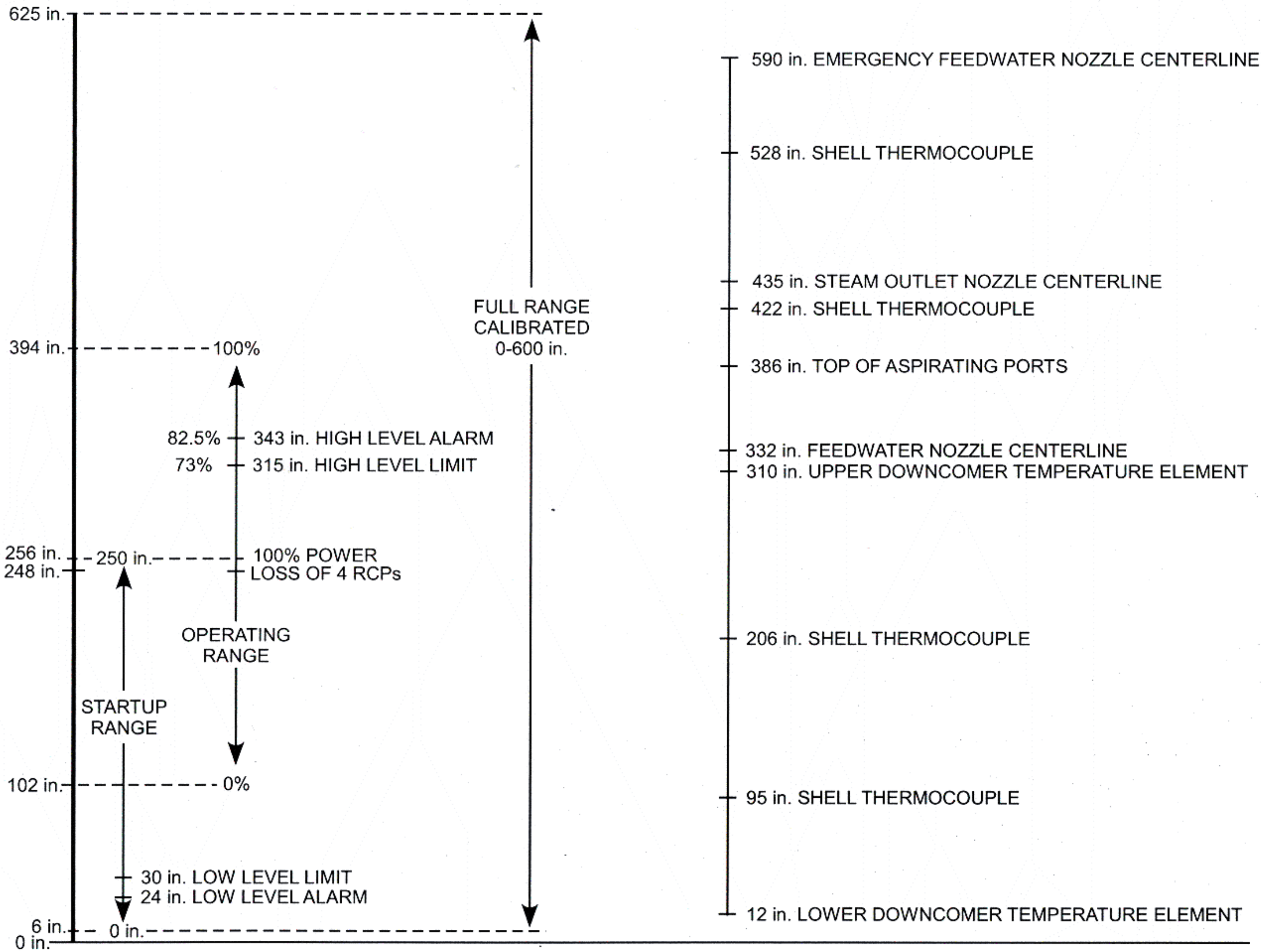
Steam Generator Tube and Shell Temperature vs. Tube Length
Fig. 2.4-6

Thermal Stresses

- Caused by differences in coefficients of thermal expansion of tubes & shell and differences in tube & shell temperatures.
- Potential to overstress tubes.
- High stress points:
  - Tubes
  - Shell

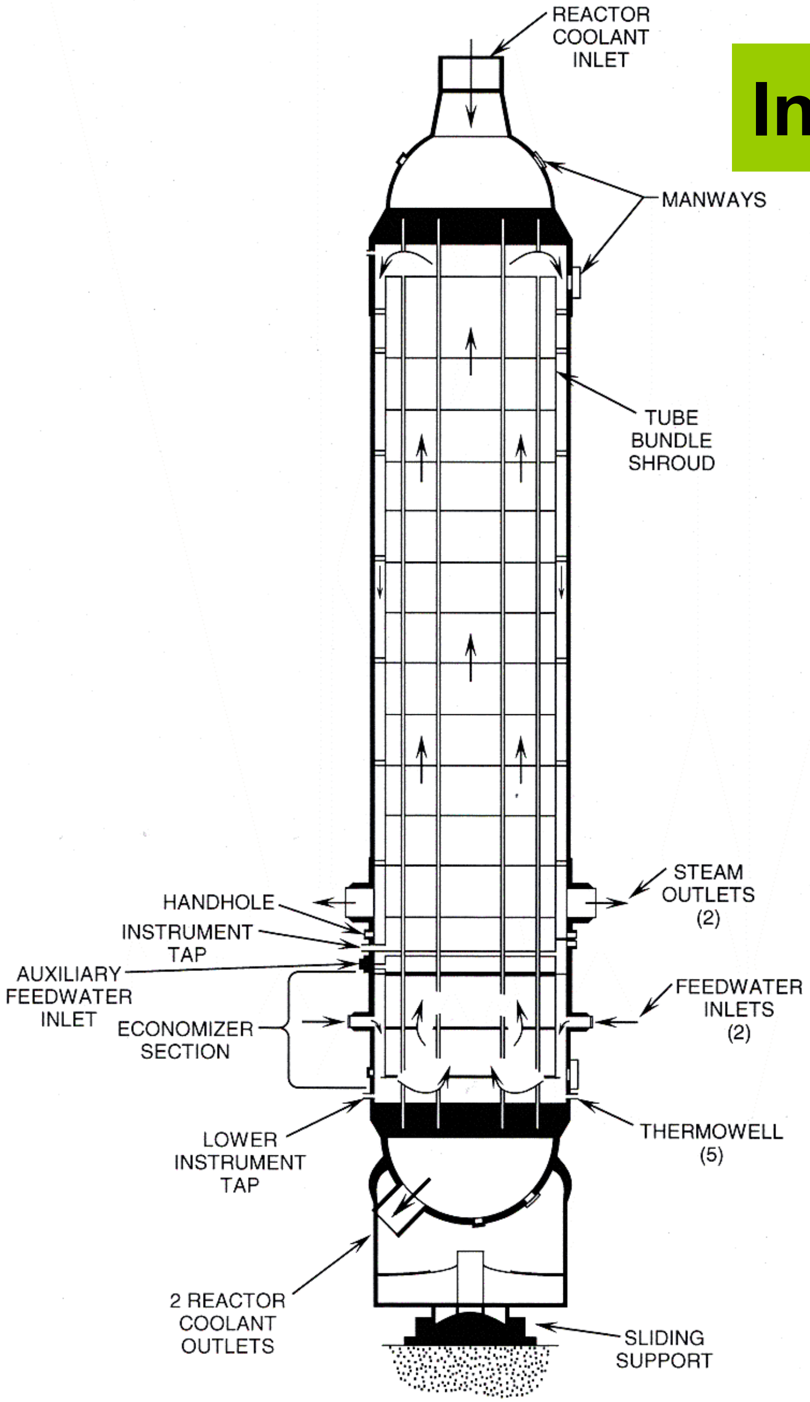
Thermal Stresses (cont)

- Normal ops, tubes hotter than shell:
  - Compressive stress on tubes, Tensile Stress on Shell.
  - Tube-to-shell ΔT minimized by:
    - Lower part of shell is heated by FW preheated from aspirating steam in FW annulus.
    - Upper part of shell is heated with superheated steam flowing down steam annulus.
- During H/U:
  - Extend vacuum to SGs, or
  - Use recirculation system to heat shell.
- During upsets in heat transfer:
  - Tube-to-shell ΔT addressed by EOPs.



OTSG Instrumentation (Fig. 2.4-7)

Integral Economizer OTSG



Integral
Economizer
OTSG
Fig. 2.4-8