### Non-Q Design Analysis Cover Sheet

**Complete only applicable items.**

**QA:** N/A

<table>
<thead>
<tr>
<th>Page</th>
<th>Of</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
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</tbody>
</table>

#### 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

<table>
<thead>
<tr>
<th>Print Name</th>
<th>Signature</th>
<th>Date</th>
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</table>
| R. Blackstone | [Signature]

FOR R. BLACKSTONE

1-24-96

<table>
<thead>
<tr>
<th>D. F. Vanica</th>
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1-24-96

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<th>R. E. Flye</th>
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<table>
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<th>G. N. Kimura</th>
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1-25-96

#### 13. Remarks

NAP-MG-013 (Effective 09/08/95)
# Design Analysis Revision Record

**Complete only applicable items.**

<table>
<thead>
<tr>
<th>4. Revision No.</th>
<th>5. Description of Revision</th>
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<tbody>
<tr>
<td>00</td>
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<tr>
<td>01</td>
<td>Reformatted per NAP-MG-013, Rev. 0</td>
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<td>Revision Title</td>
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<tr>
<td></td>
<td>Removed TBV-122</td>
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<tr>
<td></td>
<td>Changed QA Classification from TBV to QA: N/A</td>
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<td></td>
<td>Editorial changes</td>
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</table>
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)  
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


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


5.7 Plumbing Drawings:

- 5.7.1 BABBAF000-01717-2100-27150-01 Change House - Bldg 5008 Plumbing Isometrics and Details
6. USE OF COMPUTER SOFTWARE

Not used.

7. DESIGN ANALYSIS

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

\[
q = \frac{2\pi L d T}{1 + \frac{1}{r_a h_a} + \frac{\ln \left( \frac{r_b}{r_a} \right)}{k_{\text{pipe}}} + \frac{1}{r_b h_b} + \frac{\ln \left( \frac{r_c}{r_b} \right)}{k_{\text{ins}}} + \frac{1}{r_c h_c}}
\]  

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

\( k_{\text{pipe}} \), pipe = 200 BTU/feet - F  
(Reference 5.6)
Solving Equation (1) for the heat loss through the insulated pipe, \( q = 3,097 \text{ BTU} \).

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

\[
Q = \frac{q}{500} \Delta T \quad \text{(Eq. 2)}
\]

where \( \Delta T \) 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 \( \Delta T \) 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 \( \Delta T \) 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 \( \frac{1}{2} \) 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 \( \frac{1}{4} \) 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

<table>
<thead>
<tr>
<th>ATTACHMENT</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Calculations</td>
</tr>
<tr>
<td>II</td>
<td>Grundfos Pump Data Sheet</td>
</tr>
</tbody>
</table>
CALCULATIONS

For heat transfer from an insulated pipe:

\[ Q = \frac{1}{\ln \left( \frac{r_2}{r_1} \right)} \cdot \left( \frac{1}{\frac{1}{r_1^{n_1} - 1} + \frac{1}{r_2^{n_2} - 1} + \frac{1}{\frac{1}{r_1^{n_3} - 1} + \frac{1}{r_2^{n_4} - 1}}} \right) \]  

(\text{Eq. 1})

Pipe Size | L/1000 | ELS | Tee's
--- | --- | --- | ---
1\(\frac{1}{2}\)" | 162 | 6 | 7
1\(\frac{1}{4}\)" | 98 | 1 | 2
1" | 115 | 4 | 2
3\(\frac{1}{4}\)" | 121 | 3 | 4
1\(\frac{1}{2}\)" | 107 | 14 | 0

Weighted average pipe size:

\[ L = \frac{1.5(162) + 1.25(98) + 1(115) + 0.75(121) + 0.5(107)}{162 + 98 + 115 + 121 + 107} = 1.04" \]

Use 1" for calculations.
CALCULATIONS (Continued)

\[
\begin{align*}
V_a &= \frac{1.025}{2} = 0.5125 \text{ ft}^2 = 0.0477 \text{ (Ref. 5.3 App. G, Pg. 3-43)} \\
V_b &= \frac{1.025}{2} = 0.5125 \text{ ft}^2 = 0.0468 \\
V_c &= \frac{1.025}{2} + 2 = 1.5375 \text{ ft}^2 = 1.307 \text{ includes 1" THK. INSULATION} \\
\rho &= 1.56 \text{ BTUH/ft}^2 \cdot \text{°F} \text{ (Ref. 5.3)} \\
\rho_0 &= 0 \\
\rho_c &= 1.6 \text{ BTUH/ft}^2 \cdot \text{°F} \text{ (Ref. 5.3)} \\
K_{ins} &= 0.0233 \text{ BTUH/ft}^2 \cdot \text{°F} \text{ (Ref. 5.3)} \\
K_{pipe} &= 0.00 \text{ BTUH/ft}^2 \cdot \text{°F} \text{ (Ref. 5.6)} \\
\text{By Substitution: } Q &= 3.097 \text{ BTUH} \\
\text{The Water Flow Rate to remove 3,097 BTUH is as follows: }
\frac{Q}{\Delta T} = \frac{3.097}{500} = 6.194 \\
\text{Limit } \Delta T \text{ to 2° for Energy Conservation (Pumping Power)}
\begin{align*}
\rho &= 6.194 \\
\rho_c &= 3.097 \text{ GPM} \\
\text{From Pg. 1-4 (Ref. 5.4) the velocity when flowing 3.15 GPM in a } \frac{1}{2} \text{" Type L Copper Tube is } 45 \text{ FPS}
\end{align*}
\end{align*}
\]
### CALCULATIONS (Continued)

The total pressure drop using pipe sizes from Eq. 15:

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Length</th>
<th>Friction Losses (ft)</th>
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</thead>
<tbody>
<tr>
<td>1 1/2&quot;</td>
<td>162</td>
<td>24.1 EQ. LENGTH</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>98</td>
<td>14 EQ. LENGTH</td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&quot;</td>
<td>115</td>
<td>14.5 EQ. LENGTH</td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>121</td>
<td>14.5 EQ. LENGTH</td>
</tr>
</tbody>
</table>

\[ \Delta P = \frac{Q \times 0.015}{100} = \text{Pressure Drop} \]

\[ \Delta P = 241 \times 0.15 \text{ PSI/100 FT} = 0.024 \text{ PSI} \]

\[ \Delta P = 98 \times 0.015 \text{ PSI/100 FT} = 0.017 \text{ PSI} \]

\[ \Delta P = 115 \times 0.015 \text{ PSI/100 FT} = 0.017 \text{ PSI} \]

\[ \Delta P = 121 \times 0.015 \text{ PSI/100 FT} = 0.017 \text{ PSI} \]
CALCULATIONS (Continued)
(REFERENCE 5.4)
<table>
<thead>
<tr>
<th>Diameter</th>
<th>Length</th>
<th>$\Delta P$</th>
<th>Pressure Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot;</td>
<td>107&quot;</td>
<td>$1.39 \times 8 \text{ PSI} / \text{100 FT} = 11.12 \text{ PSI}$</td>
<td></td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>107&quot;</td>
<td>$1.47 \times 1.5 \text{ PSI} / \text{100 FT} = 2.20 \text{ PSI}$</td>
<td></td>
</tr>
<tr>
<td>Revised</td>
<td>4.95 $\text{ PSI} = 11.47 \text{ FT}$</td>
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</table>

Based on the revised AP, a UPS 15-42E pump meets the H-Q requirements. This is a 1/2" I.E. pump at 115 V.

Temperature of Return Water:

$$\Delta T = \frac{369.7}{500 \times 2.1} = 0.998^\circ F$$

$$T_2 = 110^\circ F - 2 = 108^\circ F$$
CALCULATIONS (Continued)

LEGEND:
- DCW = Domestic Cold Water
- HWS = Hot Water Supply
- HWR = Hot Water Return
- WH = Water Heater
- T = Temperature Sensor
**Performance**

**CLOSED System Models**
Cast iron construction — flange mount

**OPEN System Models**
Stainless steel or bronze construction — flange, union, or sweat mount

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**Electrical Data**

**CLOSED System Models**

<table>
<thead>
<tr>
<th>MODEL</th>
<th>VOLTS</th>
<th>AMPS</th>
<th>WATTS</th>
<th>HP</th>
<th>CAPACITOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>UP24-20RF</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP24-22T (115V)</td>
<td>115</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP24-22T (230V)</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
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<tr>
<td>UP24-24TP</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
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<td>UP24-26RF</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
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</table>

**OPEN System Models**

<table>
<thead>
<tr>
<th>MODEL</th>
<th>VOLTS</th>
<th>AMPS</th>
<th>WATTS</th>
<th>HP</th>
<th>CAPACITOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>UP15-185 &amp; 87</td>
<td>115</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP15-185, SF, &amp; 45</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP15-185T</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP15-285, SF, &amp; 45</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
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<tr>
<td>UP15-285T</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP15-445 &amp; 87</td>
<td>115</td>
<td>.16</td>
<td>35</td>
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<td>2uf 400V</td>
</tr>
<tr>
<td>UP15-445, SF, &amp; 45</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP15-445T</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP15-995 &amp; 87</td>
<td>115</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
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<tr>
<td>UP15-995, SF, &amp; 45</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
<tr>
<td>UP15-995T</td>
<td>230</td>
<td>.16</td>
<td>35</td>
<td>1/2</td>
<td>2uf 400V</td>
</tr>
</tbody>
</table>

**NOTE**: All UP models are single speed except for the 3-speed UP15-445, 115 and 230 volt.

**Materials of Construction**

**CLOSED System Models**

- **STAINLESS STEEL**: Inlet cones, bearing plate and bearing retainers, motor can, motor cladding, shaft retainer, and impeller (UP26 & UP45).
- **ALUMINUM**: Sprocket housing.
- **ALUMINUM OXIDE CERAMIC**: Shaft and upper and lower radial bearings.
- **METAL IMPREGNATED CARBON**: Thrust bearing, cast iron: Pump housing (value).
- **EP (Ethylene Propylene Rubber)**: O-ring and gaskets.
- **PES COMPOSITE**: 30% Glass filled: Impeller (UP13).

**OPEN System Models**

- **STAINLESS STEEL**: Inlet cone, bearing plate and bearing retainers, motor can, motor cladding, shaft retainer, impeller (UP26 & UP45), and pump housing (value) on UP15-185 & 87, UP15-185SF, UP15-485SF, and UP26-185 models.
- **ALUMINUM**: Valve retainers (SU & SF models) and sprocket 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 (value) for UP15-185 & 87, UP15-185SF, UP26-185SF, UP26-995SF, UP26-995SF, and UP45-725SF.
- **PES COMPOSITE**: 30% Glass filled: Impeller (U140 & UP15).

*Note:® Terminal box.*