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**F 700** PUMPING PLANTS AND FORCE MAINS

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<td>F 726.4</td>
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<td>&quot;</td>
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</tbody>
</table>

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<th>Date</th>
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F 700  INTRODUCTION

The City of Los Angeles wastewater system is served by several major collection systems, outfalls, pumping plants and treatment plants. Due to the difference in elevation of some low-lying service areas relative to the treatment plants, it would be impossible or prohibitively expensive to install gravity mains or interceptors to convey wastewater to the treatment plants. In those areas, pumping plants are required to lift wastewater to the nearby force main or gravity sewer line, or treatment plant.

The purpose of this Section is to establish standard design criteria which sets the level of quality for the City's pumping plant designs. Included are guidelines, references and standards for the design, construction, start-up and operation and maintenance of the pumping plants. This Section defines the quality level of the equipment to be furnished, establishes the pumping plant control philosophy for maximum reliability of operation, and influences the designer to produce quality contract documents with minimum change orders during construction.

This Section was written for a wide variety of readers; hence, some of the text may seem elementary to experienced designers. Nonetheless, it is hoped that every user will benefit from the practical approach and the detailed presentation of the standard design criteria for pumping plants and force mains.

Design procedures have been simplified and hydraulic equations shown are generally accepted in the industry. It is the responsibility of the designer to refer to the referenced textbooks and standards for formula derivations and complex principles. Graphical illustrations and layouts are included in order to enhance understanding of the subject.
F 710  PUMPING PLANT AND FORCE MAIN OVERVIEW

Each pumping plant must be designed to match the operation and hydraulic characteristics of the collection system it is serving. Familiarization of the operation of the collection system by the designer prior to detailed design is imperative.

The City of Los Angeles presently owns and operates more than 55 pumping plants located throughout the City's wastewater service areas. Most of these plants will undergo rehabilitation, or expansion, while others will be replaced by new larger stations. Many of the existing plants are of the dry pit type, equipped with vertical non-clog centrifugal pumps. Small pumping plants are of the submersible type. Other plants are still equipped with pneumatic ejector type pumps.

F 711  DUTIES AND RESPONSIBILITIES

The design of the pumping plants and force mains is a complex activity which requires the expertise of various design disciplines and close coordination with the Bureau of Sanitation. The project's Design Engineer is responsible for the production of the contract documents. The Bureau of Sanitation, however, is responsible for the operation and maintenance of the plants. The project Design Engineer should discuss with the Bureau of Sanitation design considerations related to operations and maintenance of the plants. The Collection Systems Design Engineering Division (CSED) should be consulted in matters related to the pumping plant design for designs performed in-house or by outside consultants. For in-house designs, CSED should be responsible for designing, coordinating and reviewing the pumping plant projects. This should be done at the conceptual, mid-design, and pre-final design stages.

F 712  UNITS

Units used in this Section are expressed in the English System.
F 713  STANDARDS, CODES AND PROCEDURAL MEMORANDA

The most commonly used Standards, Codes and Procedural Memoranda used in pumping plant design are:

Hydraulic Institute Standards (HIS)  
American Society for Testing Materials (ASTM)  
American Water Works Association (AWWA)  
National Electrical Code (NEC)  
American Iron and Steel Institute (AISI)  
NFPA 820 Fire Protection in Wastewater Treatment Plant and Collection System Facilities  
Standard Specifications for Public Works Construction (Green Book)  
The City of Los Angeles Wastewater Program Master Specifications  
The City of Los Angeles Clean Water Capital Improvement Program Procedural Memoranda (Guidelines)  
The City of Los Angeles Program Advanced Planning Report  
The City of Los Angeles Bureau of Engineering Standard Plans  
The City of Los Angeles Building Code  
The City of Los Angeles Plumbing Code  
The City of Los Angeles Mechanical Code  
The City of Los Angeles Electrical Code

F 714  REFERENCE TEXTBOOKS AND MANUALS

Recommended textbooks commonly used as reference in the design of wastewater pumping plants are:


Hydraulic Institute: Hydraulic Institute Standards for Centrifugal, Rotary and Reciprocating Pumps, 14th ed., Cleveland, Ohio, 1983


FLYGT Corporation, Pumping Stations for Large Submersible Pumps: Recommendations for Designs and Dimensioning.
F 720 DESIGN CRITERIA

All pumping plants shall be designed to conform to the design criteria as specified herein. In case of conflict between the design criteria and the latest Special Order, provisions of the Special Order shall govern.

Table F 720
MINIMUM DESIGN PERIODS FOR WASTEWATER FACILITY/ COMPONENTS

<table>
<thead>
<tr>
<th>Wastewater Facility/ Component</th>
<th>Minimum Design Period (Yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumping plant structures</td>
<td>60 - 100</td>
</tr>
<tr>
<td>such as storage basins,</td>
<td></td>
</tr>
<tr>
<td>wet well, dry pit and</td>
<td></td>
</tr>
<tr>
<td>pumping plant superstructure</td>
<td></td>
</tr>
<tr>
<td>Mechanical, electrical</td>
<td>20</td>
</tr>
<tr>
<td>and controls</td>
<td></td>
</tr>
<tr>
<td>Electrical Wiring and</td>
<td>60</td>
</tr>
<tr>
<td>conduits</td>
<td></td>
</tr>
<tr>
<td>Force mains</td>
<td>60</td>
</tr>
</tbody>
</table>

F 721 DESIGN FLOWS AND SYSTEM HEADS

Each pumping plant should be designed to deliver the design flow at system head. The units should be expressed in gallons per minute (gpm) for flow and feet (ft) of water for system head.

Wastewater flows from each pumping plant's service area must be carefully investigated. The minimum, average and peak flows corresponding to the dry and wet weather flows (MDWF, MWWF, ADWF, AWWF, PDWF and PWWF) should be estimated in order to determine the size and number of pump units required. When flow from the service area is projected to increase in the future, the pumping plant should be designed to accommodate the increased wastewater flows.
The pumping plant structure should be provided with space for future pumps, stub-out piping with blind flange, or space for additional hydraulic structure. Present, future and ultimate flows should be calculated. For area growth projection, refer to the WPMD Advance Planning Report. To determine wastewater flow projection refer to Section F 220 of this Manual.

The system head is the total calculated head required to discharge wastewater at a given flow rate through a force main from a given elevation in the wet well. It is the sum of the static lift, the velocity head and the head losses in the force main. The force main head losses include friction loss and minor losses caused by valves, fittings, meters and other turbulence or friction causing items in the system.

Force main friction losses can be calculated by using Hazen and Williams empirical formula:

\[ h_f = 0.002083 \frac{L}{c^{1.85}} \left( \frac{100Q}{d^{4.8655}} \right) \]

where:
- \( h_f \) = head loss due to friction, ft of water
- \( d \) = inside diameter of the force main, inches
- \( L \) = length of pipe, including equivalent length for loss through fittings, ft
- \( Q \) = pump discharge, gpm
- \( c \) = roughness constant for Hazen & Williams

The roughness factor to be used for calculating force main friction losses should be \( C=100 \) for very old pipes, and \( C=140 \) for clean new pipes. The roughness constant should be determined on a case by case basis.

F 722  PUMP VERSUS SYSTEM HEAD/CAPACITY CURVES

The total discharge head (TDH) of a pump is the total head capable of being developed by a pump at a specific flow rate. The TDH of
the pump must be sufficient to overcome the system head at the
design flow rate.

Pump head/capacity (performance) curves are graphical plots of the
heads developed by a pump with respect to corresponding capacities.
These are normally determined by laboratory tests of pumps
performed by the pump manufacturers. Families of such performance
curves are published in the manufacturers' catalogs for different
pump models and sizes and for different impeller types, trims and
speeds. Figure F 722 A is a typical family of pump performance
curves for a particular pump at the stated impeller speed. Pump
performance curves also normally show the pump efficiencies, Net
Positive Suction Heads required and Brake Horsepower requirements,
all plotted with respect to the corresponding flow rates.

Because flows from a given service area vary, the pumping plant
must be capable of accommodating a range of flows at the
corresponding system heads. A system head/capacity curve is a
graphical plot of the (calculated) system heads with respect to
corresponding flow rates. Figure F 722 B is an example of a system
head/capacity curve.

Fluctuating water levels in the wet well and in the receiving
reservoir or pipeline at the downstream end of the force main must
be considered in determining the static lift of a system. Figure
F 722 C shows two system head curves starting at different static
lifts.

Not only does the flow from a service area and the static lift
requirement vary, but also the C-value of the force main decreases
with aging piping. The pumping plant must be designed to
accommodate all these variations expected during the life of the
system. For example, friction losses for the range of C values
from 140 for new pipe to 100 for aging pipe interiors should be
considered. Figure 722 D is an example of such a plot showing
curves for the C value of 120 and the C value of 100 starting from
different static lifts.

Pumping flow from a service area can be accomplished by three
commonly used methods:
a. Constant speed pumps with "fill-and-draw" control;

b. Variable speed pumps with "matched flow" control; and

c. Combination constant and variable speed pumps.

Constant speed pumps with "fill-and-draw" mode normally requires larger wet well storage volume in order to provide enough capacity to limit starting/stopping cycles of the pumps to prevent premature failures of the motors. The minimum recommended cycling time is shown in Section F725.1. This method is commonly used for smaller capacity pumping plants with adequate space for wet well construction. Figure 722 E shows performance curves for single and multiple pump conditions.

Pumping with variable speed pumps is the modern approach, requiring smaller wet wells, and fewer starts and stops of the pump units. In addition, variable speed pumping plants produce less hydraulic surges and smoother flow variation into the treatment plant.

In pumping systems with combination constant and variable speed pumps, the variable speed pump normally is used to trim flows in excess of what the constant flow pumps can handle. These plants require a larger wet well than the all variable speed pumping systems.

The pumping configuration should be determined based on analysis of the pump versus system curves. Various combinations can be used such as multiple pumps, combinations of small and large pump units, all variable speed pumps, a combination of constant and variable speed pumps. The best choice is the one which provides the best overall plant efficiency, range of operation, and reliability. Figure F 722F shows a plot of combination pump system characteristics with fixed and variable speed pumps.

F 722.1 PUMP SELECTION

From the manufacturer's published performance curves, select the pump with the best efficiency at the design point, or within the operating range where the pumps are likely to operate most of the time, and with the required net positive suction head (NPSH) of at
least 5 feet below the available NPSH at the maximum flow range. Most systems require pumps with steep curves. A sudden "dip" in the pump curve inherent to mix flow impellers normally will result in unstable operation and must not fall within the operating range of the pump. Operating beyond the manufacturer's recommended points in the curve should be avoided because it would shorten the life of the pumps due to cavitation or excessive vibration and may void the warranty.

The selected pump curves should be plotted against the system curve. The operating point of the pump is where the pump curve intersects with the system curve. It is important to plot the curves to determine set points of pressure switches, initial settings of pump speeds in the case of variable speed pumps, and setting of pressure relief valves when required by the system.

Manufacturers catalogs available to Design Engineers may not be up-to-date. The designer must verify with the pump manufacturer all performance curves, pump size and models prior to final selection of the pumps. Some pump manufacturers may have available unpublished pump curves for special applications, and some pump manufacturers may be able to custom design impellers to best meet the required characteristics of the system. It is recommended that during design, the Design Engineer should have the pump Manufacturer review pump selection and layout to insure that the pumps will perform throughout its operating range free from damaging cavitation, vibration or premature failure.

For operation and maintenance purposes, it is to the Bureau of Sanitation's advantage to have the same type and manufacturer of equipment in all pumping plants. In this regard, selection of manufacturer and equipment model should be given careful consideration. The pumping plant operation group should be consulted for the final selection of the equipment to determine if the equipment being considered by the Design Engineer has had a good track record of performance and service.
F 722.2 SAMPLE CALCULATION

Design a pumping plant which is able to pump wastewater from a wet well at a water surface elevation of -14.0 ft and deliver it to an elevation +43 ft through a force main 10,500 ft long (see Figure F722.A-1).

The pumping plant should be designed to handle the present, future and ultimate flows. Space should be provided to allow for additional pump units to handle future and ultimate flows.

The service area flow projections as estimated by using Projection of Flows in Section F220 or shown in the Advance Planning Report (APR) are as follows:

<table>
<thead>
<tr>
<th>FLOWS (GPM)</th>
<th>Present (YR2010)</th>
<th>Future (YR2050)</th>
<th>Ultimate (YR2090)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADWF</td>
<td>15,700</td>
<td>20,200</td>
<td>22,500</td>
</tr>
<tr>
<td>PDWF</td>
<td>30,000</td>
<td>35,000</td>
<td>40,000</td>
</tr>
<tr>
<td>PWWF</td>
<td>60,000</td>
<td>70,000</td>
<td>80,000</td>
</tr>
</tbody>
</table>

SOLUTION:

1. From the tabulated flows, determine the range of flows the pumping plant and force main should be designed for. In this case it is the flow from 15,700 gpm to 80,000 gpm.

2. Determine the size of the force main(s) based on velocities and operational criteria. The velocity should be kept between 2 fps and 7 fps because settlement of solids occurs when the velocity is less than 2 fps, and velocity above 7 fps results in high head loss. Velocity can be calculated from the following formula for any given pipe size:
V = \text{GPM} \times 0.409 \\
\text{ID}^2

Where:

V = \text{force main velocity in feet per second (fps).}

ID = \text{inside diameter of force main in inches.}

Trying a 48 inch pipe, single or dual force mains, the following tabulation of velocities were determined for the service area flow projections, shown in the Single 48" column below.

<table>
<thead>
<tr>
<th>Flows</th>
<th>Force Main Velocities (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single 48&quot;</td>
</tr>
<tr>
<td>Present (YR2010)</td>
<td></td>
</tr>
<tr>
<td>ADFW 15,700</td>
<td>2.7</td>
</tr>
<tr>
<td>PDWF 30,000</td>
<td>5.3</td>
</tr>
<tr>
<td>PWWF 60,000</td>
<td>10.65</td>
</tr>
<tr>
<td>Future (YR2050)</td>
<td></td>
</tr>
<tr>
<td>ADFW 20,200</td>
<td>3.5</td>
</tr>
<tr>
<td>PDWF 35,000</td>
<td>6.2</td>
</tr>
<tr>
<td>PWWF 70,000</td>
<td>12.42</td>
</tr>
<tr>
<td>Ultimate (YR2090)</td>
<td></td>
</tr>
<tr>
<td>ADFW 22,500</td>
<td>3.99</td>
</tr>
<tr>
<td>PDWF 40,000</td>
<td>7.10</td>
</tr>
<tr>
<td>PWWF 80,000</td>
<td>14.20</td>
</tr>
</tbody>
</table>

From the tabulated velocity data, one 48" diameter force main could handle the present flows, both ADFW and PDWF within the velocity range, but not the present PWWF of 60,000 gpm.
Therefore, the use of dual 48" force mains is considered in this example. The velocities for dual 48" force mains are shown in the second column. A review of the dual 48" force main velocities shows that the velocity can be kept within the design range for future and ultimate flow projections.

3. Calculate the pump station system heads.

a. Suction Head Loss

Use formula \( h_1 = K \frac{v^2}{2g} \).

Where \( K \) is the Resistance Coefficient. (\( K \) values for piping fittings are widely published in piping handbooks.)

\( h_1 \) is the head loss in feet

\( V \) is velocity in feet per second

<table>
<thead>
<tr>
<th>Resistance Coefficient &quot;K&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flared suction bell</td>
</tr>
<tr>
<td>Long radius 90 degree elbow</td>
</tr>
<tr>
<td>Isolation gate valve</td>
</tr>
<tr>
<td>Long radius 90 degree elbow at pump suction</td>
</tr>
</tbody>
</table>

Total resistance coefficient = 0.72

Assuming a velocity of 5 fps in the suction piping;

\[
h_{suction} = K \frac{v^2}{2g} = 0.72 \times \frac{5^2}{64.4} = 0.279 \text{ ft}
\]
b. Discharge Head Loss

<table>
<thead>
<tr>
<th>Resistance Coefficient &quot;K&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump control ball valve</td>
</tr>
<tr>
<td>Discharge isolation gate valve</td>
</tr>
<tr>
<td>Standard tee - flow thru branch</td>
</tr>
<tr>
<td>Gradual constriction before meter</td>
</tr>
<tr>
<td>Magnetic Meter</td>
</tr>
<tr>
<td>Gradual expansion after meter</td>
</tr>
<tr>
<td>Isolation gate valve after the meter</td>
</tr>
<tr>
<td>Pipe exit</td>
</tr>
</tbody>
</table>

Total resistance coefficient = 4.46

Assuming a velocity of 8 fps at the discharge of the pump;

\[
h_{\text{discharge}} = K \frac{V^2}{2g} = 4.46 \times \frac{8^2}{64.4} = 4.94 \text{ ft}
\]

c. Friction Loss Through Force Main

Friction loss through the reinforced concrete pipe (RCP) force main, 10,500 feet plus 10 per cent allowance for fittings and bends. Thus, total equivalent pipe length is 11,550 feet.

Use "C" factor of 150 for clean new RCP, and 120 for old RCP. Note: PVC lined RCP force mains will have much higher "C" factor.

The calculation for the friction loss through the force main, using the Hazen and Williams formula is:

\[
h_f = 0.002083(L) \left( \frac{100}{C} \right)^{1.85} \left( \frac{Q^{1.85}}{d^{4.8655}} \right)
\]

or:
\[ h_l = (10.44)(L) \times \frac{(gpm)^{1.85}}{(C)^{1.85}(d_{\text{inches}})^{4.8655}} \]

**Present (2010) - One 48" diameter force main**

<table>
<thead>
<tr>
<th>Flow (gpm)</th>
<th>Friction Loss (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADWF 15,700</td>
<td>6.5 4.3</td>
</tr>
<tr>
<td>PDWF 30,000</td>
<td>21.6 14.3</td>
</tr>
<tr>
<td>PWWF 60,000</td>
<td>77.9 51.6</td>
</tr>
</tbody>
</table>

**Future (2050) - Dual 48" diameter force main**

<table>
<thead>
<tr>
<th>Flow (gpm)</th>
<th>Friction Loss (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADWF 20,200</td>
<td>10,100 2.9 1.9</td>
</tr>
<tr>
<td>PDWF 35,000</td>
<td>17,500 8.0 5.3</td>
</tr>
<tr>
<td>PWWF 70,000</td>
<td>35,000 28.8 19.0</td>
</tr>
</tbody>
</table>

**Ultimate (2090) - Dual 48" diameter force main**

<table>
<thead>
<tr>
<th>Flow (gpm)</th>
<th>Friction Loss (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADWF 22,500</td>
<td>11,250 3.5 2.3</td>
</tr>
<tr>
<td>PDWF 40,000</td>
<td>20,000 10.2 6.8</td>
</tr>
<tr>
<td>PWWF 80,000</td>
<td>40,000 36.8 24.4</td>
</tr>
</tbody>
</table>

**d. Calculate Total Dynamic Head (TDH)**

\[ \text{TDH} = h_{\text{suction}} + h_{\text{discharge}} + h_{\text{force main}} + (Z_2 - Z_1)_{\text{static head}} \]
TDH = Hs + Hd + Hf + (Z₂ - Z₁)_{static\ head}

= 0.279 + 4.94 + Hf + 57

Present (YR2010), PWWF of 60,000 gpm:

Single FM, C-120: TDH = 0.279 + 4.94 + 77.9 + 57
= 140.11 ft

C-150: TDH = 0.279 + 4.94 + 51.6 + 57
= 113.8 ft

Future (YR2090), PWWF of 80,000 gpm:

Dual FM, C-120: TDH = 0.279 + 4.94 + 36.8 + 57
= 99.0 ft

C-150: TDH = 0.279 + 4.94 + 24.4 + 57
= 86.6

4. Using data above, plot the System Head Curves.

a. System Head Curves (Refer to Figure F722G)

Curve No. 1 Represents a single 48" diameter force main, with C-120.

Plot the range of the curve;

Static head: 57 ft
60,000 gpm @ 140 ft TDH.

Locate a point on the ordinate equal to a static head of 57 feet. Then locate a point at the intersection of 60,000 gpm on the abscissa and 140 ft TDH on the ordinate. These two points determine the range of the system head curve.
To plot any point in the system curve, assume a flow, calculate head loss with C-120, at assumed flow, and calculate TDH. The resulting system head curve will be Curve No. 1 in Figure F722G.

The same procedure applies for Curves No. 2 through 4.

**Curve No. 2**
Represents single 48" diameter force main, with C-150.

Static head: 57 ft,
60,000 gpm @ 114 ft TDH.

**Curve No. 3**
Represents dual 48" diameter force main with C-120.

Static head: 57 ft,
80,000 gpm @ 99 ft TDH.

**Curve No. 4**
Represents dual 48" diameter force main with C-150.

Static head: 57 ft,
80,000 gpm @ 87 ft TDH.

b. **Determine Design Points**

Analyze the system head curves and determine design points. Refer to Figure F722G - System Head Curve.

At the present PWWF of 60,000 gpm through a single force main, the maximum TDH is 140 ft as shown in Curve No. 1. At 60,000 gpm, the head loss for a single force main, TDH minus the static head (140-57=83 ft) is more than three times that of dual force mains as shown in intersection of Curve No.3 and 60,000 gpm (84-57=27 ft). The higher head loss results in a steeper system curve.
When the flow is directed through dual force mains as represented by Curves No. 3 and 4, the TDH decreases as represented by the intersection (y).

From the analysis of the system curves the reasons for the selection of the dual force main alternative become more defined. The advantages of using dual force mains are to allow a wide range of flows to be handled within the design criteria, provide greater flexibility in operation of the force mains, and maintain a lower energy consumption than with a single force main.

The system can be operated as follows:

1) For the present flows from 15,700 to 40,000 gpm, use one force main. During PWWF of greater than 40,000 gpm up to 60,000 gpm, use dual force mains. This operating condition would enable the system to control the velocity in the force mains to prevent settlement of solids during low flows and also save energy cost during high flows.

2) For future and ultimate flows, the dual force mains will be utilized.

3) Force mains should be alternated in their use so that neither remains out of service for a long period of time. This needs to be done to prevent septic conditions from developing.

4) One force main can be taken out of service for maintenance while the other handles the flow, under low flow conditions up to 40,000 gpm.

Further economic evaluation can be performed to compare various sizes of force mains versus pumping plant capital cost, energy cost and O&M costs.
5. Pump Selection

a. First, determine the type of pump suitable for the application. A non-clog type impeller pump suitable for unscreened municipal type sewage with impeller clear openings capable of passing 3 inch diameter solids is recommended.

For this example, use Flygt Corporation non-clog submersible dry pit pump Model C 3531/935 with impeller no. 675 to match the following operating range:

1) Design point at maximum speed per pump unit

20,000 gpm @ 100 ft TDH

2) Minimum operating range with one pump unit in operation at minimum speed

15,700 gpm @ 65 ft TDH

From the manufacturer's pump head-capacity curve (Figure F722H), you will find data such as flow in gpm on the abscissa, head in ft on the ordinate, a family of curves representing different sizes of impellers plotted diagonally from left to right, impeller efficiencies that intersect the pump curve, and the NPSH required in ft absolute plotted vertically intersecting the pump curves. For some pump manufacturers, the NPSHR is plotted diagonally from left to right.

The power curve shows KW or horsepower required by the pump corresponding to the size of impeller.

Other information such as the pump speed, size of inlet and outlet, the number of impeller blades are also shown on the manufacturer's pump performance sheets.
b. How to select a pump. Due to wide variation of flows, it would be more expensive to use constant speed pumps because it will require more pump units and larger wet well and dry pit. For this sample calculation, let's use all variable speed pumps with variable frequency drives. Plot the design point on the pump curve which is the intersection of the flow and head. The design point should be at or near the best efficiency point. For this example, impeller no. 675 will be the selected impeller with efficiency of 82 per cent and a non-overloading 500 KW motor at rated speed of 895 rpm. (See Figure F722H). The pump performance curve for impeller No. 675 show pump performance from 100% (60 Hz) speed to 50% (30 Hz) speed. (See Figure F722I).

c. Plot Pump Performance Curve against the System Head Curve. From manufacturer's published performance curve, Figure F722I, impeller no. 675, rated at 895 rpm, read points along the pump curve and plot as follows:

<table>
<thead>
<tr>
<th>Flow (gpm)</th>
<th>TDH (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscissa</td>
<td>Ordinate</td>
</tr>
</tbody>
</table>

75% Speed  0 (shut off) 120
Curve (a)  5,000  100
          10,000  90
          15,000  65
          20,000  40

100% Speed  0 (shut off) 185
Curve (b)  5,000  165
          10,000  150
          15,000  127
          20,000  100
          25,000  65

For two pumps in parallel operation, Curve (c) at 895 rpm, the flow will double at a given head.
<table>
<thead>
<tr>
<th>Flow (gpm)</th>
<th>TDH (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscissa</td>
<td>Ordinate</td>
</tr>
<tr>
<td>0 (shut off)</td>
<td>185</td>
</tr>
<tr>
<td>10,000</td>
<td>165</td>
</tr>
<tr>
<td>20,000</td>
<td>150</td>
</tr>
<tr>
<td>30,000</td>
<td>127</td>
</tr>
<tr>
<td>40,000</td>
<td>100</td>
</tr>
<tr>
<td>50,000</td>
<td>65</td>
</tr>
</tbody>
</table>

For three pumps in parallel operation, Curve (d) at 895 rpm, the flow will triple at a given head.

<table>
<thead>
<tr>
<th>Flow (gpm)</th>
<th>TDH (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscissa</td>
<td>Ordinate</td>
</tr>
<tr>
<td>0 (shut off)</td>
<td>185</td>
</tr>
<tr>
<td>15,000</td>
<td>165</td>
</tr>
<tr>
<td>30,000</td>
<td>150</td>
</tr>
<tr>
<td>45,000</td>
<td>127</td>
</tr>
<tr>
<td>60,000</td>
<td>100</td>
</tr>
<tr>
<td>75,000</td>
<td>65</td>
</tr>
</tbody>
</table>

For four pumps in parallel operation, Curve (d) at 895 rpm, the flow will be four times at a given head.

<table>
<thead>
<tr>
<th>Flow (gpm)</th>
<th>TDH (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscissa</td>
<td>Ordinate</td>
</tr>
<tr>
<td>0 (shut off)</td>
<td>185</td>
</tr>
<tr>
<td>20,000</td>
<td>165</td>
</tr>
<tr>
<td>40,000</td>
<td>150</td>
</tr>
<tr>
<td>60,000</td>
<td>127</td>
</tr>
<tr>
<td>80,000</td>
<td>100</td>
</tr>
<tr>
<td>100,000</td>
<td>65</td>
</tr>
</tbody>
</table>

Using the above data, plot pump curves (a), (b), (c), (d), and (e). The resulting curves are shown in Figure F722J. Plot the pump curves over the system head curves. The intersection of pump and
system curves is the operating point of the pumps. See Figure F722K. From Figure F722K, the operating points are as follows:

1) Present ADWF, pump minimum operating point, one pump in operation at 75 percent speed curve (a), point (w), the flow will be approximately 15,000 gpm at 65 ft.

3) Present PDWF, Point (x) represents two pumps in operation, at approximately 78 percent speed to deliver the present PDWF of 30,000 gpm at 85 ft TDH.

4) Present PWWF, Point (y) represents three pumps in operation at approximately 86 percent speed to deliver the present PWWF of 60,000 gpm at 75 ft TDH.

5) Future PWWF, Point (z) represents four pumps in operation at approximately 95 percent speed, to deliver the future PWWF of 70,000 gpm at 85 ft TDH.

6) Ultimate PWWF, Design point represents four pumps in parallel at maximum speed, to deliver PWWF of 80,000 gpm at 100 ft TDH.

c. Determine the operating range of each pump. From Figure F722K, the pump operating range would be from design point of 20,000 gpm at 100 ft to approximately 26,000 gpm at 58 ft at maximum speed as shown in curve (b). Also note that the corresponding NPSHR at 26,000 gpm is extremely high (70 ft). It would be necessary to check the NPSHA in the system and compare to NPSHR by the pump.

d. Determine size of electric motor drive. From Figure F722H, Pump Performance Curve, Pump Model
CS331, curve no. 63-830-1, impeller no 675, the non-overloading motor size throughout the pump curve is 500KW.

e. Determine number of pumps. From Figure F722K, Pump/System Head Curve, four duty pumps in parallel with variable speed drives will provide the ultimate flow of 80,000 gpm at 100 ft TDH. Force mains friction loss would have to be evaluated periodically. Future pumping plant expansion should provide necessary adjustment for the actual friction losses at that time.

<table>
<thead>
<tr>
<th>Number of Units</th>
<th>Approx. Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present (2010)</td>
<td>3+2 standby</td>
</tr>
<tr>
<td>Future (2050)</td>
<td>4+2 standby</td>
</tr>
<tr>
<td>Ultimate (2090)</td>
<td>4+2 standby</td>
</tr>
<tr>
<td></td>
<td>60,000 gpm</td>
</tr>
<tr>
<td></td>
<td>80,000 gpm</td>
</tr>
<tr>
<td></td>
<td>80,000 gpm</td>
</tr>
</tbody>
</table>

Other items which should be determined as soon as the preliminary pumping plant layout is completed are:

1) NPSH required versus NPSH available
2) Confirmation by the pump manufacturer of the availability of pump and delivery.
3) Factory certified performance curve (Standard Catalog Cut not acceptable)

F 723 STANDBY EQUIPMENT

All pumping plants should be designed to have adequate standby units capable of pumping the peak wet weather flow in case of equipment or power failure. The pumping plant must be capable of pumping the projected peak flow with the largest two units out of service. This criteria applies to all electro-mechanical equipment that is subject to failure. Unless otherwise requested by the Bureau of Sanitation, the minimum acceptable criteria should be as shown in Table F 723.
**Table F 723**

**MINIMUM CRITERIA FOR STANDBY EQUIPMENT**

(At least one or more units sized for PWWF)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>No. Units in Operation</th>
<th>No. Units Standby</th>
<th>Total No. Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pumps</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>1 small + 1 large</td>
<td>2 large</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1 small + 2 large</td>
<td>2 large</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>1 small + 3 large</td>
<td>2 large</td>
<td>6</td>
</tr>
<tr>
<td>2. Air Compressors</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3. Sump Pumps</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4. Hydraulic Pumps (for valve operators)</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
| 5. Variable Frequency drives (VFD): One VFD for each variable speed pump with by-pass starter to operate the motor at maximum constant speed.

**F 723.1 POWER SUPPLY**

Where only one power supply grid of the local utility is servicing the pumping plant, a standby generator and an automatic transfer switch should be provided. The generator should be sized to start and operate the total number of pumps operating with capacity equal to the maximum capacity of the pumping plant plus accessories such as dewatering sump pumps, ventilation fans, lighting and instrumentation and control equipment.

Where two power supply grids service the pumping plant, automatic switch-over should be provided to switch power from one supply to the other. Life cycle cost comparison between the installation of the second power supply versus the cost of standby generator should
be prepared in both cases. Normally, a standby generator when properly maintained and exercised is more reliable than an alternate power supply.

F 724 STORAGE BASINS

Historical data from the Bureau of Sanitation indicates most plant overflows are caused by power failures. When an overflow connection into an adjacent sewer system is not available upstream of the pumping plant, a storage basin may be provided to retain the flow for a predetermined period of time in order to allow the operations personnel adequate time to restore power to the pumping plant. The need to provide storage basins should be determined on a case by case basis by the Bureau of Sanitation.

Bureau of Sanitation operation personnel normally require 3 hours or less to restore power, depending on the distance of the pumping plant from operations headquarters. All storage basins should, therefore, have a minimum storage capacity of three hours.

When a storage basin is required for a pumping plant, the storage capacity should be based on future maximum peak wet weather flow (PWWF) into the pumping plant with space for ultimate capacity. The maximum high water elevation in the storage basin should be set lower than the top of the lowest maintenance hole in the system, basement, or other plumbing fixture upstream of the basin.

F 724.1 TYPES OF STORAGE BASINS

There are two types of storage basins, inline and bypass storage basins. The inline (sewer-to-sewer) storage basins are normally located in series with the gravity sewer upstream of the pumping plant. The bypass type storage basin is usually located inside the pumping plant site and is connected to the gravity sewer by an overflow outlet pipe from an inline overflow maintenance hole (MH) and a gravity drain. The gravity drain from the bypass reservoir drains through the overflow MH to the pump station wet well. Figure F 724 A shows schematics of the plan of both types.

The inline storage basin should have the same invert elevation as the invert of the incoming and outgoing sewer piping, and all sides
should slope towards the flowline in order to prevent accumulation of solids inside the storage basin. See Figure F 724 B.

For the bypass storage basin, the hydraulic grade line at the outlet of the overflow MH should be lower than the top of the lowest upstream maintenance hole or fixture in the collection system which is likely to overflow during extreme surcharge conditions (see Figure F 724 C). The gravity drain from the storage basin shall be equipped with a flap or sluice gates as shown schematically in Figure F 724 C. Where space inside the pumping plant site is limited, a deep storage basin may be provided with basin drainage accomplished by the use of a portable submersible pump. The portable pump size should be determined by the Wastewater Collection Systems Division and should be coordinated by the Project Design Engineer.

All storage basins should be provided with an access hatch, slide rails, piping and a power supply suitable to allow installation of a portable submersible pump. A minimum of three access maintenance holes, 27-inches inside diameter minimum, should be provided at maximum spacing of 50 feet apart and at all four corners of the basins to allow entry of maintenance personnel and for ventilation ducts suitable for a ventilation rate of 60 air changes per hour. A 2-1/2-inch hydrant water connection shall be provided for hose down of the storage basin during periodic cleaning. A backflow preventer should be provided between the potable and utility water connection.

The storage basins should be underground, and of reinforced concrete construction. Interior surfaces exposed to wastewater and sewer gases should be lined with PVC T-lock, Poly-Tee liners or equal for corrosion protection.

F 725 WET WELLS

Each pumping plant shall be provided with a sufficiently large wet well to prevent frequent pump starting and stopping (cycling). The wet well should be designed to provide adequate submergence to the pump suction, configured to preclude formation of vortices and flow pre-rotation that could cause pump cavitation. The determination of storage volume of the wet well should be based on the rate of
inflow, size of pumps and the type of pump drive. Figures F 725A, F 725B and F 725 C may be used for dimensional guidance. For submersible pump wet well, refer to Flygt Corporation, Recommendation for Design and Dimensioning for Large Submersible Pump Stations.

F 725.1 STORAGE CAPACITY.

The wet well shall be designed to have adequate storage capacity to sustain the pump operation without exceeding the recommended number of motor starts per hour:

<table>
<thead>
<tr>
<th>Motor Hp.</th>
<th>Max. Starts per Hour</th>
<th>Min. Cycling Time Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 50</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>60 to 75</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>100 and larger</td>
<td>2</td>
<td>30</td>
</tr>
</tbody>
</table>

For sizing wet well volumes, see Subsection F 725.4.

F 725.2 SUCTION CONSIDERATIONS

The wet well should be designed to provide adequate submergence of the pump suction to prevent air from being drawn into the pump by a vortex when the system is operating at low wet well levels. The submergence required to prevent vortexing is a function of inlet velocity and the configuration of the inlet nozzle. The depth of submergence, H minus C as shown in Figure F 725B, shall be determined from the "H" and "C" graphs of Figure F 725C for the appropriate flow rate or as recommended by the pump manufacturer, whichever is greater. The values of "C" however would vary depending on the way the entrance to the suction pipe is positioned relative to the water surface.

Head losses, $H_L$, through the suction piping, fittings and valves shall be calculated for use in the following formula for determining the net positive suction head available (NPSHA) in feet of liquid absolute in the suction system (see Figure F725D):
$$NPSHA = \frac{144}{w \times SG} \left( P_a - P_{vp} \right) - H_1 \pm Z$$

where:

- $P_a$ = Atmospheric pressure, psia
- $P_{vp}$ = Vapor pressure of water at the maximum temperature expected. For raw sewage at 85 degrees F use 0.59 psia.
- $H_1$ = Friction and minor losses, including entrance loss in the suction piping, feet of liquid.
- $Z$ = Difference in elevation between the wet well low water level and the pump datum elevation, feet. When the pump datum is above the wet well low water level, use minus (-) sign. When the pump datum is below the wet well low water level, use plus (+) sign.
- $w$ = Specific weight of liquid. Clean water use 62.4 pounds per cubic foot
- $SG$ = Specific gravity of liquid. For raw sewage use specific gravity of 1.03.

The pump should be selected such that the minimum NPSHA in the system is at least five feet greater than the Net Positive Suction Head Required (NPSHR) by the pump for the maximum expected flow through the pump. The NPSHR is the net positive suction head required by the pump to prevent cavitation (pitting) of the impeller or casing when the absolute pressure of the fluid entering the impeller drops below the vapor pressure of the liquid.

**F 725.3 VORTICES AND PRE-ROTATION**

The wet well configuration should be designed to preclude vortices leading into the pump. Side entry to the wet well must be avoided to prevent prerotation of flow into the pump suction. Prerotation of flow will cause turbulence and in some instances submerged vortices can develop which can result in minor column separation in the suction piping. Turbulence in the wet well must be avoided to prevent air entrainment into the pump which can cause the pump to
cavitate or otherwise operate inefficiently. To prevent turbulence, the velocity into the wet well should be maintained below 2 feet per second and abrupt turns should be avoided. Wet well configurations should be designed in accordance with the Hydraulic Institute Standards and recommended design guide by FLYGT Corporation, pumping stations for large submersible pumps for design and dimensioning.

The wet well bottom corners are to be grouted with a slope of 1:1 and slope towards the suction pipe inlet to prevent the accumulation of solids.

For large pumping plants that are served by more than two sets of identical pumps, a partition wall should be provided with sluice gates in order to be able to isolate one side of the wet well for cleaning. All inlets to the wet well should be provided with sluice gates to allow the wet well to be isolated from the collection system for a short period of time for cleaning and other maintenance.

F 725.4 WET WELL VOLUME

The required volume of the wet well depends on the way the pumping plant is to be operated. Pumping plants equipped with constant speed pumps will normally require larger wet wells than those with variable speed pumps. Pumping plants equipped with any size combination of constant speed pumps, or combination of constant speed and variable speed pumps shall have a storage volume sufficiently large to accommodate the cycling time requirement of the largest constant speed pump.

The wet well volume should be large enough to prevent short cycling of the pump motor. The cycle time is the time between starts of the pump motor as recommended by the motor manufacturer. Maximum recommended cycle time is as shown in Subsection F 725.1. The wet well should be sized not only to provide adequate storage time but also to allow time for a change in capacity when a pump is started or stopped before the next start or stop point is reached. This time allowance should take into consideration the time starting when the level sensor first senses the level in the wet well, plus
the time for that signal to activate the starting sequence, plus
the time to start the motor, plus the time to open the pump control
valve (if equipped) and the time to verify that the starting has
been completed. This sequence usually takes between one to three
minutes depending on the required opening and closing time of the
pump control valves. Stopping time should follow in reverse order
by closing the pump control valve first, then stopping the pump.
It should be noted that in some situations, momentary vibration
would normally be expected when the pump operates against shut off
head. The pump control valve opening and closing times should be
field adjusted to prevent extended operation of the pumps between
shut off and operating duty point. For pumping units equipped with
check valves the starting and stopping times will usually be less
than a minute.

The following method of computing cycle time and wet well volume
was extracted from "Wastewater Engineering Collection and Pumping
of Wastewater" by Metcalf & Eddy, Inc.

The time between starts is a function of the pumping rate and the
quantity of flow entering the station. For multiple-speed pumps,
the pumping rate is the difference in flow between the two speed
steps. The volume of the wet well between start and stop elevations
for a single pump or a single-speed control step for multiple-speed
operation is given by the following equation:

\[ V = \frac{tg}{4} \]

where:

- \( V \) = Required wet well capacity, gal
- \( t \) = Minimum time in minutes of one pumping cycle (time
  between successive starts or changes in speed of a
  pump operating over the control range)
- \( q \) = Pump capacity, gal/min, or increment in pumping
  capacity where one pump is already operating and
  the second pump is started, or where pump speed is
  increased.
The minimum cycle time for single-pump operation occurs when the inflow is exactly half the pump capacity. Under this condition, the on and off times are equal. The pump is on a longer time and off a shorter time for larger inflows and vice versa for smaller inflows; in both cases, the cycle time is greater.

F 725.5 WET-WELL MODIFICATION

This Subsection was also extracted from "Wastewater Engineering, Collection and Pumping of Wastewater" by Metcalf & Eddy, Inc.

Most state regulatory agencies now include maximum retention time in the wet well design criteria to minimize the potential for the development of septic conditions and the resultant odors. A maximum retention time of 10 minutes at average design flow rates is often quoted. Unfortunately, this requirement may conflict with the need for adequate volume to prevent short-cycling of the pumps. In these cases, multiple pumps or multiple-speed pumps should be considered to reduce the incremental change in the pumping rate and, therefore, the required volume. Also, odors can be minimized if the lowest liquid level in the well is set above the sloping portion of the wet well. This can be accomplished by making this level the stop point for the lead pump in the sequence.

The more common problem is obtaining sufficient wet well volume at a reasonable cost. If the pump start elevation in the wet well is below the invert elevation of the sewers, no storage is available. However, if the pump start elevation is above the invert, backwater curves can be computed to obtain the effective volume in the sewers between the various control settings. This storage often amounts to over 50 percent of the total volume. This system is commonly used in stations that have mechanically cleaned bar screens.

When using the storage in the incoming sewers, care shall be taken to insure that adequate velocities are maintained in the sewers and through the screens. The use of sewer storage is not common in small plants having comminutors because the storage available in the smaller sewers is small and the comminutor could be flooded.
FORCE MAINS

The force main is the pumping plant discharge piping which conveys wastewater under pressure and discharges from the pumping plant to another force main, another pumping plant wet well, a gravity sewer, or into a treatment plant.

In order to provide the wastewater system the reliability and capacity needed, some of the existing force mains may require rehabilitation or replacement, or additional pumping plants may be required in the future. When a pumping plant is planned for rehabilitation or expansion, the condition of the force main should be checked, hydraulic capacity and design pressure verified, and the suitability of the pipe material for the type of wastewater being conveyed investigated.

The Design Engineer should make a determination of the size, type of piping material, joints, alignment and method of installation most economically feasible for the project.

The force mains shall be provided with thrust blocks, pig launching and recovery stations for internal cleaning, force main taps to bypass the pumping plant, and whenever possible, dual force mains with isolation valves.

The force mains shall be designed for an economic life expectancy of 60 years.

DESIGN CAPACITIES AND VELOCITIES

The force main shall be designed for a minimum velocity of 3 feet per second (fps) to maintain solids in suspension. The maximum force main velocity should be calculated with respect to the cost of the installation of the force main versus the power cost over the 60 year life expectancy. The recommended velocity of the force mains would normally be between 5 to 7.5 fps, with the maximum velocity not exceeding 10 fps during intermittent flow conditions. The Design Engineer should consider the most economical pipe size, material and piping alignment.
F 726.2 MATERIALS OF CONSTRUCTION

The piping material should be designed and selected considering the environment normally encountered in wastewater system applications and buried conditions. The recommended force main piping materials are reinforced concrete pressure pipe (RCPP) and ductile iron pipe (DIP). Although for high pressure and large force main, cement mortar lined and coated steel pipe (CML&CSP) may be used. Polyvinyl Chloride (PVC) piping material may be used for smaller diameter force mains subject to approval by the Bureau of Sanitation.

In selecting the type of materials to use for force main construction, the following factors should be considered:

a. External corrosion caused by aggressive soils, groundwater, and stray currents.

b. Internal corrosion caused by sulfides and other chemical constituents.

c. Internal erosion from abrasive solids.

d. Ground movements, such as those caused by subsidence, landslides, earthquakes and differential settlement.

e. External loading.

f. Normal operating internal pressures and surge pressures.

g. Construction methods suitable and most economical for the selected alignment.

Force main piping accessories are as follows:

a. Sewage type air and vacuum release valves at high points.

b. Blowoffs valves at low points.

c. Access maintenance holes and bypass valves.
d. Pig launchers and retrievers for internal cleaning.

e. Joint bonding and other cathodic protection measures for metallic bonding especially pipelines located along the light rail transit alignment or near power stations.

f. Location of pipeline for least possible failures.

g. Where possible, installation of dual force main for added reliability.

h. Place marker or locating tape in the trench above the pipe.

Most commonly found problems are related to internal and external corrosion. Internal corrosion is normally caused by hydrogen sulfides accumulation inside the pipeline especially at high points in the piping system. When possible, high points in the piping system shall be avoided. Where high points are unavoidable, sewage type air and vacuum release valves should be installed. External corrosion is normally found where the pipe is in contact with seawater, corrosive liquid, or corrosive soils. Ground movements such as differential settlement, subsidence or earthquakes are considered secondary causes of piping system failures.

Most pipe materials, except plastic pipes (PVC, PP, ABS, etc.) are susceptible to corrosion by the formation of acids in the sewer gas space when the pipe is not flowing full. The results of sulfide corrosion are similar for both metallic and cementitious pipes. Internal corrosion will result in reduction of the pipe wall thickness and ultimately holes will form in the top of the pipe. Progressive corrosion will lead to weakening of the pipe wall which could result in pipe collapse.

The pipe wall thickness shall be calculated based on the internal pressure and the external load (trench load) plus corrosion allowance. In addition, the wall thickness shall be based on the predetermined bedding and backfill conditions. Pipe material, size, thickness, type of joints and installation shall be shown on plans and specifications.
F 726.21 DUCTILE IRON PIPES (DIP)

Ductile iron pipe may be used in force mains, especially in railroad and channel crossings. Where cast iron or ductile iron pipe is to be used for a force main, the nominal size, class, grade, and joint type must be shown on the plans and specifications. Ductile iron pipe should conform to ANSI A21.51 (AWWA C151) and the latest edition of the SSPWC as amended by Standard Plan S-610.

F 726.211 LINING AND COATING DUCTILE IRON PIPE

Unless otherwise specified, the internal surfaces of cast iron and ductile iron pipe and fittings for wastewater service should be lined with a uniform thickness of mortar, then sealed with a bituminous coating in accordance with ANSI A21.4 (AWWA C104). Mortar lining should be Type II or V cement. The outside coating of cast iron and ductile iron fittings for general use should be coated with a bituminous coating 1 mil thick in accordance with ANSI A21.6 or ANSI A21.51. Where required for corrosive service, internal surfaces of ductile iron pipe and fittings should be polyethylene lined.

For external corrosion protection, buried pipes, and ductile iron pipe and fittings should be encased with loose polyethylene encasement in accordance with ANSI A21.5 (AWWA C105).

For ductile iron piping and fittings located inside the pumping station, the external surfaces should be epoxy coated as follows:

Prime Coat: Carbo Zinc 11 HS, Tnemec 90-92 or equal, Dry Film Thickness (DFT) = 2 mils.

Intermediate: Carboline 893, Tnemec 104 or equal, DFT = 3 mils.

Finish coat: Carboline D134 HS, Tnemec 73 or equal, DFT = 3 mils.
F 726.212 PIPE JOINTS FOR DUCTILE IRON PIPE

Force mains normally carry thrust loads as a result of internal and surge pressures. All buried cast iron and ductile iron pipes and fittings should have the Tyton as manufactured by U. S. Steel or equal type push-on joints. In addition, concrete thrust blocks should be provided. All ductile iron pipe and fittings inside the pumping plant or inside a valve structure should be flanged or have threaded flanged joints.

<table>
<thead>
<tr>
<th>Joint Type</th>
<th>Standards</th>
</tr>
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<tbody>
<tr>
<td>Mechanical Joint</td>
<td>ANSI A21.11 (AWWA C111)</td>
</tr>
<tr>
<td>Flanged Joint</td>
<td>ANSI B16.1, B16.2 AND A21.10 (AWWA C 110)</td>
</tr>
<tr>
<td>Flanged Joint</td>
<td>ANSI B2.1</td>
</tr>
<tr>
<td>(Threaded Flanges)</td>
<td></td>
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</tbody>
</table>

For ease of maintenance and removal of valves, sleeve type or mechanical type couplings should be used. Sleeve couplings should be provided with restraint type joints designed to absorb the thrust loads imparted in the piping system. Mechanical couplings should not be used for buried piping installation. Restraint type joints should be sized in accordance with AWWA Design Manual M-11. Sleeve couplings are as manufactured by Rockwell, Gustin-Beacon or equal. Mechanical couplings are manufactured by Victaulic, Gustin-Beacon or equal.

Where differential settlement between the pumping plant structure and the force main piping is expected, sleeve coupling with restraint joints at both ends shall be provided. Where excessive ground movement is expected, ball type joints should be provided at both ends. Ball joint piping are as manufactured by U.S. Pipe or equal.

Design Engineers should check the prevailing cost of piping materials during the design phase when preparing an economic comparison study. In general, the installed cost of ductile iron pipe from 4 inches to 18 inches in diameter is normally less than that of reinforced concrete pipe (RCP) or cement mortar lined and coated steel pipes. For 20-inch pipe and larger, RCPP is less costly (with the exception of the AWWA C301 Prestressed Steel Wire
Reinforcement and Cylinder Type) than ductile iron pipe, whereas cement mortar lined and coated steel pipe is slightly less expensive than ductile iron pipe.

F 726.3 REINFORCED CONCRETE PRESSURE PIPE (RCPP)

There are three different types of RCPP pipe available for use in the force main system to carry wastewater under pressure. These are the AWWA C300, AWWA C301 and AWWA C302. Their use is dependent on size, pressure and external loading.

The Project Design Engineer should determine the system pressure of the force main and prepare an economic comparison between power consumption versus pipe diameter and installed cost of different materials available for use as force mains.

The RCPP pipe and fittings should be manufactured and tested to conform to the following specifications:

a. AWWA C300 for the steel bar reinforcement and cylinder type with 42 inches and larger in diameter, and design pressures of 40 to 260 psi and external loading required by the project.

b. AWWA C301 for the prestressed steel wire reinforcement and cylinder type with 30 inches and larger in diameter, and design pressures to maximum of 350 psi and external loading required by the project. This pressure range is not expected in any of the City's force main due to topographic location of the wastewater service areas. Special attention by the Design Engineer is required in the use of this type of pipe especially in design and manufacturing process. Numerous failures have been reported where this type of pipe was used. Some failures were caused by corrosion of reinforcement bars.

c. AWWA C302 for the steel bar reinforcement (without cylinder type with pipe diameters 12 inches and larger, and design pressures of not more than 45 psi and external loading conditions required by the project.
d. Lined reinforced concrete pipe should be PVC lined to conform with Section 207-3 of the SSPC and as amended by the Standard Plans S-610.

The internal pressure rating and external loading conditions should be shown in the project plans and specifications.

F 726.4 CEMENT MORTAR LINED AND COATED STEEL PIPE (CML&CSP)

The costs of CML&CSP force mains with diameters of 20 inches and larger are generally less than that of CIP or DIP, due to the high cost of DIP fittings. CML&CSP should be designed with internal mortar coating allowance for corrosion and fabricated in accordance with AWWA C200 and SSPWC specifications. The pipe should have welded joint or push-on type joints as required for the project. Lining and coating shall be Type II or V cement. The pipe size, type, and cylinder thickness or pressure class shall be specified and indicated on the plans.