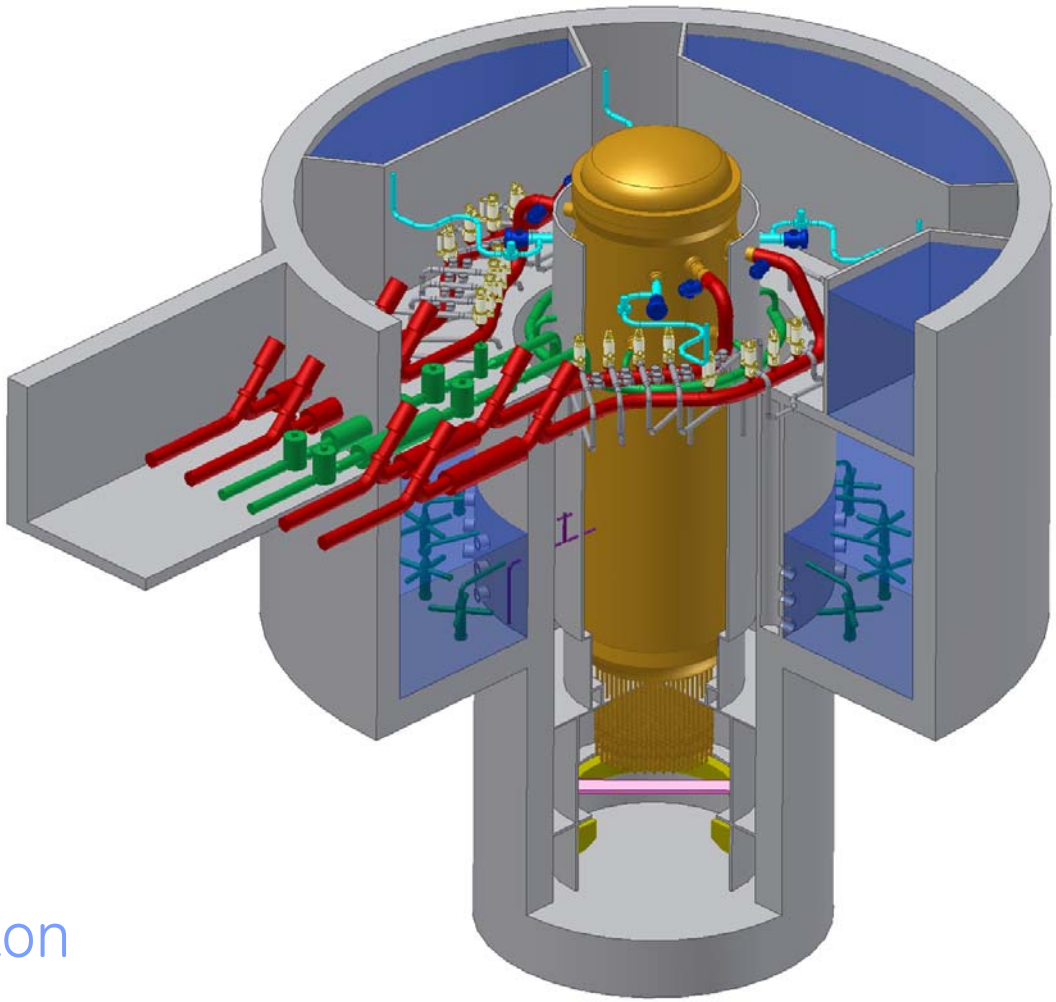
Steam and Power Conversion System

Overview



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September 27, 2005

Steam and Power Conversion System Overview

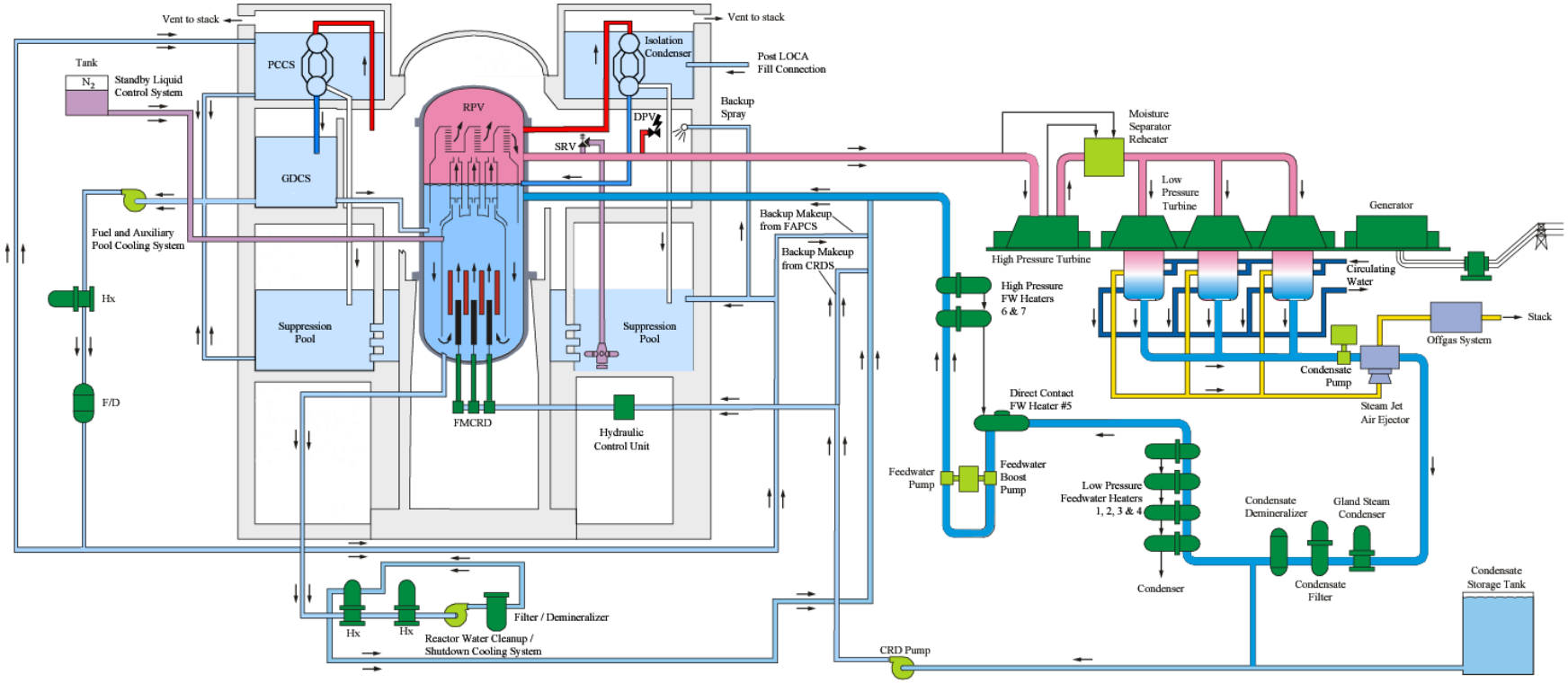
- Summary Description
- Turbine Generator
- Turbine Main Steam System
- Other Features of Steam and Power Conversion Systems
  - Main Condenser
  - Condenser Air Removal System
  - Turbine Gland Seal System
  - Condensate Purification System
  - Turbine Bypass System
  - Condensate and Feedwater System
- Alternative Design for Steam and Power Conversion System

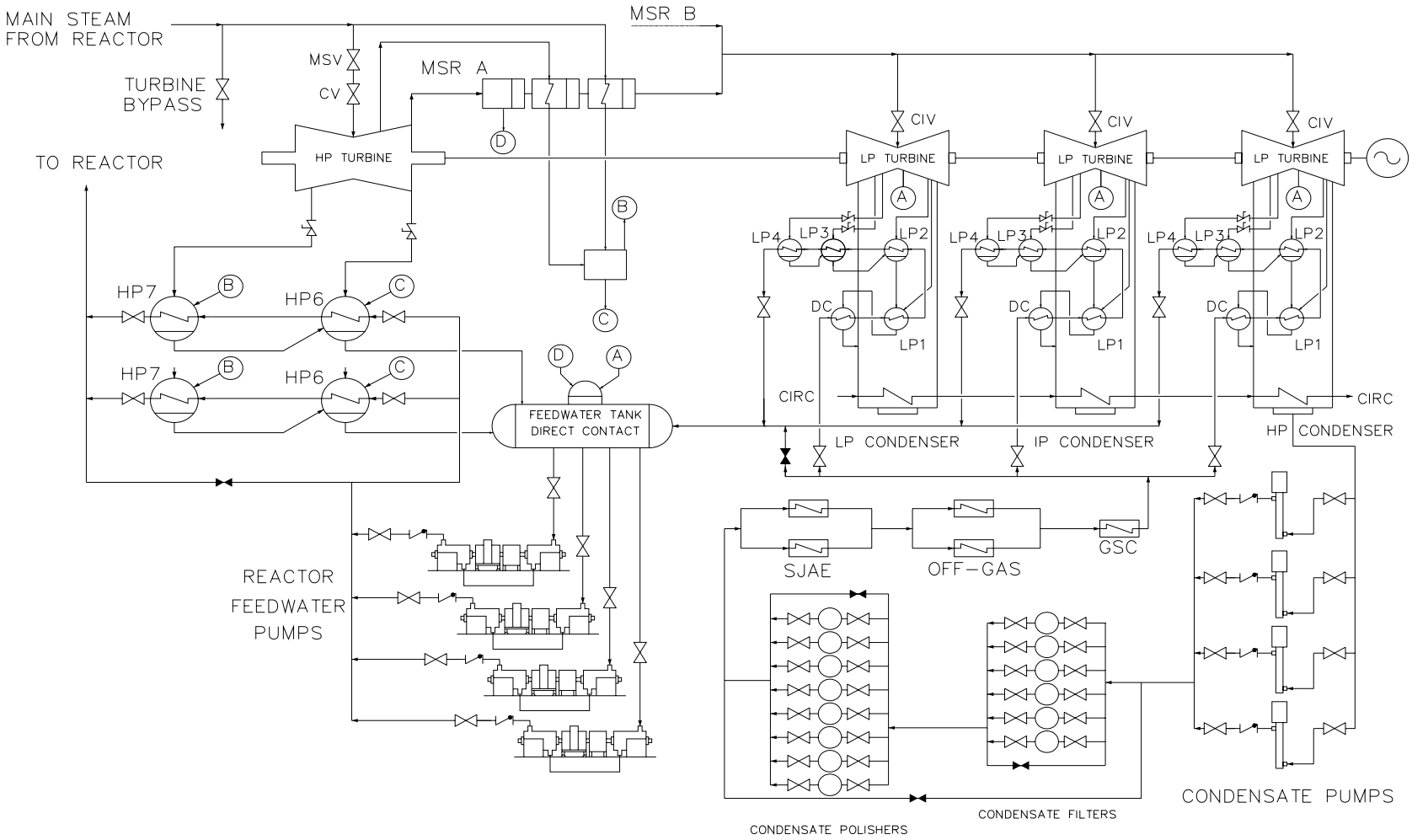
Steam and Power Conversion System

- Steam and Power Conversion System is a non-safety related system
- Designed to convert 4500 MWt to approximately 1550 – 1650 MWe (depending on type of TG and site specific circulating water temperature and condenser vacuum conditions)
- Reference design conditions are based on typical central US site conditions.
- ESBWR Steam and Power Conversion System is a direct cycle system slaved to the reactor at a turbine throttle pressure of 6.63 MPa (961 psia) (See Figure 1 for top level illustration of turbine cycle)
- System is designed with 110% bypass capacity and is capable of Island Mode Operation
- The reference TG is a tandem compound, six flow machine with 132 cm (52-in) LSB. The TG operating speed is 1800 rpm/60 Hz.
- Entire system housed in the Seismic Category II Turbine Building
- Radiation Shielding has been provided to keep personnel exposure ALARA

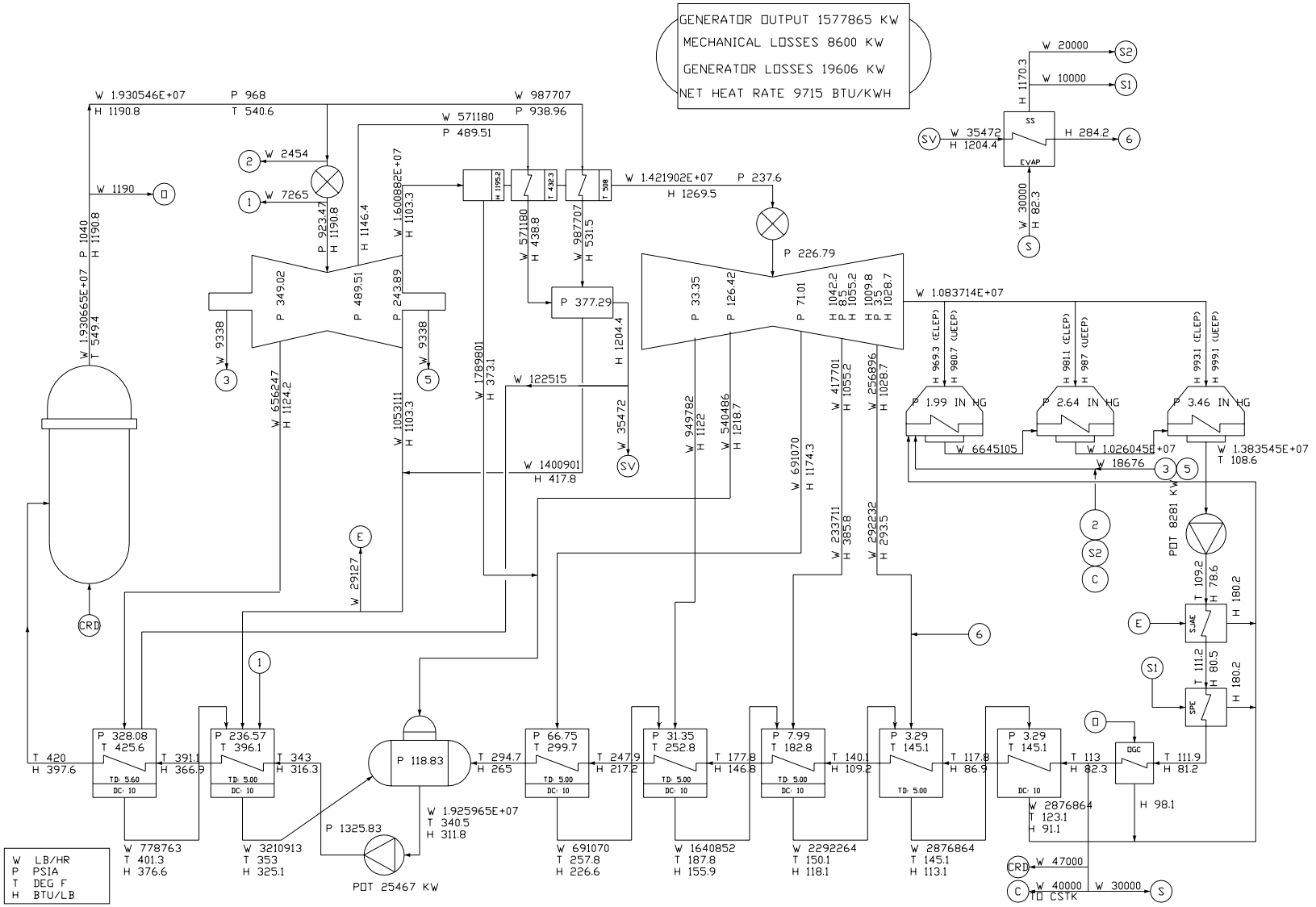
Steam and Power Conversion System

- Condensate pumps: four fixed speed, centrifugal, vertical can type motor driven pumps. Required pumping power = 4.3 MWe/pump
- Reactor Feedwater Pumps: four variable speed, centrifugal, horizontal motor driven pumps. Booster pump and main pump are on a common shaft. Required pumping power = 12.8 MWe/pump
- RFP runout is 135% of rated feedwater flow.
- Cycle relies 2 moisture separator/reheaters and seven stages of feed water heating for improved cycle efficiency.
- Condensate Purification System designed with deep bed demineralizers and hollow fiber filters to achieve reactor water quality requirements and to minimize Radwaste.
- Safety-related instrumentation measures turbine main steam header pressure, main condenser pressure, main turbine stop valve position, EHC pressure of turbine control valves and bypass valve position. These signals are provided to RPS


Vent to stack
Vent to stack
Tank
N_2
Standby Liquid Control System
PCCS
Isolation Condenser
Post LOCA Fill Connection
RPV
DPV
SRV
Backup Spray
GDCS
Moisture Separator Reheater
Low Pressure Turbine
Generator
Backup Makeup from FAPCS
Backup Makeup from CRDS
Fuel and Auxiliary Pool Cooling System
High Pressure Turbine
Circulating Water
Hx
High Pressure FW Heaters 6 & 7
Stack
Offgas System
Suppression Pool
Suppression Pool
Condensate Pump
F/D
Direct Contact FW Heater #5
Steam Jet Air Ejector
FMCRD
Hydraulic Control Unit
Feedwater Pump
Feedwater Boost Pump
Low Pressure Feedwater Heaters 1, 2, 3 & 4
Condensate Demineralizer
Gland Steam Condenser
Condenser
Condensate Filter
Condensate Storage Tank
Hx
Hx
Filter / Demineralizer
Reactor Water Cleanup / Shutdown Cooling System
CRD Pump



Power Cycle Schematic



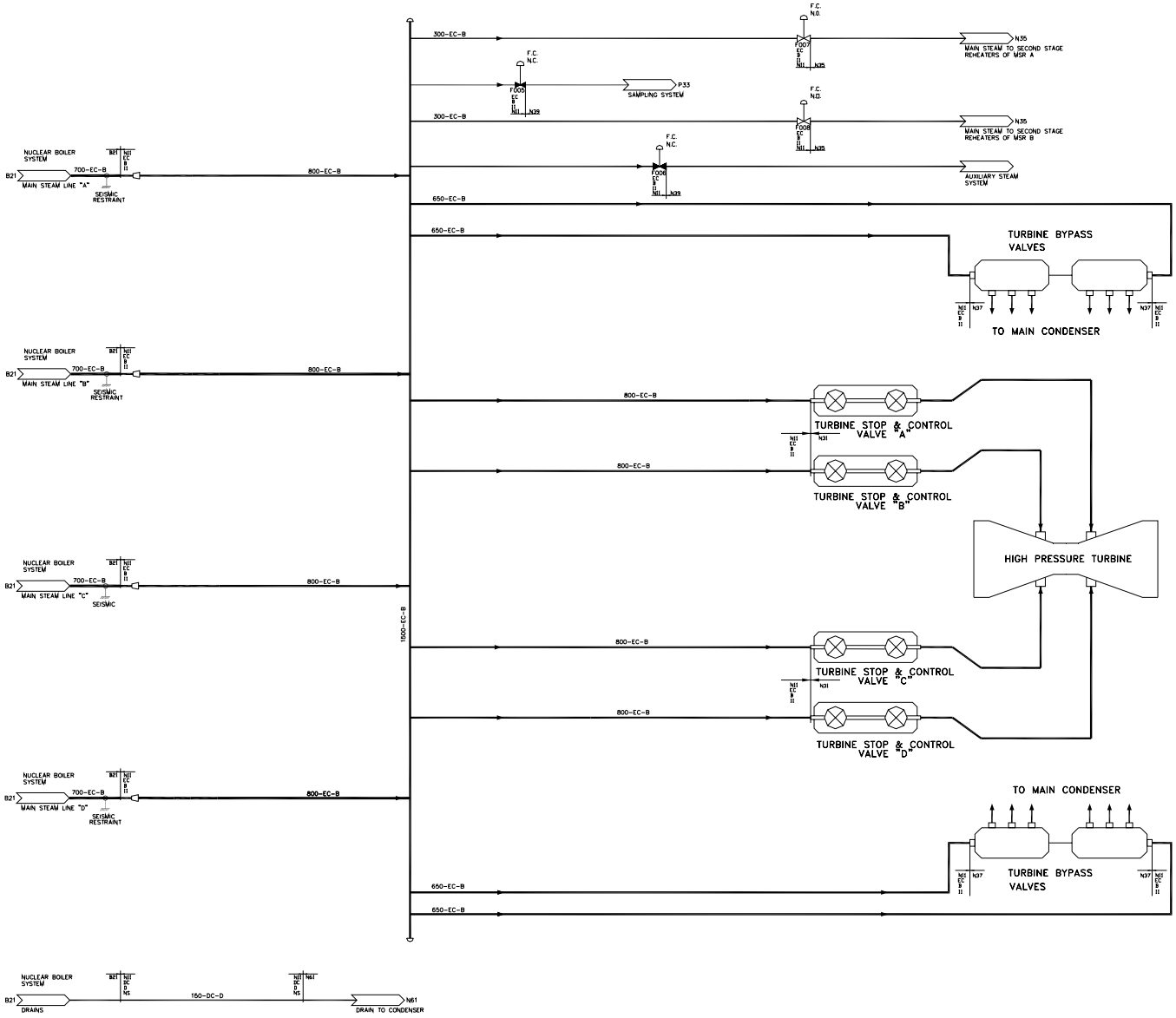
Rated Heat Balance (US Units)

Turbine Generator

- The TG does not perform or support any safety-related functions.
- The reference turbine is a tandem compound, six flow machine with 132 cm (52-in) LSB. HP turbine has two stages of steam extraction.
- The reference generator is a direct driven, three phase, 60 HZ, 1800 rpm synchronous generator with a water cooled stator and a hydrogen cooled rotor.
- MSRs are located on each side of the TG centerline.
- TG uses digital monitoring and control in conjunction with SBPC system.
- Controls turbine speed, load, and flow for S/U and normal ops. Control system operates TSV, CV and CIVs.
- The TG can either be base base loaded or load follow at 1%/minute between 50% and 100% CTP.
- The TG is designed to accommodate a 20% step demand increase or decrease within 10 minutes.
- The TG can accept sudden full load rejection with sufficient margin to overspeed trip and still be able to recover to power house loads.

Turbine Main Steam System

- System is non safety-related and is designed to deliver reactor nuclear steam to the TG.
- Provides seismically analyzed fission path to the main condenser.
- The TMSS is not required to perform or support any safety-related function but, safety-related instrumentation measures TMSS header pressure and hydraulic pressure of turbine control valves for input to the RPS.
- The TMSS consists of four lines from the seismic interface restraint to the Main Turbine Stop Valves and branches off to the Turbine Bypass Valves, Auxiliary Steam, Second Stage Reheaters, and Sampling System.
- Four MSLs connect to to a header upstream of TSVs to permit testing of MSIVs during operation.



Turbine Main Steam System

Main Condenser

- Main Condenser performs no safety-related function. It is designed with the necessary shielding to protect plant personnel from radiation.
- Hotwell provides a holdup volume for MSIV fission product leakage.
- Reference condenser is a multi-pressure, three shell reheating/deaerating unit. Three shells are as follows: LP shell, IP shell and HP shell.
- Circulating water flows in series through the three single pass shells.

Condenser Air Removal System

- Removes H_2 and O_2 produced by radiolysis of water in the reactor and other noncondensible gases and exhausts them to to the Offgas System or Turbine Building Compartment Exhaust at the beginning of each S/U
- Consists of two 100% capacity, double stage, steam jet air ejector (SJAE) units for normal power operation and two 50% capacity mechanical vacuum pumps for use during S/U.
- One SJAE is normally in operation and one is in standby
- System failure will cause gradual condenser vacuum pressure increase and reduces turbine cycle efficiency.
- Will eventually lead to trip the turbine upon reaching the high condenser pressure turbine trip set point.

Turbine Gland Seal

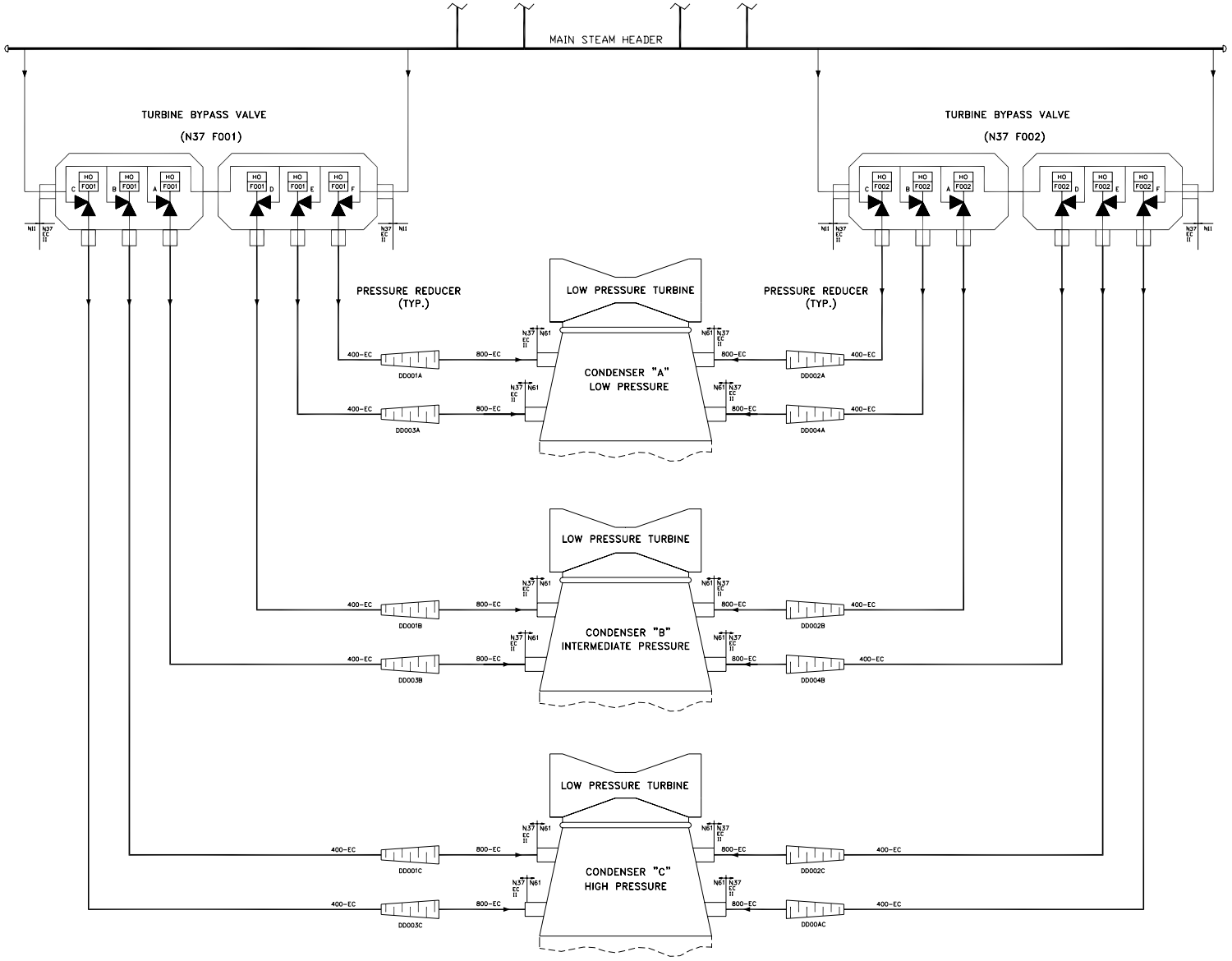
- System is not safety-related.
- Prevents the escape of radioactive steam from the turbine shaft/casing penetrations and valve stems and prevents air inleakage through subatmospheric turbine glands.
- TGSS consists of a gland steam evaporator, sealing steam pressure regulator, sealing steam header, a gland steam condenser with two full capacity exhauster blowers and associated piping, valves and instrumentation.

Condensate Purification Systems

- The CPS continuously removes dissolved and suspended solids from the condensate.
- Establishes Reactor feedwater quality during startup and maintains it during operation.
- Maintains condensate storage tank water quality as required for makeup.
- Consists of high efficiency hollow fiber filters and bead resin, mixed bed ion exchange demineralizer vessels. A resin trap is installed downstream of the demineralizer to prevent gross resin leakage.

Turbine Bypass System

- System is not safety-related and has a capacity of 110% of the rated main steam flow.
- Designed to bypass steam to condenser during plant startup and permit normal cooldown of the reactor from a hot shutdown to a point consistent with initiation of shutdown cooling system.
- System capacity and response time is such that system is capable of handling a full load rejection or turbine trip without a reactor scram or lifting the SRVs.
- No single failure can disable more than 50% of the installed bypass capacity.
- The TBS is designed with twelve Turbine Bypass Valves (TBV) mounted on four chests (three valves per chest) connected to the TMSS main steam line equalizing header.



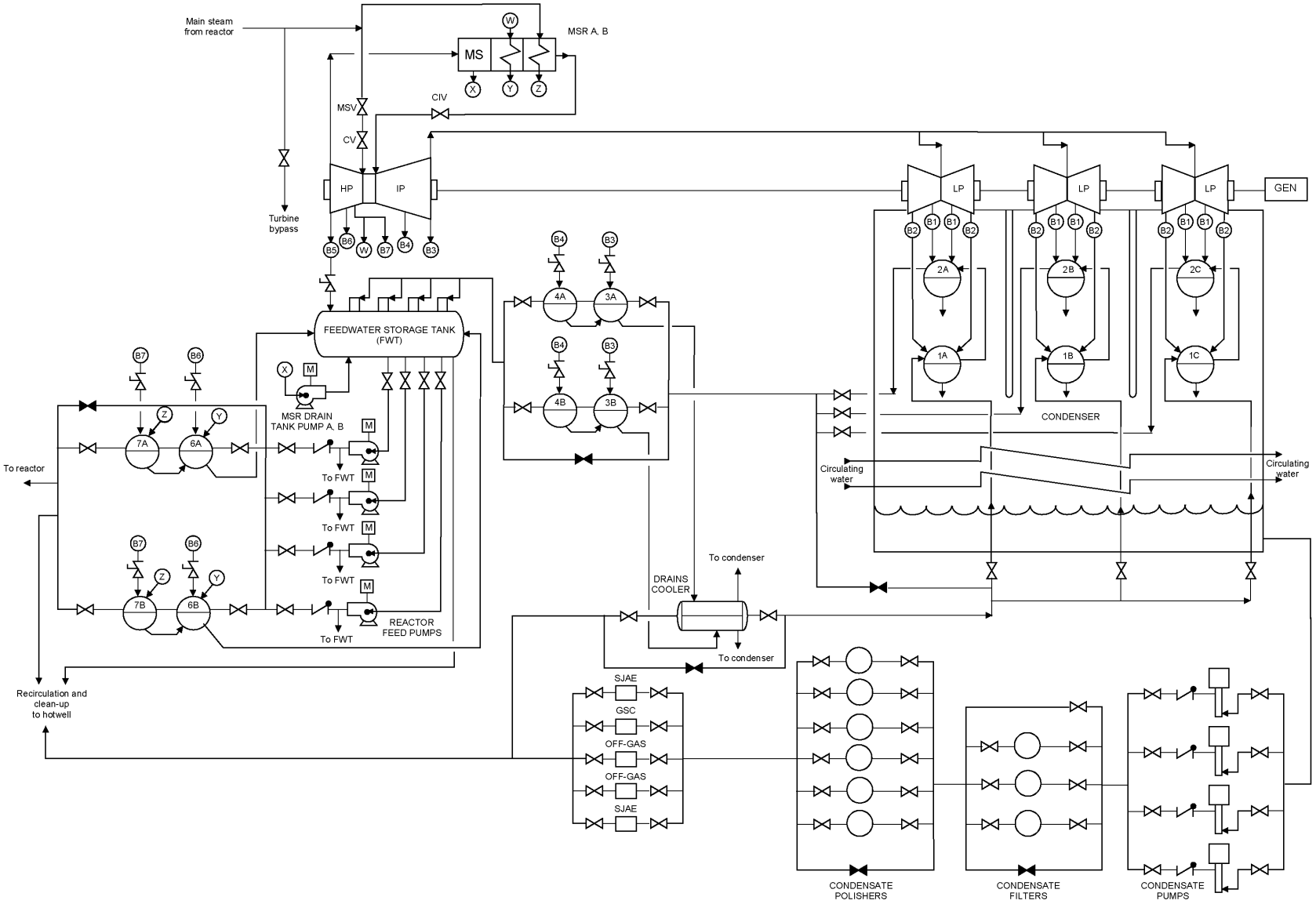
Turbine Bypass System

Condensate and Feedwater System

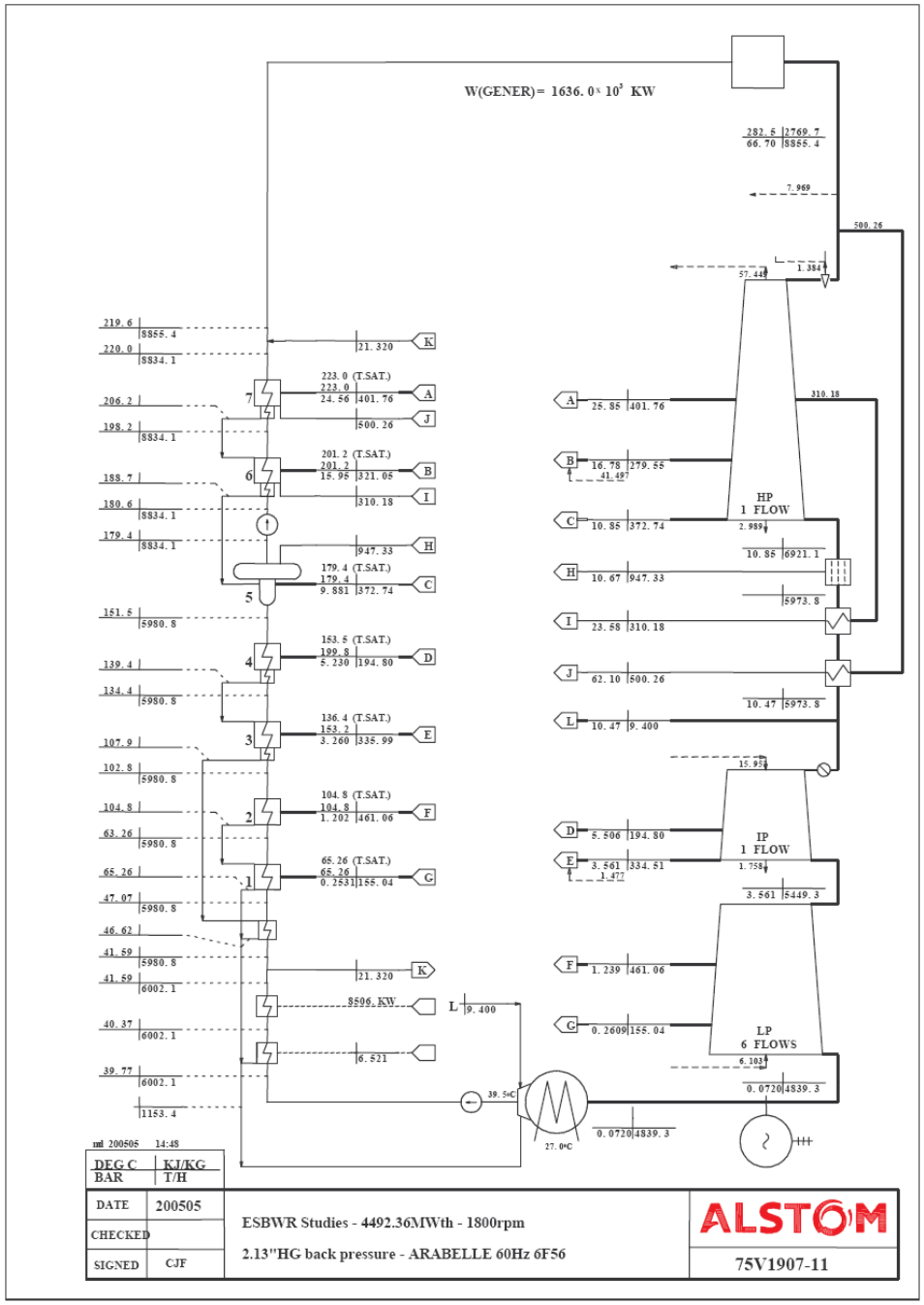
- The C&FS does not perform, ensure or support any safety-related function.
- The Condensate and Feedwater System (C&FS) receives condensate from the condenser hotwells, supplies condensate to the CPS and delivers high purity FW to the reactor, at the required flow rate, pressure, and temperature.
- C&FS designed to permit full power operation with the following equipment out of service: one FW pump, one condensate pump, and/or one HP heater string isolated and bypass open with slightly reduced final FW temperature.
- C&FS design allows operation at approximately 85% of rated power with one LP heater string isolated and the bypass open.
- During plant startup, the C&FS is designed to pump preheated FW from the 5th stage FW heater to the RPV for inventory heating prior to control rod withdrawal if sufficient core decay heat is not available.
- C&FS designed so that no single operator error or component failure shall cause more than 100 degrees F decrease in temperature at reactor inlet.

Alternate Steam and Power Conversion System

- Appendix 10 A presents an alternate steam and power conversion system coupled to the ESBWR.
- The appendix is arranged showing where the steam and power conversion system is different from the standard design presented in Chapter 10.
- There is no difference between the reference and alternate design with respect to nuclear safety.
- Both comply with reactor interface requirements.
- Appendix 10A reference TG is a tandem compound HP, IP and six flow LP turbine with 57 inch LSB.
- Power cycle heat sink is a lake and Circ Water System is an open circuit.
- Main Condenser has a single pressure – therefore all LP turbines see same exhaust pressure.
- Final Feedwater temperature is higher 220° C (428° F).
- Design of the condenser and some FW heaters are different



Alternate Steam and Power Conversion System


W(GENER)= 1636.0 x 10³ KW
HP
1 FLOW
IP
1 FLOW
LP
6 FLOWS
8596. KW
ESBWR Studies - 4492.36MWth - 1800rpm
2.13"HG back pressure - ARABELLE 60Hz 6F56
ALSTOM
75V1907-11
DATE 200505
CHECKED
SIGNED CJF