TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

400 Chestnut Street Tower II

September 7, 1979

Director of Nuclear Reactor Regulation
Attention: Mr. L. S. Rubenstein, Acting Chief
Light Water Reactors Branch No. 4
Division of Project Management
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Rubenstein:

In the Matter of the Application of	)	Docket Nos. 50-327
Tennessee Valley Authority	)	50-328

Enclosed is our response to the Reactor Systems Branch question on Net Positive Suction Heat (NPSH) calculations for the ECCS pumps transmitted by your letter to H. G. Parris dated August 23, 1979. This response will be incorporated in Amendment 62 of the Sequoyah Nuclear Plant Final Safety Analysis Report as question 6.63.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills, Manager
Nuclear Regulation and Safety

Enclosure

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ENCLOSURE

6.63 Reactor Systems Branch (212.0)

Provide the following information to resolve the staff's concerns whether sufficient NPSH is available to RHR pumps during a worst-case flow condition:

(a) Show that the kinetic head loss term ($V^2/2g$) has been appropriately factored into the NPSH analysis by identifying that it was included in the pump manufacturer's specification of required flow, or by including it in the calculations provided.

(b) Provide preoperational test results which demonstrate that for a worst-case flow condition flow through the as-built RHR pumps will not exceed that assumed in the analysis (4500 gallons per minute). Include discussion(s)/data interpretation to verify the worst-case flow condition (i.e., address the RHR auxiliary containment spray) from the sump and to confirm that sufficient NPSH is available to the ECCS pumps.

Response

(a) The kinetic head contribution to suction head for the RHR pumps was included in the manufacturers NPSH test curves which were individually determined for each pump.

(b) Refer to the "Revised NPSH Calculations for the RHR and Containment Spray Pumps Operating in the Recirculation Mode" as revised August 23, 1979, to account for RHR flow rate of 5500 gpm (attached).

REVISED NPSH CALCULATIONS FOR THE RHR AND

CONTAINMENT SPRAY PUMPS

OPERATING IN THE RECIRCULATION MODE

REVISED AUGUST 23, 1979

to Account for RHR Flow

Rate of 5500 gpm

Objective

The purpose of these calculations is to confirm that the net position suction head available (NPSHA) exceeds the net positive suction head required (NPSHR) for the residual head removal (RHR) and contained spray system (CSS) pumps under worst case ECCS conditions.

Conditions

1. Physical configuration of piping as per isometric sketch, figure 1,
2. Both RHR and both CSS pumps operating at rated flow (5500 gpm and 4750 gpm respectively),
3. NPSHR for the pumps as per figures 2 and 3,
4. Maximum water temperature 160°F (per FSAR fig 6.2-31),
5. Containment post-LOCA pressure, atmospheric (P = 14.7 psia),
6. Containment flooded to elevation 693'0" (technical specification minimum injection volume and ice melt per FSAR figure 6.2 -3/c).

References

1. "Model Study of the Sequoyah RHR Sump," TVA Report No. WM 28-1-45-102, October 1978.
2. "Flow of Fluids Through Valves, Fittings, and Pipe," Technical Paper No. 410, Crane, 1969.

Calculations

The NPSH is the total suction head (absolute at the impeller eye) minus the vapor head (absolute) of the liquid being pumped.

$$NPSH = h_a - h_{vpa} + h_{st} - h_{fs} \quad (1)$$

where:

h_a = atmospheric head, absolute pressure (in feet of liquid) on the surface of the liquid being pumped.

H_{vpa} = vapor head, the head in feet corresponding to the vapor pressure of liquid at the temperature being pumped.

h_{st} = static head, static height in feet that the liquid supply lebel is above the impeller eye.

h_{fs} = friction head, all suction line losses (in feet) including all sump screen and form losses, and friction losses through pipe, valves, and fittings.

Of these, the atmospheric head is the product of the containment pressure and the specific volume.

$$h_a = 14.7 \times 144(0.01639) = 34.694 \text{ ft.}$$

The vapor head is the product of the saturation pressure at 160°F and the specific volume.

$$h_{vpa} = 4.7414 \times 144(0.01639) = 11.191 \text{ ft.}$$

As defined above, the static head for the RHR pumps is:

$$h_{st} = 693'0'' - 655'7\text{-}1/2'' = 37'4\text{-}1/2''$$

and for the CSS pumps:

$$h_{st} = 693'0'' - 656'0'' = 37'0''$$

The friction head loss is the sum of sump screen and form losses and the pipe, valve, and fitting losses. Of these, the loss through the sump, beginning at, and including the inlet screen and ending at, and including the discharge pipe inlet, may be computed using:

$$h_{sump} = C_L \frac{V2}{2g}$$

where: C_L = the sump loss coefficient as determined in the physical model tests at Norris Engineering Laboratory (Reference 1)

and $\frac{V^2}{2g}$ = the velocity head in the discharge pipe

given $C_L = 0.45$

and an 18" sch 10 outlet pipe

then $V = \frac{\text{flow rate}}{\text{area}} = \frac{(20500)(144)(4)}{(7.48)(60)(3.1416)(17.5)^2} = 13.675$ ft/sec

and $h_{sump} = \frac{(0.45)(13.675)^2}{(2)(32.2)} = 1.306$ ft.

The friction losses for the common piping are greatest in the longer length, W to X in figure 1. Losses in this section computed using reference 2 are:

Straight pipe: 34' of 18" sch 10
42' of 18" sch 40
76' of 18" sch 40 (used for calculations)

Fittings:	LR 90° elbow	(2)	L/D = 20	L = 28(2) = 56'
	LR 50° elbow	(1)	L/D = 12	L = 18'
	Tee - run	(1)	L/D = 20	L = 28'

Total = 120' of 18" sch 40

Valve: fully open gate, L/D = 13 L = 19' of 18" sch 40

Water properties:

$$P = 14.7 \text{ psia}$$
$$T = 160°F$$
$$p = 60.99 \text{ lb/ft}^3$$
$$u = .41 \text{ centipoise}$$
$$Re = \frac{50.6\,Qp}{du} = \frac{50.6\,(5500 + 4750)\,60.99}{16.876\,(0.41)}$$
$$= 4.57 \times 10^6 \quad \text{(fully turbulent)}$$
$$f = 0.0138$$
$$h_{wx} = \frac{0.0311\,fLQ^2}{d^5}$$
$$= 0.0311\,(0.0138)\,\frac{(76 + 102 + 19)\,(10250)}{16.876^5}$$
$$= 6.483 \text{ft.}$$

The friction losses to the RHR pump are greatest in the longest length, B to C in Figure 1. Losses in this section computed using reference 2 are:

Straight pipe: 36' of 14" sch 40

Fittings:	LR 90° elbow	(3)	L/D = 20	L = 22 (3) = 66'
	45° elbow	(1)	L/D = 16	L = 18'
	Tee - run	(1)	L/D = 20	L = 22'

Total = 106' of 14" sch 40

Treat the 18" x 14" reducer as a contraction

$$\frac{d_1}{d_2} = \frac{13.124}{16.876} = 0.78$$

K = 0.15 4D = 12 L = 14'

Water properties: P, T, p, u as above

$$Re = \frac{50.6\,Q\,p}{} = \frac{50.6\,(5500)\,(60.99)}{13.124\,(0.41)}$$
$$= 3.15 \times 10^6 \text{ (turbulent)}$$
$$f = 0.0148$$
$$h_{BC} = \frac{0.0311\,(0.0148)\,(36 + 106 + 14)\,5500^2}{13.124^5}$$
$$= 5.57 \text{ ft}$$

The friction losses to the CSS pumps are greatest in the longest lengt... X to Z in Figure 1. Losses in this section computed using reference 2 are:

12" straight pipe:	41' of 12" sch 40			
12" fittings:	LR 90° elbow	(2)	L/D = 20	L = 2(20) - 40'
	Tee - leg	(1)	L/D = 60	L = 60'
	12" x 20" Reducer (expand)	K = .4	L/D = 30	L = 30'
			Total	130' of 12" sch 40

Valve: fully open gate L/D = 13 L = 13'

Water properties: P, T, p, u as above

$$Re = \frac{50.6\ Qp}{du} = \frac{50.6\ (4750)\ 60.99}{11.938\ (0.41)}$$

$$Re = 2.99 \times 10^6 \text{ (turbulent)}$$

$$f = 0.0144$$

$$h_{xz12"} = \frac{0.0311\ (0.0144)\ (41 + 130 + 13)\ (4750)^2}{11.938^5}$$

$$= 7.67 \text{ ft}$$

20" straight pipe: 25' of 20" sch 20

20" fittings:	LR 90° elbow	(2)	L/D = 20	L = 2(32) = 64'
	20" x 16" reducer K = 0.12		L/D = 10	L = 16'
	20" Tee - run		L/D = 20	L = 32'
			Total	112' of 20" sch 20

Water properties: P, T, p, u as above

$$Re = \frac{50.6\ Qp}{du} = \frac{4750\ (60.99)}{19.25\ (0.41)}$$

$$Re = 1.86 \times 10^6 \text{ (turbulent)}$$

$$f = 0.0158$$

$$H_{xz20"} = \frac{0.0311\ (0.0158)\ (112 + 25)\ (4750)^2}{19.25^5}$$

$$= 0.58 \text{ ft.}$$

$$h_{xz} = H_{xz12"} + h_{xz20"} = 7.67 + 0.58 = 8.25 \text{ ft.}$$

Summary of friction losses in feet:

Item	RHR Pump	CSS Pump
Sump (including screen loss)	1.306	1.06
Common pipe (W to X)	6.483	5.28
RHR Suction pipe (B to C)	5.57	--
CSS Suction Pipe (X to Z)	--	8.25
h_{fs} (total)	13.36	14.59

Therefore, from (1):

$$NPSHA_{RHR} = H_a - h_{vpa} + h_{st} - h_{fs}$$
$$= 34.694 - 11.191 + 37.375 - 13.36$$
$$= 47.376 \text{ ft.}$$

and

$$NPSHA_{CSS} = h_a - h_{vpa} + h_{se} - h_{fs}$$
$$= 34.694 - 11.191 + 37.0 - 14.59$$
$$= 45.913 \text{ ft.}$$

The $NPSHR_{RHR}$ is 34 ft. from Figure 2.

and

The $NPSHR_{CSS}$ is 17.0 ft. from Figure 3.

Conclusion

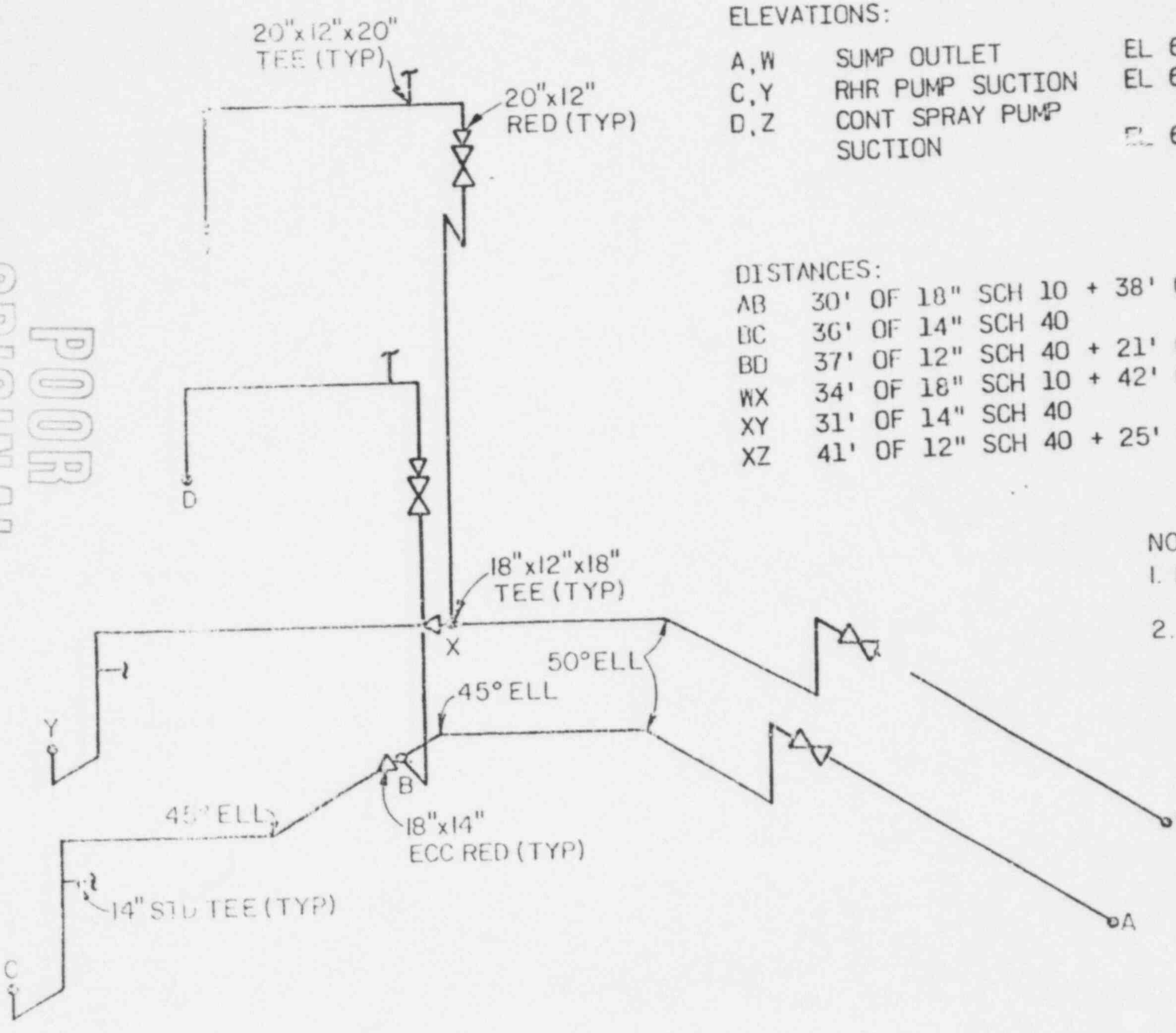
The above calculations show that:

1. The RHR pumps available suction head exceeds the minimum required by at least 13.4 ft.

   $$\text{Excess head}_{RHR} = NPSHA_{RHR} - NPSHR_{RHR} = 47.376 - 34.0$$
   $$= 13.4 \text{ ft.}$$

   The CSS pumps available suction head exceeds the minimum required by at least 28 ft.

   $$\text{Excess head}_{RHR} = NPSHA_{CSS} - NPSHR_{CSS} = 45.913 - 17.0$$
   $$= 28.913 \text{ ft.}$$



ELEVATIONS:

A, W	SUMP OUTLET	EL 669'-8-3/16"
C, Y	RHR PUMP SUCTION	EL 655'-7-1/2"
D, Z	CONT SPRAY PUMP SUCTION	EL 656'-0"

DISTANCES:

AB	30' OF 18" SCH 10 + 38' OF 18" SCH 40
BC	36' OF 14" SCH 40
BD	37' OF 12" SCH 40 + 21' OF 20" SCH 20
WX	34' OF 18" SCH 10 + 42' OF 18" SCH 40
XY	31' OF 14" SCH 40
XZ	41' OF 12" SCH 40 + 25' OF 20" SCH 20

NOTES:

1. ILLUSTRATIVE ONLY, N TO SCALE.
2. ALL BENDS ARE 90° UNLESS OTHERWISE N

FIGURE 1- SUCTION PIPING FROM ECCS SUMP

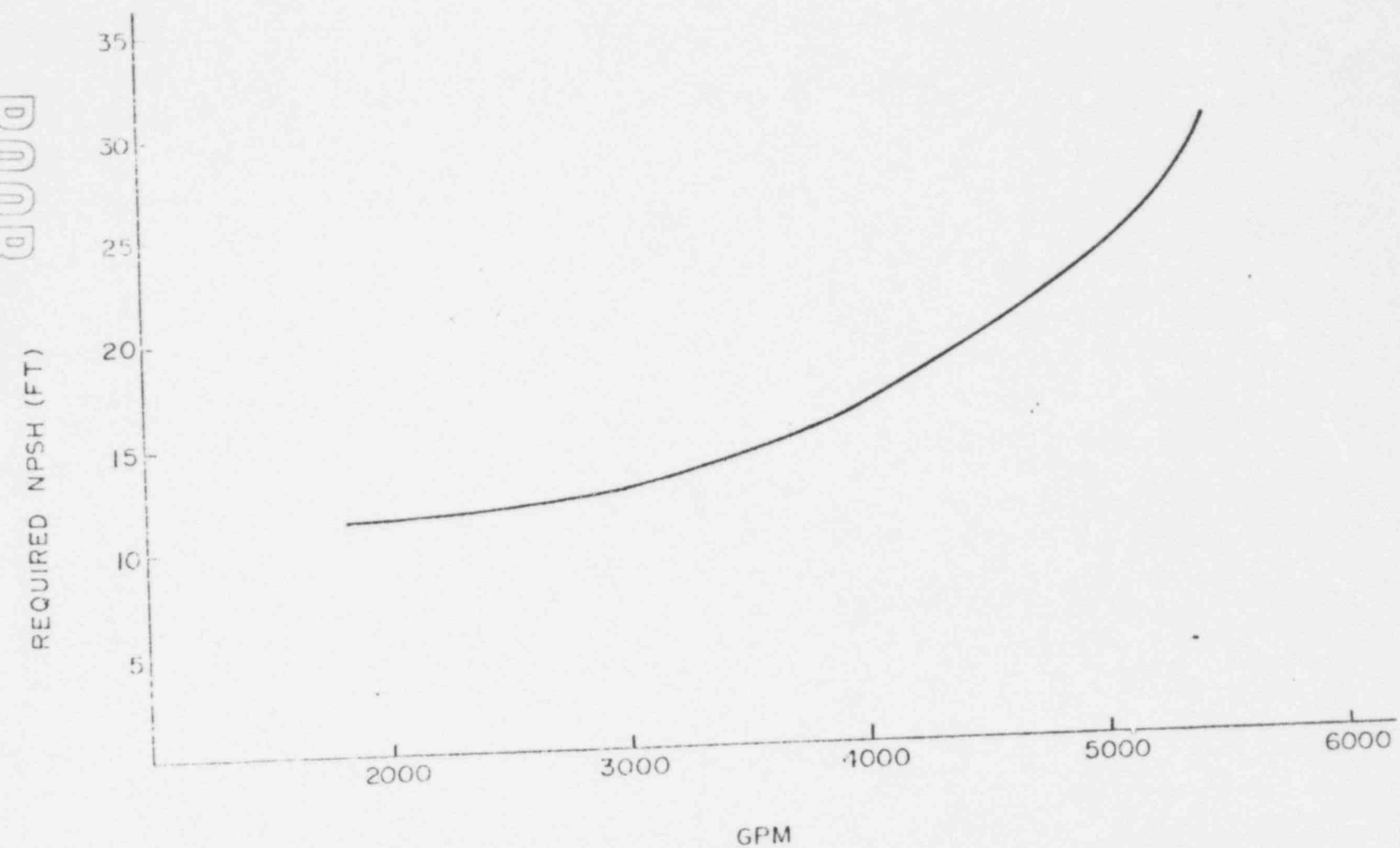


FIGURE 2 - RESIDUAL HEAT REMOVAL PUMP

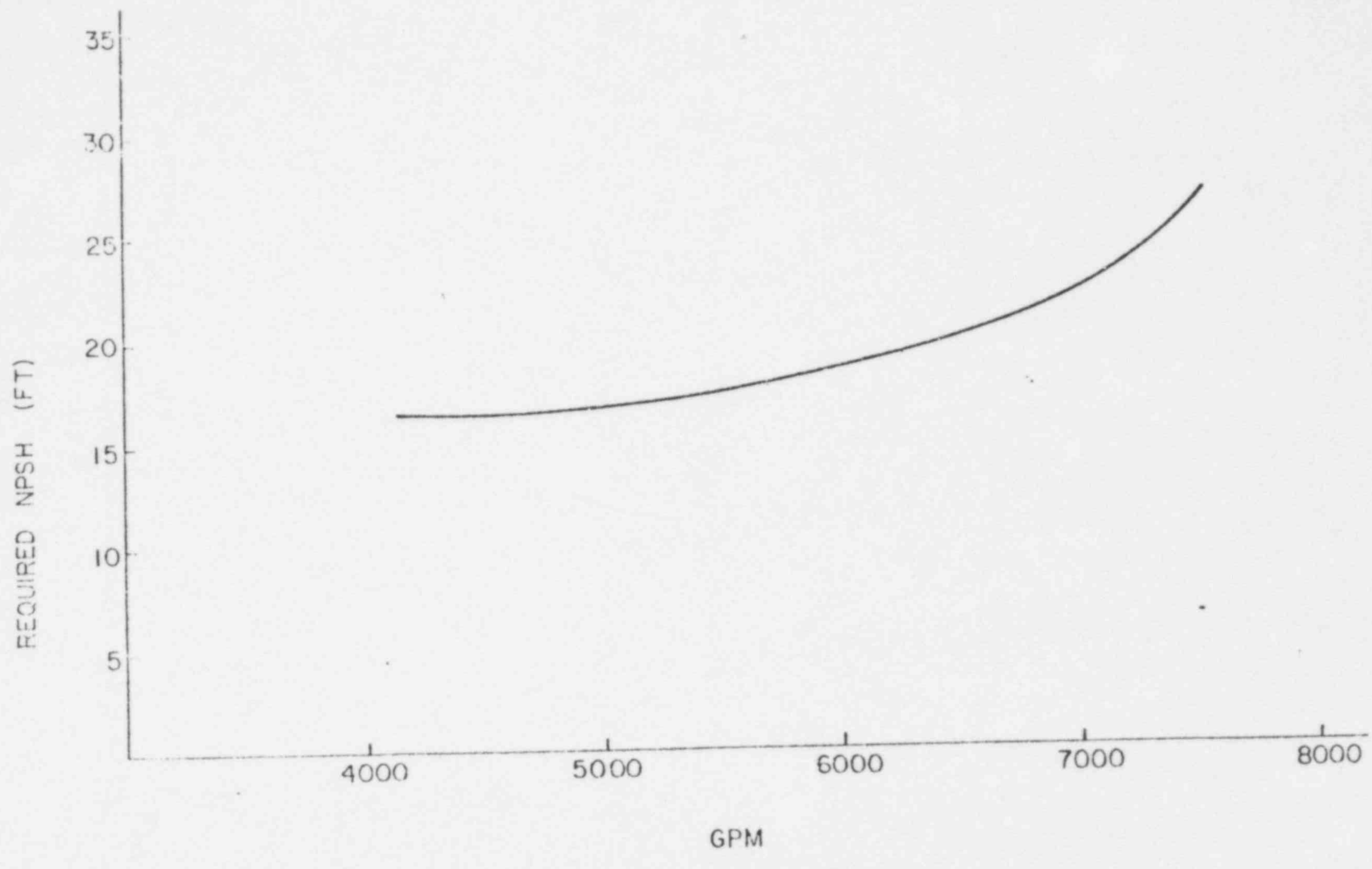


FIGURE 3 - CONTAINMENT SPRAY PUMP