| ACME NucPower Procedure | | | OPS-N-0001-E |
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| Title: | **ACME NucPower Unit 1 Reactor Start up** | | |
| Author: | R.J.Smith | Authorised by: | John Hancock |
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## Summary

This procedure provides a step by step instruction for ACME NucPower Unit 1 Reactor start up from cold conditions. It shall be used as a reference each time this plant is started and a record kept of plant start up progress and any issues, events or error for future improvements.

The reactor has 5 operating modes as described below;

**Mode 5** Cold shutdown - reactor is sub-critical with 0% power output and primary coolant average temperature $< 95$ degC.

**Mode 4** Hot shutdown - reactor is sub-critical with 0% power output and primary coolant average temperature is $> 95$ degC and $< 176$ degC.

**Mode 3** Hot standby - reactor is sub-critical with 0% power output and primary coolant average temperature $> 176$ degC.

**Mode 2** Startup - reactor is critical with power output $< 5\%$

**Mode 1** Power operations - reactor is critical with power output $> 5\%$


## Start Up procedure

The following is an operations procedure to take the plant from a Cold Shutdown condition (mode 5) and pass through all the steps required to commence Power Operation (Mode 1) and then achieve plant full load.

The reactor has just completed a refuelling where approximately 33% of the spent fuel rod have been removed for reprocessing and replace with new, therefore most of the the plant equipment is shutdown and will need to be re-started in the correct order to ensure safe operation.

- Reactor SCRAM active and at Mode 5 condition (Cold Shutdown).
- Pressuriser wet stored (water level raised to near top of vessel to prevent corrosion).
- Reactor primary circuit filled with borated water - current concentration is 2450 ppm.
- Refuelling Water Storage Tank (RWST) filled with borated water
- Containment vessel HVAC (Heating, Ventilation and Air Conditioning) system (0KLA10AN001) is running.

- Condensate system filled with demin water and Condenser Hotwell (01MAG10BB001) is at normal working level.
- Feedwater system filled with demin water and Deaerator vessel (01LAA10BB001) is at normal working level.
- All Steam Generators are wet stored.
- Cold Leg accumulator are filled with highly borated water and isolated.
- Electrical system are on line and Emergency Diesel Generators (EDG's) selected to Auto start.

The step by step procedure below should now be followed to start the reactor in a safe manner.

1. START Cooling Water system controller (01PAA10AH001). This will start the following pumps in sequence so as to place the Main Cooling Water, Service Water and Closed Cooling Water systems in service;
   - 01PAC10AP001 - Main Cooling Water pump
   - 01PJA10AP001 - Service Water pump
   - 01KAA10AP001 - Closed Cooling Water pump
2. OPEN valve 01LAC60AA501 to drain Steam Generator 1 (01JEA10BB001) down to Normal Working Level (NWL). Steam Generators have been wet stored so the level must be reduced before Feedwater pump start permissive is obtained. Once level is at 50% (NWL) then valve 01LAV60AA501 will automatically CLOSE. The level of SG1 can be monitored on level gauge 01JEA10CL001.
3. OPEN valve 01LAC70AA501 to drain Steam Generator 2 (01JEA20BB001) down to NWL.
4. OPEN valve 01LAC80AA501 to drain Steam Generator 3 (01JEA30BB001) down to NWL.
5. OPEN valve 01LAC90AA501 to drain Steam Generator 4 (01JEA40BB001) down to NWL.
6. START Chemical and Volume Control system (CVCS) Charging pump (either 01KBD10AP001 or 01KBD20AP001).
7. SELECT CVCS mode to DRAIN. This will reduce the Pressuriser level from its wet stored condition to NWL. Once Pressuriser NWL is achieved then draining will stop.
8. SELECT Condensate system controller (01LC10AH001) to AUTO. This will start the sequence for placing these system in service as follows;
   - START Condensate Extraction Pump 1 (01LCA10AP001).
   - Clean up the condensate system by recirculating the condensate water back to the condenser (and through a mixed bed vessel) by OPENING valve 01LCA50AA001.
   - Once Condensate system clean-up completed CLOSE valve 01LCA50AA001.
   - Place all remaining Condensate Extraction pumps on AUTO, so they will START and STOP as required by reactor load.
9. START Feedwater Pump 1 (01LC10AP001). NOTE: This pump is electrically driven so can be started now. Feedwater Pumps 2, 3 and 4 are turbine driven using bled steam from the main turbine and can only be started once sufficient steam is available. Feedwater Pump 1 has a capacity from Zero to approx. 40% feedwater flow.
10. NOTE: The first start of Feedwater Pump 1 after a long shutdown will initiate a feedwater system clean up routine to ensure the water quality is sufficient before feeding water to the Steam Generators. The clean up process is as follows;
    - Clean up the Feedwater system by recirculating the feedwater back to Deaerator storage tank (01LAA10BB001) by OPENING valve 01LAC60AA001.
    - Once Feedwater system clean-up completed CLOSE valve 01LCA60AA001.
11. PREPARE Steam Turbine systems.
    - SELECT Lube Oil Heater (01MAV10AH001) to AUTO. This will increase lube oil temperature up to approx. 45 deg C and then control it to maintain this value.
    - START Auxiliary Lube Oil Pump (01MAV10AP001) when lube oil tank temperature (01MAV10CT001) is $>$ 40 deg C

- START Turbine turning gear (01MAK10AH001). Turbine rotor will start to rotate and increase upto approx. 30 rpm.

12. Take first ESTIMATE of CRITICALITY.
13. SELECT ECCS (Emergency Core Cooling System) system (01JNB00AH001) to AUTO. This will align pump suction valves to accept feed from RWST tank (valve 01JNK10AA001 OPEN) and isolate suction from reactor containment sump (valve 01KPF10AA001 CLOSED). All Emergency Cooling water pumps (HP and LP) will now automatically start when required.
14. SELECT Containment Spray system (01JMN10AH001) to AUTO.
15. START Residual Heat Removal pump (01JNA10AP001).
16. SELECT Pressuriser Spray valve (01JEF10AH001) controller to AUTO. After a short interval spray water block valve (01JEF10AA001) will open fully and spray water control valve (01JEF10AA151) will open to minimum opening of 5%.
17. SELECT Pressuriser Heater controller (01JEF10AH002) to AUTO. This will cause Pressuriser heaters to go to 100% power and start warming primary circuit coolant from ambient conditions up to operating Pressure and Temperatures.
18. MONITOR primary circuit Pressure and Temperature as these increase. Note - as primary circuit temperature rises the water within this circuit will expand and Pressuriser level will increase.
19. START Reactor Coolant Pump (RCP) 1 (01JEB10AP001) after Reactor pressure (01JKA10CP001) is $>$ 20 bar.
20. STOP Residual Heat Removal pump (01JNA10AP001) as it is no longer required for circulating primary circuit coolant.
21. START RCP 4 (01JEB40AP001) after Reactor pressure (01JKA10CP001) is $>$ 30 bar.
22. START RCP 2 (01JEB20AP001) after Reactor pressure (01JKA10CP001) is $>$ 40 bar.
23. START RCP 3 (01JEB30AP001) after Reactor pressure (01JKA10CP001) is $>$ 50 bar.
24. When reactor primary circuit pressure (01JKA10CP001) is $>$ 142 bar OPEN Safety Injection Isolation valve (01JNG60/70/80/90AA001).
25. REACTOR is now ready to reset SCRAM.
26. Take second ESTIMATE of CRITICALITY.
27. If indicated boron concentration from Criticality Estimate is different than current primary circuit boron concentration (01KTA10CQ001), adjust primary circuit boron concentration by either diluting or borating using CVCS Control panel.
28. WAIT until boron concentration in primary circuit (01KTA10CQ001) has reached required value before proceeding.
29. SELECT Source Range flux meter (01JKA10CR001).
30. RESET SCRAM (01JKA10AH001). This will allow Reactor Protection Rods to be withdrawn.
31. SELECT retract (R) for Reactor Protection Rod 01JDA10CG001.
32. MONITOR Source range flux meter for increasing activity and Neutron trend for any sudden increases. If this trend increases suddenly then stop rod withdrawal and reassess Criticality Estimate.
33. MONITOR Start Up Rate (SUR) gauge (01JSA10CR001) to ensure increase in reactivity rate stays within design limits (SUR High alarm at 2 decades, whilst Reactor SCRAM at 3 decades).
34. WAIT until Reactor Protection Rod 01JDA10CG001 is fully retracted (NOTE - rod position 100% equals fully inserted, whilst 0% equal fully retracted.
35. SELECT retract (R) for Reactor Protection Rod 01JDA10CG002.
36. Again MONITOR Source range flux meter for increasing activity and Neutron trend for any sudden increases.

37. WAIT until Reactor Protection Rod 01JDA10CG002 is fully retracted. Note - Once both Reactor Protection Rods (01JDA10CG001 and 01JDA10CG002) are fully retracted it will be possible to retract any of the 4 Control Rods.

38. CONTINUE to RETRACT Reactor Control Rods 01JDA20CG001, 01JDA20CG002, 01JDA20CG003, 01JDA20CG004. MONITOR Start Up Rate (SUR) gauge (01JSA10CR001) to ensure increase in reactivity rate stays within design limits.

39. MONITOR Source range flux meter (01JKA10CR001) for increasing activity and Neutron trend for any sudden increases. As trend Neutron detection line takes higher and higher vertical steps it may be necessary to change the vertical scale.

40. If Criticality Estimate is accurate then Source range flux meter will go off-scale and Neutron detection trend off scale vertically (i.e. the number of released Neutrons has increased exponentially and the reactor is now Critical (i.e. the chain reaction is self sustaining).

41. SELECT Intermediate range flux meter (01JKA10CR002).

42. CONTINUE retracting Reactor control rods 01JDA20CG001, 01JDA20CG002, 01JDA20CG003, 01JDA20CG004 until desired rod configuration is achieved. Note - At higher reactor loads all Reactor Control Rods must be near to fully retracted. Any deeply inserted rods will distort the core power distribution forcing the lower half of the reactor core to contribute more of the reactor load and the upper half less which can lead to a fuel rod experiencing higher than design temperatures in the lower core. To protect against this Axial Displacement gauge (01JSA10CR003) monitors this power distribution and will initiate an alarm or even Reactor SCRAM if over design limits.

43. Once Reactor Control Rods are at required position it is necessary to dilute the primary circuit boron concentrations to further increase Reactor load.

44. DILUTE primary circuit boron concentrations whilst monitoring Start Up Rate (SUR) gauge (01JSA10CR001) if reactor power $< 5\%$ or Load Increase Rate (LIR) gauge (01JSA10CR002) if reactor power $> 5\%$. LIR will monitor rate and if necessary give High alarm at 3.2 and even Reactor SCRAM at 5.2.

45. START gland steam system (01MAW10AH001) when Reactor power $> 2\%$. This will initiate the following sequence;

    - Gland steam supply isolation valve (01MAW20AA001) will OPEN.
    - Gland steam exhauster fan (01MAW30AN151) will START.
    - Gland steam pressure control valve (01MAW10AA151) will SELECT to AUTO.
    - Gland Steam pressure (01MAW20CP001) will increase to approx. 320 mbar and be controlled at this pressure by the actions of gland steam pressure control valve (01MAW10AA151).

46. SELECT Pull Condenser Vacuum (01MAJ10AH001).

47. When Reactor power $> 5\%$ SELECT Power range flux meter (01JKA10CR003A/B).

48. DILUTE primary circuit boron concentrations until reactor load is $> 20\%$

49. MONITOR Load Increase Rate (LIR) gauge (01JSA10CR002) as Reactor power increases

50. CALIBRATE Power range flux meter (01JKA10CR003A/B) regularly.

51. START turbine Control Oil Pump (01MAX10AP001).

52. SELECT AUTO or MANUAL turbine runup (01MAA10AH001). AUTO mode will run turbine to synchronise speed, start excitation and auto-sync to 500kV grid. Manual mode will run turbine to FSNL (Full Speed No Load) and the operator will then need to START excitation and manually Synchronise the generator to grid.

53. RESET STG Trip (01MAA10AH001). Steam Turbine should now automatically do the following steps;

    **Cold start** Steam Turbine rotor temperature (01MAB10CT005) is $< 150$ deg C.

    - Steam Chest Warming valves (01MAA10AA003 and 01MAA10AA501) will OPEN and start warming valve body until approx. 250 deg C.
    - Turbine Rotor Warming valves (01MAA10AA003 and 01MAA10AA004) will OPEN and start warming turbine HP rotor until approx. 250 deg C.
    - Steam Turbine Emergency Stop Valve (01MAA10AA001) will OPEN to 100%.

- Steam Turbine Steam Admission Control Valve (01MAA10AA002) will open sufficiently to accelerate steam turbine rotor speed upwards.
- Steam Turbine speed will HOLD at 900 rpm to ensure complete rotor warming.
- Steam turbine will again accelerate up to synchronise speed.

**Hot start** Steam Turbine rotor temperature (01MAB10CT005) is > 150 deg C.

- Steam Turbine Emergency Stop Valve (01MAA10AA001) will OPEN to 100%.
- Steam Turbine Steam Admission Control Valve (01MAA10AA002) will open sufficiently to accelerate steam turbine rotor speed upwards to synchronise speed.

**AUTO runup** The following steps will occur automatically;

- Excitation ON.
- Auto-Sync ON.
- Generator Circuit Breaker (01MKA10GS001) will CLOSE.

**MANUAL runup** Once Steam Turbine speed is at FSNL (Full Speed No Load), the following steps must be undertaken by the Operator;

- SELECT Excitation ON.
- SELECT Synchroscope ON
- USE Generator Transformer OLTC (On Load Tap Changer) to make coarse adjustments to Generator Voltage.
- USE Excitation INC and DEC buttons to make fine adjustments to Generator Voltage.
- MATCH Generator output voltage to Bus voltage.
- USE Turbine Speed Control INC and DEC buttons to adjust turbine speed and hence generator frequency.
- MATCH Generator output frequency to Bus frequency.
- WAIT until synchroscope needle is at the 12 o'clock position (indicating Bus and Generator Frequency are in phase) then;
- CLOSE Generator Circuit Breaker (01MKA10GS001)

54. The Generator is now connected to the electrical grid and the electrical power output will show on gauge 01MAB50CE001.

55. Steam Turbine Steam Admission Control Valve (01MAA10AA002) will continue to OPEN to increase Steam Turbine Load. Simultaneously Turbine Bypass Valves (01LBA60AA251 and 01LBA60AA252) will CLOSE.

56. Steam Turbine load will increase to the point where all steam generated by the Reactor is utilised. To Further increase Steam Turbine load Reactor power must be increased.

57. DILUTE primary circuit boron concentrations until reactor load is = 30%.

58. NOTE: Bled steam from the main steam turbine will be available at approx 285 MW load. At this time bled steam to Low Pressure (LP) and High Pressure (HP) fedwater heaters will automatically go into service. Bled steam will also now be available for Feedwater Pumps 2, 3 and 4.

59. START Feedwater Pump 2 (01LAC20AP001). Each turbine drive feedwater pump has a minimum flow of 15% and a maximum of 35% of total Steam Generator feedwater requirements.

60. DILUTE primary circuit boron concentrations until reactor load is = 40%.

61. START Feedwater Pump 3 (01LAC30AP001).

62. STOP Feedwater Pump 1 (01LAC10AP001).

63. DILUTE primary circuit boron concentrations until reactor load is = 50%.

64. START Feedwater Pump 4 (01LAC40AP001).

65. DILUTE primary circuit boron concentrations until reactor load is = 100%.

66. at 50% Reactor load CALIBRATE Power range flux (01JKA10CR003A/B).

67. at 90% Reactor load CALIBRATE Power range flux (01JKA10CR003A/B).

68. at 95% Reactor load CALIBRATE Power range flux (01JKA10CR003A/B).

69. at 100% Reactor load CALIBRATE Power range flux (01JKA10CR003A/B).

# Full Load Achieved

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