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ATOMIC PRODUCTS DIVISION

ATOMIC POWER EQUIPMENT DEPARTMENT

DOCKET NO. 50-249

August 10, 1966

Mr. E. Case
Division of Reactor Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Case:

Transmitted herewith are thirty (30) copies of a draft memorandum entitled, "Provisions for Emergency Core Cooling." These copies are being forwarded in response to your request for additional information pertaining to the provisions for core flooding under postulated loss-of-coolant accidents to be considered at the ACRS meeting on August 12, 1966, for Dresden Unit 3.

Very truly yours,

W. D. Gilbert

W. D. Gilbert, Manager
Licensing

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Enclosures: 30

D R A F T

PROVISIONS FOR EMERGENCY CORE COOLING

DRESDEN UNIT 3

August 10, 1966

PROVISIONS FOR EMERGENCY CORE COOLING

A. INTRODUCTION

In a previous draft memorandum dated July 26, 1966, entitled "Description and Evaluation of Dresden Unit 3 Emergency Core Cooling Provisions." it was stated that two core spray cooling systems and the high pressure coolant injection system are provided to assure continuity of core cooling for those postulated conditions wherein it is assumed that mechanical failures occur and coolant is partially or completely lost from the reactor vessel. These systems together with other design features of Dresden Unit 3 are provided to prevent fuel clad melting for the entire spectrum of assumed accidental conditions.

In addition to these provisions, it is now proposed that certain design changes be made to incorporate a low pressure coolant injection system (flooding system), independent of and in addition to the above emergency cooling provisions. As indicated in the information previously transmitted, it is the design objective of the emergency core cooling systems to prevent fuel clad melting and limit to a negligible amount any metal water reaction for all primary system mechanical failures up to and including those equivalent to the double ended severance of a recirculation pipe.

This memorandum summarizes the design features of the low pressure coolant injection system and identifies other design and operational considerations which assure high reliability for continuity of core cooling under the postulated accident conditions including provisions for adequate emergency electrical power supply, provisions for increased feedwater inventory, and further considerations of vessel internal integrity under postulated reactivity transients. A diagram of the several emergency core cooling systems is shown in Figure 1.

B. LOW PRESSURE COOLANT INJECTION SYSTEM

1. Design Basis

a. A low pressure coolant injection system is provided to prevent fuel clad melting as a result of various postulated but improbable loss of primary coolant accidents for a range of failure sizes from those for which the core is adequately cooled by the high pressure coolant injection system up to and including the design basis accident i.e., the instantaneous mechanical failure of a size equivalent to the largest primary system pipe.

b. The low pressure coolant injection system will be provided with redundancy of pumping capacity.

c. The low pressure coolant injection system shall operate without reliance upon external sources of power.

d. The low pressure coolant injection system shall be designed so that each component of the system can be tested and inspected periodically.

2. Description

The low pressure coolant injection system is designed to pump water directly from the suppression pool into the reactor vessel under accidental loss of coolant conditions.

This system also provides adequate containment spray cooling if ever required and will be specifically designed to provide required flow rate and pump discharge heads for low pressure coolant injection. A schematic diagram for the system is shown in Figure 2.

The system is provided with four pumps, any three of which will provide the design flow rate of 16,000 gpm from the pressure suppression pool through the heat exchangers to the space inside the vessel shroud. The system flow rate is established to accommodate possible leakage flows. Design modifications will be incorporated to minimize leakage caused by thermal differential expansions during flooding. The water will be pumped directly inside the shroud without employing a sparger or spray nozzles. At this time several arrangements have been evaluated and found to be satisfactory for coolant delivery within the shroud.

At this time, the preferred arrangement involves the injection of the flooding flow through eight penetrations in the bottom of the reactor vessel. Standpipes are incorporated within the vessel to insure maintenance of flooding capability within the shroud.

The design flow rate will assure injection of an adequate inventory of water inside the shroud to prevent fuel clad melting. Special design considerations will be given to the vessel-shroud configuration to assure component integrity under the postulated conditions of use.

The piping system will be fabricated of carbon steel from the suppression chamber to the outer containment isolation valve. Relief valves are utilized for pressure protection of this section of the system. From the outer isolation valve into the reactor the system is fabricated of stainless steel and designed for service at 1250 psig and 575°F.

All portions of the system will be designed in accordance with applicable codes.

This low pressure coolant injection system is designed to be placed into service automatically and concurrently with activation of one of the two core spray systems. The pumping equipment of this system will be activated on a signal of reactor "low low" water level similar to the pumping equipment of the core spray system. The valve opening action of this system will be activated on a preset low pressure signal again similar to the valving of the core spray system.

A test line capable of full system flow (16,000 gpm) is connected from the outside isolation valve back to the pressure suppression pool. Flow can be diverted into this line to test operability of the pumps and control system during reactor operation. As shown on Figure 2, water can also be pumped from the condensate storage tank to permit functional testing of the system periodically when the reactor is shutdown.

3. Summary of System Performance

a. Breaks Below Water Level (Liquid Flow)

Either of the two core spray systems will protect the core through a range of break sizes, without assistance from any other safeguard system, from a small break of 0.16 ft^2 thru the design basis break. With the assistance of the HPCI system, acting as a primary system depressurizer the core spray becomes effective for break down to breaks as small as 0.02 ft^2. Feedwater availability also performs this same function when AC power is available.

The core flooder injects water inside the shroud in sufficient quantities to cover the core to 2/3 of its height, thus effectively cooling it, in sufficient time after uncovery to prevent core melting. Without assistance from any of the other systems the LPCI flooder will protect the core through all break sizes from the design break down to 0.4 ft^2. With the assistance of the HPCI system (or automatic relief or the feedwater system), the flooder can protect the core down to breaks as small as 0.02 square feet. Again this is possible because either the HPCI system or the feedwater system will reduce the vessel pressure for breaks in excess of 0.02 ft^2 thereby permitting the LPCI system to make up inventory. Thus between breaks of 0.02 ft^2 and 0.4 ft^2 the core flooder functioning in conjunction with the HPCI system will prevent clad melting. For some breaks in this range the core may uncover momentarily, but never long enough to cause clad melting.

The HPCI system injects cold water into the feedwater sparger to assure mixing and is capable of making up any inventory losses for breaks below about .02 ft^2 thus maintaining level. For break sizes between .02 ft^2 and .4 ft^2 the HPCI system acts as an effective depressurizer by virtue of its lowering the average temperature of the vessel contents, thus allowing the core spray (or core flooder system) to become effective. The pressure at which the HPCI system ceases to function, approximately 150 psig, is sufficiently overlapped by the static pressure head of the core spray pumps, 300 psig to insure that complete depressurization occurs to allow the core spray system to reach rated flow. The head of the core flooder pumps is such that they can deliver rated flow at 150 psig.

The HPCI system is backed up by automatic actuation of relief valves in terms of depressurizing the system for those break sizes which require the HPCI system. This relief action is based on simultaneous signals from high drywell pressure, reactor scram, loss of level as well as non-operation of the HPCI system. Protection can be provided to preclude inadvertent operation.

It should be noted that throughout the entire spectrum of breaks, there is at least two processes for adequately cooling the core even under conditions of no external power supply. This was the basis for satisfying the emergency core cooling design objective. However, in the more probably event of the maintenance of external power, the additional cooling provision offered by the feedwater system is also demonstrated on Figure 3. For a liquid flow break and considering the infinite water supply made available with the service water pumps as discussed in Section D of this report, all break sizes up to the approximate size of one square foot could be handled adequately by the feedwater system.

b. Breaks Above the Water Level

For all accidental breaks above the water level with no assistance from any of the other provided safeguards systems, the low pressure coolant injection system will protect the core against clad melting for the spectrum of breaks from the design breakdown to about 0.25 ft^2. With the assistance of either the HPCI system or the feedwater system acting as a depressurizer, the core can be protected against all breaks down to those as small as .06 ft^2 by the low pressure coolant injection system.

Either of the core spray systems without assistance from other systems will prevent clad melting down to breaks of 0.32 ft^2. In conjunction with the HPCI system, either core spray will prevent clad melting down to break sizes of .06 ft^2.

The HPCI system maintains the level above the core for all break sizes under about .06 ft^2 without assistance from other systems. Beyond .06 ft^2, it also acts as an effective depressurizer, thereby, permitting the low pressure coolant injection system or either of the core spray systems to become effective in adequate time to prevent fuel clad melt.

Automatic relief is a backup to the HPCI system. It permits activation of the core flooder for the break sizes for which it is required. As discussed above, with respect to the liquid flow break conditions for the more probably case of external power being maintained and therefore feedwater supply being available, an additional coolant supply is provided in excess of those required to satisfy the design objective. Figure 3 demonstrates that for the steam flow break considerations, the entire spectrum of breaks can be adequately handled by the inexhaustible feedwater supply.

4. Surveillance and Testing

To assure that the low pressure coolant injection system will function properly, if required, specific provisions are made for testing the operability and performance of the several components of the system. Testing will be done periodically at a frequency that will assure availability of the systems. In addition, surveillance features will provide continuous monitoring of the integrity of vital portions of the system.

a. Pre-Operational Testing

Prior to plant startup, a pre-operational test of the complete system will be conducted. This test will assure the proper functioning and operation of all instrumentation, pumps, heat exchangers, and valves. This test will verify that the system meets its design performance requirements. In addition, system reference characteristics, such as pressure differentials and flow rates, will be established at this time to be used as base points for check measurements in the testing to be done during plant operation.

b. Periodic Surveillance and Testing

The pumps can be started and full flow established through the bypass line back to the pressure suppression pool to determine availability of pumps and control circuits. The motor-operated valves can be exercised and their operability demonstrated. Leak tightness of the system can be demonstrated. These tests can be performed while the unit is operating or pressurized at hot standby.

When the unit is shut down and depressurized, flow rate measurements can be made with water pumped into the reactor vessel. Also, relief valves on the low pressure lines can be removed and tested for set point.

During refueling, visual inspections can be made of internal piping. Components inside the primary containment can be visually inspected when the drywell is open for access.

c. Continuous Surveillance

Pressure differential between the system piping inside the vessel and an internal reference pressure will be continuously monitored during power operation. Changes in these pressure readings will provide indication of loss of integrity of piping within the reactor vessel. Also, all pipes, pumps, heat exchangers, valves, and other working components outside of the primary containment can be visually inspected at any time.

C. ELECTRICAL POWER SUPPLY

The power for the low pressure coolant injection system can be supplied from the reserve auxiliary transformer, the standby diesel generator supply, or the standby transformer. It is proposed that three diesel generator units be provided and connected electrically to serve both Dresden Unit 2 and Unit 3. The diesel power supply is sized to provide required power capacity with two of the three diesel generators in operation. This capacity includes operation of required engineered safeguards and other auxiliaries for one reactor as listed below plus operation of necessary cooling equipment in the second reactor to accomplish and maintain a safe shutdown.

Equipment Automatically Placed in Service

- One Core Spray Pump
- Three Low Pressure Coolant Injection Pumps
- One Service Water Pump
- Standby Gas Treatment Equipment
- All Power Operated Valves Not on D.C.
- Emergency A-C Lighting
- Instrumentation and Control Motor-Generator

D. FEEDWATER SYSTEM INVENTORY UNDER ACCIDENT CONDITIONS

Detailed evaluations of the feedwater system have indicated that the potential inventory which can be pumped into the reactor under loss-of-coolant conditions is unlimited. In preliminary discussions with respect to the potential inventory offered by the feedwater system under accident conditions, a claim of only approximately four minutes of rated feedwater flow from the condenser hotwell was available. The detailed evaluations have indicated that the hotwell of the main condenser can be, and has been, provided with a water supply of as much as 18,000 gpm by any one of the three service water pumps. Therefore, with a full feedwater flow from the hotwell to the reactor occurring, an acceptable hotwell water level could be maintained for continuous feedwater flow. The influence of this additional coolant supply under accident conditions is demonstrated in Figure 3.

E. EXCURSION ANALYSIS

An examination has been made of the possible uncertainty in the excursion analysis for a 2.5 percent ΔK rod dropped at 5 ft/sec in order to evaluate the hydrodynamic effects on the core internals.

The uncertainties in the physics calculations are presented in Dresden Unit 3 Plant Design and Analysis Report, Amendment Number 3. The resulting peak fuel enthalpy is 210 $\pm$ 20 calories per gram. This value is slightly below the incipient melting point of the fuel.

Experimental data[1] are available which indicates that the fuel rods will retain their integrity after super-prompt critical excursions which raise the fuel temperature to the incipient melting point.

Assuming integral fuel pins, the maximum heat flux to the water in the hottest channel is less than twice the heat flux of the hot channel for normal power operation. This ratio (hot channel power, accident)/(hot channel power, normal) drops to unity approximately five seconds later.

This value of heat flux is limited to four channels and will result in some film boiling (also observed in the Pulstar tests), but no gross clad melting is expected. This results in channel exit flow velocities which would not result in distortion or damage to the core spray spargers or to the vessel-shroud configuration.

[1] "Summary Report, Pulstar Pulse Tests - II," [illegible], February 19[illegible].

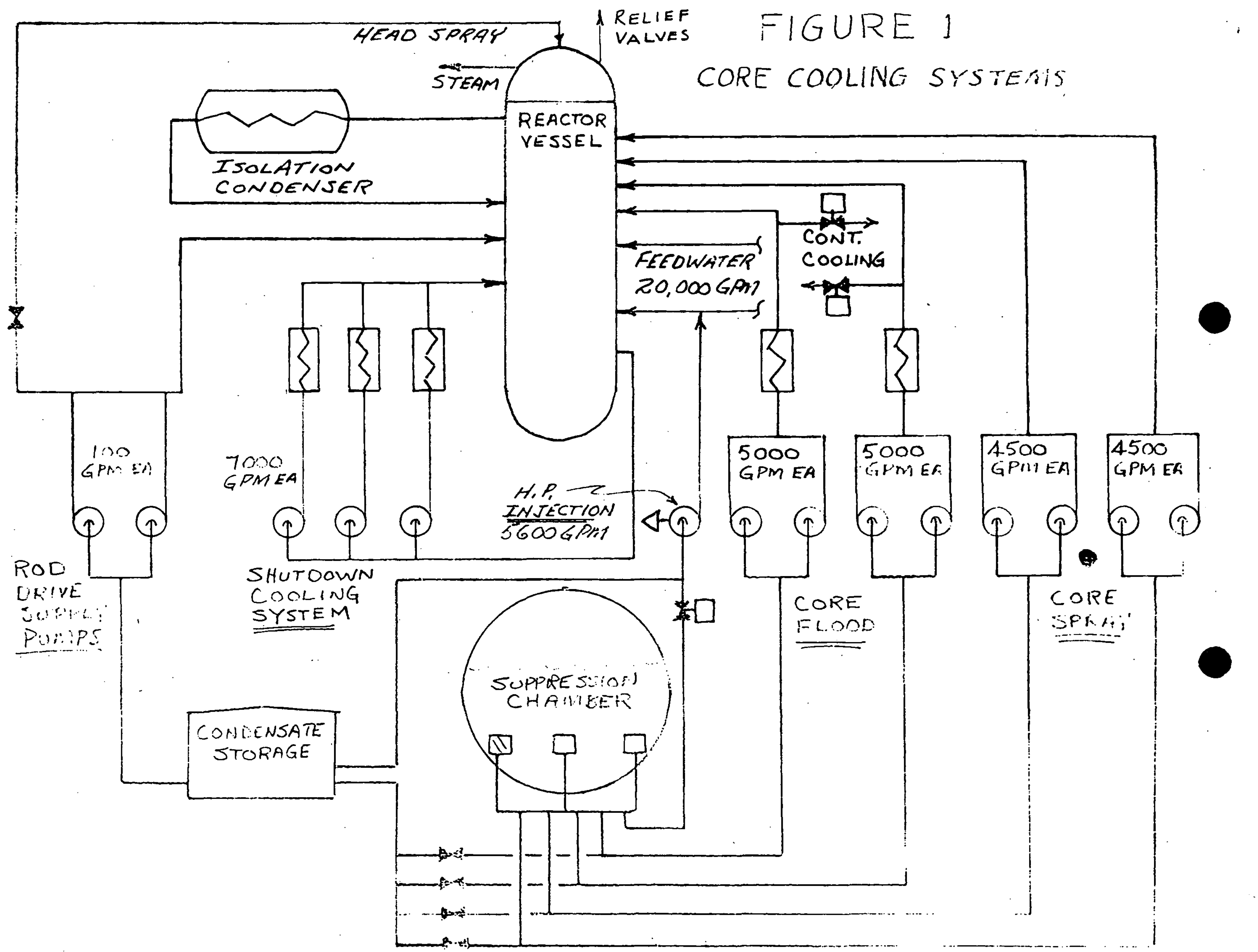

FIGURE 1
CORE COOLING SYSTEMS
HEAD SPRAY
RELIEF VALVES
STEAM
REACTOR VESSEL
ISOLATION CONDENSER
FEEDWATER 20,000 GPM
CONT. COOLING
100 GPM EA
7000 GPM EA
H.P. INJECTION 5600 GPM
5000 GPM EA
5000 GPM EA
4500 GPM EA
4500 GPM EA
ROD DRIVE SUPPLY PUMPS
SHUTDOWN COOLING SYSTEM
CORE FLOOD
CORE SPRAY
SUPPRESSION CHAMBER
CONDENSATE STORAGE

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TITLE FIGURE 2

LOW PRESSURE COOLANT INJECTION

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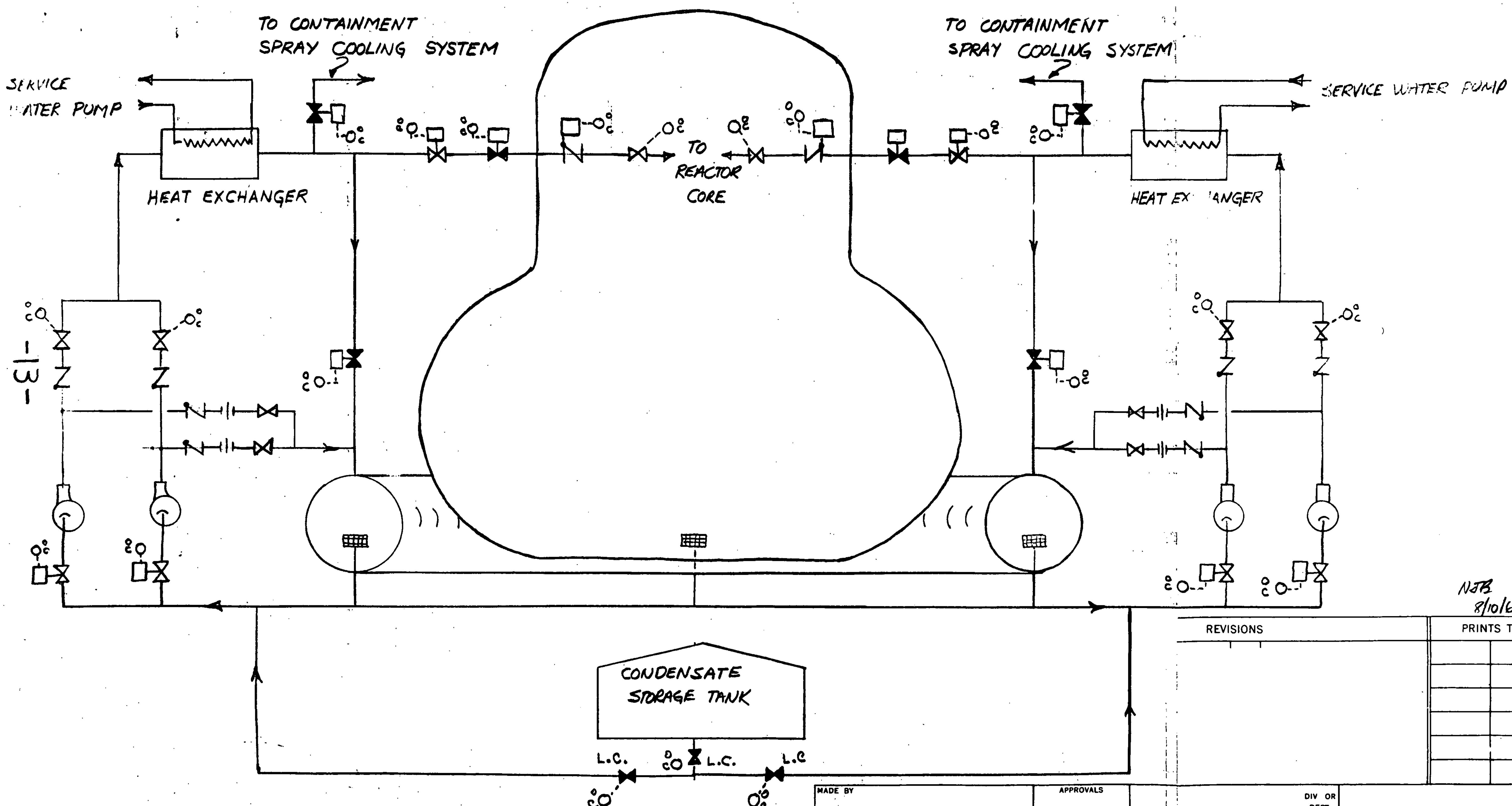

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FIGURE 3

Dresden III Integrated Performance Core Cooling