



Status of Fukushima Lessons

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Status to date

Good*

My focus today will be on the mitigating strategies order. Many themes are applicable to other Fukushima lessons.

On the Good Side

Station blackout rule assumed that alternating current power would be restored within the plant-specific coping duration (typically 4 or 8 hours)

Mitigating strategies order seeks to provide core, containment and spent fuel cooling for an infinite period.

On the Caveat Side

Original assumption that Fukushima invalidated has been replaced by the assumption that FLEX equipment can be placed and operated in time.

Is this assumption also invalid?

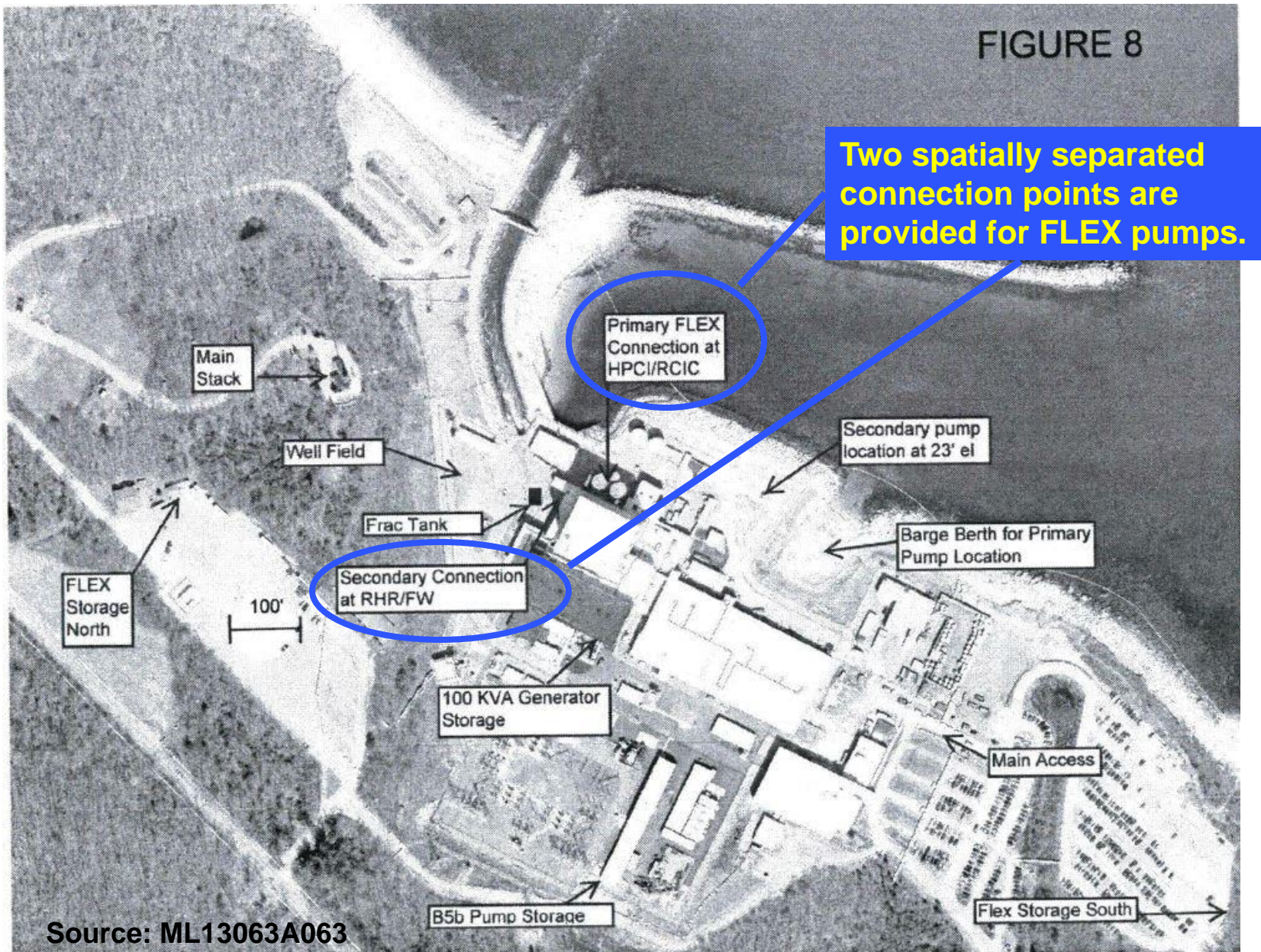
On the Good Side

February 2013 FLEX Integrated Plan

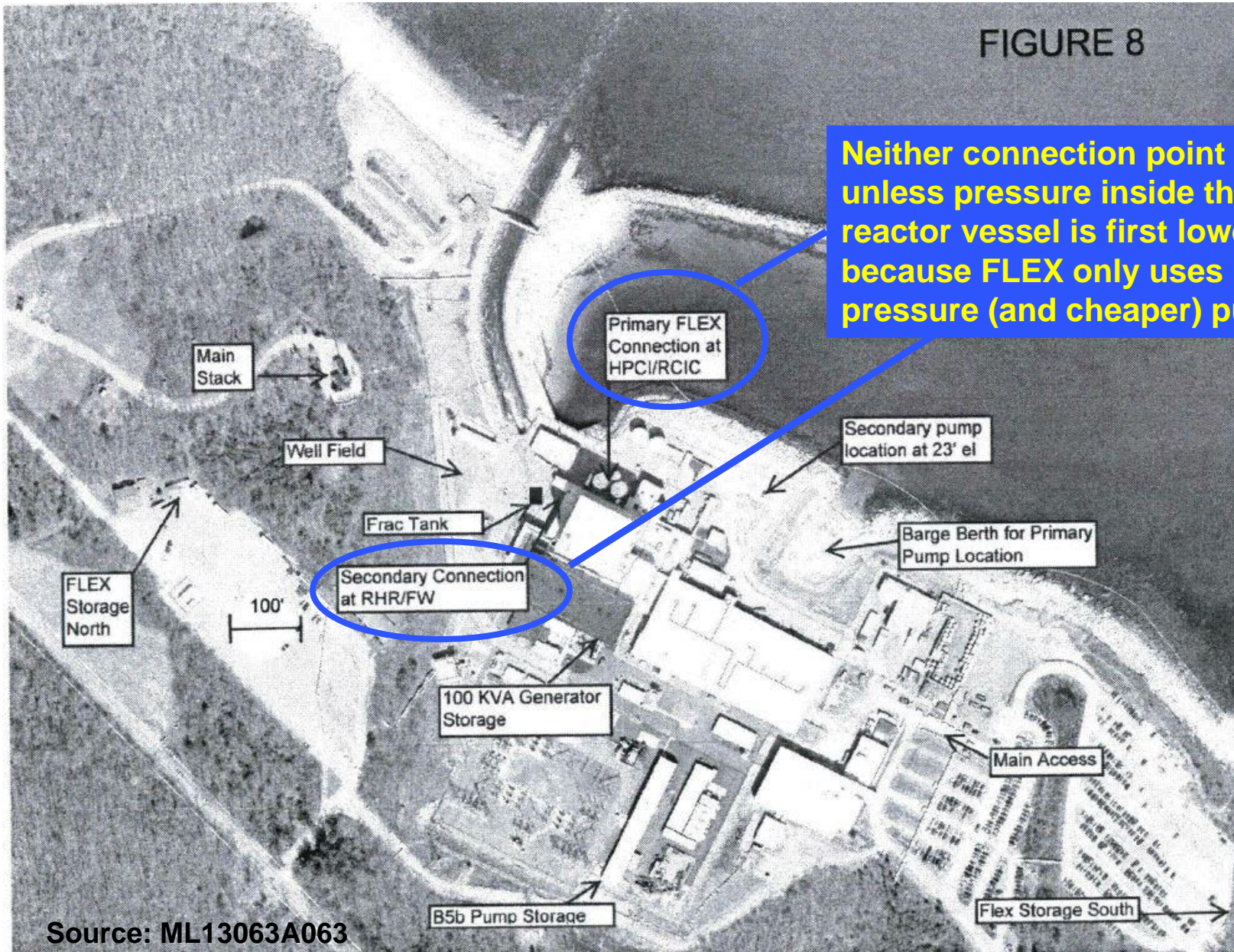
Equipment / Event (Note 1)	Qty	Seismic	External Floods	Hurricane / Tornado	Snow, Ice, Cold	High Temps
Duplex Strainer Trailer 400 GPM 1/8 Inch Size Req'd N = 1						
FLEX-North	1	1	1	1 or 0	1	1
FLEX-South	1	1	1	1 or 0	1	1
Total Available	N+1	N+1	N+1	N	N+1	N+1
Resin Demin Skid 60 cu-ft Mixed Bed Req'd N = 2						
FLEX-North	2	2	2	2 or 0	2	2
FLEX-South	2	2	2	2 or 0	2	2
Total Available	N+2	N+2	N+2	N	N+2	N+2
Frac or Bladder Tank Req'd N = 1						
On-Site North - Frac	1	1	1	1 or 0	1	1
FLEX-North - Bladder	1	1	1	1 or 0	1	1
FLEX-South - Bladder	1	1	1	1 or 0	1	1
Total Available	N+2	N+2	N+2	N	N+2	N+2
Air-Powered Diaphragm Pumps Req'd N = 2						
FLEX-North	2	2	2	2 or 0	2	2
FLEX-South	2	2	2	2 or 0	2	2
Refuel Floor	1	1	1	1 or 0	1	1
Total Available	N+3	N+3	N+3	N	N+3	N+3
Battery Room Fans						

**In general,
FLEX provides
at least N+1
widgets or
connections
when N is
required for
success.**

On the Good Side



On the Caveat Side



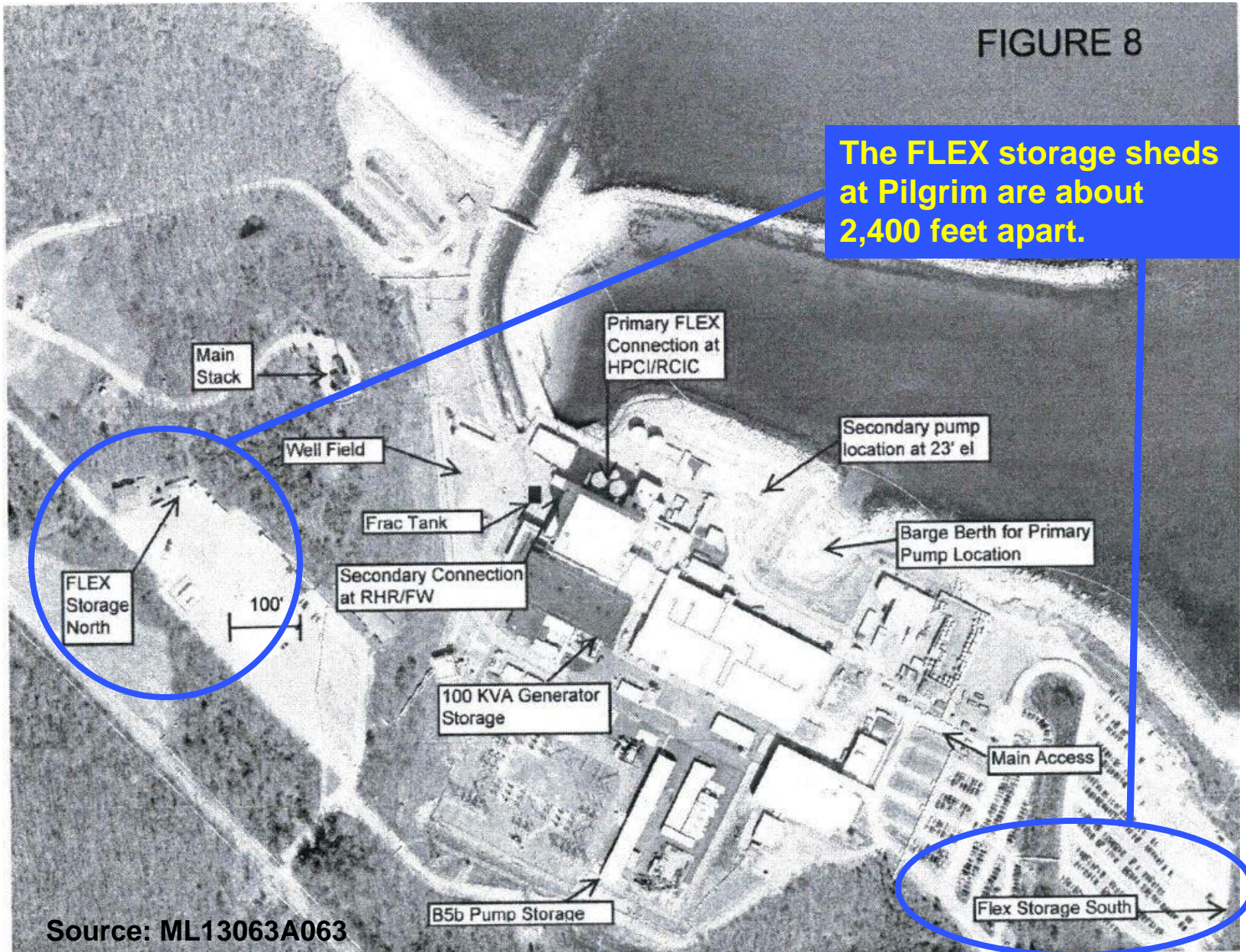
On the Caveat Side

February 2013 FLEX Integrated Plan

Equipment / Event (Note 1)	Qty	Seismic	External Floods	Hurricane / Tornado	Snow, Ice, Cold	High Temps
Duplex Strainer Trailer 400 GPM 1/8 Inch Size Req'd N = 1						
FLEX-North	1	1	1	1 or 0	1	1
FLEX-South	1	1	1	1 or 0	1	1
Total Available	N+1	N+1	N+1	N	N+1	N+1
Resin Demin Skid 60 cu-ft Mixed Bed Req'd N = 2						
FLEX-North	2	2	2	2 or 0	2	2
FLEX-South	2	2	2	2 or 0	2	2
Total Available	N+2	N+2	N+2	N	N+2	N+2
Frac or Bladder Tank Req'd N = 1						
On-Site North - Frac	1	1	1	1 or 0	1	1
FLEX-North - Bladder	1	1	1	1 or 0	1	1
FLEX-South - Bladder	1	1	1	1 or 0	1	1
Total Available	N+2	N+2	N+2	N	N+2	N+2
Air-Powered Diaphragm Pumps Req'd N = 2						
FLEX-North	2	2	2	2 or 0	2	2
FLEX-South	2	2	2	2 or 0	2	2
Refuel Floor	1	1	1	1 or 0	1	1
Total Available	N+3	N+3	N+3	N	N+3	N+3
Battery Room Fans						

**0 < N and
nature rather
than the NRC's
assessment
determines the
outcome.**

On the Good Side



On the Caveat Side

NRC *assumes* that “Should one storage area be lost, the surviving storage area has adequate equipment.”



Tornado that devastated Moore, OK must not have been aware of the 2,400 foot rule.

Disaster Picture: FEMA

On the Caveat Side

February 2013 FLEX Integrated Plan

Equipment / Event (Note 1)	Qty	Seismic	External Floods	Hurricane / Tornado	Snow, Ice, Cold	High Temps
(Note 5) Req'd N = 2						
FLEX-North	1	1	1	1 or 0	1	1
FLEX-South	1	1	1	1 or 0	1	1
Batt Room, Staged	2	2	2	2	2	2
Total Available	N+2	N+2	N+2	N+1	N+2	N+2
Small Diesel Generator, 120/240 VAC 1-PH Req'd N = 1 - 12 kW Req'd N = 2 - 6 kW						
FLEX-North	3	3	3	3 or 0	3	3
FLEX-South	3	3	3	3 or 0	3	3
Total Available	N+3	N+3	N+3	N	N+3	N+3
Debris Removal Wheel Loader On-Site, Req'd N = 1	N	N	N	N	N	N

Notes:

1. The Tornado Event is the most limiting and potentially results in only "N" FLEX Equipment available, including the loss of the B.5.b Pump, but this event has no potential to drain the SFP, which is the basis for the primary SFP Spray capability of the B.5.b Pump in accordance with 10 CFR 50.54(hh) for Security-Related Events. All other events will result in at least "N+2" FLEX Pumps available, each of which has the same capability as the B.5.b Pump and can provide SFP Spray at the same flow rates and conditions. The B.5.b requirement includes a SFP makeup rate of at least 500 GPM and SFP Spray requirement of 250 GPM and is not based on a particular leakage or boil-off makeup rate, it is the required spray flow needed to prevent exposed spent fuel from reaching the oxidation temperature after a SFP draindown. This B.5.b capability is not compromised in any way by the simultaneous deployment of FLEX Equipment. For all ELAP and LUHS Events, "N" FLEX Pumps provide the required capacity for Core Cooling, Containment Heat Removal, and SFP Makeup Water.

N+3 = N when only one debris remover is provided, unless events are "tidy" and only deposit debris in designated places.

Source: ML13063A063

On the Caveat Side

NRC technical evaluation report:

“The single debris removal equipment identified may not be able to move debris to enable transport of equipment within the 6-9 hour time restriction for the pumps and generators.”

On the Good Side

February 2013 FLEX Integrated Plan

Attachment 5 PNPS FLEX Equipment Storage Sea Vans

PNPS will be storing FLEX equipment in Sea Vans at two separate locations at the opposite extremes of the Owner Controlled Area (approximately 1800ft geographically separated). The locations are also at the higher elevations on the site, a minimum of 30ft above mean sea level. The North Storage Area is partially established and is as shown in the photos below. The Sea Vans are supplied with AC power for equipment heaters and lighting, one Sea Van is environmentally controlled, and the others ventilated. The site storage is located and arranged to also support equipment testing, operability, and provide for rapid deployment.



FLEX Storage North; lighting and power is provided to each Sea Van.

**Equipment
over and
above that
provided
for B.5.b is
now onsite.**

Source: ML13063A063

On the Caveat Side

Equipment heaters protect FLEX equipment from cold weather damage before the BDBEE.

NRC Bulletin 79-24 discussed events at nuclear plants where safety-related systems were disabled by cold weather. These systems were monitored and surveilled, yet failed.

On the Caveat Side

NRC requires that workers periodically check air inlet and outlet ventilation ports for dry casks for blockage, but not for FLEX storage pods.



Source: NRC Flickr Gallery

Pilgrim's BDBEE Plan

A simplified description of the Pilgrim Integrated Plan to mitigate the postulated extended loss of ac power (ELAP) event is that the licensee will initially remove the core decay heat by using the Reactor Core Isolation Cooling (RCIC) system. The steam-driven RCIC pump will initially supply water to the reactor from the condensate storage tank, or the suppression pool, depending on availability. Steam from the reactor will then be vented through the safety relief valves to the suppression pool in the torus to gradually cool down the reactor pressure vessel (RPV). RPV depressurization will be stopped at a pressure of about 120 pounds per square inch gauge (psig) to ensure sufficient steam pressure for continued RCIC operation. Once FLEX pumps are deployed, with suction aligned to Cape Cod Bay, the RCIC turbine will be shut down and the FLEX pumps will be used to inject seawater into the RPV. Water will fill the RPV and flow out the SRVs to the suppression pool. Before the suppression pool temperature exceeds 281 degrees Fahrenheit, the suppression pool (torus) will be vented to atmosphere using the hardened vents to release heat and stop the temperature increase. In the long term, the licensee will fill a tank with fresh water from wells at the site, and then inject fresh water into the RPV and establish a stable water level with heat removal by boiling. The licensee's analysis shows that the suppression pool will not overflow during this event. **Source: ML13225A587**

The plan non-conservatively *assumes* that the reactor vessel pressure gets lowered enough to let FLEX's low pressure pump(s) provide makeup flow.

Pilgrim's BDBEE Plan

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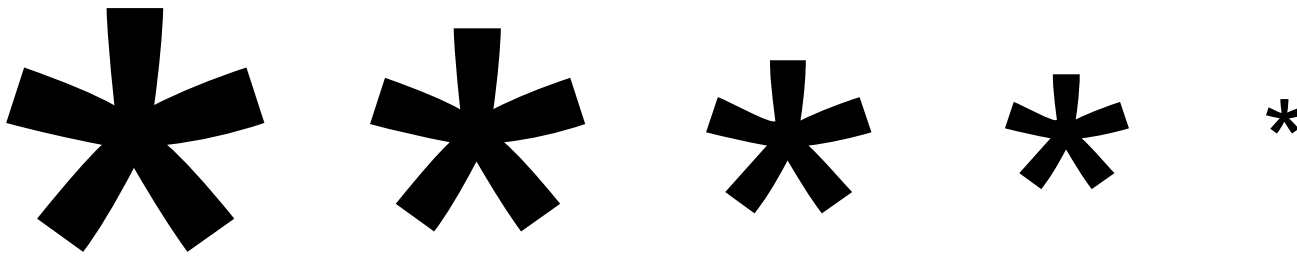
The plan non-conservatively *assumes* that instrumentation not covered by post-Fukushima orders will guide operators into taking proper and timely actions.

Pilgrim's BDBEE Plan

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Source: ML13225A587

The plan non-conservatively assumes that RCIC takes suction from the suppression pool. When RCIC takes suction from its normal and usual source, the suppression pool fills more.



The caveat would shrink if:

- **FLEX employed both high and low pressure pumps**
- **FLEX storage sheds were less vulnerable to common-mode losses**
- **Regulatory requirements governed FLEX equipment while in storage**
- **Non-conservative assumptions that transform BDBEE into BBDBEE were eliminated**

Acronym List

BDBEE – one acronym too many in the series of Class 9, severe accident, and Beyond Design Basis External Event labels for bad days

FLEX – Diverse and Flexible Mitigation Capability

NRC – Nuclear Regulatory Commission

RCIC – Reactor core isolation cooling

SBO – station blackout where all AC power is unavailable

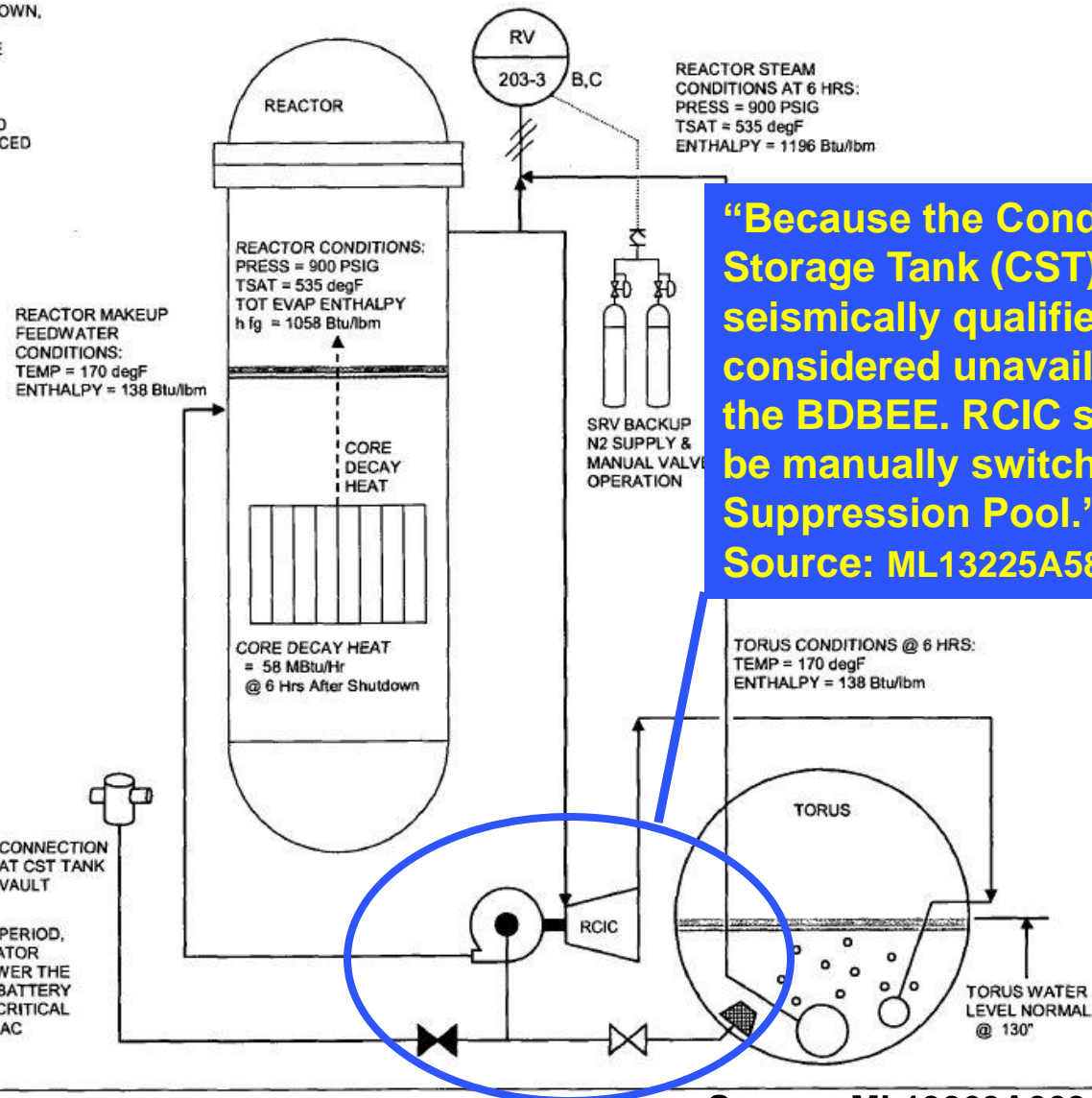
Backup Slides

Pilgrim's BDBEE Plan

REACTOR / TORUS CONDITIONS DURING FIRST 6 HOURS

FIGURE 1

DURING THE FIRST 6 HOURS AFTER SHUTDOWN, THE REACTOR REMAINS ISOLATED AND PRESSURIZED WITH RCIC PROVIDING CORE COOLING, DRAWING WATER FROM THE SUPPRESSION POOL (TORUS). AT 6 HOURS AFTER RX SHUTDOWN, THE TORUS IS AT 170°F AND A CONTROLLED REACTOR DEPRESSURIZATION IS COMMENCED BASED ON THE EOP-11 HCTL CURVE.



"Because the Condensate Storage Tank (CST) is not seismically qualified, it is considered unavailable for the BDBEE. RCIC suction will be manually switched to the Suppression Pool."

Source: ML13225A587

DURING THIS INITIAL SBO PERIOD, A 100 kVA MOBILE GENERATOR WILL BE SET UP TO REPOWER THE STATION'S 125 & 250 VDC BATTERY CHARGERS TO MAINTAIN CRITICAL INSTRUMENTS AND VITAL AC POWER OPERATING.

Source: ML13063A063

Pilgrim's BDBEE Plan

REACTOR / TORUS CONDITIONS DURING REACTOR DEPRESSURIZATION FROM 6 TO 9 HOURS

FIGURE 2

DURING THE PERIOD 6 TO 9 HOURS AFTER SHUTDOWN, THE REACTOR REMAINS ISOLATED AND PRESSURIZED WITH RCIC PROVIDING CORE COOLING, DRAWING WATER FROM THE SUPPRESSION POOL (TORUS). STARTING AT 6 HOURS AFTER RX SHUTDOWN, WITH THE TORUS AT 170 degF, A CONTROLLED REACTOR DEPRESSURIZATION IS COMMENCED BASED ON THE EOP-11 HCTL CURVE. RCIC AND SRVs ARE USED TO REDUCE REACTOR PRESSURE TO 120 PSIG OVER A 3-HOUR PERIOD, AT WHICH TIME THE TORUS IS UP TO 235 degF AND CORE COOLING IS TRANSITIONED FROM RCIC TO FLEX LOW PRESSURE INJECTION PUMPS. WHEN NO OTHER SOURCES OF WATER ARE AVAILABLE, SEAWATER WILL BE USED WITH TWO TANDEM FLEX PUMPS TO PROVIDE SUBCOOLING FLOW TO THE REACTOR VESSEL AT TWICE THE BOIL-OFF RATE.

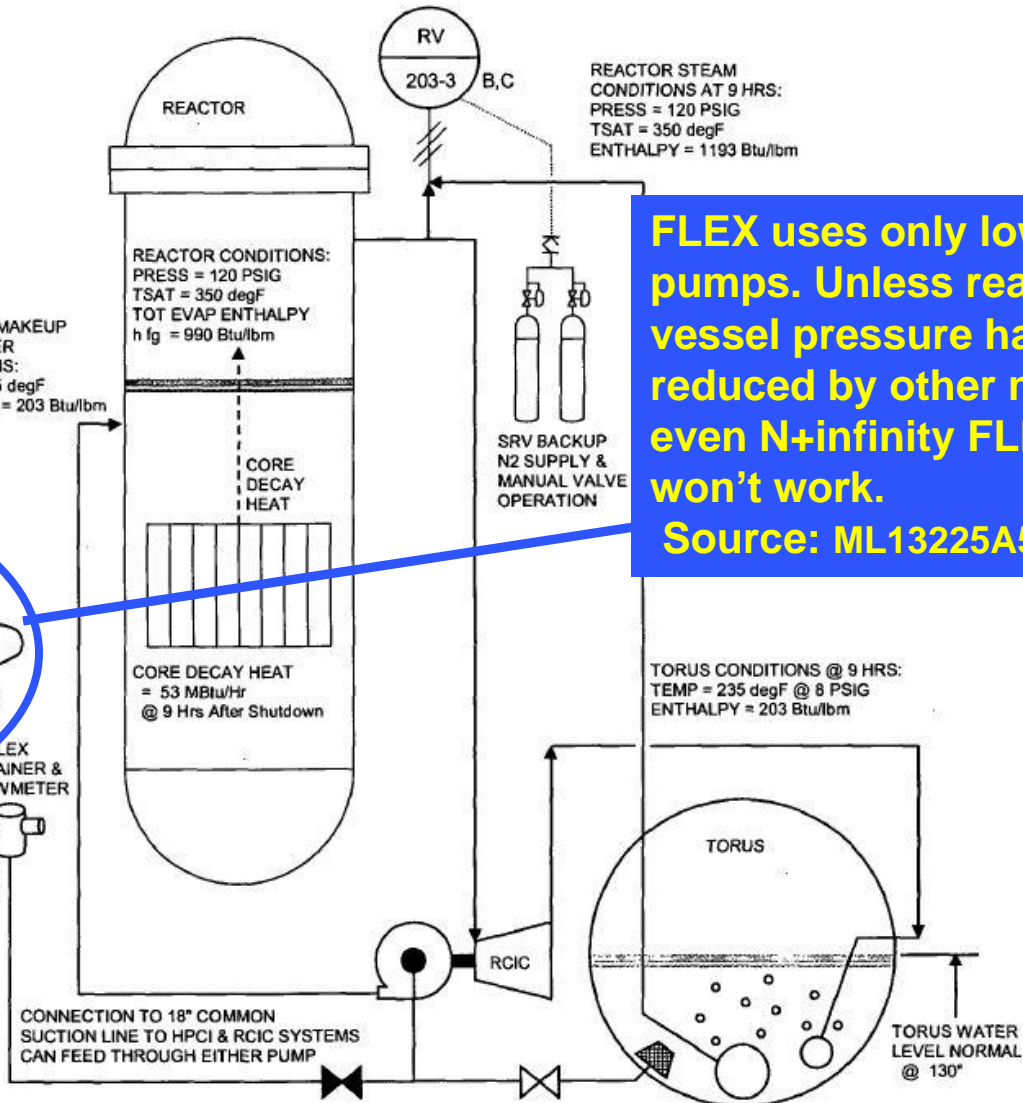
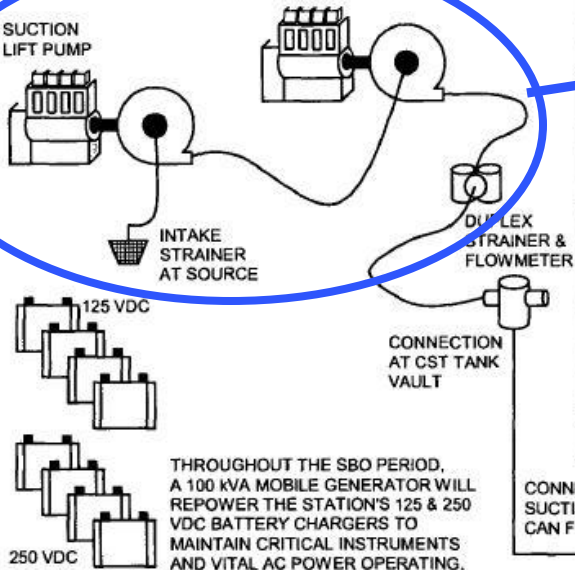
TWO GODWIN HL100M PUMPS ARE SET UP IN TANDEM USING 5" HOSES WITH SUCTION LIFT FROM SEAWATER SOURCE. DISCHARGE LINE INCLUDES A DUPLEX STRAINER AND FLOW RATE METER & TOTALIZER WITH INJECTION CONNECTION POINT LOCATED AT VAULT BETWEEN CST TANKS FEEDING INTO THE UNDERGROUND HPCI / RCIC COMMON SUCTION LINE.

REACTOR MAKEUP FEEDWATER CONDITIONS:
TEMP = 235 degF
ENTHALPY = 203 Btu/lbm

REACTOR STEAM CONDITIONS AT 9 HRS:
PRESS = 120 PSIG
TSAT = 350 degF
ENTHALPY = 1193 Btu/lbm

FLEX uses only low pressure pumps. Unless reactor vessel pressure has been reduced by other means, even N+infinity FLEX pumps won't work.

Source: ML13225A587



Pilgrim's BDBEE Plan

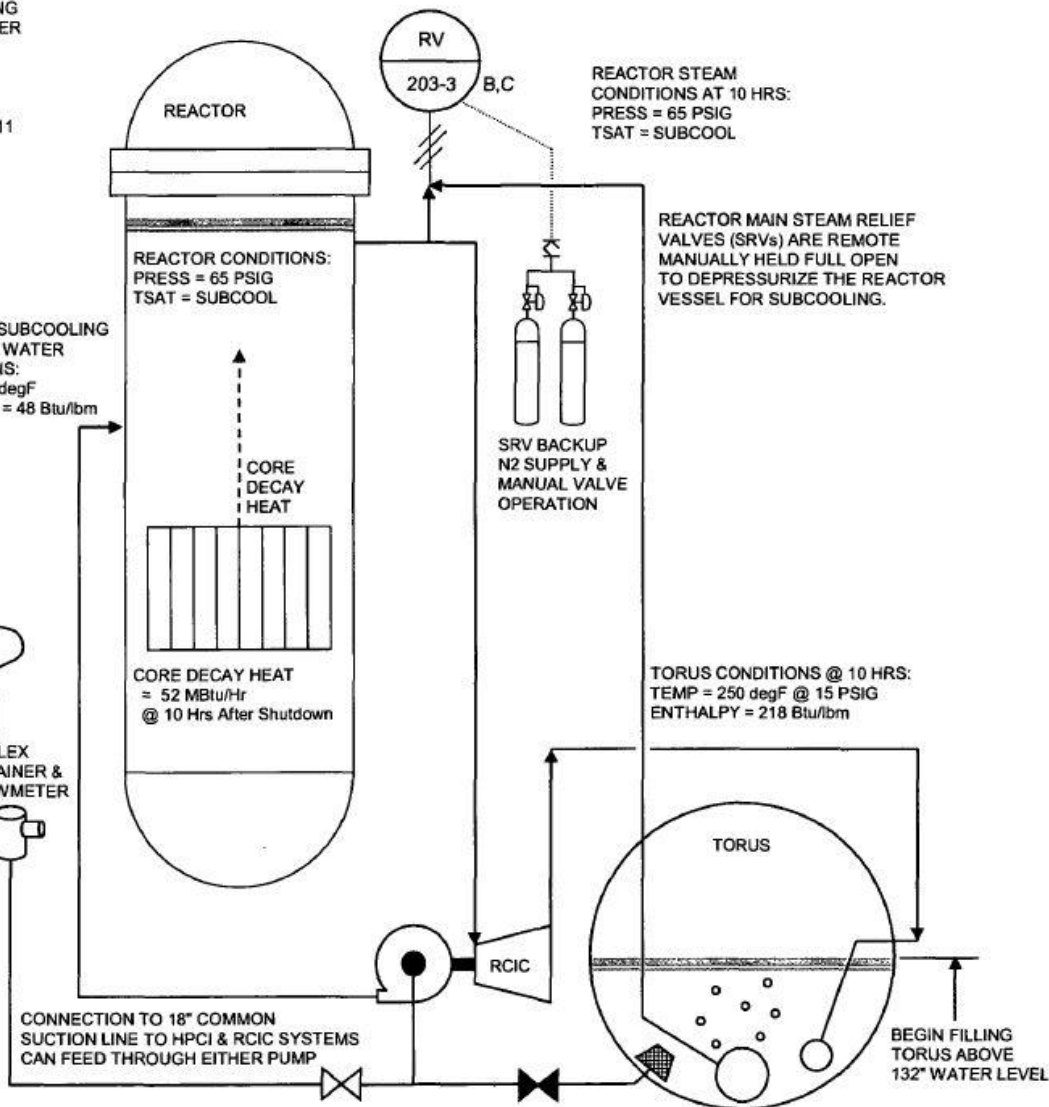
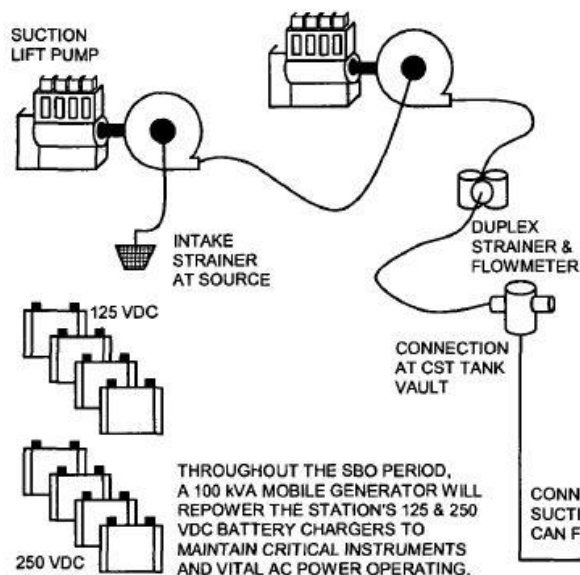
REACTOR / TORUS CONDITIONS DURING REACTOR FINAL DEPRESSURIZATION FROM 9 TO 10 HOURS

FIGURE 3

WHEN THE TORUS EXCEEDS 230 degF AT 9 HOURS AFTER SHUTDOWN, THE REACTOR IS DEPRESSURIZED BY OPENING THE SRVs AND TRANSITIONING FROM RCIC DRAWING WATER FROM THE TORUS TO THE FLEX LOW PRESSURE PUMPS INJECTING VIA THE RCIC PUMP FLOW PATH. STARTING AT 9 HOURS AFTER RX SHUTDOWN, WITH THE TORUS AT 235 degF, THE FINAL REACTOR DEPRESSURIZATION IS COMMENCED BASED ON THE EOP-11 HCTL CURVE. SRVs ARE OPENED TO REDUCE REACTOR PRESSURE TO 50 PSIG AT WHICH TIME CORE COOLING IS TRANSITIONED FROM RCIC OPERATION TO FLEX LOW PRESSURE PUMPS CONNECTED TO THE ISOLATED CST SUCTION LINE TO HPCI / RCIC. TANDEM FLEX PUMPS WILL PROVIDE SUBCOOLING INJECTION FLOW TO THE REACTOR VESSEL WITH HEATED LIQUID FLOW OUT THE SRVs TO THE TORUS.

INITIAL FLEX PUMP FLOW RATE DURING FINAL DEPRESS TO 50 PSIG IS 400 GPM TO RESTORE RX WATER LEVEL THEN IS REDUCED TO 180 GPM FOR CONTINUOUS SUBCOOLING OF CORE AT 10 HRS.

REACTOR SUBCOOLING INJECTION WATER CONDITIONS:
TEMP = 75 degF
ENTHALPY = 48 Btu/lbm

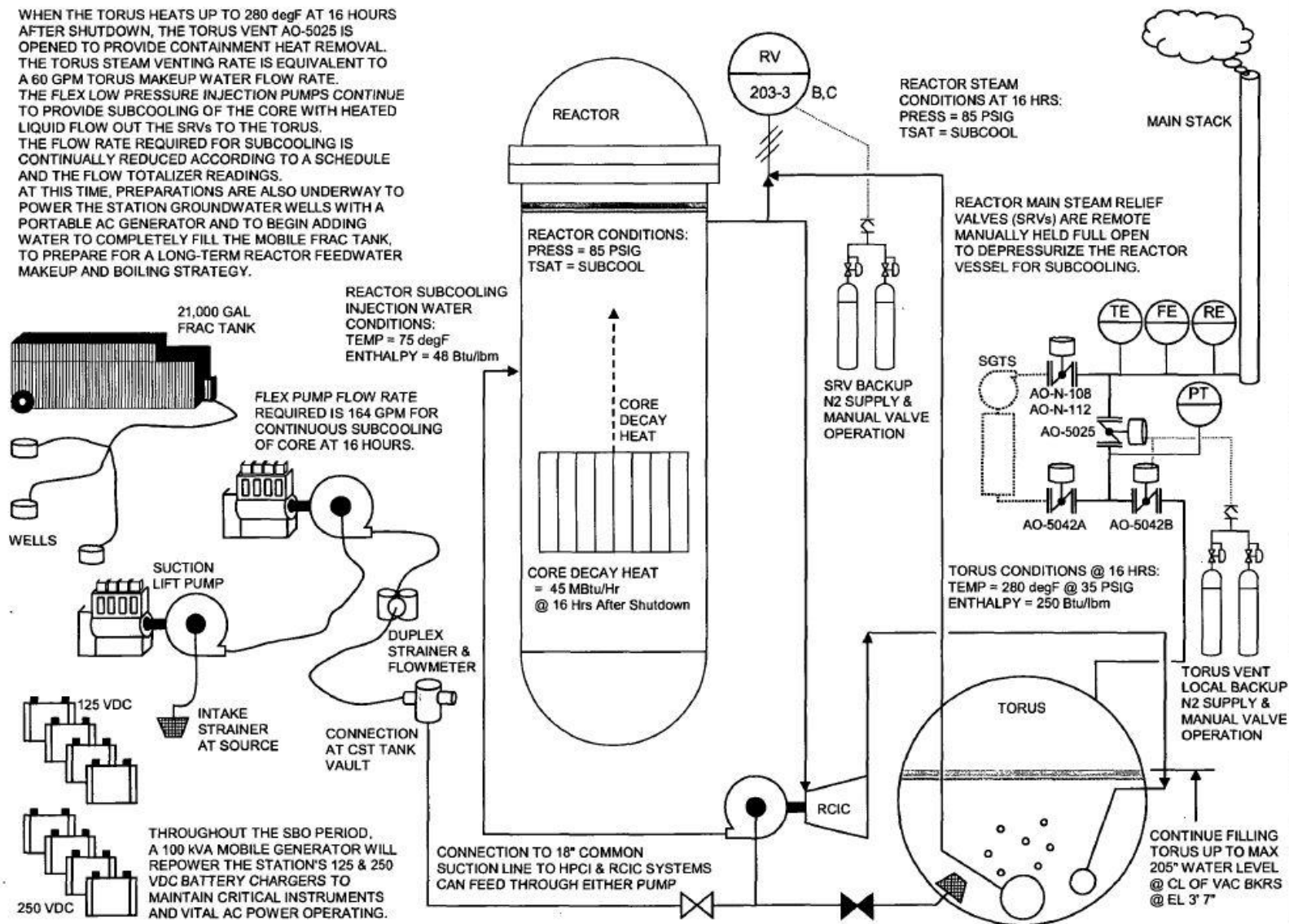


Pilgrim's BDBEE Plan

REACTOR / TORUS CONDITIONS FROM 10 HOURS TO THE START OF TORUS VENTING AT 16 HOURS

FIGURE 4

WHEN THE TORUS HEATS UP TO 280 degF AT 16 HOURS AFTER SHUTDOWN, THE TORUS VENT AO-5025 IS OPENED TO PROVIDE CONTAINMENT HEAT REMOVAL. THE TORUS STEAM VENTING RATE IS EQUIVALENT TO A 60 GPM TORUS MAKEUP WATER FLOW RATE. THE FLEX LOW PRESSURE INJECTION PUMPS CONTINUE TO PROVIDE SUBCOOLING OF THE CORE WITH HEATED LIQUID FLOW OUT THE SRVs TO THE TORUS. THE FLOW RATE REQUIRED FOR SUBCOOLING IS CONTINUALLY REDUCED ACCORDING TO A SCHEDULE AND THE FLOW TOTALIZER READINGS. AT THIS TIME, PREPARATIONS ARE ALSO UNDERWAY TO POWER THE STATION GROUNDWATER WELLS WITH A PORTABLE AC GENERATOR AND TO BEGIN ADDING WATER TO COMPLETELY FILL THE MOBILE FRAC TANK, TO PREPARE FOR A LONG-TERM REACTOR FEEDWATER MAKEUP AND BOILING STRATEGY.



Pilgrim's BDBEE Plan

REACTOR / TORUS CONDITIONS DURING TORUS VENTING AFTER 16 HOURS TO MAKEUP MODE AT 72 HOURS

FIGURE 5

THE TORUS COOLS DOWN TO 250 degF AT 72 HOURS AFTER SHUTDOWN, THE TORUS VENT AO-5025 WAS OPENED TO PROVIDE CONTAINMENT HEAT REMOVAL AT 16 HOURS. THE TORUS STEAM VENTING RATE IS EQUIVALENT TO A 60 GPM TORUS MAKEUP WATER FLOW RATE. THE FLEX LOW PRESSURE INJECTION PUMPS HAVE BEEN PROVIDING SUBCOOLING OF THE CORE WITH HEATED LIQUID FLOW OUT THE SRVs TO THE TORUS, WHICH MAY BE APPROACHING THE MAX LEVEL. AT THIS TIME, THE STATION GROUNDWATER WELLS ARE FEEDING THE MOBILE WATER TANK AND THE SKID-MOUNTED DEMINERALIZER VESSEL IS SET UP WITH THE FLEX PUMP TO BEGIN A LONG-TERM REACTOR FEEDWATER MAKEUP AND BOILING STRATEGY. THE VESSEL IS FLUSHED WITH SUBCOOLED WATER FROM THE MOBILE FRAC TANK AND THEN ALLOWED TO BOIL DOWN TO A STABLE WATER LEVEL.

