



by Gardner Denver

# GUIDE TO VACUUM CLEANING SYSTEM DESIGN

By Hoffman & Lamson

“Vacuum Cleaning System” refers not only to cleaning by means of vacuum hose and tools, but also to a multitude of tasks which can be accomplished by the same basic system components: a vacuum producer and separators.

A central vacuum cleaning system can be installed in many types of plants and buildings to accomplish one or more of the following objectives:

1. Good house cleaning - a labor saving device
2. Material recovery
3. Capture of dangerous and hazardous dust
4. Vacuum conveying of material

In this paper, however, we have attempted to cover the vacuum cleaning system as a tool for good housekeeping only. Such a system is generally designed to pick up and convey dry and free-flowing material that can enter and pass through the vacuum cleaning tool and hose. Further, the system is designed to allow for a selected number of operators.

### **Step One**

Determine the following:

1. The maximum number of operators to be using the system simultaneously
2. Whether any future expansion is anticipated
3. A convenient location for installing the main components: vacuum producer and separators

The above points should be discussed with your Hoffman & Lamson representative or someone else who has the experience and know-how to design and furnish the system. The rep should be shown all the areas to be served by the system. It is most important that the main components - vacuum producer and separators - are located in an area providing easy disposal of the collected material.

### **Layout of Piping System**

In the vast majority of systems, there is no need for schedule 40 pipe and fittings, as light

gauge steel tubing and fittings easily satisfy the requirements.

The layout must show the piping or tubing runs, location of the main equipment, and the inlet valves. The length of runs is to be clearly indicated and all 45° and 90° elbows are to be shown. No line sizing is to be done at this point.

### **Inlet Valve Locations**

The inlet valves are located at the end of the branches coming off the main or sub-main piping. The inlet valve with a spring loaded cover is a device which allows the connection of a flexible vacuum hose to the piping system. The system should have as many inlet valves as required to facilitate cleaning every area. However, the design of the system dictates the maximum number of inlet valves that can be used simultaneously.

### **Vacuum Cleaning Hose**

The main factor in locating the inlet valves in this type of system is the length of the vacuum cleaning hose to be used. Hose is available in various designs and lengths of 15, 25 and 50 feet. However, for this type of system the best results are obtained with a basic length of 25 feet. Hoses longer than 50 feet are not recommended, as they are too heavy and cumbersome. As a general rule, a distance of 30 to 35 feet between two inlet valves, for use with a 25 foot length of hose, is considered ideal.

### **Step Two**

Once the piping or tubing layout has been checked, the process of line sizing begins. The sizes depend on a number of factors:

1. The air volume per hose
2. The number of hoses to be used simultaneously
3. The correct air velocities for conveying the material to the separators

Air Volume per Hose

The hose diameter, the particle size and the quantity of material to be conveyed determines the air volume. From actual tests, Hoffman has established that 80 SCFM in 1.5" diameter hose satisfies the needs of most vacuum cleaning systems. However, for light cleaning, such as an office with carpets or wooden floors, the air flow can be reduced to 70 SCFM. For heavier material, the air flow can be increased to suit the system requirements.

Step Three

System Losses

In order to select the proper vacuum producer for the system, we must establish the total system loss (pressure drop or resistance) measured in inches of mercury (11Hg) vacuum. This total system loss consists of the sum of:

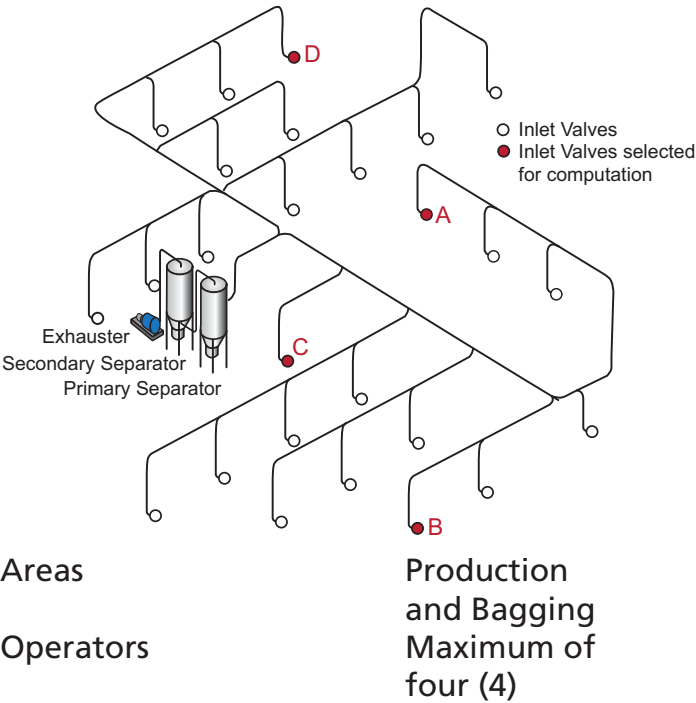
- 1. Loss through the hose and tools
- 2. Loss through the lines (straight runs and bends)
- 3. Loss through the separator(s)

Notes on Losses

- 1. Fig 2 "Hose and Tool Friction Loss" indicates the total loss for a given hose length with tool.
- 2. The friction loss in the lines (tubing and piping) can be obtained from Fig 4 "Vacuum Line Loss Chart."
- 3. The friction loss through 45° and 90° elbows are higher than the loss through the same diameter straight piping or tubing. Hoffman has established that the average friction loss through 45° and 90° elbows are equivalent to 7 ft. and 12 ft. of straight pipe respectively.

System Requirements

Type of Plant	Fertilizer
Particle Size	Fine to 1/4" Granular
Total Material Picked Up	Approximately 18 ft <sup>3</sup> /8 hour day
Operation	General Cleaning



After surveying the plant, deciding on the location of the main equipment (vacuum producer and separators) and the inlet valves, we prepare the layout as shown in Figure 1.

Figure 1: Piping Layout Showing Inlet Valve Locations & System Components

We have selected four inlet valve locations for design purpose, to establish the friction loss as well as line sizes for the system. Inlet Valve (A) is the farthest from the vacuum producer, while inlet valve (C) is closest to the vacuum producer. Inlet Valves (B) and (D) can be located in areas or branches more-or-less in equal distance to the vacuum producer. This selection of active inlet valve locations will allow us to design a system with proper line sizes to insure optimum system capability. From actual plant size and observation of building and production facilities, we have decided that a 25 ft length of 1.5" diameter hose and tool will satisfy the system requirements. Based on the particle size, amount, and density of material to be picked up it is determined that 80 SCFM/hose would be adequate for our system.

## Losses

### Tool Entrance and Hose at Point (A)

When handling 80 SCFM/25 ft of 1.5" diameter hose and tool we read a total friction loss of 1.75" Hg. The pressure drop in flexible hose is generally 2 to 2.5 times the pressure drop for the same length and size of pipe.

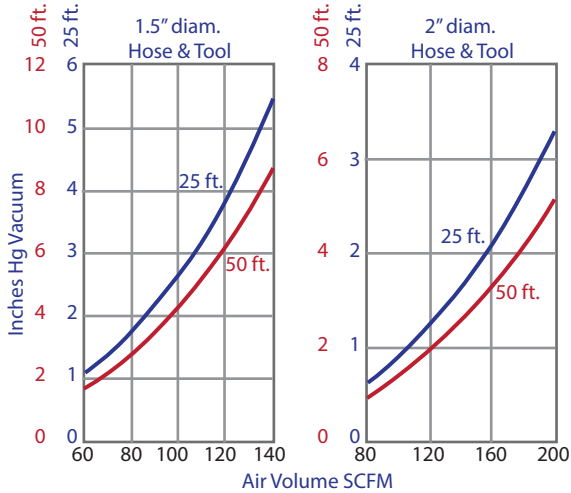


Fig. 2: Hose & Tool Friction Loss

Looking at Figure 3 at point (A), 80 SCFM enters the system and flows to point (E). The total equivalent piping length from point (A) to point (E) is:

2" line	<b>107 ft.</b> in length
5-90° elbows	<b>60 ft.</b> in equivalent length
Total	<b>167 ft.</b> in equivalent length

Using a vacuum line loss chart (Figure 4), at 80 SCFM and 2" diameter line, we find .75" Hg loss per 100 ft. line.

$$(167 \times .75) / 100 = 1.25" \text{ Hg}$$

At point (B), an additional 80 SCFM enters the system. This combines with the flow from point (A) (80 SCFM + 80 SCFM) for a total of 160 SCFM at point (E). The total equivalent piping from point (E) to (F) (there are no elbows) is 65 ft.

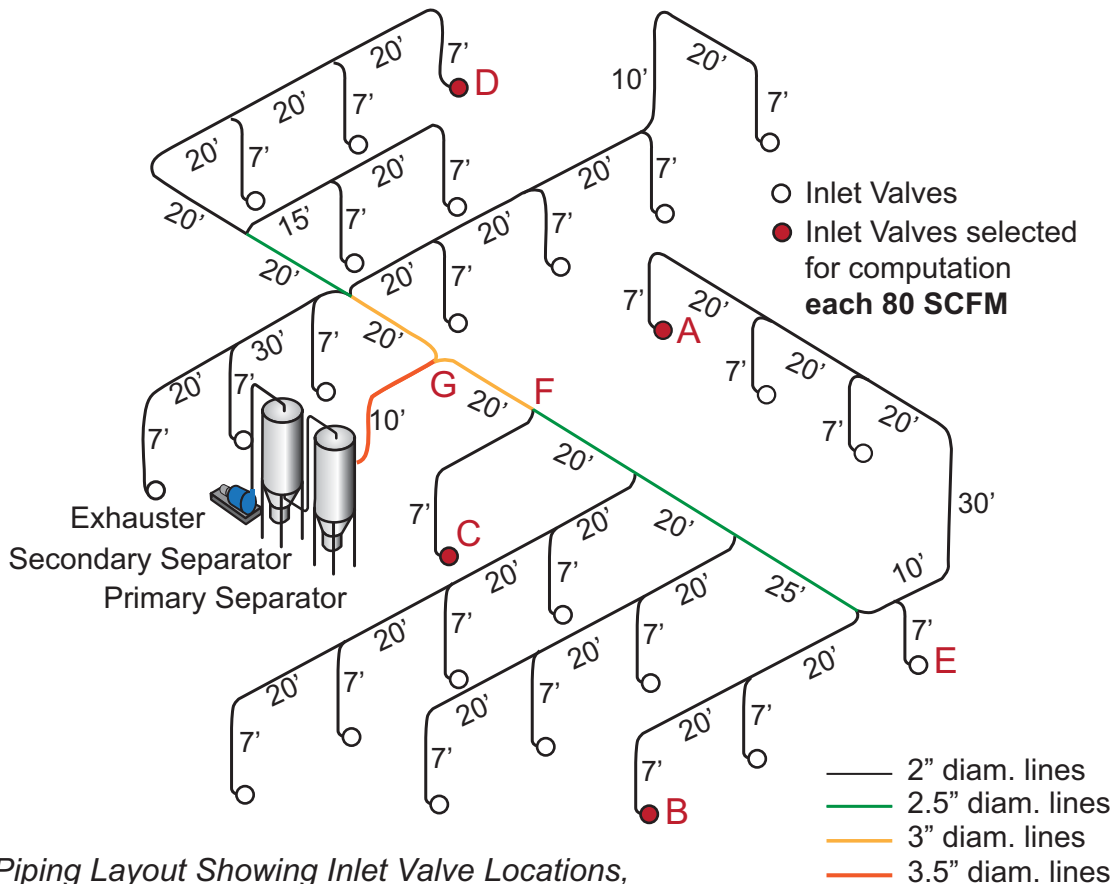


Figure 3: Piping Layout Showing Inlet Valve Locations, System Components and Dimensions

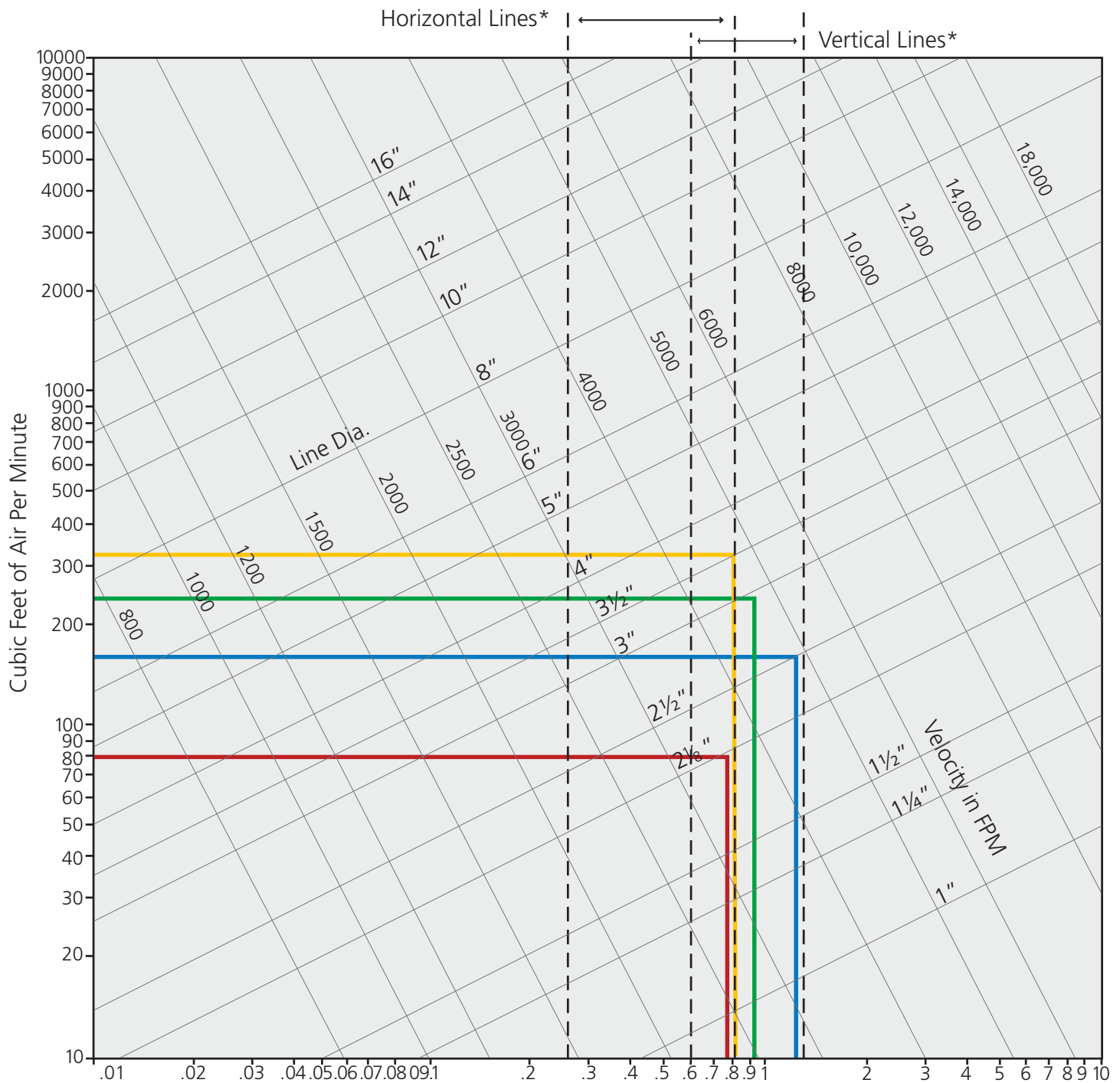


Figure 4: Vacuum Line Loss Chart

Using the same chart, at 160 SCFM, with a 2.5" diameter line, we find:

1.2" Hg loss/100 ft. line

$$(65 \times 1.2)/100 = .78" \text{ Hg}$$

At point (C), an additional 80 SCFM enters the system. This combines with the flow from point (E) (80 SCFM + 160 SCFM) for a total of

240 SCFM at point (F). The total equivalent line (there are no elbows) is 20 ft. At 240 SCFM with a 3" diameter line we find:

.90" Hg loss/100 ft. line

$$(20 \times .90)/100 = .18 \text{ Hg}$$

At point (G), an additional 80 SCFM enters the system. This combines with the flow from

point (F) (80 SCFM + 240 SCFM) for a total of 320 SCFM at point (G). The total equivalent piping length from point (G) to the primary separator inlet is:

3.5" diam. line	30 ft. in length
3-90° elbows	36 ft. equivalent length
Total	66 ft. in equivalent length

From the chart, we read 320 SCFM at a 3.5" diameter line:

.8" Hg loss/100 ft. line  
**(66 X .8)/100 = .52" Hg**

Separator loss is added to our total system loss. The loss will not exceed .25" Hg for the primary and .75" Hg for the secondary separator.

Total separator losses = 1" Hg. In general, the line between the separators and the vacuum producer are generously sized and, for all practical purposes, line losses are insignificant.

Therefore, the total friction loss for the system is:

(a) Hose & Tool loss	1.75" Hg
(b) Line loss from (A) to (E)	1.25"
(c) Line loss from (E) to (F)	0.78"
(d) Line loss from (F) to (G)	0.18"
(e) Line loss from (G) to separators	0.52"
(f) Separator losses	1.00"
<b>Total system loss</b>	<b>5.48" Hg</b>

The total system air volume is determined by:  
**80 SCFM/1.5" diameter hose x 4 operators = 320 SCFM**

This figure of 320 SCFM (standard at 29.92" Hg and 68° F) is then multiplied by the ratio of the standard barometric pressure divided by the standard barometric pressure minus the exhaustor inlet vacuum in inches of Hg to obtain the volume under inlet vacuum conditions. We do this since all Hoffman Exhauster performance curves are based at ICFM (inlet cubic ft. per minute):

**320 x (29.92 / (29.92 – 5.48)) = 392 ICFM**

We therefore require a vacuum producer capable of exhausting 391 ICFM of air at a vacuum of 5.48 "Hg. The Hoffman & Lamson cast multistage centrifugal exhauster model 407 with a 10 HP - 3,600 RPM motor is selected (See Chart 1).

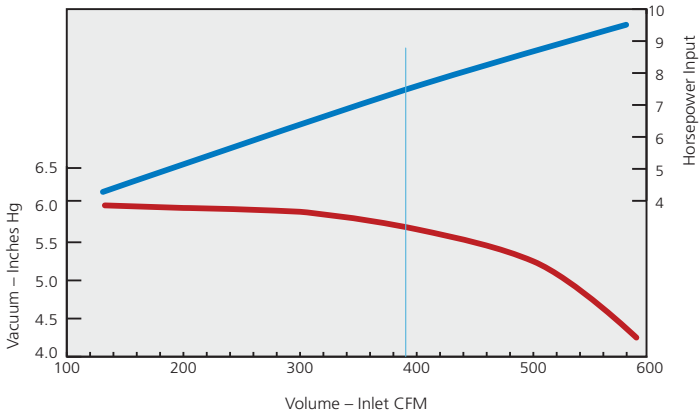


Chart 1: 407 performance curves

Basic Primary Separator Data					
Diameter-inches	24	30	36	48	60
Straight shell – inches*	66	66	96	96	120
Storage – cubic feet	16	24	53	96	185
Leg length - inches*	66	71	77	87	97
Weight – lbs.	650	750	1150	1900	2600

Table 1

\* The height can be modified to suit

Basic Secondary Separator Data									
Filter Area – sq. feet	86	128	174	221	338	431	512	651	1106
Diameter-inches	30	30	36	36	48	48	60	60	75
Straight shell – inches	66	96	96	120	96	120	96	120	120
Storage – cubic feet	4.2	4.2	10.2	10.2	27	27	38	38	61
Leg length - inches*	71	71	77	77	87	87	97	97	111
Weight – lbs.	800	1000	1250	1400	2000	2100	2700	2800	3900

Table 2

\* The height can be modified to suit

Based upon the system air flow and required storage capacity of 18 ft<sup>3</sup>, a 30" diameter primary separator is selected, see Table 1. The diameter of the primary should be equal to or greater than the square root of the total system air flow in ICFM.

Based on the system air flow, a 30" diameter secondary separator is selected with a total filter area of 128 ft. See Table 2.

### Ratio of Air Flow/Filter Area

The particle size and volume of material picked up by the system, in addition to the frequency of bag cleaning, will determine the ratio of air flow (ICFM) to square feet of filter area. Table 3 provides approximate guidelines for adequate air/filter ratio.

### Hose & Tools

Always start with a standard set of tools and add any extras required by your specific application, by referring to Hoffman Hose & Tool brochure.

### Piping/Tubing Installations

It is important that care be taken in connecting all piping/tubing joints to insure an air tight installation as air leakage will decrease system efficiency. When a system is to be installed at an elevation above sea level, certain corrections to vacuum producer performance become necessary since exhaustor performance curves are based on standard sea level conditions.

Air/Filter Ratio		
Material	Manual Cleaning	Automatic Cleaning
Carbon black, talc or other fine fugitive material	1	1-2
Usual dust and debris encountered in shops and similar industrial work or storage areas.	3	6-10
Commercial installations & hospitals (light dust conditions).	5	8-10
Little or no dust, as for white rooms	Up to 8	12

Table 3: Maximum recommended ICFM passing through each square foot of Filter Area.