Attachment
ST-HL-AE-2483
File No.: G02

HYDRAULIC TRANSIENT

IN MAIN FEEDWATER

DURING FILLING OF STEAM

GENERATORS

SOUTH TEXAS PROJECT

DOCKET NO. STN-50-498

HOUSTON LIGHTING AND POWER COMPANY

JANUARY 1988

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ABSTRACT

On January 11, 1988 with Unit 1 in Mode 5, several hydraulic transients occurred while filling steam generators A, B, and C using main feedwater. The hydraulic transients are attributed to flashing flow conditions caused by introduction of feedwater into portions of the feedwater piping at a temperature greater than the saturation temperature corresponding to the pressure in the steam generator and feedwater piping. Condensation-induced water hammer occurred at the interface of cold water and steam in feedwater piping to the three steam generators.

The piping systems were walked down and evaluated to assure system integrity. No damage was found. Procedures have been revised and Operators are being trained to prevent similar recurrences.

These events have no relationship to the auxiliary feedwater hydraulic transient events described in our report to the NRC dated December 24, 1987.

I. DESCRIPTION OF OCCURRENCE

On January 11, 1988, with Unit 1 in Mode 5, three hydraulic transients occurred while filling steam generators A, B, and C with main feedwater as a source of supply. It should be noted that at the South Texas Project main feedwater is preheated with a full flow deaerator.

The steam generators were being filled to raise operating levels using main feedwater. Main feedwater is the preferred supply source when chemistry specifications have been satisfied. (Refer to Figure 2, Sequence Chart, for clarification of the following description). During initial filling operations feedwater was recirculating to the condenser to maintain a feedwater temperature of approximately 290°F. The steam generator temperatures were approximately 180°F.

The Shift Supervisor stationed an operator in the Isolation Valve Cubicle (IVC) prior to the initiation of feedwater flow to steam generator C. A valve lineup was performed to initiate feedwater flow to the upper nozzle via the preheater bypass line (See Figure 1). The preheater bypass line is the crosstie between the main feedwater and the auxiliary feedwater piping to the upper nozzle. The Feedwater Bypass Control Valve (FBCV) was shut and flow was then established to the steam generator by opening the Feedwater Preheater Bypass Valve (FPBV) and throttling open the Feedwater Bypass Control Valve (FBCV). The stationed observer noted a slight clicking of the check valve downstream of the FPBV but no piping vibration.

The Reactor Operator proceeded to fill steam generator B in the same manner. The stationed observer reported noise and vibration in the preheater bypass and auxiliary feedwater lines after flow was established. Flow was secured and the hydraulic transient was terminated. The same procedure was repeated for steam generator B with additional observers from the control room in the IVC and no noise and/or vibration was noted. The same sequence was then performed to fill steam generator A and vibration and noise was reported. Flow was secured to steam generator A and the hydraulic transient was terminated. Flow was then secured to B and C steam generators. Recirculation flow was also secured at this time.

It was then decided to fill steam generator C by using the main feedwater line to the lower steam generator nozzle. The FBCV was shut and the Feedwater Isolation Bypass Valve (FIBV) was opened. The FBCV was throttled open to establish flow. Noise was heard and flow was secured, terminating the transient.

II. CAUSE OF OCCURRENCE

The hydraulic transients were determined to have been caused by steam condensation. Due to the lower steam generator backpressure, steam was formed when the feedwater pressure dropped below the saturation pressure corresponding to the feedwater temperature. When the steam came in contact with the relatively cold water downstream of the FBCV, steam condensation occurred causing a hydraulic transient.

The root cause of the event has been determined to be that the method of filling the steam generators did not assure that steam generator pressures would be maintained sufficiently high to preclude flashing. This event has no relationship to the auxiliary feedwater transients that occurred at STP in November 1987.

III. ANALYSIS OF EVENTS

DESCRIPTION OF SYSTEM

Figure 1 depicts the applicable portions of the main feedwater and auxiliary feedwater systems that are required for makeup to the steam generators. The upper nozzle of the steam generator can be fed from either the main feedwater system via the FPBV or the auxiliary feedwater system. Makeup to the steam generators from main feedwater to the lower steam generator nozzle is prohibited if the feedwater temperature is less than 250 ^{o}F.

INVESTIGATION OF EVENTS

Subsequent to the hydraulic transients, the Reactor Operators were debriefed and written statements were obtained documenting their actions and observations. Computer archival data were obtained including analog process data documenting feedwater pressures, temperatures, steam generator levels, and digital data on valve positions. The piping layouts were reviewed for each steam generator flow path to identify differences. A review was performed of the process conditions to identify sources of the hydraulic transients, in particular the potential for two phase flow. As discussed in Section V, a review of the plant procedures for filling the steam generators was also initiated.

ANALYSIS OF DATA

(a) REVIEW OF PIPE LAYOUT

The piping profile schematic for each of three upper nozzle flowpaths in use during the events are shown in Figures 3, 4 and 5. The figures identify the areas where the greatest vibration was observed as well as the auxiliary feedwater and main feedwater interface. As can be seen from these diagrams, there is 52.5 feet of static head between the upper nozzle and the interface. Also, the configuration of A and B at this interface is different than C. The auxiliary feedwater line in flowpath C connects horizontally to the feedwater line, whereas on A and B the auxiliary feedwater line connects vertically. This has significance as explained in Subsection (C) of this section as to why C did not experience a hydraulic transient while feeding the upper nozzle.

(b) REVIEW OF SYSTEM PROCESS AND VALVE POSITION DATA

The computer data indicates that the feedwater temperature was approximately 290 °F when filling was initiated. Steam generator levels were approximately 40% of narrow range indication. Steam generator temperature was approximately 180 °F. Feedwater booster pump #11 was in operation and the long recirculation flowpaths to the condenser were established. Pressure upstream of the Feedwater Bypass Control Valves (FBCV) was approximately 300 psia. The FBCV's were less than 5% open while feeding the steam generators.

(c) ANALYSIS OF SYSTEM DATA AND PIPING LAYOUT CONSIDERATIONS

Based on the system data summarized above, when the FBCV's were opened to fill the steam generators through the upper nozzles, a two phase flow condition occurred downstream of the FBCV's. This is due to the fact that the pressures downstream of the control valves were below saturation pressure corresponding to approximately 290 °F. Saturation pressure at 290 °F is 58 psia and the pressure due to the static head of water from the upper nozzle plus the steam generator pressure results in a pressure of approximately 30 psia at the interface between auxiliary feedwater and feedwater piping. The result of this is a two phase flow condition. The hydraulic transient occurred when the steam in the two phase flow displaced the cold water in the vertical auxiliary feedwater lines. The cold water mixing with the two phase flow caused a series of steam bubble collapses resulting in a hydraulic transient. When steam generator B was fed the second time no hydraulic transient occurred. At this point the vertical auxiliary feedwater line was purged of cold water.

(c) ANALYSIS OF SYSTEM DATA AND PIPING LAYOUT CONSIDERATIONS (Cont.)

The hydraulic transient on steam generator C occurred when the Feedwater Isolation Bypass Valve (FIBV) was opened and flow was established by throttling the FBCV. This system configuration resulted in a two phase flow. Cold water between the Feedwater Isolation Valve (FIV) and the downstream check valve mixed with the two phase flow coming from the FIBV causing a series of steam bubble collapses, resulting in a hydraulic transient.

SUMMARY OF ANALYSIS

The hydraulic transients which occurred using both flowpaths resulted from the formation and collapse of steam in the feedwater line downstream of the throttling valves. The feedwater temperature was above the saturation temperature for the feedwater line to the steam generators.

IV. SAFETY EVALUATION

The hydraulic transients were of short duration and no damage was observed. A walkdown was performed of pipe supports on the affected piping (see Figure 1). Vents and drains were inspected at the welds and heat affected zones for cracks. Also inspected were locations where the piping is routed in close proximity to other commodities i.e., elec/HVAC supports, penetrations, pipe supports, for evidence of damage to pipe or insulation that would indicate excessive movement. No evidence of physical damage or excessive movement was identified.

No physical damage was detected on any pipe support. Parts of supports inaccessible due to insulation of the pipe were not inspected because there was no evidence of damage elsewhere.

Vents and drains in the affected piping were visually inspected. No damage was found. Non-Destructive Examination (NDE) was performed at two locations, one vent and one drain valve, specifically identified by the operators as having the largest displacements (See Figure 3). No damage was found.

V. CORRECTIVE ACTIONS

To prevent recurrence of these events, the following corrective actions are being taken:

1. The applicable procedures for filling the steam generators will be reviewed and revised to include additional guidance to prevent a similar occurrence. This guidance will consist of limitations on feeding with main feedwater unless adequate steam generator pressure exists to assure a subcooled liquid flow at all times. If these conditions do not exist, auxiliary feedwater will be used.

2. Training of the Operators is being performed on the revised procedures.

3. A test will be performed to ensure that filling the steam generators using the revised procedures will not result in hydraulic transients.

All corrective actions will be completed prior to entering Mode 3.

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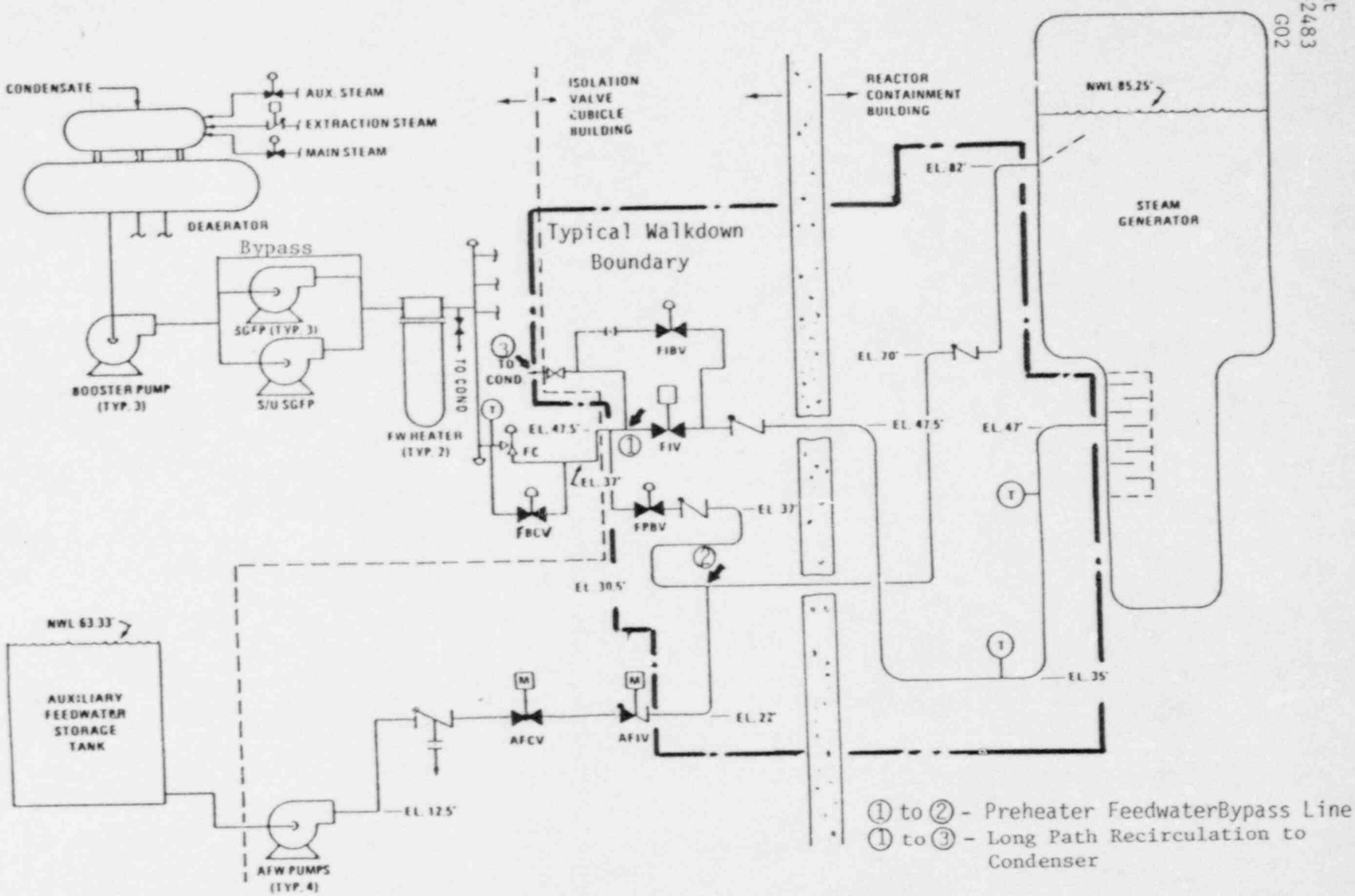


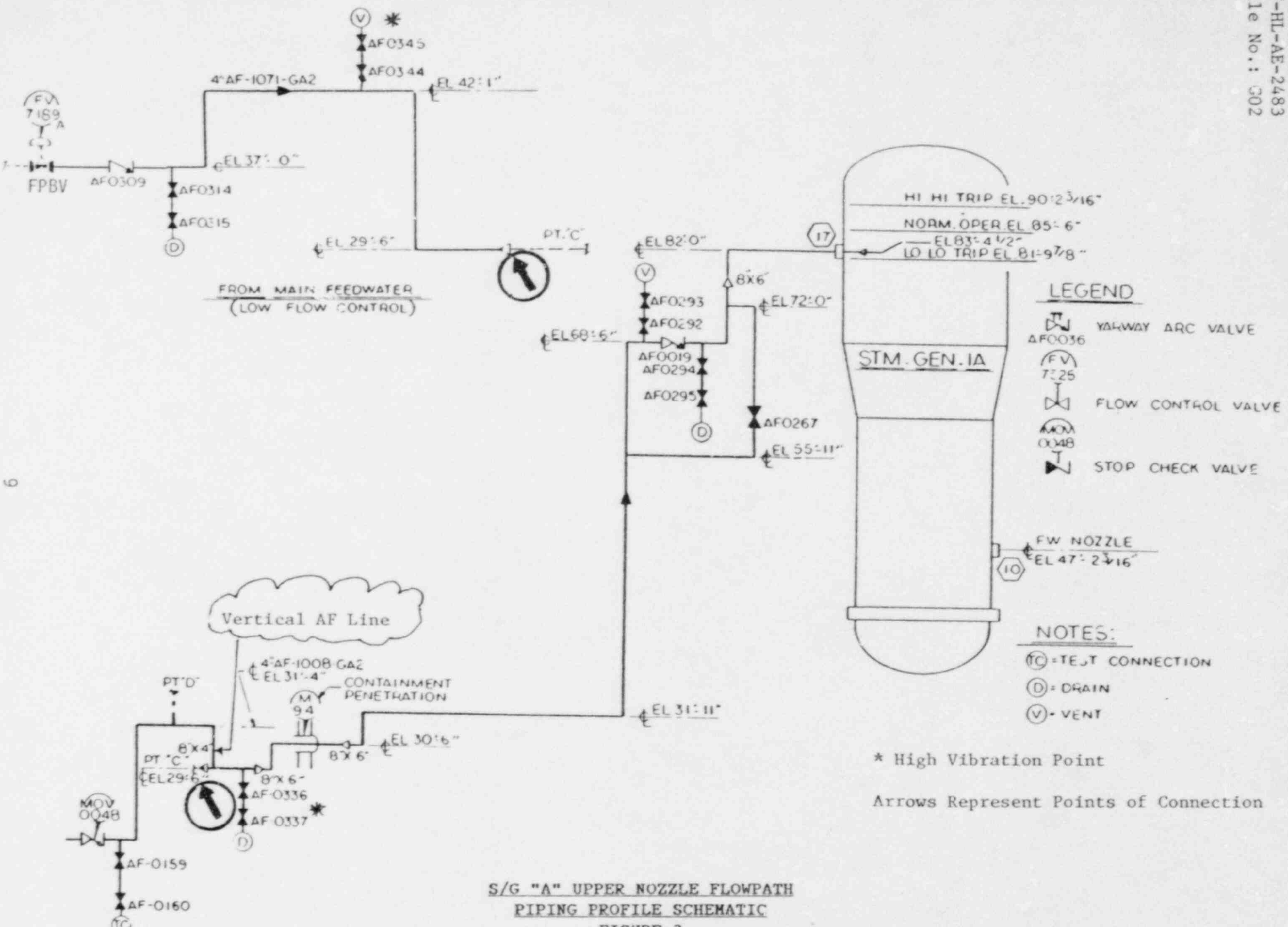
STP FEEDWATER/AUXILIARY FEEDWATER INTERFACE

Figure 1

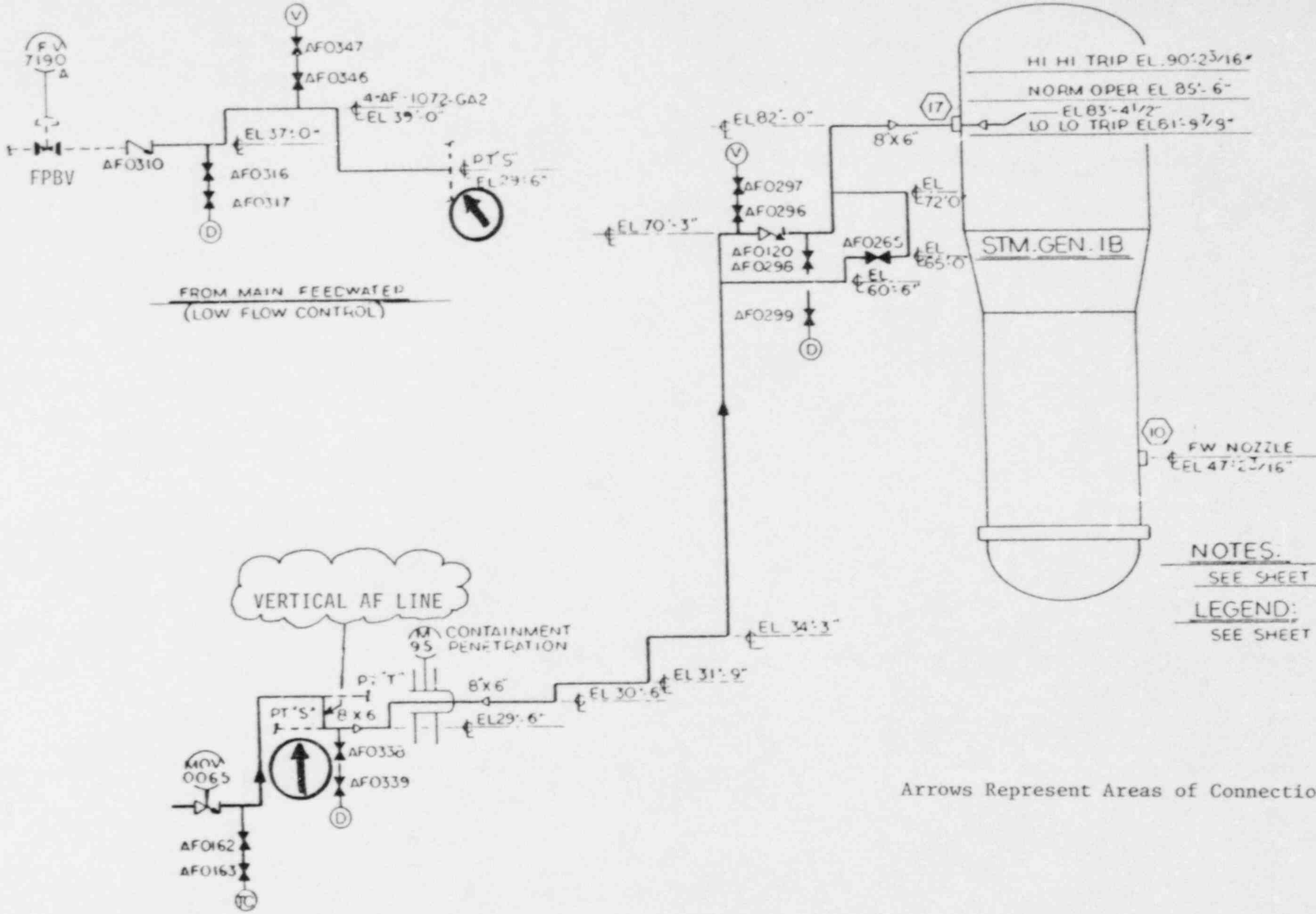
STEAM GENERATOR A	STEAM GENERATOR B	STEAM GENERATOR C	
		FPBV OPEN	
	FPBV OPEN	FEEDING	
	EVENT	FEEDING	1st Transient
	SECURED	FEEDING	
	FPBV OPEN	FEEDING	
FPBV OPEN	FEEDING	FEEDING	
EVENT	FEEDING	FEEDING	2nd Transient
SECURED	SECURED	SECURED	
		FIBV OPEN	
		EVENT	3rd Transient
		SECURED	

SEQUENCE CHART

FIGURE 2

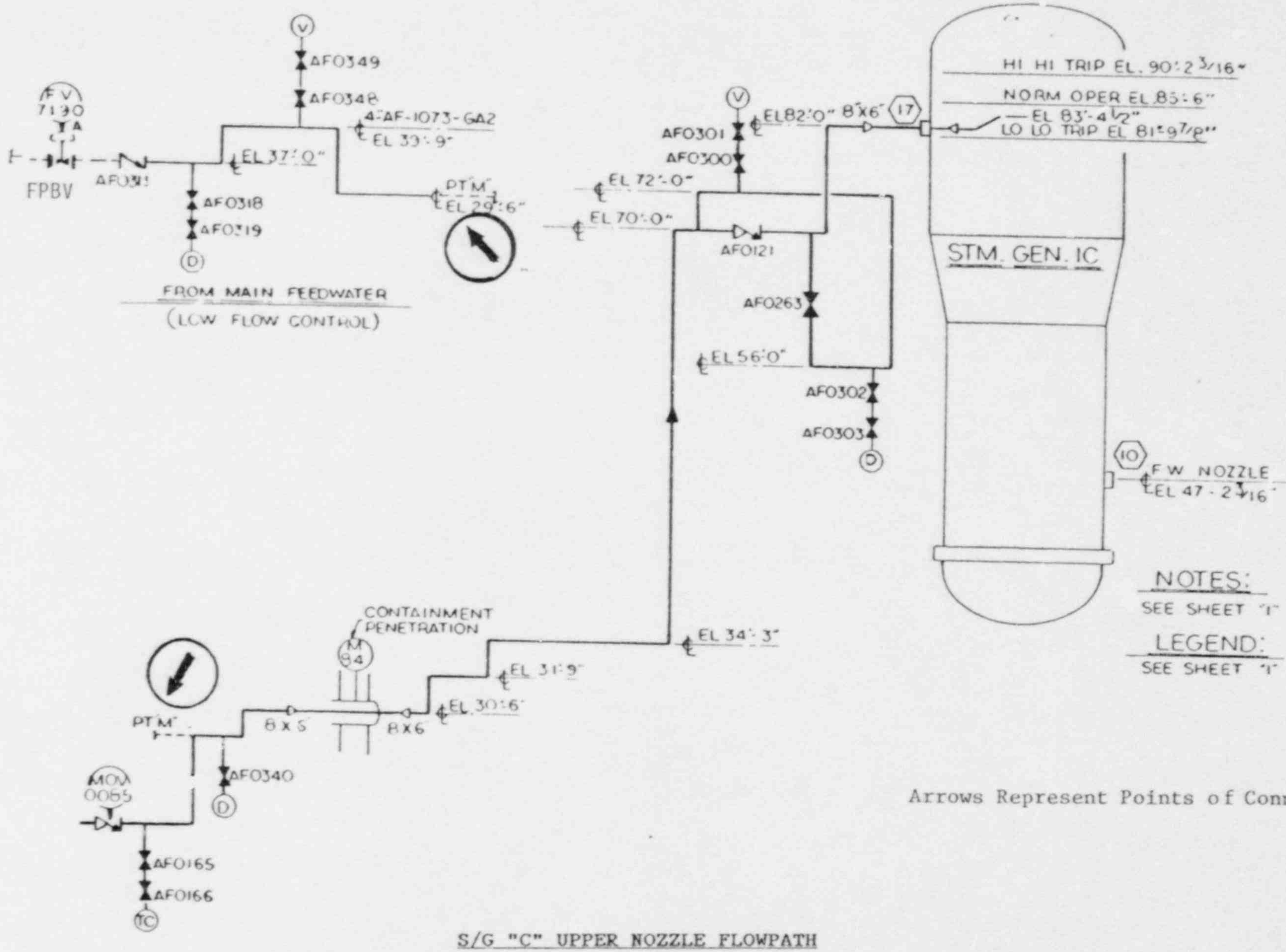


S/G "A" UPPER NOZZLE FLOWPATH
PIPING PROFILE SCHEMATIC
FIGURE 3



Arrows Represent Areas of Connection

S/G "B" UPPER NOZZLE FLOWPATH
PIPING PROFILE SCHEMATIC
FIGURE 4



NOTES:
SEE SHEET "1"

LEGEND:
SEE SHEET "1"

Arrows Represent Points of Connection

S/G "C" UPPER NOZZLE FLOWPATH
PIPING PROFILE SCHEMATIC
FIGURE 5