Design Seminar

- **Review of Design Fundamentals**
  - System schematic

- **General Project Guidelines**
  - Explanation of flow path
  - Explanation of “Q-Mean”
  - Sample profile
  - Summary of fundamentals
Design Seminar

- **Sample Problem**
  - Plan and Profile Design
  - Design Software
  - Station Calculations

- **Standard Details**

- **Factory Collection Stations**

- **Questions and Answers**
General Guidelines for Vacuum System Design
Determine the geographical limits of the service area

- The vacuum system is a mechanical system
  - Component sizing based on total system flow
  - This is a most critical step in the analysis
Analyze topography of site to select ideal site for central vacuum station

- Locate point that utilizes as much natural ground slope as possible
  - Start with the lowest elevation in the complex
  - Optimum point is the lowest point nearest the geographical center of the site

- Review available property
  (other municipal works or public properties)
  - Use lowest centrally located property as guide

- Review final sewage outfall
  - Minimize forcemain length if possible
Route sewer lines along public right-of-way

- Take advantage of as much natural ground slope as possible
- Analyze approximate lift for each flow path
  - Compare ground elevation difference between the end of line and the vacuum station
  *Note the highest elevation this flow path must ascend*
Route sewer lines along public right-of-way

- Using 13 Ft. as maximum static loss, the following are approximate grade elevation differences for various pipe sizes using normal lifts:
  - 4” = 15 Ft. (Based on 1.0’ Lifts)
  - 6” = 17 Ft. (Based on 1.5’ Lifts)
  - 8” = 19 Ft. (Based on 1.5’ Lifts)

Additional grade elevation differences can be overcome using slightly deeper trenches and/or lower lift heights.
Determine input flow for each vacuum main or branch

- Account for the total number of:
  - Homes
  - Schools
  - Apartments
  - Commercial Businesses
  - Etc.

See Chapter 2 of 2005 Design Manual for recommended flows
- **Place interface valve pits at property corners**
  - Indicate gravity connections to various lots
  - To minimize gravity sewer depth
    - Use two (2) homes per valve pit as a general guideline and a maximum of four (4) homes per valve pit

- **Place single, dual or other buffer tanks at appropriate high flow locations**
  - Additional buffer tank limitations in Chapter 6 of 2005 Design Manual

- **Analyze each vacuum line for future growth potential**
  - Add this flow to existing flow

- **Ideally, total peak flow for each main line entering the vacuum station should be as close to equal as possible**
Determine peak design flow to vacuum collection station and calculate major station components.

- Use criteria found in Chapters 2 and 3 of 2005 Design Manual.
After final line routing and vacuum station site selection, line routing should be field surveyed for exact length and ground contours.

- Prepare plan and profile sheets on a split or combined plan
  - Profile page using aerial photography or other techniques to locate homes, streets, right-of-ways, existing utilities, etc.
  - A scale of 1” = 50’ horizontal and 1” = 5’ vertical is typical

- Select the vacuum collection tank connection point as main line station 0+00
  - Continue outward toward main line extremities
Where branch lines connect to main lines or each other, their connection point becomes 0+00 for that line.

Preferred direction of profile design in the flow direction:
- It is recommended that profile design start at the end of each main line.

Starting elevation should include:
- Frost cover (as dictated by local conditions)
- Plus the diameter of a 3" cross-over
- Plus the invert to invert dimension of a 3" cross-over to mainline wye fitting as shown on Figure F4-8 (normally 1’-0” minimum).
Lifts are placed as required

- To minimize trench depth
- To ascend uphill grades
- Generally speaking if ground is flat, a 1.0 foot lift at 500’ centers or a 1.5 foot lift at 750’ centers will result in an elevation equal to elevation at starting point
  
  \[(500 \text{ Ft.} \times 0.2\% = 1.0 \text{ Ft.} \text{ or } 750 \text{ Ft.} \times 0.2\% = 1.5 \text{ Ft.})\]

- All lifts will result in a designed vacuum loss equal to the lift height minus the pipe diameter

- The sum of all vacuum losses from the end of a “flow path” to the vacuum collection station should not exceed 13.0 Ft. without consulting AIRVAC
Vacuum process begins at the vacuum valve and collection sump assembly

- When the volume of sewage in sump reaches approximately 10 gallons
  - The AIRVAC valve opens
  - Differential pressure between the vacuum sewer and the atmosphere forces the 10 gallons of sewage into the vacuum main
    - While accelerating, sewage is rapidly transformed into foam
    - Soon occupies only part of the sewer pipe cross section;
      - momentum transfer from air to water takes place largely through the action of shear stresses
    - The magnitude of the propulsive forces start to decline noticeably when the AIRVAC valve closes
  - It remains important as the admitted air continues to expand
  - Eventually friction and gravity bring the sewage to rest below several lifts
As the process continues

- Liquid will be transported downstream by in-rushing air
- Sewage admitted to a sewer through an AIRVAC valve initially moves in two directions.
  - 80% flows toward the collection station
  - 20% flows in the opposite direction
- When the backsurge slows, flow moves toward the collection station (schematics follow)

- Sewage scouring velocities of 15 to 18 feet per second are attained using the standard air/liquid ratio
INTERFACE VALVE IN STANDBY POSITION

AIR INTAKE PLACED NEAR HOME W/INLET ABOVE HIGHEST WATER

VALVE IS CLOSED SEPARATING ATMOSPHERIC PRESSURE FROM VACUUM

VACUUM FROM SEWER LINES SUB-ATMOSPHERIC 6 PSIA APPROXIMATELY

SEWAGE FROM HOME OR BUSINESS

VALVE CYCLE AUTOMATICALLY

ATMOSPHERIC AIR PRESSURE 14.7 PSIA

SEWAGE COLLECTED IN SUMP

SEWAGE MAIN DIRECTION OF FLOW INTO PAPER
Interface Valve in Open Position

Valve is now open.

Sewage flows thru interface valve & is followed by atmospheric air.

Vacuum sewer main (direction of flow into paper).

Liquid is extracted from sump in approximately 8 seconds.

Atmospheric air.

Grade.
Vacuum Line Thrust

A Backsurge can travel several feet before slowing and reversing towards the collection station.

Main flow:
- Air space open from end of line to vacuum station
- High velocity liquid contacts liquid at rest & propels the mass downstream
- 0.2% fall

Sewage at rest:
- From valve pit

Sealage inlet
- Backsurge
Example of Flow Path
Explanation of Q (MEAN)

To determine the friction loss for this section of vacuum main:
Determine the value of Q (Mean):
This is the sum of all homes along this section \( \times \frac{0.64 \text{ gpm}}{2} \)
Plus the Total flow from all previous sections.

Using friction loss tables, find head loss per hundred feet
Multiply by the length of pipe in this section (hundreds)

\[
Q \text{ (MEAN)} = Q_{\text{ACCUM PREV}} + Q_{\text{AVERAGE FOR SECTION}}
\]

\[
= 100 \text{ GPM} + \frac{24 \text{ HOMES} \times 0.64 \text{ GPM}}{2}
\]

\[
= 100 \text{ GPM} + 7.68 \text{ GPM} = 107.68 \text{ GPM}
\]

LENGTH OF PIPE FOR THIS SECTION

Nominal Distance of 1 ft.

\[
Q_{\text{ACCUM}} = Q_{\text{ACCUM PREV}} + Q_{\text{ACCUM THIS SECTION}} + Q_{\text{BRANCH FLOW}}
\]

\[
= 100 \text{ GPM} + (24 \times 0.64 \text{ GPM}) + 20 \text{ GPM} = 135.36 \text{ GPM}
\]
Vacuum Main Profile Design Example

Profile Designed for 4" or Larger Vacuum Mains

Maximum Fall Between Lifts:

- 3" 0.20% 0.2% of Distance
- 4" 0.25% 0.2% of Distance
- 5" 0.25% 0.2% of Distance
- 6" 0.25% 0.2% of Distance
- 8" 0.25% 0.2% of Distance

Use 1' Lifts Whenever Possible for 6" or Larger Vacuum Mains. Use 1' Lifts in Areas of Lifts Over 3'.

Schedule 40 or Std 21 PVC Pipe.

Vacuum Main Profile Design Examples

AIRVAC - STANDARD

VACUUM SEWER SYSTEMS

AIRVAC - 1/04/99 44B
Summary of Vacuum Piping Design
Fundamentals

- **SLOPES**
  - Use natural ground slope if greater than 0.2%
  - Use 0.2% slope for flat terrain
  - Use saw tooth profile for uphill transport
  - Use 0.2% slope at 50’ minimum prior to first lift in any series
Summary of Vacuum Piping Design

Fundamentals

- **FALL BETWEEN LIFTS**
  - Use larger of two values
  - $0.2\% \times \text{Length}$
  - 0.20 Ft. fall for 3” service laterals if lifts are closer than 100 Ft. apart
  - 0.25 Ft. minimum fall for ALL vacuum mains and branches 4” and larger if lifts are closer than 125 Ft. apart
Summary of Vacuum Piping Design

Fundamentals

- **LIFTS**
  - Use 1'-0" for 3" or 4" pipe
  - Use 1'-6" for 6" or larger pipe
  - Static loss = Lift height – Pipe diameter
  - Maximum vacuum loss due to lifts from any AIRVAC valve to the collection station = (13 Ft. Static Loss + 5 Ft. Friction Loss)
  - Maximum series of lifts = 5 at 20 Ft. centers
  - First lift on a branch minimum 20 Ft. from connection to main
Summary of Vacuum Piping Design

Fundamentals

- CONNECTIONS
  - Use wye connectors for all branch and lateral connectors
    - Wye may be vertical or at 45° angle
  - Use long sweep 90° ell for 3” service connectors ONLY
  - Use 45° ells for 4” and larger connectors and any directional change
  - Recommended minimum Invert to Invert elevation difference for connections:
    - 4 x 3 = .73 Ft.
    - 6 x 3 = .80 Ft.
    - 8 x 3 = .99 Ft.
    - 10 x 3 = 1.08 Ft.
    - 4 x 4 = .71 Ft.
    - 6 x 4 = .78 Ft.
    - 8 x 4 = 1.05 Ft.
    - 10 x 4 = 1.18 Ft.
Summary of Vacuum Piping Design
Fundamentals

- **FLOW LIMITS**
  - Maximum Friction Loss not to exceed 5 feet
  - 3” = 4 homes or equivalent
  - 4” = 38 GPM
  - 6” = 106 GPM
  - 8” = 210 GPM
  - 10” = 375 GPM
Summary of Vacuum Piping Design

Fundamentals

- MAXIMUM LINE LENGTHS

  3” = 300 Ft.

  4” = 2,000 Ft.

  6” & Larger determined by static limits or friction
Minimum Slopes

Minimum fall for all pipe sizes = 0.25 ft

Upgrade Transport

Vacuum main

Fall = 0.2% × Length = 500 × 0.002 = 1.0 ft

Flow

Level grade transport
50' @ 0.2% Rule

ELEV ▲ = NUMBER LIFTS X LIFT HT
- (NUMBER LIFTS -1)(FALL BETWEEN LIFTS)

FLOW

SERIES OF LIFTS

50 FT MIN @ 0.2% SLOPE

DOWNHILL SLOPE GREATER THAN 0.2%
SAMPLE PROFILE SHOWING TOLERANCE FROM PLANNED ELEVATION @ 0.05 FT PER 100 FT

- PLANNED ELEV = 500.00
- PLANNED PROFILE @ 0.2% SLOPE
- PROFILE WITH MAXIMUM DEVIATION FROM PLAN
- MINIMUM ELEV = 499.75
- MAXIMUM ELEV = 499.85
- PLANNED ELEV = 499.80
- PLANNED ELEV = 499.60
- 100 FT
- 100 FT
Static Loss Diagram

45° PVC SOLVENT WELD, SCHEDULE 40 PRESSURE FITTINGS.

LIFT HEIGHT

VACUUM LOSS

VACUUM LOSS = LIFT HEIGHT
MINUS PIPE DIAMETER, FOR ALL PIPE SIZES

SCHEDULE 40 OR SDR21 PVC PIPE
Service Connections

FLOW

SCHEDULE 40
WYE FITTING

90° LONG RADIUS
SCH 40 ELL, TURNED
TO SIDE.

3" SERVICE LATERTAL
2" OR 0.2% FALL FROM
VALVE TO MAIN (MIN.)

FROM VALVE PIT

VALVE PIT TO MAIN CONNECTIONS

B

A

D

C

(2)

(1)

BASED ON SPEARS MFG PVC
SCH 40 PRESSURE FITTINGS

(2) SCH 40 X 90° ELL SOLVENT WELD
(2) SCH 40 WYE SOLVENT WELD

<table>
<thead>
<tr>
<th>WYE SIZE</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D - INVERT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot; x 4&quot; x 3&quot;</td>
<td>9 1/4&quot;</td>
<td>3 25/32&quot;</td>
<td>9.38&quot;</td>
<td>0.78&quot;</td>
</tr>
<tr>
<td>6&quot; x 6&quot; x 3&quot;</td>
<td>10 1/2&quot;</td>
<td>3 25/32&quot;</td>
<td>10.21&quot;</td>
<td>0.85&quot;</td>
</tr>
<tr>
<td>8&quot; x 8&quot; x 3&quot;</td>
<td>13&quot;</td>
<td>3 25/32&quot;</td>
<td>11.86&quot;</td>
<td>100&quot;</td>
</tr>
<tr>
<td>10&quot; x 10&quot; x 3&quot;</td>
<td>14 3/8&quot;</td>
<td>3 25/32&quot;</td>
<td>12.84&quot;</td>
<td>110&quot;</td>
</tr>
</tbody>
</table>
SCHEDULE 40
WYE FITTING

6' MINIMUM FROM TOP OF LIFT

FLOW

45° ELBOW

FLOW

45° ELBOW

VACUUM SEWER MAIN

2' MINIMUM

VACUUM SEWER BRANCH

45° ELBOW

20' MINIMUM FROM A LIFT

VACUUM BRANCH TO MAIN CONNECTION

BASED ON SPEARS MFG.
(1) 45° WYE, SOCKET x SOCKET x SOCKET
(2) 45° ELL, SOCKET x SOCKET

<table>
<thead>
<tr>
<th>WYE SIZE</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D - INVERT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x 4 x 4</td>
<td>8 3/4&quot;</td>
<td>3 5/16&quot;</td>
<td>8.53&quot;</td>
<td>0.71'</td>
</tr>
<tr>
<td>4 x 4 x 3</td>
<td>9 1/4&quot;</td>
<td>3 1/16&quot;</td>
<td>8.70&quot;</td>
<td>0.73'</td>
</tr>
<tr>
<td>6 x 6 x 6</td>
<td>12 1/8&quot;</td>
<td>5 9/16&quot;</td>
<td>12.5&quot;</td>
<td>1.04'</td>
</tr>
<tr>
<td>6 x 6 x 4</td>
<td>10&quot;</td>
<td>3 5/16&quot;</td>
<td>9.41&quot;</td>
<td>0.78'</td>
</tr>
<tr>
<td>6 x 6 x 3</td>
<td>10 1/2&quot;</td>
<td>3 1/16&quot;</td>
<td>9.59&quot;</td>
<td>0.80'</td>
</tr>
<tr>
<td>8 x 8 x 8</td>
<td>18 3/4&quot;</td>
<td>6 13/16&quot;</td>
<td>18.07&quot;</td>
<td>1.52'</td>
</tr>
<tr>
<td>8 x 8 x 6</td>
<td>16 1/4&quot;</td>
<td>6 3/8&quot;</td>
<td>15.42&quot;</td>
<td>1.30'</td>
</tr>
<tr>
<td>8 x 8 x 4</td>
<td>14 1/4&quot;</td>
<td>3 5/16&quot;</td>
<td>12.42&quot;</td>
<td>1.05'</td>
</tr>
<tr>
<td>8 x 8 x 3</td>
<td>13&quot;</td>
<td>3 1/16&quot;</td>
<td>11.36&quot;</td>
<td>0.99'</td>
</tr>
<tr>
<td>10 x 10 x 10</td>
<td>22 3/8&quot;</td>
<td>8 19/32&quot;</td>
<td>21.90&quot;</td>
<td>1.89'</td>
</tr>
<tr>
<td>10 x 10 x 8</td>
<td>20 1/4&quot;</td>
<td>6 13/16&quot;</td>
<td>19.13&quot;</td>
<td>1.61'</td>
</tr>
<tr>
<td>10 x 10 x 6</td>
<td>17 3/4&quot;</td>
<td>5 9/16&quot;</td>
<td>16.48&quot;</td>
<td>1.42'</td>
</tr>
<tr>
<td>10 x 10 x 4</td>
<td>15 3/4&quot;</td>
<td>3 5/16&quot;</td>
<td>13.48&quot;</td>
<td>1.18'</td>
</tr>
<tr>
<td>10 x 10 x 3</td>
<td>14 3/4&quot;</td>
<td>3 1/16&quot;</td>
<td>12.33&quot;</td>
<td>1.08'</td>
</tr>
</tbody>
</table>
Alternate Vacuum Branch to Main Line Connection

Connections
7'-6" APPROX.

GRAVITY STUB INDICATING END OF

HOUSE

2 X 4 OR SIMILAR

DEVICE NEAR GRADE

2'-0"

(CAN BE AS

MUCH AS 6'-6"

WITH DEEP SUMP)

EXISTING GRAVITY LINE

FROM RESIDENCE

AIRVAC VALVE PIT

LOCATED IN RIGHT-OF-WAY

3" VACUUM LINE

PREVIOUSLY INSTALLED

AND CONNECTED

TO VACUUM STATION

4" GRAVITY LINE STUBBED OUT

AND CAPPED OFF (MAY BE AS

MUCH AS FOUR CONNECTIONS)

20' MINIMUM IN NORTHERN CLIMATES

4" AIR INTAKE PIPE USING DWV

90° PVC ELLS. CONNECTION

TO RISER NEED NOT BE GLUED.

HEIGHT TO BE ABOVE WATER,

BUT BELOW BUILDING FLOOR

CAST IRON COVER WITH

NO SEALING RING-

CONTACT AIRVAC FOR

OPTIONAL SEALING METHODS

VALVE AND ASSOCIATED

INSTALLATIONS BY

MUNICIPALITY

PORTION OF 3" SUCTION

PIPE REMOVED FOR CLARITY

DO NOT INSTALL VACUUM

VALVE UNTIL 4" AIR INTAKE

IS IN PLACE

FIGURE 3-2 VALVE PIT PRIOR TO HOME CONNECTION

FIGURE 3-3 VALVE PIT WITH HOME CONNECED
3” Service Line Lifts

Connect over top

Slope between lifts equal to 0.2% fall or 80% pipe diameter whichever is greater.

With long uphill crossover an increased air to liquid ratio will be required.

Airvac® valve

Gravity from 2 homes

Method of connecting Airvac valve sited close to sewer crossover laid in sewer trench and enters ‘over top’ details above apply.

See installation drawings
Design Example

- **Consider vacuum sewer layout**
  - Locations of collection station, sewers and AIRVAC valves selected in accordance with requirements of AIRVAC 2005 Design Manual
    - Locate sewers to
      - Minimize lift
      - Minimize length
      - Equalize flows on each sewer (where possible)
  - Locate AIRVAC valves to serve two or more homes per valve
    - See Chapter 5
Design Example

- **Assumptions**
  - Each AIRVAC valve to serve two (2) homes
  - Peak flow per home .64 GPM or 1.28 GPM / AIRVAC valve installation

- To efficiently serve the areas in the design example layout
  - Three (3) main sewers required
  - Each main connected directly to vacuum tank at collection station
  - Sewers are not joined together into bus main outside the station
Design Example

- Division valves located to isolate areas of sewer network for troubleshooting purposes
- Profiles prepared for Main #2
  - Profiles for Branches, Main #1 and Main #3 would be similar
Design Example

- Location of AIRVAC valves and branch sewer connection points follow principles in Chapters 4 and 5

- Buffer tank valve installation on Branch C
  - Represents high flow user (ex: laundromat or school)
  - Ten (10) GPM used as inflow rate for this location

- Main #3 represents sewer main laid in alley way
  - Allows up to four (4) homes to be connected to each AIRVAC valve installation
### Figure F4-17 – Piping Calculation Sheet

**PROJECT:** Design Example  
**STATION NUMBER:** 1  
**DATE:** 6/25/03  
**Peak Flow Rate per Home = .64 gpm**

<table>
<thead>
<tr>
<th>LINE</th>
<th>4” PIPE</th>
<th>6” PIPE</th>
<th>8” PIPE</th>
<th>10” PIPE</th>
<th>PEAK</th>
<th># SVCE LATERALS</th>
<th># AIR/VAC VALVES</th>
<th>HOMES (or EDUS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2400</td>
<td>1400</td>
<td>79.4</td>
<td>62</td>
<td>62</td>
<td>124</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3700</td>
<td>2200</td>
<td>49.9</td>
<td>10</td>
<td>32</td>
<td>78</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| | **Average Service Lateral Length** | **Total 3” Pipe** |
| | | |

**VOLUME OF PIPEWORK (BASED ON SDR-21 PVC PIPE)**

\[
V_p = (.0547 \times \text{Length 3”}) + (.0904 \times \text{Length 4”}) + (.1959 \times \text{Length 6”}) + (.3321 \times \text{Length 8”}) = (.5095 \times \text{QTY 10”}) \text{ FT}^3
\]

\[
V_p = (\text{____ + ____ + ____ + ____ + ____}) \text{ FT}^3
\]

\[
V_p = 7.5 (\text{____}) \text{ GALLONS}
\]

\[
V_p = \text{____ GALLONS}
\]

\[
\frac{2}{3} V_p = \text{____ GALLONS}
\]
### Figure F4-17 – Piping Calculation Sheet

**PROJECT:** Design Example  
**STATION NUMBER:** 1  
**DATE:** 6/25/03  
**Peak Flow Rate per Home = .64 gpm**

<table>
<thead>
<tr>
<th>LINE</th>
<th>4” PIPE</th>
<th>6” PIPE</th>
<th>8” PIPE</th>
<th>10” PIPE</th>
<th>PEAK</th>
<th># SVCE LATERALS</th>
<th># AIR/VAC VALVES</th>
<th>HOMES (or EDUS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2400</td>
<td>1400</td>
<td></td>
<td></td>
<td>79.4</td>
<td>62</td>
<td>62</td>
<td>124</td>
</tr>
<tr>
<td>2</td>
<td>3430</td>
<td>3410</td>
<td>3015</td>
<td></td>
<td>145.9</td>
<td>114</td>
<td>114</td>
<td>228</td>
</tr>
<tr>
<td>3</td>
<td>3700</td>
<td>2200</td>
<td></td>
<td></td>
<td>49.9</td>
<td>10</td>
<td>32</td>
<td>78</td>
</tr>
<tr>
<td>TOTALS</td>
<td>9530</td>
<td>7010</td>
<td>3015</td>
<td></td>
<td>275.2</td>
<td>186</td>
<td>208</td>
<td>430</td>
</tr>
</tbody>
</table>

**Average Service Lateral Length:** 20’

**Total 3” Pipe:** 3720

**VOLUME OF PIPEWORK (BASED ON SDR-21 PVC PIPE):**

\[
V_p = (0.0547 \times \text{Length 3”}) + (0.0904 \times \text{Length 4”}) + (0.1959 \times \text{Length 6”}) + (0.3321 \times \text{Length 8”}) = (0.5095 \times \text{QTY 10”}) \text{ FT}^3
\]

\[
V_p = (\_\_\_ + \_\_\_ + \_\_\_ + \_\_\_ + \_\_\_ ) \text{ FT}^3
\]

\[
V_p = 7.5 (\_\_\_ ) \text{ GALLONS}
\]

\[
V_p = \_\_\_ \text{ GALLONS}
\]

\[
\frac{2}{3} V_p = \_\_\_ \text{ GALLONS}
\]
**Figure F4-17 – Piping Calculation Sheet**

<table>
<thead>
<tr>
<th>LINE</th>
<th>4” PIPE</th>
<th>6” PIPE</th>
<th>8” PIPE</th>
<th>10” PIPE</th>
<th>PEAK</th>
<th># SVCE LATERALS</th>
<th># AIR/VAC VALVES</th>
<th>HOMES (or EDUS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2400</td>
<td>1400</td>
<td></td>
<td></td>
<td>79.4</td>
<td>62</td>
<td>62</td>
<td>124</td>
</tr>
<tr>
<td>2</td>
<td>3430</td>
<td>3410</td>
<td>3015</td>
<td></td>
<td>145.9</td>
<td>114</td>
<td>114</td>
<td>228</td>
</tr>
<tr>
<td>3</td>
<td>3700</td>
<td>2200</td>
<td></td>
<td></td>
<td>49.9</td>
<td>10</td>
<td>32</td>
<td>78</td>
</tr>
<tr>
<td>TOTALS</td>
<td>9530</td>
<td>7010</td>
<td>3015</td>
<td>275.2</td>
<td>186</td>
<td>208</td>
<td>430</td>
<td></td>
</tr>
</tbody>
</table>

Average Service Lateral Length 20’

Total 3” Pipe 3720

**VOLUME OF PIPEWORK (BASED ON SDR-21 PVC PIPE)**

\[
V_p = (0.0547 \times \text{Length 3’}) + (0.0904 \times \text{Length 4’}) + (0.1959 \times \text{Length 6’}) + (0.3321 \times \text{Length 8’}) = (0.5095 \times \text{QTY 10’}) \text{ FT}^3
\]

\[
V_p = (203 + 861 + 1373 + 1001 + \ldots) \text{ FT}^3 = 3438 \text{ FT}^3
\]

\[V_p = 7.5 (3438) \text{ GALLONS} \quad (7.5 \text{ gal} / \text{ FT}^3)\]

\[V_p = 25,785 \text{ GALLONS} \quad \text{TOTAL PIPE VOLUME (Sewage & Vacuum)}\]

\[\frac{2}{3} V_p = 17,018 \text{ GALLONS} \quad \text{VACUUM ONLY}\]
Peak Flow (Qmax)  

\[ Q_{max} = \text{gpm} \]

Average Flow (Qa)  

\[ Q_a = \frac{Q_{max}}{2.5} = \text{gpm} \]

Minimum Flow (Qmin)  

\[ Q_{min} = \frac{Q_a}{2} = \text{gpm} \]

Vacuum Pump Capacity Required (Qvp)  

\[ Q_{vp} = \frac{A \times Q_{max}}{7.5 \text{ gal/ft}^3} = \frac{Q_{vp}}{7.5 \text{ gal/ft}^3} = \text{a.c.f.m} \]

(use 300 c.f.m.)

*Longest Line Length (A)  

<table>
<thead>
<tr>
<th>Length (ft)</th>
<th>5,000'</th>
<th>7,000'</th>
<th>10,000'</th>
</tr>
</thead>
<tbody>
<tr>
<td>0' - 5,000'</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>5001' - 7,000'</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7001' - 10,000'</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10,001' - 12,000'</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12,001' - 15,000'</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discharge Pump Capacity (Qdp)  

\[ Q_{dp} = Q_{max} \]

Collection Tank Operating Volume (Vo)  

\[ Vo = 15 Q_{min} (Q_{dp} - Q_{min}) \]

Total Volume Collection Tank (Vct)  

\[ Vct = 3 Vo \]

Vacuum Reservoir/Moisture Removal Tank (Vrt)  

(Recommended Volume Vrt = 400 gal)

System Pump Down Time for Operating Range of 16" to 20" Hz Vacuum (t)  

\[ t = \frac{(0.045 \text{ cfm min}) \times (2/3 V_p + (V_{ct} - V_o) + V_{rt})}{Q_{vp} \text{ cfm}} \]

"t" should be 1 to 3 mins.

if over 3, increase Qvp / if under 1, increase Vrt
**PROJECT: Example Problem**

**STATION #:** 1  
**DATE:** 6/25/03

---

### Peak Flow

| Qmax | = | 275.2 gpm |

### Average Flow (Qa)

\[
Q_a = \frac{Q_{\text{max}}}{\text{Peak Factor}}
\]

| Qa | = | 78.6 gpm |

### Minimum Flow (Qmin)

\[
Q_{\text{min}} = \frac{Q_a}{2}
\]

| Qmin | = | 39.3 gpm |

### Vacuum Pump Capacity Required (Qvp)

\[
Q_{\text{vp}} = \frac{A^* \times Q_{\text{max}} \text{ c.f.m}}{7.5 \text{ gal/ft}^3}
\]

| Qvp | = | 256.8 a.c.f.m. (use 300 c.f.m.) |

---

*Longest Line Length (A)*

<table>
<thead>
<tr>
<th>Length</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>0’</td>
<td>5,000’</td>
</tr>
<tr>
<td>5,001’</td>
<td>7,000’</td>
</tr>
<tr>
<td>7,001’</td>
<td>10,000’</td>
</tr>
<tr>
<td>10,001’</td>
<td>12,000’</td>
</tr>
<tr>
<td>12,001’</td>
<td>15,000’</td>
</tr>
</tbody>
</table>
**PROJECT: Example Problem**  
**STATION #: 1**  
**DATE: 6/25/03**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Value/Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge Pump Capacity (Qdp)</td>
<td>Qmax = 275.2 gpm</td>
</tr>
<tr>
<td>Collection Tank Operating Volume (Vo*) (for 15 min. cycle at Qmin)</td>
<td>Vo = 506.3 gal</td>
</tr>
<tr>
<td>Total Volume Collection Tank (Vct) -INCLUDE 400 gallons for Reserve Tank</td>
<td>Vct = 1519 gal</td>
</tr>
<tr>
<td>Vacuum Reservoir / Moisture Removal Tank (Vrt) (if separate vessel is desired)</td>
<td>Vrt = 0 gal (include in Vct)</td>
</tr>
</tbody>
</table>

* Vo = 1.84 Qmax for 3.5 Peak Factor  
  = 1.64 Qmax for 4.0 Peak Factor
<table>
<thead>
<tr>
<th>System Pump Down Time for Operating Range of 16” to 20” Hg Vacuum (t)</th>
<th>( \frac{(0.045 \text{ cfm min})}{\text{gal}} \times \frac{(2/3 \text{ Vp } + (\text{Vct-Vo} + \text{Vrt}) \text{ gal})}{Qvp \text{ cfm}} )</th>
<th>t = 1.83 mins</th>
</tr>
</thead>
<tbody>
<tr>
<td>(t) should be 1 to 3 mins</td>
<td>( (0.045 \times (17,018) + (2,000 - 506) + (0)) )</td>
<td>455 cfm</td>
</tr>
<tr>
<td>- if over 3, increase Qvp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- if under 1, increase Vrt</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PROJECT: **Example Problem**  
Project No.: **951075**  
Station Number: **1**  
Date: **6/25/03**

### Peak Flow (Qmax)

\[
Q_{\text{max}} = \text{gpm}
\]

### Average Flow (Qa)

\[
Q_a = \frac{Q_{\text{max}}}{\text{Peak Factor}} = \frac{Q_{\text{max}}}{3.5} = \text{gpm}
\]

### Minimum Flow (Qmin)

\[
Q_{\text{min}} = \frac{Q_a}{2} = \frac{Q_{\text{max}}}{2} = \text{gpm}
\]

### Vacuum Pump Capacity Required (Qvp)

\[
Q_{\text{vp}} = \frac{A}{7.5 \text{ gal/ft}^3} \times Q_{\text{max}} = \text{a.c.f.m}
\]

*Longest Line Length (A)*

| 0' - 5,000' | 6 |
| 5001' - 7,000' | 7 |
| 7001' - 10,000' | 8 |
| 10,001' - 12,000' | 9 |
| 12,001' - 15,000' | 11 |

### Discharge Pump Capacity (Qdp)

\[
Q_{\text{dp}} = \frac{Q_{\text{max}}}{Q_{\text{vp}}}
\]

### Collection Tank Operating Volume (Vo)

\[
Vo = 15 Q_{\text{min}} (Q_{\text{dp}} - Q_{\text{min}}) = \frac{Q_{\text{max}}}{Q_{\text{dp}}}
\]

(15 min. cycle at Qmin)

1.84 Qmax for 3.5 Peak Factor
1.64 Qmax for 4.0 Peak Factor

### Total Volume Collection Tank (Vct)

\[
Vct = 3 Vo
\]

*INCLUDE 400 Gallons for Reserve Tank*

(Recommended Volume Vrt= 400 gal)

### Vacuum Reservoir/Moisture Removal Tank (Vrt)

\[
Vrt = 400 \text{ gal}
\]

(If separate vessel is desired)

(include in Vct)

### System Pump Down Time for Operating Range of 16" to 20" Hg Vacuum (t)

\[
t = \frac{(0.045 \text{ cfm min}) (2/3 Vp + (Vct-Vo)+Vrt) \text{ gal}}{Q_{\text{vp}} \text{ cfm}}
\]

\[
t = \frac{(0.045 (\text{gal}) + (\text{gal}) + (\text{gal}))}{\text{cfm}}
\]

*t* should be 1 to 3 mins.

if over 3, increase Qvp / if under 1, increase Vrt
PROJECT:  Example Problem
Project No.:  951075
Station Number:  1
Date:  6/25/03

Peak Flow (Qmax)  

\[ Q_{max} = 275.2 \text{ gpm} \]

Average Flow (Qa)  

\[ Q_{a} = \frac{Q_{max}}{3.5} = 78.6 \text{ gpm} \]

Minimum Flow (Qmin)  

\[ Q_{min} = \frac{Q_{a}}{2} = 39.3 \text{ gpm} \]

Vacuum Pump Capacity Required (Qvp)  

\[ Q_{vp} = \frac{7 \times Q_{max}}{7.5 \text{ gal/ft}^3} = \frac{7 \times 275.2 \text{ c.f.m.}}{7.5 \text{ gal/ft}^3} = 256.8 \text{ a.c.f.m.} \]

*Longest Line Length (A)  

\[
egin{array}{c|c|c|c|c}
\text{Length} & 0' & 5000' & 6 & 7001' & 1000' & 1200' & 1500'
\end{array}
\]

----- 6045

Discharge Pump Capacity (Qdp)  

\[ Q_{dp} = Q_{max} = 275.2 \text{ gpm} \]

Collection Tank Operating Volume (Vo)  

\[ Vo = \frac{15 Q_{min}}{Q_{dp}} = \frac{15 	imes 39.3}{Q_{dp}} = 506.3 \text{ gal} \]

Total Volume Collection Tank (Vct)  

\[ V_{ct} = 3Vo = 3 	imes 506.3 = 1519 \text{ gal} \]

Vacuum Reservoir/Moisture Removal Tank (Vrt)  

\[ V_{rt} = 0 \text{ gal} \]

System Pump Down Time for Operating Range of 16" to 20" Hg Vacuum (t)  

\[ t = \frac{(0.045 \text{ cfm min}) (2/3 V_{p}+(V_{ct}-V_{o})+V_{rt}) \text{ gal}}{Q_{vp} \text{ cfm}} = \frac{(0.045 \times 17,018) + (2000 - 506) + 0}{455 \text{ cfm}} \approx 1.83 \text{ mins.} \]
Peak Flow (Qmax) = 275.2 gpm

Average Flow (Qa) = \( \frac{Q_{\text{max}}}{\text{Peak Factor}} = \frac{Q_{\text{max}}}{3.5} \)

Minimum Flow (Qmin) = \( \frac{Q_{\text{a}}}{2} = \frac{78.6}{2} \)

Vacuum Pump Capacity Required (Qvp) = \( A* \times Q_{\text{max}} \text{ c.f.m.} \)

\[ Q_{\text{vp}} = 256.8 \text{ a.c.f.m} \]

(use 300 c.f.m.)

Discharge Pump Capacity (Qdp) = Qmax = 275.2 gpm

Collection Tank Operating Volume (Vo) = 15 Qmin (Qdp-Qmin)

Vo = 506.3 gal

Total Volume Collection Tank (Vct) = 3Vo = 1519 gal

Vacuum Reservoir/Moisture Removal Tank (Vrt) = 400 gal

Recommended Volume Vrt= 400 gal

System Pump Down Time for Operating Range of 16" to 20" Hg Vacuum (t) = \( \frac{(0.045 \text{ cfm min}) (2/3 V_{\text{p}}+(V_{\text{ct}}-V_{\text{o}})+V_{\text{rt}}) \text{ gal}}{Q_{\text{vp}} \text{ cfm}} \)

\[ t = 1.83 \text{ mins.} \]
Peak Flow (Qmax) = 275.2 gpm

Average Flow (Qa) = \( \frac{Qmax}{3.5} \) = 78.6 gpm

Minimum Flow (Qmin) = \( \frac{Qa}{2} \) = 39.3 gpm

Vacuum Pump Capacity Required (Qvp) = \( \frac{A^* \times Qmax \text{ c.f.m.}}{7.5 \text{ gal/ft}^3} \) = 256.8 a.c.f.m

<table>
<thead>
<tr>
<th>Longest Line Length (A)</th>
<th>0' - 5,000'</th>
<th>5,001' - 7,000'</th>
<th>7,001' - 10,000'</th>
<th>10,001' - 12,000'</th>
<th>12,001' - 15,000'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>

Discharge Pump Capacity (Qdp) = 275.2 gpm

Collection Tank Operating Volume (Vo) = \( \frac{15 \text{ Qmin (Qdp-Qmin)}}{Qdp} \) = 506.3 gal

Total Volume Collection Tank (Vct) = 3Vo = 1519 gal

Vacuum Reservoir/Moisture Removal Tank (Vrt) = 0 gal (include in Vct)

System Pump Down Time for Operating Range of 16" to 20" Hg Vacuum (t) = \( \frac{(0.045 \text{ cfm min}) (2/3 \text{ Vp+(Vct-Vo)+Vrt}) \text{ gal}}{Qvp \text{ cfm}} \)

\[ t = \frac{(0.045 \times 17,018) + (2000 - 506) + 0}{455} = 1.83 \text{ mins.} \]
The AIRVAC Hydloss spreadsheet shown is one example of a hydraulic analysis of Main #2 in the Design Seminar Example.
The AIRVAC Hydloss spreadsheet shown is one example of a hydraulic analysis of Main #2 in the Design Seminar Example.
Figure F6-5 Sample Profile

Legend:
- DIVISION VALVE
- CONNECTION OF BRANCH

Scale:
- HORIZ: 1" = 200'
- VERT: 1" = 5'

Vacuum Main #2 Flow

End of Line
EL = 513.91
@ 53+95

Point "F"
EL = 502.71
@ 36+00

Point "D"
EL = 502.20
@ 38+45

Connect Line "D"
EL = 502.60
@ 40+45

Change to 4"
EL = 507.08
@ 44+40

Connection of Branch
EL = 503.20
@ 38+00

EL = 502.00
@ 42+45
Design Example Procedure

- To provide adequate space for liquid level controls within the collection tank
  - Estimate minimum 5.5 ft elevation between incoming vacuum sewers and building floor
  - This places building floor at elevation 496.50 for this example

- See pages Chapter 4 of 2005 Design Manual for calculation of line losses in main #2
  - Friction losses for slopes greater than 0.2% are ignored
  - Calculated static losses due to profile change equal lift height minus the pipe I.D.
Design Example Procedure

- Select suitable standard size pumps and tanks
  - Consult manufacturers literature
  - Recalculate vacuum stations calculations using selected equipment sizes
  - Size vacuum and sewage pumps
    - Allow for additional house connections without overloading
  - For large vacuum stations three (3) vacuum pumps may be used to prevent use of extremely large pumps
  - Typically 25hp sliding vane pumps are largest model used by AIRVAC – standard models are:
    - 170 CFM @ 10HP
    - 305 CFM @ 15HP
    - 455 CFM @ 25 HP
Figure F5-2
Calculation of NPSHA in AIRVAC System with Typical Values
**Nomenclature**

\[ \text{NPSHA} = \text{Net positive suction head available (feet of water)} \]

\[ \text{NPSHA} = h_{avt} + h_s - h_f - h_{vpa} \]

\( H_a \) = Head available due to atmospheric pressure (see below)

<table>
<thead>
<tr>
<th>Height above sea level</th>
<th>( h_a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ft</td>
<td>33.9 ft</td>
</tr>
<tr>
<td>500 ft</td>
<td>33.3 ft</td>
</tr>
<tr>
<td>1000 ft</td>
<td>32.7 ft</td>
</tr>
<tr>
<td>1500 ft</td>
<td>32.1 ft</td>
</tr>
</tbody>
</table>

\( H_{avt} \) = Head available due to atmospheric pressure at liquid level less vacuum in collection tank (feet of water)
Nomenclature

\[ \text{Havt} = \text{ha} - \text{Vmax} \] (for maximum collection tank vacuum of 20” Hg at sea level \( \text{havt} = 33.9 \text{ ft} - 22.6 \text{ ft} = 11.3 \text{ ft} \)

\[ \text{Vmax} = \text{Maximum collection tank vacuum in feet of head} \]

\[ 20” \text{ mercury} = 22.6 \text{ ft} \]
\[ 16” \text{ mercury} = 18.1 \text{ ft} \]

\[ \text{Hs} = \text{Depth of sewage above pump centerline} - \text{typically 1’ minimum} \]

\[ \text{Hvpa} = \text{Absolute vapor pressure of sewage at its pumping temperature} (@ 68 degrees, \text{hvpa} = 0.78’) \]

\[ \text{Hf} = \text{Friction loss in suction pipes} (\text{approximately 2 feet for vertical pumps, 1 foot for horizontal pumps}) \]

\[ \text{NPSHR} = \text{NPSH required by pump selected} \]
\[ \text{NPSHA must be greater than NPSHR} \]
Total Dynamic Head on Discharge Pump (TDH) = Head Due to Vacuum + Static Head + Friction Loss (at 16” Hg vacuum head due to vacuum = 18.1’)

= 18.1’ + 12’ + 14.75’

(at 20” Hg vacuum head due to vacuum = 22.6’)

= 22.6’ + 12’ + 14.75’

TDH = 44.85’
TDH = 49.4’

NPSH Calculation NPSHA
*(havt = ha + Vmax) = 33.9 + (-) 22.6 = 11.3

NPSHA = 11.02’

VEL = 4.24 FPS

Hₗ / 100’ = 1.46 FT.

Hₗ = \left( \frac{1010}{100} \right) (1.46) = 14.75
USE WHICHEVER SLOPE IS GREATER BETWEEN LIFTS. ABOVE THIS LENGTH IN DISTANCE, THE 0.2% SLOPE IS GREATER. ANYTHING SHORTER THAN THIS DISTANCE SHOULD USE MINIMUM FALL INDICATED. WHEN NOT BETWEEN TWO LIFTS, USE 0.2% SLOPE.
Standard Skid (2) 300 CFM Vacuum Pumps & 1500 Gal. Collection Tank
Two-Skid Package Station – (2) 430 CFM Vacuum Pumps  2400 Gal. Tank