Guide to Commercial Vacuum System Design

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TABLE OF CONTENTS

GUIDE TO CENTRAL CLEANING SYSTEM DESIGN

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INTRODUCTION:

A central cleaning 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. Also, the system should be designed to allow for a certain number of users. In order not to over-design or under-design the central cleaning system, a number of things should be taken into consideration.

- Material to be handled
- Number of vacuum inlets to be used simultaneously
- Layout of system
- Pressure losses
- Air flow required for cleaning
- Selection of vacuum power units

1. MATERIAL TO BE HANDLED

The central vacuum system is capable of handling all dry granular material or low viscosity fluids; however, care should be taken in handling toxic, hygroscopic, or sticky materials.

The area to be cleaned or the amount of material to be moved will determine the size of the hose, wand, or tools necessary for the particular installation. For cleaning small areas or moving small amounts of material, a 1-1/4" hose and tools will suffice, but for larger volume or areas, it may be necessary to use 1-1/2" hose and tools. For special applications 2" diameter hose and tools may be required.

The size of hose and tools, in turn, help determine the size of the vacuum power unit necessary for the particular job.

2. NUMBER OF VACUUM OUTLETS TO BE USED SIMULTANEOUSLY

The number of inlets in a given vacuum system has little to do with determining the size of power unit required for the installation. The number of inlets that will be in use at one time, however, does govern the design of the system.

If the vacuum system is primarily used for cleaning, the first thing to establish is the maximum number of operators available to use the system at one time. The next thing to consider would be the minimum number of operators required to do the necessary cleaning in the allotted time. The designer should keep in mind that cleaning with a central system is less time-consuming than other cleaning methods such as the use of brooms, mops, and portable cleaning units (see page 13 by the Dutch Government study on portables vs. central vacuumns). In one hour, one operator should be able to clean approximately 3000 square feet of smooth floor when using a central system if he does not encounter too many obstructions to be moved or swept around. Rougher floors, or ones with many obstructions, may require an hour for approximately 2000 square feet of floor space. The size of the particular cleaning system and how the operators will be using it will determine how many vacuum power units will be required and where they will be located.

It is well to remember that if your estimate of operators using the system is to low, then the system you design will probably be underpowered and give unsatisfactory or poor service; however, if you overestimate the number of operators using the system, then the system's initial cost will be unnecessarily high.

3. LAYOUT OF THE CENTRAL VACUUM SYSTEM

The vacuum inlets should be located in accessible places so that they are convenient to the area to be cleaned. Actually, the more inlets available, the more convenient the system will be to use; however, the cost of the system will be unnecessarily increased if the inlets are installed where they are not absolutely necessary. The inlet should be spaced to allow for the 20% overlap in cleaning areas. If a 20 foot hose is to be used, the inlets should be spaced approximately 30 feet apart; if a 25 foot hose is used, inlets should be spaced approximately 30 feet apart; and if a 30 foot hose is used, the inlets should be spaced approximately 46 feet apart. In some areas, the figures may not hold due to obstructions such as furniture, walls, machinery, or storage cabinets.

It is always desirable to use the minimum length of hose possible, since it is easier to work with and store. It also will have less pressure loss in the hose and thus requires less vacuum to operate. A few extra wall inlets may make it possible to reduce the number or size of power units required for the installation. The cost of the extra piping and wall valves will have to be weighed against the cost of larger or additional power units.

The power units should be located in an area where they can be serviced conveniently and the piping should be laid out to require the minimum amount of pipe and fittings, thus minimizing the friction losses in the pipe and the cost of the installation. From the standpoint of friction losses in the pipe, it is better to use several feet of pipe rather than a 90 degree or 45 degree turn. It is also better from the friction standpoint to use a 45 degree bend rather than a 90 degree bend.

The size of the pipe to be used in the installation will depend on the volume of air flowing, so it is dependent upon the number of inlets that will be in use at any one time. It is good to maintain a velocitiy of air through the pipes greater than the minimum values given in Table II. In general, air flow through the pipes should be in the range of 2000 to 6000 feet per minute.

As a general rule, it is permissible to operate two 1-1/4" diameter hoses but only one 1-1/2" or 2" hose on a 2 inch diameter pipe line and a maximum of three 1-1/2" hose or five 1-1/4" hoses on a 3 inch diameter pipe line.

The piping should be laid out to minimize the possibility of filling the pipes with material. In large installations, provisions should be taken to see that there is a way of cleaning out the pipes if they do become clogged with materials that should not have been picked up.

NOTE: 3-1/2 inch diameter pipe is referred to as 3 inch (inside) diameter pipe. The 2 inch diameter pipe has an inside diameter of approximately 1.875 inches so because of the small variations in outside/inside diameters and to make it easier to read the graphs we will use the 2 inch diameter.

In some installations, it will be necessary to install an automatic pressure release valve in the line so that the cleaning tools will not stick to the carpet or floors when only one inlet is being used or when the system is being used in a dental operation or barber shop. This valve must be installed at the end of the pipe run that is the **greatest distance from the unit** so that air velocity through the pipes will be great enough to carry the material being picked up.

4. PRESSURE LOSSES

To select the proper vacuum power unit for the system, the total system loss (pressure drop or resistance) must be determined and is measured in water lift (" H_2O) or inches of mercury (" Hg) vacuum. The system losses consist of the following:

A. Loss through the hose and tools
B. Loss through the piping
(straight runs and bends)
C. Loss through the separator (s)

4a. HOSE AND TOOL FRICTION LOSS

1. Hose and Tool Friction Loss

Hose size with tool	Friction Loses (" H_2O)	or (" Hg)
1-1/4" (25 feet @ 40 CFM)	32"	2.34"
1-1/4" (30 feet @ 80 CFM)	34"	4.65"
1-1/2" (25 feet @ 40 CFM)	24"	3.27"
1-1/2" (30 feet @ 80 CFM)	26"	3.56"

NOTE: CFM is cubic feet per minute

2. Friction loss in the line (tubing and piping) can be obtained from Chart I "Friction Loss Chart".

3. The friction loss through 45 degree and 90 degree elbows are higher than the loss through the same diameter of straight piping or tubing. The average friction loss for 2" tubing through 2" 45 degree and 90 degree elbows are equivalent to 5 feet and 10 feet of straight tubing, respectively. The average friction loss for 3" piping through 3" 45 degree and 90 degree elbows are equivalent to 7 feet and 12 feet of straight pipe respectively.

5. AIR FLOW REQUIRED FOR CLEANING

The hose diameter, the particle size and the quantity of material to be conveyed determines the air volume. The air required for each 1-1/4" cleaning tool is approximately 40 CFM; for each 1-1/2" cleaning tool approximately 80 CFM. However, for light cleaning, such as an office with carpets or wooden floors, the air flow can be reduced slightly. For heavier material, the air flow can be increased to suit the system requirements.

6. SELECTION OF VACUUM POWER UNITS

The size or number of power units required for the installation will be determined by the amount of water lift and air flow required to make the system operate efficiently.

A) CR-1400 Series

The CR-1400 series power units are designed for one user only. In some cases when there is very light dust, two users may be used, but in this case please verify with the factory for proper use.

The P-2500/CR-1500 series power unit is designed for multiple users. Up to five operators at one time may use 1-1/4" cleaning hoses depending on the length of hose, type of tool used and type of floor to be cleaned (tile or concrete vs. high or low pile carpet) in a balanced system. Up to three operators at one time may use 1-1/2" cleaning hoses depending on the items listed above. It is important to contact the factory for assistance in designing when the maximum number of users may be used as outlined above.

B) Power Unit Reference

LMI	Main Line Size	" H_2O	CFM	Sq. Ft.	Length of Run[2]	# of Valves
CR-1400 Series[1]	2"	112	210	*	250 Ft.	10-15
P-2500 and CR-1500 Series	***3"	100, 112	360, 410	**	450 Ft.	Up to 100

* Up to a maximum of 12,000 sq. ft. *** Internal pipe diameter
** Up to a maximum of 80,000 sq. ft.

[1] Must use 3 to 5 feet of metal tubing in the exhaust line coming out of the unit. It is recommended (CR-1400 Series only) to use the PF-200 muffler on this unit to reduce exhaust noise.

[2] Length of run is for equivalent feet of tubing. Please refer to page 3 , "Hose and Tool Friction Loss", for the calculation of equivalent feet of tubing.

NOTE: The above figures are approximate and is for reference only and not intended as a strict guide.

C. Number of Units

In some cases when two users are required it may be more economical to use two CR-1400's (separate system) than one P-2500/CR-1500. Also, if one unit goes down for repair you could hook the working unit into the other system and still be able to clean for both areas.

The same applies for the P-2500/CR-1500. If a job requires a larger unit you may be able to use two or more P-2500/CR-1500 units by placing them in different cleaning zones and arrange them in such a way that you could connect one of the units into another zone and still clean both areas if one of the units goes down for repair.

7. DESIGNING A SYSTEM

(example - See Figure 1 - Page 10)

Piping and tubing layout:

Legend: ⛶ -Inlet valves
■ -Inlet valves selected for calculation (A,B,and C)

Three Inlet valve locations have been selected for design purpose, to establish the friction losses as well as line sizes for the system. Inlet valves (A) and (B) are the farthest from the vacuum pump. Inlet valve (C) is located in a branch about equal distance to the vacuum pump. This selection of active Inlet valve locations will aid in designing the system with proper line sizes to insure the system capability. After looking over the requirements for this plant we have decided to use a 1-1/2" x 25 foot hose size and tools.

Conversion from inches of mercury (Hg) to inches of water (H_2O) as follows:		
	1" Hg =	13.62" H_2O
or	1" H_2O =	.0734" Hg

LOSSES

TOOL ENTRANCE AND HOSE AT POINT (A)

From paragraph 4, "Hose and Tool Friction Loss" when handling 80 CFM using a 1-1/2" x 25 foot hose the hoses and tool total friction loss is -------1.76" Hg (24" H_2O)

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

2" line	28 Ft. in length
2 - 90 Deg. Elbows	20 Ft. in equivalent length
TOTAL	48 Ft. in equivalent length

From chart I "Friction Loss Chart", at 80 CFM and a 2" diameter line we read:

0.75" Hg loss/100 Ft. line

or 10.24" H_2O loss/100 Ft. line

$$\frac{48 \times 10.24}{100} = \underline{4.92" \ H_2O \ (0.36" \ Hg)}$$

At point (D) to (F) we have:

3" line	198 Ft. in length
0 - 90 deg. elbows	0 Ft. in equivalent length
TOTAL	198 Ft. in equivalent length

From Chart I "Friction Loss Chart" at 80 CFM and 3" diameter line, we read:

0.18" Hg loss/100 Ft. line

or 1.29" H_2O loss/100 Ft. line

$$\frac{198 \times 1.29}{100} = \underline{2.55" \ H_2O \ (0.19" \ Hg)}$$

From Figure I

At point (B) 80 CFM enters the system. The total equivalent piping from (B) to (E) is as follows:

2" line	23 Ft. in length
2 - 90 deg. elbows	20 Ft. in equivalent length
TOTAL	43 Ft. in equivalvent length

From Chart I "Friction Loss Chart", at 80 CFM and a 2" diameter line we read:

0.75" Hg loss/100 Ft. line

or 10.24" H_2O loss/100 Ft. line

$$\frac{43 \times 10.24}{100} = \underline{4.40" \ H_2O \ (0.32" \ Hg)}$$

At point (E) to (F) we have:

3" line	63 Ft. in length
1 - 90 deg. elbow	12 Ft. in equivalent length
TOTAL	75 Ft. in equivalent length

From Chart I "Friction and Loss Chart", at 80 CFM and 3" diameter line we read:

0.18" Hg loss/100 Ft. line
or 1.29" H_2O loss/100 Ft. line

$$\frac{75 \times 1.29}{100} = \underline{0.97" \ H_2O \ (0.07" \ Hg)}$$

From Figure I at point (C) 80 more CFM enters the system. The total equivalent piping from (C) to (G) is as follows:

2" line	28 Ft. in length
2 - 90 deg. elbows	20 Ft. in equivalent length
TOTAL	48 Ft. in equivalent length

From Chart I "Friction Loss Chart" at 80 CFM and a 2" diameter line we read:

0.75" Hg loss/100 Ft. line
or 10.24" H_2O loss/100 Ft. line

$$\frac{48 \times 10.24}{100} = \underline{4.92" \ H_2O \ (0.36" \ Hg)}$$

From Figure I at point (F) 80 more CFM enters the system. This combines with the flow from point (B) (80 CFM + 80 CFM) for a total of 160 CFM at point (F). The equivalent piping length from (F) to (G) is:

3" line	20 Ft. in length
0 - 90 deg elbows	0 Ft. in equivalent length
TOTAL	20 Ft. in equivalent length

From Chart I "Friction Loss Chart" at 160 CFM and a 3" diameter line we read:

0.38" Hg loss/100 Ft. line
or 5.17" H_2O loss/100 Ft. line

$$\frac{20 \times 5.17}{100} = \underline{1.03" \ H_2O \ (0.08" \ Hg)}$$

From Figure I at point (G) 80 more CFM enters the system. This combines with a flow from points (A) and (B) (80 + 160) for a total of 240 CFM at point (G). The equivalent piping length from (G) to the separator inlet is:

3" line	94 Ft. in length
3 - 90 deg. elbows	36 Ft. in equivalent length
TOTAL	130 Ft. in equivalent length

From Chart I "Friction Loss Chart" at 240 CFM and a 3" diameter line we read:

0.90" Hg loss/100 Ft. line

or 12.26" H_2O loss/100 Ft. line

$$\frac{130 \times 12.26}{100} = \underline{15.94'' \; H_2O \; (1.17'' \; Hg)}$$

Separator loss is added to the system loss. The loss is <u>3.40" H_2O (0.25" Hg)</u>. In general, the line between the separator and the vacuum pump is insignificant for all practical purposes.

Therefore, the total friction loss for the system is:

1. Hose and tool loss(page 3)..24.00" H_2O
2. Line loss from (A) to (D)..4.92" H_2O
3. Line loss from (D) to (F)..2.55" H_2O
4. Line loss from (B) to (E)...4.40" H_2O
5. Line loss from (E) to (F)..0.97" H_2O
6. Line loss from (C) to (G)...4.92" H_2O
7. Line loss from (F) to (G)...1.03" H_2O
8. Line loss from (G) to separator...................................15.94" H_2O
9. Separator loss..3.40" H_2O

TOTAL SYSTEM LOSS 62.13" H_2O (4.56" Hg)

The total system air volume is determined by 80 CFM/1-1/2" diameter hose x 3 operators = 240 CFM.

The figure of 240 CFM (at standard conditions is 29.92" Hg and 68 deg F) is then multiplied by the ratio of the standard barometric pressure divided by the standard barometric pressure minus the vacuum pump inlet vacuum in inches of H_2O to obtain the volume under <u>inlet vacuum condititons.</u>

$$240 \times \frac{29.92}{29.92 - 4.56} = 283.2 \text{ ICFM}$$

Therefore we select the P-2500/CR-1500 Series pump for the application:

P-2500/CR-1500 Unit
360 to 380 CFM Airflow
100" H_2O Water Lift @ sealed conditions

Check: 360 CFM > 283.2 ICFM
100" H_2O > 62.13" H_2O

The P-2500/CR-1500 Series should be ok for this application.

8. PIPING/TUBING INSTALLATIONS

It is very important that care be taken in connecting all piping/tubing joints to insure an airtight system as air leaks will decrease the vacuum system efficiency.

8a. ELEVATION INSTALLATIONS

When a central vacuum system is to be installed at an elevation above sea level, corrections to the vacuum pump performance becomes necessary since the vacuum pump performance graphs and charts are based on standard sea level conditions.

Example - 7,000 Ft. elevation

Referring to our previous example, it was based on total air volume of 240 CFM/283.2 ICFM. For the adjusted barometric pressure of 23.1" Hg (7,000 Ft. elevation), see Chart II

Air volume correction:

$$240 \text{ CFM} \times \frac{29.92}{23.1 - 4.56} = 387.3 \text{ ICFM}$$

Therefore the P-2500/CR-1500 Series may not work in this application since 387.3 ICFM > 360 CFM. You could in this case use two P-2500/CR-1500 Series units by splitting the system in two separate systems with no more than two operator per unit or use the smaller 1-1/4" hose which would allow three users and only one P-2500/CR-1500 Series unit.

FIGURE 1

(10)

CHART I

TABLE I

Conveying Velocities in Dust Exhast System

Material	Velocity Feet/Minute
Grain, Dust	2,000
Sawdust, Dry	2,000
Sawdust, Damp	3,000
Wood Shaving, Chips	3,000
Wood Hogging Material	4,000
Cotton	2,000
Lint	1,500
Metal Grindings	2,500 & Up
Lead Dust	5,000
Fine Brass Turnings	4,000
Pulverized Coal	4,000
Sand Blasting	3,500 & Up

STUDY BY DUTCH GOVERNMENT
On Vacuuming Rates

Comparison of vacuuming rates for portable and central vacuums in square feet of office area cleaned per hour. Savings in annual cleaning costs for offices can quickly justify the cost of a central system.

	Portable	Central
Thorough Vacuuming	2,500 - 4,000 Sq. Ft.	3,150- 4,800 Sq. Ft.
Quick Vacuuming	3,600 - 4,500 Sq. Ft.	4,800 - 6,000 Sq. Ft.

Note: We plan systems based on a conservative vacuuming rate of 2000 square feet per hour.

CHART II

Average Absolute Atmospheric Pressure

Altitude in Feet reference to sea level	Inches of Mercury (" Hg)
sea level 0	29.92
+ 500	29.39
+ 1,000	28.87
+ 1,500	28.33
+ 2,000	27.82
+ 3,000	26.81
+ 4,000	25.85
+ 5,000	24.90
+ 6,000	23.98
+ 7,000	23.10
+ 8,000	22.22
+ 9,000	21.39
+ 10,000	20.58

TERMS AND DEFINITIONS

C^0 = $5/9\ (F^0 - 32)$ = Degrees Centigrade

F^0 = $(C^0 \times 9/5) + 32^0$ = Degrees Fahrenheit

CFM = Cubic feet per minute (airflow)
FPM = Feet per minute (velocity)

Water Lift = H_2O
Water Lift = Static pressure
= Suction

Hg = Mercury

1" H_2O = .073431" Hercury (Hg)

1" Hg = 13.6230" H_2O @ 68^0 F and barometric pressure of 29.92" Hg

I.D. = Inside Diameter
O.D. = Outside Diameter

P.S.I. = Pounds per square inch (pressure)
1 P.S.I. = 26.680" H_2O (vacuum pressure)

Micron = The millionth part of a meter
1 Micron = .00003935 inches

mm	=	millimeter	cm	=	cubic meter
1"	=	25.4 mm	1"	=	2.54 cm
m	=	meter	L	=	liter
1m	=	39.37"	1L	=	2.113 pints
g	=	gram	1 oz.	=	28.375 g.
l lb.	=	454 g.			
ohms	=	Volts/amperes	amperes	=	Volts/ohms
Volts	=	Amperes x ohms	Watt	=	Volts x amperes

Horsepower = $\frac{\text{volts} \times \text{amperes} \times \text{efficiency}}{746}$

Torque (1b-ft) = $\frac{\text{horsepower} \times 5250}{\text{RPM}}$

Horsepower = $\frac{\text{torque (1lb-ft)} \times \text{RPM}}{5250}$