FAN-JET VENTILATION SYSTEMS

REASONS FOR A FAN-JET MINIMUM VENTILATION SYSTEM

During cool nights of spring, summer and fall and on most sunshiny winter days, minimum ventilation is needed to control the house temperature. This type of ventilation, using cool or cold outside air, is quite different from summer ventilation and evaporative cooling. The flow must be turbulent with small to moderate quantities of air required, while in the summer the flow should be smooth and use large quantities of air.

SUFFICIENT AIR FLOW CAPACITY

The minimum ventilation system is an important part of the climate control system and requires several distinct characteristics. First, it must have ample air flow capacity to maintain a proper heat balance by removing the excess solar heat on mild sunlit days.

THOROUGH MIXING AND DISTRIBUTION

Secondly, the minimum ventilating system must be able to introduce the very cold winter air into the greenhouse without producing cold drafts on the plants. This requires a very thorough mixing of the cold outside air with the warm inside air before the plant level is reached. Since powered ventilating has the energy available to produce the turbulence necessary for thorough mixing, it supplies properly tempered fresh air.

CONTINUOUS AIR CIRCULATION

Thirdly, it is important that all parts of the greenhouse be at the same temperature. To achieve this, the ventilating system must distribute the air very uniformly throughout the house and maintain positive air movement and continuous circulation. A powered ventilating system has a real advantage over gravity systems that rely on thermal air currents, since it has the energy required to provide uniform air distribution and mixing. Continuous circulation also produces a gentle air movement that maintains a better leaf surface micro climate and prevents pockets of disease producing high humidity.

MINIMUM AND MAXIMUM SYSTEMS ARE DIFFERENT

Essentially minimum and maximum ventilation systems are two separate systems having different characteristics and requirements, yet they must tie in with each other to switch from one system to the other during the in-between seasons. The tie-in or transition point is very important as it determines the minimum inside to outside temperature difference available on a mild sunny day while it establishes the airflow design capacity of the minimum ventilation system.

The flow rate for the transition point is determined by the heat removal capabilities of the air and is largely affected by the increase in latent heat of the air going through the house. The increase depends on the outside wet bulb temperature and the transpiration rate of the greenhouse crops. Increased transpiration results in an increase in the cooling effect for a given flow rate. For average conditions an air flow of 1½ to 2 cfm per square foot of floor space will hold the house temperature within 15°F of outside temperature. For hobby greenhouses 3 cfm/sq. ft. will be required. Obviously, a larger ventilation rate will reduce the inside to outside temperature differential and a smaller one will increase it. The selection charts that follow are designed for selection of Fan-Jet equipment to hold a 15°F inside to outside temperature differential at elevations below 1,000 ft. with a maximum interior light intensity of 5,000 foot candles. For other conditions refer to Tables 5, 6 and 7 and the explanation of the Fan-Jet adjustment factors.

DESCRIPTION OF THE FAN-JET CLIMATE CONTROL SYSTEM

A MULTI-PURPOSE SYSTEM

The use of exhaust fans for mechanical ventilation of greenhouses combined with perforated transparent plastic tubes made an ideal method of introducing cold air into a greenhouse in the winter without cold drafts. The development of these principles has produced the Acme Fan-Jet Climate Control System. This is a multi-purpose system that can alternatively heat, dehumidify, ventilate or recirculate the air in a greenhouse for proper climate control in the fall, winter and spring seasons. This system is not designed to provide temperature control in warm seasons. Moreover, the exhaust fans of this system can also serve as the fans for the summer fan and pad cooling system.

DESCRIPTION OF EQUIPMENT

The Fan-Jet system consists of a specially constructed pressurizing fan attached to a custom designed perforated plastic tube located in the upper section of the house that extends along the length of the greenhouse with its far end closed.

The pressurizing fan runs continuously inflating the tube and blowing air through the holes in the form of jets into the greenhouse space. This uniformly distributes the air for the full length of the tube creating turbulence, thorough mixing and active air motion throughout the entire greenhouse. It maintains a more uniform temperature and humidity, and prevents cold spots.

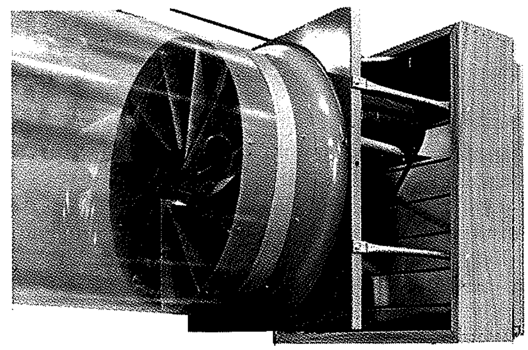


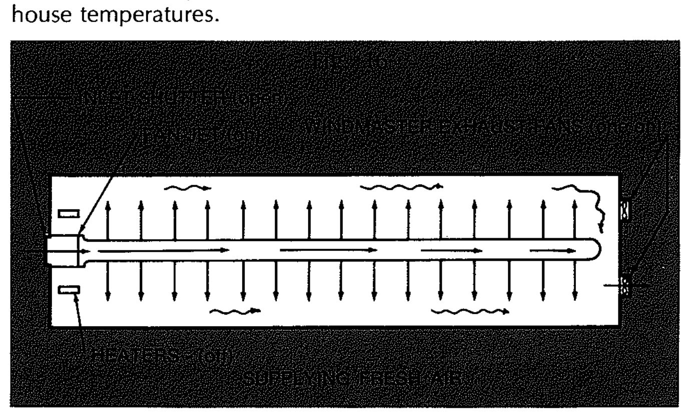
Fig. 15

The fan is mounted inside the greenhouse a specified distance from the gable end wall in front of a special sized motorized shutter that functions as the fresh air inlet. Several sizes of Fan-Jets with matching air inlet shutters and perforated tubes are offered for different requirements and often two or more units are needed for a greenhouse depending on its size.

OPERATION OF THE FAN-JET SYSTEM

SUPPLYING FRESH AIR

When the house temperature becomes too high and cooling is needed, the equipment controller or cooling thermostat simultaneously opens the motorized shutter and energizes an exhaust fan. The vacuum produced by the exhaust fan draws fresh, cold outside air in through the shutter which enters the inlet of the pressurizing fan. The air is propelled down the tube and discharges through the custom sized perforations in the form of jets. It is rapidly mixed with the warm greenhouse air and distributed uniformly within the greenhouse space to lower the temperature. When the desired temperature has been reached, the equipment controller or thermostat turns off the inlet shutter and the exhaust fan, thereby shutting off the supply of outside air. The Fan-Jet unit which is manually controlled continues to recirculate the air within the house. This cycle is repeated as necessary to maintain desired house temperatures.



CONTINUOUS RECIRCULATION

When temperature and humidity conditions in the greenhouse are at the desired control level, neither heating nor cooling is required and the continuous running Fan-Jet recirculates the air within the house providing a gentle air movement.

The result is a uniform climate without cold and humid pockets and the maintenance of a better leaf surface micro climate. It is also ideal for distribution of air borne materials such as insecticides or CO_2 gas for plant feeding.

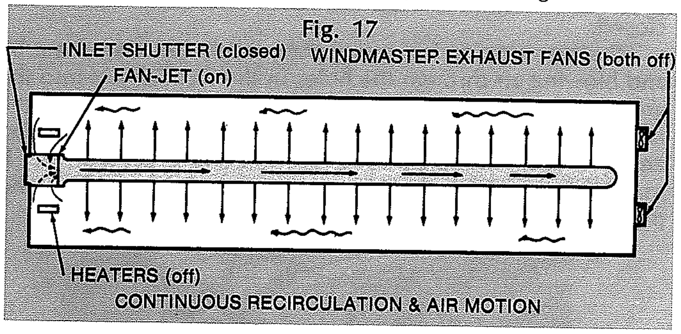


Fig. 17

DEHUMIDIFICATION

When the relative humidity in the house exceeds the desired level it can be reduced by bringing in cooler outside air that has a lower water vapor content. The humid house air is expelled by the exhaust fan while the drier incoming air is heated and mixed with the house air.

This method of humidity control has been programmed into the ACC-I and Grotron II equipment controllers and can be automatically controlled by using a humidistat, thermostats, relays and other related switches in proper combination with each other.

SUPPLYING HEAT

Since the Fan-Jet ventilating system provides excellent distribution and circulation of air it can also serve as a highly efficient heat distribution system. When equipped with an accessory "heat kit" package it becomes part of a heating system without affecting its other functions of minimum ventilation and recirculation. The heat kit comprises a baffle arrangement that permits the use of conventional horizontal discharge type unit heaters in combination with Fan-Jet units to make an efficient and economical heating system.

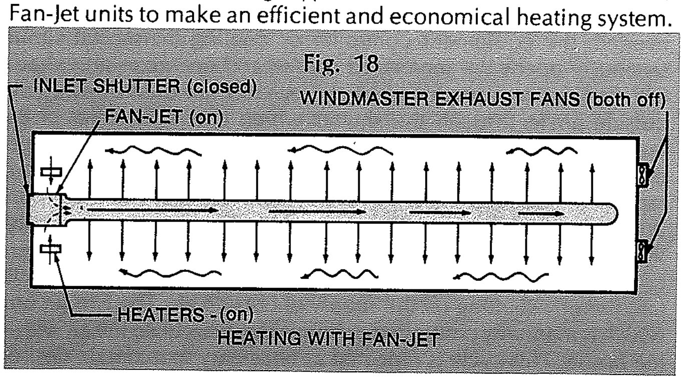


Fig. 18

QUICK RESPONSE

Since the Fan-Jet Climate Control System works directly with the air it reacts quickly to changes in requirements. By using high velocities and the rapid mixing turbulence of the jets, it achieves the maximum capability of the equipment in a matter of seconds and provides the quick response necessary for maintaining a uniform climate.

SELECTION OF EQUIPMENT

The equipment for Fan-Jet ventilation systems includes Fan-Jet units, motorized air inlet shutters, plastic tubes and exhaust fans. To provide the best ventilation for a wide range of design requirements, the Fan-Jet units are offered in four sizes with matching motorized air inlet shutters and custom punched tubes.

Certain other criteria must also be considered to select the proper equipment from the tables and charts that follow. For good air distribution, the maximum width a Fan-Jet and tube should cover is 30 ft. of actual house width. Houses from 30 to 60 ft. wide should use two Fan-Jets and tubes. For very wide houses, three or more systems may be necessary.

FAN-JET DESIGN ADJUSTMENT FACTORS

The elevation of the greenhouse and the interior light intensity have a direct bearing on the amount of air needed to control the house temperature with Fan-Jet ventilation in the fall, winter and spring just as they do in summer cooling. These factors have been explained in detail under Design Factors in the section on THE GREENHOUSE COOLING SYSTEM, and are also used in designing Fan-Jet ventilation systems. For convenience $F_{Elev.}$ and F_{Light} are shown in Tables 5 and 6.

One other element of winter climate control that needs further consideration in controlling the house temperature is how small a difference in the inside to outside temperature is desired on a mild sunny day.

Standard Fan-Jet selection charts are based on maintaining about a 15°F maximum differential between inside and outside temperature during a mild sunny day. For example, with a 15° differential system, a 65° house temperature could be maintained provided the outside temperature does not exceed 50°. But, to hold 65° inside with a 55° outside temperature would allow only a 10° differential. Obviously more air would be required to achieve this, and this can be accomplished by applying the design factor F_{Winter} shown in Table 7.

The final Fan-Jet adjustment factor F_{Jet} is obtained by

$$F_{Jet} = F_{Elev} \times F_{Light} \times F_{Winter}$$

SELECTION OF FAN-JET UNITS

To select the correct Fan-Jet units consider the elevation, interior light intensity and the temperature differential adjustment factors to obtain the Fan-Jet factor F_{Jet} .

$$F_{Jet} = F_{Elev} \times F_{Light} \times F_{Winter}$$

Multiply F_{Jet} times the actual house width W under consideration to obtain the equivalent house width.

$$W_{Equiv.} = F_{Jet} \times W$$

Refer to the Fan-Jet ventilation selection Chart 2 to select the proper Fan-Jet unit for each house based on the equivalent house width $W_{Equiv.}$ and the actual length. Select the model number designated. **If the Fan-Jet ventilation system is also to be used for a Winter Overhead Heating System, then be sure to check the heat distribution requirements before selecting the equipment. Oftentimes, larger Fan-Jet sizes are required for heating than for ventilating and in such cases the larger sizes should be used.**

TABLE 5
Elevation, feet above sea level

feet	Under 1000	1000	2000	3000	4000	5000	6000	7000	8000
$F_{Elev.}$	1.00	1.04	1.08	1.12	1.16	1.20	1.25	1.30	1.36

TABLE 6
Maximum Interior Light Intensity, foot candles

FC	4000	4500	5000	5500	6000	6500	7000	7500	8000
F_{Light}	.80	.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60

TABLE 7
House Temperature above Outdoor Temperature °F

°F	18	17	16	15	14	13	12	11	10	9
F_{Winter}	.83	.88	.94	1.00	1.07	1.15	1.25	1.37	1.50	1.67

TABLE 8

FAN-JET PERFORMANCE DATA										
Fan-Jet Model	HP	RPM	Tube Size	System CFM	▼Motorized Shutter Model	Heat Accessory	‡Heating Capacity With Heat Kit BTU/hr. Output Heater Temperature Rise of			
							40°	50°	60°	70°
†RC12D4	1/6	1725	12"	1180/780	WAAC1818	Not Available	NOT APPLICABLE			
RC18E6	1/4	1160	18"	3120	WAAC2626	HT18	112,000	138,000	163,000	186,000
RCA/RC24F	1/3	735	24"	5420	WAAC3333	HT24	172,000	212,000	250,000	287,000
RCA/RC30G	1/2	607	30"	8550	WAAC4040	HT30	278,000	342,000	403,000	463,000
RCP12B4	1/10	1625	12"	1100	WAAC1818	Not Available	NOT APPLICABLE			
RCP18B4	1/10	1625	18"	2140	WAAC2626	PHT18	77,000	95,000	112,000	128,000
RCP18F4	1/3	1625	18"	3050	WAAC2626	PHT18	109,000	135,000	159,000	182,000
RCP24G6	1/2	1075	24"	5115	WAAC3333	PHT24	162,000	200,000	236,000	271,000

†RC12D4 has a 2-speed motor therefore two different system CFM's.

‡The Output rating for gas fired heaters is 80% of their input BTU ratings.

▼*Order CAM motorizing kits separately.*

*** The unit heater louvers should be at the same elevation as the Fan-Jet inlet opening and spaced a proper distance from it, with the axis of the unit heater discharge opening directed toward the Fan-Jet inlet opening. If the heater must be positioned below the level of the Fan-Jet inlet opening to maintain the proper spacing, the louvers should be adjusted to direct the heated air upward toward the top of the Fan-Jet inlet opening.**

If the Fan-Jet end of the greenhouse is colder than the remainder of the house, this condition usually can be corrected by adjusting one or two of the lower louvers of the heater to a downward position to divert part of the heated air to the end wall area.

CAUTION

Caution: to avoid combustion malfunctions when two heaters are used with one Fan-Jet; the minimum heater distance from Fan-Jet opening must be maintained, both heaters must operate simultaneously, unless center baffle is used, and the discharge louvers must be directed toward the top of the Fan-Jet Opening.

CHART 2

FAN-JET VENTILATION SELECTION CHART

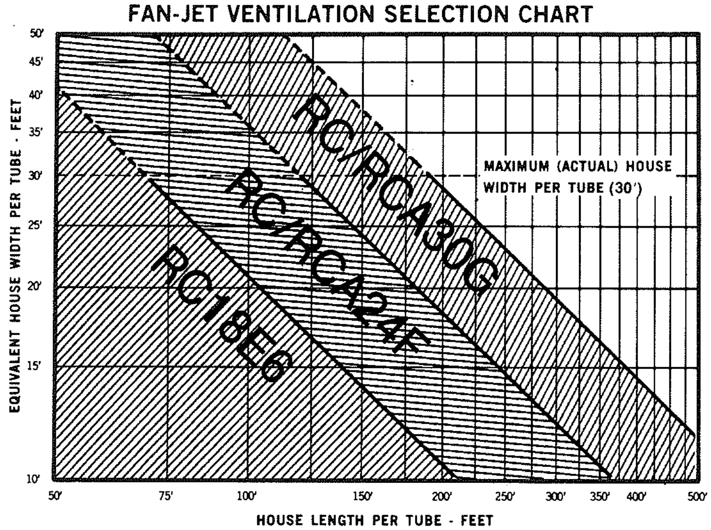


CHART 2A

FAN-JET VENTILATION SELECTION CHART

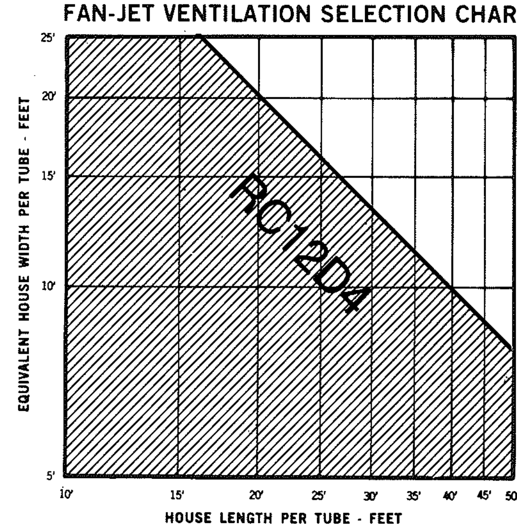


CHART-2B

FAN-JET VENTILATION SELECTION CHART

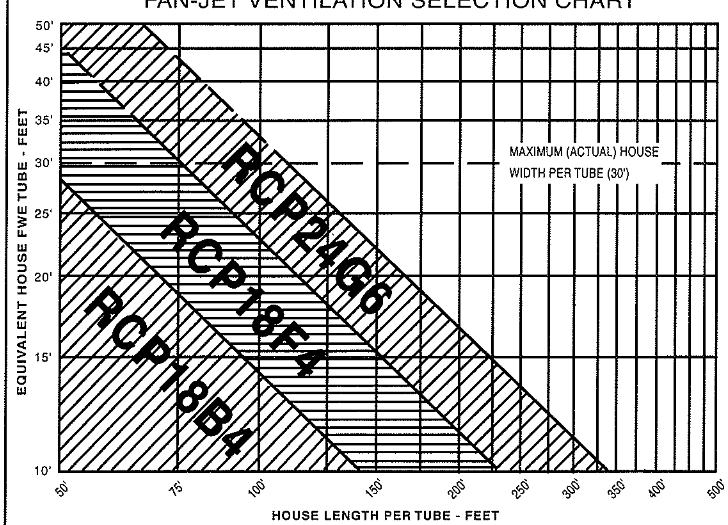
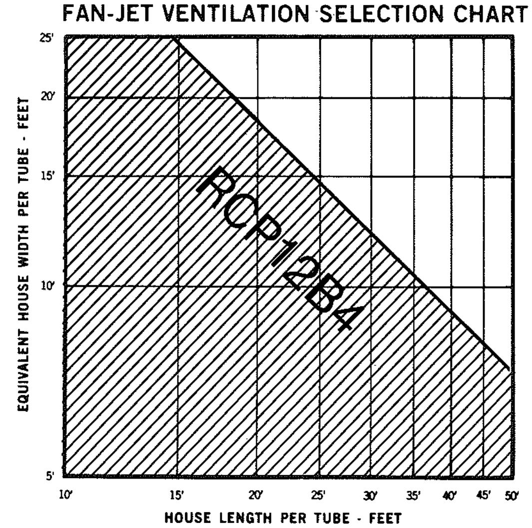
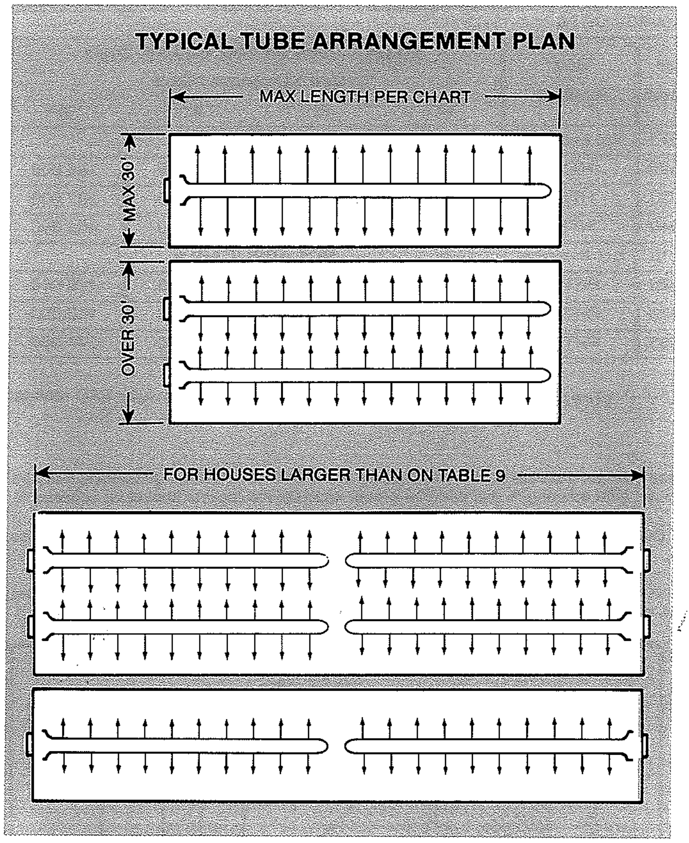


CHART 2C

FAN-JET VENTILATION SELECTION CHART





For houses longer than those shown on the chart, consider using Fan-Jets on each end. Divide the house at the midpoint and make a selection for each half of house. For long houses having only one exposed gable end, divide the house lengthwise into narrower sections and select the equipment for each section.

When ordering Fan-Jet units, also order the matching motorized air inlet shutter for each. Order by Model Number and specify phase and voltage for all equipment.

SELECTION OF TUBES

All tubes are custom punched using different sizes or spacings of holes to provide the best distribution and greatest airflow capacity for each application. Refer to tube selection Table 9 to select the correct tube for each Fan-Jet unit. Note that each tube model number covers a specific minimum and maximum tube length.

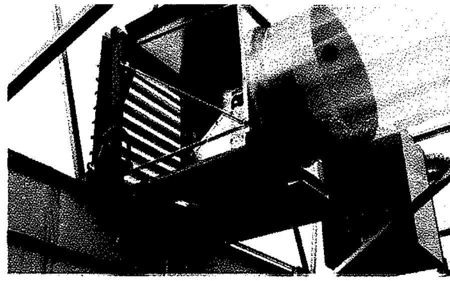
When ordering, specify the tube Model Number for each Fan-Jet unit and state the length of tubing required. (Since all tubes are custom made, orders already processed or shipped cannot be cancelled nor returned for credit.)

SELECTION OF EXHAUST FANS

As previously explained, exhaust fans are required to supply the fresh air needed. It is important that the total capacity of the exhaust fans match the total CFM capacity of the Fan-Jets used to achieve the full benefit of the system. **But in no event, during cold weather should the exhaust fan capacity exceed that of the Fan-Jets. This would draw in more air through the inlet shutter than the Fan-Jet system could handle and might cause cold air to spill out and create a cold spot in that area.**

Greenhouses already equipped with fan and pad cooling systems would have sufficient exhaust fans for a Fan-Jet system. But, it may be necessary to install a smaller capacity fan or equip one of the existing fans with a two speed motor to reduce its capacity to match the Fan-Jet system. The low speed capacity of a two speed fan is about 1/2 of its high speed capacity.

Refer to the Windmaster Certified Performance Table in Catalog C29 and select the appropriate models based on their performance capacity at 0.1" SP. (Use .05" SP for slant housing).



View of Fan-Jets, motorized inlet shutters and tubing with Heat Kit.

TABLE 9
FAN-JET TUBE SELECTION TABLE

12" FAN-JET		18" FAN-JET or 18" INLET		24" FAN-JET or 24" INLET		30" FAN-JET or 30" INLET	
TUBE MODEL	TUBE LENGTH	TUBE MODEL	TUBE LENGTH	TUBE MODEL	TUBE LENGTH	TUBE MODEL	TUBE LENGTH
HFT	10' - 20'	HFY	18' - 20'	HKX	24' - 27'	HKT	39' - 42'
HLT	20' - 25'	HDY	20' - 22'	HJX	27' - 30'	HJT	42' - 47'
HRT	25' - 30'	HCY	22' - 25'	HHX	30' - 33'	HHT	47' - 52'
HLW	30' - 35'	HBY	25' - 27'	HFX	33' - 37'	HFT	52' - 58'
HMW	35' - 40'	HKN	27' - 30'	HDX	37' - 41'	HDT	58' - 66'
HLY	40' - 50'	HJN	30' - 33'	HCX	41' - 45'	HCT	66' - 77'
HRY	50' - 60'	HHN	33' - 36'	HBX	45' - 48'	HKS	77' - 84'
HMZ	60' - 75'	HFN	36' - 40'	HKP	48' - 53'	HJS	84' - 94'
HRZ	75' - 100'	HDN	40' - 45'	HJP	53' - 59'	HHS	94' - 104'
		HCN	45' - 50'	HHP	59' - 66'	HFS	104' - 116'
		HBN	50' - 55'	HFP	66' - 73'	HDS	116' - 129'
		HKA	55' - 61'	HDP	73' - 81'	HCS	129' - 145'
		HJA	61' - 68'	HCP	81' - 90'	HBS	145' - 163'
		HHA	68' - 76'	HBP	90' - 101'	HKU	163' - 183'
		HFA	76' - 85'	HKI	101' - 112'	HJU	183' - 206'
		HDA	85' - 96'	HJI	112' - 126'	**HHU	206' - 232'
		HCA	96' - 108'	HHI	126' - 142'	HFU	232' - 263'
		*HBA	108' - 121'	HFI	142' - 160'	*HDU	263' - 305'
		**HKE	121' - 138'	**HDI	161' - 182'	HCU	305' - 348'
		HJE	138' -154'	*HCI	182' - 206'	HBU	348' - 405'
		HHE	154' - 177'	HBI	206' - 233'		
		HFE	177' - 205'	HKO	233' - 269'		
				HJO	269' - 311'		
				HHO	311' - 360'		

* Maximum tube length for Fresh Air Convection Tube System.
** Maximum tube length for Fan-Jet with Heat Kit.
+ When 12" tubing is used for Perimeter Heating the Tube Model is prefixed by the letter P.

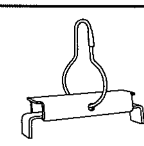
POLYETHYLENE TUBING

All tubes are engineered for uniform distribution and proper mixing of air to produce the best aerodynamic effect in greenhouse structures.

- Furnished in clear 4 mil thick UV stabilized polyethylene material.
- Each tube is custom punched to match the selected Fan-Jet Unit with each specific house. Since tubes are custom punched, orders already processed or shipped cannot be cancelled or returned for credit.

THE HANGER SET

Unique hanger clamps onto tubing for easy attachment to overhead support wire with snap ring.



RECOMMENDED SPACING

12" Tubing every 10 ft.
18" Tubing every 10 ft.
24" Tubing every 8 ft.
30" Tubing every 6 ft.

Wire support kits, available in 50', 100', 150', 200', and 300' lengths, include six strand 10 gauge wire, turnbuckle and 2 securing clips.

***CAUTION!** This tubing, for use in greenhouses, does not contain fire retardants. Due care should be taken during installation and operation to keep away from open flame.

EXAMPLE — DESIGN PROCEDURE

Design Calculations

Consider the three gutter connected houses each 28 ft. wide by 200 ft. long located at 3,000 ft. elevation and having a winter interior light intensity of 5,000 foot candles. Assume a 15° allowable inside to outside temperature difference. Refer to Tables 5, 6 and 7 for adjustment factors to select proper Fan-Jet Units.

$$\begin{aligned} F_{Jet} &= F_{Elev} \times F_{Light} \times F_{Winter} \\ &= 1.12 \times 1.00 \times 1.00 \\ &= 1.12 \\ W_{Equiv} &= F_{Jet} \times W \\ &= 1.12 \times 28 \text{ ft.} \\ &= 31.4 \text{ ft.} \end{aligned}$$

Fan Jet Selection

Refer to selection Chart 2 for a 31.4 equivalent width and 200' length which shows that a single Fan-Jet unit is inadequate. Divide the house at its mid-point and for minimum ventilation select a Model RC24F for each half. Each house therefore requires two RC24F Fan-Jets, one centered at each end. If the Fan-Jet ventilation system is also to be used for an overhead heating system, then be sure to check the heat distribution requirements before selecting the equipment. Often times for heating, a larger size Fan-Jet is required.

Tube Selection

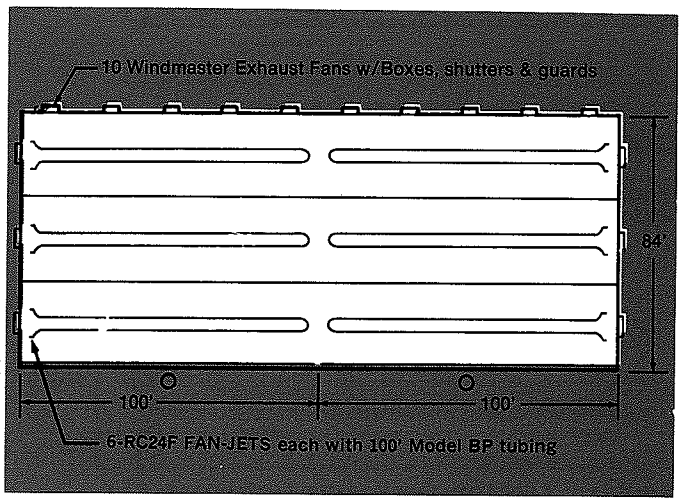
Refer to Fan-Jet Tube Selection Table 9 to select 100 ft. of Model BP tubing for each unit.

Exhaust Fan Selection

The three gutter connected houses require 6 — RC24F Fan-Jets having a total capacity of 32,520 cfm. For fall, winter and spring ventilation only, 3 Model DC36G Windmaster fans would provide 31,500 cfm, a satisfactory selection.

In an earlier example this block of houses was equipped with fan and pad cooling and required much more air. However, in that group of fans a combination of models was selected to provide the proper volume of air for the Fan-Jets.

1 — Model DC48H	= 17,800 CFM
1 — Model DC48G	= 14,600
Total for Fan-Jets	= 32,400 CFM



OVERHEAD HEATING SYSTEM

NEED FOR WELL DISTRIBUTED HEAT

A greenhouse is a difficult structure to heat and it contains plants that are extremely sensitive to temperature variation. The greenhouse heating process is in itself unstable since the warmed air being lighter rises to the roof, while the cold air produced near the glass or plastic covering is heavier and tends to settle to the floor. Should this settling occur at any point, which it tends to do with still air in the house, a cold spot with extreme humidities may develop.

Overhead air motion and mixing will help prevent this settling action from the roof, but will only partially reduce the normal cold film of air flowing down the walls. This film of cold air is best handled by the release of heat from a perimeter heating system to intercept the cold air pouring down the walls before it gets to the floor. Also, in those areas where snow melting is required in gutter connected houses, provision should be made to supply gutter heat.

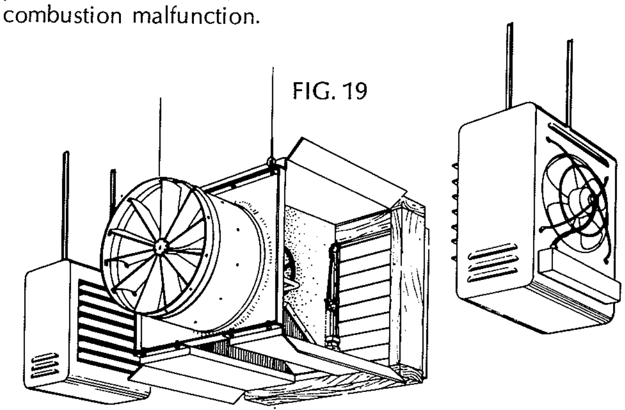
Since the temperature of the plants in a greenhouse is primarily determined by the inside air temperature, the main function of the heating system is to maintain a uniform air temperature in the house. The Fan-Jet systems both overhead and perimeter working directly with all the air in the greenhouse make an ideal method of heating the air and achieving this uniformity.

DESCRIPTION OF A FAN-JET HEATING SYSTEM

USE OF A HEAT KIT

The Fan-Jet unit with a heating accessory "heat kit" is designed to receive the heated air from conventional type unit heaters, and in turn distribute this heated air uniformly throughout the house. The heating accessory consists of a baffle arrangement that closes the top and bottom space between the pressurizing fan and the inlet shutter. The sides remain open to admit the heated air blown from conventional horizontal discharge type unit heaters spaced a fixed distance away from the side inlets. A center baffle accessory for the heat kit is included for use when opposing heaters are not operating simultaneously. The baffle prevents blow-through of heated air and possible heater motor, or heater combustion malfunction.

FIG. 19



When the equipment control calls for heat and turns on the unit heaters, they blow heated air into the open sides of the Fan-Jet which is propelled down the tube and distributed uniformly within the house. After the desired temperature is reached the unit heaters are automatically turned off while the Fan-Jet continues running and recirculating the air within the house.

UNRESTRICTED AIR FLOW

Since the heaters are not built into the main air flow path of the Fan-Jet system, they never restrict the flow of air whether the system is supplying fresh air, heating, or recirculating air within the greenhouse. This results in much higher efficiency than other systems thus providing much more air flow for all its uses and at lower horsepower and operating costs. Moreover, steam or hot water type unit heaters may be used without any risk of freeze up.

DESIGN OF OVERHEAD HEATING SYSTEM

To design an overhead air heating system, it is necessary that the heat loss of each house in the range be known. The exact calculations for this determination are given by the *Standards for Greenhouse Heat Loss Calculation* prepared by the National Greenhouse Manufacturers Association. The following tables and charts derived from that standard simplify the method of determining greenhouse heat losses and are based on a 6/12 roof pitch.

DETERMINE GABLE HOUSE HEATING LOAD

Table 10 gives the overhead and gable heat losses in 1000's of BTUH (BTU per Hour) per house for various lengths and widths and having conventional roof pitches. This data is also satisfactory for arched roof houses. Table 10 also list separately the losses for both gable ends. Table 11 gives the heat losses for the walls. These tables and charts are based on a 70°F temperature differential and a 15 mph wind. For other temperature differentials and wind velocities refer to Table 12 for correction factor K. Table 13 shows the Construction Factor C that is determined by the type of house construction. Although the wall heat loss factor for curtain walls around the greenhouse is less than that of the glazing system, the effect on the total heat loss is insignificant and, therefore, not included in the calculation.

TABLE 10 OVERHEAD HEAT LOSS (SLOPED ROOF)

Roof Length feet	HOUSE WIDTH — feet 16'	18'	20'	22'	24'	26'	28'	30'	32'	34'	36'	38'	40'	50'	60'
Gable Loss (both) MBTUH	5	6	8	10	11	13	15	18	20	23	26	29	32	50	72
Roof Loss MBTUH															
5	7	8	9	10	11	12	12	13	14	15	16	17	18	22	26
10	14	16	18	19	21	23	25	27	28	30	32	34	35	45	54
20	28	32	35	39	42	46	50	53	57	60	64	67	71	88	106
30	42	48	53	58	64	69	74	80	85	90	96	101	106	133	160
40	57	64	71	78	85	92	99	106	113	120	127	135	142	177	212
50	71	80	89	97	106	115	124	133	142	151	159	168	177	222	266
60	85	96	106	117	127	138	149	159	170	181	191	202	212	265	318
70	99	112	124	136	149	161	173	186	198	211	223	235	248	310	372
80	113	127	142	156	170	184	198	212	227	241	255	269	283	354	424
90	127	143	159	175	191	207	223	239	255	271	287	303	319	398	478
100	142	159	177	195	212	230	248	266	283	301	319	336	354	443	532
200	283	319	354	390	425	460	496	531	567	602	637	673	708	885	1062
300	425	478	531	584	637	690	743	797	850	903	956	1009	1062	1328	1594
400	566	637	708	779	850	920	991	1062	1133	1204	1274	1345	1416	1770	2124
500	708	797	885	974	1062	1150	1239	1328	1417	1505	1593	1682	1770	2213	2666

TABLE 11 (WALL HEAT LOSS)

Wall Length feet	Wall Height - feet 2'	4'	6'	8'	10'
	Wall Loss MBTUH				
5	1	2	2	3	4
10	2	3	5	6	8
20	3	6	9	13	16
30	5	9	14	19	24
40	6	13	19	26	32
50	8	16	24	32	40
60	9	19	28	38	47
70	11	22	33	44	55
80	13	25	38	51	63
90	14	28	43	58	71
100	16	32	47	64	79
200	32	63	95	128	158
300	47	95	142	192	237
400	63	127	190	256	316
500	79	158	237	320	395

TABLE 12 CLIMATE FACTOR K

Inside Outside ΔT°	Wind Velocity - mph 15	20	25	30	35
30	.41	.43	.46	48	.50
35	.48	.50	.53	.55	.57
40	.55	.57	.60	.62	.64
45	.62	.65	.67	.70	.72
50	.69	.72	.74	.77	.80
55	.77	.80	.83	.86	.89
60	.84	.88	.91	.94	.98
65	.92	.96	.99	1.03	1.07
70	1.00	1.04	1.08	1.12	1.16
75	1.08	1.12	1.17	1.21	1.25
80	1.16	1.21	1.26	1.30	1.35
85	1.25	1.30	1.35	1.40	1.45
90	1.33	1.38	1.44	1.49	1.54

TABLE 13
CONSTRUCTION FACTOR C

All metal (good tight glass house — 20 or 24 in. glass spacing) 1.08
Wood & steel (good tight glass house — 16 or 20 in. glass spacing) Metal gutters, vents, headers, etc.) 1.05
Wood houses (glass houses with wood bars, gutters, vents, etc. — up to and including 20 in. glass spacing)
  Good tight houses 1.00
  Fairly tight houses 1.13
  Loose houses 1.25
Corrugated Fiberglass covered wood houses 1.06
Corrugated Fiberglass covered metal houses 1.09
Double glazing with 1" air space .... .70
Plastic covered metal houses (single thickness) 1.08
Plastic covered metal houses (double thickness) .... .70
Plastic structured sheet metal frame (16mm thick) .... .54
Plastic structured sheet metal frame (8mm thick) .... .60
Plastic structured sheet metal frame (6mm thick) .... .67

TOTAL HEAT LOSS = [OVERHEAD LOSS (TABLE 10 OR 15) + SIDE LOSS (TABLE 11)] x K FACTOR (TABLE 12) X C FACTOR (TABLE 13)

DETERMINE QUONSET HEATING LOAD

Since quonset houses have no clear delineation between the roof and sidewall, the total heat loss must be obtained in one calculation. Table 15 is provided for this purpose. The wall loss can be taken as 35% of this total to be supplied by a perimeter heating system and the roof loss becomes 65% of the total to be supplied by the overhead heating system.

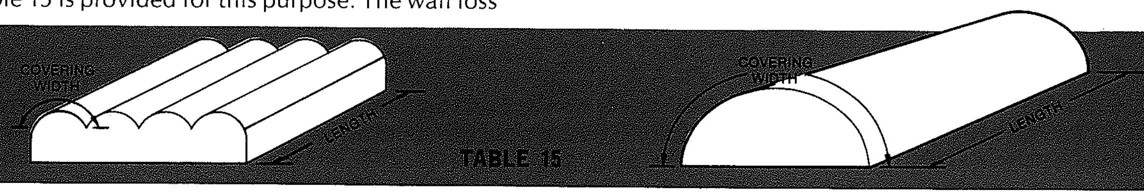


TABLE 15

QUONSET TYPE GREENHOUSE OR ARCHED ROOF HEAT LOSS

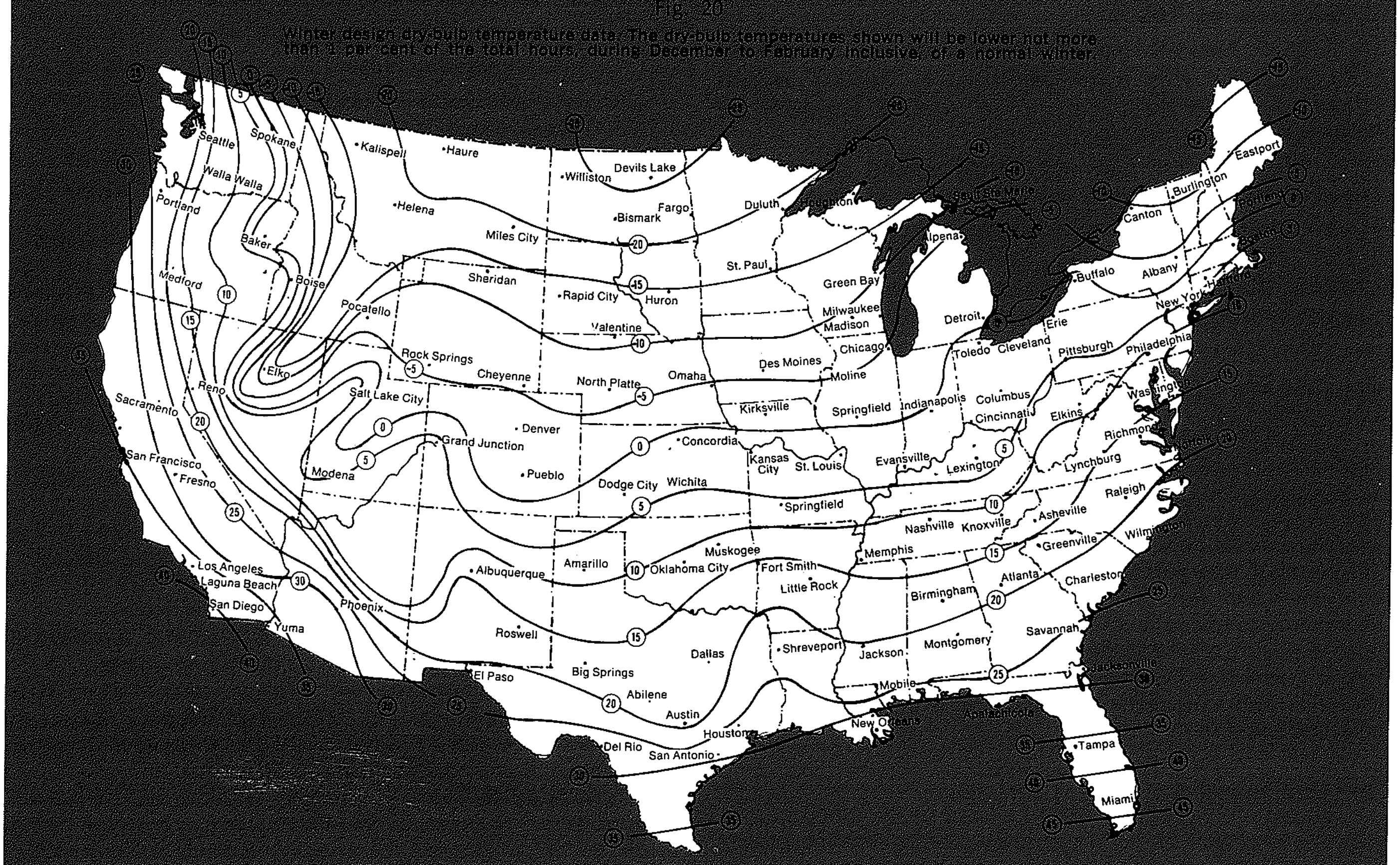
Roof Length feet	18'	20'	22'	24'	26'	28'	30'	32'	34'	36'	38'	40'	48'
	COVERING WIDTH — feet												
	End Loss (both) MBTUH												
	8	10	12	15	17	20	23	26	29	33	36	40	60
	Covering Loss MBTUH												
5	7	8	9	9	10	11	12	13	13	14	15	16	18
10	14	16	17	19	21	22	24	25	27	28	30	32	38
20	28	32	35	38	41	44	47	51	54	57	60	63	76
30	43	47	52	57	62	66	71	76	81	85	90	95	114
40	57	63	70	76	82	89	95	101	108	114	120	127	152
50	71	79	87	95	103	111	119	127	134	142	150	158	190
60	85	95	104	114	123	133	142	152	161	171	180	190	228
70	100	111	122	133	144	155	166	177	188	199	211	222	266
80	114	127	139	152	164	177	190	202	215	228	240	253	304
90	128	142	157	171	185	199	214	228	242	256	271	285	342
100	142	158	174	190	206	221	237	253	269	285	301	316	380
200	285	316	348	380	411	443	475	506	538	570	601	633	760
300	427	475	522	569	617	664	712	759	807	854	902	949	1138
400	570	633	696	759	822	886	949	1012	1075	1139	1202	1265	1518
500	712	791	870	949	1028	1107	1187	1265	1345	1424	1503	1582	1898

WINTER DESIGN TEMPERATURE MAP

Recommended outdoor winter design temperatures for localities throughout the United States are shown in Fig. 20. These are used to select the proper inside to outside temperature difference (ΔT°) in Table 12 to determine the correct climate factor K. For example, for an outdoor winter design temperature of -10°F and a required greenhouse temperature of 60°F, the outside to inside temperature difference ΔT° would be 70°.

Fig. 20

Winter design dry-bulb temperature data. The dry-bulb temperatures shown will be lower not more than 1 per cent of the total hours, during December to February inclusive, of a normal winter.



EXAMPLE — DESIGN PROCEDURE

Design Calculations

Assume an all metal framed glass covered greenhouse 36 ft. wide by 210 ft. long with 6/12 roof pitch and 6 ft. glass side walls on a 2 ft. high transite wall. The winter wind velocity is 20 miles per hour and the indoor-outdoor design temperature difference is 70°F. Find the design heat loss and select equipment for an overhead heating system.

From Table 10 the gable loss = 26		**26,000 BTUH**
From Table 10 the roof loss is		
for 200′ length = 637		**637,000 BTUH**
for 10′ length = 32		**32,000 BTUH**
Total Overhead heat loss		**695,000 BTUH**

Applying correction factors found in Tables 12 and 13 for temperature differential, wind velocity and type construction:
K = 1.04, C = 1.08, therefore KC = 1.04 x 1.08 = 1.12
Corrected overhead heat loss = 1.12 x 695,000 = 778,400 BTUH

It requires 778,400 BTU per hour to provide the necessary overhead heat for the prescribed design conditions.

Selection of Fan-Jet Units

Refer to heat distribution capacity Table 8 to determine the size and number of Fan-Jets needed. Two Model RC30G Fan-Jets are needed, each having a heat distribution capacity of 403,000 BTU per hour with unit heaters rated to deliver this heat at a 60°F rise.

Selection of Tubes

Each Fan-Jet would use 206 ft. of Model JU tubing. For this application each Fan-Jet would need unit heaters having an output capacity of about 390,000 BTUH.

In case overhead structurals would not permit using 30″ tubes then consider four Model RC24F units, two at each end with the tubes extending to the center of the house. Each Fan-Jet would need about 200,000 BTUH supplied by unit heaters and each would need 102 ft. of Model KI tubing.

NEED FOR PERIMETER HEATING SYSTEM IN COLD CLIMATES

In a typical greenhouse heating system, the lighter, warmer air rises to the top portion of the greenhouse, while the heavier, colder air produced along the roof and sidewalls flows down the roofline and sidewalls to settle on the floor. Unless this natural tendency is overcome the house will be too hot overhead, yet have cold floors. This results in poor plant growing conditions and a needless waste of heat and fuel. The Fan-Jet Overhead System does a good job of distributing overhead heat in a greenhouse but supplies a rather limited amount of heat to the perimeter walls of the house. Therefore, a greenhouse heating system, particularly in colder climates, should include a perimeter heating system in addition to the overhead heating system.

DETERMINE PERIMETER HEATING LOAD

The perimeter heating system should be designed to provide the total heat loss of the entire wall area. Within reasonable limits, the overhead and perimeter heating system are complimentary and one can be increased in capacity and the other reduced as long as the total input to the house is the correct amount for all losses.

INSECT SCREENS

Before sizing screens it is imperative that the characteristics of the exhaust fans be known as different sizes and horsepower combinations have different maximum performance limitations. Refer to Catalog C29 for fan limitations. It is suggested that a safety operating range of .05′′ static pressure be provided to account for catching insects and debris. As an example, if the maximum performance of the fan was .30′′ static pressure, the design calculations would not exceed .25′′ static pressure.

In order to maintain the proper cooling (heat removal), it is necessary that the calculated CFM requirements be maintained. If fans were preselected prior to the additions of screens, the performance or CFM of air could drop below the calculated requirements. This will result in an increase in house temperature, increased electrical consumption and reduced motor life.

EXAMPLE

A greenhouse calculated requirements of 29,000 Total CFM has fans selected or installed that deliver 30,000 CFM at .10″ SP.

Now, with the addition of screens, the pressure increases to .20″ SP and the fan performance drops to 25,500 CFM. This is approximately a 15% reduction of CFM, which will result in an increase of the temperature rise from pad or inlet to exhaust fans of 15% and approximately 40% increase in operating cost.

EXAMPLE

A greenhouse that we want to screen both inlet and outlet (fan discharge) are utilizing two fans that have a maximum static pressure of .25″.

House ventilation requirements: 24,000 CFM.

Maximum fan static pressure	.25″ SP
Safety operating range	−.05″ SP
Available operating range	.20″ SP
Standard operating pressure before applying screens	−.10″ SP
Available for screen use	.10″ SP

Divide available screen use static pressure by number of areas to be screened. In this example we have two, the inlet and the outlet areas. It should be noted that the available static pressure may be divided into any proportion desired (i.e., .03″ SP for inlet and .07″ SP for outlet area) as long as total available static pressure is not exceeded. For purposes of this example, we will treat inlet and outlet areas equal. Taking .10″ SP divided by two areas equals .05″ SP static pressure available per screen (inlet and outlet).

Looking at chart 3 for screen material "A" shows that for .05″ static pressure, the velocity is 200 ft. per minute.

24,000 CFM divided by 200 ft. per minute = 120 sq. ft. of screening required for screen "A" for each inlet and outlet area (fans). Using two fans will require 60 sq. ft. each of screen area (120 sq. ft. divided by 2 fans = 60 sq. ft. each).

Now look at chart 3 for screen "B" material. It shows for .05″ static pressure, the velocity is 400 ft. per minute.

24,000 CFM divided by 400 ft. per minute = 60 sq. ft. of screening required for screen "B" for each inlet and outlet area (fans). Using two fans will require 30 sq. ft. for each of screen area (60 sq. ft. divided by 2 fans = 30 sq. ft.).

By looking at the two materials you can see that it will require twice as much of the screen area of material "A" as material "B" to provide the same air entry into the structure at .05″ static pressure.

OTHER CONSIDERATIONS

If there are other air entry levels such as roof vents which lead into a corridor area and allows air to go into individual greenhouse cubicles or units, it will be necessary to calculate the additional static pressure of the vent opening area and the vent screening area.

$$\text{Vent opening vel} = 4005\sqrt{pv}$$

It is also recommended that the screen be kept dry as possible. This would require putting it on the inlet side of an evaporative cooling system so that the water is not pulled off of the pads into the screen.

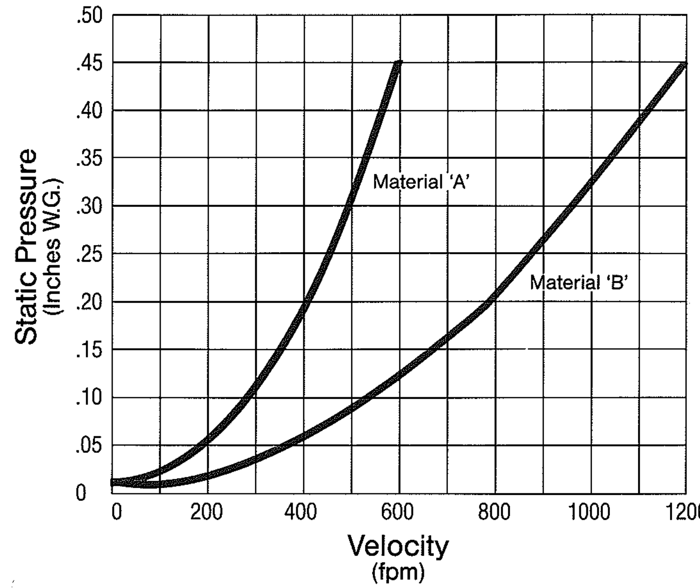
It is also recommended that the screens be placed on the inside of the fan where they will not produce as much restriction as when placed on the discharge side of the fan where the air is coming off of the blades in a turbulent motion.

If using different materials for inlet and outlet areas, it would be necessary to look at the performance characteristics of each material when determining the velocity or screening area required. Some growers have determined they want a finer mesh screen on the air entry into the structure with a coarser mesh material on the discharge or fan area.

DAILY OPERATION

It is highly recommended to use a manometer to measure pressure in the house. This will allow the grower to know when to clean the screens following the screen manufacturer's recommended methods. If the screens are allowed to accumulate with insects or debris the result will be a static pressure buildup which will then result in reduced air flow through the structure and a resultant higher temperature in the greenhouse structure.

CHART 3



If one point is known on the curve then others can be calculated. The formula is:

$$v = c\sqrt{pv}$$

v = face velocity
c = resistance constant
pv = velocity pressure

Calculate the constant, c, using the tested data then develop other points using tested constant and selected velocities.

SERVICE AND MAINTENANCE

FANS

Guards should be installed before operating fans which are within reach of personnel.

The fan shaft bearings are prelubricated and sealed and no service is ever required.

The motor bearings are prelubricated and should not require relubrication until after 5 years of continuous duty or 10 years of intermittent duty. Consult information printed on motor for lubrication instructions. Both the fan shaft and motor bearings should be protected from the weather or from direct exposure to water, paint and chemicals.

Belt tension should be checked after first month of operation and every two months thereafter. A firm thumb pressure on the belt midway between the pulleys should depress the belt about ⅜ inches. Use of belt dressing is not recommended on V belts.

When replacing worn belts, closely inspect the motor pulley for a "shoulder" worn in the V groove. Replace the pulley if a shoulder exists. Do not replace with a larger diameter pulley as this will overload the motor. Special high quality belts are used on Windmaster fans. For your protection order replacements from your Acme distributor stating fan model and serial number.

Automatic belt tighteners are available for Windmaster fans to provide optimum performance and longer belt life.

PAD SYSTEM

The holes in the overhead pipe distributor for the pad system must be kept open and periodic clean out should be done when necessary as described in the Water System section under Piping & Pumping, page 12.

The sump will require periodic draining or flushing-out to remove the accumulation of sediment. The filter in the pump-to-water distributor pipe system should be flushed out weekly or as needed. The pump and piping system should be drained before cold weather to avoid freeze damage.

The pumps are of the centrifugal type, positive self-priming, and when once filled will reprime themselves without aid of auxiliary devices. The pumps come equipped with a self-lubricating mechanical shaft seal which requires no oil or grease. Should the shaft seal begin to leak or the pump lose its prime, the seal should be replaced to insure proper operation of pump.

An important point in maintaining a good pad condition is the water quality. As the water is continuously evaporated and replaced by fresh water, the salts and minerals are left behind in the recirculating water. As these impurities become more concentrated they build up in the pad. It first appears as a frosty deposit on the outside of the pad but can be reduced or even eliminated with proper bleed-off of the recirculating water. Depending on the hardness of the water and the intensity of the evaporation the rate of bleed-off water should range from 1 to 2% of the recirculating water. For Kool-cel pads a bleed-off should definitely be considered as these pads, if properly cared for and maintained, can last for many years.

FOR MORE INFORMATION REFER TO CATALOG C29