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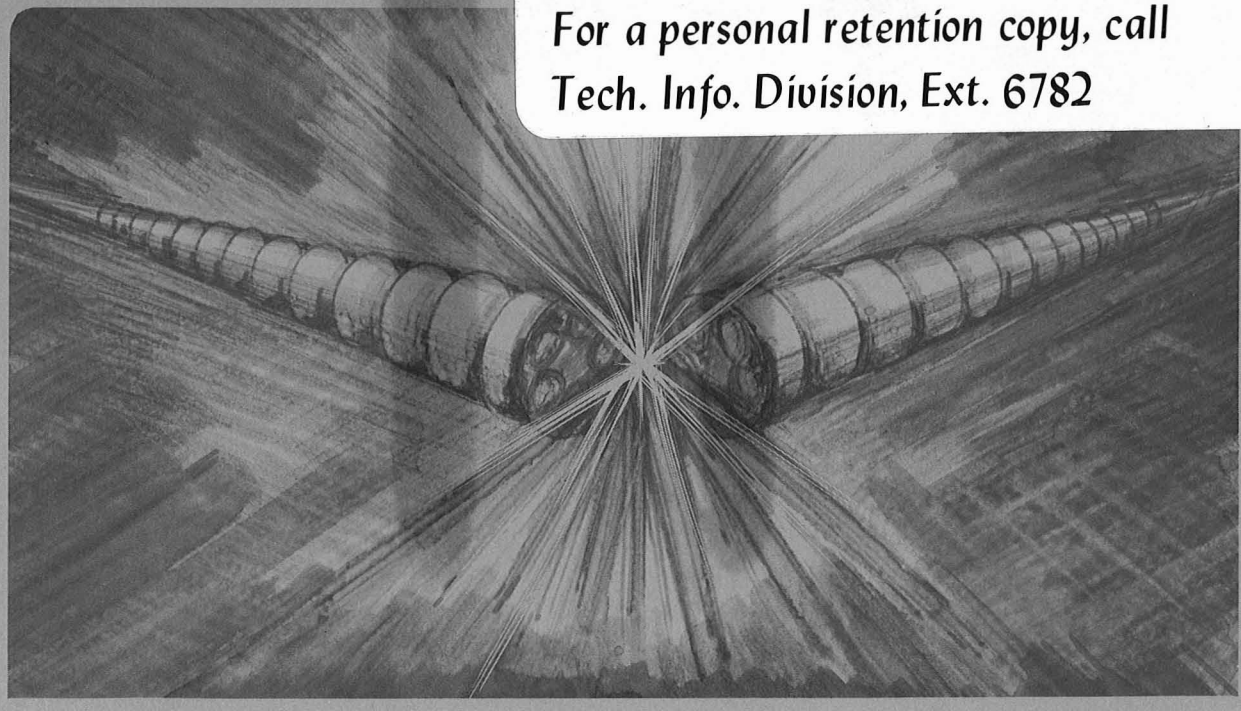

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PULSED COOLING WATER SYSTEMS FOR ACTIVELY COOLED BEAM DUMPS

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Summary

A pulsed water system offers an economically attractive way of supply cooling water for beam dumps, as the water flow and pressure requirements increase. A pilot system was built and used in testing prototype beam dumps. Operating experience gained with the pulsed water system has proved the feasibility of this design.

Introduction

The Neutral Beam Engineering Test Facility (NBETF) is being constructed at the Lawrence Berkeley Laboratory (LBL). The test facility will have the capability of testing 170 KeV, 65 A beams of 30 sec pulse length, operated with a 10% duty factor. Because of the beam energy density and pulse length actively cooled beam dumps have to be used. To get adequate heat transfer, large amounts of cooling water at relatively high pressure is required. The two beam dump designs being presently evaluated require test stand pump capacities of 5200 gpm at 755 psig and 3430 gpm at 380 psig.

For a continuously pumped cooling water system the energy expended by the pump between beam pulses is wasted. This results in high operating costs for such systems, which because of the pulse length and duty cycle cannot be reduced by stopping and restarting the pump. A pulsed water system is an alternate way of meeting the design requirements at a lower total cost. The system consists of a low volume high pressure pump, a high pressure water tank and a high pressure gas accumulator. Nitrogen is used in the gas accumulator. During the beam off time the pump charges the water tank compressing the gas in the accumulator. The compressed gas is then used to drive the water through the beam dumps. In the pulsed water system, a smaller horsepower pump is delivering useful work for almost all of the cycle time, resulting in considerably lower operating costs.

A pilot pulsed water system was built to gain design and operating experience and was used in testing prototype beam dump subpanels for the NBETF.[1] The system was installed for use with neutral beam test stand IIIA at LBL.

System Description

The charge pump operates continuously. The flow is delivered to the charge tank or when the charge tank is full, the pump delivers the flow directly to the dump through the bypass. An orifice in the bypass line keeps the pump outlet pressure above the minimum design pressure.

The flow from the beam dump is delivered to a divided reservoir, where the water from the hot side is circulated through a heat exchanger. The heat is rejected to cooling tower water and the cooled water dumped in the charge pump suction side of the reservoir. The divided reservoir ensures that the charge pump has a supply of cooled water available at all times.

Pressure relief valves and safety interlocks are provided to protect the beam dumps. Fig. 1 shows the charge pump and the high pressure tanks. The system schematic Fig. 2, identifies the various components including the safety interlocks.

The maximum allowable working pressure for the system is 1460 psig.

System Operation

Operation of the system starts with the tank charged to the required pressure and level, and the charge pump delivering flow to the beam dump, through the pump bypass. Valve AV3 is open, AV1 and AV2 are closed. When cooling water is required by the dump, valve AV2 opens and the water is supplied by both the charge tanks and the pump. The flow is controlled by control valves that regulate the inlet and outlet pressure to the beam dump. When the beam is shut off the cooling system cycles back to the start condition. The system is automatic and can be operated remotely from the test stand control room or from the charge tank location.

A detailed valve opening and safety interlock sequence is shown in Fig. 3.

Beam Dumps

The pilot pulsed water system was used in testing the two beam dump subpanel designs now being evaluated. The beam dumps consist of a number of subpanels and the subpanel design parameters are shown in Table I.

Table 1

	UTC	MDAC
Flow - gpm	117.5	57
Inlet pressure - psia	600	235
Outlet pressure - psia	100	120
Max Inlet Temperature - F	109.4	109.4

UTC - United Technology Corp.
MDAC - McDonnell Douglas Astronautics Corp.

Operating Experience

The UTC and MDAC dump subpanels are being tested at the flow rates and pressures shown in Table I.

Fig. 4 shows oscilloscope traces of a UTC dump subpanel test. The traces, starting from the bottom are as follows:

1. P_o - Pressure at the beam dump outlet.
2. P_{in} - Pressure downstream of valve AV2, which is approximately equal to the tank pressure.

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3. F - Flow.

4. AV2 - Valve AV2 stem position.

Fig. 4 shows one complete system cycle starting with opening of valve AV2 at A. From point A to B both the charge tank and the pump are delivering flow to the beam dump. At B valve AV2 closes, AV1 opens and AV3 closes. The pump is now delivering flow only to the charge tank. At C the charging is completed and valve AV3 opens and AV1 closes. The system is now ready for another cycle, the charge tank is fully charged and the pump is delivering flow to the beam dump through the bypass.

The maximum tank pressure at the start of the cycle was 820 psig. The valve AV2 opening time was about 3 seconds and the closing time about 2 seconds.

A pressure transient with a peak pressure of about 200 psia, or about 100 psia above the back pressure can be seen when AV2 is opened. The pressure and flow transients die out in 3 seconds. Pressure transients of about 25 psia above back pressure can also be seen when valve AV2 closes and when the charge pump starts on the bypass mode.

The transients are of such short duration, that they have no adverse effect on the dump operation, since the beam can be timed to start after steady state flow has been reached.

The pump output pressure changes occured smoothly and quietly as the system goes through the cycle. The pump curve is shown in Figure 5. The letters on the curve correspond to the points shown on the oscilloscope trace, Fig. 4, and follow the pump output pressure through one cycle.

During bypass flow the pump outlet pressure is 320 psig. When valve AV2 opens the pump pressure climbs from 320 psig to 860 psig to match the bypass and tank pressures. As the charge tank pressure decreases the pump pressure drops until B, where tank charging starts. The flow time between A and B was about 10 seconds, for longer flow times B would end up at a lower pressure. When the tank is fully charged the pump flow is switched to the bypass line and the pressure drops back to 320 psig.

The pump output pressure change, going from 320 psig to 860 psig occured in less than one second.

Fig. 6 shows the oscillograph traces of a MDAC dump subpanel test. The traces have the same identification as in Fig. 4, with the exception that P_{in} is the pressure at the beam dump inlet.

The pressure in the charge tank of the start of the cycle was 320 psig. The pressure and flow transients were smaller than in the higher pressure UTC test.

The opening and closing time of valve AV2 were 3 seconds and 2 seconds, respectively, the same as in the higher pressure test.

Conclusions

Operating experience gained with the pulsed water system has proved the feasibility of the design. The system met the beam dump cooling requirements and the tests showed that there are no technical reasons why a larger pulsed cooling water system could not be built for the NBETF.

Acknowledgements

This work was supported by the Director, Office of Energy Research, Office of Fusion Energy, Development and Technology Division, of the U.S. Department of Energy under Contract No. W-7405-ENG-48.

References

1. J.A. Paterson, G. Koehler, and R.P. Wells, "The Design of Actively Cooled Beam Dumps for the Neutral Beam Engineering Test Facility," this conference.

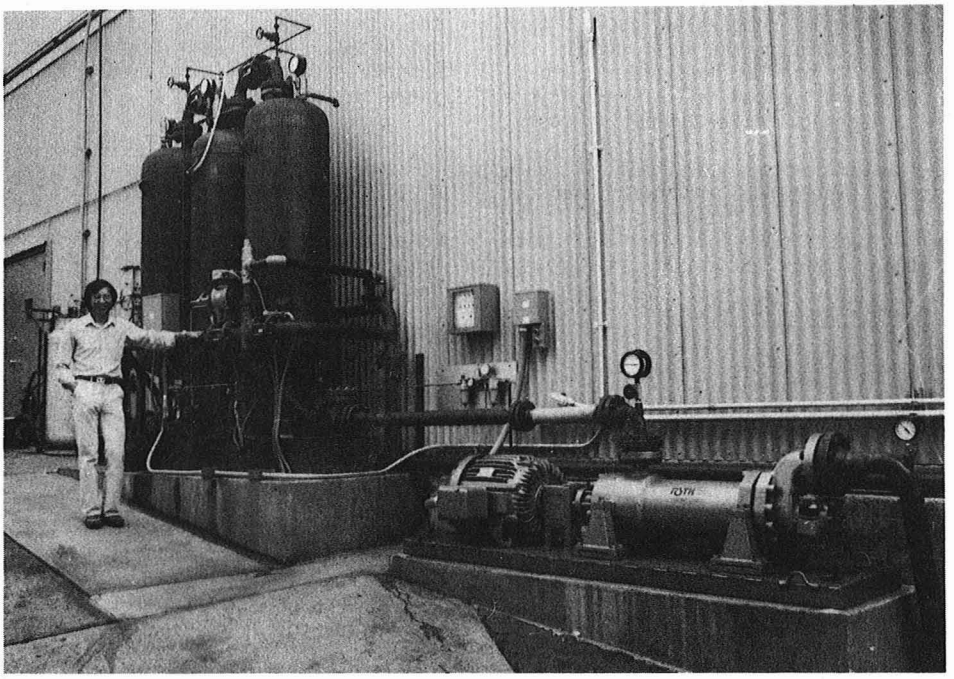

Figure 1: Charge pump, accumulator, and charge tank.

SYMBOL	IDENT.	DESCRIPTION	SERVICE/FUNCT.
	AV1, AV2 AV3	BALL VALVE, 3 FLANGELESS, PNUEMATIC ACTUATED (1500 PSI BETWEEN 600# FLANGES) CARB STL	HI PRESSURE ON-OFF
	MV1, MV2 MV5, MV6	BALL VALVE, 3 FLANGELESS, CARB. STL, 1500 PSI	HI PRESSURE SHUT OFF
	MV3	BALL VALVE, 3 FLANGELESS, STNLS STL 1500 PSI	
	MV21	BALL VALVE, 1 SCR'D, BRONZE	VACUUM PUMP OUT
	MV25, MV26	BALL VALVE, ¾ SCR'D, BRONZE	LOW PRES. DRAIN
	MV4	GATE VALVE, 1½ SCR'D, STNLS, 800#WOG	HI PRES. SHUT OFF
	MV7	GATE VALVE, 3" 600# FLANGE, CARB STL	SUCTION SHUT OFF
	MV2, MV22	GATE VALVE, SCR'D CARB STL 2000#WOG	HI PRES BLOW DOWN
	MV23, MV24	GATE VALVE, 2 SCR'D, BRONZE	LOW PRES. SHUT OFF
	MV8, MV12 MV13, MV17	GLOBE VALVE, 1 SCR'D, CARB STL 2000# WOG	HI PRES. SHUT OFF OR DRAIN
	MV7	GLOBE VALVE, 2 SWEDED, STNLS, 2000#WOG	
	MV10	GLOBE VALVE, ¾ SCR'D, CARB STL, 2000#WOG	
	MV11	GLOBE VALVE, 2" SCR'D, CARB STL, 2000#WOG	
	MV15	GLOBE VALVE, 2" SCR'D, BRONZE, 125#	LOW PRES CONTROL
	MV14 to MV16	GLOBE VALVE, ¾ SCR'D, CARB STL, 2000#WOG	HI PRES. SHUT OFF
		SAFETY RELIEF VALVE, ¾"x1" CARB STL, O RING SEAT, TEXSTEAM #7145COAN	PRESSURE RELIEF
		SAFETY RELIEF VALVE, 2 x 2 CARB STL, O RING SEAT, TEXSTEAM #7165OIAN	
		¼" RELIEF VALVE, O-RING SEAT	PRESSURE RELIEF
	FV1	FOOT VALVE, 3 GALVANIZED	SUCTION
		NORMALLY OPENED VALVES	
		NORMALLY CLOSED VALVES	
	P1 - P19	COMPOUND GAGE 30"-0 150PSI	ALL PRESSURE GAGES AND SWITCHGAGE MAKE MOUNTED WITH SNUBBER
	P2, P4, P5	0-3000 PSI PRES. GAGE, BLOW OFF BACK	
	P7, P8	0-2000 PSI PRES. GAGE, BLOW OFF BACK	
	P10 to P17	0-200 PSI PRES. GAGE	
	P18	0-1000 PSI PRES. GAGE, BLOW OFF BACK	
	P3	0-3000 PSI HI-LOW PRES. SWITCHGAGE	
	P6	0-2000 PSI HI LOW PRES. SWITCHGAGE	
	P9	0-400 PSI HI-LOW PRES. SWITCHGAGE	
	T1 to T6	0-150°C DIAL THERMOMETER, 3" STEM	
	BR1	BACK PRES REGULATOR, 0-200 PSI, CARB. STL, 1"	
	PR1	PRES. CONTROL VALVE, 0-100 PSI CARB. STL, 1"	
	PR6	PRES. REDUCER, 0-75 PSI, BRONZE	

SYMBOL	IDENT.	DESCRIPTION	SERVICE/FUNCT.
	PR2, PR3	PRES. REGULATOR	NITROGEN CYLINDER
	PR4	PRES. REGULATOR	AIR
	PR5	PRES. REGULATOR	GAS
	FM1	FLOW METER, RAMAPO MARK V-3 CF	17-170 GPM
	FM2, FM3	FLOW METER, 2" SCR'D, BRONZE RCM 2"-71-R-100	0-100 GPM
	FS1, FS2, FS3	FLOW SWITCH, PADDLE TYPE, 1" GEMS FS-550	
	LS1	LEVEL CONTROL SWITCH	
	PS1, PS2	PRESSURE SWITCH	
	TS1	TEMPERATURE SWITCH	
	DP1	DIFF. PRES INDICATING SWITCH, ORANGE RESEARCH 1516 DGS-1A-3.5L-13-13, 0-100" H_2O	
	DG1	DIFF. PRES. GAGE, ORANGE RESEARCH 1502 DG-1A-2.5L, 0-25 PSID	
	OL	OIL LUBRICATOR, ⅜"	HOUSE AIR
	FT3	FILTER/SEPARATOR, ⅜"	HOUSE AIR
	FT1, FT2	FILTER, CUNO GALI-44080-S	WATER, LOW PRES.
	ST2	STRAINER, WEAMCO TYPE FV, 3"-600# RF. FLANGE	WATER, HI PRES.
	ST1	Y STRAINER, 3"-600# R.F. FLANGE	WATER, HI PRES.

SYMBOL	IDENT.	DESCRIPTION	SERVICE/FUNCT.
		FLEX HOSE, 2" 600# R.F. FLANGES, STNLS, DOUBLE BRAIDED	HI PRES.
		FLEX HOSE, 1½" SCR'D, STNLS DOUBLE BRAIDED	LOW PRES
		SWING CHECK VALVE, 3"-600# R.F. FLANGES, CARB STL	HI PRES
		SWING CHECK VALVE, 2" SCR'D, BRONZE	LOW PRES
		INLINE CHECK VALVE, ¾" SCR'D, BRASS	HI PRES.
		REDUCER	
		ORIFICE UNION, 1½ OR 2" 3000# CARB STL	HI PRES
		ORIFICE UNION, 2" 3000# STNLS	HI PRES
		UNION, 2", 1", 3000# CARB STL	HI PRES
		UNION, 2", 1½", 1¼", 1", ¾" MALEABLE IRON	LOW PRES.
		UNION, 2" BRONZE	LOW PRES
		NOMINAL PIPE SIZE & FLOW DIRECTION	
		TUBE O.D. & FLOW DIRECTION	
		PRES. TRANSDUCER, MOUNTING ⅜"-24 NF	

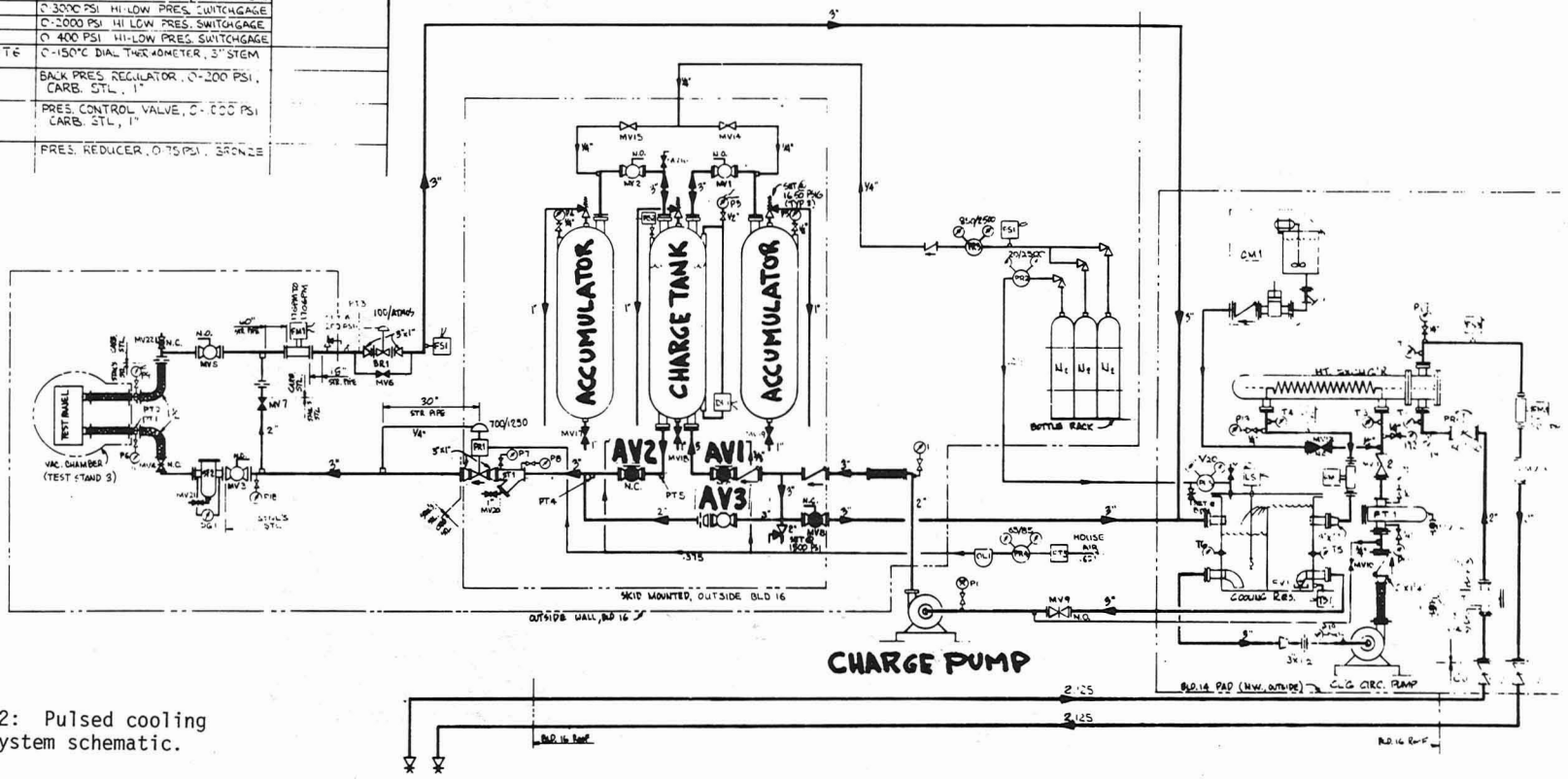

Figure 2: Pulsed cooling water system schematic.

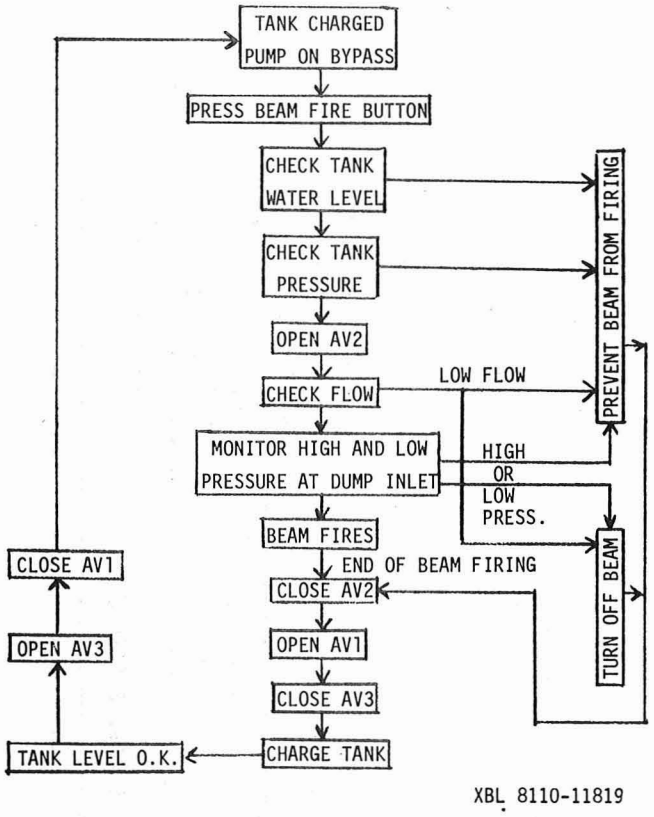

Figure 3: Valve opening and cooling system safety interlock sequence.

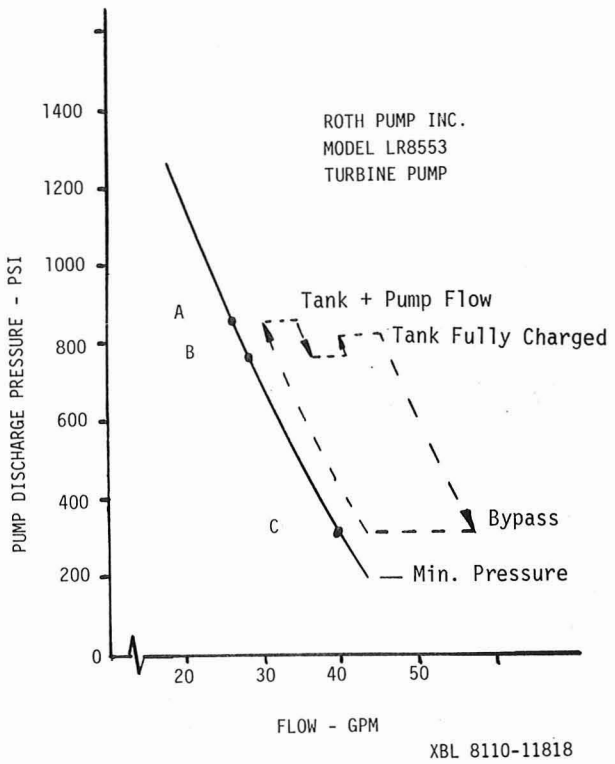

Figure 5: Pump head capacity curve. The dashed lines indicate the pump outlet pressure at various times during a complete cycle.

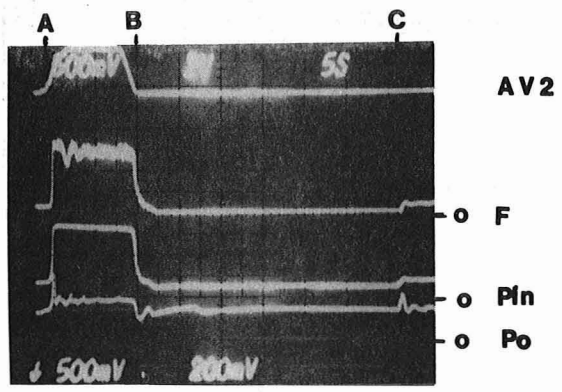

Figure 4: UTC dump subpanel flow test. See text for discussion.

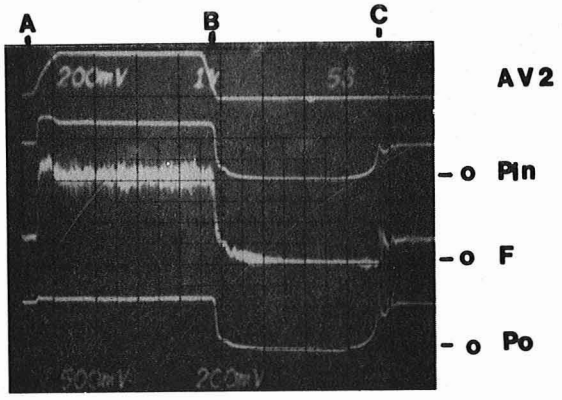

Figure 6: MDAC dump subpanel flow test. See text for discussion.

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