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4/6/79/1

TMI CORE ASSESSMENT

IA-E-103

IA-8

OBJECTIVE:

Determine the events within the TMI primary system insofar as they might indicate core configuration.

METHOD:

Core density changes were inferred from reduced radiation transmission to intermediate and source range detectors.

Reactor coolant system pressure, reactor inlet and outlet temperatures, and steam generator pressure and levels were obtained from recorder plots.

Operator actions were obtained from computer events monitor.

System behavior was theorized by a process of hypothesis and test for data consistency.

When possible, simple calculations were performed relative to heat up, boiloff, and volume changes to confirm reasonableness of process understanding.

Time inferred from graphs and/or recorder charts. Estimated ±3 minute accuracy for event specification.

RESULTS:

The sequence of inferred events one hour after turbine trip is attached. This sequence states as fact many items that are conclusions and hypotheses that seem to fit the available data, and it should be used accordingly. Where facts are unable to be tested, a (?) is shown.

Also attached is a diagram summarizing core density behavior in the period from 70 to 220 minutes as deduced from ion chamber traces. In these traces, changes in transmissivity are interpretted as fluid/core density changes. Changes in slope are considered important as indication of phase changes or elevation change. Also included in the diagram are plant and process information considered relevant and calculational notes.

CONCLUSIONS:

1. Significant core damage occurs in the one hour period from 6 a.m. to 7 a.m.

   Ion chamber signals suggest significant voiding at this time. Significant superheat occurs. Relatively little inflow to lower plenum is noted during early portion of period when significant heating of voided core occurs. Spike in ion chambers at 146 minutes suggests structure change. Radiation noted in containment. More than enough time and heat exists to cause metal reactions if cooling restricted.

CONCLUSIONS (Cont.):

2. Greater damage on B-leg side of core than A-leg.

Significant flow noted on A-leg throughout period between 6 a.m. and 7 a.m. as signaled by preferential heatup of outlet RTD and more rapid temperature decrease on A-leg inlet RTD during latter part of period.

3. Core ΔP greater than combined ΔP of pump and steam generator.

Whenever pressure is reduced following 7 a.m., cold HPI and seal water flow from pump and pump discharge toward outlet temperature detector in the pump suction. This conclusion could be erroneous if the A-Generator outlet tap were cooler than mixture of lower plenum and HPI water. Additionally, magnitude of temperature surges indicate A-leg in highly vaporous state.

Reverse flow occurs in A-leg starting about 2 p.m. and lasting until 7 p.m. During this period, the plant is at low (500 psi) pressure and blowing down with flood tanks providing cold water to lower plenum.

4. Additional damage during period following 7 a.m. possible, but not certain.

Outlet temperatures at superheat or saturation and cold water from HPI and/or core flood tanks in inlet plenum suggests core flow between 7 a.m. and 2 p.m. Ion detectors suggest some density change, but nothing approaching the response noted at 6 a.m. From 7 a.m..(204 minutes) on, HPI, core flood, A-Generator and relief valve suggest ample heat removal capability.

On the other hand, high ΔP and reverse flow suggests low flow given lack of pump.

5. Metal/Water Reaction Rate might be bounded by Hydraulic Data

From 130 to 176 minutes, the primary system pressure rises following valve closure. This rise might well include contribution from H_2 associated with metal/water reaction. During this pressure rise, the in core density decreased by a factor of 1.5 to 2.5. With available pressures and temperatures, it should be possible to estimate H_2 fraction in steam and thus, reaction fraction. It might also be possible to bound the energy added in addition to decay heat which caused pressure rise, thus scoping exothermic reaction.

TMI SEQUENCE OF EVENTS AFTER THE FIRST HOUR FOLLOWING TURBINE TRIP

73 min. - B-loop flow stops, B-Generator pressure begins to decrease, primary pressure quasi-stable at 1100 psi, with relief valve lifted and choke flow, T out near saturation, T inlet subcooled, HPI off (?), A-Generator level slowly dropping, B-Generator level increasing.

90 min. - Increase in B-Generator level occurs.

90 - 100 min. - Cold fluid on B-Generator causes depressurization of primary system with density changes in core region. Density decreases nearly linearly for 8 minutes as presssure decreases. Magnitude is 1/3 of subsequent density change. Temperature at saturation in both inlet and outlet legs. A-Generator pressure begins to fall coincident with flashing, suggesting reduced heat removal due to reduced fluid density.

100 min. - A-loop flow stops. A quench occurs from fall back of cold water from head or B-loop or possibly from core barrel check valve leakage, although source is uncertain. Quench inferred from nearly step wise density increase. B-Generator pressure drop stops. A-Generator level begins to rise and pressure drop continues, suggesting continued low density in primary side of A-Generator.

100 - 116 min. - Pressure continues decrease, water now in core reheats. Rough calculation estimates 12 minutes required to reheat two times core volume up to saturation (factor of 2 is allowance for inflow). Inflow indicated by inlet temperature decrease. Core outlet at or near saturation.

116 min. - Voids begin to form in core. Voids (rather than water density change) marked by slope change in source range detector. Outlet begins to show superheat. Pressure continues to fall. A-Generator level stabilizes, indicating some heat rejection. Rate of pressure decrease in A-Generator decreases.

116 - 124 min. - Upper half of core voids, superheated steam in outlet. Hot spot probably steam cooled or voided at 121 minutes. Significant steam flow in A-leg and B-leg core inlet at 124 minutes. Significant steam flow in A-leg outlet, less in B-leg.

124 - 132 min. - Rest of core voids at 128 to 132 minutes. At 132 minutes, gate valve on pressurizer relief valve closed by operator. Pressure begins to rise. Inlet temperature indicates little, if any, flow from A-leg to inlet, but some flow from B-leg to inlet. A-leg superheat rate of at least 10°F/min.

132 - 150 min. - Core appears voided with some density reduction as pressure rises. Outlet plenum contains superheated steam. Some flow from B-leg to lower plenum, little or no flow from A-leg. At 146 minutes, the neutron detectors indicate one or more changes in core structure possible.

150 min. - Indication of steam on both generators since little or no heat removal. Lower flow rate in B-leg finally raises outlet temperature detector to superheat indication 30 minutes later than A-leg. Containment radiation spike reported. Adiabatic calculation (characteristic of dry out) would permit metal/water reaction in 6 min. at hot spot and 10-15 minutes for fuel rod of average heat. Simple calculation would permit core volume and downcomer volume at core height to be boiled out at 152 minutes.

150 - 176 min. - Pressure continues to increase with exponential appearance from 660 psi at 130 minutes to 2200 at 176 minutes. Outlet temperatures in both legs indicate superheated steam. Increased flow at inlet indicated by decreasing temperatures, with greater flow from the A-leg. Little or no cooling indicated at either generator. Apparent exponential rise suggests autocatalytic H_2 generation. Core density indicated by ion chambers decreased less than expected from change in pressure, suggesting H_2 presence.

176 - 180 min. - Quench of core and collapse of voids indicated. Pressure discharge from relief valve. Lower plenum water forced into cold legs, with greater flow to A than B (A contains less water) and some cooling by the A-Generator. Main steam isolation valve and turbine bypass valve on B-Generator closed at 180 minutes. Outlet temperature indicates superheat. Quench suspected to be from water or steam from A-leg.

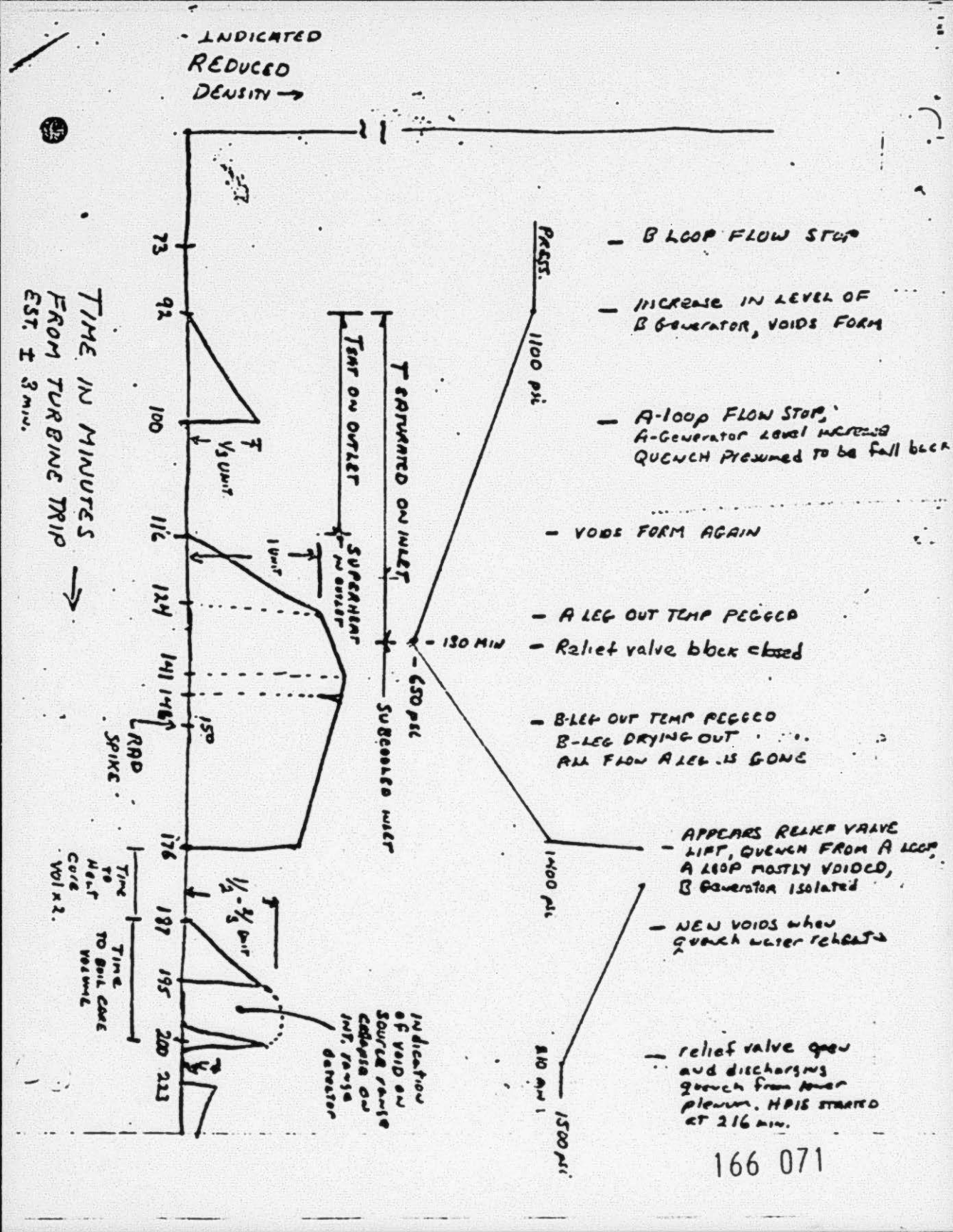
180 - 204 min. - Quench water/steam reheats and, in 7 to 11 minutes, voids again begin forming in the core, although not as extensively as before (about one-half). Little flow (possible backflow) in the A-leg as indicated by hot water at inlet temperature detector. More flow on B-leg and toward inlet plenum. Outlet temperatures at saturation. Relief block valve opened at 204 min.

204 - 450 min. - HPI turned on. Pressure drops to 1200 and is maintained between 1200 and 1700 psi until 5.5 hours, when the relief block valve was closed. When valve closed, pressure rose to 2100 psi and remained there through period. Throughout period, outlet temperatures were near saturation and inlet temperature generally decreased as the result of HPI flow. Periodic surges of lower plenum water move into cold legs whenever system pressure decreases, more so in the A-leg than B-leg, indicating greater vapor volume in A-leg. Core voids or significant density decrease noted at 223 minutes, associated with pressure surge and backflow from lower plenum to inlet legs. Slow correction or collapse noted in this case.

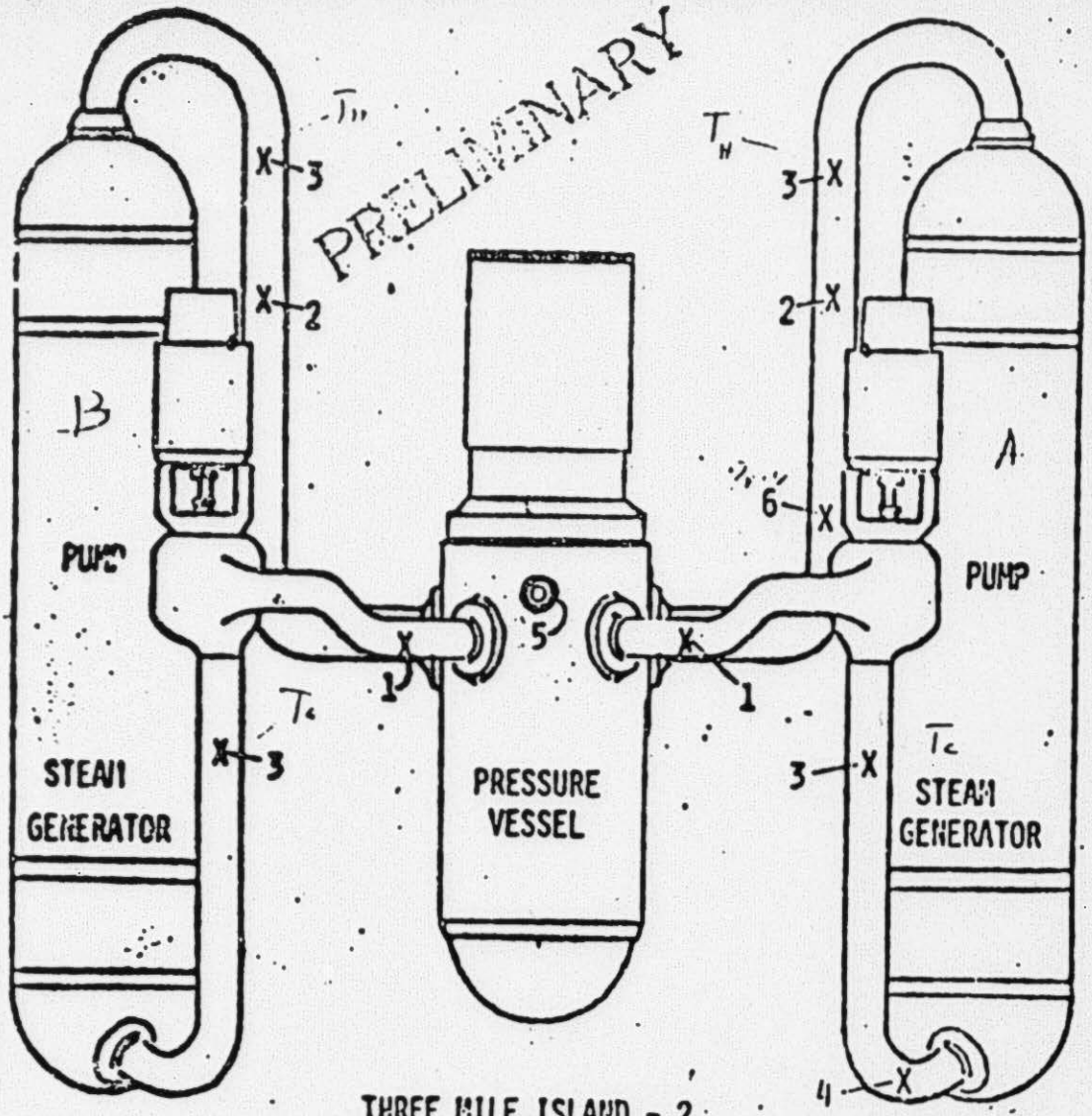
7.5 - 10 hours - Relief block valve opened at 7.5 hours and pressure drops to 500 psi in 1.5 hours. At 8.5 hours, the core flood actuates. Outlet temperatures show superheated steam. Generators cease to remove heat for 2 hours starting at 8.0 hours. During this 2 hour period, inlet temperature decreases and outlet temperature is at superheat condition. Small change in core density occurs at 9.6 hours.

10 - 16 hours - Reverse flow in A-leg begins at 10.5 hours. B-leg may have tried to reverse at 14 hours. Unexplained level change in B-Generator at 11.5 hours that appears to be from charging, although logs and data sheets contain no reference to such action. Primary side contraction pulls lower plenum water into B-leg. Even though HPI flow is increased at 12.5 hours, reverse flow continues in A-leg. Relief valve again closed at 13.5 hours and pressure rise begins. Increasing pressure pushes HPI water toward A-leg generator and pushes lower plenum water into inlet of B-leg. Pressure increase and its effects extend from 13.5 to 14.5 hours. During the episode, cooling occurs in A-Generator. Some density change noted in core as pressure increased, then a general density decrease occurs. Suspect hot fluid from upper plenum pushed through core.

At 16 hours, A-loop Primary pump turned on and significant events end.


- INDICATED REDUCED DENSITY →
TIME IN MINUTES FROM TURBINE TRIP →
EST. ± 3 min.
73
92
100
116
124
141
146
150
176
187
195
200
223
T SATURATED ON INLET
TEMP ON OUTLET
SUPERHEAT IN OUTLET
T Vs UNIT
1 UNIT
650 psi
SUBCOOLED INLET
RAD SPIKE
1/2 - 2/3 DIP
TIME TO HALF CORE VOLUME x2.
TIME TO BOIL CORE VOLUME
INDICATION OF VOID ON SOURCE RANGE CATHODE OR INT. RANGE detector
PRESS.
1100 psi
1400 psi
810 psi
1500 psi
130 MIN
- B LOOP FLOW STOP
- INCREASE IN LEVEL OF B GENERATOR, VOIDS FORM
- A-loop FLOW STOP, A-Generator Level increasing QUENCH Presumed to be full blo
- VOIDS FORM AGAIN
- A LEG OUT TEMP PEGGED
- Relief valve block closed
- B-LEG OUT TEMP PEGGED B-LEG DRYING OUT ALL FLOW A LEG IS GONE
- APPEARS RELIEF VALVE LIFT, QUENCH FROM A LOOP, A LOOP MOSTLY VOIDED, B Generator Isolated
- NEW VOIDS when QUENCH WATER RELEASED
- relief valve open and discharging quench from lower plenum. HPIS started at 216 min.

166 071



THREE MILE ISLAND - 2

KEY

1 HIGH PRESSURE INJECTION

2 FLOWMETERS

3 RESISTANCE TEMPERATURE INDICATOR

4 LETDOWN

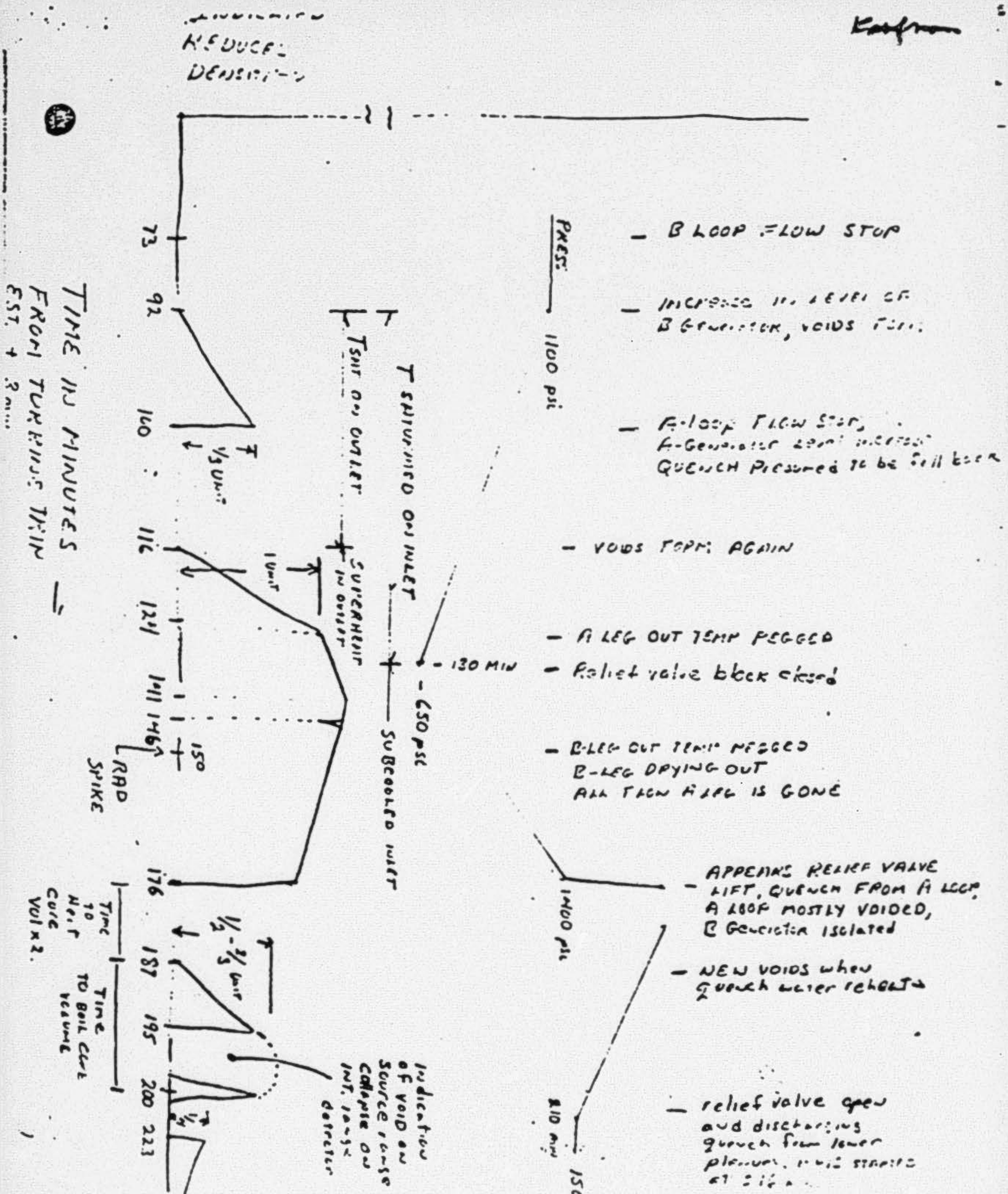
5. CORE FLOODING NOZZLE

6 PRESSURIZER CONNECTION

SUBJECT NO.

166 072

Kaufman



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