CRWMS/M&O

Non-Q Design Analysis Cover Sheet

Complete only applicable items.

(1.) QA: N/A

Page: 1 Of: 6

(SCPB: N/A)

2. DESIGN ANALYSIS TITLE		
NORTH PORTAL - HOT WATER CIRCULATION PUMP CALCULATION - CHANGE HOUSE FACILITY #5008		
3. DOCUMENT IDENTIFIER (Including Rev. No.) BABBAF000-01717-0200-00158 REV 01	4. REV. NO. 01	5. TOTAL PAGES 6
6. TOTAL ATTACHMENTS 2	7. ATTACHMENT NUMBERS - NO. OF PAGES IN EACH I-6, II-2	8. SYSTEM ELEMENT MGDS

	Print Name	Signature	Date
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13. Remarks

2. DESIGN ANALYSIS TITLE

NORTH PORTAL - HOT WATER CIRCULATION PUMP CALCULATION - CHANGE HOUSE FACILITY #5008

3. DOCUMENT IDENTIFIER (Including Rev. No.)

BABBAF000-01717-0200-00158 REV 01

4. Revision No.	5. Description of Revision
00	Initial Issue
01	Reformatted per NAP-MG-013, Rev. 0 Revision Title Removed TBV-122 Changed QA Classification from TBV to QA: N/A Editorial changes

1. PURPOSE

The purpose of this design analysis and calculation is to size and select a circulating pump for the Change House Facility hot water system, in accordance with the Uniform Plumbing Code (Section 4.4.1) and U.S. Department of Energy Order 6430.1A-1540 (Section 4.4.2).

2. QUALITY ASSURANCE

This analysis is non-Q because it is for a temporary item. The Determination of Importance Evaluation (Reference 5.1) of the Change House Facility has determined that no quality assurance (QA) controls are applicable within the context of this analysis.

3. METHOD

The method used for the calculations is based on Reference 5.2. The first step is to determine the total heat loss from the service hot water system piping to the surrounding environment. The heat loss is then used to define the total pumping capacity based on a temperature change in the circulating hot water. The total pumping capacity is used to tentatively select a pump model from manufacturer's literature. This establishes the head generation for that given capacity and particular pump model. The total length of all hot water supply and return piping including fittings is then estimated from the plumbing drawings which defines the pipe friction losses. Several iterations may be required before a pump can be selected that satisfies the head - capacity requirements.

4. DESIGN INPUTS

4.1 DESIGN PARAMETERS

Water temperature at most remote outlet = 110 degrees F (Reference 4.4)

Ambient Temperature = 70 degrees F (Reference 4.4)

Flow Velocity = 5 feet/second (Reference 5.4)

Length of Pipe:	1/2"	=	107 feet	(Reference 5.7)
(Attachment I)	3/4"	=	121 feet	(Reference 5.7)
	1"	=	115 feet	(Reference 5.7)
	1-1/4"	=	98 feet	(Reference 5.7)
	1-1/2"	=	162 feet	(Reference 5.7)

4.2 CRITERIA

The Plumbing Design for the Change House Facility will be designed in accordance with DOE Order 6430.1A (Section 4.4.2) and appropriate state and local codes (ESFDR Sections 3.2.1Q, 3.2.1R, and 3.2.1S, Reference 5.8).

4.3 ASSUMPTIONS

Not used.

4.4 CODES AND STANDARDS

4.4.1 International Association of Plumbing and Mechanical Officers:

UPC 1991 — Uniform Plumbing Code

4.4.2 U.S. Department of Energy (DOE):

DOE Order 6430.1A-89 — General Design Criteria

5. REFERENCES

5.1 BABBA0000-01717-2200-00007 Rev 00, Determination of Importance Evaluation for ESF Change House Facility and Shop Building

5.2 1991 American Society of Heating, Refrigeration, and Air Conditioning Engineers Handbook, HVAC Applications I-P Edition, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.

5.3 Michael R. Lindeburg, P.E., Mechanical Engineering Reference Manual, Eighth Edition, Professional Publications, Inc., 1990

5.4 Crane Technical Paper No. 410, "Flow of Fluids," Crane Co., 1988

5.5 American Society of Heating, Refrigeration, and Air Conditioning Engineers/Illuminating Engineering Society of North America Standard 90.1b, Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings, 1992

5.6 Mohinder L. Nayyar, P.E., Piping Handbook, Sixth Edition, McGraw-Hill, Inc.

5.7 Plumbing Drawings:

5.7.1 BABBAF000-01717-2100-27150-01 Change House - Bldg 5008 Plumbing Isometrics and Details

5.7.2 BABBAF000-01717-2100-27151-00 Change House - Bldg 5008 Plumbing and Piping Plan

5.7.3 BABBAF000-01717-2100-27152-00 Change House - Bldg 5008 Plumbing Enlarged Plans

5.8 Yucca Mountain Site Characterization Project Exploratory Studies Facility Design Requirements, YMP/CM-0019, REV. 1, ICN 3

5.9 Grundfos Pumps Corporation Bulletin L-UP-TL-007, Dated 1/15/93

6. USE OF COMPUTER SOFTWARE

Not used.

7. DESIGN ANALYSIS

The radial heat flow out of an insulated pipe can be expressed as follows:

$$q = \frac{2\pi L \Delta T}{\frac{1}{r_a h_a} + \frac{\ln\left(\frac{r_b}{r_a}\right)}{k_{pipe}} + \frac{1}{r_b h_b} + \frac{\ln\left(\frac{R_C}{r_b}\right)}{k_{ins}} + \frac{1}{r_c h_c}} \qquad \text{(Eq. 1)}$$

Where film coefficient, h_a water= 150 (British thermal unit) BTU/feet^2 - F (Reference 5.3)

h_b = 0 (no film between pipe and insulation)

h_c, still air = 1.65 BTU/feet^2 - F (Reference 5.3)

radius r_a, pipe I.R. = 0.0427 feet (Reference 5.3)

r_b, pipe O.R. = 0.0468 feet (Reference 5.3)

r_c, insulation O.R.= 0.130 feet (Derived)

thermal conductivity, k_{ins}, insulation = 0.0233 BTU/feet - F (Reference 5.5)

k_{pipe}, pipe = 200 BTU/feet - F (Reference 5.6) length of pipe, L = 600 feet of 1 inch based on weighted average (Attachment I)

Solving Equation (1) for the heat loss through the insulated pipe, q = 3,097 BTU.

The water flow rate in gal/min to remove the heat q is defined as

$$Q = q/500 \ \Delta T \qquad \text{(Eq. 2)}$$

where ΔT is the difference in temperature of the water leaving and returning to the water heater. The water flow limitation in piping systems is related to the velocity of flow and/or pressure drop which affects pumping costs. To minimize the effects of high velocities, the ΔT in the hot water return is limited to 2 degrees, which is reasonable for an insulated small diameter pipe for service hot water. By substituting the heat loss and ΔT into Eq. 2, a flow rate of 3.1 gallons per minute (gpm) results. The velocity of flow is approximately 5 feet/second and the friction loss is 8 pound per square inch/100 feet of pipe length if ½ inch copper tubing is the minimum size used in the hot water return as shown in Figure 1, Page I-3, Attachment I, which is extracted from the UPC (Reference 4.4.2). However, as shown in Attachment I the use of some ½ inch tubing in the return results in a relatively high pressure drop. The minimum size tubing was increased to 3/4 inch which resulted in the selection of a circulating pump closely matching the required performance.

8. CONCLUSIONS

The hot water circulating pump performance requirements are approximately 3.1 gpm at a system head of 11.44 feet. A Grundfos closed system pump Model UPS 15-42F shown in Attachment II was selected as the design basis for the hot water return in the Change House. The pump is rated at 1/25 horsepower at 115 V.

The minimum pipe size is 3/4 inch Type L copper water tubing. The pipe is designed for a minimum of 1 inch thick insulation for added energy conservation while maintaining a hot water return temperature of 108 degrees F.

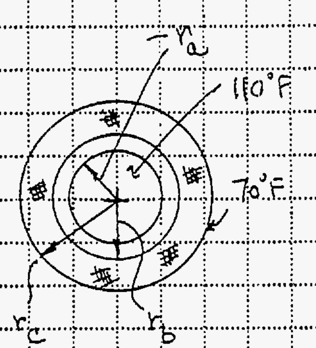
9. ATTACHMENTS

ATTACHMENT	TITLE
I	Calculations
II	Grundfos Pump Data Sheet

CALCULATIONS

FOR HEAT TRANSFER FROM AN INSULATED PIPE

$$q = \frac{2\pi \, \Delta T \, L}{\frac{1}{r_a h_a} + \frac{\ln(r_b/r_a)}{K_{PIPE}} + \frac{1}{r_b h_b} + \frac{\ln(r_c/r_b)}{K_{INS}} + \frac{1}{r_c h_c}} \quad \text{(EQ. 1)}$$



PIPE SIZE	LGTH	ELLS	TEES
1 1/2"	162'	6	7
1 1/4"	98	1	2
1"	115	6	2
3/4"	121	3	4
1/2"	107	16	Ø

WEIGHTED AVERAGE PIPE SIZE

$$\frac{1.5(162) + 1.25(98) + 1(115) + .75(121) + .5(107)}{162 + 98 + 115 + 121 + 107} = 1.04''$$

USE 1" FOR CALCS

CALCULATIONS (Continued)

$r_a = 1.025/2 = .512'' = .0427'$ (REF 5.3 APP G, PG 3-43)

$r_b = 1.125/2 = .562'' = .0468'$

$r_c = 1.125/2 + 1 = 1.562'' = .130'$ INCLUDES 1" THK INSULATION

$h_a = 156$ BTUH/FT² - °F (REF 5.3)

$h_b = 0$

$h_c = 1.65$ BTUH/FT² - °F (REF 5.3)

$K_{INS} = .0233$ BTUH/FT - °F (REF 5.5)

$K_{PIPE} = 200$ BTUH/FT - °F (REF 5.6)

BY SUBSTITUTION, q = 3,097 BTUH

THE WATER FLOW RATE TO REMOVE 3,097 BTUH IS AS FOLLOWS:

$$Q = \frac{q}{500\ \Delta T} = \frac{3{,}097}{500\ \Delta T} = \frac{6.194}{\Delta T}$$

LIMIT ΔT TO 2° FOR ENERGY CONSERVATION (PUMPING POWER)

$$\therefore\ Q = \frac{6.194}{2} = 3.097\ \text{GPM}$$

FROM PG I-4 (REF 5.4) THE VELOCITY WHEN FLOWING 3.1 GPM IN A 1/2" TYPE L COPPER TUBE IS 4.5 FPS

CALCULATIONS (Continued)

ALSO, FROM PG I-4 THE ΔP = 8+ PSI/100 FT

THE TOTAL PRESSURE DROP USING PIPE SIZES FROM PG AND FRICTION LOSSES FROM PG 15 ;

1 1/2"
162' LENGTH = 162
6 - ELLS @ 5' EA = 30
7 - TEES @ 7' EA = 49
241 EQ LGTH

ΔP = 241' x .01 PSI/100' = 0.024 PSI

1 1/4"
98' LENGTH = 98
1 - ELL @ 4' EA = 4
2 - TEES @ 6' EA = 12
114 EQ LGTH

ΔP = 114' x .015/100 = 0.017 PSI

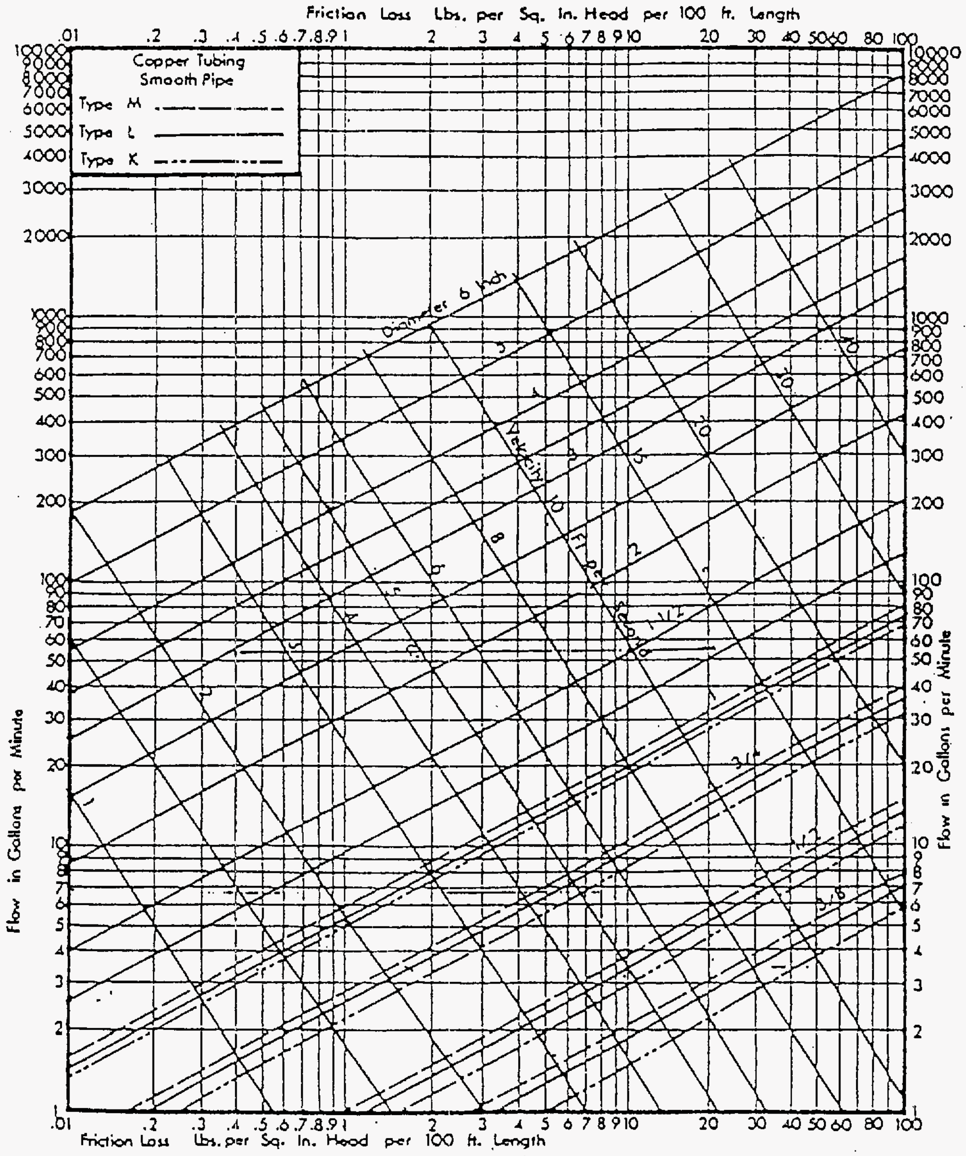
1"
115' LENGTH = 115
6 - ELLS @ 3' EA = 18
2 - TEES @ 5' EA = 10
143' EQ LGTH

ΔP = 143 x .38/100 = 0.54 PSI

3/4"
121' LENGTH = 121
3 - ELLS @ 2.5' EA = 7.5
4 - TEES @ 4' EA = 16
145' EQ LGTH

ΔP = 145 x 1.5/100 = 2.17 PSI

CALCULATIONS (Continued)
(REFERENCE 5.4)



CALCULATIONS (Continued)

1/2"

107' LENGTH	=	107
16-ELLS @ 2' EA	=	32
		139' EQ LGTH

$\Delta P = 139' \times 8 \text{ PSI}/100' = 11.12 \text{ PSI}$

TOTAL PRESSURE DROP = 13.87 PSI = 32.0 FT

A REVIEW OF PUMP PERFORMANCE DATA ON PG INDICATES THAT ONE PUMP (UP 26-99 F) BARELY MEETS REQUIREMENTS.

SINCE MOST OF THE FRICTION LOSSES OCCUR IN THE 1/2" TUBE SIZE THE PRESSURE DROP WILL BE EVALUATED USING 3/4" IN LIEU OF THE 1/2".

107' LENGTH	=	107
16-ELLS @ 2.5' EA	=	40
		147'

$\Delta P = 147' \times 1.5 \text{ PSI}/100' = 2.20 \text{ PSI}$

REVISED ΔP = 4.951 PSI = 11.44 FT

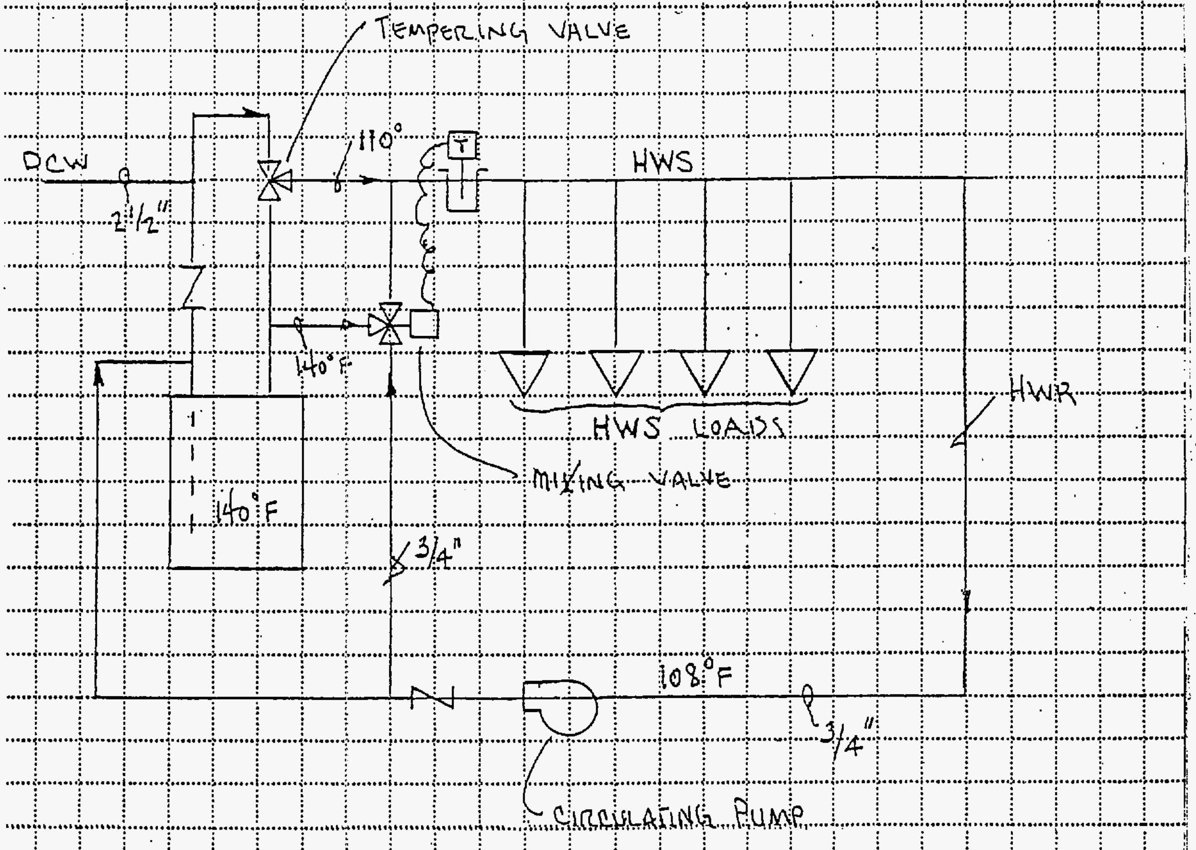
BASED ON REVISED ΔP A UPS 15-42F PUMP MEETS THE H-Q REQUIREMENTS. THIS IS A 1/25 HP PUMP AT 115 V.

TEMPERATURE OF RETURN WATER

$$\Delta T = \frac{3097}{500 \times 3.1} = 1.998^{\circ}$$

$T_2 = 110 - 2 = 108^{\circ}F$

CALCULATIONS (Continued)



LEGEND:

DCW = DOMESTIC COLD WATER
HWS = HOT WATER SUPPLY
HWR = HOT WATER RETURN
WH = WATER HEATER
T = TEMPERATURE SENSOR

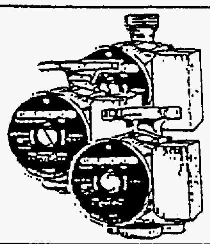
GRUNDFOS PUMP DATA SHEET
(REFERENCE 5.9)

GRUNDFOS

Wet-rotor, in-line, single stage, maintenance free, circulator pumps

Series UP
OPEN & CLOSED SYSTEMS

Submittal Data — 60 Cycle



JOB or CUSTOMER:
ENGINEER:
CONTRACTOR:
SUBMITTED BY: DATE:
APPROVED BY: DATE:
ORDER NO.: DATE:
SPECIFICATION REF.:

QUANTITY	TAG NO.	MODEL NO.	GPM	FEET	VOLT	PHASE	COMMENTS

Technical Data (For open and closed system applications)

FLOW RANGE: 0 to 45 U.S. GPM
HEAD RANGE: 0 to 30 Feet
MOTOR: 2 Pole, Single Phase
MIN. FLUID TEMP.: 50°F (10°C)
MAX. FLUID TEMP. – OPEN SYSTEMS: 140°F (60°C)

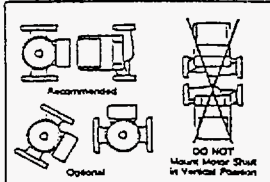
MAX. WORKING PRESSURE: 145 PSI
MIN. REQUIRED INLET PRESSURE:

190°F (88°C)	165°F (74°C)	140°F (60°C)
5 ft. (1.5m)	4.5 ft. (1.4m)	3 ft. (.9m)
2.2 psi	1.9 psi	1.3 psi

MAX. FLUID TEMP. – CLOSED SYSTEMS:

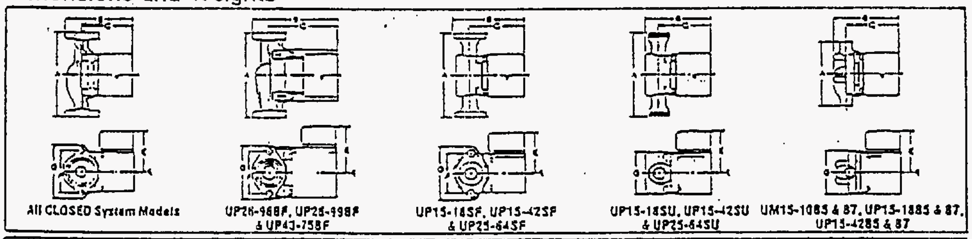
AMBIENT AIR TEMP.	104°F (40°C)	120°F (49°C)	140°F (60°C)	160°F (71°C)	175°F (79°C)
MAX. WATER TEMP.	230°F (110°C)	220°F (104°C)	210°F (99°C)	190°F (88°C)	175°F (79°C)

Mounting Positions



FOR INDOOR USE ONLY

Dimensions and Weights



CLOSED System Models	A	B	C	D	E	F①	Connection Type and Size	Shipping Wt. (Lbs.)
UP15-42F/FR (8RUTa) & UPS15-42F	6 ½	5 ¼	4	4 3/16	3 ¼	3 5/32	FLANGE – (2) ½" dia. bolt holes	7 ¼
UP26-64F & UP26-96F	6 ½	6 3/8	5 1/16	4 1/8	3 ½	3 5/32	FLANGE – (2) ½" dia. bolt holes	11 ¼
UP26-99F	6 ½	6 3/8	5 1/16	4 1/8	3 ½	3 5/32	FLANGE – (2) ½" dia. bolt holes	2 ½
UP43-75F	8 ½	6 11/16	5 3/16	4 ¾	3 ½	3 7/16	FLANGE – (2) ½" dia. bolt holes	13 ½

OPEN System Models	A	B	C	D	E	F①	Connection Type and Size	Shipping Wt. (Lbs.)
UM15-1085	5	4 11/16	4	4	3 ½	—	SWEAT – ¾"	5 ¾
UM15-1087	6 3/8	5 1/8	4	3 11/16	3 ¼	—	SWEAT – ¾"	6
UP15-18SU & UP15-42SU	6	5 1/16	4	3 7/16	3 ¼	—	UNION – 1¼ NPSM	5
UP15-18SF & UP15-42SF	6 ½	5 ¼	4	4 3/16	3 ¼	3 5/32	FLANGE – (2) ½" dia. bolt holes	5 ¾
UP15-1885 & UP15-4285	5	4 11/16	4	3 7/16	3 ¼	—	SWEAT – ¾"	5 ¾
UP15-1887 & UP15-4287	6 ¾	5 1/8	4	3 11/16	3 ¼	—	SWEAT – ¾"	6
UP25-64SU	5 7/8	5 13/16	4 13/16	4	3 ½	—	UNION – 1¼ NPSM	9 ¾
UP25-64SF	6 ½	6 1/16	4 13/16	4 3/16	3 ½	3 5/32	FLANGE – (2) ½" dia. bolt holes	10
UP26-96BF	6 ½	5 3/8	5 1/16	4 1/8	3 ½	3 5/32	FLANGE – (2) ½" dia. bolt holes	11 ¾
UP26-99BF	6 ½	6 3/8	5 1/16	4 1/8	3 ½	3 5/32	FLANGE – (2) ½" dia. bolt holes	12 ½
UP43-75BF	8 ½	6 11/16	5 3/16	4 ¾	3 ½	3 7/16	FLANGE – (2) ½" dia. bolt holes	14 ¼

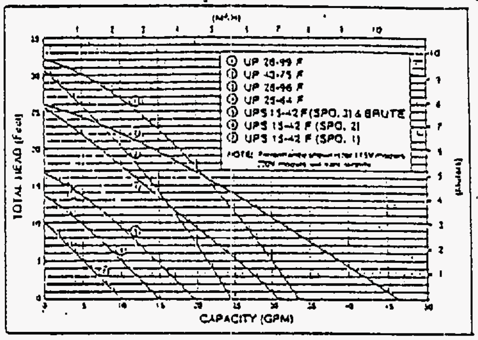
NOTES: All dimensions are in inches. ① "F" dimension is the flange bolt centerline to centerline.

GRUNDFOS PUMP DATA SHEET (Continued)

Performance

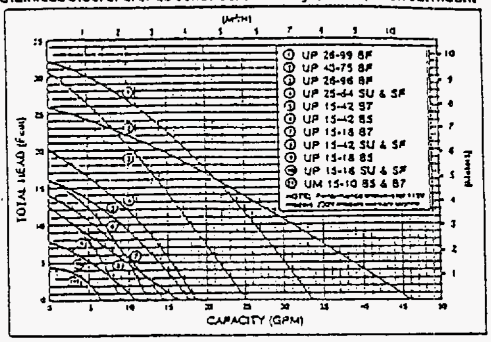
CLOSED System Models

Cast iron construction – flange mount



OPEN System Models

Stainless steel or bronze construction – flange, union, or sweat mount



Electrical Data

CLOSED System Models

MODEL	VOLTS	AMPS	WATTS	HP	CAPACITOR
UP15-42F/FR (BRUTE)	115 230	.74 .43	85 95	1/25 1/25	10μF/180V 2μF/400V
UPS15-42F (115V) Spd. 3 Spd. 2 Spd. 1	115 115 115	.74 .57 .40	85 65 45	1/25 1/25 1/25	10μF/180V 10μF/180V 10μF/180V
UPS15-42F (230V) Spd. 3 Spd. 2 Spd. 1	230 230 230	.43 .19 .14	95 40 30	1/25 1/25 1/25	2μF/400V 2μF/400V 2μF/400V
UP26-64F	115 230	1.70 .30	185 175	1/12 1/12	8μF/180V 2.5μF/380V
UP26-96F	115 230	1.70 .30	205 205	1/12 1/12	10μF/180V 2.5μF/380V
UP26-99F	115 230	2.15 1.07	245 245	1/6 1/6	10μF/180V 2.5μF/380V
UP43-75F	115 230	2.15 1.07	215 220	1/6 1/6	10μF/180V 2.5μF/380V

NOTE: All UP models are single speed except for the 3-speed UPS15-42F, 115 and 230 volt.

OPEN System Models

MODEL	VOLTS	AMPS	WATTS	HP	CAPACITOR
UM15-10BS & B7	115	.40	38	1/25	14μF/100V
UP15-18SU, SF, & BS	115 230	.74 .40	85 90	1/25 1/25	10μF/180V 2μF/400V
UP15-18B7	115 230	.74 .40	85 96	1/25 1/25	10μF/180V 2μF/400V
UP15-42SU, SF, & BS	115 230	.74 .41	85 95	1/25 1/25	10μF/180V 2μF/400V
UP15-42B7	115 230	.74 .41	85 95	1/25 1/25	10μF/180V 2μF/400V
UP25-64SU & SF	115 230	1.70 .80	180 175	1/12 1/12	8μF/180V 2.5μF/380V
UP26-96BF	115 230	1.70 .30	205 205	1/12 1/12	10μF/180V 2.5μF/380V
UP26-99BF	115 230	2.15 1.07	245 245	1/6 1/6	10μF/180V 2.5μF/380V
UP43-75BF	115 230	2.15 1.07	215 220	1/6 1/6	10μF/180V 2.5μF/380V

Materials of Construction

CLOSED System Models

STAINLESS STEEL: Inlet cone, bearing plate and bearing retainers, rotor can, rotor cladding, shaft retainer, and impeller (UP26 & UP43)

ALUMINUM: Stator housing.

ALUMINUM OXIDE CERAMIC: Shaft and upper and lower radial bearings.

METAL IMPREGNATED CARBON: Thrust bearing.

CAST IRON: Pump housing (volute).

EP (Ethylene Propylene Rubber): O-ring and gaskets.

PES COMPOSITE, 30% Glass Filled: impeller (UP15).

Noryl®: Terminal box.

OPEN System Models

STAINLESS STEEL: Inlet cone, bearing plate and bearing retainers, rotor can, rotor cladding, shaft retainer, impeller (UP25, 26, & 43), and pump housing (volute) on UP15-18 SU/SF, UP15-42 SU/SF, and UP25-64 SU/SF models.

ALUMINUM: Volute retainer(SU & SF models) and stator housing.

ALUMINUM OXIDE CERAMIC: Shaft and upper and lower radial bearings.

METAL IMPREGNATED CARBON: Thrust bearing.

EP (Ethylene Propylene Rubber): O-ring and gaskets.

BRONZE: Pump housing (volute) for UM15-10BS & B7, UP15-18BS & B7, UP15-42BS & B7, UP26-96BF, UP26-99BF, and UP43-75BF.

PES COMPOSITE, 30% Glass Filled: Impeller (UM10 & UP15).

Noryl®: Terminal box.

Noryl® is a registered trademark of General Electric Company.

GRUNDFOS®

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Support Centers: Allentown, PA • Atlanta, GA

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