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1962

Status reports of research project on improving design of a hopper dredge pump, January-July 1962

J. B. Herbich

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CIVIL ENGINEERING DEPARTMENT

FRITZ ENGINEERING LABORATORY

HYDRAULICS DIVISION

Memorandum No. M-32

STATUS REPORT OF RESEARCH PROJECT

ON

IMPROVING DESIGN OF A HOPPER DREDGE PUMP

Prepared by

John B. Herbich

Prepared for

U.S. Army Engineer District, Philadelphia

Corps of Engineers

Philadelphia 29, Pennsylvania

Contract No. DA-36-109-CIVENG-59-112

January 1962

Bethlehem, Pennsylvania

F.L. Report No. 277.34.1

STATUS REPORT OF RESEARCH PROJECT

ON

IMPROVING DESIGN OF A HOPPER DREDGE PUMP

I. INTRODUCTION

The following report summarizes the studies per-
formed during the months of November and December 1961,
at the Hydraulics Division of Fritz Engineéring Labora-
tory, under terms of Contract No. DA-36-109-CIVENG-59-112.
Earlier work was described in Status Reports dated:
December 1958(1)*, February 1959, April 1959, June 1959,
December 1959, February 1960, March 1960, April 1960,
May 1960, June 1960, July 1960, August 1960, Septem-
ber 1960, October 1960, November 1960, December 1960,
February 1961, March 1961, April 1961, May 1961, July
1961, August 1961, October 1961, and Project Reports
dated September 1959 and September 1961.

II. EXPERIMENTAL STUDIES

A. General Comments

The detailed analysis of the performance of the
pump under the variety of conditions investigated under
phases 2 and 3 is under way as part of phase 4 of the
project.

- -

* Numbers in parentheses indicate References

B. Discussion of Results

   1. Effect of Vane Shape

   (a) Comparison of efficiencies between a plain arc
and an involute curve (constant flow = 1000gpm, all speeds,
entrance angle 45°, exit angle 35°).

Density (g/1)	Plain Arc (No. 1)	Involute Curve (TD-8)	Increase in Efficiency
1000	73.2	79.0	5.8
1170	72.1	78.9	6.7
1240	69.4	78.5	9.1
1320	67.8	77.4	9.6
1380	72.1	76.2	4.1

   As shown above, the involute curve is consider-
ably more efficient than the plain arc, particularly for
densities of 1240 and 1320 g/1.

   (b) Comparison of efficiencies between a logarith-
mic spiral and an involute curve (constant flow = 1000
gpm, all speeds, entrance angle 45°, exit angle 28°45').

Density g/1	Logarith-mic Spiral (TD-5)	Involute Curve (TD-6)	Increase in Efficiency
1000	82.9	82.4	-0.5
1170	78.9	80.9	1.0
1240	80.4	79.2	-1.2
1320	78.8	78.8	0
1380	77.1	77.9	0.8

There is very little difference in efficiency between a logarithmic spiral and an involute curve.

2. Effect of Exit Angle

The effect of vane exit angle on efficiency for various values of fluid density are shown in Figure 1. It appears that the maximum efficiency was between 22-1/2° and 28° 45' for densities of 1000 and 1170 g/l, and close to 22-1/2° for other densities.

There is a possibility that the maximum efficiency might occur for lower exit angle, particularly for densities of 1240, 1320, and 1380 g/l. An additional series of tests of an impeller with 16-1/2° exit angle and 45° entrance angle, and an involute shape would, no doubt, clear up this point. Additional funds, however, would be required to study this question.

C. Volute Studies

Further analysis of data is planned; it appears that the volute casing should be re-designed and the clearance between the volute tongue and the impeller reduced from the present 16 inches in the prototype by one-third, to about 11 inches. A word is being awaited from the sponsor's representatives whether this reduction is feasible from the operational standpoint.

X. High-Speed Movies

Several high-speed movies were taken of flow in the 4-1/2 inch plexiglas section of the suction pipe. One-eighth inch diameter plastic balls were introduced into the flow. The movies indicate some pre-rotation in the pipe, particularly at high rates of flow. Detailed analysis is being planned, and additional movies will be taken after the high-speed camera is returned from the repair shop.

X. Project Report No. 33

Twenty-five copies of the complete report on Phases 2 and 3 of the dredge pump investigation have been submitted to the sponsor late in December 1961.

R E F E R E N C E S

(1) Herbich, J.B.   STATUS REPORT OF RESEARCH PROJECT ON
        et al   IMPROVING DESIGN OF A HOPPER DREDGE
                      PUMP. Fritz Engineering Laboratory
                         Memoranda No. M-1 to M-6, M-8 to
                         M-15, M-17, M-19 to M-22, M-24,
                         M-26 to M-28, M-31
                              Lehigh University, 1958-1961

(2) Herbich, J.B.   CHARACTERISTICS OF A MODEL DREDGE PUMP
                         Fritz Engineering Laboratory Report
                         No. 277-P.R. 31,
                           Lehigh University, 110 pages
                                          September 1959

(3) Herbich, J.B.   EFFECT OF IMPELLER DESIGN CHANGES ON
    Vallentine, H.R.   CHARACTERISTICS OF A MODEL DREDGE
                      PUMP
                         Fritz Engineering Laboratory Report
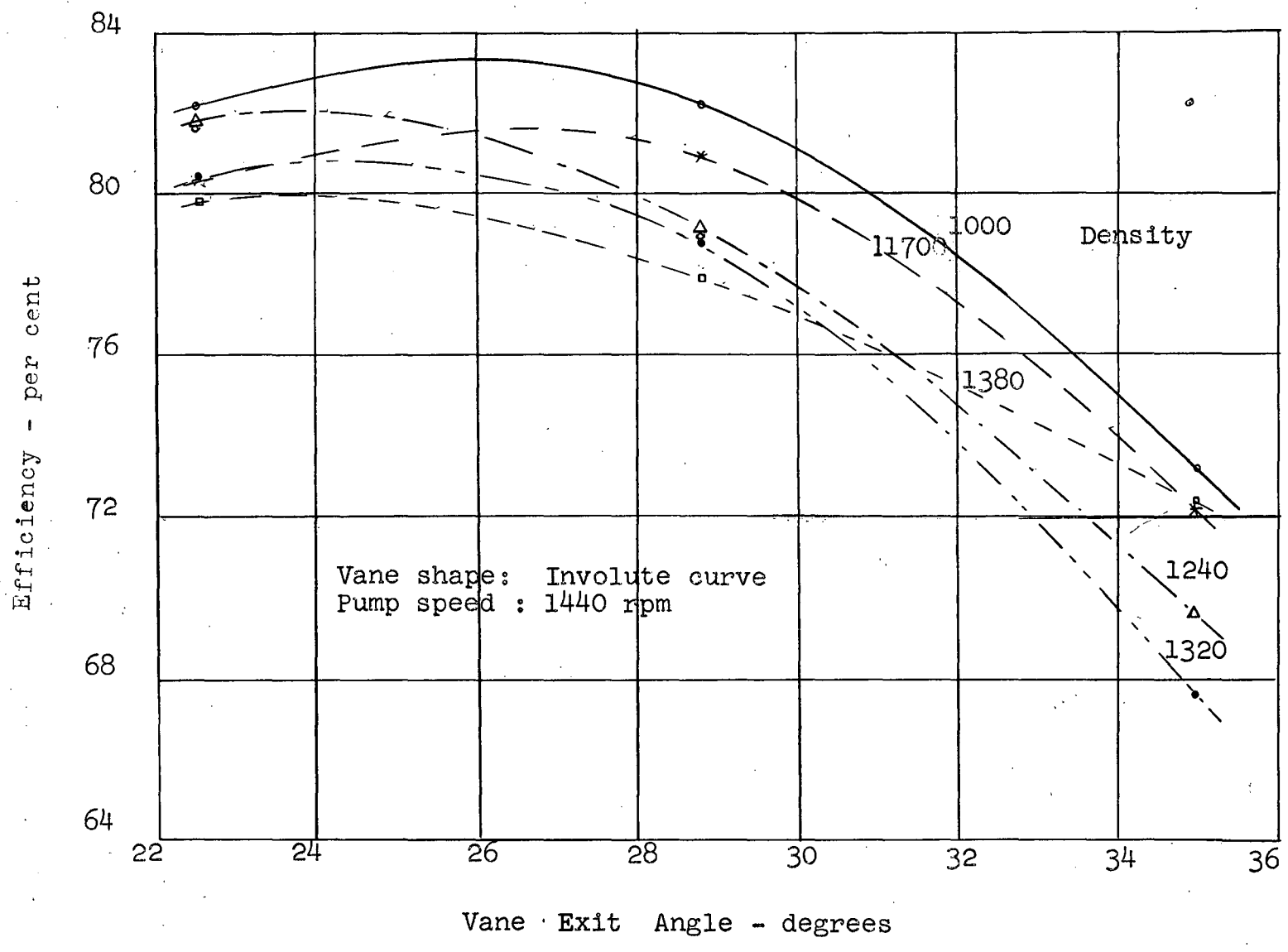   No. 277-P.R. 33,
                           Lehigh University, 207 pages
                                          September 1961

Fig. 1   Effect of vane exit angle on pump efficiency

CIVIL ENGINEERING DEPARTMENT

FRITZ ENGINEERING LABORATORY

HYDRAULICS DIVISION

Memorandum No. M-33

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ON

IMPROVING DESIGN OF A HOPPER DREDGE PUMP

Prepared by

John B. Herbich

Prepared for

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Philadelphia 29, Pennsylvania

Contract No. DA-36-109-CIVENG-59-112

March 1962

Bethlehem, Pennsylvania

F.L. Report No. 277.34.2

STATUS REPORT OF RESEARCH PROJECT

ON

IMPROVING DESIGN OF A HOPPER DREDGE PUMP

I.   INTRODUCTION

The following report summarizes the studies per-
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ber 1960,   October 1960,   November 1960,   December 1960,
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Project Reports dated September 1959 and September 1961.

II.   EXPERIMENTAL STUDIES

A. General Comments

The detailed analysis of the performance of the
pump under the variety of conditions investigated under
phases 2 and 3 is under way as part of phase 4 of the
project.

- -

* See References for complete listing

B. <u>Discussion of Results</u>

    1. Effect of Exit Angle

     The effect of vane exit angle on efficiency for a number of densities, constant model flow of 1000 gpm, and constant model speed of 1440 rpm, was presented in Memorandum No. M-32. Additional plots for model speeds of 1150, 1300, 1550, 1650, and 1760 rpm, and for two model discharges of 800 and 1000 gpm were prepared.

    In general, the maximum efficiencies for flow of 1000 gpm were obtained at vane exit angle of 22-1/2° for the majority of fluid densities and all speeds with the exception of 1150 rpm. The data for 800 gpm for the same speeds and densities tend to substantiate the conclusions drawn from the exit angle-efficiency curves for 1000 gpm. A typical curve tends to show that the most efficient exit angle may be below 22-1/2°.
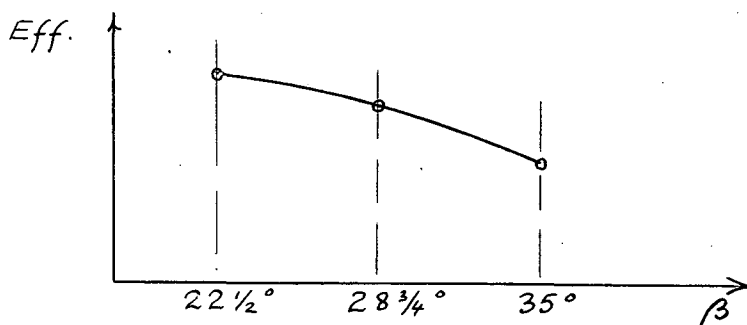

    The data also indicates that:

(a) Efficiency decreases as fluid density increases

(b) Higher efficiencies were obtained at 1000 gpm, as compared with 800 gpm, as was expected

(c) Since there is a possibility that the most efficient
exit angle may be below 22-1/2°, it is recommended
that an additional series of tests with an impell-
er having a 16-1/2° exit angle will be authorized.

C. Clearance Tests

One of the criteria of selecting a dredge pump im-
peller is the amount of clearance it has to permit passage
of large objects through the pump.

(a) The first approach to this problem was to measure
the smallest width between the impeller vanes on
a two-dimensional drawing of an impeller. A sketch
herewith shows the approximate location of this
dimension.
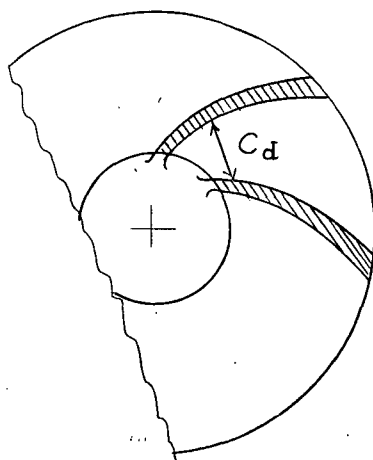
The results of
the measurements are
shown in the table be-
low. These measurements
are of value when one
considers the largest
size spherical object
that can pass through
the impeller. However, they do not indicate the
effect of vane design on passage of objects of
other geometry, such as long and narrow objects.
In such cases the three-dimensional nature of the
impeller passages should be considered.

TABLE I

Impeller Number	Critical Dimension (C_d) (inches)
No. 1	1.8
TD-4	2.0
TD-5	2.1
TD-6	1.9
TD-7	2.1
TD-8	1.8

Table I indicates that all trial design impellers have a slightly larger clearance, as determined by the "critical dimension", than the original impeller (No.1), with the exception of TD-8 which has an equal value to impeller No. 1.

(b) Since an object must pass through the grating on the drag head before it can enter the impeller, the greatest danger of clogging would come from an object that is long and narrow. To study the passage of such objects through the pump, wooden blocks of the following sizes were used:

Block Number	Model Size (inches)	Prototype Size (inches)
1	1 x 1-1/2 x 4	8 x 12 x 32
2	1 x 1-1/2 x 5	8 x 12 x 40
3	1 x 1-1/2 x 5-1/2	8 x 12 x 44
4	1 x 1-1/2 x 6	8 x 12 x 48
5	1 x 1-1/2 x 6-1/2	8 x 12 x 52
6	1 x 1-1/2 x 7	8 x 12 x 56
7	1 x 1-1/2 x 8	8 x 12 x 64
8	1 x 1-1/2 x 9	8 x 12 x 72

It was attempted to fit these blocks through the impeller, making sure that they would also pass through the suction pipe into the pump.

The following results were obtained:

Impeller	Smallest block not passing through impeller
No.1	8
TD-5	6
TD-6	2
TD-7	3
TD-8	7

Next, the drawings of the drag head of ESSAYONS were examined and a check made to determine the maximum length of the same cross-section (8" x 12") that would pass through the grating. The maximum length was found to be 46 inches, or halfway between blocks No. 3 and 4. Theoretically, therefore, such a block may not pass through impellers TD-6 and TD-7. However, considering this size range and the path the object must travel to reach the impeller, it may be concluded that clearance is not a major problem with any of the impellers tested.

(c) Additional check was made to determine the maximum block size which would clear the volute cut-off under the worst possible condition, With the present prototype clearance of 16 inches between volute tongue and impeller, block No. 6 would pass through the pump.

Should the clearance between volute cut-off and impeller be reduced to 11 inches, block No. 4 would pass through the pump.

D. Volute Studies

The design considerations indicate that the clearance between volute cut-off and impeller should be reduced to 11 inches. It is understood that a private company is considering reducing this distance to about 8 inches for a similar size dredge pump.

The volute casing is now being re-designed, using the 11-inch clearance value and four centers of circular arcs defining the volute shape (3).

It is recommended that additional series of tests with re-designed volute and the most efficient impeller be authorized.

E. High-Speed Movies

High-speed movies of flow in the suction pipe were analyzed, but no appreciable prerotation was observed for any speed or flow conditions.

A bronze impeller with a plexiglas shroud on the suction side was received from the manufacturer; however, as the preparations for movie taking were being made, the camers was found to be defective and is being returned to the manufacturer's repair shop. This is unfortunate, as it will cause a total delay of approximately six weeks on this phase of the project.

F. <u>Dimensionless Plots</u>

Figures 19 to 22 of Reference 3, showed the performances of the impellers TD-5, TD-6, TD-7, and TD-8, in the form of dimensionless plots of gH/D^2N^2 versus Q/ND^3. In these plots N was calculated in radians per second, and H in feet of water. If the H units are expressed in feet of liquid, all the data tends to fall on the one curve for the H-Q relationship, as H in feet of liquid (Euler's head, etc.) is independent of density.

The curves were re-plotted and are presented in Figures 1 to 4.

III. PROJECT REPORT NO. 33

The following misprints were noticed in the Project Report No. 33.

p. 45 - Equation 9 SHOULD READ $\alpha_D = \theta_D + \gamma_D - \beta_D$

p. 57 - First line SHOULD READ:

"proper, $360° - \theta$, is equally ...."

IV. FUTURE STUDIES

It is recommended that additional studies should be performed with an impeller having a 16-1/2° exit angle, 45° entrance angle, and an involute shape vane.

It is also recommended that additional studies be performed with a re-designed volute.

We shall be glad to prepare proposals outlining this work.

R E F E R E N C E S

(1) Herbich, J.B.   STATUS REPORT OF RESEARCH PROJECT ON
        et al   IMPROVING DESIGN OF A HOPPER DREDGE
                      PUMP. Fritz Engineering Laboratory
                        Memoranda No. M-1 to M-6, M-8 to
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                             Lehigh University, 1958-1962

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                                             September 1959

(3) Herbich, J.B.   EFFECT OF IMPELLER DESIGN CHANGES ON
    Vallentine, H.R.   CHARACTERISTICS OF A MODEL DREDGE-
                        PUMP
                          Fritz Engineering Laboratory
                          Report No. 277-P.R. 33,
                            Lehigh University, 207 pages
                                          September 1961
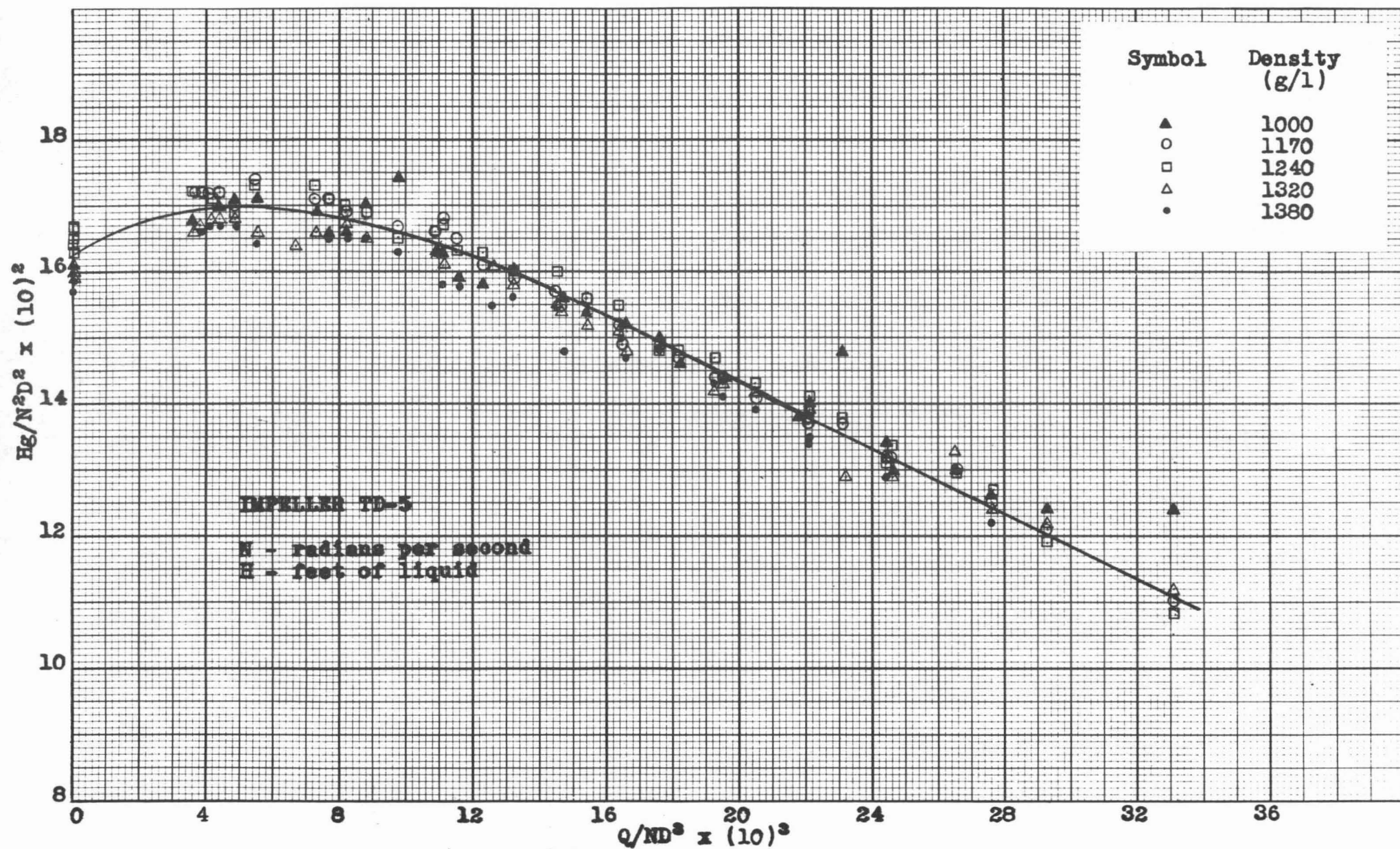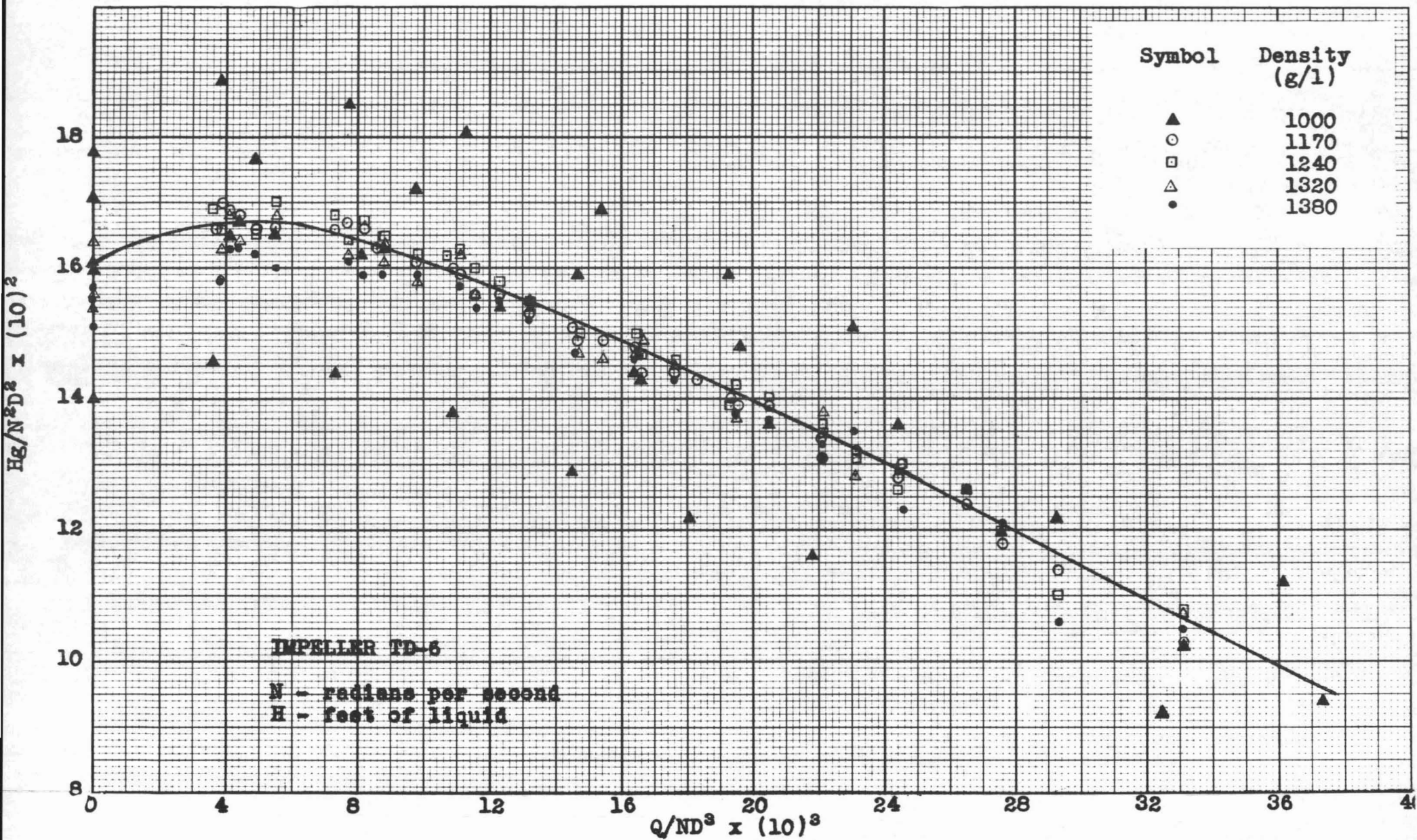
Fig. 1 Dimensionless Head – Flow Curves for Impeller TD-5

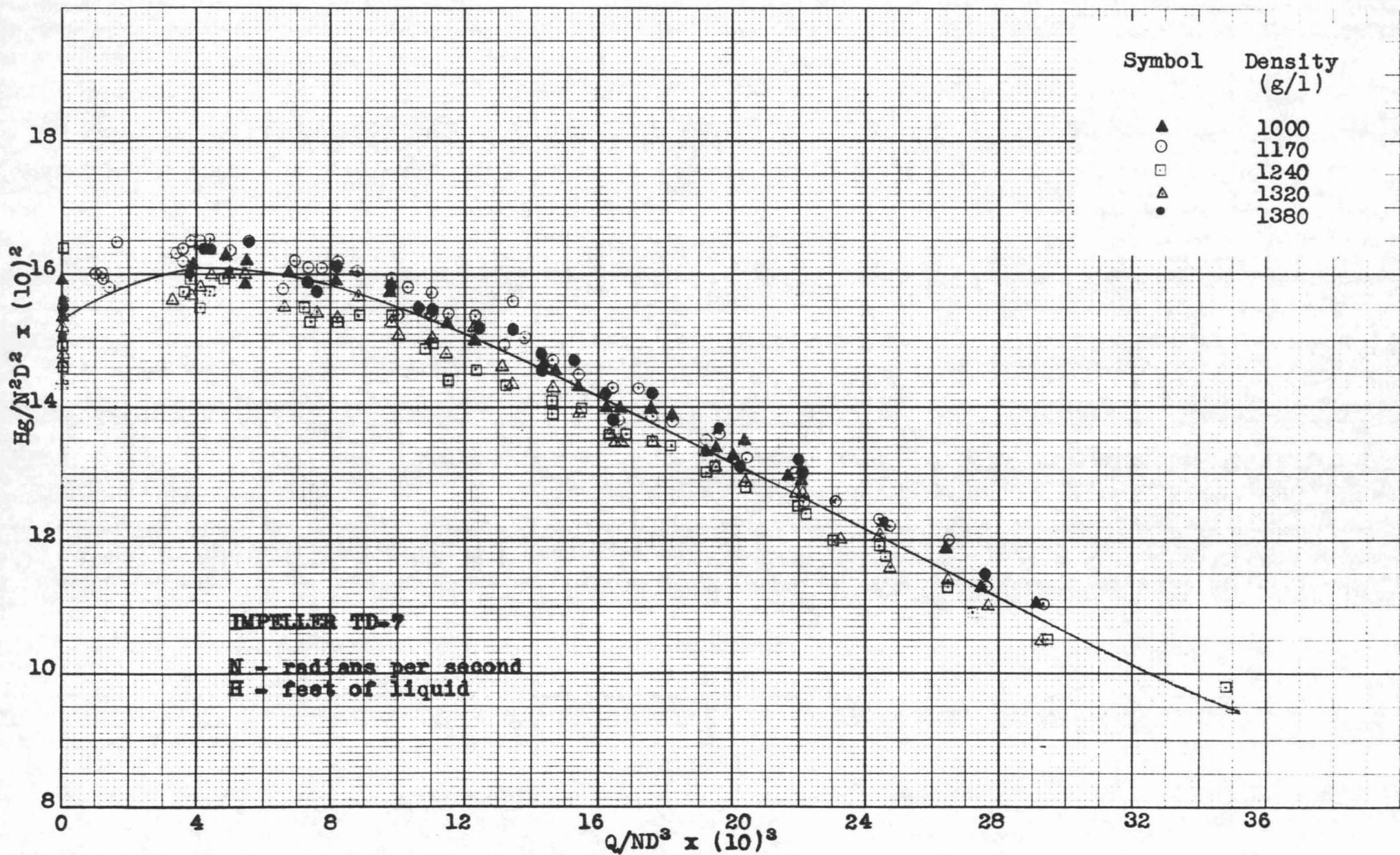Fig. 2 Dimensionless Head - Flow Curves for Impeller TD-6

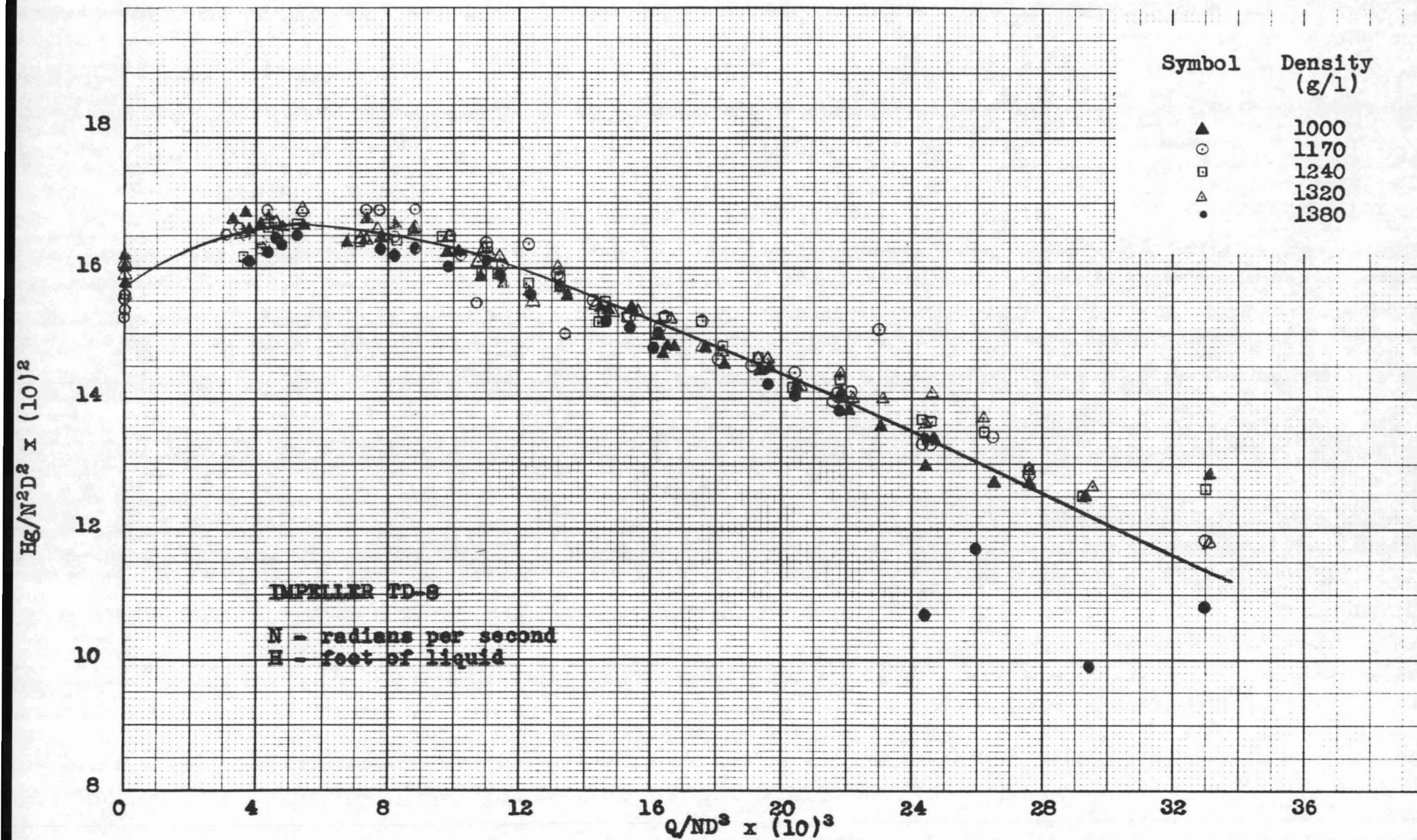Fig. 3 Dimensionless Head - Flow Curves for Impeller TD-7

Fig. 4 Dimensionless Head — Flow Curves for Impeller TD-8

Civil Engineering Department

Fritz Engineering Laboratory

Hydraulics Division

Memorandum No. 34

STATUS REPORT OF RESEARCH PROJECT

ON

IMPROVING DESIGN OF A HOPPER DREDGE PUMP

Prepared by

John B. Herbich

Prepared for

U. S. Army Engineer District, Philadelphia

Corps of Engineers

Philadelphia 29, Pennsylvania

Contract No. DA-36-109-CIVENG-59-112

May 1962

Bethlehem, Pennsylvania

Fritz Laboratory Report No. 277.34.3

STATUS REPORT OF RESEARCH PROJECT

ON

IMPROVING DESIGN OF A HOPPER DREDGE PUMP

I. INTRODUCTION

The following report summarizes the studies performed
during the months of March and April 1962, at the Hydraulics
Division of Fritz Engineering Laboratory, under terms of
Contract No. DA-36-109-CIVENG-59-112. Earlier work was
described in Status Reports dated: December 1958*,
February 1959, April 1959, June 1959, December 1959,
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July 1960, August 1960, September 1960, October 1960,
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April 1961, May 1961, July 1961, August 1961, October 1961,
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II. EXPERIMENTAL STUDIES

A. General Comments

The detailed analysis of the performance of the pump
under the variety of conditions investigated under phases 2
and 3 is under way as part of phase 4 of the project.

- -

* See References for complete listing

B. <u>Discussion of Results</u>

    1. Effect of Exit Angle

It was recommended in Memorandum No. M-33 that an additional series of tests with an impeller having a 16 1/2° exit angle be authorized. A word is awaited from the Sponsor on this matter.

C. <u>Volute Studies</u>

The volute casing has been redesigned, using the 11-inch clearance value and having four centers of circular arcs defining the volute shape. The method used was that described in Reference (3).

D. <u>High-Speed Movies</u>

The analysis of high-speed movies of flow in the suction pipe was completed, but no appreciable prerotation was observed for any speed or flow conditions. The movie has been edited and spliced.

In addition, movies taken earlier in the program have been edited and spliced.

A bronze impeller with plexiglas shroud on the suction side was installed in the pump and preparations for high-speed

movie are being taken. However, the camera has not arrived back from the repair shop. After repeated inquiries we were assured that the camera will be delivered this week.

<p style="text-align:center">III ANALYSIS</p>

A. <u>Dimensionless Plots</u>

Plots of dimensionless head versus dimensionless discharge or gH/D^2N^2 versus Q/ND^3 were presented in Memorandum No. M-33. A sample plot of dimensionless brakehorsepower $BHP/N^3D^5\rho$ versus dimensionless discharge Q/ND^3 was prepared and is attached to this report (Fig. 1).

The dimensionless head is sometimes called the head coefficient and the dimensionless discharge the capacity coefficient. With these curves we may determine head and brakehorsepower for any geometrically similar pump at a certain flow and speed.

The following is an example of the use of these curves.

Given: Pump geometrically similar to dredge pump with impeller TD-7

      Impeller diameter of 60 inches

      Density of mixture is 1200 grams/liter

      Flow rate is 35000 gallons per minute

      Speed is 200 revolutions per minute

Find: Brakehorsepower, head and efficiency

Solution: $Q/ND^3 = 35,000 \ (2.228 \times 10^{-3})/200 \ (.1047)(60/12)^3$

$= 30.5 \times 10^{-3}$

From Fig. 1, $BHP/N^3 D^5 \rho = 7.35 \times 10^{-6}$

Thus $BHP = 7.35 \times 10^{-6} (N^3 D^5 \rho)$

$= 7.35 \times 10^{-6} \{200 \ (.1047) \}^3 \ (5)^5 (1.94)(1.2)$

$\underline{BHP = 503}$

Also, from Fig. 2, $Hg/N^2 D^2 = 11.0 \times 10^{-2}$

Thus $H = 11 \times 10^{-2} \{200 \ (.1047)\}^2 (5)^2 /32.17$

$\underline{H = 37.7 \text{ feet of liquid}}$

$\text{Efficiency} = \dfrac{\text{Water Horsepower}}{\text{Brake Horsepower}} \times 100$

$\text{Water Horsepower} = Q \gamma H/550$

$= \dfrac{35000 (2.228 \times 10^{-3})(1.2)(62.4)(37.7)}{550}$

$= 348$

$\text{Efficiency} = (348/503) \times 100$

$= \underline{69.3\%}$

REFERENCES

Herbich, J. B. et al
STATUS REPORT OF RESEARCH PROJECT ON IMPROVING DESIGN OF
A HOPPER DREDGE PUMP. Fritz Engineering Laboratory
Memoranda No. M-1 to M-6, M-8 to M-15, M-17, M-19 to M-22,
M-24, M-26 to M-28, M-31, M-32, M-33,
Lehigh University, 1958-1962

Herbich, J. B.
CHARACTERISTICS OF A MODEL DREDGE PUMP, Fritz Engineering
Laboratory Report No. 277-P.R. 31,
Lehigh University, 110 pages, September 1959

Herbich, J. B., Vallentine, H. R.
EFFECT OF IMPELLER DESIGN CHANGES ON CHARACTERISTICS OF
A MODEL DREDGE PUMP, Fritz Engineering Laboratory
Report No. 277-P.R. 33,
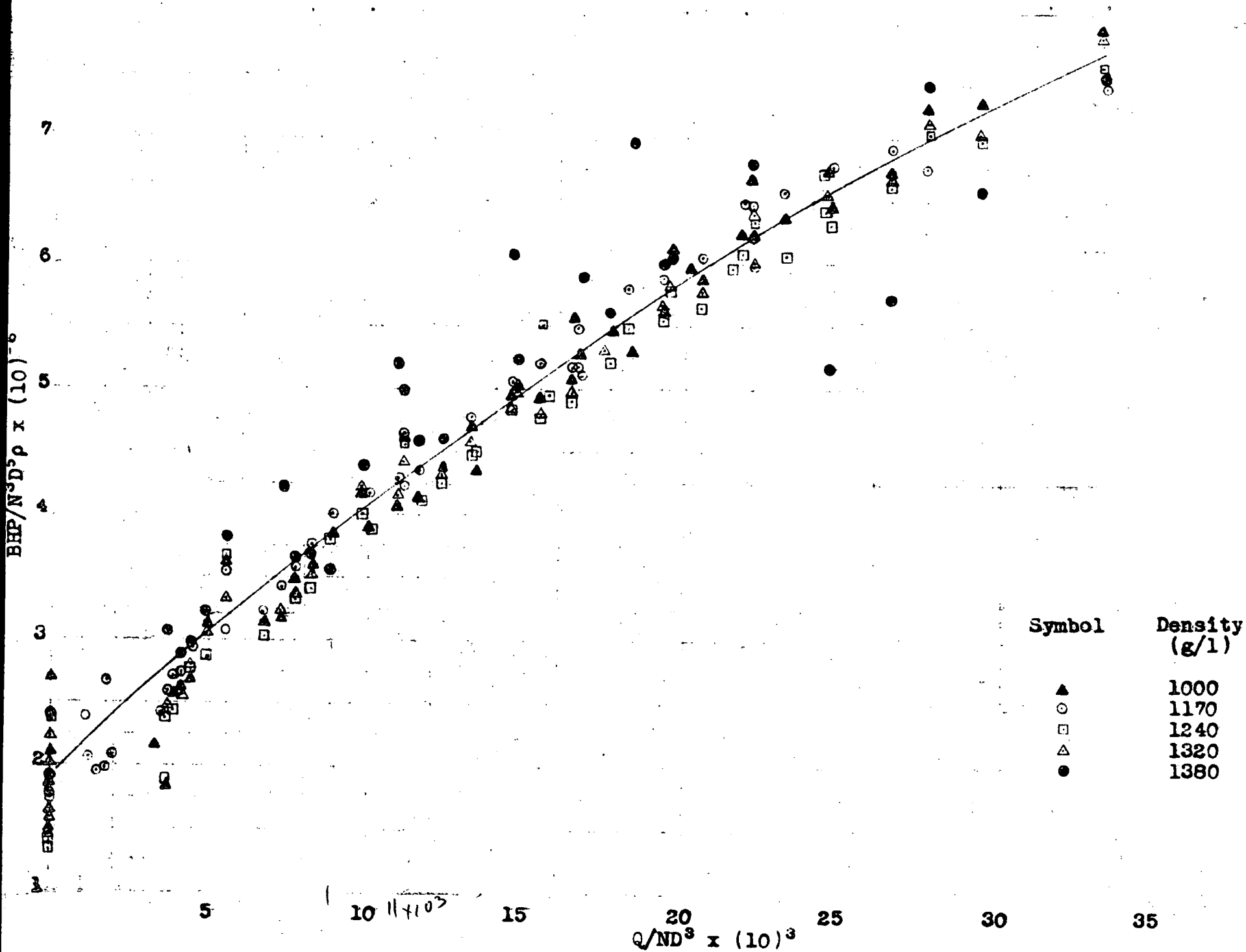Lehigh University, 207 pages, September 1961

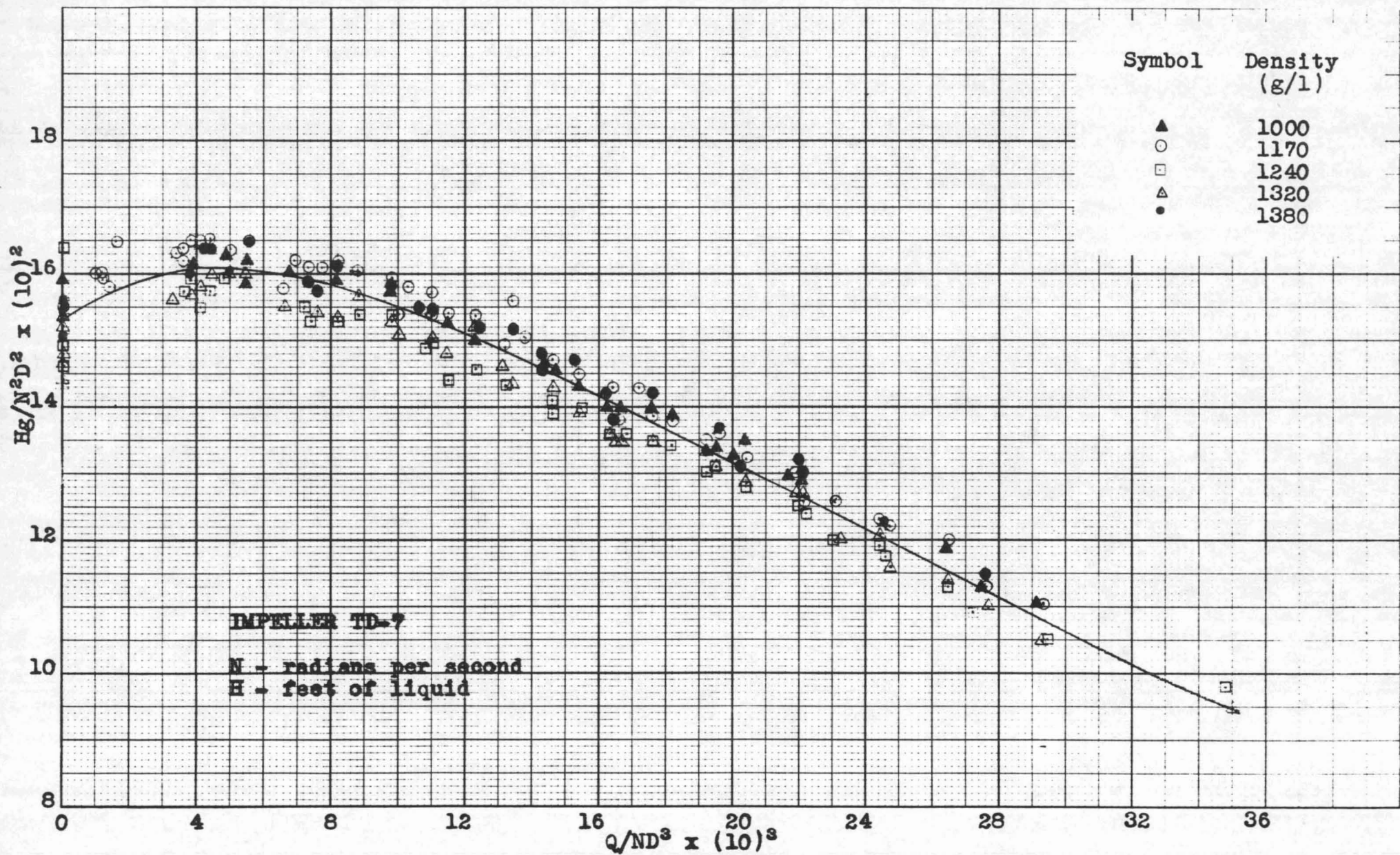**Fig. 1**   Dimensionless Brake Horsepower - Flow Curves for Impeller TD-7

Fig. 2 Dimensionless Head - Flow Curves for Impeller TD-7

Civil Engineering Department

Fritz Engineering Laboratory

Hydraulics Division

Memorandum No. 35

STATUS REPORT OF RESEARCH PROJECT

ON

IMPROVING DESIGN OF A HOPPER DREDGE PUMP

Prepared by

John B. Herbich

Prepared for

U. S. Army Engineer District, Philadelphia

Corps of Engineers

Philadelphia 29, Pennsylvania

Contract No. DA-36-109-CIVENG-59-112

July 1962

Bethlehem, Pennsylvania

Fritz Laboratory Report No. 277.34.4

STATUS REPORT OF RESEARCH PROJECT

ON

IMPROVING DESIGN OF A HOPPER DREDGE PUMP

I. INTRODUCTION

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the months of May and June 1962, at the Hydraulics Division of
Fritz Engineering Laboratory, under terms of Contract No. DA-36-
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A. General Comments

The detailed analysis of the performance of the pump under the
variety of conditions investigated under phases 2 and 3 is under
way as part of phase 4 of the project.

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* See References for complete listing

B. High-Speed Movies

The high-speed camera was received back from the Fairchild
Camera and Instrument Company and the majority of the high-
speed movies were taken during the report period. Three series
of movies were taken:

(1) One series with discharge kept constant at 1000 GPM
and the following pump speeds: 1150, 1300, 1440,
1550, 1650, and 1750 RPM.

(2) Second series with pump speed kept constant at 1440
RPM and the following discharges: 0, 200, 400, 600,
800, 1000, 1200, and 1400 GPM.

(3) Third series with pump speed kept constant at 1300
RPM and the following discharges: 600, 800, 1000,
and 1200 GPM.

All recent movies were taken with impeller No. TD-7 installed
in the pump, the impeller has a plexiglas shroud on the suction
side of the pump.

Analysis of the movies is proceeding at an accelerated pace,
and the results of the analysis will be presented in the final
report currently in preparation.

III. ANALYSIS

A. Dimensionless Plots

Dimensionless brake-horsepower $BHP/N^3D^5\rho$ versus dimensionless
discharge Q/ND^3 plots similar to Figure 1 of Memorandum M-34 were

prepared for other impellers. It is believed that dimensionless plots are very useful in predicting performance of prototype pumps.

B. Specific Speed - Efficiency Plot

A sample plot of specific speed versus efficiency was prepared for pump with impeller No. TD-7 handling water. The maximum efficiency is for a specific speed of about 1800 as compared with ESSAYONS'S specific speed of 1680. (Fig. I)

C. Additional Plots

Additional plots are being prepared for the final report; these include, but are not limited to, the "efficiency % of normal" versus "capacity, % of normal", "head, % normal" versus "capacity, % of normal, etc.

REFERENCES

Herbich, J. B. et al

   STATUS REPORT OF RESEARCH PROJECT ON IMPROVING DESIGN OF
   A HOPPER DREDGE PUMP. Fritz Engineering Laboratory
   Memoranda No. M-1 to M-6, M-8 to M-15, M-17, M-19 to M-22,
   M-24, M-26 to M-28, M-31, M-32, M-33, M-34

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   CHARACTERISTICS OF A MODEL DREDGE PUMP, Fritz Engineering
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Herbich, J. B., Vallentine, H. R.
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   Report No. 277-P. R. 33,
   Lehigh University, 207 pages, September 1961

SPECIFIC SPEED vs. EFFICIENCY
IMPELLER ID #7
$\rho = 1000 \ gm/l.$

EFFICIENCY, %

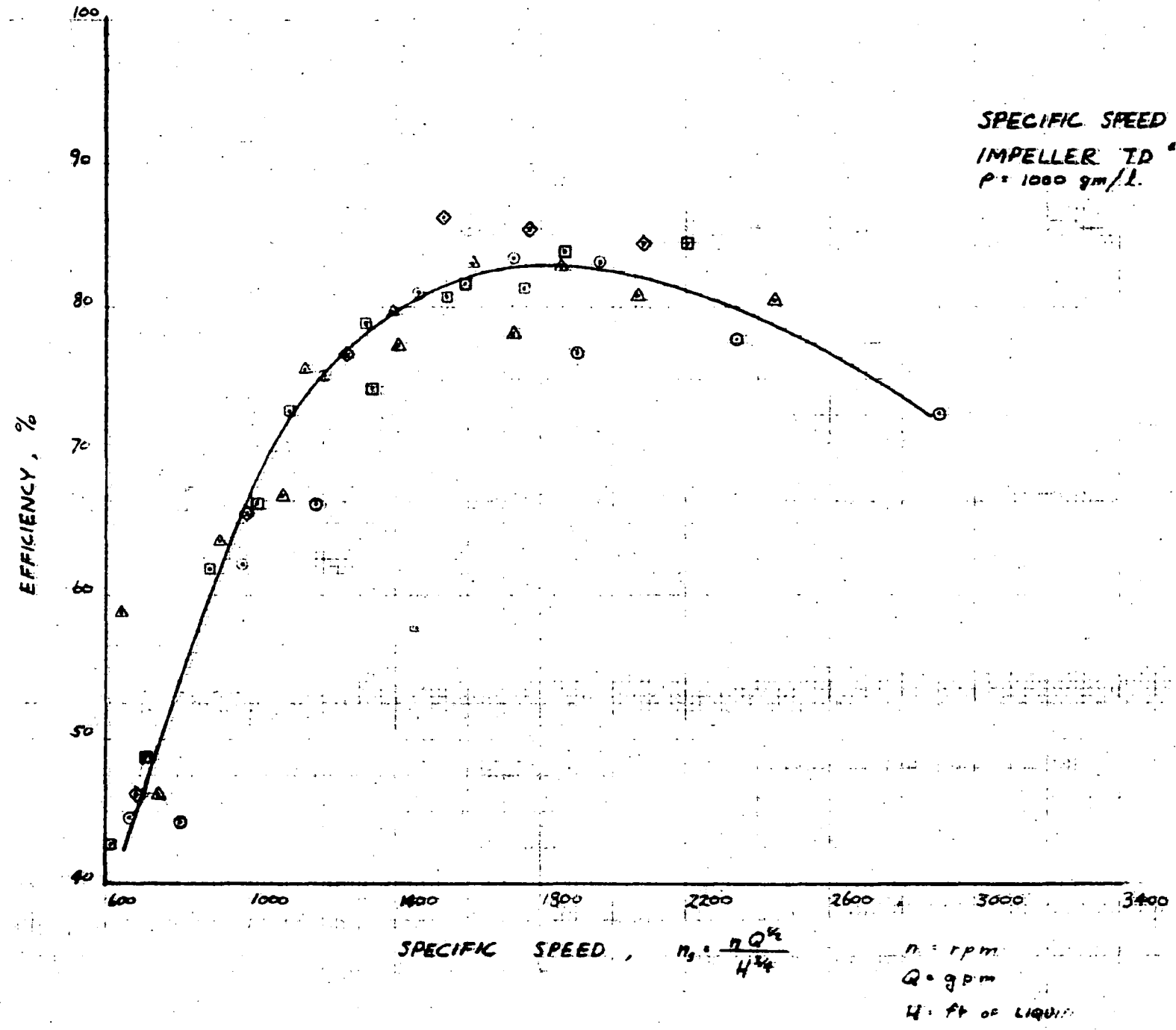SPECIFIC SPEED , $n_s = \dfrac{n \, Q^{1/2}}{H^{3/4}}$

$n = rpm$
$Q = gpm$
$H = ft \ of \ liqui$

Fig.1 EFFICIENCY as a function of SPECIFIC SPEED