UNITED STATES ATOMIC ENERGY COMMISSION

SAFETY EVALUATION BY THE RESEARCH AND POWER REACTOR SAFETY BRANCH

DIVISION OF REACTOR LICENSING

IN THE MATTER OF

SAXTON NUCLEAR EXPERIMENTAL CORPORATION

PROPOSED CHANGE NO. 16

DOCKET NO. 50-146

Introduction

By letter dated October 8, 1964, the Saxton Nuclear Experimental Corporation (SNEC) submitted Change Request No. 16 which would authorize performance of the Supercritical Technology Program. This program is a part of the SNEC five-year research and development program. Supplementary technical information was submitted by letters dated February 26, 1965 and March 5, 1965.

Discussion

The applicant intends to install a UO_2 fueled loop within the Saxton reactor which will operate at supercritical coolant conditions (up to 1000°F at 3600 psig). The only coupling between the reactor core and the loop will be via the neutron flux. Thus, all coolant connections, heat exchangers, and instrument connections to the loop will be completely independent of the remainder of the primary nuclear system.

The loop will consist of the major components listed below in the sequence of coolant flow in the loop starting at the outlet of the supercritical pressure tube:

1. An interchanger which is a regenerative heat exchanger used to recover heat from the coolant outlet stream.

2. A high pressure heat exchanger which further cools the loop coolant so that it will not flash on pressure reduction. The heat sink for this heat exchanger is the facility component cooling water.

3. A pressure reducing valve which reduces the coolant pressure.

4. A low pressure heat exchanger which further reduces the temperature of the coolant. The heat sink for this heat exchanger is also the facility component cooling water.

5. A deaerator which is installed to remove entrained gases from the coolant. The gaseous effluent from the deaerator is directed to a catalytic recombiner to reconstitute the evolved hydrogen and oxygen into water.

6. Condensate pumps which direct the liquid effluent from the deaerator to the demineralizer and loop pumps.

7. A demineralizer and filter which are designed to pass full-flow loop coolant.

8. Two two-speed (15 and 7.5 gpm) pumps which are installed to supply coolant to the pressure tube at specified pressure and flow. Since one pump is sufficient to supply the required coolant flow, the second pump is physically piped into the system, but is not electrically connected. A 5.3 gpm single speed standby pump is available in event of failure of the loop pump. This pump is electrically connected and may be actuated from a flow controller, or manually.

9. A heater which is an automatically controlled 650 KW electrical heater to maintain specified pressure tube inlet conditions. The coolant enters the heater after passing through the interchanger discussed earlier.

The final component in the loop is the stainless steel pressure tube. The pressure tube assembly will extend the entire length of the reactor pressure vessel. It will enter through an existing nozzle in the head and terminate at the lower core plate. The fueled lower portion will be positioned with a standard SNEC fuel assembly from which 21 of the central fuel rods have been removed leaving a hole of sufficient size (2.735-inch minimum diameter) to accept the outside diameter of the pressure tube.

Coolant will enter the lower jumper which is just above the head penetration nozzle and flow downward through an annulus formed by pressure tube baffles. At the bottom of the pressure tube, the coolant will enter the fueled region and flow upward through the center of the assembly and exit at the upper jumper tube.

The pressure tube will be designed for the most severe conditions of pressure and temperature. Thus, although the normal pressure differential between the loop and reactor will be 1600 psig (2000 psig reactor pressure and 3600 psig loop pressure), the pressure tube assembly will be designed to withstand 4000 psig internal pressure at zero external pressure, and 2200 psig external pressure at zero internal pressure at the design temperature of 675°F. The reactor head nozzle penetration will be maintained below its design temperature of 650°F by a cooling system which bleeds a flow of 500 lb/hr of reactor coolant through an annulus between the pressure tube and the nozzle. Low flow will be alarmed and flow stoppage will cause the supercritical loop heaters to be shut off.

The fueled portion of the loop will contain seven fuel rods containing 21 w/o enriched UO_2 fuel in the form of either sintered pellets or vibration compacted and swaged powder. All fuel rods will be subjected to a pressure of 3000 psi at 700°F to seat the clad against the fuel. In addition, the fuel rod material, as received, will be given dimensional and physical property checks and burst tests. After fuel loading but prior to the final weld the moisture content of the fuel will be measured. After the final end plug weld, all welds will be dye-checked and helium leak-tested. The rods containing sintered pellets will also be radiographed to check for gaps or chipped pellets.

The fuel rods will be fabricated of either 16 Cr-20 Ni stainless steel or Incoloy 800. The nominal wall thickness will be 10.5 mils and the cladding will rely upon the enclosed fuel for support. The fuel assembly will be supported by an upper and lower grid and will be surrounded by coolant flow baffles. Two such fuel assemblies will be supplied.

The applicant has calculated that the reactivity effect of pressure, temperature, and density changes in the loop as well as flooding of the loop would have only a second order effect on the core reactivity. For instance, a pressure increase of 3000 psi would result in a reactivity increase of less than 0.001. The change from supercritical fluid to water in the loop would result in a reactivity addition of 0.0005. The other parameters have a comparably small effect on the reactor.

Under some conditions of loop operation, namely, non-supercritical operation with temperature and pressure about the same as that of the reactor, the peak specific power of the fuel may be as high as 13.2 Kw/ft, with a surface heat flux of 383,000 Btu/hr-ft^2. These values are below those approved for other fuel in the core. During loop operation with supercritical coolant conditions, the coolant density will be low and the nominal specific power of the fuel will be 9.2 Kw/ft with a surface heat flux of 266,000 Btu/hr-ft^2.

The remaining principal components of the loop are emergency systems to be used in case of loss of loop coolant or loss of loop flow. If either of these were to occur, water stored in a 25 gallon capacity coolant reservoir would be injected automatically into the loop using compressed nitrogen as the driving force. Subsequent makeup would be service water. In the case of a loss of coolant flow, the water in the coolant reservoir and service water make up the loss in volume when the supercritical fluid becomes water and assures a continuous supply of water during cooling with the emergency condenser. The emergency condenser will be physically situated above the pressure tube and will be installed to remove residual fission product heat from the fuel in the event of either of the above named accidents. The emergency condenser is designed for 6% of full loop power at 300°F. In addition, during loop maintenance, the emergency condenser may be used in lieu of the high and low pressure coolers to remove fission product decay heat.

Where applicable, components of the loop will be fabricated in accordance with appropriate ASME Boiler and Pressure Vessel Codes.

During operation, the temperature and pressure of the loop will be maintained by automatic controllers that regulate the heater output and the pressure control valve downstream of the high pressure cooler. The reactor will be scrammed automatically by a reduction in loop flow to below 50% of set point cooling would be supplied by the emergency condenser, and additional make up water to the loop would be from the service water system.

For both the loss of coolant and loss of flow accident, the contents of the coolant reservoir would be injected at 5 gpm which the applicant has calculated would be sufficient to maintain clad mperature below about 1700°F. Fuel damage would be expected to occur at . [illegible] d temperature of about 2000°F.

For a loss of loop coolant, the pressure rise in the containment would be less than 1 psig. The amount of fission products released to containment would be on the order of 6 curies if the injection system were to function as designed, because the only source of activity would be that in the loop water. If the injection system did not function, fuel failure would be expected within about 5 seconds and about 10^5 curies of fission products could be released to the containment. This compares to 2.5×10^7 curies released as a consequence of the maximum hypothetical accident. The release of 10^5 curies to the containment is considered the upper limit of hazard incident to operation of the loop. Off-site doses from such a release would be at least two orders of magnitude lower than those already calculated in the Final Safeguards Report in connection with the maximum hypothetical accident.

Due to the small percent of supercritical loop fuel in the reactor, concurrent failure of the loop and the reactor primary system would not result in a measurable increase in off-site exposures.

The applicant considered two assumed pressure tube casualties, a two-inch diameter hole, and a complete severence of the bottom of the tube. In each case the applicant states that the reaction force may be sufficient to distort some adjacent fuel, but not sufficient to damage a control rod channel. A control rod channel is not adjacent to core position N-4 in which the supercritical loop will be placed. Thus, a steam jet would have to carry through the partial fuel element in position N-4 plus another complete fuel element before reaching a control rod channel.

We believe that the above summary of calculations made by the applicant is a reasonable assessment of the hazards incident to operation of the supercritical loop.

Technical Specifications

Attachment A contains the Technical Specification changes which reflect operation of the SNEC reactor with the supercritical loop.

Conclusion

Based on the foregoing, we believe that operation of the SNEC facility with this proposed change involves no significant hazards considerations not described or implicit in the Final Safeguards Report, as amended, and that there is reasonable assurance that the health and safety of the public will not be endangered.

Original signed by:
Roger S. Boyd

Roger S. Boyd, Chief
Research & Power Reactor Safety Branch
Division of Reactor Licensing

Enclosure:
Attachment A

Date: MAY 5 1965

ATTACHMENT A

SAXTON NUCLEAR EXPERIMENTAL CORPORATION

CHANGES TO TECHNICAL SPECIFICATIONS

CHANGE NO. 16 - LICENSE NO. DPR-4

SUPPLEMENT NO 2 TO TECHNICAL SPECIFICATIONS INCORPORATING CHANGES APPLICABLE TO CONDUCT OF A SUPERCRITICAL TECHNOLOGY PROGRAM AS IDENTIFIED IN APPLICATIONS FOR CHANGES DATED OCTOBER 8, 1964, FEBRUARY 26, 1965, AND MARCH 5, 1965 IN THE SAXTON REACTOR PLANT

During the conduct of tests and experiments contained in the Supercritical Technology Program, the Technical Specifications shall be changed to the extent specified below, when fuel is installed in the supercritical loop and the Saxton reactor is above 1 MWt. Except as authorized for this program, all of the remaining provisions of the Technical Specifications shall remain in effect. Saxton shall advise the Commission in writing upon termination of this program.

A. Supercritical Fuel Assembly

1. Uranium dioxide (UO_2) enriched to 21% ± 1% shall be used for fuel, either sintered in the form of pellets, or vibration compacted and swaged, or vibration compacted and "pressure bonded."

2. The fuel pellets shall have dished ends initially and a void shall be provided in the upper end plug to accommodate fission gas buildup.

3. The fuel clad shall be Type 16-20 stainless steel or Incoloy, with nominal wall thickness of 10.5 mils. The clad shall rely upon the enclosed fuel for support against the coolant pressure.

4. Seven fuel rods form the fuel assembly. The fuel rods shall have an active length of 3 ft. and a diameter of 0.450 in.

5. The fuel assembly shall be bolted to the upper grid. The rods shall be slipped into the lower grid with sufficient clearance for axial expansion.

6. The Saxton fuel assembly, into which the pressure tube is to be inserted, shall be located in the core position E-1.

B. Supercritical Coolant System

The supercritical coolant system shall consist of at least the following equipment. All equipment shall be fabricated of austenitic stainless steel or equivalent corrosion resistant material in accordance with the applicable ASME Boiler and Pressure Vessel Code or ASA Pressure Piping Code.

1. Pressure Tube

The pressure tube assembly shall consist of three components; the pressure tube, connector body and head adaptor flange assembly, all made of AISI Type 316 stainless steel.

The pressure tube shall be designed for 4000 psig internal pressure and zero external pressure at 675°F, and 2100 psig external pressure and zero internal pressure at 675°F.

The minimum wall thickness of the pressure tube section shall be 0.350 inches. The maximum wall thickness of the connector body section shall be 0.360 inches.

2. Pumps

Two electrically driven pumps shall be provided to supply coolant to the pressure tube. One two-speed pump is rated at 15 gpm at full speed and 5000 psig discharge pressure and 7.5 gpm at half speed at the same discharge pressure. A single speed standby pump is provided as a reserve which is rated at 5.3 gpm at the same discharge pressure. (A second two-speed pump, with the same characteristics, may be piped in parallel with the aforementioned two-speed pump).

All parts in contact with the supercritical loop coolant shall be fabricated of austenitic stainless steel or equivalent corrosion resistant material.

3. Heat Exchangers

Equipment shall be supplied which will provide specified operating temperatures throughout the supercritical coolant system.

4. Purification Equipment

Equipment shall be supplied which will maintain coolant impurity levels below those specified in Section G.

An in-line radiation monitor shall be located downstream of the condensate pump to provide an indication of the supercritical loop coolant radiation level.

5. Accumulator

An accumulator shall be provided to reduce pressure pulsations from the main coolant pumps. The accumulator shall be constructed of carbon steel lined with a protective coating.

6. Piping and Valves

All valves containing radioactive fluids, except instrument valves, shall be provided with leakoffs or backseats.

C. Auxiliary Systems

At least the following auxiliary systems shall be installed:

1. Shutdown Cooling

Shutdown cooling capability shall be available which utilizes the high pressure and low pressure coolers with circulation provided by the condensate pumps. Emergency cooling can be effected by using the emergency condenser.

2. Safety Injection

A supply of pressurized water held in the coolant reservoir shall be discharged automatically to the accumulator connection of the loop following loss of flow, or to the pressure tube outlet line upon a loss of coolant upstream of the pressure tube.

a. Coolant Reservoir - The coolant reservoir shall have a 25-gallon capacity and be constructed of carbon steel designed for 5000 psig at 200°F. It shall contain demineralized water pressurized by the reservoir gas cylinder. The coolant level in this reservoir shall not fall below 15 gallons.

b. Reservoir Gas Cylinder - The reservoir gas cylinder shall be of all welded joint construction, carbon steel, and designed for 5000 psig. Pressure in this cylinder shall not fall below 4000 psig.

c. Emergency Condenser - The emergency condenser shall be fabricated of austenitic stainless steel, provided with an overflow and vacuum break, and designed for 15 psig shell and 4400 psig at 1000°F tube side. Sufficient makeup water shall be supplied for unlimited operation.

3. Pressure Relief

The supercritical loop shall be protected from overpressure by relief valves having the following nominal settings:

a. Outlet line from the pressure tube, two valves with set pressures of 4000 and 4120 psig.

b. Discharge side of the loop pumps and standby pump, set pressure of 5000 psig.

c. Discharge side of the gas compressor, set pressure of 5000 psig.

d. Demineralized water line supplying the coolant reservoir, set pressure of 200 psig.

e. Component cooling water line, set pressure of 150 psig.

f. Diluent steam generator line, set pressure of 60 psig.

g. Sample ion exchangers lines, set pressures of 150 psig.

4. Sampling

Provision shall be made to obtain supercritical loop coolant samples.

5. Reactor Head Nozzle Cooling System

A system shall be provided for cooling the reactor nozzle penetration used for the supercritical loop.

D. Radioactive Waste Disposal

Liquid wastes from the supercritical loop shall be directed to the Saxton Radioactive Waste Disposal Facility.

The supercritical loop gaseous waste, after recombination shall be directed to the Saxton Radioactive Waste Disposal Facility.

E. Electric Power

Standby electric power shall be taken from the facility inverter for critical temperature, pressure, level and flow instruments.

F. Instrumentation

Equipment shall be provided to measure and record pressures, temperatures, and flows, at points in the supercritical loop and auxiliary systems.

G. Operating Limitations

The following operating limitations shall apply to the supercritical loop operation:

Maximum supercritical fuel assembly power level	115 KWt
Maximum pressure tube inlet pressure	4000 psig
Minimum pressure tube inlet pressure	2000 psig
Maximum supercritical pressure tube outlet temperature	1000°F
Maximum 15-minute degassed gross activity of coolant	20 μc/cc
Maximum chloride concentration in loop coolant	0.1 ppm
Maximum temperature of reactor vessel head flange	650°F
Maximum thimble pressure drop	600 psi
Minimum loop flow	50% of the flow control set point for the test being conducted

If any of these limits are exceeded, action will be initiated to restore the condition to within limits.

In Supplement No. 1 to Technical Specifications, page 4, change section labeled "Change Item G.3" to read:

Change Item G.3

The reactor shall be automatically scrammed under the following conditions:

Conditions	Set Point
Fast startup rate (maximum)	2 decades/min.
High power level at startup (maximum)	25% full power
High power level at power	
20 MWt operation (maximum)	24 MWt
23.5 MWt operation (maximum)	27 MWt
Low main coolant pressure (minimum)	1600 psig
Low main coolant flow above 1 MWt (minimum)	2.2×10^6 lb/hr
Low water level in pressurizer (minimum)	8.3%
Loss of main coolant pump power	Contact on breakers, failure of power supply, or loss of variable frequency set clutch excitation when variable frequency set is supplying power for main coolant pump operation
Main coolant temperature (hot leg) (Maximum)	554°F (23.5 MWt operation) 600°F (20.0 MWt operation)

When fuel is installed in the supercritical loop and the reactor is above 1 MWt:

Condition	Set Point
Loss of supercritical loop flow (minimum)	50% of normal flow set point, exceeding a preset time delay
Loss of supercritical loop coolant pressure (minimum)	2000 psig
Loss of supercritical loop coolant	Pressure drop reversal across pressure tube

The scram signal conditions associated with the supercritical loop need be operational only if a fueled pressure tube is installed in the reactor.