ELECTRON TUBES

RCA Application Note

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Blower Requirements for RCA Forced-Air-Cooled Tubes

The selection of a suitable fan or blower for cooling the external anode of an electron tube, a tube header or electrode seal, or the glass envelope of a tube having a radiation-cooled anode is a problem that often confronts an equipment designer. It is the purpose of this Application Note to assist the designer by discussing blower requirements in general and by listing representative blowers by type number and manufacturer.

General Considerations

The selection of a fan or blower for a particular tube or application requires that three important factors be known. These factors are (A) the airflow required, (B) the static pressure at blower outlet, and (C) the amount of permissible noise. Although these factors apply generally to cooling any part of an electron tube, attention is directed in the following to the problem of selecting a blower for cooling the radiator (cooler) of an external anode tube, particularly when duct work is used. The results obtained, however, are equally applicable to the problem of selecting a blower for cooling any other part of a tube.

A. The airflow required depends upon the amount of anode dissipation and upon the maximum ambient temperature expected in a given application. This value of required airflow, usually measured in cubic feet per minute (cfm), and the corresponding value of anode temperature rise above the ambient value are given as part of the tube data. In no case should the sum of the ambient temperature and the anode temperature rise above ambient exceed the maximum rated value of anode temperature as given in the tube ratings. Because the cfm value is based on air of standard density (0.075 lbs/ft^3), a correction should be made for applications at altitudes greater than 5000 feet above sea level.

B. The static pressure (P_s) at the blower outlet depends upon the pressure-versus-airflow characteristics of the system into which the blower must deliver the required volume of air. A typical system characteristic is shown in Fig. 1. The static pressure for any system varies approximately as the square of the cfm[1] and is determined by the following factors:

1. The static pressure rating of the tube cooler when the required airflow or cfm is passing through it. This rating is given in the tube data as a function of airflow or cfm. When the outlet of a blower discharges into free air as is the case when a blower is directed at a tube header, bulb, or seal, the static pressure at the blower outlet is zero, provided no ducts, constrictions, or nozzles are used. This discharge rating in cfm of a blower at zero static pressure is sometimes called the "free delivery" rating of the blower.

2. The friction losses in connecting pipes and components such as elbows, interlock vanes, and air filters. Standard tables of duct-pressure loss may be used for estimating duct friction if the effective duct length is large.[1, 2, 3, 4]

3. The change in static pressure in a duct due to changes in cross-sectional area which increase or decrease the velocity of the air in the duct. Whenever there is any change in cross-sectional area between the blower outlet and the tube inlet, a correction for velocity changes must be added algebrically to the static pressure at the blower outlet. This correction, which is positive for a contraction in area and negative for an expansion in area, is given by the relation

$$P_s(\text{inches of water}) = \frac{V_2^2 - V_1^2}{(4000)^2} \qquad (1)$$

where V_1 is the velocity of the air in feet per minute before the change in area and V_2 is the velocity of the air in feet per minute after the change. These velocities may be found from the expression

$$V\ (\text{feet per minute}) = \frac{\text{cfm}}{A} \qquad (2)$$

where A is the cross-sectional area in square feet at the place of measurement. The factor 4000 of Equation (1) is the velocity constant for air of standard density of 0.075 lb/ft^3. Corrections should be made for different values of air density from the data given in Table I.

A change in cross-sectional area also causes friction losses. Such losses are small and can be ignored when the change in cross-sectional area is gradual and occurs over a duct length of more than six duct diameters. When, however, the change is abrupt, that is, when it occurs over a duct length of less than one diameter, a correction for friction losses must be made in addition to the correction made for velocity changes in the duct. For duct changes occurring over intermediate lengths, a correction for friction losses should be estimated. Corrections for friction losses, whether due to either a contraction or expansion in duct area, are always positive and are added to the system static pressure.

a. A sudden contraction increases the static pressure at the blower outlet according to the relation[5]

$$P_s \text{ (inches of water)} = \frac{K_c V_2^2}{(4000)^2} \qquad (3)$$

where K_c is a constant which depends upon the amount of contraction and may be determined from the curve given in Fig. 2.

b. A sudden expansion increases the static pressure at the blower outlet according to the relation[5]

$$P_s \text{ (inches of water)} = \frac{(V_1 - V_2)^2}{(4000)^2} \qquad (4)$$

The static pressure rating of the tube, item 1, and the friction losses in air filters and exit louvers, item 2, produce nearly all of the static pressure at the blower outlet. The correction for changes in cross-sectional area, item 3, are usually negligible unless the area changes are very large and the air velocities are high.

C. The third important factor which should be considered in the selection of a fan or blower is the amount of noise which can be tolerated. In general, a blower operating with high blade-tip velocity and developing a value of P_s in excess of two inches of water will usually produce a noticeable amount of noise in quiet surroundings. The recommendations of the manufacturer should be obtained in applications where low noise output[6] is important.

A matter of lesser importance but which may require some design consideration is the effect of the temperature of the air leaving the tube cooler on some of the circuit components such as filament bypass capacitors. If some components are exposed to temperature exceeding their normal ratings, it will be necessary to reduce the temperature of the outgoing air by selecting a blower which will provide a greater airflow. The rise in temperature (ΔT) of the outgoing air in the cooler may be determined from

$$\Delta T \text{ (degrees centigrade)} = \frac{T_1 + 273}{169} \times \frac{P_p + P_f}{\text{cfm}} \qquad (5)$$

where T_1 is the temperature of the incoming air in degrees centigrade; P_p is the plate dissipation in watts; and, P_f is the filament power in watts. For incoming air at room temperature (25°C), this relation may be simplified to

$$\Delta T = 1.75 \times \frac{P_p + P_f}{\text{cfm}} \qquad (6)$$

The calculated value of ΔT will usually be higher than the measured value because some of the heat produced by the plate and by the filament will be carried away by conduction in the filament leads and cooler support. A further reason is that the heated outgoing air, because of its relatively high velocity, mixes immediately with the surrounding air.

A further matter which is also usually of minor importance is the question of motor overload when the tube is removed from its socket. When this matter is important, a non-overloading type of blower such as one having backwardly inclined blades can be selected. Because higher blade-tip speeds are usually necessary with this type of blower, the noise output may be increased.

permissible anode temperature at a

550

Examples of Calculations

By way of illustration, take the problem of choosing a suitable blower for two RCA-7C24 tubes used in an air system employing some duct work and an air filter. The arrangement contemplated is shown in Fig. 3. The tube data state that a total airflow of 500 cfm for both tubes is required to keep within the maximum rated dissipation of 2 kilowatts per tube when the maximum ambient temperature is 45°C. The 7C24 curve of airflow requirements shows that the static pressure required at the cooler inlet is 1.5 inches of water. The airflow cross-sectional area (A_s) of the anode socket for the 7C24 is

$$A_s = \frac{\pi D^2}{4} = \frac{\pi (4.7)^2}{4} = 17.4 \text{ square inches or } 0.12 \text{ square feet.}$$

The blower outlet area should be approximately twice this area for two tubes or 0.24 square feet.

A tabulation of the pressure losses in this system shows

ITEM	STATIC PRESSURE	
Tube cooler	1.5	inches of water
Transformation section	0	
Air interlock	0.1	inches of water
Air filter	0.25	inches of water
TOTAL	1.85	inches of water

The value of pressure loss in the air filter is an average for different types of filters. The air interlock value is an estimate.

The requirements, then, are for a blower having an approximate outlet area of 0.25 square feet and a rated delivery of 550 cfm at a static pressure of 1.85 inches of water. A blower such as an American Blower Corp., 90 Sirocco Fan, Series 81, Class I, 1/2 Width, Arrangement 4 with Steel Housing - Discharge Clockwise Upblast - Direct Connected to 1750-rpm, 1/2-hp Motor will fulfill this requirement.

The outlet area of this fan is approximately 0.25 square feet in 1/2-width size. A plot of the cfm characteristic of the fan versus static pressure as obtained from catalog data is shown in Fig. 1. Also shown in Fig. 1 is the system static-pressure curve obtained by plotting the equation

$$P_s \text{ (for system)} = K \text{ (cfm)}^2 \qquad (7)$$

Where K is a constant for a particular system and is equal to the system pressure at some specific value of airflow divided by the square of that value of airflow.

$$\text{Thus, } K = \frac{1.85}{(550)^2} = 6.13 \times 10^{-6} \text{ inches of water/(cfm)}^2$$

The intersection of these two curves occurs at $P_s = 2.15$ inches of water and cfm = 590. This intersection is the operating point of the particular blower chosen for the system described. The blower choice is conservative because more air than the amount required is delivered into the system and some margin of safety is available for eventual increases in the system static pressure due to partially clogged air filters or other duct components.

Other makes and types of blowers having characteristics similar to the one chosen can be selected from catalog ratings in the same manner. The 1/2-width size chosen for this application permits operation near the maximum static efficiency of the fan and, therefore, produces minimum noise output.

It is not always possible to select a blower having the same outlet area as the air inlet area of the tube or tubes being cooled. When these areas are not the same, a correction is necessary. For example, the RCA-5592 requires an airflow of 1100 cfm at a static pressure of 2.4 inches of water at the tube air inlet in order to dissipate 17.5 kilowatts at an ambient temperature of 45°C. The air inlet area of the RCA-5592 is 0.55 square feet. A blower such as the Buffalo "Limit-Load" Single-Width, Type LL, Size 2 is suitable for this application, but the blower outlet area is 0.826 square feet. Because this change in cross-sectional area causes a change in the velocity of the air, the correction given by Equation (1) must be added to the static pressure at the blower outlet. In this example,

$$V_2 = \frac{\text{cfm}}{A_2} = \frac{1100}{0.55} = 2000 \text{ feet per minute}$$

$$V_1 = \frac{\text{cfm}}{A_1} = \frac{1100}{0.826} = 1330 \text{ feet per minute}$$

$$\text{Therefore, } P_s = \frac{V_2^2 - V_1^2}{(4000)^2} = \frac{(2000)^2 - (1330)^2}{(4000)^2} = 0.14 \text{ inches of water}$$

If this area change is made gradually, that is if it occurs over a duct length of more than six duct diameters, no further ~~connection~~ correction for friction losses need be added and the static pressure at the blower outlet is $2.4 + 0.14 = 2.54$ inches of water.

If, however, because of space limitations or other reasons the change in airflow cross-sectional area is made abruptly, an additional correction for the friction losses due to the sudden contraction must be made as given by Equation (3).

$$P_s \quad \frac{K_c V_2^2}{(4000)^2} = \frac{(0.22)\ (2000)^2}{(4000)^2} = 0.055 \text{ inches of water}$$

The value of K_c is obtained from the curve in Fig. 2. The static pressure at the blower outlet becomes $2.4 + 0.14 + 0.055 = 2.6$ inches of water.

Performance Check

After the system has been installed, the P_s-versus-cfm curve, when given for the tube type, may be used to determine whether sufficient air is being supplied to the cooler. A simple "U-tube" manometer may be constructed as shown in Fig. 4, using water as the manometer liquid. The value of P_s may be read directly as the difference in height of the liquid levels. To make this measurement, drill a small hole (#40 drill size) in the air-supply duct at some suitable place at least three inches below the cooler. Care should be taken that the hole is free from burrs and is located in a smooth section of tubing at least 3 inches away from any joints, airflow interlock vanes, or other obstructions. Make an air-tight connection to a suitable length of rubber tubing connected to one inlet of the "U-tube" manometer. No connection is made to the outlet of the manometer which is exposed to atmospheric pressure. The value of P_s thus obtained may be directly converted into cfm from the curve of airflow versus P_s given in the tube data.

If only one value of P_s and its corresponding value of cfm is available for the tube type, a P_s-versus-cfm curve may be constructed from Equation (7) given in the 7C24 example or by drawing a straight line having a slope of 2 on loglog graph paper through the known point.

Operation at High Altitudes

A correction for blower operation at reduced atmospheric pressure should be made when tubes are to be cooled at high altitudes. If, as a first approximation, it is assumed that the same mass rate of flow in pounds of air per minute is required at high altitudes as at sea level, the blower requirements may be computed as in the following example.

It is required to cool a tube operating at an elevation of 5000 feet above sea level. Assume that the airflow requirement given in the tube data is 1000 cfm at 1.0 inches of water for air at a standard density of 0.075 lbs/ft^3. From Table I, the density of air at 5000 feet is given

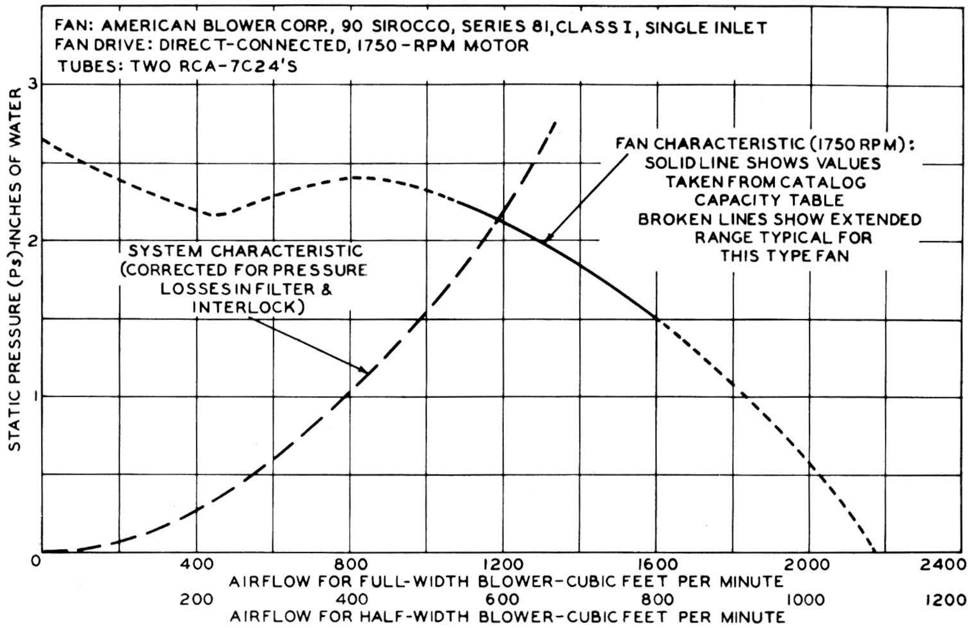

Fig. 1 - Fan Performance and System Characteristic Curves.

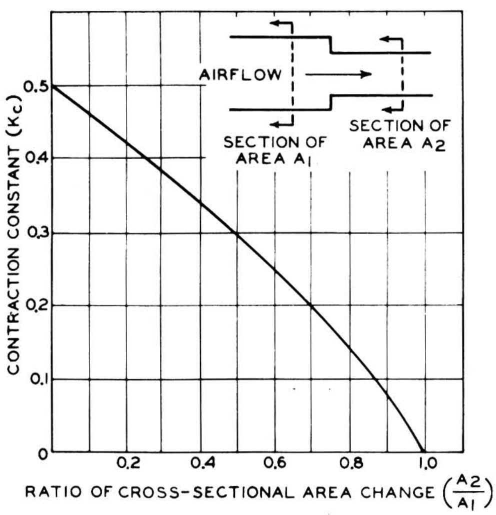

Fig. 2 - Chart for Determining Contraction Constant K_c.

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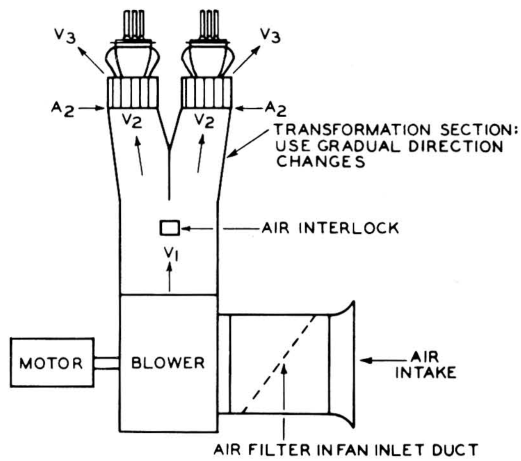

Fig. 3 - Air Duct System Used in Example.

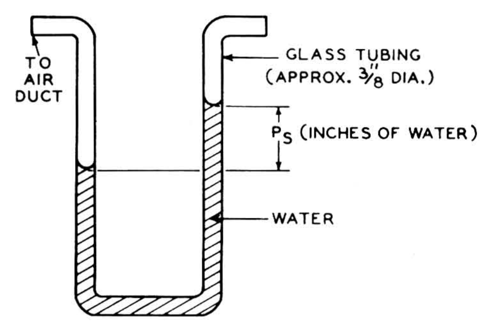

Fig. 4 - Simple "U-Tube" Manometer.

as 0.062 lbs/ft^3. For the same mass rate of flow, the cfm at 5000 feet altitude is

$$\left.\mathrm{cfm}\right]_{5000} = \frac{0.075}{0.062} \times \left.\mathrm{cfm}\right]_{0} = 1.21\ (1000) = 1210\ \mathrm{cfm}$$

The static pressure against which the blower must operate is

$$\left.P_s\right]_{5000} = \frac{0.075}{0.062} \times \left.P_s\right]_{0} = (1.21)\ (1.0) = 1.21 \text{ inches of water}$$

This value is the static pressure that would be measured at the tube inlet when the fan is handling 1210 cfm of air having a density of 0.062 lbs/ft^3. Since a fan or blower may be considered a constant cfm device at fixed rpm regardless of air density, the standard catalog ratings may now be consulted for a blower capable of delivering 1210 cfm against the equivalent static head of the tube for standard density air. This equivalent static head is found from the square-law relation between P_s and cfm

$$\left.P_s\right]_{1210\ \mathrm{cfm}} = \frac{(1210)^2}{(1000)^2} \times \left.P_s\right]_{1000\ \mathrm{cfm}} = (1.46) \times 1.0 = 1.46 \text{ inches of water}$$

A blower such as a Buffalo "Limit-Load" Conoidal Fan, Size 2, Single Width will supply 1210 cfm at 1-1/2 inches of water, at a speed of 1880 rpm. The horsepower required for standard density air is 0.421. At 5000-feet elevation, the horsepower required will be

$$\left.\mathrm{hp}\right]_{5000} = \frac{(0.062)}{(0.075)} \times \left.\mathrm{hp}\right]_{0} = 0.826\ (0.421) = 0.348\ \mathrm{hp}$$

In comparison, the same blower if used at sea level would have to operate at 1527 rpm to deliver 1000 cfm at a static pressure of 1 inch of water. The horsepower rating would be 0.225.

As an aid in selecting suitable blowers for RCA Forced-Air-Cooled Tubes, Tables II, III, and IV have been prepared listing representative blowers for most applications. Allowance has been made for a nominal value of system static pressure over and above the normal static-pressure requirement of the tube. The blowers listed have been selected for tube operation at maximum rated plate dissipation. For a lower value of plate dissipation, a smaller blower may be used.

TABLE I. Density of Air and Velocity Constants vs Altitudes

Altitude above Sea Level (ft)	*Density of Air* (lbs/ft3)*	*Velocity Constant (see text)*
0	0.0750	4000
1000	0.0722	4080
2000	0.0695	4165
3000	0.0668	4240
4000	0.0643	4320
5000	0.0619	4410
6000	0.0596	4500
7000	0.0573	4580
8000	0.0552	4670
9000	0.0532	4760
10000	0.0511	4850

* *Temperature is constant at approximately 70°F.*

TABLE II. Blowers for Cooling Headers, Seals, and Bulbs

Tube Type	*Part Cooled*	*cfm*	*Cooling Recommended*†
6C24	Filament Seals and Grid Connector	–	Deflect portion of main air stream used to cool anode.
7C24 9C21 9C22 9C25 9C27	Header and Filament Seals	10	Deflect portion of main air stream or use blower such as A, B, C, D, or E.
9C21 9C27	Bulb	250	Use blower such as F.
8D21	Bulb and Electrode Seals	40	Use blower such as A, B, C, or E.
833-A		40	Use blower such as A, B, C, or E.
880		20	Use blower such as A, B, C, or E.
889		15	Use blower such as A, B, C, D, or E.
889RA		15	" " " " " " " " " "
806 826 829-B 834 8012-A 8025-A 4-125A/ 4D21	Bulb	-	Use ordinary small propeller fan or blower such as A, B, C, D, or E.

† *For description of blowers, refer to Table IV.*

TABLE III. Blowers for Cooling External-Anode Type Tubes Having Integral Air Coolers.

These blower recommendations are based upon tube operation at maximum rated plate dissipation under class "C" Telegraphy conditions at an ambient temperature of 45°C and at sea level. Unless otherwise specified, the static pressure at the tube inlet has been increased by 0.25 inches of water to allow for incidental pressure losses due to air filters, interlocks, etc. Direct-connected units are specified where possible.

Tube Type	*Area* (ft^2)	*Volume (cfm)*	P_S *(inches of water)*	*Blower Recommended*[a]
6C24	0.022	135	0	Use blower such as G or H, if a gradual transition is made from 3-inch outlet diameter of blower to 2-inch nozzle diameter required by 6C24.
7C24	0.12	275	1.75	Use blower such as J, K, L, or M
9C22	0.74	1800	2.4	Use blower such as N, P, Q, or BB
9C25	0.55	1000	2.25	Use blower such as R, S, or CC
827-R	0.12	100	0.45	Use blower such as X or Y
889R-A	0.31	500	0.95	Use blower such as T or U
891-R 892-R	0.31	450	0.5	Use blower such as V or W
5588	0.012	10	0.4**	Use blower such as A, B, or C
5592	0.55	1100	2.65	Use blower such as AA or DD

[a] *For description of blowers, refer to Table IV.*

** *Without allowance for incidental pressure losses.*

TABLE IV.

Blower	*Manufacturer*°	*Description*
A	ILG	#6S, 70 cfm free delivery.
B	Delco	#5062369, 60 cfm free delivery.
C	F. A. Smith	#50747, 50 cfm free delivery.
D	F. A. Smith	#50745, 15 cfm free delivery.
E	Amer. Blower	#30H, 83 cfm free delivery.
F	Amer. Blower	#B Type P, 268 cfm at 2-1/2 inches of water.
G	Amer. Blower	Type P Cat. #A; 1/8-hp, 3450-rpm motor - direct connected.
H	ILG	Type P #7-1/2P; 1/8-hp, 3400-rpm motor - direct connected.
J	ILG	Type B9; 1/4-hp, 3450-rpm motor - direct connected.
K	Amer. Blower	Type P Cat. #B; 1/3-hp, 3450-rpm motor - direct connected.
L	Buffalo	Type E #3E; 1/3-hp, 3450-rpm motor - direct connected.
M	Clarage	Type CI #6 ("C" wheel); 1/4-hp, 1750-rpm motor - direct connected.
N	Amer. Blower	#105 utility set direct driven at 1725-rpm from suitable 1-1/2-hp motor.
P	Clarage	Type HV #7/8 single width - single inlet belt driven at 1550 rpm by suitable 1-1/2-hp motor.
Q	ILG	Type BW - #25 single width - single inlet belt driven at 1450-rpm by suitable 1-1/2-hp motor.
R	Clarage	Type HV #3/4 single width - single inlet; 1.0-hp, 1750-rpm motor - direct connected.
S	ILG ~~Amer.~~ Blower	#B18; 1-1/4-hp, 1750-rpm motor - direct connected.
T	Amer. Blower	#1-1/4-H utility set; 1/3-hp, 1725-rpm motor - direct connected.
U	Clarage	DF #1/2; 1/4-hp, 1750-rpm - direct connected.
V	Buffalo	Size D baby vent set, 1/6-hp, 1750-rpm motor - direct connected.
W	ILG	B-12; 1/6-hp, 1750-rpm motor - direct connected.
X	ILG	#B-9; 1/20-hp, 1750-rpm motor - direct connected.
Y	Buffalo	Size B baby vent set; 1/20-hp, 1750-rpm motor - direct connected.
AA	ILG	#BC-25 single width type BC - belt driven at 2250-rpm by suitable 1-hp motor.
BB	Buffalo	#2-1/4 single width type LL - belt driven at 2160 rpm by suitable 1-1/2-hp motor.
CC	Buffalo	#2 single width type LL - belt driven at 2080 rpm by suitable 3/4-hp motor.
DD	Buffalo	#2 single width type LL - belt driven at 2400 rpm by suitable 1-hp motor.
EE	Buffalo	#2-EH, 1/8-hp, 3450-rpm motor - direct connected.

°*For complete name and address, refer to Table V.*

TABLE V.

Abbreviation	*Name and Address*
ILG	ILG Electric Ventilating Company 2850 N. Crawford Ave Chicago, Ill
Delco	Delco Appliance Division General Motors Corporation Rochester, New York
F. A. Smith	F. A. Smith Mfg. Company, Inc. P. O. Box 509 Rochester 2, New York
Amer. Blower	American Blower Corporation P. O. Box 58 Roosevelt Park Annex Detroit, Michigan
Buffalo	Buffalo Forge Company Buffalo, New York
Clarage	Clarage Fan Company Kalamazoo, Michigan

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