The HYDROPAD

The Hydropad was developed to provide fluid control in process piping systems. The results are protection for piping systems from the destructive effects of water hammer produced by quick closing valves, pulsations from reciprocating pumps, and absorption of thermal fluid expansion. They have also found wide usage as accumulators in hydraulic systems.

The Hydropad acts as a shock absorber for fluid in motion. The cushion it provides absorbs kinetic energy, which provides the necessary control of fluid dynamics. This is essential to many systems.

The use of all metal, all welded construction with the almost limitless range of bellows sizes provides unequaled flexibility of capacity for any system, maximum safety to personnel, no maintenance requirements and the widest possible range of temperature and pressure limits. The Hydropad provides the best performance possible.

How to Order

To insure proper design and sizing of Hydropads for your system, as complete information as possible on the system design and flowing liquid is needed. To make preparation of this material as simple as possible, forms F-801 (Surge Suppression Data Sheet), F-802 (Pulsation Dampener Data Sheet) and F-803 (Thermal Expansion Data Sheet) have been included with this catalog. They are useful in requesting engineering recommendations and quotations from Flexicraft Industries engineers, and also for submittal when purchase orders are issued.

If you prefer, you may use the calculations provided in this catalog to select Hydropads, or simply reference the calculations to better understand Hydropad applications and sizing.

Flexicraft has been supplying industry with quality piping products for over 40 years. Our reputation for superior products and technical support sets us apart from our competition.

In addition to Hydropads, Flexicraft is a supplier of metallic and non-metallic expansion joints, braided hose, expansion loops, and other specialty piping products using bellows technologies. For more information or to order,

Contact us at:

FLEXICRAFT INDUSTRIES

800-533-1024
(312) 738-3588 • (312) 421-6327 Fax
www.flexicraft.com

or contact the representative in your area - see back cover.
Applications

Pulsation Dampening
Systems that include positive displacement pumps must control the pulsations that result from pump’s stroking action. The Hydropad is normally used on process lines to reduce the normal pressure and flow fluctuations.

Benefits
- Provides steady flow in product and proportioning additives
- Provides steady application in spraying
- Ensures full suction stroke of pump cylinders
- Eliminates splashing and foaming
- Protects system components

Surge Suppression
Pipeline surges are created by sudden changes in velocity of the liquid flowing in the system. This surging is often called “water hammer”, and can result in pressures of six times normal operating pressure. It can be caused by quick closing valves, pump start up or shut down, back surge, and other system effects. Normal Hydropad selection is made to reduce this sudden pressure rise to below one and one-half times the operating pressure of the pipeline.

Benefits
- Protects piping and fittings
- Protects valves
- Protects meters and instrumentation

Thermal Expansion
When the fluid in a closed system experiences an increase in temperature, the thermal growth of the fluid manifests itself as an increase in pressure. Since the coefficient of thermal expansion for conduit/piping materials is usually an order of magnitude (or more) less than the coefficient for most fluids, conduit expansion is insufficient to absorb all the expansion of the fluid. Unfortunately, use of devices such as burst disks or pressure relief valves may cause other problems.

Benefits
- Protects against ruptured piping and fittings from thermal expansion
- Prevents total loss of system pressure when using relief devices
- Prevents loss of process fluid when using relief devices
- Protects against contamination of the surrounding area when using relief devices
The Hydropad is a pressure vessel containing an inner expandable and collapsible bellows assembly. A suitable connection is provided to permit liquid displaced from the system to enter the inside of the bellows assembly. Inside the pressure vessel and surrounding the outside of the bellows assembly, a suitable gas, usually nitrogen, is sealed at a pressure equal to line pressure so that under normal flowing conditions the internal and external pressures on the bellows unit are equal. The housing is designed to allow for the expansion of the bellows within the shell as it absorbs surges from the main flow line, thus preventing excessive pressure and line shock.

All metal, all welded construction, using various steel and stainless steel alloys and other metals as needed to meet system requirements avoids the faults of units using rubber and other compounds in the flexible member. Standard Hydropads are suitable for almost any fluid such as water, hydraulic fluids, all hydrocarbons having viscosities below 10,000 s.s.u., liquefied gases, and a large number of corrosive chemical solutions.

All Hydropads are designed and welded to meet ASME unfired pressure vessel codes. ASME code stamping and Canadian registration are available. The attention to design and fabrication details, together with the use of inert gas as the precharging medium, assures maximum safety, particularly in systems handling inflammable or explosive fluids.

Screwed, flanged or welded connections are available.

### MATERIALS OF CONSTRUCTION

<table>
<thead>
<tr>
<th>PART</th>
<th>HYDROPAD</th>
<th>ALL STAINLESS STEEL HYDROPAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bellows Assembly</td>
<td>Type 316L Stainless</td>
<td>Type 316L Stainless</td>
</tr>
<tr>
<td>Housing</td>
<td>Carbon Steel</td>
<td>Type 304 Stainless</td>
</tr>
<tr>
<td>Entrance Connection</td>
<td>Type 316L Stainless</td>
<td>Type 316L Stainless</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>-20° F. to +650° F.</td>
<td>-325° F. to +1200° F.</td>
</tr>
</tbody>
</table>

Individual parts can be supplied with any weldable metal, including monel, inconel and others.
## Selection Charts

### STANDARD SERIES HYDROPADS

#### 200 PSI

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>NOMINAL GAS CAPACITY, Ccu-in</th>
<th>FLUID DISPLACEMENT C₂ (Max) cu-in</th>
<th>HOUSING</th>
<th>ENTRANCE CONNECTION* SIZE, NPS</th>
<th>APPROX. WT (LBS)</th>
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</thead>
<tbody>
<tr>
<td>11</td>
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<td>10-1/2&quot;</td>
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<tr>
<td>12</td>
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<td>120</td>
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<td>2&quot; Nipple</td>
<td>60</td>
</tr>
<tr>
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<td>3&quot; Flange</td>
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<tr>
<td>17</td>
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<td>6,000</td>
<td>24&quot;</td>
<td>4&quot; Flange</td>
<td>570</td>
</tr>
<tr>
<td>175</td>
<td>25,000</td>
<td>15,000</td>
<td>42&quot;</td>
<td>6&quot; Flange</td>
<td>2200</td>
</tr>
<tr>
<td>18</td>
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<td>48&quot;</td>
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</table>

#### 500 PSI

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>NOMINAL GAS CAPACITY, Ccu-in</th>
<th>FLUID DISPLACEMENT C₂ (Max) cu-in</th>
<th>HOUSING</th>
<th>ENTRANCE CONNECTION* SIZE, NPS</th>
<th>APPROX. WT (LBS)</th>
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<tbody>
<tr>
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<td>120</td>
<td>10-3/4&quot;</td>
<td>2&quot; Nipple</td>
<td>85</td>
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<tr>
<td>23</td>
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<td>2&quot; Nipple</td>
<td>175</td>
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<td>36&quot;</td>
<td>4&quot; Flange</td>
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<td>275</td>
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<td>15,000</td>
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#### 1000 PSI

<table>
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<tr>
<th>MODEL NO.</th>
<th>NOMINAL GAS CAPACITY, Ccu-in</th>
<th>FLUID DISPLACEMENT C₂ (Max) cu-in</th>
<th>HOUSING</th>
<th>ENTRANCE CONNECTION* SIZE, NPS</th>
<th>APPROX. WT (LBS)</th>
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<tbody>
<tr>
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<td>10-1/2&quot;</td>
<td>1&quot; Flange</td>
<td>100</td>
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<td>200</td>
<td>120</td>
<td>10-1/2&quot;</td>
<td>1&quot; Flange</td>
<td>125</td>
</tr>
<tr>
<td>33</td>
<td>500</td>
<td>300</td>
<td>16&quot;</td>
<td>1&quot; Flange</td>
<td>250</td>
</tr>
<tr>
<td>34</td>
<td>1,000</td>
<td>600</td>
<td>16&quot;</td>
<td>1&quot; Flange</td>
<td>300</td>
</tr>
<tr>
<td>35</td>
<td>2,000</td>
<td>1,200</td>
<td>24&quot;</td>
<td>1&quot; Flange</td>
<td>600</td>
</tr>
<tr>
<td>36</td>
<td>50,000</td>
<td>30,000</td>
<td>24&quot;</td>
<td>1&quot; Flange</td>
<td>675</td>
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#### 3000 PSI

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>NOMINAL GAS CAPACITY, Ccu-in</th>
<th>FLUID DISPLACEMENT C₂ (Max) cu-in</th>
<th>HOUSING</th>
<th>ENTRANCE CONNECTION* SIZE, NPS</th>
<th>APPROX. WT (LBS)</th>
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<tbody>
<tr>
<td>41</td>
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<td>10-3/4&quot;</td>
<td>1&quot; Flange</td>
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<td>200</td>
<td>120</td>
<td>10-3/4&quot;</td>
<td>1&quot; Flange</td>
<td>275</td>
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<tr>
<td>43</td>
<td>500</td>
<td>300</td>
<td>16&quot;</td>
<td>1&quot; Flange</td>
<td>700</td>
</tr>
</tbody>
</table>

* Other connection sizes and types (nipples, welding ends, flanges) available on request.

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**Diagram:**
- **Dial:** Diameter of the gauge
- **Pressure Gauge:** The gauge used to measure pressure
- **Charging Valve:** Valve used for filling the tank
- **Carbon Steel:** Material used for the external housing
- **External Housing:** The outer part of the device
- **All Material In Contact With Line Fluid:** Stainless steel unless otherwise specified.
## MINIATURE SERIES HYDROPADS

### 500 PSI

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>NOMINAL GAS CAPACITY, C (cu-in)</th>
<th>FLUID DISPLACEMENT, C (_d) (Max) (cu-in)</th>
<th>HOUSING</th>
<th>APPROX. WT (LBS)</th>
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<td>4-1/2&quot;</td>
<td>2-7/8&quot;</td>
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<tr>
<td>320500</td>
<td>32</td>
<td>19.0</td>
<td>4-1/2&quot;</td>
<td>5&quot;</td>
</tr>
</tbody>
</table>

### 1000 PSI

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>NOMINAL GAS CAPACITY, C (cu-in)</th>
<th>FLUID DISPLACEMENT, C (_d) (Max) (cu-in)</th>
<th>HOUSING</th>
<th>APPROX. WT (LBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>161000</td>
<td>16</td>
<td>9.5</td>
<td>4-1/2&quot;</td>
<td>2-7/8&quot;</td>
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<tr>
<td>321000</td>
<td>32</td>
<td>19.0</td>
<td>4-1/2&quot;</td>
<td>5&quot;</td>
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</table>

### 2000 PSI

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>NOMINAL GAS CAPACITY, C (cu-in)</th>
<th>FLUID DISPLACEMENT, C (_d) (Max) (cu-in)</th>
<th>HOUSING</th>
<th>APPROX. WT (LBS)</th>
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</thead>
<tbody>
<tr>
<td>162000</td>
<td>16</td>
<td>9.5</td>
<td>5-9/16&quot;</td>
<td>4-1/4&quot;</td>
</tr>
<tr>
<td>322000</td>
<td>32</td>
<td>19.0</td>
<td>5-9/16&quot;</td>
<td>7&quot;</td>
</tr>
</tbody>
</table>

### 3000 PSI

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>NOMINAL GAS CAPACITY, C (cu-in)</th>
<th>FLUID DISPLACEMENT, C (_d) (Max) (cu-in)</th>
<th>HOUSING</th>
<th>APPROX. WT (LBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>163000</td>
<td>16</td>
<td>9.5</td>
<td>5-9/16&quot;</td>
<td>5&quot;</td>
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<td>323000</td>
<td>32</td>
<td>19.0</td>
<td>5-9/16&quot;</td>
<td>7&quot;</td>
</tr>
</tbody>
</table>
Important features of the Hydropad are its ease of initial installation and lack of maintenance requirements. Once the means of connection to the systems have been provided, it is only necessary to connect the Hydropad by the screwed, flanged or weld end connection furnished, using accepted procedures.

The housing should be located above the point of connection and installed vertically. If horizontal or inverted vertical installation is necessary, additional instructions can be obtained from the factory.

Unless instructed otherwise, the Hydropad is pre-charged with nitrogen at the factory to the pressure specified by the customer, or as calculated from given system data. If the customer wishes to pre-charge after installation, the nitrogen gas pressure should be held to a value of 3 to 5 psi below flow pressure as measured at the point of installation for surge suppression, or between 80 and 90% of the mean pressure for pump pulsation dampening.

For assurance that the Hydropad has been properly precharged at the time of system start-up, follow these simple steps:

**SurgeSuppressor Applications**

a. With Hydropad isolated from line pressure, note reading on Hydropad pressure gauge. Pressure should be 3 to 5 psi below line pressure.

b. Start up system.

c. Again note pressure on gauge. Indicated pressure should be 3 to 5 psi above that noted in (a).

d. If pressure does not increase, excessive precharge pressure is indicated. Charging valve should be opened and gas bled from the Hydropad housing. When precharge pressure equals flow pressure, gauge pressure will stop falling and charging valve should be closed. (This should be done with system on and valve(s) open).

e. Re-seal charging valve and repeat steps (a) through (c) to assure that precharge pressure (a) is 3 to 5 psi below reading obtained in step (c).

**Note:** Under no circumstances should the bellows be exposed to pressure more than 5 psi greater than the precharge pressure at time of installation.

**Note:** If environmental temperature will be higher than installation temperature, initial precharge pressure must be adjusted to allow for the effect of increased temperature on the gas charge.

To precharge the Hydropad after installation, follow this procedure:

a. Shut off line pressure (isolate Hydropad from line pressure).

b. Attach gas charging chuck cc300 to charging valve.

c. Turn 3/4" hex swivel nut counter-clockwise a maximum of 3/4 turn after resistance is felt to open.

d. Charge with nitrogen gas to pressure shown on name plate or to system pressure (flowing) as measured at the point of installation. Use the latter pressure when system flow pressure has changed.

e. Turn 3/4" hex swivel nut clockwise and apply 50 to 70in. lb. torque to close.

**Note:** Charging gas pressure should be adjusted to allow for effect of a change in environmental temperature.

**Pulsation Dampener Applications**

Warning: Read all instructions carefully. Exposing the inlet side of an undercharged Hydropad to line pressure may damage unit. NEVER exceed the maximum operating pressure stamped on the nameplate of the vessel.

To ensure correct precharge, the Hydropad must be isolated from line pressure. The normal precharge pressure for pulsation dampeners is 80 to 90% of the mean pump output pressure. For a pump with a mean output pressure of 100 psi, the precharge should be between 80 and 90 psi.

With correct precharge pressure, the unit may be exposed to line pressure. With the pump operating, the Hydropad pressure gauge should read the mean output pressure +/− the allowable variation in output pressure.

**If the Hydropad is overcharged:**

a. Isolate the unit from line pressure.

b. Slowly turn the 3/4" hex swivel nut counterclockwise until nitrogen can be heard escaping and the gauge pressure begins to drop.

c. When the correct precharge pressure has been reached, turn the 3/4" hex swivel nut clockwise to close and apply 50-70 in. lb. torque.

**If the Hydropad is undercharged:**

a. Attach gas charging chuck cc300 to charging valve.

b. Attach nitrogen supply to charging chuck (1/8" tubing compression fitting).

c. Turn 3/4" hex swivel nut on charging valve 3/4 turn counter-clockwise to open valve.

d. Open valve on nitrogen bottle and increase Hydropad precharge pressure to required level.

e. Turn the 3/4" hex swivel nut clockwise to close and apply 50-70 in. lb. torque.

f. Disconnect nitrogen supply line and charging chuck.
**Typical Specifications**

**Surge Suppression**
Surge dampeners shall be installed upstream of all quick closing or solenoid operated valves as noted on drawings. Surge suppressors shall be Hydropads as manufactured by FLEXICRAFT or equal, and shall consist of a diaphragm-type stainless steel bellows unit enclosed by an outer steel shell. Bellows shall be of multiple-type diaphragms, and heli-arc welded at the inner and outer peripheries. Bellows shall be exposed internally to line pressure and all material in contact with line fluid shall be stainless steel.

Unit shall have sufficient volume between bellows and outer steel shell to limit maximum surge pressure to 1-1/2 times normal line pressure or to value noted, whichever is lower. Unit shall be filled with nitrogen gas between bellows and steel shell. **Nitrogen gas pressure shall be 3 to 5 PSIG below the normal line pressure at point of installation** under normal flowing conditions. Hydropads should be as close to the valve as possible, and in no case further than 6 feet from the valve.

**Pulsation Dampening**
Pulsation dampeners shall be installed at outlet of pump or manifold as noted on drawing.

Pulsation dampeners shall be Hydropads as manufactured by FLEXICRAFT or equal, and shall consist of a diaphragm-type stainless steel bellows unit enclosed by an outer steel shell.

Belows shall be exposed internally to line pressure and all material in contact with line fluid shall be stainless steel.

Unit shall have sufficient volume between bellows and outer steel shell to limit pulsation to values noted on drawings. **Unit shall be precharged with nitrogen gas.**

**Thermal Expansion**
Thermal Expansion Units shall be Hydropads as manufactured by FLEXICRAFT or equal, and shall consist of a diaphragm-type stainless steel bellows unit enclosed by an outer steel shell.

Belows shall be exposed internally to line pressure and all material in contact with line fluid shall be stainless steel.

Unit shall have sufficient volume between bellows and outer steel shell to limit pulsation to values noted on drawings. **Unit shall be precharged with nitrogen gas.**
HYDROPAD
SURGE SUPPRESSOR FORM

Customer ___________________________ Date __________________

Street Address ____________________________________________

City ___________________________ State ___________________________ Zip ______________

Hydropad Surge Suppressors are designed to reduce the pressure rise or water hammer in a piping system caused by quick-closing valves. A value of one and one-half times the normal operating pressure of the system is used for design purposes unless a closer value is specified by the user.

1. Type of fluid in line: ___________________________

2. Pipe size ____________ in. NPT; Type (Schedule 40, Standard, etc.) ______________
Length ______________ ft.
NOTE: If there is more than one pipe size in piping run, show pipe size and length of each section from valve to point of origin.

3. Discharge rate in gal/min. or velocity in ft./sec. at valve: ___________ [gpm] ___________ [ft./sec.]


5. Normal line pressure or static pressure at point of origin: ______________ psi.


7. Style of entrance connection: (Flanged ___) (Threaded ___) (Weld Nipple ___);
Size: ____________ in. NPT.

* If this not known, furnish a drawing showing length and size of pipe, indicating all changes in direction and rise and/or fall of piping, plus discharge pressure at point of origin.
** If not answered, a value of one and one-half times normal line pressure will be assumed.

Submitted by ___________________________

FLEXICRAFT INDUSTRIES
2315 W. HUBBARD ST. ▪ CHICAGO, IL 60612 ▪ 312-738-3588 ▪ FAX 312-421-6327
HYDROPAD
PULSATION DAMPENER FORM

Customer ____________________________ Date _____________

Street Address ________________________

City ____________________________ State ____________ Zip ____________

Pulsation dampeners are normally used in processing lines to reduce the normal pressure and flow fluctuations associated with positive displacement pumps (piston types). Such fluctuations in many cases can be regulated to 1/2% above and below the mean operating pressure of the pump by installing properly sized Hydropads. More frequently a variation of ±10% is considered adequate, thus permitting the use of smaller Hydropads.

1. Type of pump (check one)
   Simplex single-acting ( ) Simplex double-acting ( )
   Duplex single-acting ( ) Duplex double-acting ( )
   Triplex single-acting ( ) Triplex double-acting ( )
   Quadruplex single-acting ( ) Quadruplex double-acting ( )

2. Type of fluid: ________________________

3. Fluid operating temperature __________ °F


6. Design operating pump pressure _______________ psi.

**7. Pressure fluctuation permissible: _______________ % operating pressure or (Maximum allowable pressure _______________ psi). (Minimum allowable pressure _______________ psi).

8. Style of entrance connection: (Flanged ___) (Threaded ___) (Weld Nipple ___);
   Size: _______________ in. NPT.

* If bore and stroke are not available, show discharge at pump _______ gpm at _________ rpm.
** If not answered, we will design for ± 10% variation in operating pressure.

Submitted by ____________________________

FLEXICRAFT INDUSTRIES

2315 W. HUBBARD ST. • CHICAGO, IL 60612 • 312-738-3588 • FAX 312-421-6327
HYDROPADE
THERMAL EXPANSION FORM

Customer ___________________________ Date ___________________________

Street Address ___________________________ State __________ Zip __________

City ___________________________

Please provide the following information for accurate sizing of HYDROPADEA as thermal expansion compensation chambers. Note that although the English system of units is specified, any convenient system may be used provided the units of measure are specified.

1. Initial pressure when system is blocked off at initial temperature _______________ psig.
2. Initial (lowest) temperature __________________ °F.
3. Maximum anticipated system temperature __________________ °F.
4. Maximum allowable system pressure __________________ psig.
5. The net excess volume due to thermal expansion of the fluid __________________ cu-in.**

** If not known, then provide the following information:

5a. Coefficient of cubical expansion of the fluid between the lowest and highest temperatures ___________________ / °F.

5b. Coefficient of linear expansion of the conduit material (if not known, then specify the type of conduit material) ___________________ / °F.

5c. Line size ___________________ in.

5d. Wall thickness of conduit or schedule number ___________________ in.

5e. Line length ___________________ ft.

6. If known, what is the bulk modulus of the liquid (for more accurate calculation) __________ psi.

FLEXICRAFT INDUSTRIES

2315 W. HUBBARD ST. • CHICAGO, IL 60612 • 312-738-3588 • FAX 312-421-6327
2. SURGE SUPPRESSION

Exact calculations for pressure rise for any condition of fluid velocity, pipe length and time of closure are very complex. A conservative figure for such pressure rise may be obtained from this equation:

**FORMULA (1)**

\[ p_f = 60V_o \times G \]

Where:
- \( p_f \) = Rise above initial flowing pressure, psi.
- \( V_o \) = Initial fluid velocity, fps
- \( G \) = Specific gravity of flowing liquid (See Table II)

**TABLE II**

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Specific Gravity, G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (Saturated) at -28°F.</td>
<td>.67</td>
</tr>
<tr>
<td>Ethyl Alcohol (100%)</td>
<td>.79</td>
</tr>
<tr>
<td>Hydrazene (100%)</td>
<td>1.01</td>
</tr>
<tr>
<td>Nitric Acid (Red or White Fuming)</td>
<td>1.54</td>
</tr>
<tr>
<td>Nitrogen (Liquid) at -321°F.</td>
<td>.80</td>
</tr>
<tr>
<td>Oxygen (Liquid) at -298°F.</td>
<td>1.14</td>
</tr>
<tr>
<td>Sea Water</td>
<td>1.03</td>
</tr>
<tr>
<td>Fresh Water</td>
<td>1.00</td>
</tr>
<tr>
<td>Butane</td>
<td>.80</td>
</tr>
<tr>
<td>Gasoline, Grade (115-145)</td>
<td>.69</td>
</tr>
<tr>
<td>Gasoline</td>
<td>.76</td>
</tr>
<tr>
<td>Kerosene</td>
<td>.82</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>.90</td>
</tr>
<tr>
<td>JP-4</td>
<td>.80</td>
</tr>
</tbody>
</table>

The 1-Hydropad provides a cushion of gas near the valve. The greater the velocity of the fluid, the larger the gas volume required to dissipate a sufficient amount of kinetic energy so that pressure rise is reduced to a safe value. From various gas laws we know that the gas volume required is a direct function of the energy absorbed.

The total kinetic energy to be absorbed due to a change in the velocity of the fluid from valve to origin may be found:

**FORMULA (2)**

\[ K = \frac{62.4 \text{ GALV}^2}{2g} = .97 \text{ GALV}^2 \]

Where:
- \( K \) = Kinetic energy, ft. lbs.
- \( g \) = Gravitational constant = 32.2 ft./sec²
- \( A \) = Transverse area of pipe, sq. ft.
- \( L \) = Length of pipe, ft.
- \( V_o \) = Initial Fluid velocity, fps.
- \( G \) = Specific gravity of flowing liquid (see Table II)

Note: Where there are combinations of different pipe sizes in a system, kinetic energy for each diameter must be calculated. Total energy to be absorbed is the sum of these. Knowing initial fluid velocity for line size at the valve, the velocity for other sizes of lines can be calculated as follows:

\[ V_1 = \left( \frac{A_0}{A_1} \right) V_0 \]

Where:
- \( A_0 \) = Transverse area of pipe (sq. ft.) with velocity of fluid \( V_0 \)
- \( A_1 \) = Transverse area of new line, sq. ft.
- \( V_1 \) = Velocity of fluid (fps) through line with area \( A_1 \)

Note: Transverse areas for pipe diameters can be found in Table VI, page 18.

**FORMULA (3)**

Calculations for Hydropad capacities involve pressure ratio factor \( Y \) which is read from Chart I, page 16. This ratio is determined as follows:

\[ Y = f \left( \frac{P_m}{P_0} \right) \]

Where:
- \( P_o \) = The flow pressure at valve (no surge) with valve open and fluid flowing, psig.
- \( P_o \) = The absolute pressure = \( P_o + 14.7 \), psia
- \( P_m \) = The maximum surge pressure at valve. This will always be higher than normal line pressure. Unless a definite value is specified by the customer, a value of 1.5 times normal line pressure will be used, psig.
- \( P_m \) = The absolute pressure = \( P_m + 14.7 \) psia

Note: Read \( Y \) from chart on page 16. Alternatively:

\[ Y = 144 \left( \frac{1}{n - 1} \right) \left( \frac{P_m}{P_o} \right) \left( 1 - \left( \frac{P_o}{P_m} \right)^n \right) \]

\[ n = 1.015 \text{ for nitrogen when calculating for surge suppressors.} \]
2. SURGE SUPPRESSION (continued)

FORMULA (4)

The required capacity, \( C \), of the Hydropad may be found as follows:

\[
C = 1728 \sqrt{\frac{K}{P_0 Y}}, \text{ cu. in.}
\]

The actual volume, \( C_a \), of liquid entering the Hydropad must be less than the displacement capacity \( C_d \) noted for the Hydropad chosen, as listed in column 3, pages 4 and 5.

FORMULA (5)

The actual volume, \( C_a \), of liquid entering the Hydropad may be computed as follows:

\[
C_a = C \left(1 - \frac{P_0}{P_m}\right) \text{, cu. in.}
\]

Example

Given: Assume instantaneous valve closure, atmospheric pressure = 14.7 psia.

Gasoline (\( G = 0.7 \)) is being pumped at 7.7 feet per second through 6" standard weight steel pipe for a total of 1200 ft. If the initial pressure, \( p_i \), is 100 psig at the valve, determine (1) maximum water hammer pressure, \( p \), without a surge suppressor; (2) Hydropad capacity required to limit the maximum surge pressure, \( p_m \), to 150 psig; and (3) the displaced liquid volume, \( C_a \).

Solution:

From Formula (1)

\[
p_i = 60 V_0 G = 60 \times 7.7 \times 0.7 = 323 \text{ psig}
\]

\[
p = P_o + p_i = 100 + 323 = 423 \text{ psig}
\]

From Formula (2)

\[
K = 0.97 \text{ GALV}_0 = 0.97 \times 7 \times 347 \times 1200 (7.7)^3 = 16,763 \text{ ft. lbs.}
\]

From Formula (3)

\[
P_m = 150 + 15 = 165 + 1.43,
\]

\[
P_o = 100 + 15 = 115
\]

Read \( Y = 8 \) (from page 16).

From Formula (4)

\[
C = 1728 \sqrt{\frac{K}{P_0 Y}} = 1728 \times 8 \times 16763 = 31485 \text{ cu. in.}
\]

From Formula (5)

\[
C_a = C \left(1 - \frac{P_0}{P_m}\right), \text{ cu. in.} = 31485 \left(1 - \frac{115}{165}\right) = 31485 \times 1.015
\]

Recommendation:

Use 200 psi Series, Model 18 (\( P_m = 150 \) psi)

Capacity 50,000 cu. in. (\( C = 31485 \) cu. in.)

Displacement 30,000 cu. in. (\( C_a = 9424 \) cu. in.)

3. THERMAL EXPANSION COMPENSATION

FORMULA (1)

\[
C_0 = \frac{\Delta V}{1 - \left(\frac{P_0}{P_1}\right)^n}, \text{ cu. in.}
\]

Where:

\( \Delta V \) = The excess fluid volume which must be absorbed

\( V_0 \) = The initial system pressure psig

\( P_0 = P_0 + 14.7 \) psig

\( P_1 = \text{The maximum allowable system pressure psig} \)

\( P_1 = P_1 + 14.7 \) psig

\( n \) = Polytropic exponent of gas expansion

\( = 1.4 \) for nitrogen

If the actual increase in fluid volume (\( \Delta V \)) is unknown, it can be determined as follows:

FORMULA (2)

\[
\Delta V = V_e - V_0 \text{ cu. in.}
\]

Where:

\( V_e \) = The net excess volume of fluid which takes into account the expansion of the fluid and the conduit due to an increase in temperature.

\( V_p \) = The amount of volume increase of the conduit due to the pressure increase from \( P_0 \) to \( P_1 \).

In most cases, \( V_p \ll V_e \) and \( V_p \) can be neglected without significant loss in accuracy.
3. THERMAL EXPANSION COMPENSATION (continued)

**FORMULA (3)**

\[ V_E = V_o \left( T_1 - T_o \right) \left( e_c - 3e_l \right) \text{ cu. in.} \]

**Where:**
- \( V_o \) = The initial fluid volume at temperature \( T_o \) and pressure \( P_o \) cu. in.
- \( T_o \) = The initial fluid temperature °F
- \( T_1 \) = The maximum expected fluid temperature °F
- \( e_c \) = The effective coefficient of cubical expansion of the fluid / °F
- \( e_l \) = The coefficient of linear expansion of the conduit material / °F

If the increase in volume of the conduit due to the pressure rise is to be considered, the following relation can be used:

**FORMULA (4)**

\[ V_p = \frac{432\pi L d^2}{k} \left( \frac{1}{e} + d \right) \left( P_1 - P_o \right) \left[ 1 - e_o \left( T_1 - T_o \right) \right] \text{ cu. in.} \]

**Where:**
- \( L \) = The conduit length Ft
- \( d \) = The inside diameter of the conduit Ft
- \( k \) = The bulk (volume) modulus of the liquid psi
- \( e \) = The thickness of the conduit wall Ft
- \( E \) = The elastic modulus of the conduit material psi

**Example**

Consider an 8" sch 20 type 304 stainless steel line 500 Ft long, which is holding gasoline at 75 psig and 60°F. It is expected that the line, when isolated, may experience temperatures up to 120°F and it is desired to limit the system pressure to 135 psig.

\[ \begin{align*}
P_o &= 75 \text{ psig} \\
P_o^* &= 89.7 \text{ psia} \\
P_1 &= 135 \text{ psig} \\
P_1 &= 149.7 \text{ psia} \\
T_o &= 60^\circ \text{F} \\
T_1 &= 120^\circ \text{F} \\
L &= 500 \text{ FT} \\
d &= 8.125/12 = 0.677 \text{ Ft} \\
e &= 0.25/12 = 0.021 \text{ Ft} \\
e_c &= 3.6 \times 10^{-6} \text{ /°F (For T-304 S/S)} \\
e_l &= 0.0006 \text{ /°F (For gasoline)} \\
k &= 96000. \text{ psi} \\
E &= 30 \times 10^6 \text{ psi (For T-304 S/S)}
\end{align*} \]

Using Formula 4:

\[ \begin{align*}
V_p &= \frac{432\pi (500)(0.677)^2}{96000} \left( \frac{1}{96000} + \frac{0.677}{(0.021)(30 \times 10^6)} \right) \\
&\quad \cdot \left( 135-75 \right) \left( 1-0.0006(120-60) \right) \\
V_p &= 207 \text{ cu. in.}
\end{align*} \]

(This is the volume that the pipe has expanded due to the pressure change.)

Using Formula 3:

\[ \begin{align*}
V_o &= \frac{4L}{\pi} \frac{d^4}{4} \text{ cu. ft.} \\
V_E &= \frac{\pi (0.677)^2}{4} \times 500(120-60) \\
&\quad \times (0.0006-3 \times 9.6 \times 10^{-5}) \times 1728. \\
V_E &= 10659 \text{ cu. in. (This is the excess volume of liquid which is not accounted for by the thermal expansion of the conduit.)}
\end{align*} \]

Using Formula 2:

\[ \begin{align*}
\Delta V &= 10659-207 \\
\Delta V &= 10452 \text{ cu. in.}
\end{align*} \]

Using Formula 1:

\[ \begin{align*}
C_o &= \frac{10452}{1-0.897} \\
&= 149.7 \\
C_o &= 34114 \text{ cu. in.}
\end{align*} \]

Use a model 18 Hydropad precharged to 75 psig.

Note that the volume stored in the expanded pipe due to the pressure increase \( V_p \) is only 2% of the total excess volume. Thus, if \( V_p \) is neglected, the required Hydropad capacity would increase by only 2% for this application.
**Reference**

**Useful Equivalents**

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Imperial Gallon</td>
<td>1.2 U.S. Gallon</td>
</tr>
<tr>
<td>1 U.S. Gallon of Water</td>
<td>8.34 Pounds</td>
</tr>
<tr>
<td>1 U.S. Gallon</td>
<td>231 Cubic Inches</td>
</tr>
<tr>
<td>1 Liter</td>
<td>.2641 U.S. Gallon</td>
</tr>
<tr>
<td>1 Cubic Foot of Water</td>
<td>62.4 Pounds</td>
</tr>
<tr>
<td>1 Cubic Meter</td>
<td>35.31 Cubic Feet</td>
</tr>
<tr>
<td>1 Pound per Square Inch</td>
<td>27.7 Inches of Water</td>
</tr>
<tr>
<td>1 Pound per Square Inch</td>
<td>.0624 Inches of Mercury</td>
</tr>
<tr>
<td>1 Cubic Foot of Air</td>
<td>.076 Pounds</td>
</tr>
<tr>
<td></td>
<td>(Std. Pres. and Temp.)</td>
</tr>
<tr>
<td>1 Pound of Air</td>
<td>13.1 Cubic Feet</td>
</tr>
<tr>
<td></td>
<td>(Std. Pres. and Temp.)</td>
</tr>
<tr>
<td>1 Cubic Ft. of Natural Gas</td>
<td>1000 BTU (Approx.)</td>
</tr>
<tr>
<td>1 Cubic Foot</td>
<td>7.48 U.S. Gallons</td>
</tr>
</tbody>
</table>

**TABLE III - CONVERSION TABLE OF PRESSURE**

Multiply known pressure units by factors given below to obtain the required pressure unit.

<table>
<thead>
<tr>
<th>KNOWN PRESSURE UNIT</th>
<th>REQUIRED PRESSURE UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>POUNDS PER SQ. IN.</td>
</tr>
<tr>
<td></td>
<td>OUNCES PER SQ. IN.</td>
</tr>
<tr>
<td></td>
<td>MILLIMETERS OF HG.</td>
</tr>
<tr>
<td></td>
<td>KILOGRAMS PER SQ. CM.</td>
</tr>
<tr>
<td></td>
<td>INCHES OF WATER</td>
</tr>
<tr>
<td></td>
<td>INCHES OF HG.</td>
</tr>
<tr>
<td></td>
<td>FEET OF WATER</td>
</tr>
<tr>
<td></td>
<td>CENTIMETERS OF WATER</td>
</tr>
<tr>
<td>Centimeters Head of Water</td>
<td>0.01409</td>
</tr>
<tr>
<td>Feet Head of Water</td>
<td>0.45310</td>
</tr>
<tr>
<td>Inches Head of Mercury</td>
<td>0.04877</td>
</tr>
<tr>
<td>Inches Head of Water</td>
<td>0.036602</td>
</tr>
<tr>
<td>Kilograms per Sq. Centimeter</td>
<td>14.234</td>
</tr>
<tr>
<td>Millimeters Head of Hg.</td>
<td>0.019282</td>
</tr>
<tr>
<td>Ounces per Sq. Inch</td>
<td>0.062500</td>
</tr>
<tr>
<td>Pounds per Sq. Inch</td>
<td>16.000</td>
</tr>
</tbody>
</table>

Table based on: (Water at 60°F. = 32.673 lbs/cu. ft.)

At Sea Level, Absolute Pressure = (Gauge Pressure psig) + 14.695

Temperature:
1. To convert temperature in degrees Centigrade (°C) to degrees Fahrenheit (°F), use the following formula: °F = °C x 1.8 + 32
2. For steam, the degree of superheat is the difference between the actual temperature and the saturation steam temperature.

**TABLE IV - FLOW CONVERSION**

Multiply the known flow in the tabulation below by the factors listed to obtain flow in desired flow units.

<table>
<thead>
<tr>
<th>KNOWN FLOW</th>
<th>GALLONS PER HOUR</th>
<th>GALLONS PER DAY</th>
<th>CU. FT. PER MIN.</th>
<th>CU. FT. PER HOUR</th>
<th>BARRELS PER MIN.</th>
<th>BARRELS PER HOUR</th>
<th>BARRELS PER DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPM</td>
<td>1.00</td>
<td>60</td>
<td>1440</td>
<td>.1337</td>
<td>.00238</td>
<td>1.459</td>
<td>34.29</td>
</tr>
<tr>
<td>Gallons/Hour</td>
<td>.01667</td>
<td>1</td>
<td>24</td>
<td>.002228</td>
<td>.000337</td>
<td>.0238</td>
<td>.5714</td>
</tr>
<tr>
<td>Gallons/Min</td>
<td>.000694</td>
<td>.017</td>
<td>1</td>
<td>.0000928</td>
<td>.0000153</td>
<td>.000921</td>
<td>.0238</td>
</tr>
<tr>
<td>Cu. Ft./Min.</td>
<td>7.48</td>
<td>448.8</td>
<td>10771.2</td>
<td>1</td>
<td>.01781</td>
<td>10.69</td>
<td>256.5</td>
</tr>
<tr>
<td>Cu. Ft./Hour</td>
<td>.01247</td>
<td>7.48</td>
<td>179.5</td>
<td>.01667</td>
<td>.002968</td>
<td>.01781</td>
<td>4.274</td>
</tr>
<tr>
<td>Barrels/Min</td>
<td>42.00</td>
<td>2520</td>
<td>60488</td>
<td>5.615</td>
<td>316.9</td>
<td>1</td>
<td>1440</td>
</tr>
<tr>
<td>Barrels/Hour</td>
<td>0.7</td>
<td>42</td>
<td>1008</td>
<td>.6936</td>
<td>6.15</td>
<td>.01667</td>
<td>24</td>
</tr>
<tr>
<td>Barrels/Day</td>
<td>.02917</td>
<td>1.75</td>
<td>42</td>
<td>.003899</td>
<td>.0234</td>
<td>.000604</td>
<td>.0417</td>
</tr>
</tbody>
</table>

Note: The barrel in the above tabulation is equivalent to 42 U.S. gallons, which is standard for petroleum products.
<table>
<thead>
<tr>
<th>Discharge</th>
<th>Pressure Drop per 100 feet and Velocity in Schedule 40 Pipes for Water at 60°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>1/8&quot;</td>
</tr>
<tr>
<td>1&quot;</td>
<td>2.00</td>
</tr>
<tr>
<td>2&quot;</td>
<td>3.00</td>
</tr>
<tr>
<td>3&quot;</td>
<td>4.00</td>
</tr>
<tr>
<td>4&quot;</td>
<td>5.00</td>
</tr>
</tbody>
</table>

For pipe lengths other than 100 feet, the pressure drop is proportional to the length. Thus, for 50 feet of pipe, the pressure drop is approximately one-half the value given in the table. For 300 feet, three times the given value, etc.

Velocity is a function of the cross-sectional flow area; thus, it is constant for a given flow rate and is independent of pipe length.
<table>
<thead>
<tr>
<th>Nominal Pipe Size, NPT</th>
<th>SCHEDULE NUMBER</th>
<th>Carbon Steel</th>
<th>Stainless Steel</th>
<th>Outside Diameter, Inches</th>
<th>Inside Diameter, Inches</th>
<th>Wall Thickness, Inches</th>
<th>Transverse Area, Square Feet</th>
<th>Transverse Ares, Square Inches</th>
<th>Nominal Pipe Size, NPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 x 10</td>
<td>40S</td>
<td>Std</td>
<td>.353</td>
<td>.153</td>
<td>.033</td>
<td>.010</td>
<td>.003</td>
<td>.014</td>
<td>3/8</td>
</tr>
<tr>
<td>1/2 x 10</td>
<td>40S</td>
<td>Std</td>
<td>.408</td>
<td>.342</td>
<td>.036</td>
<td>.012</td>
<td>.004</td>
<td>.018</td>
<td>1/2</td>
</tr>
<tr>
<td>3/4 x 10</td>
<td>40S</td>
<td>Std</td>
<td>.460</td>
<td>.390</td>
<td>.040</td>
<td>.014</td>
<td>.006</td>
<td>.023</td>
<td>3/4</td>
</tr>
<tr>
<td>1 x 10</td>
<td>40S</td>
<td>Std</td>
<td>.551</td>
<td>.481</td>
<td>.046</td>
<td>.018</td>
<td>.010</td>
<td>.034</td>
<td>1</td>
</tr>
<tr>
<td>1 1/2 x 10</td>
<td>40S</td>
<td>Std</td>
<td>.687</td>
<td>.617</td>
<td>.053</td>
<td>.022</td>
<td>.016</td>
<td>.046</td>
<td>1 1/2</td>
</tr>
<tr>
<td>2 x 10</td>
<td>40S</td>
<td>Std</td>
<td>.813</td>
<td>.743</td>
<td>.062</td>
<td>.028</td>
<td>.023</td>
<td>.060</td>
<td>2</td>
</tr>
<tr>
<td>2 1/2 x 10</td>
<td>40S</td>
<td>Std</td>
<td>1.000</td>
<td>.930</td>
<td>.074</td>
<td>.034</td>
<td>.032</td>
<td>.084</td>
<td>2 1/2</td>
</tr>
<tr>
<td>3 x 10</td>
<td>40S</td>
<td>Std</td>
<td>1.562</td>
<td>1.492</td>
<td>.112</td>
<td>.054</td>
<td>.068</td>
<td>.137</td>
<td>3</td>
</tr>
<tr>
<td>3 1/2 x 10</td>
<td>40S</td>
<td>Std</td>
<td>2.000</td>
<td>1.930</td>
<td>.141</td>
<td>.073</td>
<td>.094</td>
<td>.190</td>
<td>3 1/2</td>
</tr>
<tr>
<td>4 x 10</td>
<td>40S</td>
<td>Std</td>
<td>2.500</td>
<td>2.430</td>
<td>.180</td>
<td>.093</td>
<td>.121</td>
<td>.242</td>
<td>4</td>
</tr>
<tr>
<td>5 x 10</td>
<td>40S</td>
<td>Std</td>
<td>3.188</td>
<td>3.118</td>
<td>.230</td>
<td>.114</td>
<td>.160</td>
<td>.324</td>
<td>5</td>
</tr>
<tr>
<td>6 x 10</td>
<td>40S</td>
<td>Std</td>
<td>3.850</td>
<td>3.780</td>
<td>.300</td>
<td>.146</td>
<td>.210</td>
<td>.416</td>
<td>6</td>
</tr>
<tr>
<td>8 x 10</td>
<td>40S</td>
<td>Std</td>
<td>5.000</td>
<td>4.930</td>
<td>.450</td>
<td>.217</td>
<td>.325</td>
<td>.635</td>
<td>8</td>
</tr>
<tr>
<td>10 x 10</td>
<td>40S</td>
<td>Std</td>
<td>6.250</td>
<td>6.180</td>
<td>.600</td>
<td>.268</td>
<td>.460</td>
<td>.870</td>
<td>10</td>
</tr>
<tr>
<td>12 x 10</td>
<td>40S</td>
<td>Std</td>
<td>7.500</td>
<td>7.430</td>
<td>.750</td>
<td>.319</td>
<td>.630</td>
<td>1.260</td>
<td>12</td>
</tr>
<tr>
<td>14 x 10</td>
<td>40S</td>
<td>Std</td>
<td>9.000</td>
<td>8.930</td>
<td>.900</td>
<td>.370</td>
<td>.810</td>
<td>1.620</td>
<td>14</td>
</tr>
<tr>
<td>16 x 10</td>
<td>40S</td>
<td>Std</td>
<td>1.000</td>
<td>0.930</td>
<td>1.050</td>
<td>.421</td>
<td>1.000</td>
<td>2.040</td>
<td>16</td>
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**Reference**

**GRAPH 1**
SIMPLEX SINGLE-ACTING PUMPS

**GRAPH 2**
SIMPLEX DOUBLE-ACTING &
DUPLEX SINGLE-ACTING PUMPS

**GRAPH 3**
DUPLEX DOUBLE-ACTING PUMPS

MINIMUM AIR VOLUME C FOR PULSATON
DAMPENING
DIAGONAL LINES ON ALL CHARTS SHOW %
VARIATION ABOVE AND BELOW MEAN
DISCHARGE PRESSURE

\[ D_v = \text{volume displaced by one cylinder} = 0.7854 \, \text{b}^3 \text{cu. in.} \]
\[ b = \text{bore of cylinder, in.} \]
\[ s = \text{stroke, in.} \]

The values of the graphs may be increased or decreased by factors of 10. Be sure that both the values of \( D_v \) and \( C \) are changed accordingly.
Terms and Conditions

1. All quotations are subject to approval, acceptance and correction at the home office. Any errors in quotations resulting in orders will be corrected and re-submitted to the customer for their acceptance or refusal.

No prices may be made up from information other than that shown in the tables.

2. All prices are F.O.B. factory, Chicago, Illinois, are quoted exclusive of any taxes.

Shipments boxed for trans-ocean export add 10% to total trade price.

Terms: Net 30 days from date of invoice.

3. Cancellation or alteration of an order or return of any product by Buyer may not be made without advance written consent of manufacturer and shall be subjected to a cancellation charge.

A 35% minimum restocking charge shall be placed on any returned goods.

4. We will not be responsible for delays in shipping due to conditions beyond our control such as strikes, fires, or accidents.

5. Any claims for shortages or damaged products must be made in writing within 10 days after receipt of shipment.

6. Prices subject to change without notice.

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The products illustrated reflect the design characteristics at time of printing.

Flexicraft reserves the right to change dimensions, materials, or methods of construction without notice. Please contact the factory for certified prints (exact dimensions) when necessary.

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If the purchaser believes a product is defective, the purchaser shall: (a) Notify the manufacturer, state the alleged defect and request permission to return the product. (b) If permission given, return the product with transportation prepaid. If the product is accepted for return and found to be defective, the manufacturer will, at its discretion, either repair or replace the product F.O.B. factory, within 60 days of receipt, or refund the purchase price. Other than to repair, replace or refund as described above, purchaser agrees that manufacturer shall not be liable for any loss, costs, expenses or damages of any kind arising out of the product, its use, installation or replacement, labeling, instructions, information or technical data of any kind, description of product or use, sample or model, warnings or lack of any of the foregoing. NO OTHER WARRANTIES, WRITTEN OR ORAL, EXPRESS OR IMPLIED, INCLUDING THE WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE AND MERCHANTABILITY, ARE MADE OR AUTHORIZED. NO AFFIRMATION OF FACT, PROMISE, DESCRIPTION OF PRODUCT OF USE OR SAMPLE OR MODEL SHALL CREATE ANY WARRANTY FROM THE MANUFACTURER, UNLESS SIGNED BY THE PRESIDENT OF MANUFACTURER. These products are not manufactured, sold or intended for personal, family or household purposes.