5.3.3 LARGE LOCA

5.3.3.1 Initiating Event

A postulated rupture in one of the large diameter pipes in the primary circuit such as the reactor inlet header, outlet header or pump suction pipe can lead to degraded fuel cooling in a large number of fuel channels in addition to radiological consequences. Hence, it is necessary to study fuel channel behaviour and estimate release of fission products following a large LOCA in order to assess the design and effectiveness of safety system performance.

The distinction between large and small breaks is somewhat arbitrary. For the purpose of this report, the distinction is defined in terms of how the break is detected and how the reactor is shut down.

A large break would lead to an increase in reactivity due to coolant voiding, such that the reactor regulating system would not be able to compensate. Thus for large breaks, there is an increase in neutron power which leads to detection and shutdown occurring from neutronic, as opposed to process trips. The minimum size of a large break, by this definition is estimated to be five percent of a "guillotine" (twice the cross sectional area) reactor inlet header break.

Initiating event label for large loss-of-coolant accident is IE-LL1.

5.3.3.2 Event Sequence

The initiating event for the development of the sequence logic is the large loss-of-coolant-accident.

This section discusses the general behaviour that would be expected to occur in the primary circuit following a large break.

Following a large break in the primary circuit steam and water would rapidly discharge into the reactor vault or steam generator room. Containment pressure, temperature and humidity would rise very quickly.

Void in the circuit would begin to increase as the primary circuit depressurizes. Trip signals for a large break would occur within one or two seconds. Shutdown systems are expected to trip the reactor on high neutron power or high rate log neutron power or high reactor building pressure.

Conditioning of the emergency core cooling logic would be provided by reactor building high pressure of 3.45 kPa(g). Dousing would be initiated when the containment pressure reach 14 kPa(g).

Containment isolation would occur either on high containment pressure or high radiation level in containment within seconds.

A large loss of coolant accident initiates a reactor trip in approximately one (1) seconds which can cause a loss of grid resulting in a total loss of Class IV power. The emergency core cooling injection logic initiates the start of Class III diesel generators and also conditions the Class III load sequencer. Power supply is interrupted to the main heat transport pumps, steam generator feedwater pumps, main moderator pumps, service water pumps and air compressors. But the above systems except heat transport pumps (Class IV power) are all designed to withstand the temporary interruption up to three minutes before power can be restored automatically from the Class III power supply system.

After reactor trip, the primary circuit would continue to depressurize. When the primary circuit pressure falls below 5.5 MPa(a) in two of the three instrumented reactor headers in either loop, a loop isolation signal would be initiated. This signal acts to isolate the two primary circuit loops. A similar signal conditioned on a high reactor building pressure, triggered earlier in the transient, called loss-of-coolant-accident (LOCA) signal would act to initiate emergency coolant injection and steam generator crash cooldown.

Upon receipt of the loop isolation signal the valves in the lines connected to the pressurizer (3332-MV1 and -MV2), the feed system (3331-MV13 and -MV22) and the purification circuit (3335-MV1, -MV2, -MV3 and -MV4) would simultaneously begin to close. Full closure of these valves would be achieved within 20 seconds of the generation of the loss-of-coolant-accident signal. Isolation is achieved even if only one valve in each pair closes.

Upon isolation of the two loops, make up water from the pressurizer and the inventory control system is terminated. However, the isolation of the two loops prevents further inventory loss from the intact loop. Fuel cooling in the intact loop is provided by forced circulation if the heat transport pumps are still operating or by thermosyponing if they are tripped.

The conditioned emergency core cooling signal is also used to open the main steam safety valves (MSSV's) 63614-PSV5#1, 2, 3, 4, PSV6# 1, 2, 3, 4, PSV7# 1, 2, 3, 4 and PSV8# 1, 2, 3, 4 causing the steam generators and hence the entire steam and feedwater system to be crash cooled. The signal to open the MSSV's is generated 30 seconds after the loss-of-coolant signal is received. Following a large break, pressure in the primary circuit would be lower than that of the steam generators by this time even if initiation of crash cooldown fails. This means the steam generators can act as a heat sink during refill. Though crash cooldown is not considered very essential for the initiation of emergency coolant injection to the broken loop, crash cooldown of steam generators reduces the net heat input into the primary circuit during this time.

High pressure injection occurs to the broken loop when the header pressure 4.14 MPa(a). At this time the intact loop pressure is higher than 4.12 MPa(a) which is above the HP injection pressure. Water stored in the high pressure tanks is emptied in about 235 seconds and pressure in the broken loop falls below 1.0 MPa(a). When the pressure in the broken loop is about 2.5 MPa(a) heat transport pump trip signal occurs. All heat transport pumps completely stop at 138 seconds. On low level in the high pressure emergency core cooling water tanks, high pressure emergency core cooling is automatically terminated by the closure of the gas and water isolation valves.

The emergency core cooling injection logic initiates the opening of the dousing tank suction valves. During this stage water is supplied from the dousing tank by the emergency core cooling pumps to the broken loop. This phase is completed in about 15 minutes. Though intact loop pressure continues to decrease, it is maintained well above medium pressure emergency core cooling injection pressure. Thus medium pressure injection does not occur to the intact loop.

By this time water from the emergency core cooling water tanks and the dousing tank would have accumulated on the Reactor Building basement floor. For details on flooding in the Reactor Building please see sheet 9 of 20 of the ESD referred to above. When the water in the dousing tank is nearly depleted, switch-over to low pressure recovery injection would be automatically initiated. During the low pressure phase of emergency core cooling, water would be pumped from the sump by the emergency core cooling pumps, cooled by at least one of the recovery heat exchangers and re-injected into the broken loop. Decay heat removal in the broken loop would be via the break.

Pressure in the intact loop would closely follow the secondary side pressure and eventually fall low enough to receive low pressure injection. Steam generators provide decay heat removal for the intact loop.

Following operator actions are required following a large LOCA.

a. To isolate instrument air to the Reactor Building and start post LOCA instrument air, at 3 hours.
b. On loss of feedwater, initiate steam generator make up via the EWS system.
c. On loss of RCW cooling initiate back up cooling to ECC heat exchangers via the EWS system.
d. If automatic PHT pumps' trip fails, operator is required to trip the pumps manually.

5.3.3.3 Event Tree

Event tree for large loss of coolant accident is developed in Figure ET5.3.3-1 and the event headers used in the event tree are explained below.

LL1: Large Loss of Coolant Accident (Large LOCA)

LL1 represents the large loss of coolant accident initiating event. This constitutes a large break in large diameter piping of the primary heat transport system.

RS: Reactor Shutdown

Following a large LOCA, shutdown systems SDS1 and SDS2 trip the reactor on high neutron power or high rate log neutron power or high Reactor Building pressure.

LI: PHT Loop Isolation

Following a large LOCA and reactor trip, heat transport system depressurizes. On heat transport system pressure reaching 5.5 MPa(a) the intact and broken loops isolate due to the closure of heat transport loop isolation valves, 3331-MV13 and MV22 (feed and bleed system), 3335-MV1, -MV2, -MV3 and -MV4 (purification system) and 3332-MV1 and -MV2 (pressurizer). The main purpose of loop isolation is to conserve inventory in the intact loop.

ECC-D and ECC-LT: Emergency Core Cooling Signal and Equipment (HP/MP/LP phase)

Following a large LOCA, ECC injection occurs to the broken loop, only if Loss-of-Coolant-Accident (LOCA) signal is initiated. LOCA signal in addition to injecting ECC into the broken loop initiates crash cooldown of steam generators. Crash cooldown is not considered a necessary function for ECC injection for a large LOCA, because the leak is so large that the PHT depressurization is fast enough for ECC to come in time.

FW: Feedwater

Steam generators provide decay heat removal of the intact loop. In order for the steam generators to function as a long term heat sink feedwater should be supplied continuously to the steam generators of the intact loop via the main or auxiliary feedwater pumps.

OEWS: Operator Action to Start Emergency Water Supply (EWS)

If a total loss of feedwater (main and auxiliary) occurs, operator action is required to initiate steam generator make up from the EWS system.

MHS: Moderator Heat Sink

Following a large LOCA, ECC is initiated automatically to function as a fully capable heat sink. However should a failure of ECC occur moderator is required to function as a heat sink on pressure tubes contacting calandria tubes.

5.3.3.4 List of Assumptions/Analysis Required

Assumptions used and analyses required in the event sequence diagram/event tree analysis for large LOCA are listed below:

a. Heating, Ventilation and Air Conditioning (HVAC) and associated support systems are available.
b. Containment functions are successful.
c. Only front line system failures are shown on the event trees. Associated support system failures will be modelled as a part of the fault tree analysis of the corresponding front line systems.
d. Heat transport pumps coast down on low pressure signal of the primary heat transport system. Steam generators remove decay heat from the intact loop with the primary heat transport system thermosyphoning.
e. Shutdown cooling system is conservatively not credited as a heat sink for the intact loop on total loss of feedwater, as there is a high likelihood of operator error in connecting the intact loop via the designated header isolation valves of the shutdown cooling system.
f. D_2O feed and recovery systems are not qualified for large LOCA events.
g. Accumulation of water in the Reactor Building basement does not impair moderator system from functioning as a heat sink.
h. Upon loss of Class IV power, RCW flow to the moderator heat exchangers is throttled via the TCV's regardless of both Class III buses energized.

i. In the event of a failure of loop isolation, it is assumed that ECC is capable of providing heat sink for both the broken and intact loops.

5.3.3.5 References

5.3.3.1. AECL, Wolsong 1 Nuclear Power Plant Safety Design Matrix Study Large Loss of Coolant Accident and Emergency Core Cooling Operation, 59 SDM-3, 1981 February.

5.3.3.2. KEPCO, KEPCO Wolsong 2 Preliminary Safety Analysis Report (PSAR) Vol. 4 1991 September.

5.3.3.3. AECL Design Manual Primary Heat Transport System (Preliminary), 86-33100/63310-DM-000, Rev. 0, 1993 January.

5.3.3.4. AECL, Design Manual, Emergency Core Cooling System Process Design, 86-34320-DM-000, Rev. 0, 1993 March.

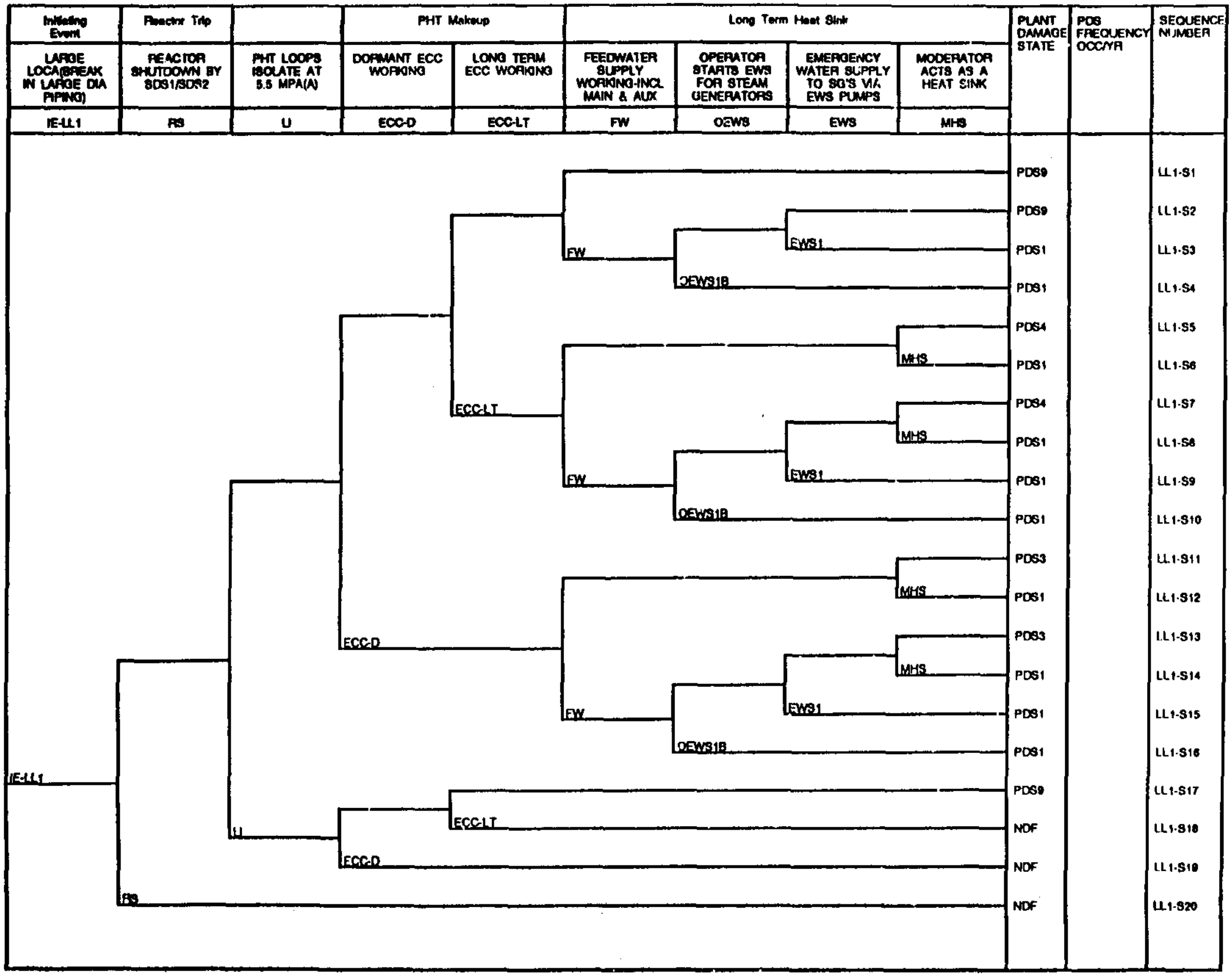

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Figure ET5.3.3-1: Large Loss of Coolant Accident (LLOCA.TRE)