SUBJECT: NPSH - Report of **SULZER BINGHAM PUMP** (previously Bingham Pump Co.)
Pump Sales.Order No. 270417/418
Pump Size: **10 x 12 x 14.5 CVDS**
Monticello (NSP) CORE SPRAY PUMPS

Review and Analysis: by SBP HYDRAULICS GROUP: June 1997 / DLE / RL

Item 1. NPSH - Margin on Curve #26603/604

NPSPr shown on Curve No. 26603/604 represents a 1% Head-Drop per NPSH Test T-270417-A for Pump S.O. 270417. See **CURVE #1**(58374) of this report. Also, on **CURVE #1**(58374) are the NPSHr for 3% and 5% Head-Drop respectively. ALL DATA HAS BEEN NORMALIZED TO 3560 RPM.

Clarification: To clear-up confusion regarding suction specific speed "Nss". (Refer to Sheet No. 3 of calculation cover sheet by Northern States Power Company dated 04-18-97) **Nss** by definition is based on a 3% Head-Drop at the Best Efficiency Point. For a Double-Suction Impeller (**CVDS**-Style Pump) only 50% of this flow is used, since it is analogous to two (2) Single-Suction Impellers in parallel.

$$N_{ss_{3\%}} = \frac{N \bullet \sqrt{Q}}{NPSHr_{3\%}}$$

, where Q = pump flow at B.E.P. and maximum diameter impeller for a single suction impeller. For double suction or double entry impellers use 50% of this flow.

Where:

- $Nss_{3\%}$ = SUCTION SPECIFIC SPEED at 3% Head-Drop, this is a nominal number;
- N = Rotative Speed in Revolution Per Minute(rpm);
- Q = Flow in USGPM at B.E.P. (0.5 Q for double-suction or double-entry impellers);
- $NPSHr_{3\%}$= **N**et **P**ositive **S**uction **H**ead required in feet based on 3% Head-Drop at B.E.P.

FOR THE "TESTED" MONTICELLO CORE SPRAY PUMPS, $NSS_{3\%}$ IS:

$$N_{ss_{3\%}} = \frac{3560 \bullet \sqrt{4250/2}}{26.2^{0.75}} \cong 14170$$

, Note: This value is calculated on an actual test data *and is not the design Nss*, which will be a different value based on the B.E.P. @ maximum diameter. Also this value has no tolerance and is subject to variance between pumping units, due to manufacturing processes. See values from **CURVE #1**(58374). The design Nss would < 14000 based on maximum diameter and including manufacturing and testing tolerances.

Comment: By current standards, this is considered a "High-Nss" impeller design. Pumps of this design have a limited "*perferred operating range*" outside of which increased vibration and internal re-circulation may take place. **CURVE #1**(58374) also identifies the recommended "continuous minimum flow" (greater than (2) two hours operation at this flow in a 24 hour-period). A second, intermittent, minimum flow is also identified. *These values*

were agreed on after the pumps were installed. Minimum flow values are based on Ns and $Nss_{3\%}$. The $Nss_{3\%}$ value of ≈14,000 along with a Ns of ≈1300 for the pump, and a head value of 615 ft were used to determine the "*minimum flow(s)*"

Pump Specific Speed is approximately:

$$N_{s_{impeller}} \approx \frac{N \bullet \sqrt{Q/2}}{H_{stage}^{\;0.75}} = \frac{3560 \bullet \sqrt{4250/2}}{615^{0.75}} \approx 1330,$$

Note: This is not at B.E.P. and maximum diameter impeller, but calculated from the "trimmed" performance curve. Some references use Ns_{pump} , which would increase the above value by a factor of 1.414 or the square root of 2 since the pump is a double suction design. The values for "*minimum flow*", in %, are taken from SBPI Standard E31.68 and are guidelines used by **SULZER BINGHAM** in establishing a recommended minimum flow.

Item 2. and 3.: NPSHa vs. Flow - Review of Cavitation Report 12 x 14 x 14.5 CVDS, Pump S.O. 270425 dated May 15 & 16, 1969

- On Pump S.O. 270417 [10 x 12 x 14.5 CVDS] a NPSH Test (T-270417-A) was performed. This test identifies NPSHr based on 0%, 1%, 3% and 5% Head-Drop in the range of 4000 to 5300 GPM. The point of head collapse was not established. This is not required for a NPSHr Test. A Cavitation Test is used to establish these values and is a much longer and demanding test to conduct.

- The Impeller in the 12 x 14 x 14.5 CVDS per S.O. 270419/426 are identical (except Trim-Diameter) to the one in S.O. 270417/418, namely pattern #1213 CVDS-1.

- The NPSHr tests base on 3% Head-Drop performed on S.O. 270425[12 x 14 x 14.5 CVDS] and S.O. 270417[10 x 12 x 14.5 CVDS] are identical in the flow regime of 4000 - 5300 GPM. On **Curve #2**(58375) the $NPSHr_{3\%}$ values have been added in dotted line from T-270425-2 in the flow ranges of 3500 to 4000 GPM and 5300 to 6000 GPM.

- On Pump S.O. 270425[12 x 14 x 14.5 CVDS] a Cavitation Test was performed. This test was conducted on May 15 and 16 of 1969. Based on these tests the NPSHa at points of head collapse have been added on **Curve #2**(58375).

- It can be stated that the CORE SPRAY pumps for MONTICELLO (Pump S.O. 270417/418) will have the same NPSHr performance and the same expected cavitation flow performance as Pump S.O. 270425, since they are of identical impeller design (same pattern) and show identical $NPSHr_{3\%}$ performances between 4000 and 5300 GPM. *It is not possible to plot pump flow vs. NPSHa, from initial value down to 20 feet, in one foot increments.* Insufficient number of NPSHr data points were taken during referenced tests to demonstrate this. In addition no NPSHr - data below 4000 GPM and no Cavitation Test data below 4000 GPM are available.

Curve #3(58376), generated from T-270417-A and T-270425-2 provides sufficient data to predict what will be happening to the pump when reduced NPSHa is encountered.

4. ***Item 3 is applicable to the MONTICELLO CORE SPRAY PUMPS***

It has been confirmed that the Core Spray Pumps S.O. 270417/418[10 x 12 x 14.5 CVDS] are hydraulically identical (same impeller pattern, same volute area, except trim diameter and pump nozzle sizes) to the residual heat removal(RHR) pumps S.O. 270419/426[12 x 14 x 14.5 CVDS]. There will be some minor performance differences due to the size of the suction and discharge nozzles.

The requested material comparison shows that both services use impellers made from ASTM A296 Gr. CA-15 (now replaced by ASTM A743 Gr. CA6NM). Both alloys have greater than 11% chrome with the CA6NM(13-4) being the easier grade to perform weld repair on.

Pump S.O. 270425 went through extensive cavitation testing for several hours without visible damage to the impeller, it can be surmised that Pump S.O. 270417/418 will experience similar wear to the impeller when operated for 10 minutes (following a LOCA) at NPSHa values 0.5 feet above head collapse value shown on **Curve #2**(58375) and **Curve #3**(58376).

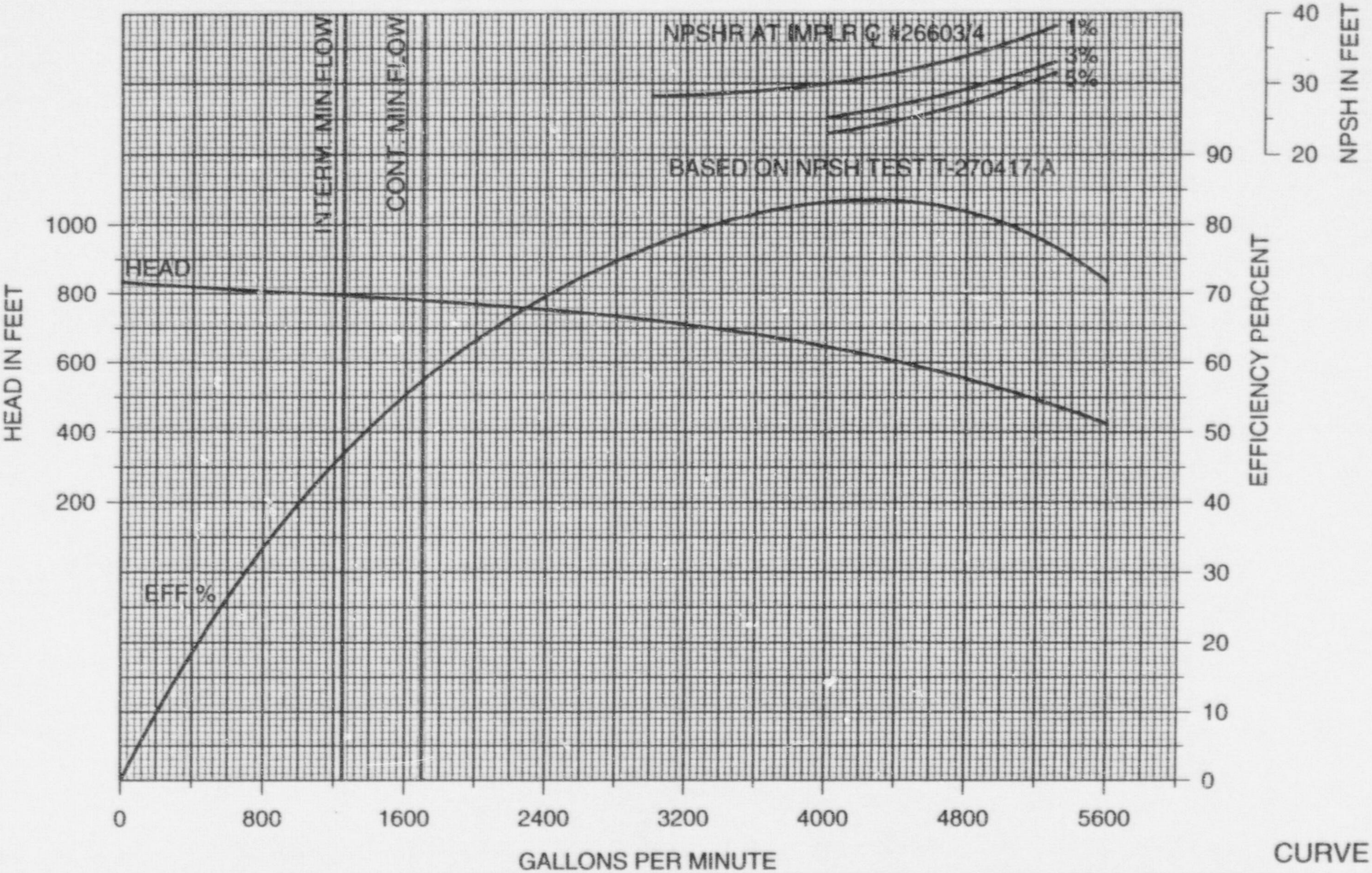
Additional Comments:

Despite the fact that the suction specific speed(Nss), based on tested 3% Head-Drop [$Nss_{3\%} \approx 14170$], is high by current standards it should not imply that when properly applied these designs are "bad". However, it should be inferred you must know the recommended operating parameters and ranges in which they should be used and the duration of these periods. It is possible to design a new impeller with a higher $Nss_{3\%}$ (larger eye-dia, flatter suction vane angle of eye, well-rounded suction vane inlet profile with reduced thickness) However, the minimum flow values would be increased over those shown on **CURVE #1**(58374).

In addition, the double-suction impeller would be designed with "staggered" pumping vane configuration to reduce pulsation-and vibration levels (this is important for pumps running at the higher rpm's). *There will be no measureable impact on the suction side of the impeller for this feature.* The "net" impeller width at O.D. would be decreased to stay with proper side-wall clearance to the volute, the vane discharge angle would be increased to stay with the same impeller outlet-area.

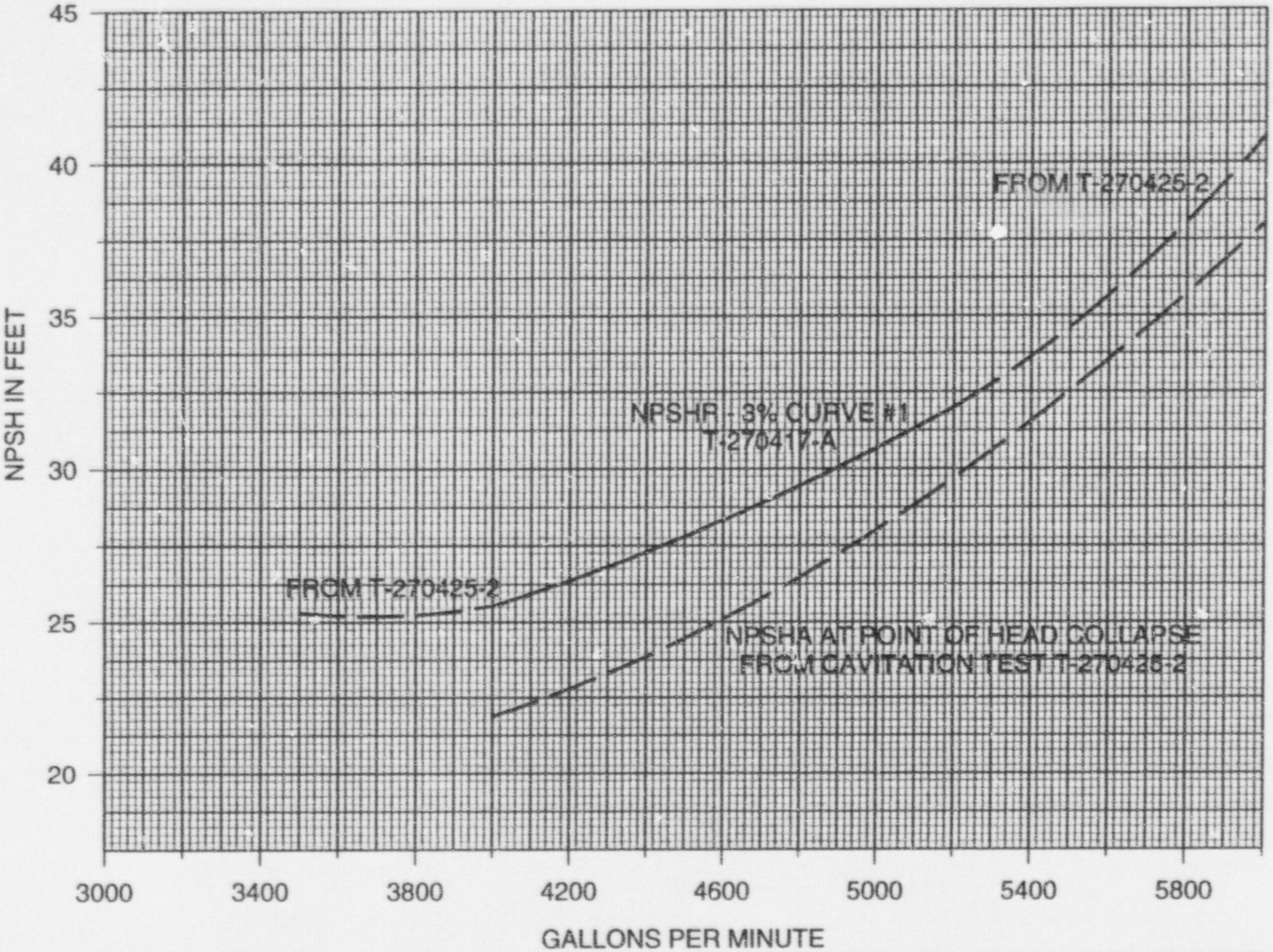
A slower pump speed, 1760 rpm, would reduce the NPSHr values, however the impeller diameter would need to be approximately double the current size to meet the same hydraulic conditions. This poses some interesting mechanical problems as well as potential hydraulic problems when operating a low flows.

58374



CURVE #1

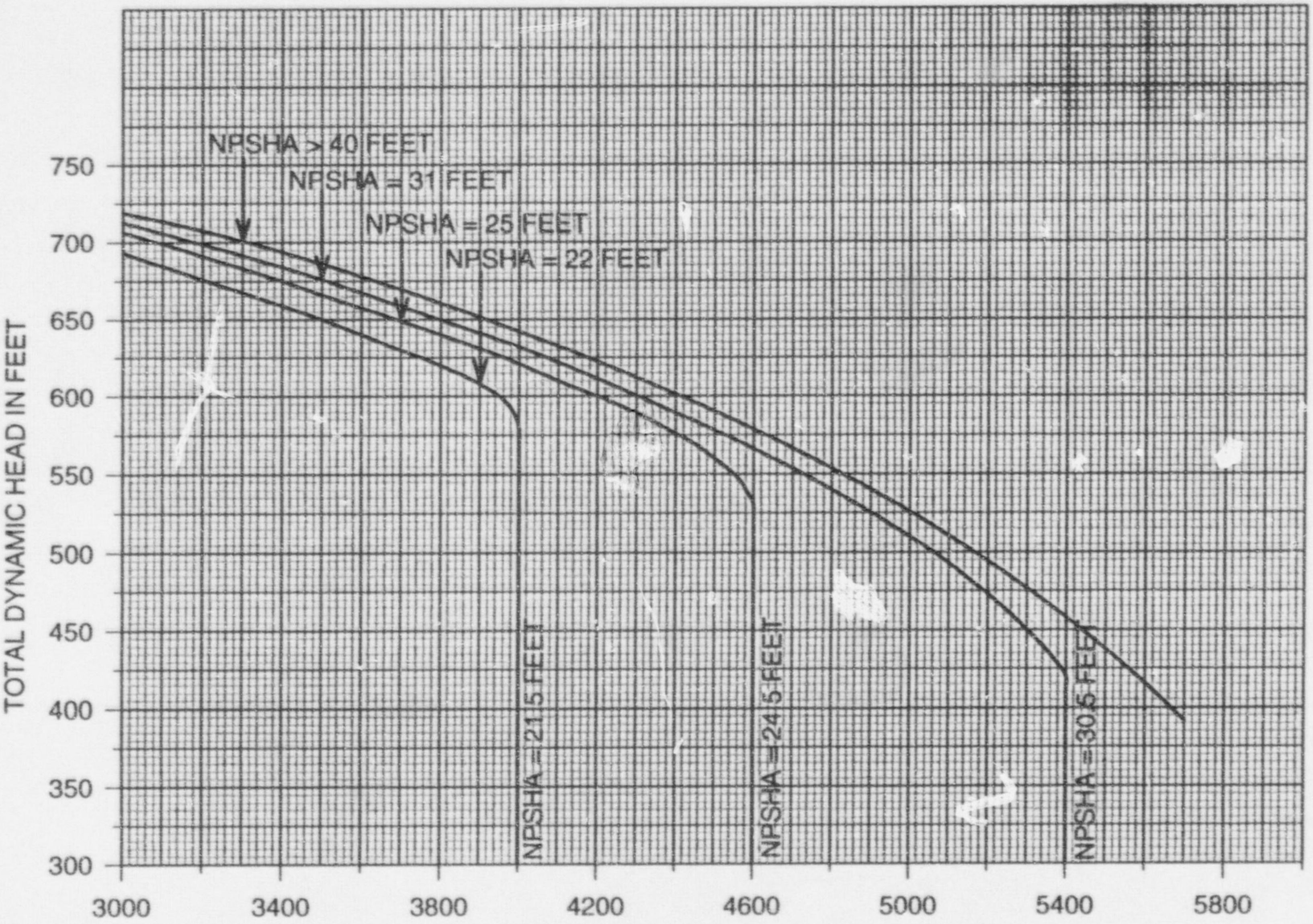
GENERAL ELECTRIC CO. MONTICELLO (NSP) CORE SPRAY PUMP 14-1 PUMP NO: 270417/418	SULZER PUMPS F97-10626-KT FEB 18-JUN-97	IMPELLER MAX DIA 14.50"	10 X 12 X 14.5 CVDS		
			DIA IMPELLER 13.69"	IMPELLER PATT 1213 CVDS-1	3560 RPM
		EYE AREA SQ IN 72.2	REFERENCE 26603/604		CURVE NO. 58374
					REV



CURVE #2

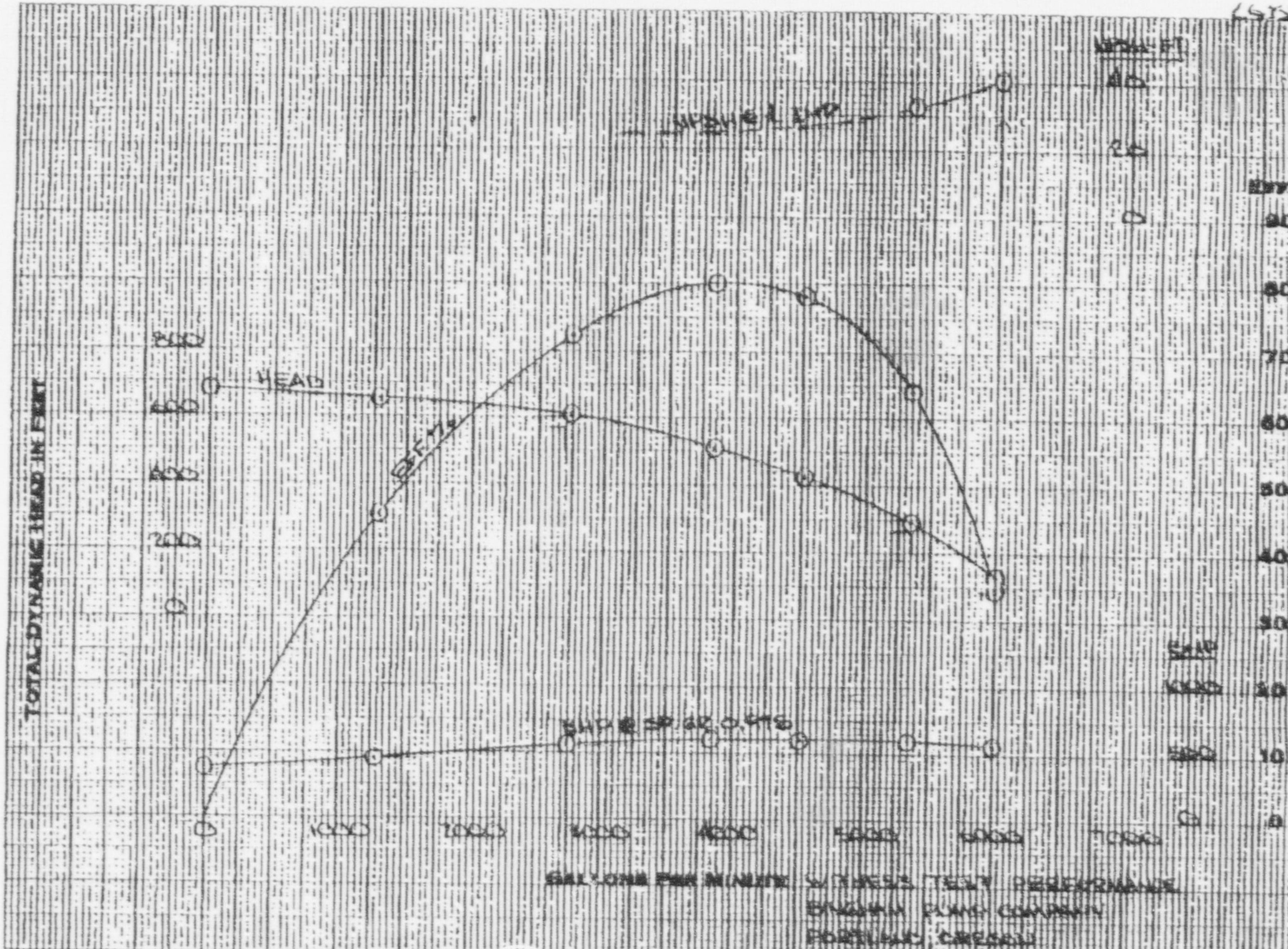
GENERAL ELECTRIC CO. MONTICELLO (NSP) CORE SPRAY PUMP 14-1 PUMP NO: 270417/418	SULZER PUMPS F97-10626-KT FEB 18-JUN-97	IMPELLER MAX DIA 14.50"	10 X 12 X 14.5 CVDS			
			DIA IMPELLER 13.69"	IMPELLER PATT 1213 CVDS-1	3560 RPM	
		EYE AREA SQ IN 72.2	REFERENCE 270417/270425		CURVE NO. 58375	REV

58376



CURVE #3

GENERAL ELECTRIC CO. MONTICELLO (NSP) CORE SPRAY PUMP 14-1 PUMP NO: 270417/418	SULZER PUMPS F97-10626-KT FEB 1? JUN-97	IMPELLER MAX DIA 14.50"	10 X 12 X 14.5 CVDS			
			DIA IMPELLER 13.69"	IMPELLER PATT 1213 CVDS-1	3560 RPM	
		EYE AREA SQ IN 72.2	REFERENCE 270417/270425		CURVE NO. 58376	REV



GENERAL ELECTRIC CO. APED COMMONWEALTH EDISON CO. QUAD CITIES, RES. HEAT REMOVAL ITEM 1002 PUMP NO. 270425	CHARACTERISTIC CURVE SHEET BINGHAM PUMP CO. PORTLAND OREGON	IMPELLER MAX. DIA. 14 1/2 MIN. DIA. EYE AREA 72.2 SQ. IN.	12 x 14 x 14 1/2 CVDS PUMP DIA. IMPELLER 12 1/16 N.P.S.H. REQUIRED	IMPELLER PATT. 1213CVDS-1 REFERENCE
				3560 R.P.M. CURVE No. 26895

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