

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 "N_{ss}". (Refer to Sheet No. 3 of calculation cover sheet by Northern States Power Company dated 04-18-97) **N_{ss}** 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.

$$N_{ss_{3\%}} = \frac{N \cdot \sqrt{Q}}{NPSH_{r_{3\%}}}, \text{ where } Q = \text{pump flow at B.E.P. and maximum diameter impeller for a}$$

single suction impeller. For double suction or double entry impellers use 50% of this flow.

Where:

- **N_{ss_{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);
- **NPSH_{r_{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, **N_{ss_{3\%}}** IS:

$$N_{ss_{3\%}} = \frac{3560 \cdot \sqrt{4250/2}}{26.2^{0.75}} \cong 14170, \text{ Note: This value is calculated on an actual test}$$

data and is not the design N_{ss}, 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 N_{ss} would < 14000 based on maximum diameter and including manufacturing and testing tolerances.

Comment: By current standards, this is considered a "High-N_{ss}" 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 N_s and $N_{ss_{3\%}}$. The $N_{ss_{3\%}}$ value of $\approx 14,000$ along with a N_s 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:

$$N_{\text{Impeller}} \approx \frac{N \cdot \sqrt{Q/2}}{H_{\text{stage}}^{0.75}} = \frac{3560 \cdot \sqrt{4250/2}}{615^{0.75}} \approx 1330,$$

Note: This is not at B.E.P. and maximum diameter impeller, but calculated from the "trimmed" performance curve. Some references use $N_{s_{\text{pump}}}$, 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.

<p style="text-align: center;">SUZLER BINGHAM PUMP HYDRAULIC REPORT: 12.5.487 - NPSHR 10 x 12 x 14.5 CVDS PUMPS FOR NORTHERN STATES POWER</p>	<p>Ref: E9710626.DOC TECHNICAL REPORT June 23, 1997</p>	<p>Page 03</p>
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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.

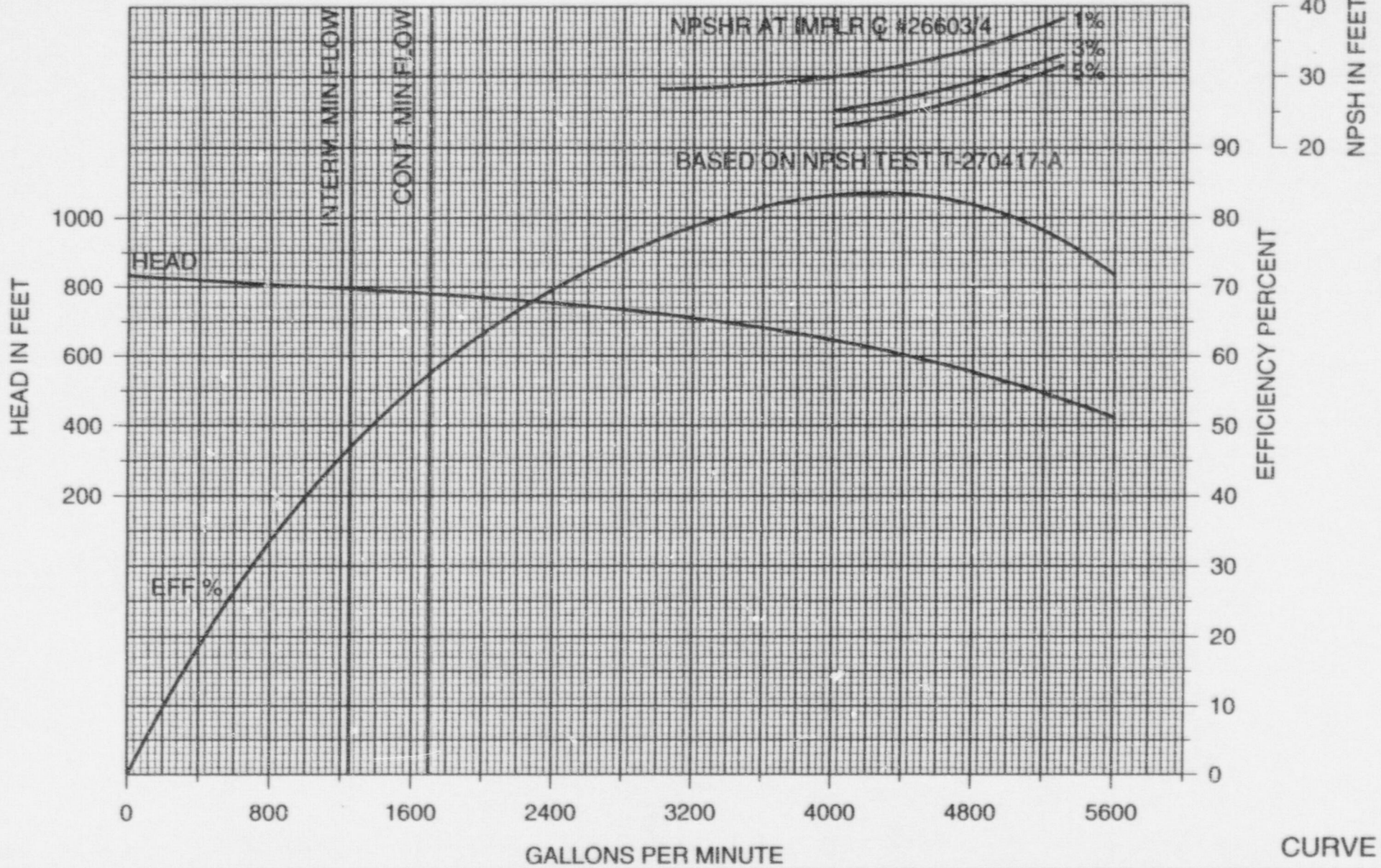
Pump S.O. 270425 went through extensive cavitation testing for several hours without visible damage to the impeller, it can be surmised that Pump S.O. 270417/418 will experience similar wear to the impeller when operated for 10 minutes (following a LOCA) at NPSHa values 0.5 feet above head collapse value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

Additional Comments:

Despite the fact that the suction specific speed(N_{ss}), based on tested 3% Head-Drop [$N_{ss_{3\%}} \approx 14170$], 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 $N_{ss_{3\%}}$ (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.



GENERAL ELECTRIC CO.
 MONTICELLO (NSP)
 CORE SPRAY PUMP 14-1
 PUMP NO: 270417/418



F97-10626-KT FEB 18-JUN-97

IMPELLER
 MAX DIA
 14.50"

EYE AREA SQ IN
 72.2

10 X 12 X 14.5 CVDS

DIA IMPELLER
 13.69"

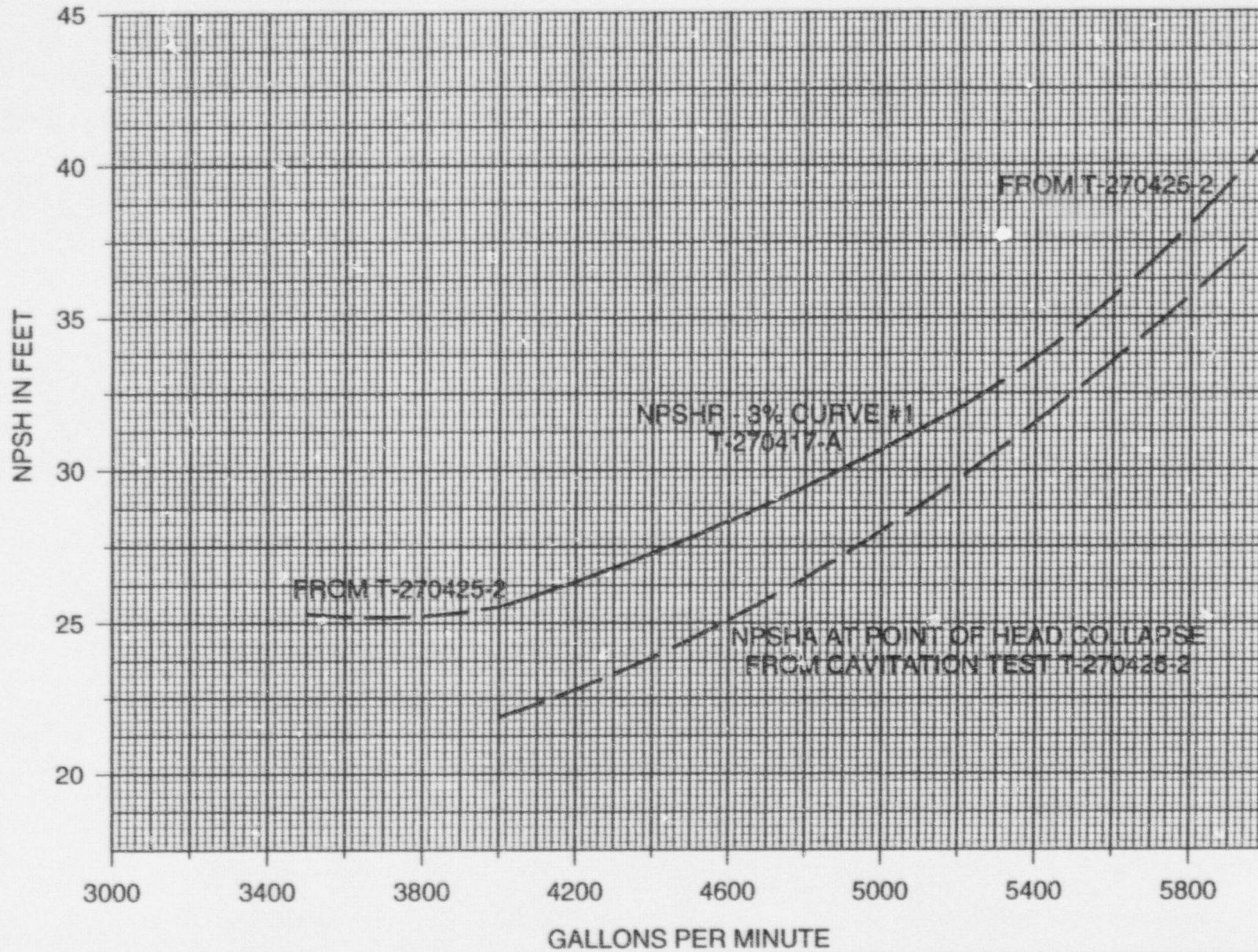
REFERENCE
 26603/604

IMPELLER PATT
 1213 CVDS-1

3560 RPM

CURVE NO.
 58374

REV



CURVE #2

GENERAL ELECTRIC CO.
 MONTICELLO (NSP)
 CORE SPRAY PUMP 14-1
 PUMP NO: 270417/418



F97-10626-KT FEB 18-JUN-97

IMPELLER
 MAX DIA
 14.50"

EYE AREA SQ IN
 72.2

10 X 12 X 14.5 CVDS

DIA IMPELLER
 13.69"

REFERENCE
 270417/270425

IMPELLER PATT
 1213 CVDS-1

3560 RPM

CURVE NO.
 58375

REV

GENERAL ELECTRIC CO.
 MONTICELLO (NSP)
 CORE SPRAY PUMP 14-1
 PUMP NO: 270417/418



F97-10626-KT FEB 19 JUN-97

IMPELLER
 MAX DIA
 14.50"
 EYE AREA SQ IN
 72.2

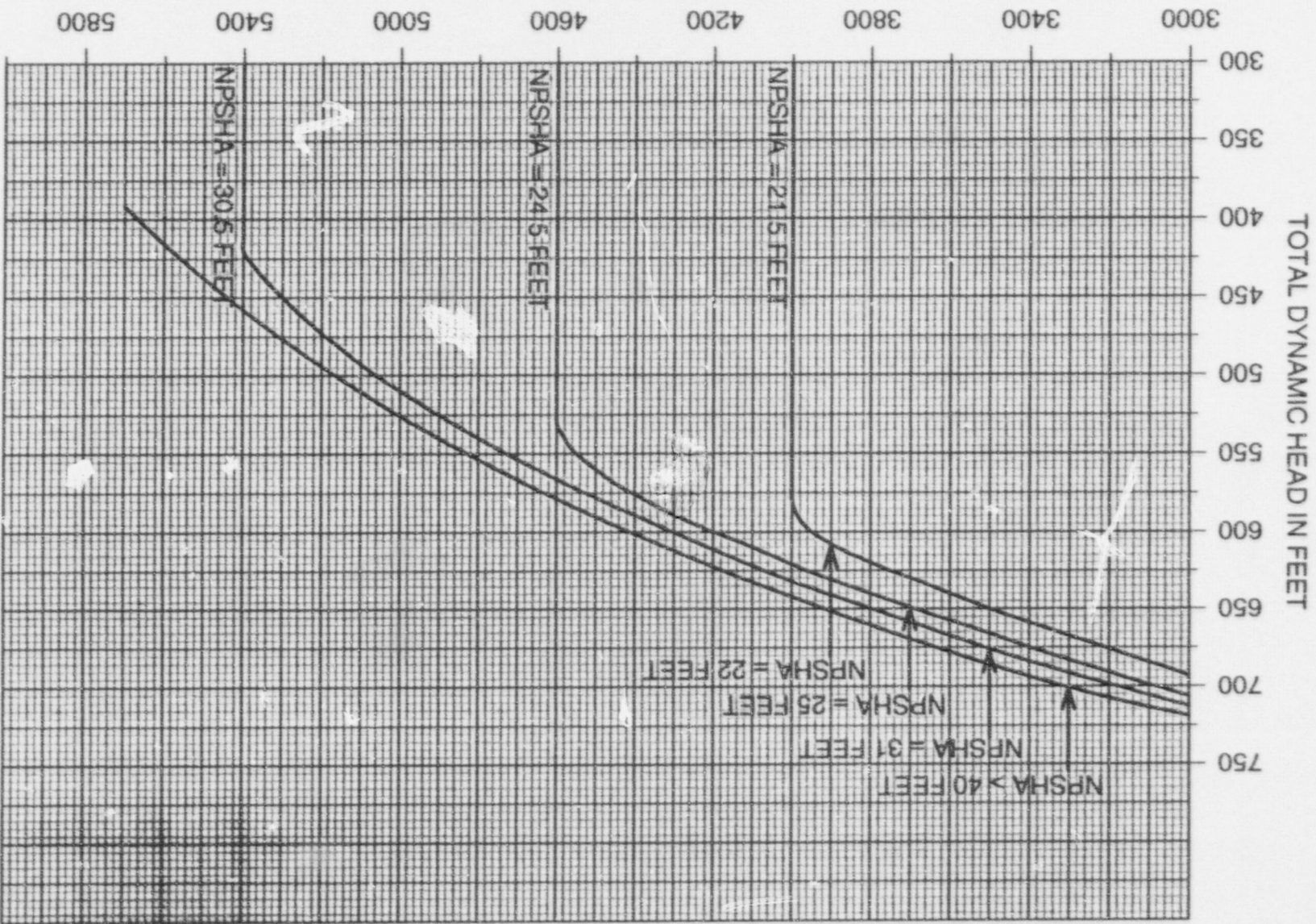
DIA IMPELLER
 13.69"
 REFERENCE
 270417/270425

IMPELLER PATT
 1213 CVDS-1

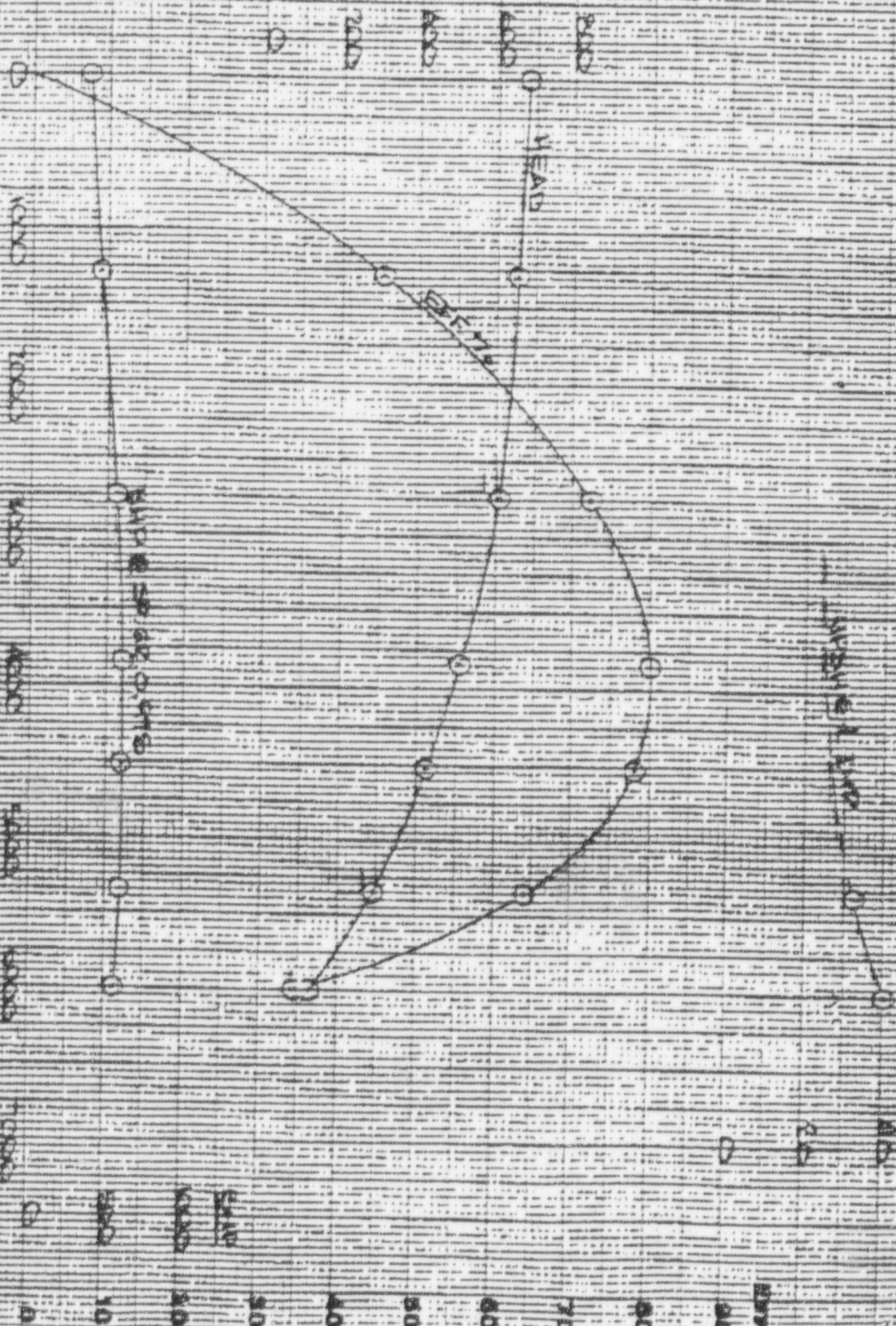
3560 RPM
 CURVE NO.
 58376

10 X 12 X 14.5 CVDS

CURVE #3



TOTAL DYNAMIC HEAD IN FEET



GENERAL ELECTRIC CO. APED
COMMON WEALTH EDISON CO.
QUAD CITIES, RES. HEAT REMOVA
ITEM 1002 PUMP NO. 270425

CHARACTERISTIC CURVE SHEET
BINGHAM PUMP CO.
PORTLAND OREGON

MAX. DIA. 14 1/2
DIA. 12 1/2
SVE 72.2
AREA

12 x 14 x 14 1/2 CVD5 PUMP
123CVD5-1 REFERENCE
3560R.P.M.
26895