Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project Internal Reference:

Project: NOvA

Title: Heat Generated in Pump at Low Flow Rates

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Key Words: NOvA

Abstract Summary: The following engineering note determines the temperature increase that will occur in the pumped product, Renoil 70T, as a result of pumping at lower flow rates.

Applicable Codes:

HEAT GENERATED BY PUMPING

PURPOSE: DETERMINE TEMPERATURE RISE IN FLUID ASSOCIATED WITH PUMPING AT FLOW RATES OF 3, 6, 9, 12 gpm.

FLUID IN SYSTEM: RENOIL 70T (LIGHT MINERAL OIL)
(SPECIFICATIONS PROVIDED ON PG. 5 OF THIS NOTE)

OTHER PROPERTIES:

$C_p = 0.4$ (MINERAL OIL)

↳ FROM www.engineeringtoolbox.com

FROM "PUMP ENGINEERING MANUAL", PG. 133
(BIRK, J.R. AND SYSKA, R.E., FLOWSERVE CORP., ROTATING EQUIPMENT DIVISION)

$$Q = \frac{5 \cdot BHP_o \cdot C_{HP}}{\Delta T \cdot C_p} \longrightarrow \Delta T = \frac{5 \cdot BHP_o \cdot C_{HP}}{Q \cdot C_p},$$

WHERE:

ΔT = TEMPERATURE RISE (°F)

BHP_o = NON-VISCOUS PERFORMANCE CURVE HORSEPOWER AT SHUT-OFF (hp)

C_{HP} = VISCOUS HORSEPOWER CORRECTION FACTOR

Q = FLOW RATE (gpm)

C_p = SPECIFIC HEAT CAPACITY

ON THE PUMP PERFORMANCE CURVE (PG. 6), THE EFFICIENCY AT VARIOUS POINTS ON THE "4.0" CURVE WERE PLOTTED AND AN EFFICIENCY TREND LINE WAS FIT TO THE POINTS. THE EFFICIENCY AT THE FOUR FLOW RATES OF INTEREST ARE AS FOLLOWS:

$\eta_3 = 0.10$

$\eta_6 = 0.18$

$\eta_9 = 0.25$

$\eta_{12} = 0.30$

OTHER NECESSARY INFORMATION FOR "4.0" CURVE:

$H_3 = 63$ ft

$H_6 = 62$ ft

$H_9 = 60.5$ ft

$H_{12} = 59.5$ ft

THESE VALUES WERE THEN USED IN THE CALCULATION OF THE BRAKE HORSEPOWER

$$BHP = \frac{\rho g Q H}{\eta}$$

$$BHP_3 = \frac{(.86)(62.4\ lb/ft^3)(3\ gpm)\left(\frac{1\ ft^3/s}{449\ gpm}\right)(63\ ft)}{(0.10)}$$

$BHP_3 = 225.9\ \frac{lb \cdot ft}{s}$ OR 0.411 hp

$BHP_6 = 247.0\ \frac{lb \cdot ft}{s}$ OR 0.449 hp

$BHP_9 = 260.3\ \frac{lb \cdot ft}{s}$ OR 0.473 hp

$BHP_{12} = 284.5\ \frac{lb \cdot ft}{s}$ OR 0.517 hp

THESE VALUES, IN TERMS OF hp, WERE ALSO PLOTTED ON THE PERFORMANCE CURVE GRAPH. BHP IS ASSUMED TO BE LINEAR OVER A SMALL RANGE OF CAPACITIES. A LINE FIT TO THESE POINTS YIELDS:

$$BHP_0 = 0.38$$

THE VISCOUS HORSEPOWER CORRECTION FACTOR WAS CALCULATED WITH THE ASSISSTANCE OF PG 101 IN THE PUMP ENGINEERING MANUAL

USING THE BEST EFFICIENCY POINT, A LINE WAS DRAWN BETWEEN THE PUMP HEAD (A) AND FLOW RATE (B). A LINE WAS THEN DRAWN FROM THE INTERSECTION ON (C) TO THE KINEMATIC VISCOSITY ON LINE (D) AND EXTENDED UNTIL IT INTERSECTED LINE (E).

THIS RESULTED IN A VALUE OF $C_{HP} = 1.16$.

(SHOWN ON PG. 7 OF THIS NOTE)

THE VALUES FOR BHP_o, C_{HP}, Q, AND C_p WERE THEN PLUGGED INTO THE FORMULA FOR TEMP. RISE. THE FOLLOWING VALUES WERE RECORDED:

$$\Delta T = \frac{5\, BHP_o \cdot C_{HP}}{Q \cdot C_p}$$

$$\Delta T_3 = \frac{5(0.38)(1.16)}{(3)(0.4)}$$

$$\boxed{\begin{aligned} \Delta T_3 &= 1.84\,°F \\ \Delta T_6 &= 0.92\,°F \\ \Delta T_9 &= 0.61\,°F \\ \Delta T_{12} &= 0.45\,°F \end{aligned}}$$

USING ANOTHER FORMULA AS A CHECK,

$$\Delta T = \frac{BHP(1-\eta)}{Q\, C_p\, \rho}$$, WHERE ρ = DENSITY

BHP = BRAKE HORSEPOWER AT EACH POINT (IN $\frac{ft \cdot lb}{s}$)

$$\Delta T_3 = \frac{\left(225.9 \frac{lb \cdot ft}{s}\right)(1-0.10)}{(3\,gpm)\left(\frac{1\,ft^3/s}{449\,gpm}\right)(.86)\left(62.4 \frac{lb}{ft^3}\right)\left(0.4 \frac{BTU}{lb \cdot °F}\right)\left(\frac{778.2\, lb \cdot ft}{1\, BTU}\right)}$$

$\Delta T_3 = 1.82\,°F$ (−0.82%)

$\Delta T_6 = 0.91\,°F$ (−1.2%)

$\Delta T_9 = 0.58\,°F$ (−4.8%)

$\Delta T_{12} = 0.45\,°F$ (−2.9%)

(THESE VALUES ARE ALL WITHIN 5% OF THE ORIGINAL VALUES)

K. BECZKIEWICZ 7/22/2010

Technical Grade White Oil Specifications

Property	Renoil 60-T	Renoil 70-T	Renoil 90-T	Renoil 105-T	Renoil 130-T	Renoil 150-T	Renoil 180-T	Renoil 200-T	Renoil 220-T	Renoil 350-T	Renoil 500-T
Viscosity SUS @ 100F	62	70	90	105	130	150	180	200	220	350	570
Viscosity cSt @40C	**9-11**	**11.5-14.1**	**15.5-17.5**	20	25	35	35	39	42.87	**60-75**	110
Viscosity cSt @ 100C	2.60	2.92	3.80	**3.9-4.3**	**4.5-5.0**	**4.9-5.4**	**5.6-6.1**	**6-6.5**	**6.1-6.7**	8.80	**10-12.6**
API Gravity	31.6	33.3	33.3	33.8	33.2	32.8	32.3	31.9	31.8	31.0	30.4
Specific Gravity @ 60F	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.87	0.87	0.87	0.87
Density lb/gal @ 60F	7.22	7.15	7.15	7.13	7.15	7.17	7.20	7.21	7.22	7.25	7.28
Pour Point F (C) max	**-27(-33)**	**-17(-27)**	**10(-12)**	**10(-12)**	**10(-12)**	**10(-12)**	**10(-12)**	**10(-12)**	**10(-12)**	**10(-12)**	**10(-12)**
Flash Point F min (C) COC	**345(174)**	**350(177)**	**350(177)**	**390(199)**	**390(199)**	**390(199)**	**390(199)**	**390(199)**	**420(216)**	**420(216)**	**482(250)**
Color Saybolt	+28	+28	+28	+28	+28	+28	+28	+28	+28	+28	+25

Specifications in **BOLD**

Meets all requirements for 21 CFR 178.3620 (b) for technical grade white oil.

http://www.renkertoil.com/documents/white.pdf

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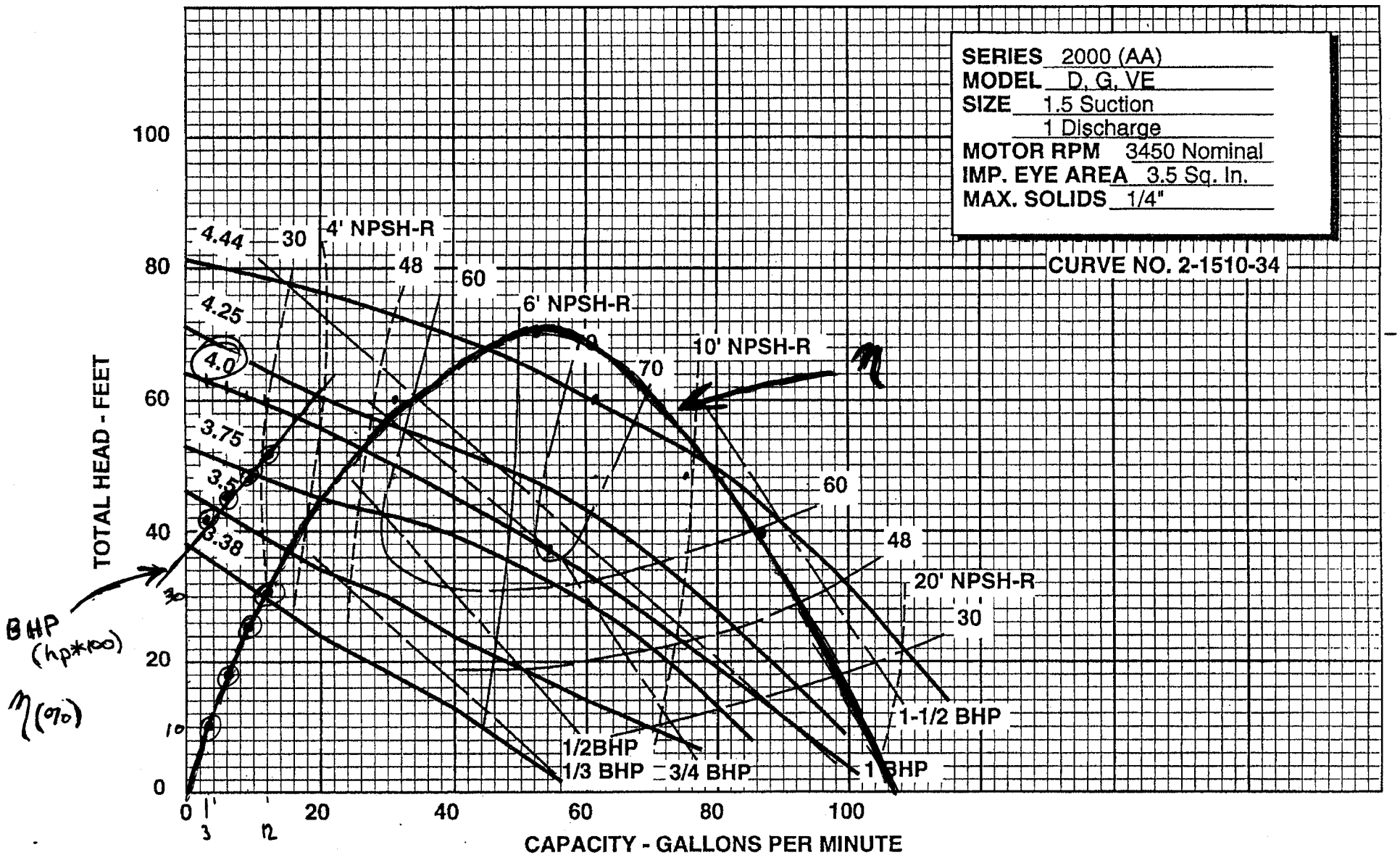

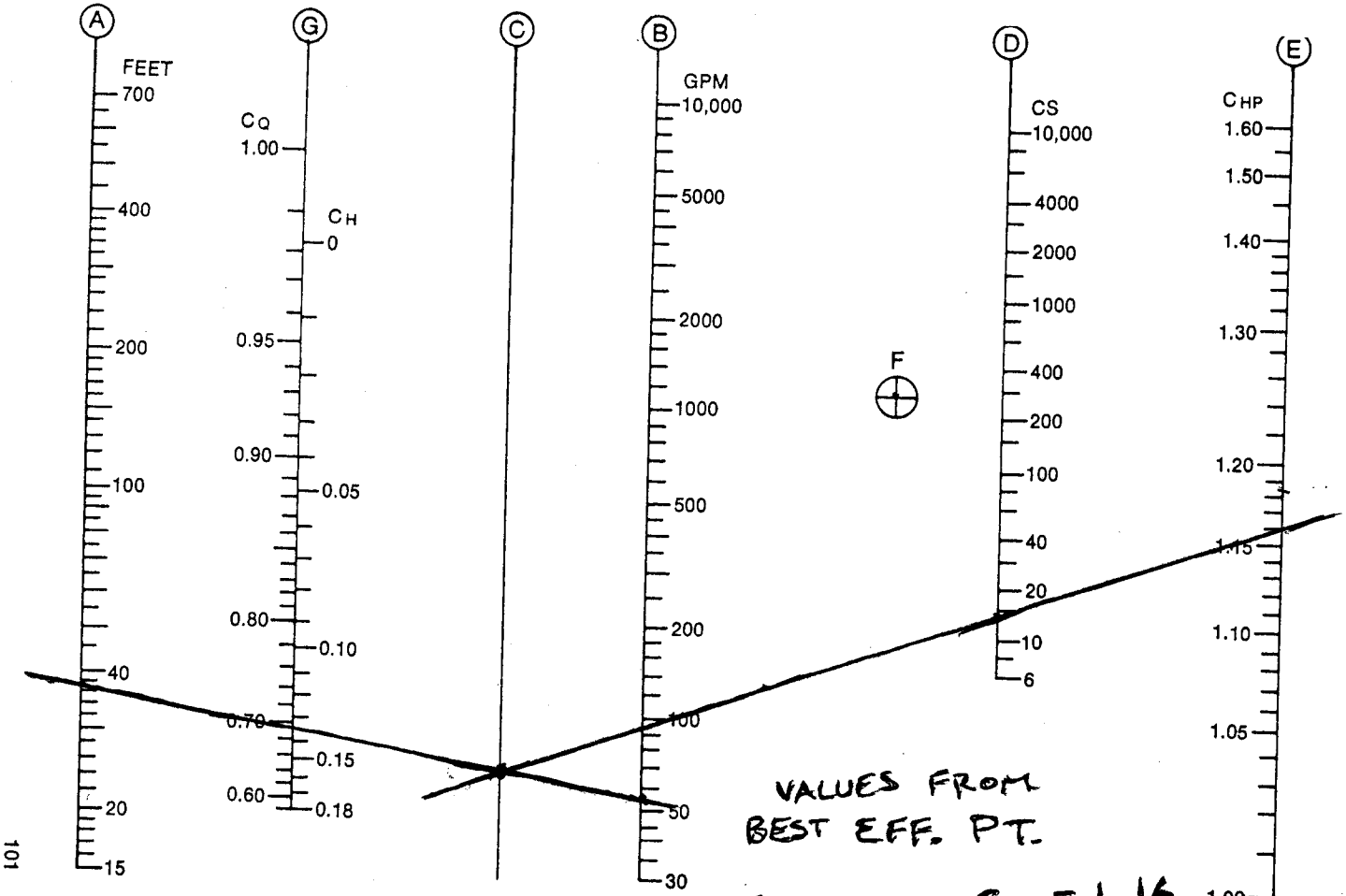

VALUES FROM BEST EFF. PT.

RESULTING $C_{HP} = 1.16$

FIGURE 8.1