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Pulsatile Fluidic Pump Performance at Elevated Temperatures

J. G. Morgan
W. D. Holland

CONSOLIDATED FUEL REPROCESSING PROGRAM

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Fuel Recycle Division

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NOTICE This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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ABSTRACT

A series of tests were conducted to evaluate the performance of a pulsatile fluidic pump operating with simulated fuel solution at high temperatures. A computer program was written to model the performance of the system. Test results indicate little change in pump performance at temperatures up to the boiling point of the solution. The computer model predicted pumping system performance within 10 to 20% depending on the pump motivation pressure.

1. INTRODUCTION

The performance of a pulsatile fluidic pump as a function of pumped liquid temperature is of special interest at temperatures near the boiling point, where pumping using a steam jet becomes inoperable. Priestman and Tippetts[1] have reported results on pumping hot water. Their "standard design" pump consists of two external pumping chambers, one reverse-flow diverter (RFD) coupled with a Y-flow junction, which allows a nearly constant pumping rate. Details of this method can be found in the work by Robinson.[2] In the work of Priestman and Tippetts, the pumping rate for water was 4.35 L/min at 20°C and fell to 1.0 L/min at 78°C. At 92°C the pump delivered 0.5 L/min, only 11% of the value at 20°C. The reduction in pumping rate was attributed to the increased liquid vapor pressure leading to cavitation in the RFD.

Oruh[3] reported work on a pulsatile fluidic pump designed to transfer the contents of a large radioactive waste storage tank. The fluid in the tank was depleted uranyl nitrate in nitric acid with particulate solids (<20 μm) of diatomaceous earth and graphite to represent undissolved waste, with a specific gravity of 1.3 to 1.6 (containing 50% by volume of suspended solids). The RFD was external to the pump chamber, and both were immersed near the bottom of a 6-m-diam tank with a full tank level of 4.5 m. Averaged pumping rates decreased as the host tank emptied. At full host tank level, the pumping rate (11.8 m^3/h) at ambient temperature decreased 5% at 60°C, 12% at 80°C, and 27% at 100°C. This was still an acceptable pumping rate. The boiling point of the liquid was not given, although Oruh states that steam-driven ejectors fail to operate at temperatures of ~70°C.

The objective of the tests described in this report was to determine the effect of temperature on the pumping performance of a pulsatile fluidic pump (FP) and to establish the validity of fluidic pumping near the boiling point of a fuel solution. The data obtained will also allow temperature to be considered a variable in a model used to predict fluidic pump performance.

2. EXPERIMENTAL PROCEDURE

2.1 BACKGROUND

In 1984 a pilot plant facility, the Integrated Equipment Test (IET) facility, designed to simulate a nuclear fuel reprocessing plant was completed at the Oak Ridge National Laboratory (ORNL). The IET facility was used to conduct the high-temperature pumping tests on simulated fuel solutions.

The bottom-loading FP used in these tests had been previously tested, and its performance at room temperature was determined.[4] It consisted of a 4-ft-long pumping chamber constructed of 4 in. schedule 40 stainless steel pipe with the RFD as an integral part of the bottom plate. During the pump stroke (as shown in Fig. 1), air enters the FP chamber, forces fluid down through the nozzle and diffuser, and exits through the liquid discharge line. A portion of the liquid, depending on the system resistance, bypasses through the RFD port during the pump stroke. When the chamber is nearly empty, the motivation air pressure is turned off and the chamber pressure is relieved to off-gas through a solenoid-operated three-way valve. The FP then refills through the port and nozzle. The liquid in the exit line also falls back into the chamber.

The FP was installed in the IET facility in the flanged well extending through the concrete floor beneath and adjacent to one of the main dissolved fuel supply tanks. It had been used routinely in the head-end process to pump fuel solution to a head tank which fed the IET feed clarifier centrifuge.

The installation of the high-temperature FP test is illustrated in Fig. 2. A branched valved header was installed in the exit line from the pump. Three-quarter-inch ball valves were used at the header to divert the output flow to a receiver tank or to return to the top of the supply tank. The ball valve directing flow to the centrifuge feed tank was always kept closed during these tests. The delivery lines were 0.75-in. OD by 0.35-in. wall 304 L stainless-steel tubing.

The simulated fuel solution in the supply tank was heated by an internal steam coil. Slight air sparging was used to ensure a uniform fluid temperature. Thermocouples were used to monitor the temperature in the supply tank, receiver tank, exit line to the FP well, and in the region of the bottom of the FP chamber inside the well. The supply tank, exit line, FP well, and liquid exit lines were insulated during the high-temperature tests.

All monitoring and control functions were done remotely from the Integrated Process Demonstration (IPD) control room. Settings of the branched valved header and motivation pressure regulator were changed manually at those stations.

2.2 PROCEDURE

With the 1500-L (20% freeboard) supply tank about half full, the solution was heated to the desired temperature and the header valved to recirculate liquid from the FP well. The FP was then actuated, and a thermal steady-state was reached. There was usually less than 2°C difference in liquid temperatures at the three locations monitored during a run. The header was then valved to close the recirculation loop and open the liquid discharge to the 500-L uninsulated receiving tank.

ORNL–DWG 86–6809

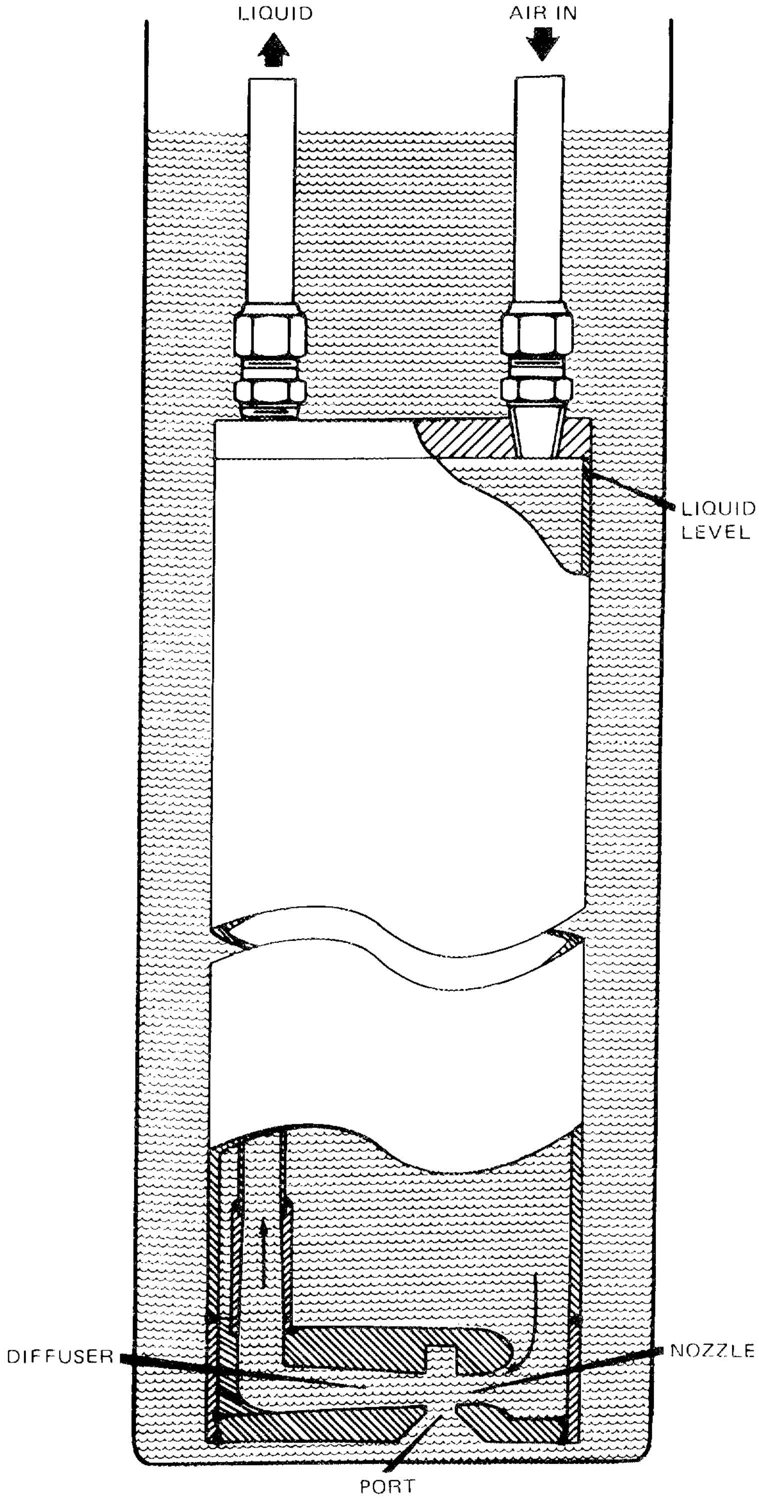

Fig. 1. Bottom-loading pump.

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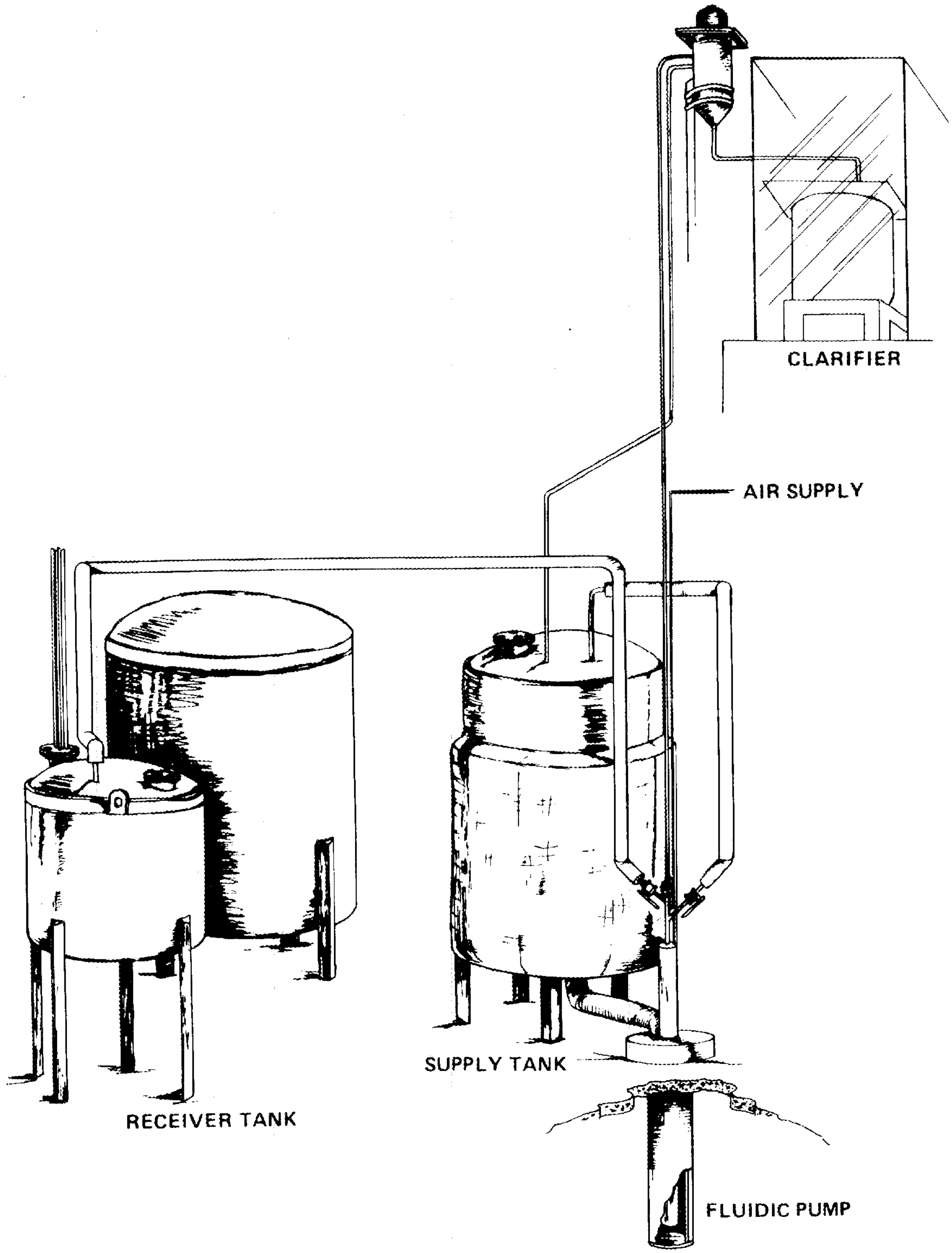

Fig. 2. IET fluidic pump installation.

Pumping and refill times were kept constant during a run at a set motivation pressure. Previous calibration tests had established the relationship between pumping time and motivation pressure as well as refill time and refill head. A microphone attached to the side of the FP well provided an audible monitor of the pump cycle. The pumping time was set just before blowout. Blowout occurs when the pump chamber has been completely emptied and the motivation air escapes through the FP port. A vent line, not shown in the illustration, connects the top of the FP well to the void volume above the supply tank. This arrangement vents any air bubbles trapped at the top of the FP well.

The liquid levels in both the supply and receiving tanks were recorded at one-minute intervals. Level and density measurements were made by bubbler tubes in both tanks. A plot of tank level change with time is shown in Fig. 3 for Run 6. In this run, the supply tank was about half full and the collection tank nearly empty. This two-hour run shows the steep level plot near the end of the run when the test ended, and solution was pumped back to the supply tank with a centrifugal pump. The flat portion of the collection tank filling curve, at about 23%, is caused by a bubbler tube being submerged by the rising liquid. Level values previous to this time were corrected by a density factor in the data analysis. The number of pump cycles are counted and recorded as they accumulate during a run.

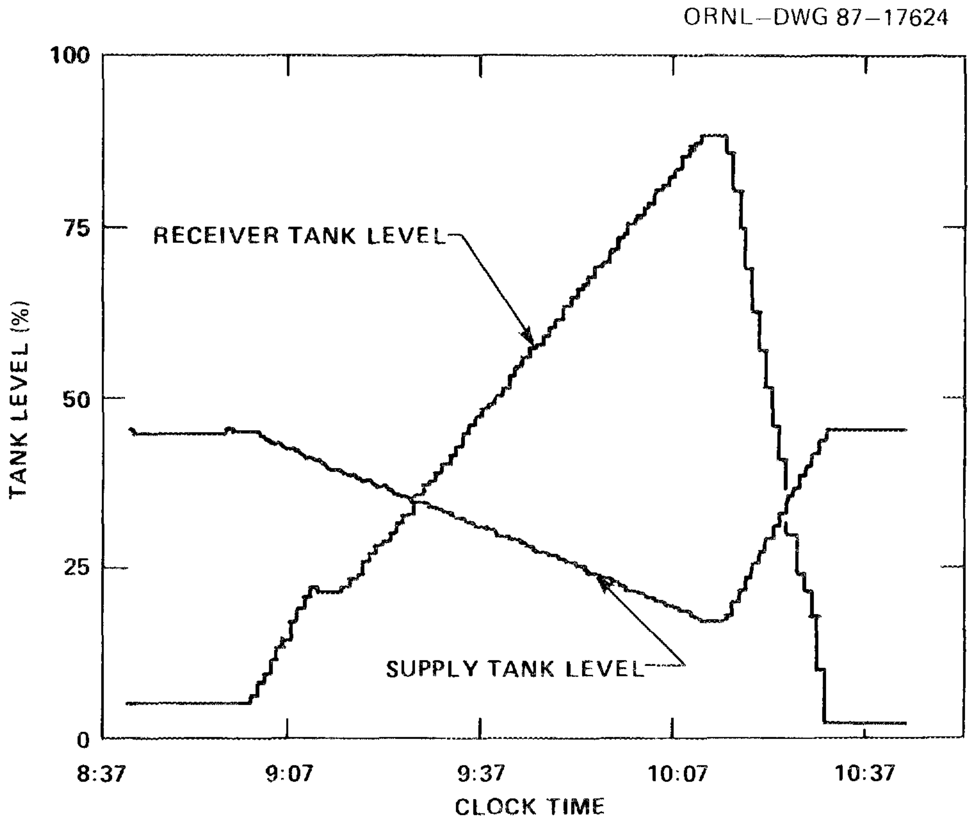

Fig. 3. Level change, Run 6.

Both supply and collection tanks were precalibrated, and plots of volume versus liquid height were available. There was generally good agreement between the volume exiting the supply tank and the volume delivered to the receiving tank. All runs showed agreement within 10% with only 6 runs showing deviations of over 5%. More than half of the runs showed agreement in the two volumes of less than 3%. The receiver volume values were used in the data analysis to calculate pumping rates.

Three parameters were varied during the test program – fluid temperature, pump motivation pressure, and system resistance to flow. Temperature was varied from 42°C to 105°C. Motivation pressures of 20, 35, and 55 psig were used. The system resistance was changed by partially closing a ball valve located in the delivery line to a preset mark, which resulted in the valve being about half closed.

The total length of the delivery line was 19 ft, and the delivered head was 7 ft 3 in. The 0.75-in. OD delivery line had three 90° bends and two 45° bends. Runs were made with the ball valve wide open (minimum system resistance) and partially closed (greater system resistance).

The simulated fuel solution consisted of depleted uranium dissolved in nitric acid. Samples were taken periodically and analyzed for uranium concentration, nitric acid molarity, and density. Several times during the tests the concentration was adjusted by adding water to compensate for evaporation losses. The uranium loading ranged from 244.6 g/L to 268.9 g/L, and densities ranged from 1.411 g/mL to 1.442 g/mL at 20.9°C. The nitric acid molarity was 3 *M*.

The viscosity of the fuel solution was determined as a function of temperature using an Ostwald viscosimeter.[5] The experimental data were fitted to the following equation:

$$\mu = 0.01247 \exp(1474/T) , \tag{1}$$

where

μ = viscosity in cp

T = °K .

A sample of the test solution was obtained for vapor pressure determination. This sample was found to have a density of 1.411 g/mL at 20.8°C, a uranium content of 244.6 mg/mL, and a nitric acid normality of 2.98. The following is a list of reported vapor pressures:

Temperature, °C	Vapor Pressure, mm Hg
25.6	24.08
50.4	75.37
74.2	216.06
94.4	488.56
106.1	739.47

The above data were fitted to the following equation with a maximum error of 1.5%:

$$\log_{10} (\text{vapor pressure}) = 0.817473 - 0.0227644T - 0.318906E - 04\ T^2 , \tag{2}$$

where T = °C.

3. PREDICTIVE MODEL

This particular pump design has been extensively tested,[4] and a previously determined normalized calibration curve was used to predict the performance for these experiments. A generalized design procedure has also been reported for pulsed-mode fluidic pumps.[6]

During the pumping stroke, the fluid exiting the pumping chamber splits into two parts, with some of the fluid leaving through the refill port and returning to the supply tank and the remainder passing through the diffuser and leaving via the delivery line.

The calculational procedure consists of assuming a split of the fluid stream, estimating the resistance to flow in the delivery line based on the assumed split, and checking the assumed split against the value obtained from the normalized calibration curve. This procedure is repeated until satisfactory agreement is obtained between assumed and resultant splits.

A computer program was written (in BASIC) to accomplish the calculations described above. The program (presented in Appendix A) is user interactive and allows the user to provide assumed "splits" which are then compared to "splits" calculated by the program. The calibration curves are fitted to polynomial approximations for calculational purposes [see Appendix B for a sample calculational run (Run 2)].

In using the model it is necessary to assign a fitting loss coefficient to determine the resistance to flow in the piping system. The loss coefficient for the three 90° bends and the two 45° bends in the piping system was estimated to be 3.6; this value was used in the calculations for the 100% open valve. Based upon data presented by Miller,[7] the 50% opened valve was assigned a loss coefficient of 9.9, yielding a total loss coefficient of 13.5 for the high-resistance system.

Although the motivation pressures were set at nominal values of 55, 35, or 20 psig, it was noted during the pumping stroke that the pressures dropped slightly; these pressures were used in the computer calculations. The values were 52.2, 33.2, and 18.8 psig, respectively.

4. RESULTS

There were a total of 40 test runs (see Table 1 for the results). The first 22 runs were made in December 1986 and the remainder in May 1987. One primary measure of pump performance is the output (given in liters/cycle). Figures 4 and 5 are plots of pump output versus temperature for the three motivation pressures and the two system resistances used in the tests. As indicated by the plots, temperature had very little effect on the pump performance at any of the conditions tested. The pump appears to work quite satisfactorily in transferring high-temperature fluids.

The percentage error between experimental and calculated pump outputs is given in Table 1. The calculational model seems to work best at a motivation pressure of 35 psig. The average percentage error for these runs is 9.1%; however, if only the high-system resistance runs at 35 psig are considered, the average error is 5.6%. Positive error indicates that the calculated values are less than the experimental values.

The model predicts too low flow rates at 55 psig with an average error of 20.1%. The errors at this motivation pressure seem to be about the same for low- or high-system resistance. At 20-psig motivation pressure, the model predicts too high flow rates by about 20%.

Even with the relatively large errors given above, the model has proven useful in designing pumps and setting operating conditions for anticipated uses. Considering the uncertainties in assigning values for the various pressure drops in the pumping system, the success of the rather simple, steady-state model is believed to be quite good.

As mentioned above, the last 18 of the 40 experimental runs were made about 5 months after the first 22 runs were made. A comparison of some of the runs from each campaign which had similar motivation pressures, temperatures, and system resistances were made. Agreement was generally within a few percent (e.g., Runs 8 and 40, 7 and 39, 16, 29, and 38) although some sets (Runs 13 and 33, 15 and 28) showed agreement within about 15%.

It was also noted that the runs occurring toward the end of the first campaign (Runs 11 through 22) showed the poorest agreement between volume change measurements for the supply and receiving tanks. The reason for this is not known. Before beginning the second series, the depth probes in both tanks were recalibrated. The data during the second series (Runs 23 through 40) show the good agreement in volume changes.

Table 1. Results of the 40 test runs

Run No.	Temp, °C	Motivation pressure, psig	Valve position, % open	Fluid density, g/mL	Pumping time, s	Refill time, s	Experimental pumping rate, L/cycle	Calculated pumping rate, L/cycle	Percent error
1	42	35	100	1.38	10	43	7.48	6.07	18.9
2	42	35	50	1.38	10	43	5.84	5.15	11.8
3	60	35	100	1.37	10	43	7.36	6.14	16.6
4	60	35	50	1.37	10	43	5.67	5.20	8.3
5	75	35	100	1.36	10	43	7.23	6.20	14.2
6	75	35	50	1.37	10	43	5.68	5.25	7.6
7	90	35	100	1.37	10	43	7.04	6.24	11.4
8	90	35	50	1.37	10	43	5.50	5.29	3.8
9	100	35	100	1.37	10	43	7.03	6.25	11.1
10	100	35	50	1.40	10	43	5.45	5.32	2.4
11	105	35	100	1.41	10	43	6.85	6.27	8.5
12	105	35	50	1.43	10	43	5.30	5.33	-0.6
13	75	55	100	1.36	9	43	7.91	7.13	9.9
14	75	20	100	1.36	10	43	3.15	4.03	-27.9
15	90	55	100	1.35	9	43	8.78	7.16	18.5
16	90	55	50	1.35	9	43	7.77	6.24	19.7
17	89	55	50	1.35	9	43	6.69	6.24	6.7
18	91	20	100	1.35	10	43	3.30	4.06	-23.0
19	100	55	100	1.36	9	43	7.65	7.18	6.1
20	100	55	50	1.35	9	43	6.91	6.28	9.1
21	105	55	100	1.37	9	43	9.71	7.19	26.0
22	105	20	100	1.37	10	43	3.83	4.10	-7.0
23	70	35	100	1.45	10	43	6.55	6.05	7.6
24	70	55	100	1.46	9	43	9.4	7.02	25.3
25	69	55	50	1.43	9	53	8.1	6.27	22.6
26	79	55	100	1.42	9	53	9.68	7.16	26.0
27	79	55	50	1.42	9	53	7.64	6.17	19.2
28	90	55	100	1.39	9	53	9.57	7.28	23.9
29	90	55	50	1.40	9	53	7.88	6.25	20.7
30	99	55	100	1.39	9	53	9.80	7.25	26.0
31	100	55	50	1.41	9	53	8.16	6.19	24.0
32	99	35	100	1.42	10	43	6.82	6.08	10.9
33	75	55	100	1.41	9	53	9.5	7.19	24.3
34	75	35	100	1.41	10	43	6.75	6.09	9.8
35	75	35	50	1.41	10	43	5.43	5.16	5.0
36	75	55	50	1.41	9	53	8.32	6.19	25.6
37	90	55	100	1.41	9	53	9.73	7.20	26.0
38	90	55	50	1.41	9	53	7.93	6.21	21.7
39	90	35	100	1.41	10	43	6.85	6.11	10.8
40	90	35	50	1.41	10	43	5.52	5.17	6.3

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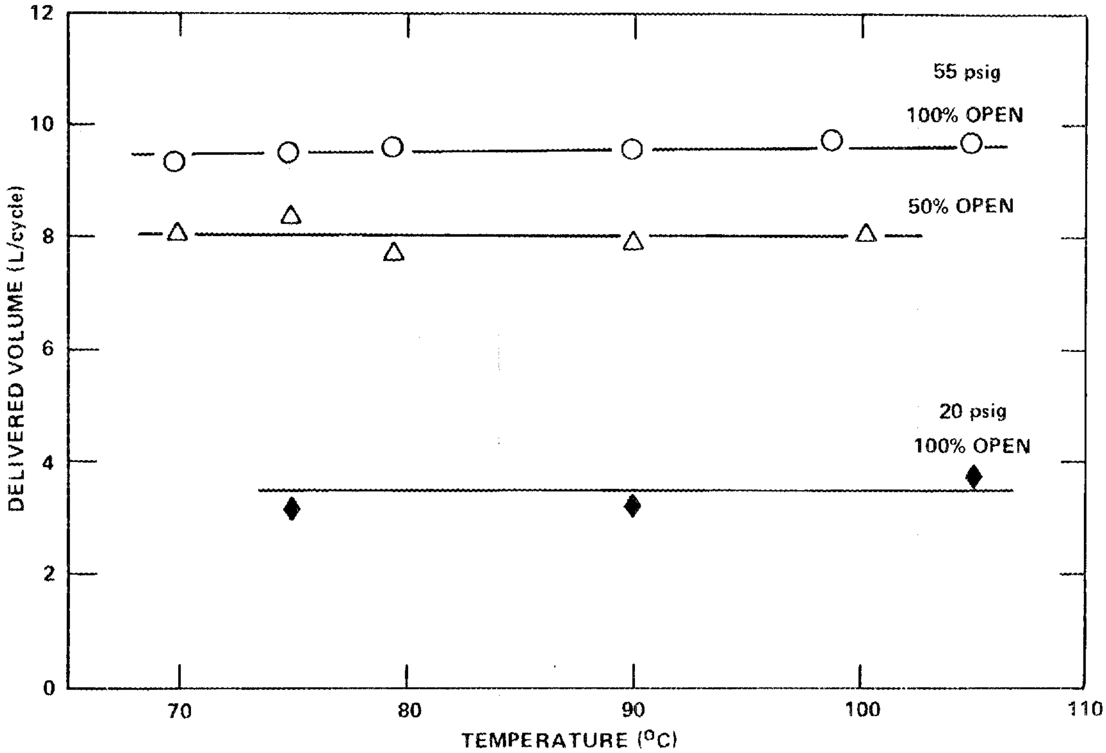

Fig. 4. Pump output.

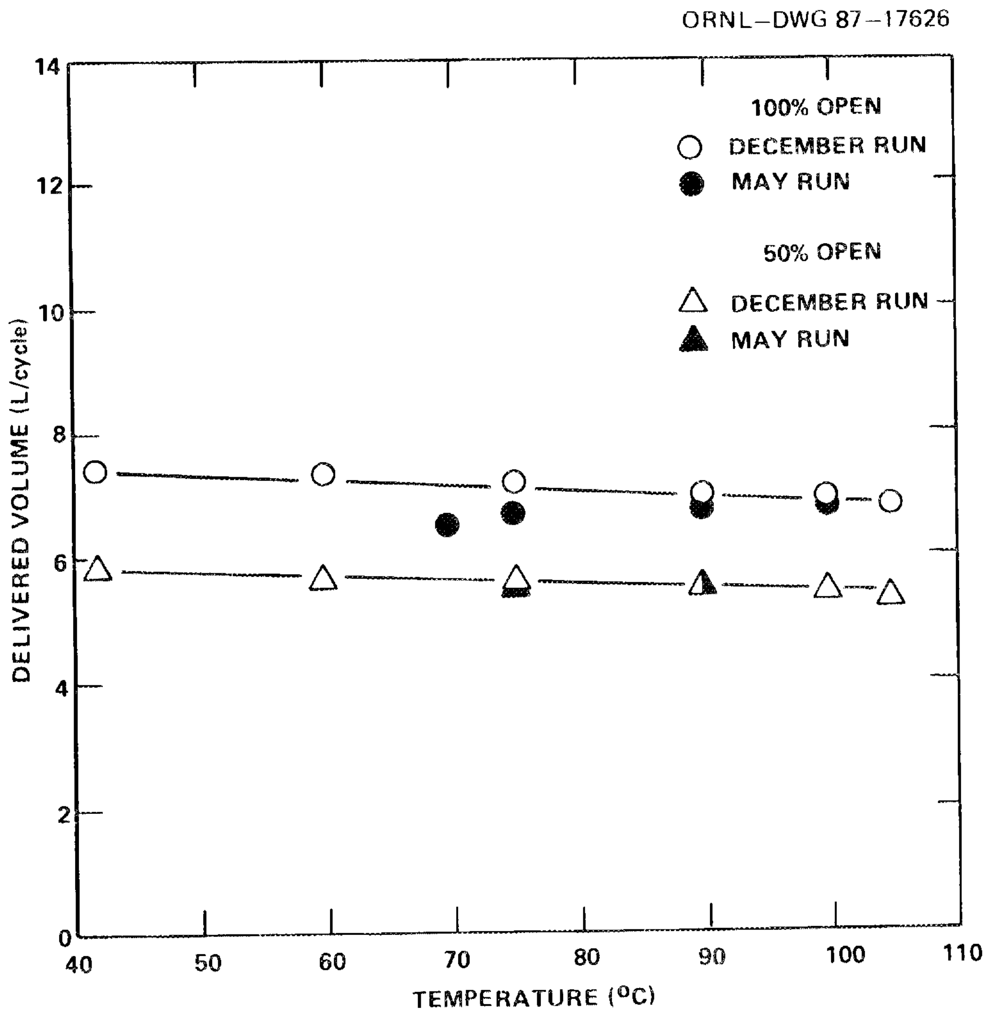

Fig. 5. Pump output at two valve settings (motivation pressure, 35 psig).

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APPENDIX A

The BASIC program FPUMP.DE2 is used to predict pump performance under various external system conditions using the calibration curve for this specific bottom-loading pump. Changing the internal geometry, such as discharge tube diameter, drastically changes pump performance. A new calibration curve should be determined if design changes are made. The program can then be used with the new data.

APPENDIX A

```
LIST
10 REM THIS IS FPUMP.DE2
20 PRINT "FPUMP.DE2"
30 PRINT "  THE PUMP IS A BOTTOM LOADER OF 4 INCH DIAM"
40 REM PUMP CALCULATIONS
50 D1 = 4
60 D3 = .35
70 PRINT "I NEED LEVEL IN PUMP (H1) IN FEET"
80 INPUT H1
90 PRINT "I NEED REFILL HEAT (H2) IN FEET"
100 INPUT H2
110 PRINT "I NEED DELIVERED HEAT (H3) IN FEET"
120 INPUT H3
130 PRINT "I NEED DELIVERY LINE LENGTH (L1) IN FEET"
140 INPUT L1
150 PRINT "I NEED DELIVERY LINE INSIDE DIAMETER (D2) IN INCHES"
160 INPUT D2
170 PRINT "I NEED MOTIVATION PRESSURE (P1) IN PSIG"
180 INPUT P1
190 PRINT "I NEED FITTING LOSS COEFFICIENT (K1)"
200 INPUT K1
210 PRINT "I NEED FLUID DENSITY (R1) IN LBS/FT3"
220 INPUT R1
230 PRINT "I NEED FLUID VISCOSITY (M1) IN CENTIPOISE"
240 INPUT M1
250 P = 3.1416
260 P2 = R1*H2/144
270 P9 = P1 - P2
280 C2 = .772 - .0014*P9
290 A1 = P/4*D3^2/144
300 G1 = 32.17
310 A2 = P/4*D2^2/144
320 M1 = M1*6.72/10000
330 V1 = P*D1^2/4/144*H1
340 Q1 = C2*A1*SQR ((2*(P1-P2)/R1*G1))*12
350 T1 = V1/Q1
360 PRINT "Q1 = "; Q1;" T1 = ";T1 ;" SECONDS TO EMPTY"
370 REM CORRECTION FOR SHORTER PUMP TIMES FOLLOWS
380 T11 = 10
390 IF P1 >50 THEN T11 = 9
400 IF T11>T1 THEN 440
410 V1 = T11/T1*V1
420 T1 = T11
430 GOTO 460
```

```
440 PRINT "BLOWOUT OCCURS ACCORDING TO CALCULATIONS"
450 REM CORRECTION ENDS
460 Q1 = V1/T1
470 PRINT "Q1 = "; Q1;" T1 = "T1 ;" SECONDS ACTUALLY PUMPED"
480 PRINT "INITIAL SPLIT GUESS PLEASE"
490 INPUT Q2
500 Q3 = Q2*Q1
510 V2 = Q3/A2
520 R2 = D2/12*V2*R1/M1
530 F1 = .0791/(R2^.25)
540 IF R2<2100 THEN F1=16/R2
550 Z1 = R1*4*F1*L1/D2*12*V2^2/(2*G1)/144
560 Z2 = R1*H3/144
570 Z3 = K1*V2^2/(2*G1)/144*R1
580 Z5 = Z1+Z2+Z3
590 P3 = Z5
600 P4 = (P3-P2)/(P1-P2)
620 IF P4<.725 THEN 650
630 Q4 = -14.38*P4^2+20.5*P4-6.61
640 GOTO 660
650 Q4 = -.7776*P4^2+9.794999E-02*P4+1.057
660 PRINT "HERE IS QS" ,Q2,Q4
670 PRINT "MORE? IF NO, ENTER ZERO; IF YES, ENTER ANOTHER VALUE"
680 INPUT M2
690 IF M2 = 0 THEN 720
700 Q2 = M2
710 GOTO 500
720 PRINT "OUTPUT"
730 PRINT "RE =" ,R2
740 PRINT " DPTOT IS" ,Z5
750 PRINT " SPLIT IS" Q2
760 PRINT "PTERM IS" P4
770 PRINT "TPUMP = "T1
780 Z6 = V1*Q2*28.316
790 PRINT "LITERS/CYCLE =",Z6
800 PRINT
810 PRINT
820 PRINT
830 PRINT "CALCULATED RESULTS"
840 PRINT
850 PRINT "TEST CONDITIONS"
860 PRINT
870 PRINT
880 PRINT "TYPE = BOTTOM-LOADED"
890 PRINT
900 PRINT " PUMP DIAM = ";D1; " PUMP HT = ";H1; " RESV HT = ";H2
910 PRINT "DELIV LINE LENGTH = ";L1;" DELIV LINE DIAM = ";D2
```

```
920 PRINT " DRIVING PRESS = ";P1; " NOZZLE DIAM = ";D3
930 PRINT " FITTING LOSS COEFF = ";K1
940 PRINT "DENSITY = ";R1;
950 PRINT "VISCOSITY = ";M1/.000672; "THE HEAD IS";H3;"FEET"
960 PRINT
970 PRINT
980 PRINT " NOW DO YOU WANT FILL TIMES AND TOTAL "
990 PRINT " CYCLE PERFORMANCE....."NO=0, YES=1"
1000 PRINT
1010 INPUT B7
1020 IF B7 = 0 THEN 1480
1030 IF D3><.35 OR D1><4 THEN 1140
1040 REM REFILL TIME - CURVES, TIME VS. REFILL HEAD.....
1050 IF H2<4.5 AND H2>3.999 THEN 1090
1060 IF H2<3.999 THEN 1110
1070 T7 = 44.6*(H2^.5 - (H2-4)^.5)
1080 GOTO 1170
1090 T7 = 39.9*(H2^.5 - (H2-4)^.5)
1100 GOTO 1170
1110 T7 = 36.7*H2^.5
1120 GOTO 1170
1130 REM CALCULATE REFILL TIME
1140 A7=P/4*D1^2/144
1150 K7 = .73*A1/A7*SQR(2*G1)
1160 T7 = 2/K7*(SQR(H2)-SQR(H2-H1))
1170 PRINT "FILLING TO A HEIGHT OF ";H1; " FEET TAKES ";T7; " SECONDS"
1180 PRINT
1190 PRINT
1200 T9 = T7 + T1
1210 PRINT " THE TOTAL CYCLE TIME IS";T9;"SECONDS"
1220 R7 = V1/T9*Q2
1230 R8 = R7*28.316*3600
1240 PRINT
1250 PRINT
1260 PRINT "AVG PUMPING RATE IS ".87;" FT3/SEC OR "88;"LITERS/HR"
1270 PRINT
1280 PRINT
1290 "WOULD YOU LIKE VALUES CORRECTED FOR "
1300 PRINT " DISCHARGE LINE VOLUME?"
1310 PRINT " YES = 1, NO = 0 "
1320 INPUT M6
1330 IF M6 = 0 THEN 1480
1340 V6 = (L1+1)*A2
1350 V7 = V6*28.316
1360 V8 = Z6 - V7
1370 PRINT "CORRECTED LITERS/CYCLE IS ";V8
1380 PRINT
```

```
1390 PRINT " AMOUNT OF FALLBACK IS " ;V7;" LITERS"
1400 R9 = V8/T9*3600
1410 PRINT
1420 PRINT " ACTUAL PUMPING RATE IS ";R9;"LITERS/HOUR"
1430 PRINT " INDIVIDUAL RESISTANCES, PSI "
1440 PRINT " DELIVERY LINE FRICTION HEAD, Z1 = ";Z1
1450 PRINT " VERTICAL HEAD, Z2= ";Z2
1460 PRINT "DROP THRU FITTINGS,Z3=";Z3
1470 PRINT "TOTAL HEAD LOSS,Z5=";Z5
1480 END
0
```

APPENDIX B

This is the result of running the predictive program FPUMP.DE2 for Run #2 with a motivation pressure of 33.2 psig.

APPENDIX B

RUN
FPUMP.DE2
THE PUMP IS A BOTTOM LOADER OF 4 INCH DIAM
I NEED LEVEL IN PUMP (H1) IN FEET
? 4
I NEED REFILL HEAD (H2) IN FEET
? 8.33
I NEED DELIVERED HEAD (H3) IN FEET
? 7.25
I NEED DELIVERY LINE LENGTH (L1) IN FEET
? 18.92
I NEED DELIVERY LINE INSIDE DIAMETER (D2) IN INCHES
? .68
I NEED MOTIVATION PRESSURE (P1) IN PSIG
? 33.2
I NEED FITTING LOSS COEFFICIENT (K1)
? 13.5
I NEED FLUID DENSITY (R1) IN LBS/FT3
? 87.61
I NEED FLUID VISCOSITY (M1) IN CENTIPOISE
? 1.32
Q1 = 2.669843E-02 T1 = 13.07443 SECONDS TO EMPTY
Q1 = 2.669843E-02 T1 = 10 SECONDS ACTUALLY PUMPED
INITIAL SPLIT GUESS PLEASE
? .87
HERE IS QS .87 .8668727
MORE? IF NO, ENTER ZERO; IF YES, ENTER ANOTHER VALUE
? .868
HERE IS QS .868 .8688608
MORE? IF NO, ENTER ZERO; IF YES, ENTER ANOTHER VALUE
? .8684
HERE IS QS .8684 .8684644
MORE? IF NO, ENTER ZERO; IF YES, ENTER ANOTHER VALUE
? 0
OUTPUT
RE = 51451.42
DPTOT IS 20.80489
SPLIT IS .8684
PTERM IS .5593946
TPUMP = 10
LITERS/CYCLE = 6.56504

CALCULATED RESULTS

TEST CONDITIONS

TYPE = BOTTOM-LOADED

PUMP DIAM = 4 PUMP HT = 4 RESV HT = 8.33
DELIV LINE LENGTH = 18.92 DELIV LINE DIAM = .68
DRIVING PRESS = 33.2 NOZZLE DIAM = .35
FITTING LOSS COEFF = 13.5
DENSITY = 87.61 VISCOSITY = 1.32 THE HEAD IS 7.25 FEET

NOW DO YOU WANT FILL TIMES AND TOTAL
CYCLE PERFORMANCE.....NO = 0, YES = 1

FILLING TO A HEIGHT OF 4 FEET TAKES 35.91676 SECONDS

THE TOTAL CYCLE TIME IS 45.91677 SECONDS

AVG PUMPING RATE IS 5.049335E-03 FT3/SEC OR 514.7171 LITERS/HR

WOULD YOU LIKE VALUES CORRECTED FOR
DISCHARGE LINE VOLUME?
YES = 1, NO = 0
? 1
CORRECTED LITERS/CYCLE IS 5.14249

AMOUNT OF FALLBACK IS 1.42255 LITERS

ACTUAL PUMPING RATE IS 403.1853 LITERS/HOUR
INDIVIDUAL RESISTANCES, PSI
DELIVERY LINE FRICTION HEAD, Z1 = 5.605435
VERTICAL HEAD, Z2 = 4.41092
DROP THRU FITTINGS,Z3= 10.78853
TOTAL HEAD LOSS,Z5= 20.80489
0

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