S9086-RS-STM-010/CH-512R2

REVISION 2

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 512

FANS

THIS CHAPTER SUPERSEDES CHAPTER 512 DATED 30 APRIL 1990

PUBLISHED BY DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND

1 SEP 1999

NAVSEA TECHNICAL MANUAL CERTIFICATION SHEET 1 of 1

Certification Applies to: New Manual ☐ Revision ☒ Change ☐

Applicable TMINS/Pub. No. S9086–RS–STM–010/CH–512R2

Publication Date (Mo, Da, Yr) September 1999

Title: NSTM Chapter 512, Fans

TMCR/TMSR/Specification No:

CHANGES AND REVISIONS:

Purpose: Side bars in the outside margin indicate changes since the last revision. This chapter was reformatted to support conversion to SGML and electronic distribution. Technical changes requested by the Life Cycle Manager have been incorporated but the chapter has not yet been approved by the Technical Authority.

Equipment Alteration Numbers Incorporated:

TMDER/ACN Numbers Incorporated:

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Authority	Name	Signature	Organization	Code	Date
Acquisition					
Technical	TIEN NGO		NAVSEA	05L21	4/5/90
Printing Release	Digital Media Publishing				

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THIS CHAPTER HAS BEEN REFORMATTED FROM DOUBLE COLUMN TO SINGLE COLUMN TO SUPPORT THE NSTM DATABASE. THE CONTENT OF THIS CHAPTER HAS NOT BEEN CHANGED.

CHAPTER 512

FANS

SECTION 1.

INTRODUCTION

512-1.1 SCOPE

512-1.1.1 This chapter discusses Navy standard fans and special application NAVSEA approved commercial fans used in ventilation supply, ventilation exhaust, and air conditioning recirculation systems of a Navy shipboard heating, ventilating, and air conditioning (HVAC) system.

512-1.1.2 Navy standard fans include both installed and portable fans and are designated as axial or centrifugal fans that conform to Navy shock, vibration, and efficiency requirements. Both are standardized by sizes, performance characteristics, and dimensions to provide a flexible means of selecting various fan sizes when designing an HVAC system and to ensure an interchangeable means for replacement. They include regular vaneaxial fans, high-pressure vaneaxial fans, gas turbine module (GTM) enclosure cooling vaneaxial fans, tubeaxial fans, centrifugal fans, and portable ventilating sets that are either electric-motor driven vaneaxial fans or air-turbine driven centrifugal fans.

512-1.1.3 Commercial fans vary in design and construction and typically do not conform to Navy shock and vibration requirements. Their use in Navy shipboard HVAC applications is avoided. When Navy standard fans do not exist to satisfy specific design requirements, commercial fans are used with NAVSEA approval. These fans are discussed in this chapter as special application fans. They are radar wave-guide pressurization and avionics shop fans, which are commercially available centrifugal fans.

512-1.1.4 Information in this chapter for Navy standard and special application fans includes fan identification information, fan application and installation considerations, fan physical and functional descriptions together with performance characteristics, and recommended maintenance and repair practices. Information provided for fan motors is brief since they are comprehensively covered in **NSTM Chapter 302, Electric Motors and Controllers** .

512-1.2 TERMINOLOGY

512-1.2.1 Terms and units of measurement used in this chapter are defined as follows:

a. Cubic feet per minute (cfm) is the unit of the rate of airflow volume.

b. Standard cubic feet per minute (scfm) is the unit of the rate of airflow volume under standard conditions with air density at 0.075 pounds per cubic foot, temperature at 69.8° F, and barometric pressure at 29.92 inches of mercury.

c. Revolutions per minute (rpm) is the unit of the fan motor speed.

d. Inches water gauge (wg) is the unit of pressure.

e. Total pressure (tp) is the difference between the total pressure at the fan outlet and the total pressure at the fan inlet. It is also the duct system total resistance. The tp unit is inches wg.

f. Brake horsepower (bhp) is the power consumption required by the fan to achieve its design point operating conditions. The bhp unit is horsepower.

512-1.3 IDENTIFICATION

512-1.3.1 GENERAL. Fans used in a Navy shipboard HVAC system are designated as as either axial or centrifugal fans depending upon the direction of airflow through their fan wheel. Axial fans have parallel inlet and outlet flange connections. The entering and leaving airflow directions are axial through the fan wheel and the correct fan wheel rotation may be clockwise or counterclockwise depending upon the manufacturer. Centrifugal fans have perpendicular inlet and outlet flange connections. The entering airflow direction is axial into the fan wheel and the leaving airflow direction is radial.

512-1.3.2 PART IDENTIFYING NUMBER. Navy standard fans are identified by a part identifying number (PIN). The number is comprised of the applicable military specification followed sequentially by a series of alternating letter and number symbols that represent various fan and motor characteristics. The following examples illustrate how a PIN is created (refer to Table 512-1-1 and Table 512-1-2).

a. A2A4W6-NM. This number indicates:
   - A = vaneaxial fan
   - 2 = nominal rated airflow volume is 2000 cfm
   - A = alternating current
   - 4 = 440 volt, 3 phase, 60 Hz
   - W = spraytight motor enclosure
   - 6 = maximum operating ambient temperature is 65°C
   - NM = nonmagnetic construction

b. L1/2A1W6. This number indicates:
   - L = tubeaxial fan
   - 1/2 = nominal rated airflow volume is 500 cfm
   - A = alternating current
   - 1 = 115 volt, 1 phase, 60 Hz
   - W = spraytight motor enclosure
   - 6 = maximum operating ambient temperature is 65°C

c. C5A4W5CW-NS-WT. This number indicates:
   - C = centrifugal fan
   - 5 = nominal rated airflow volume is 5000 cfm
   - A = alternating current
   - 4 = 440 volt, 3 phase, 60 Hz
   - W = spraytight motor enclosure
   - 5 = maximum operating ambient temperature is 50°C
   - CW = rotation clockwise (viewed from drive side)

NS = nonsparking motor

WT = watertight construction

NOTE

If the first symbol is preceded by an X as in XC5A4W5CW-NS-WT, it indicates not shock tested; if S is the first symbol instead of X it indicates special electrical characteristics identified by applicable data on fan/motor identification plate.

512-1.3.3 PIN DESIGNATION TABLES. Table 512-1-1 defines the symbol sequence that follows the applicable military specification and lists the options for each characteristic. Table 512-1-2 lists the nominal rated airflow volume in scfm for each Navy standard fan type and size.

512-1.4 APPLICATION AND INSTALLATION CONSIDERATIONS

512-1.4.1 GENERAL. Although installation location is not always an optional matter, wherever a choice can be made proper access for maintenance and repairs should be a prime consideration. Locations that may later become congested with mechanical and electrical equipment should be rejected if there is any other possible location.

512-1.4.1.1 Proper access for fans means the provision of adequate space for inspection, cleaning of fan wheel blades, and removing the entire fan from the duct system for motor servicing. Fans with dc motors have transparent ports for viewing of the brushes and commutator and should not be installed in a manner where the line of sight to the brushes is obstructed. Incorporated in the design of Navy standard fan motor bearings is a grease reservoir to enhance the life of motor bearings and thus minimize motor repairs. To gain access to the motors, when motor repairs are necessary for axial fans, the fans are removed from their duct system. They are then transported to the electrical shop for necessary repairs. Fan rooms with doors too small for fan removal from the fan room are provided with bolted accesses or plates to permit fan removal.

512-1.4.2 REGULAR VANEAXIAL FANS. Regular Navy standard vaneaxial fans (type A fans, Figure 512-1-1) are preferred, compared to an equivalent centrifugal fan for shipboard HVAC installations due to their compactness and ability to be fitted to simpler ductwork having fewer bends. They are ideal for use in applications where both the inlet and outlet ducts align and where there is no requirement for change in direction of airflow.

512-1.4.2.1 Type A fans are vibrationally isolated as a result of resilient mounts, flexible ductwork connections, and flexible electrical conduit connections. This minimizes the transmission of vibration to adjacent ductwork. The motor is grounded to the fan casing and conduit box by electrical conduit that is watertight and shielded against radio frequency interference. Fans that are resiliently mounted on vibration isolators have a separate grounding strap from the fan casing to the ship's structure. The electrical conduit box on horizontally mounted fans is on or above the horizontal axis of the fan to prevent drainage of motor condensate to the conduit box. Type A fans may be installed vertically, horizontally, obliquely, parallel to ship's centerline, or athwartship. General installation requirements for type A fans are as follows:

- Proper fan wheel rotation
- Proper airflow direction, which is first into the fan wheel and then across the motor

- Proper access in and around connecting ductwork necessary for cleaning and maintaining the fan

512-1.4.2.2 On installations where a Navy standard vaneaxial fan takes suction from a plenum, compartment, or duct that is larger than the fan inlet, an inlet bellmouth is used on the fan inlet. Bellmouth inlets reduce total system resistance, turbulence, and noise and equalize airflow over the fan inlet face to improve fan performance. Bellmouths are standardized rounded inlets with flanges welded to their converging ends. They fit Navy standard vaneaxial fans and therefore have the same size numbers. They are of steel construction except when nonmagnetic construction is required, in which case aluminum is used. When nonmagnetic construction is required, it is specified as NM after the size number (for example, Bellmouth A3-NM).

512-1.4.2.3 Sometimes in systems having confined space requirements, vaneaxial fans are used for handling airstreams of explosive and flammable gases (such as hydrogen generated by charging batteries). Particularly in systems where accessibility for maintenance presents a problem, vaneaxial fans selected for this application should be driven by ac explosionproof motors. Vaneaxial fans driven by dc motors are more frequently subject to motor maintenance problems due to improper commutation resulting in sparking of the brushes. Therefore, dc motor-driven vaneaxial fans are considered unsafe for handling airstreams of explosive and flammable gases and are not used for these applications. In addition, due to frequent maintenance problems of dc motors, most U.S. Navy ships are now equipped with ac motor driven fans.

512-1.4.3 HIGH-PRESSURE VANEAXIAL FANS. Navy standard high-pressure vaneaxial fans (a special version of the type A fan, Figure 512-1-2) are specifically designed for higher operating pressure applications than the regular Navy standard vaneaxial fans. They are used in collective protection systems (CPS) in ship design as required by the Navy for protection of personnel and equipment from chemical, biological, and radioactive (CBR) contaminants. They may be installed vertically, horizontally, obliquely, parallel to ship's centerline, or athwartship. General installation requirements for high-pressure vaneaxial fans are as follows:

Table 512-1-1. NAVY STANDARD FANS-PIN DESIGNATIONS

SYMBOL SEQUENCE	CHARACTERISTICS	SYMBOL	MEANING
1 (letter)[1]	Type of fan	Type A Type TA Type L Type O Type C Type CC	Vaneaxial Vaneaxial, GTM Enclosure Cooling Tubeaxial Portable Centrifugal[2] Centrifugal
2 (figure)	Fan size	See Table 512-1-2	Nominal scfm in thousands (1/2 = 500 cfm) (3/4 = 750 cfm)
3 (letter)[3]	Type of drive or current	A D T	Alternating current (ac) motor-driven Direct current (dc) motor-driven Air-turbine driven
4 (figure)	Voltage and phase (frequency) of ac is 60 Hz)	1 2 4	115 volt, 1 phase ac 220 volt, 3 phase ac 440 volt, 3 phase ac

Table 512-1-1. NAVY STANDARD FANS-PIN DESIGNATIONS - Continued

SYMBOL SEQUENCE	CHARACTERISTICS	SYMBOL	MEANING
5 (letter)	Motor enclosure	W X S D	Spraytight Explosionproof Submersible - 15 ft Dripproof
6 (figure)	Maximum operating ambient temperature	5 6 8	50°C[4] 65°C[5] 65°C
7 (letters-centrifugals) (letters-all other fans)	Rotation (viewed from drive side) Construction	CW CCW NM	Clockwise Counterclockwise Nonmagnetic (this seventh symbol is omitted unless applicable)
8 (letters-centrifugals) (letters-all fans)	Construction Construction	NM NS WT AR TP	Nonmagnetic (this symbol is omitted unless applicable) Nonsparking Watertight Acid resisting paint on air handling parts Thermal protection[6]

[1]a. If this letter is preceded by an X, the motor is service C.
b. If this letter is preceded by an S, the fan is special as identified by applicable data on fan or motor identification plate.

[2]No longer available - replaced by type CC.

[3]D and T drive for type O portable fans are special order items.

[4]No longer available.

[5]Standard. High-pressure vaneaxial fans are only available with 65°C motors.

[6]Standard on high-pressure vaneaxial fans. Special order items for all other fans.

Table 512-1-2. NAVY STANDARD FANS-NOMINAL RATED AIRFLOW VOLUMES (SCFM)

FAN SIZE	FAN TYPE				
	A[1]	TA	L	CC	O
1/4	250		-	250	-
1/2	660		450	500	500
3/4	-		-	-	750
1	1,030		1,000	900	
1-1/2	1,500		-	1,200	
2	2,000		1,900	1,300	
2-1/2	2,600		-	-	
3	3,200		2,250	1.950	

Table 512-1-2. NAVY STANDARD FANS-NOMINAL RATED AIRFLOW VOLUMES (SCFM) - Continued

FAN SIZE	FAN TYPE				
	A[1]	TA	L	CC	O
3-1/2	3,750			-	
4	4,300[2]			2,500	
4-1/2	3,220	4,500		-	
5	4,200	5,000		3,000	
6	6,300			5,000	
7	5,200			-	
8	7,300			4,500	
10	8,500			7,000	
11	8,700				
12	10,250				
16	13,200				
17	12,300	17,000			
20	18,000				
22-1/2	-	21,200			
25	22,000				
28	18,750				
30	25,000				
101	1,200/1,320				
102	1,800/1,980				
103	2,400/2,640				
104	3,600/3,960				
105	5,400/5,940				

[1]Fan sizes 101, 102, 103, 104, and 106 are high-pressure vaneaxial fans and have rated airflow volumes as first shown at 14 inches wg (with dirty filters), followed by rated airflow volumes at 12 inches wg (with clean filters). They also have maximum effective stall at 85 percent of airflow volumes (with dirty filters) or 1020 cfm for size 101; 1530 cfm for size 102; 2040 cfm for size 103; 3060 cfm for size 104; and 4590 cfm for size 105 which shall be the greater of the three following capacity values used to measure aerodynamic stall:
(a) Throttled stall capacity
(b) Stall recovery capacity
(c) Stable start-up capacity

[2]Discontinued axial fan size.

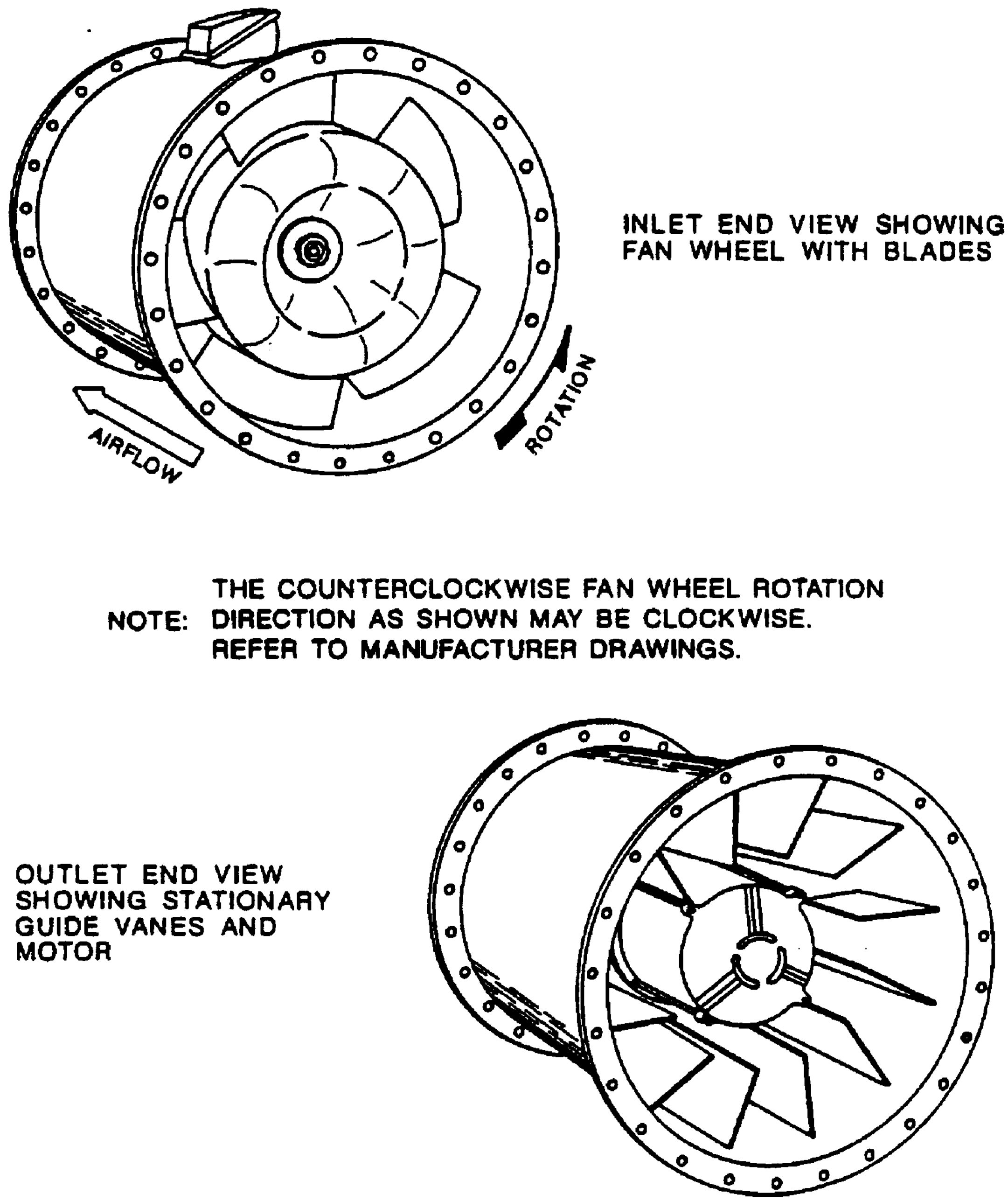


Figure 512-1-1 Typical Navy Standard Vaneaxial Fan (Type A)

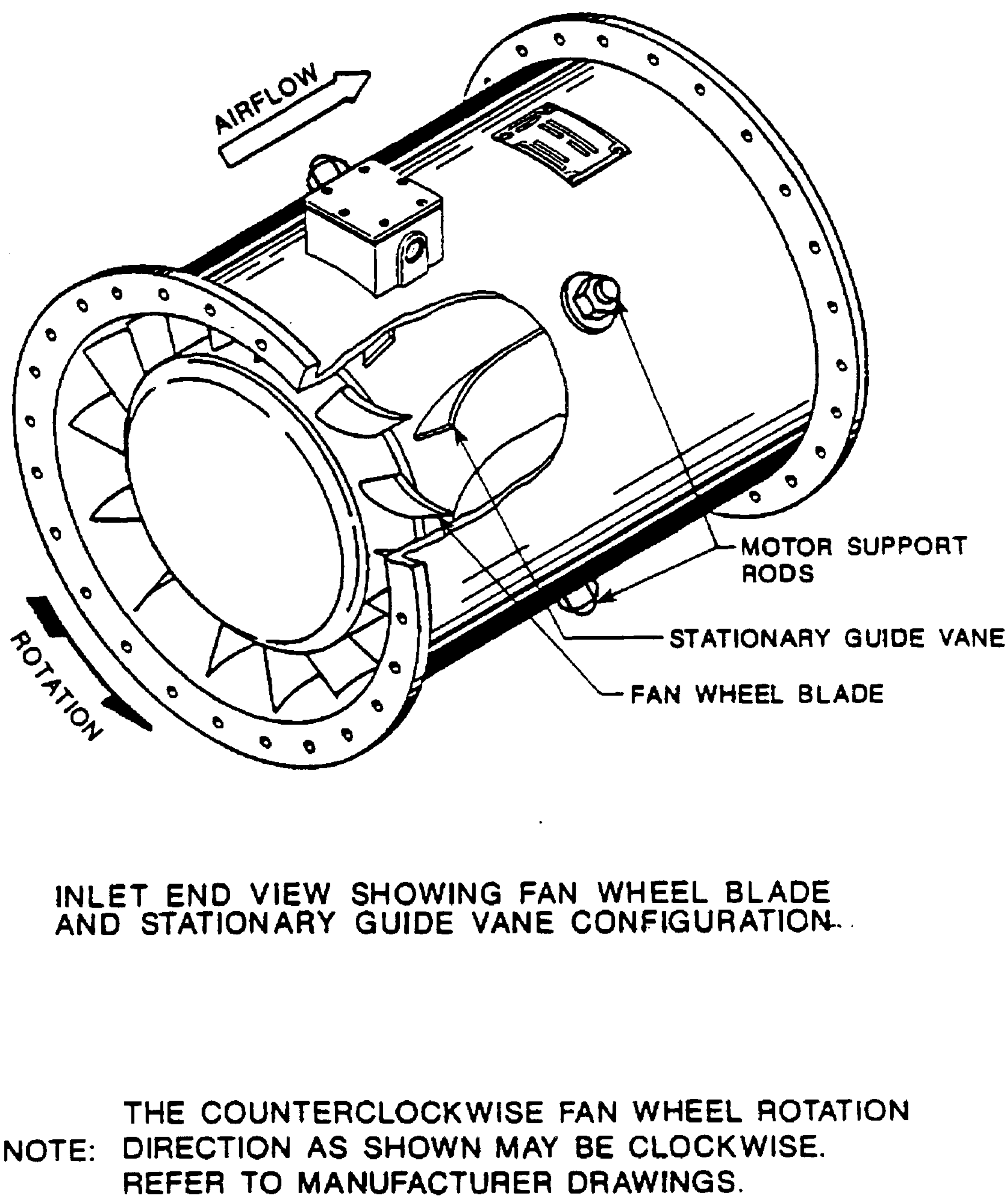


Figure 512-1-2 Typical Navy Standard High-Pressure Vaneaxial Fan (also Type A)

- Proper fan wheel rotation
- Proper airflow direction, which is first into the fan wheel and then across the motor
- Proper access around the fan necessary for cleaning and maintaining the fan

512-1.4.4 GAS TURBINE MODULE (GTM) ENCLOSURE COOLING VANEAXIAL FANS. There are two classes of Navy standard GTM enclosure cooling vaneaxial fans (type TA fans): propulsion (Figure 512-1-3) and generator (Figure 512-1-4). Both classes are standard designed with a sound trap to lower the fan sound level. The propulsion GTM enclosure cooling fans are typically mounted in a vertical position with the fan wheel end up so that, at normal operating speed, the fan wheel tends to lift the rotor assembly, relieving the bearings of axial loads. The generator GTM enclosure cooling fans are typically mounted in either a vertical or horizontal position.

512-1.4.4.1 Various installation configurations are possible for each type of fan depending on shipboard requirements. The application and installation of these fans are ship class dependent and the particular Ship Information Book (SIB) should be accessed for ship specific information. Each GTM requires an enclosure assembly to provide a cool environment around the gas turbine and a thermally and acoustically insulated barrier to minimize the transmission of thermal and sound energy from the gas turbine to surrounding areas. Each enclosure is functionally identical in that they all incorporate thermal and acoustical insulation and are provided with supply and exhaust airflow capability. The cool environment provided by the ventilation airflow through the enclosure is required to cool external surfaces of the gas turbine and interior surfaces of the enclosure walls.

512-1.4.4.2 Currently there are two typical propulsion GTM enclosure cooling design configurations. Each configuration utilizes a separate propulsion GTM enclosure cooling fan and ductwork in conjunction with the gas turbine (engine) exhaust uptake system to ventilate the GTM enclosure. In the first configuration, see Figure 512-1-5, weather air is drawn into the plenum of the engine's intake system. The GTM enclosure cooling air is drawn from the plenum through a moisture separator (demister) into the cooling air ductwork. The ductwork then splits into two separate vertical parallel (side-by-side) ducts. One duct contains the propulsion GTM enclosure cooling fan and a vent damper (firedamper) downstream of the fan. The other duct contains a bypass damper around the fan. The two parallel ducts then converge by means of a transition section into a single round duct which is connected to the supply ventilation flex duct connection on the GTM enclosure. The vent damper remains open during engine operation and during shutdown of the engine when the ambient air temperature is above 70°F. It closes when the engine is shut down and the ambient temperature is below 70°F and when serving as a firedamper during release of the fire extinguishing system in the GTM enclosure. The bypass damper is spring-loaded such that it automatically closes when its downstream duct air pressure is greater than its upstream duct air pressure. Consequently the bypass damper will be closed during fan operation preventing reverse airflow through it. GTM enclosure cooling air is provided by either the fan or by the induction action created by the engine exhaust eductor. Below 3,000 engine horsepower or when the engine is not operating and the enclosure air temperature is above 125°F, cooling air is provided by the fan. The fan pressurizes the GTM enclosure which closes the bypass damper and pushes the GTM enclosure exhaust air into the engine's uptake system through the opening between the engine's exhaust eductor and exhaust duct flex connection. When the engine is not operating and the enclosure air temperature is below 125°F, or when the engine is operating above 3,000 horsepower, the fan is shut off. As the engine power exceeds 3,000 horsepower, eductor action provided by the engine's exhaust eductor creates sufficient negative pressure for the bypass damper to open. The eductor action then causes the cooling air to be induced through both parallel ducts into and to be drawn through the GTM enclosure and out into the engine's uptake system through the opening between the engine's exhaust eductor and exhaust duct flex connection. The engine's exhaust uptake system then conducts the enclosure exhaust air with the engine's combustion exhaust gases to weather.

512-1.4.4.3 In the second configuration, see Figure 512-1-6, weather air is drawn into the engine's intake system. The GTM enclosure cooling air is drawn from the engine's intake system through the cooling air duct intake in the intake system trunk upstream of the combustion air intake silencer section. The air then enters the cooling air duct system, which is a separate vertical duct system that is parallel to the engine's combustion air intake system trunk. The cooling air duct system contains a duct silencer, the propulsion GTM enclosure cooling fan, a ventilation firedamper, and ductwork that connects to the supply ventilation flex duct connection on the GTM enclosure. During engine operation, the ventilation firedamper is open and the cooling fan is in operation. During engine shutdown or release of the fire extinguishing system in the GTM enclosure, the ventilation firedamper is closed and the fan is shut down. During engine operation the fan provides cooling air as it pressurizes the GTM enclosure. The cooling air flows through the supply ventilation flex duct connection and enters the GTM enclosure through the ventilation firedamper located in the ceiling of the GTM enclosure. The air then flows through and ventilates the GTM enclosure and is vented through an opening between the engine's exhaust extension and exhaust duct flex connection into the engine's exhaust uptake system. The uptake system then conducts the enclosure exhaust air with the engine's combustion exhaust gases to weather.

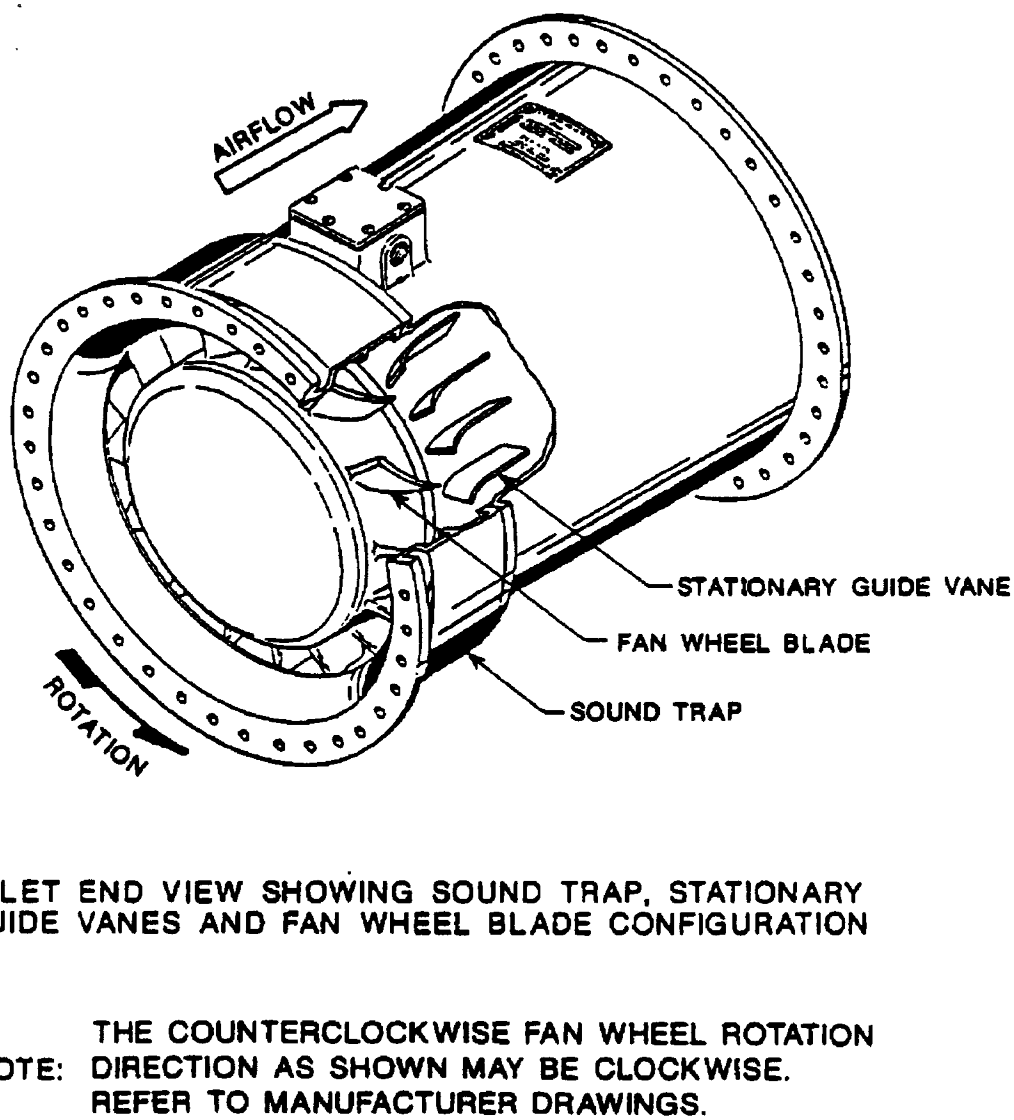


Figure 512-1-3 Typical Propulsion GTM Enclosure Cooling Vaneaxial Fan (Type TA)

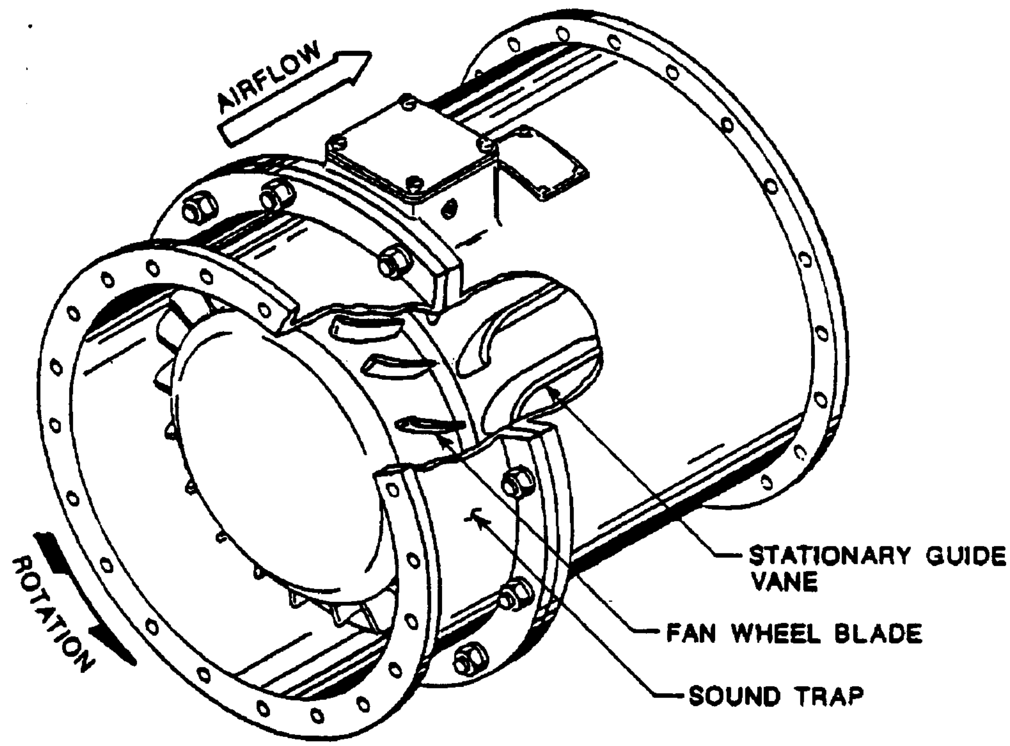


Figure 512-1-4 Typical Generator GTM Enclosure Cooling Vaneaxial Fan (Type TA)

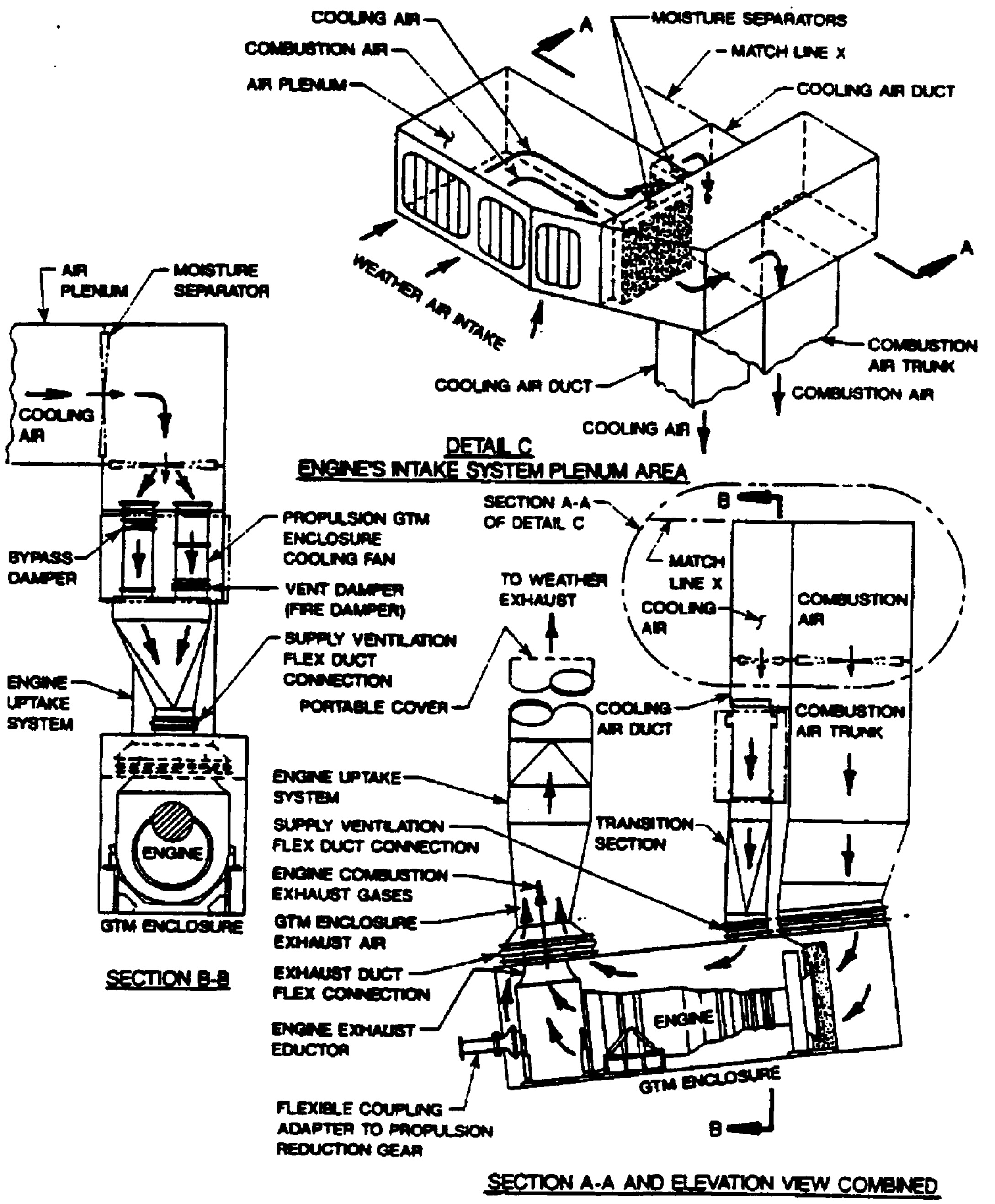


Figure 512-1-5 Typical Propulsion GTM Enclosure Cooling Design Configuration No. 1

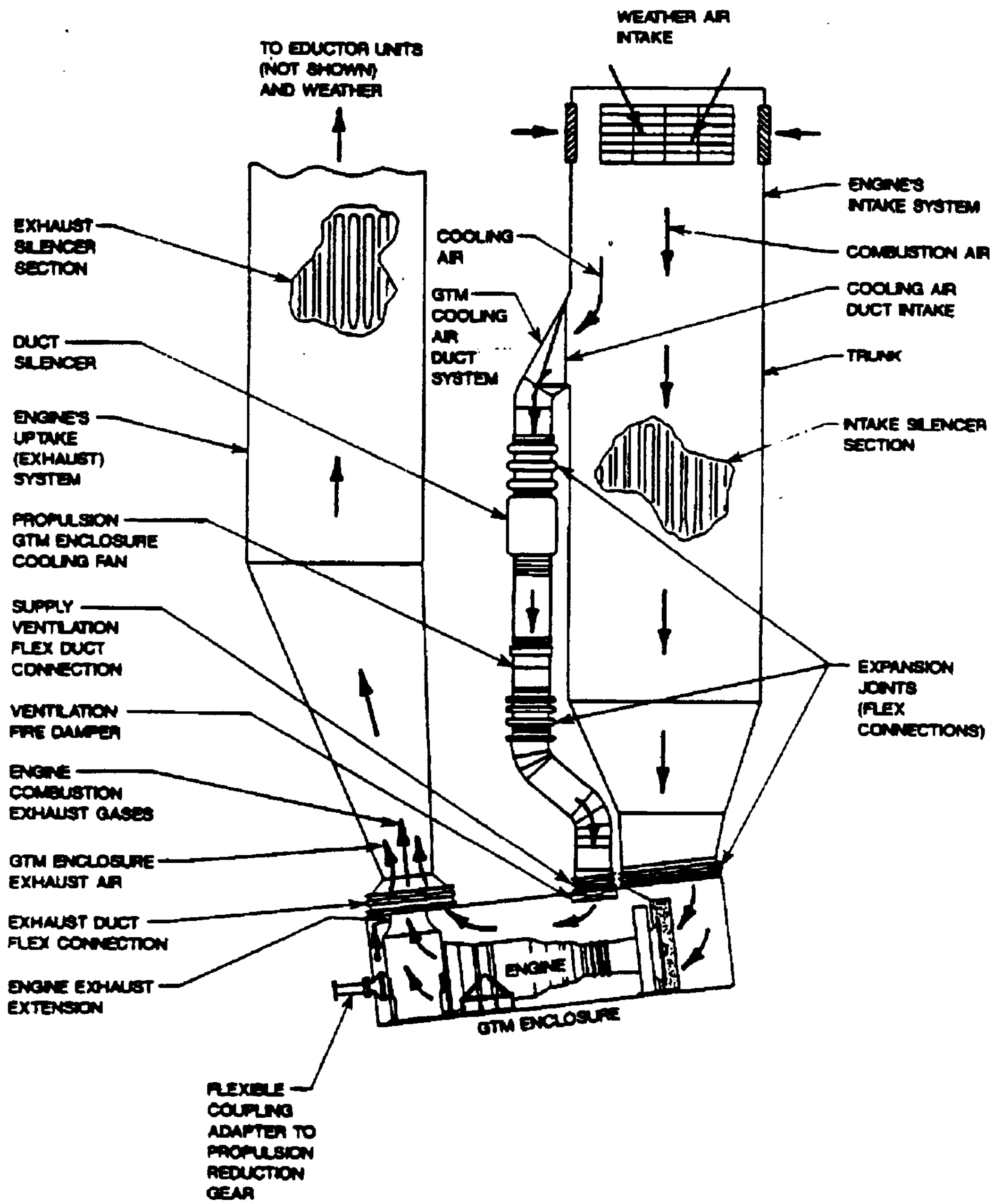


Figure 512-1-6 Typical Propulsion GTM Enclosure Cooling Design Configuration No. 2

512-1.4.4.4 The typical generator GTM enclosure cooling fan application utilizes either one or two cooling fans mounted in independent ducts. In a typical two fan application, each cooling fan is independently and automatically operated, as needed, to cool the GTM enclosure.

512-1.4.5 TUBEAXIAL FANS. Navy standard tubeaxial fans (type L fans, Figure 512-1-7) are particularly suitable for low pressure applications such as unit heaters and coolers and ventilating systems not requiring ductwork. If ductwork is necessary, care must be taken in the duct system design because of the low pressure available by the fan. Tubeaxial fans are typically mounted using the fan's outlet flange with safety screens installed on both the outlet and inlet ends for personnel protection.

512-1.4.6 CENTRIFUGAL FANS. Navy standard centrifugal fans (type CC fans, Figure 512-1-8) have limited use on shipboard HVAC installations because of their physical size and weight. Normally these fans are limited to applications where the motor should be located outside the airstream. Such applications are used in systems handling hot and humid airstreams where fans may be secured making conditions detrimental to fan motors situated within the airstream, and in systems handling airstreams of explosive and flammable gases where it is required that the fan motor be located outside of the airstreams containing the gases. Centrifugal fans are also sometimes used to save space in applications where the ductwork configuration requires the fan inlet and outlet to be at right angles.

512-1.4.7 PORTABLE VENTILATING SETS. Navy standard portable ventilating sets (type O fans) are either electric-motor driven vaneaxial fans (class O-1/2A or O-1/2D, Figure 512-1-9) or air-turbine driven centrifugal fans (class O-3/4T, Figure 512-1-10). They provide temporary ventilation for unventilated spaces and for damage control purposes. Class O-1/2A or D is commonly called a red devil. Both classes are included in the allowance of all ships, being assigned in varying quantities according to the ship type. They are highly standardized to permit lower stock levels and easier shipboard replacement. They are suitable for operation in any position, weigh under 100 pounds, and are transportable by two individuals to any shipboard area. Either class is used for supplying or exhausting air. The fans are placed in the space to be ventilated or are positioned remotely from the space. When positioned remotely, a flexible, lightweight, fabric ventilation hose is attached to either the inlet or outlet end of the fans with adapter fittings. No more than three 15-foot lengths of ventilation hose are used with each fan. A longer system may be made by arranging two or more fans each separated by three 15-foot lengths of ventilation hose and connected sequentially in series. Where explosive and flammable gases exist or are suspected of existing in a particular area to be ventilated, it is necessary to exercise care in the choice of portable ventilating sets. If the space contains explosive and flammable gases and an alternating current power source is not available for the class O-1/2A electric-motor driven fan, the class O-3/4T air-turbine driven fan is used for handling the gases. The class O-1/2D dc electric-motor driven fan is not to be used in a space that contains explosive and flammable gases due to the possibility of improper commutation resulting in sparking of the brushes.

512-1.4.8 SPECIAL APPLICATION FANS. Currently there are two special application fans, radar wave-guide pressurizations fans and avonics shop fans, covered separately in the following paragraphs 512-1.4.8.1 and 512-1.4.8.2, respectively.

512-1.4.8.1 The NAVSEA approved radar wave-guide pressurization fan (Figure 512-1-11) is an electric motor-driven commercially available centrifugal fan. The fan is designed to provide full performance in any mounting position. Typically it is installed on the outside of the radar wave-guide enclosure that runs between the radar antenna and receiver. The fan exhausts a small portion of environmental air from the space where it is installed to purge the enclosure of weather air and moisture. Air purged from the enclosure returns to weather.

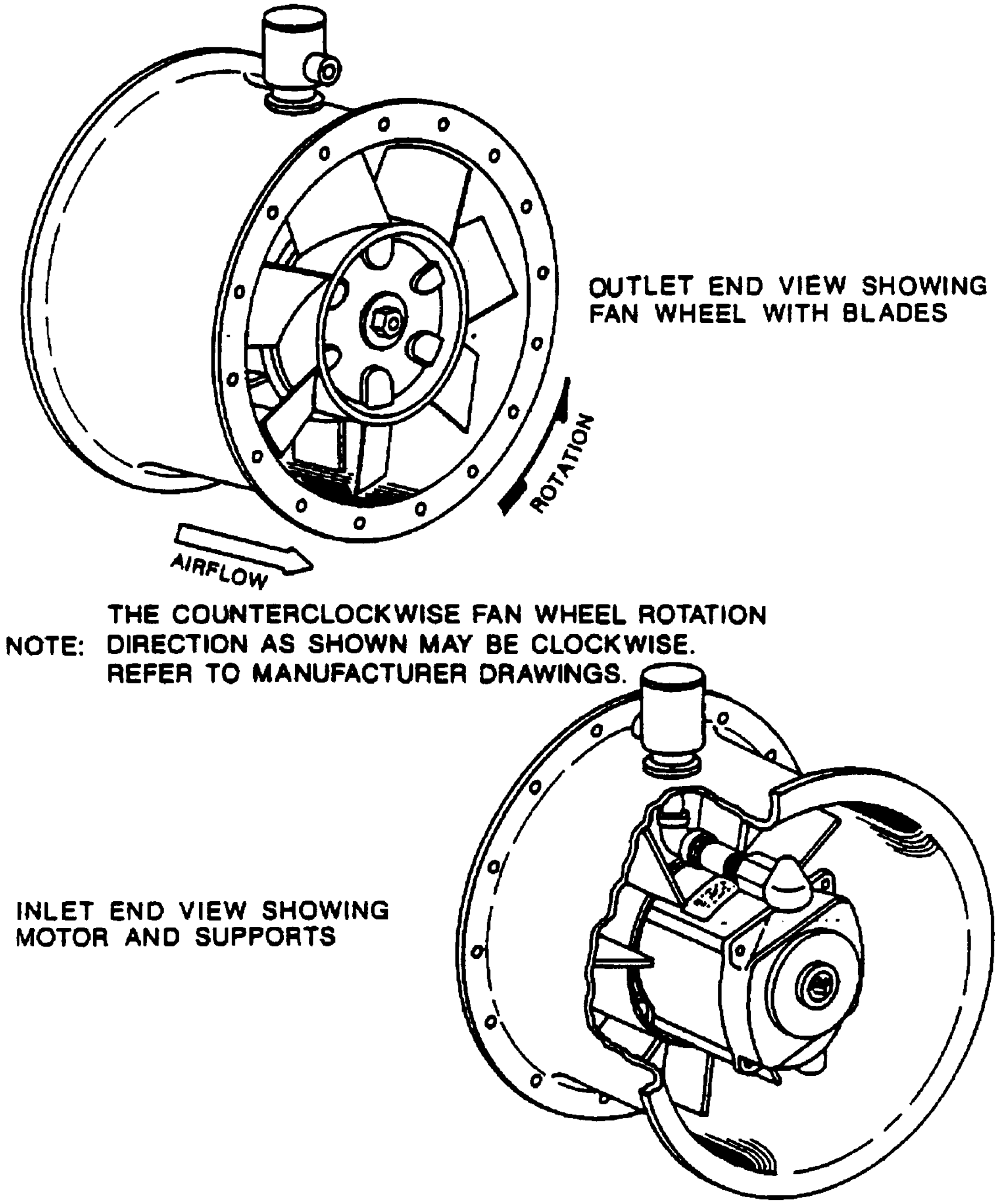


Figure 512-1-7 Typical Navy Standard Tubeaxial Fan (Type L)

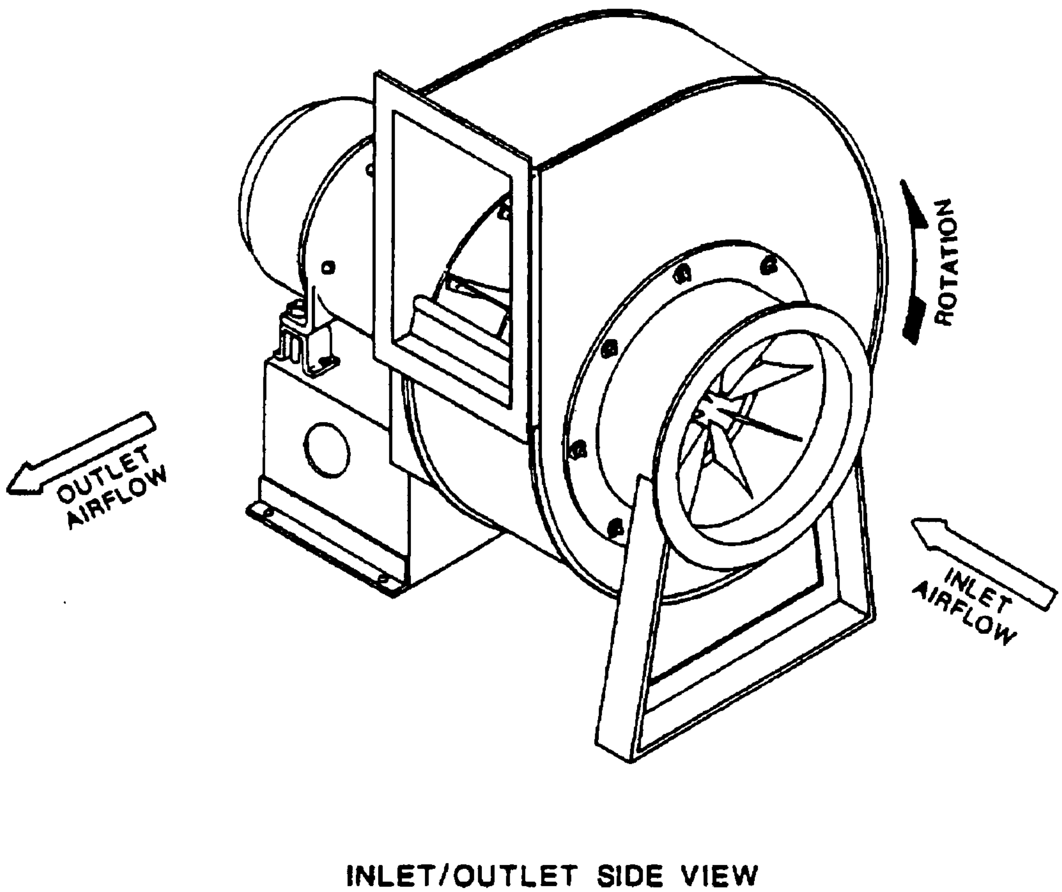
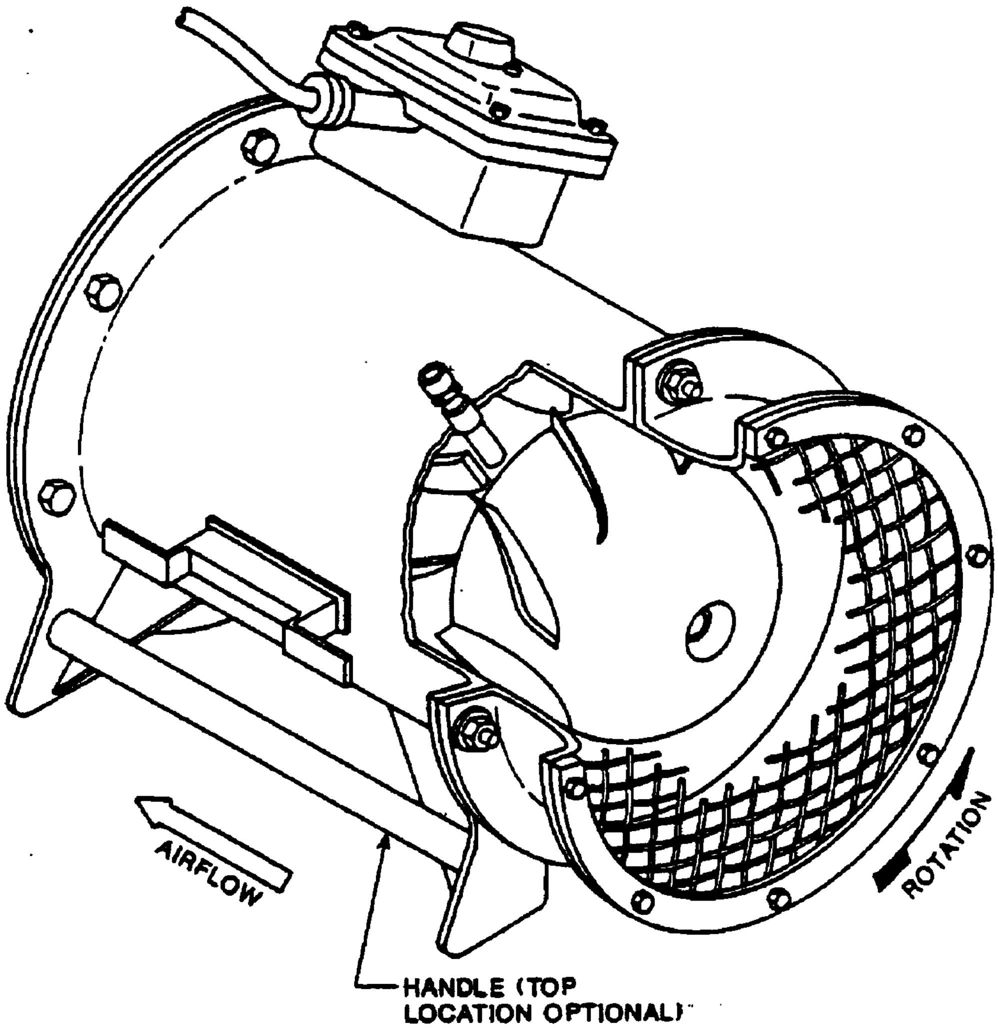


Figure 512-1-8 Typical Navy Standard Centrifugal Fan (Type CC)



INLET END VIEW SHOWING SCREENED INLET BELLMOUTH, FAN WHEEL BLADE AND STATIONARY GUIDE VANE CONFIGURATION

Figure 512-1-9 Typical Navy Standard Portable Ventilating Set (Type O Fan, Class O-1/2A or D)

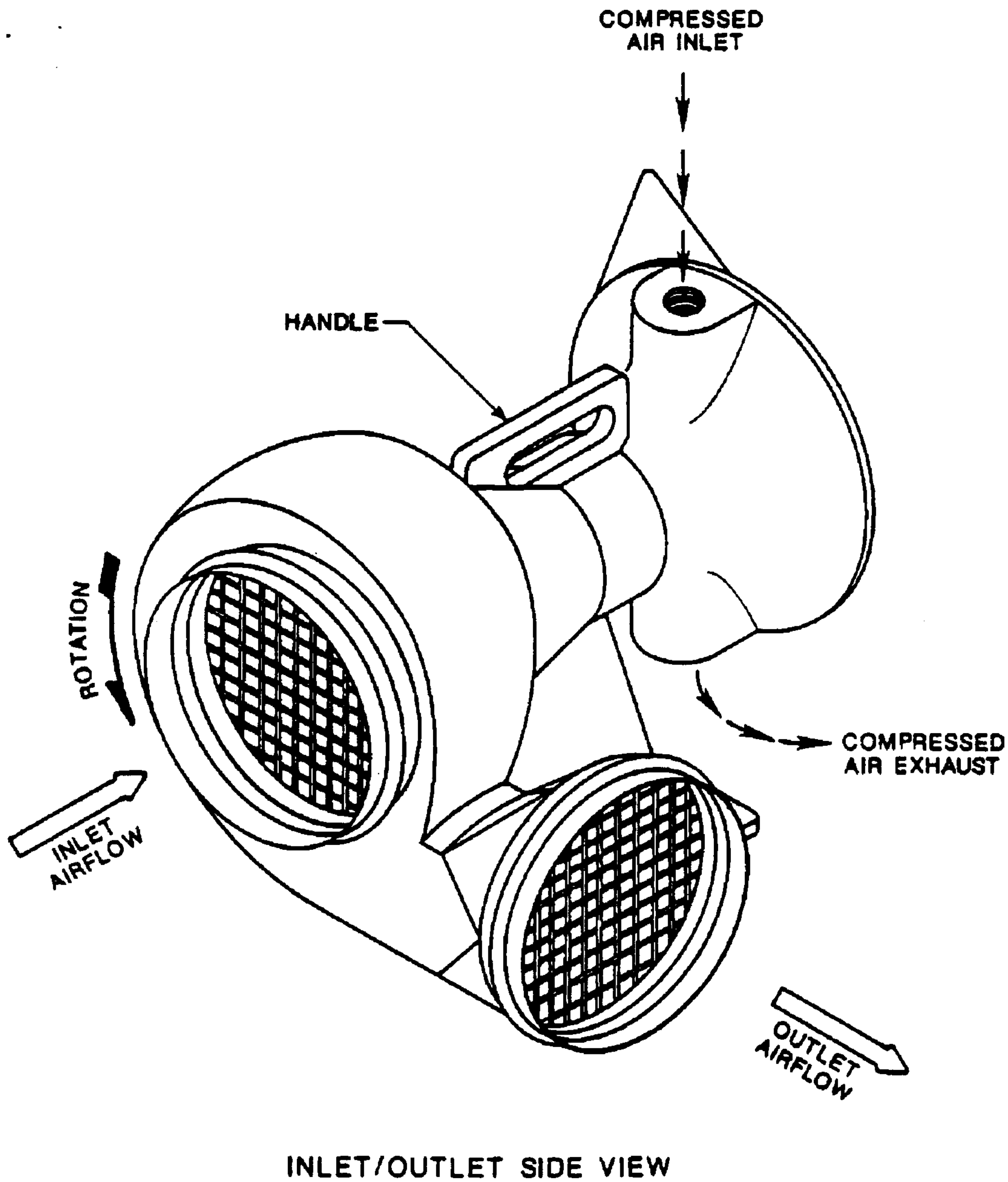


Figure 512-1-10 Typical Navy Standard Portable Ventilating Set (Type O Fan, Class O-3/4T)

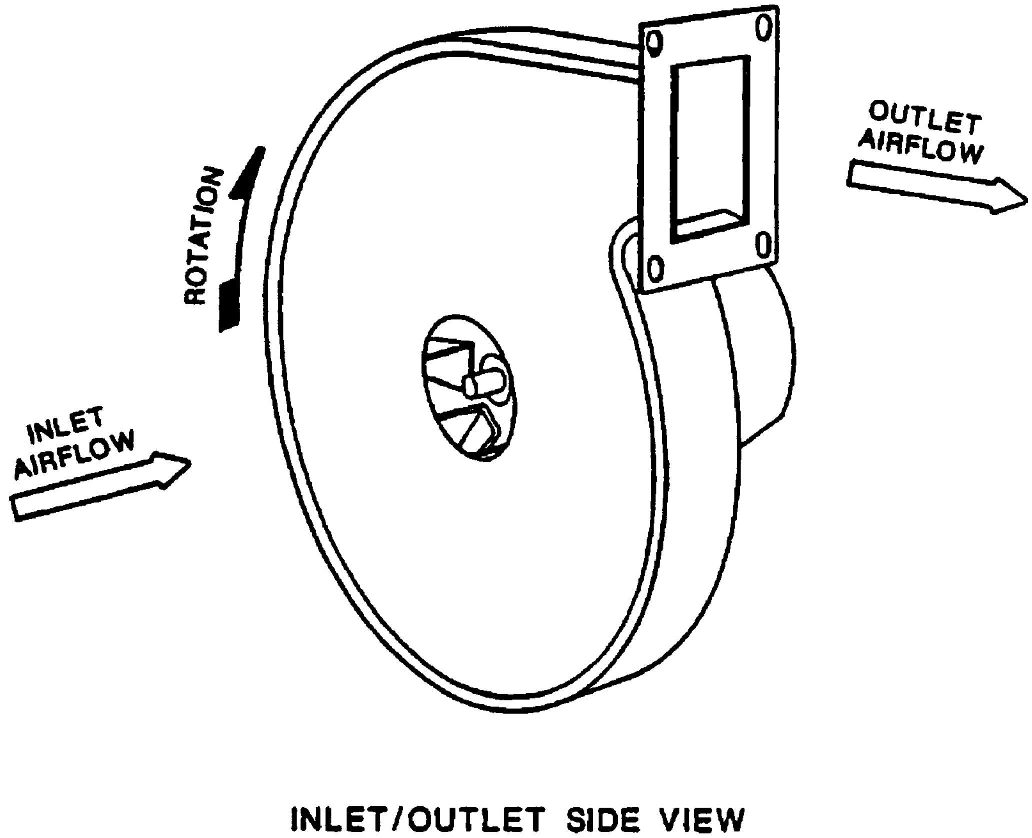


Figure 512-1-11 Typical Radar Wave-Guide Pressurization Fan

512-1.4.8.2 The NAVSEA approved avionics shop fan (Figure 512-1-12) is an electric-motor-driven, commercially available blower class of centrifugal fan. Typically it is installed in avionics shops and uses environmental air from the space to purge stationary equipment. Air purged from the stationary equipment returns to the space.

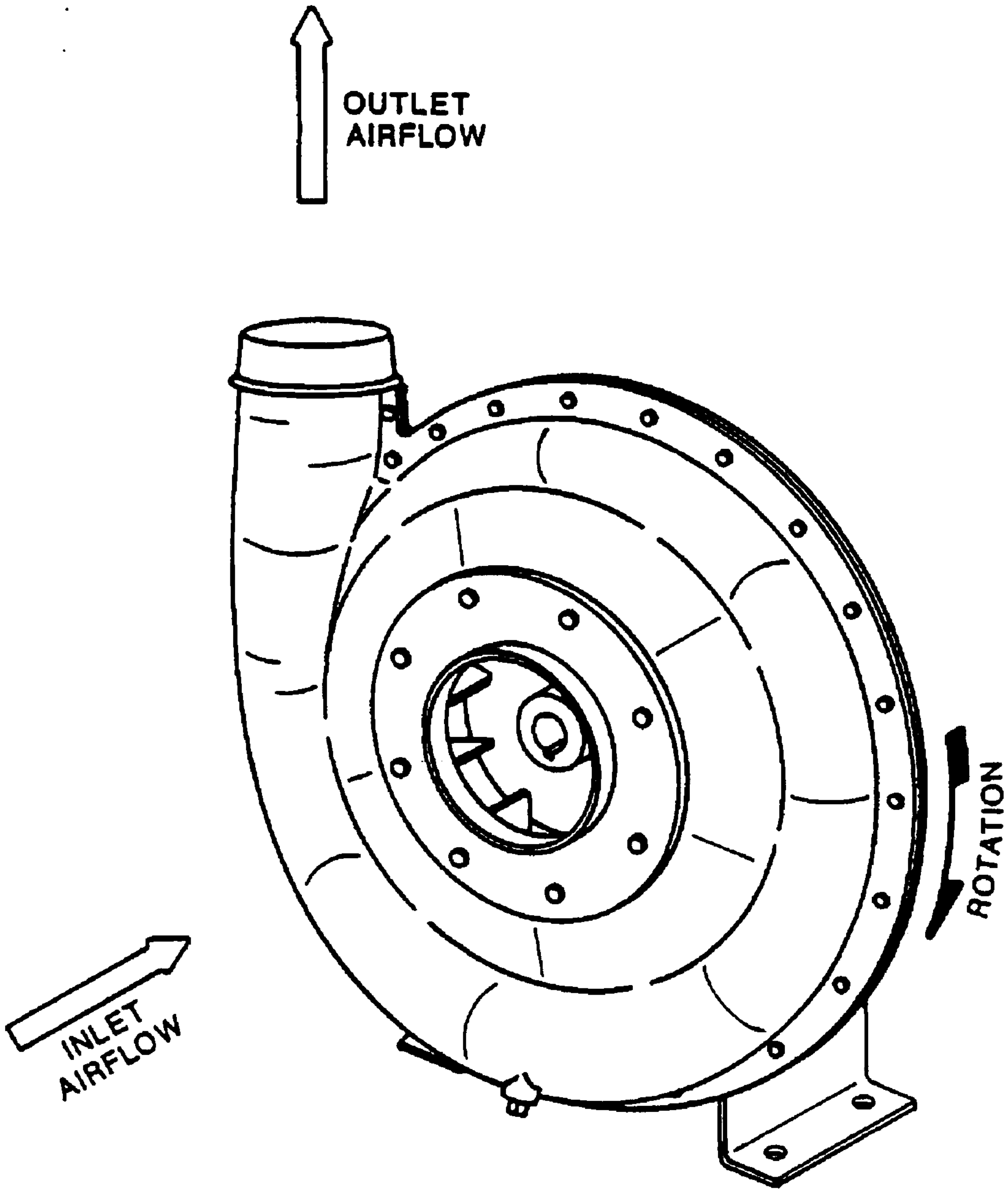
512-1.5 SAFETY PRECAUTIONS

512-1.5.1 General. Safety precautions shall be observed when working around electrical equipment to avoid injury to personnel and damage to equipment. **NSTM Chapter 300, Electric Plant - General** , provides detailed procedures and precautions. Check to ensure that the fan electrical power circuitry is de-energized at the fan controller prior to attempting any maintenance or repairs. Always attach warning tags to fan controllers which shall remain in the OFF position while maintenance or repairs are in progress. Special attention shall be given to observation of the fan wheel to certify that it is not rotating due to natural draft or other causes prior to attempting any internal fan maintenance or repairs. Staging and rigging safety precautions shall always be observed when removing, installing, or transporting a fan.

512-1.5.2 GROUNDING. The frame of each fan motor shall be effectively grounded to the ship's ground potential for personnel safety. On Navy standard fans, an integral or wired circuit is provided between the motor frame and fan casing, and between the motor and conduit box. Such a circuit shall be verified and not assumed.

Continuation of the grounding circuit to ship's structure is inherent for hard mounted fans, but a grounding strap or an extra wire in the electric cable is required for all fans rubber-mounted for resiliency, or otherwise electrically isolated from ship's ground.

512-1.5.3 MOTOR CONDENSATE DRAINAGE. When installing a new fan or reinstalling a repaired fan (except those with explosionproof motors), remove and discard the lowest condensation drain plug from the fan motor, based on the fan installation position, to permit continual drainage of condensate by gravity. This applies to all shipboard fans. All fans exhausting from hot, humid spaces such as scullery, laundry, and shower rooms shall be checked to ensure that their motors have their lowest condensate drain plug removed.



INLET/OUTLET SIDE VIEW

Figure 512-1-12 Typical Avionics Shop Fan

SECTION 2.
DESCRIPTION AND PERFORMANCE

512-2.1 PHYSICAL AND FUNCTIONAL DESCRIPTION

512-2.1.1 REGULAR VANEAXIAL FANS. The Navy standard vaneaxial fan (type A) consists of flanged cylindrical casing with stationary vanes and an internal concentric mounted electric motor with a bladed fan wheel mounted directly on the motor shaft extension upstream of the stationary vanes. The motor is mounted in a ring that is supported to the casing by the stationary vanes. The fan wheel is constructed of a nonsparking aluminum alloy and its rotation may be clockwise or counterclockwise depending upon the manufacturer. During operation, the stationary vanes increase fan efficiency by straightening the rotary motion of the airstream created by the rotating blades of the fan wheel. This produces axial airflow through the cylindrical casing. The fan is available in nonmagnetic construction to provide minimum electromagnetic interference (EMI). Fan sizes A3 and larger, with the exception of A3-1/2 and A4-1/2, are driven by a 2-speed ac electric motor. The low speed is one-half of the high speed for the A7A fans, three-fourths for the A25A and A30A fans, and two-thirds for the remaining fans. If the low speed is not required, only the high speed winding is connected. Navy standard type A vaneaxial fans used in new ship construction have fan motors equipped with sealed insulation windings. When ordering a new fan for replacement, it is recommended that the fan motor be equipped with sealed insulation windings. Due to the close similarity of performance characteristics of the A4 and A5 fans, the A4 fan has been deleted in production. When ordering a replacement for the A4 fan, the A5 fan should be selected and the ductwork modified to accommodate the A5 fan.

512-2.1.2 HIGH-PRESSURE VANEAXIAL FANS. The Navy standard high-pressure vaneaxial fan (a special version of the type A fan) consists of a flanged cylindrical casing with stationary vanes and an internal concentric mounted electric motor with a bladed fan wheel mounted directly on the motor shaft extension upstream of the stationary blades. The annulus area between the inside of the casing and the fan wheel blades is designed with close clearances to provide higher operation pressures than those provided by regular Navy standard vaneaxial fans. Fan wheel rotation may be clockwise or counterclockwise depending upon the manufacturer. The motor is a special spraytight, high efficiency, high-impact shock service type with sealed insulation windings and thermal protection.

512-2.1.3 GAS TURBINE MODULE (GTM) ENCLOSURE COOLING VANEAXIAL FANS. The Navy standard GTM enclosure cooling vaneaxial fan (type TA fan) consists of a cast aluminum cylindrical housing with a sound trap and an internal concentric mounted electric motor with a bladed fan wheel mounted directly on the motor shaft extension. The cast aluminum housing consists of a flanged outer casing and a concentric inner sleeve connected by vanes. The inner sleeve serves as the motor casing where the motor stationary electrical windings are inserted. The vanes support the inner sleeve and its integral motor components. The vanes also serve as the fan's stationary vanes for directing movement of air passing through the annular space between the outer casing and the sleeve. The fan wheel may be single or dual staged and is designed with close clearance between the tips of the fan wheel blades and the inside diameter of the fan casing for providing maximum performance. Fan wheel rotation may be clockwise or counterclockwise depending upon the manufacturer. Both the propulsion and generator GTM enclosure cooling fans are ac motor-driven. The propulsion GTM fan is typically provided with a motor that is desirable for vertical fan mounting (see paragraph 512-1.4.4).

512-2.1.4 TUBEAXIAL FANS. The Navy standard tubeaxial fan (type L fan) consists of a flanged cylindrical casing of rolled steel or cast aluminum with integral or welded motor supports, and an internal concentric mounted electric motor having a fan wheel. The motor is held by a clamp around its frame or is face-mounted to a ring suspended from the casing. The cast aluminum fan wheel is mounted on the motor shaft extension. Fan wheel rotation may be clockwise or counterclockwise depending upon the manufacturer. Airflow is axial; in this respect the tubeaxial fan is similar to the vaneaxial fan. Differences between the tubeaxial and vaneaxial fan include the absence of stationary vanes, greater ratio of blade tip to blade hub diameter, and airflow direction. In the tubeaxial fan, air is first drawn over the motor and then discharged from the fan wheel end. (This is the reverse of the vaneaxial fan airflow direction.) The tubeaxial fan is inherently nonsparking, but an explosionproof motor is required if the fan is installed in a system handling an airstream of explosive or flammable gases. Tubeaxial fans used in new ship construction have an extended casing and are equipped with a conduit box. The motor lead wires to the conduit box are enclosed in a watertight conduit arrangement that provides damping of rotor vibration and an effective electrical ground circuit from the motor frame to the fan casing and the conduit box. The conduit box and the conduit arrangement are required to be explosionproof if the fan is utilized in an explosive or flammable atmosphere. When ordering a new fan for replacement, it is recommended that the fan be equipped with a conduit box and arrangement as discussed above.

512-2.1.5 CENTRIFUGAL FANS. The Navy standard centrifugal fan (type CC fan) consists of a scroll-shaped housing, a motor and motor support base, and a cylindrical-shaped fan wheel. The scroll-shaped housing is bolted to the motor support base. The cylindrical-shaped enclosed end-suction type fan wheel is mounted on the motor shaft extension inside the fan housing. Most of the pressure is produced by centrifugal force within the fan wheel, but there is also some velocity pressure conversion in the scroll area of the fan housing. Entering airflow direction is axial and leaving (discharge) airflow direction is radial to the fan wheel. The fan can be provided with its housing rotated to a variety of positions to provide the desired discharge airflow direction such as top horizontal, bottom horizontal, upblast, downblast, or other variations of these positions (see Figure 512-2-1).

512-2.1.5.1 All type CC centrifugal fan sizes, except the size CC1/4, have backward-curved fan wheel blades with a characteristically lower horsepower requirement at free airflow delivery volume than at peak total pressure. The size CC1/4 fan has forward-curved fan wheel blades with a characteristically higher horsepower requirement at free airflow delivery volume than at peak total pressure. The motor may become overloaded if the fan is operated at its free airflow delivery volume. If the fan is bench tested, the discharge airflow is partially blocked to reduce motor current to the nameplate value. Type CC fans have inlet vanes for better intake conditions and straight inlet side legs for greater shock resistance. They are quieter and stronger, and have gradually replaced type C fans. Dimensions of type CC fans differ slightly from those of type C fans.

512-2.1.5.2 Centrifugal fans produced since 1950 and all type CC fans are of nonsparking construction. The fans are provided with housing handholes for inspection and cleaning of fan wheel blades. All housings are convertible in that their inlet and drive-side plates have center openings of the same diameter, allowing them to be interchanged, thereby permitting the housing to be used for either clockwise or counterclockwise fan wheel rotation. Fan wheels and inlet vanes are not convertible. The fan motor is not convertible if it contains an internal cooling fan with curved blades. Type CC fans (sizes CC 1/4 to CC 2, inclusive) have single-speed electric motors less than 2 horsepower. Sizes CC 3 to CC 10 inclusive have 2-speed electric motors greater than 2 horsepower.

512-2.1.6 PORTABLE VENTILATING SETS. There are two basic classes of portable ventilating sets (type O fans), class O-1/2A or D and class O-3/4T described separately in the following paragraphs 512-2.1.6.1 and 512-2.1.6.2, respectively.

512-2.1.6.1 Class O-1/2A or D portable ventilating sets (type O fans) are a version of the vaneaxial fan. The fans, ventilation hose, and adapters are of nonsparking construction to avoid sparks when contacted by other metallic surfaces. Class O-1/2D fans are of nonmagnetic construction to minimize electromagnetic interference (EMI). New class O-1/2A fans being supplied to the fleet have solid state motor start/disconnect switches and sealed insulation motor windings. Older models, having the centrifugal switch, are being modified to incorporate the features of the new models. Both fans have explosionproof motors and casing switch boxes, permanently attached 50-foot, 3-wire grounding type electrical power cables and plugs, and low voltage starting capability with thermal protection. The fans are provided with a cast aluminum screened bellmouth and adapters to fit the standard 8-inch and 10-inch diameter ventilation hose. When the ventilation hose is connected to the fan outlet, the screened bellmouth is placed on the fan inlet and an adapter screen is placed on the outlet end of the ventilation hose. When the ventilation hose is connected to the fan inlet, the screened bellmouth is removed and placed on the fan outlet, and an adapter screen is placed on the inlet end of the ventilation hose. The screened bellmouth is removed during transportation to avoid damage.

512-2.1.6.2 Class O-3/4T portable ventilating sets (type O fans also) are a version of the centrifugal fan. Like the class O-1/2A or D fans, these fans, ventilation hose, and adapters are of nonsparking construction to avoid sparks when contacted by other metallic surfaces. They are driven by an air-turbine which uses ships service 80 psi compressed air at a rate of 60 scfm to attain the fan’s rated design point. The fans are provided with inlet and outlet connections that provide an exact fit for connecting standard 8-inch diameter ventilation hose. They are furnished with the following accessories:

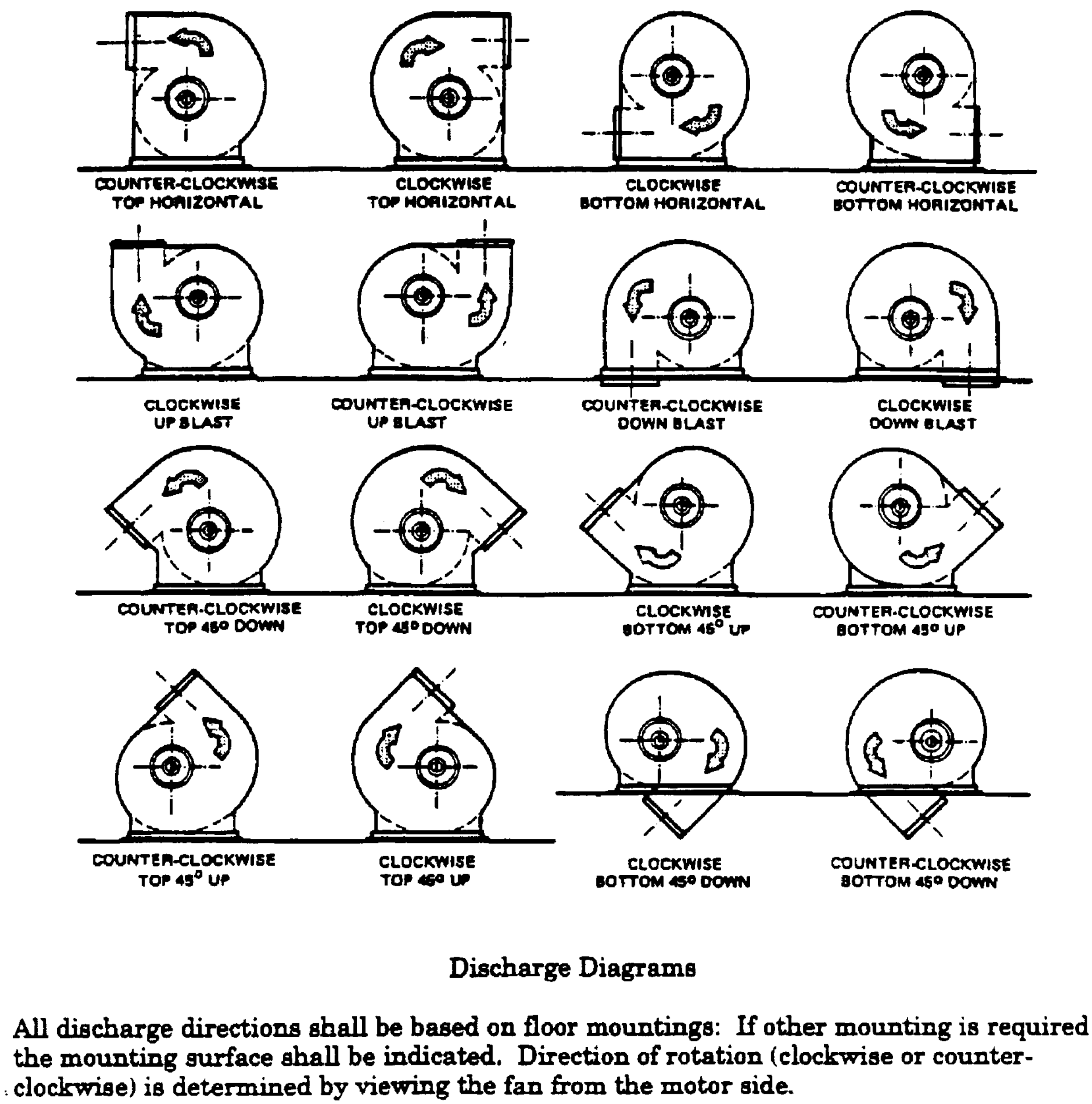


Figure 512-2-1 Centrifugal Fan Discharge Diagrams

- 10-inch diameter hose adapters - to connect the standard 10-inch diameter ventilation hose to either the fan inlet or outlet.
- Compressed air hose adapters - to adapt the 1/2-inch compressed air connection on the fan to a 5/8-inch standard female threaded hose connection (standard on shipboard compressed air hose).
- Screens - to prevent injury to personnel and damage to equipment.

512-2.1.7 SPECIAL APPLICATION FANS. A general description of the two special application fans, radar wave-guide pressurization fans and avionics shop fans, is presented separately in the following paragraphs 512-2.1.7.1 and 512-2.1.7.2, respectively.

512-2.1.7.1 The NAVSEA approved radar wave-guide pressurization fan consists of a scroll-shaped housing, an electric motor, and a circular open type fan wheel having straight blades. The housing is directly attached to the motor face plate. The fan wheel is mounted on the motor shaft extension inside the fan housing.

512-2.1.7.2 The NAVSEA approved avionics shop fan is of the blower class of centrifugal fan. It consists of a narrow scroll-shaped fan housing typically having a noticeable progressively expanding circular volute, a narrow cylindrical-shaped enclosed-end suction type fan wheel having straight blades, and an electric motor with a motor support base. The fan housing is bolted to the motor support base and the fan wheel is mounted on the motor shaft extension inside the fan housing.

512-2.2 PERFORMANCE CHARACTERISTICS

512-2.2.1 GENERAL. Fan performance is described in terms of performance characteristic curves which include airflow delivery volume (cfm), fan wheel speed (rpm), power consumption (bhp), total pressure (inches wg), total efficiency, and sound level (decibels). These curves are established from laboratory testing for each type and size of fan approved for Navy shipboard use. Typical performance characteristic curves of a Navy standard vaneaxial fan (size A3) are delineated in Figure 512-2-2. When properly applied at a specific fan wheel speed, they indicate the fan's airflow delivery volume, total efficiency, power consumption, and sound level at the fan-duct system's volume-pressure operating point. Navy standard fan pressure curves show total pressure instead of static pressure, which is common for commercial fans. Total pressure is the true indication of all of the energy (kinetic and potential) imparted by the fan to its airflow delivery volume. The kinetic energy in a unit volume of air is attributable to the density and velocity of the airstream and is represented by velocity pressure. The potential energy in a unit volume of air is attributable to the density and degree of compression of the airstream and is represented by static pressure. Representation or evaluation of fan performance characteristics based upon something other than total pressure is incomplete for Navy application. Complete fan performance characteristic curves (such as Figure 512-2-2) which delineate fan performance from free airflow delivery volume to shutoff (no airflow delivery volume) are available from the fan manufacturer for Navy standard fans and NAVSEA-approved special application fans. Navy HVAC system design is based on Navy standard fan performance data and curves (see paragraph 512-2.2.11), not on a specific manufacturers' fan performance data or curves, to ensure satisfactory HVAC system performance regardless of which manufacturers' fan is used. Navy standard fan performance data and total pressure-volume performance curves from fan nominal rated airflow delivery volumes to free airflow delivery volumes are provided in the following paragraphs 512-2.1.1 to 512-2.2.8.2 inclusive.

512-2.2.2 REGULAR VANEAXIAL FANS. Navy standard vaneaxial fans (type A fans) have a rising total pressure-volume performance characteristic curve (see Figure 512-2-2). The curve rises from the fan's free airflow delivery volume to the fan's peak total pressure point which occurs at an airflow volume of about 50 percent of the fan's free airflow delivery volume. The curve then exhibits a dip in total pressure to the left of the fan's peak total pressure point due to aerodynamic stall. Aerodynamic stall is briefly discussed in the fan sizing section (see paragraph 512-2.2.11). Aerodynamic stall is an inherent vaneaxial fan operational problem as fan operation under the aerodynamic stall condition is unstable. Consequently aerodynamic stall is not permissible. Maximum efficiency for vaneaxial fans occurs at about 65 percent of free airflow delivery volume (slightly to the right of peak pressure). Maximum power consumption usually occurs at about 75 percent of free airflow delivery volume, but it can also occur at shutoff. Figure 512-2-3 shows the family of performance curves for Navy standard vaneaxial type A fans.

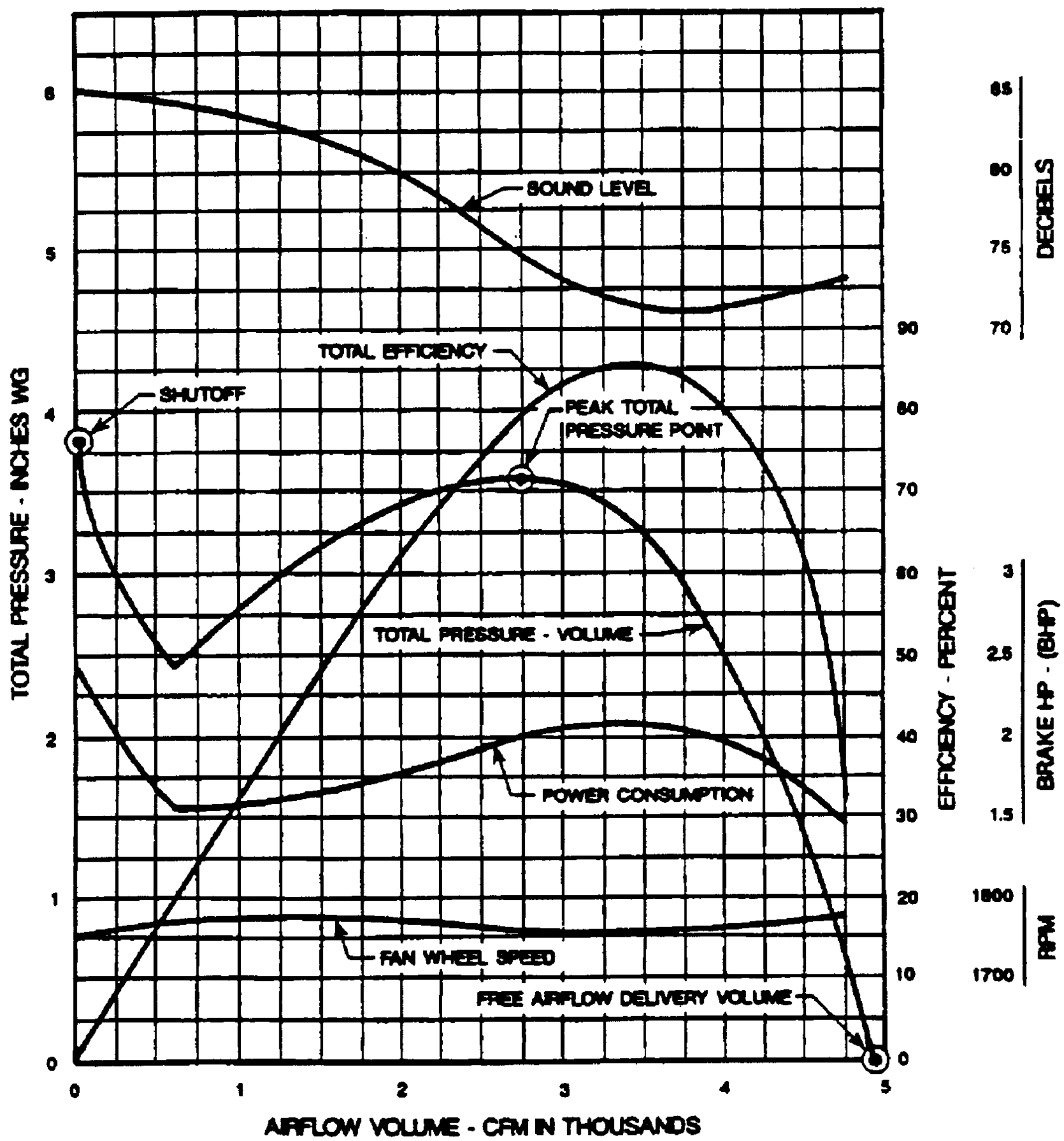


Figure 512-2-2 Typical Performance Characteristic Curves of a Navy Standard Vaneaxial Fan (size A3)

512-2.2.3 HIGH-PRESSURE VANEAXIAL FANS. Navy standard high-pressure vaneaxial fans are capable of developing an airflow volume that corresponds to the specific airflow volume of CBR filter banks. Both fans and filter banks are designed for CPS systems having specific airflow volumes at total system pressures of 14 inches wg for systems having fully-loaded (dirty) CBR filter banks, and 12 inches wg for systems having clean CBR filters installed. Each fan also has a specific airflow volume for maximum effective stall requirements at these total system pressures (see Table 512-1-2). Unlike regular type A vaneaxial fans, high-pressure vaneaxial fans do not represent their performance characteristics in a curve form. Therefore it is critical that the performance characteristics of these fans satisfy the airflow volume requirements for proper fan performance.

512-2.2.4 GTM ENCLOSURE COOLING VANEAXIAL FANS. There are two classes of Navy standard GTM enclosure cooling type TA vaneaxial fans: propulsion and generator. Propulsion GTM enclosure cooling fans are available in two sizes, TA17 and TA22-1/2. Size TA17 has a rated volume-pressure capacity of 17,000 cfm at 20 inches wg. Size TA22-1/2 has a rated volume-pressure capacity of 21,200 cfm at 22 inches wg. Generator GTM enclosure cooling fans are also available in two sizes, TA5 and TA4-1/2. Size TA5 has a rated volume-pressure capacity of 5,000 cfm at 10 inches wg. Size TA4-1/2 has a rated volume-pressure capacity of 4,500 cfm at 18 inches wg. Figure 512-2-4 shows the family of performance curves for GTM enclosure cooling fans.

512-2.2.5 TUBEAXIAL FANS. Navy standard tubeaxial type L fans are constructed similar to Navy standard vaneaxial fans except that they do not have guide vanes and consequently have lower pressure capability and lower efficiency than vaneaxial fans. Figure 512-2-5 shows the family of performance curves for Navy standard tubeaxial type L fans.

512-2.2.6 CENTRIFUGAL FANS. Navy standard centrifugal type CC fans have a rising total pressure-volume performance characteristic curve from free airflow delivery volume nearly all the way to shutoff. Centrifugal fans having forward-curved fan wheel blades have a total pressure-volume performance characteristic curve, similar to regular Navy standard vaneaxial type A fans, that exhibits a dip in pressure to the left of the fan's peak total pressure point due to aerodynamic stall. For maximum efficiency and to avoid aerodynamic stall, these fans should be sized so that the duct system characteristic curve intersects the fan's total pressure-volume performance characteristic curve to the right of the fan's peak total pressure point. Centrifugal fans having backward-curved fan wheel blades are not so critical as to their point of operation, but should be sized to operate near their point of maximum efficiency. For both types of fan wheels peak fan efficiency and power consumption occur at about 60 to 75 percent of the fan's free airflow delivery volume. Figure 512-2-6 shows the family of performance curves for Navy standard centrifugal type CC fans.

512-2.2.7 PORTABLE VENTILATING SETS. There are two classes of Navy standard portable ventilating sets (type O fans), class O-1/2A or D, and class O-3/4T. Class O-1/2A or D fans are available in only one size having a rated volume-pressure capacity of 500 cfm at a minimum total pressure of 2.5 inches wg when connected to three lengths (totaling 45 feet) of standard 8-inch diameter ventilation hose. Class O-3/4T fans are also available in one size having a rated volume-pressure capacity of 750 cfm at a minimum total pressure of 3 inches wg when connected to three lengths (totaling 45 feet) of standard 8-inch ventilation hose.

512-2.2.8 SPECIAL APPLICATION FANS. General performance coverage of the two special application fans, radar wave-guide pressurization fans and avionics shop fans, is presented separately in the following paragraphs 512-2.2.8.1 and 512-2.2.8.2, respectively. Performance characteristics for these fans are specific to their special application and the fan manufacturers should be consulted.

512-2.2.8.1 Radar wave-guide pressurization fans are specifically designed to have performance characteristics for maximum efficiency in the movement of small airflow volumes up to approximately 250 cfm against total pressures up to approximately 7 inches wg. Figure 512-2-7 shows performance curves for radar wave-guide pressurization fans.

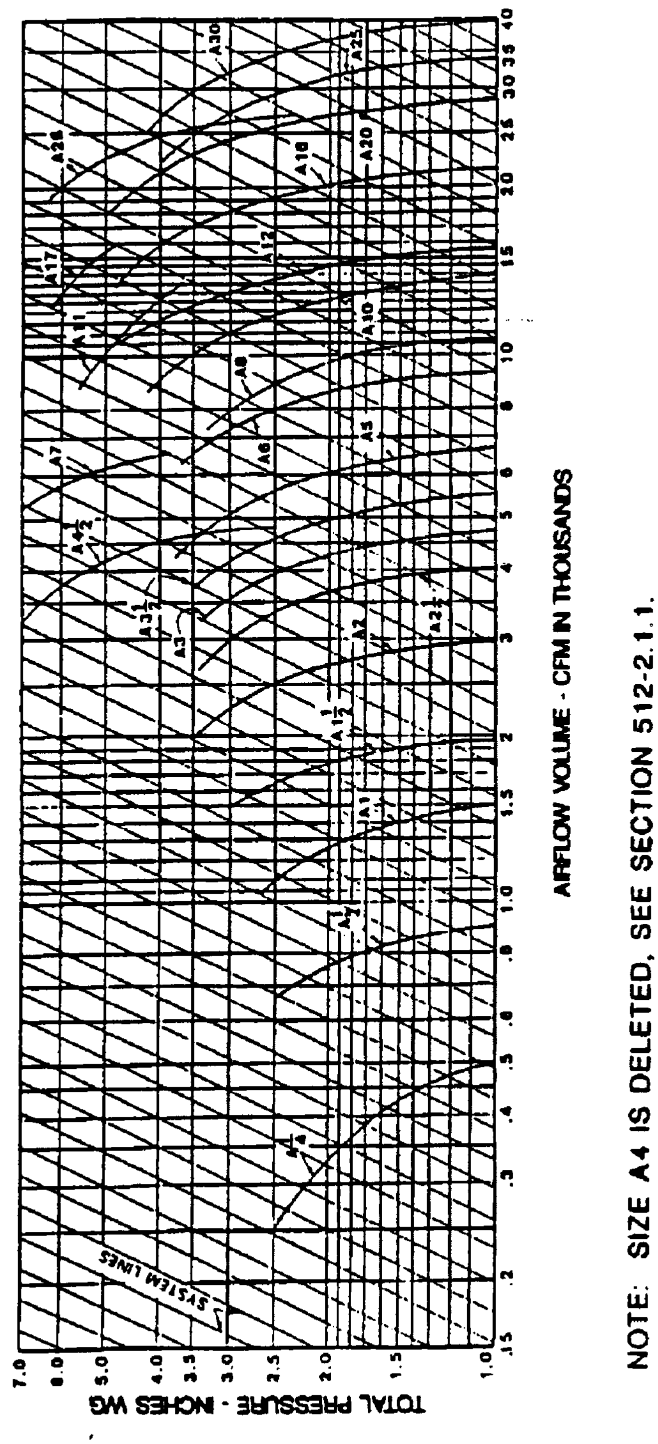


Figure 512-2-3 Vaneaxial Fan (type A) Performance Curves

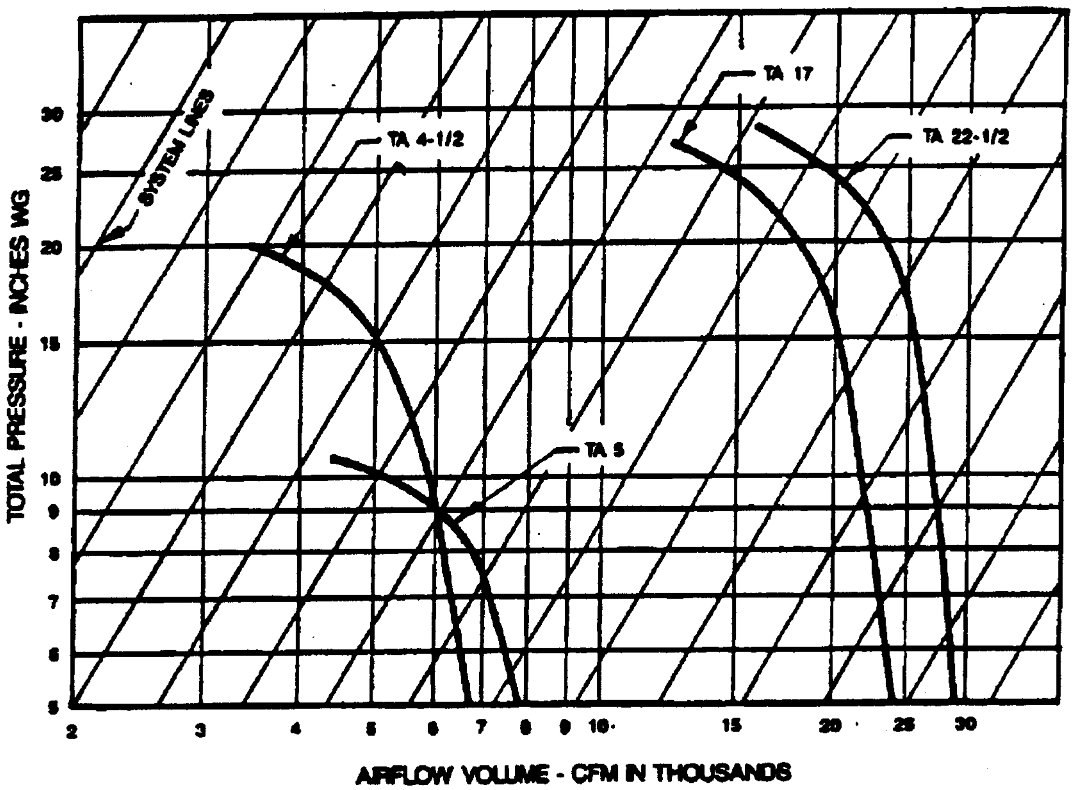


Figure 512-2-4 GTM Enclosure Cooling Vaneaxial Fan (type TA) Performance Curves

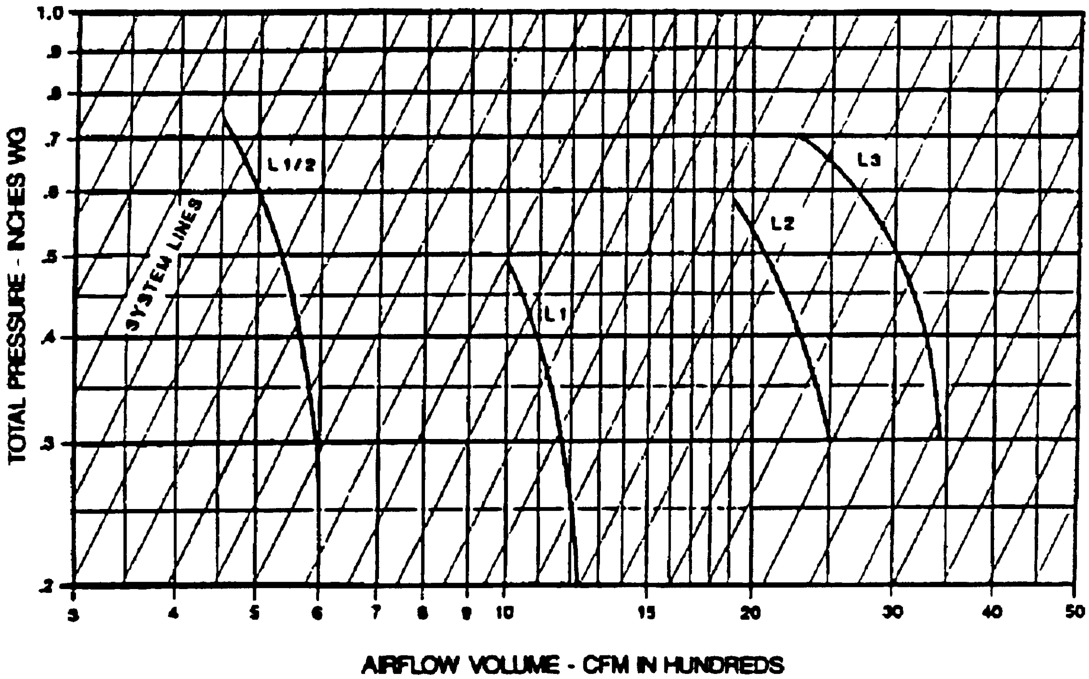


Figure 512-2-5 Tubeaxial Fan (type L) Performance Curves

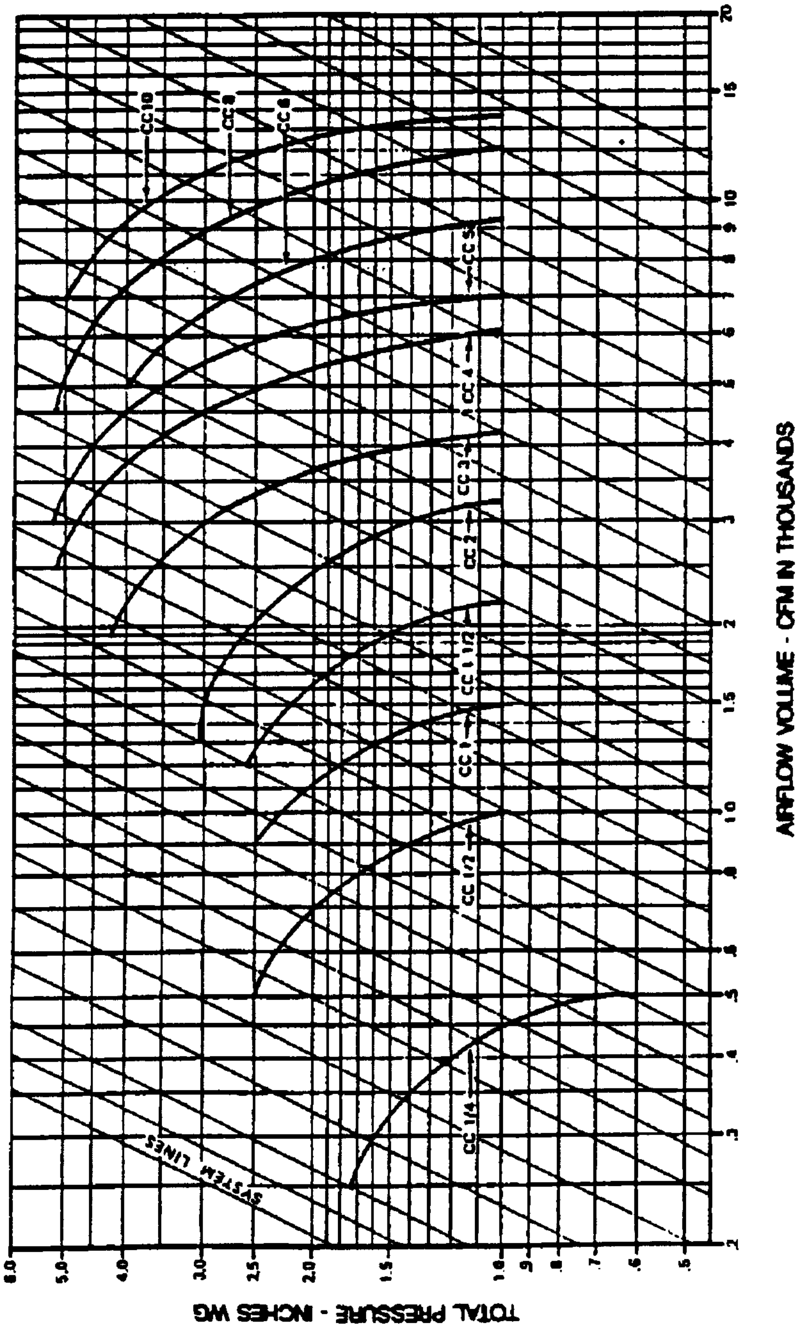


Figure 512-2-6 Centrifugal Fan (type CC) Performance Curves

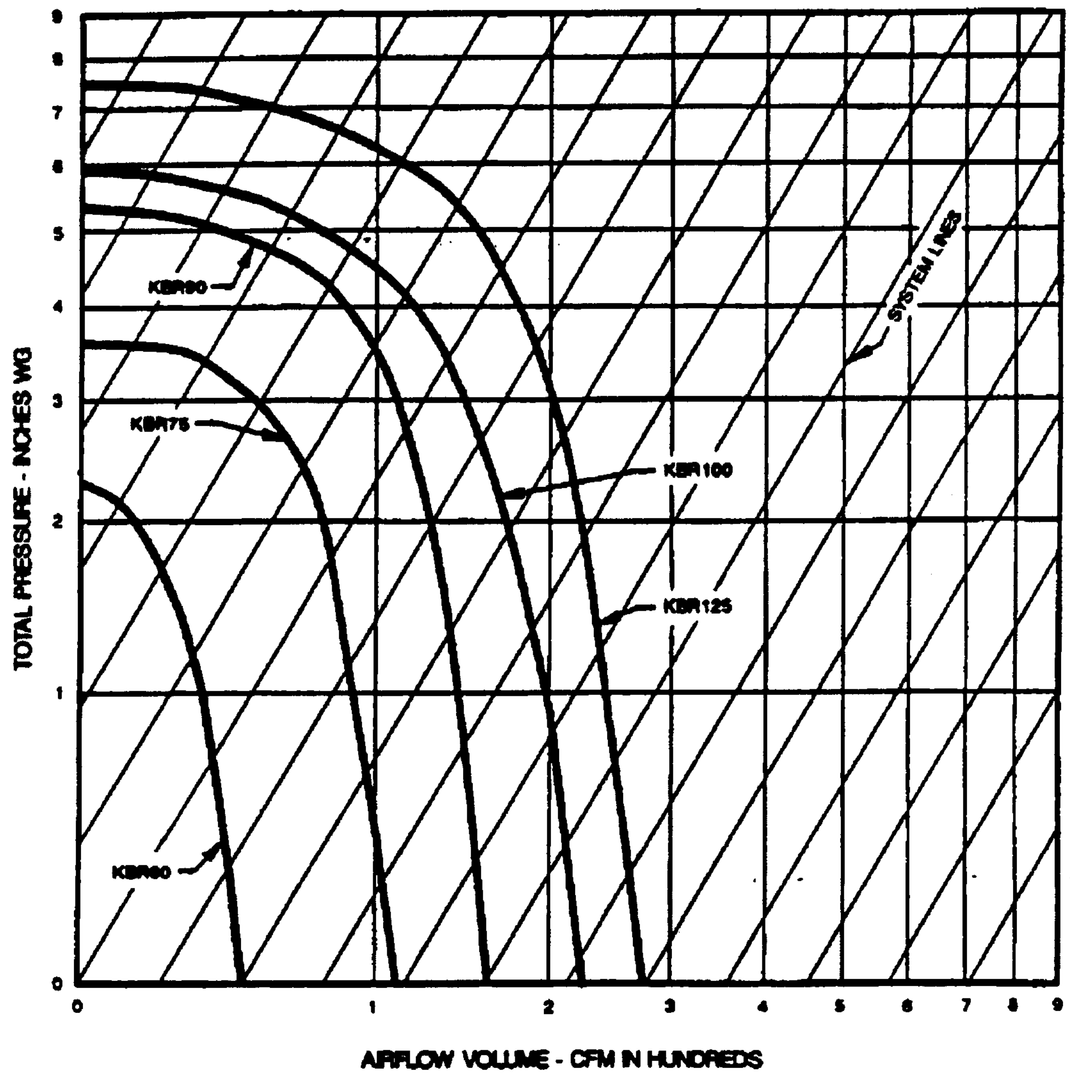


Figure 512-2-7 Radar Wave-guide Pressurization Fan Performance Curves

512-2.2.8.2 Avionics shop fans are available in two models, E and RE with various fan wheel sizes to satisfy airflow volume requirements from 50 to 10,000 cfm at total pressures up to 83 inches wg. The difference between the two models is that model E provides higher airflow volumes at lower total pressures and model RE provides lower airflow volumes at higher total pressures. Figure 512-2-8 shows typical performance curves for the largest size (size 8E) of avionics shop fans.

512-2.2.9 FAN AFFINITY LAWS. Where a change in fan capacity is desired or required for a given duct system, fan affinity laws governing fan performance based on fan wheel speed provide the means for determining the new requirements. At a new estimated fan wheel speed, the new operating point on the fan performance curve can be determined by the fan laws summarized in Table 512-2-1.

Table 512-2-1. FAN LAWS

Fan Law No.	Equation
1	$cfm_2 / cfm_1 = rpm_2 / rpm_1$
2	$tp_2 / tp_1 = (rpm_2 / rpm_1)^2$
3	$bhp_2 / bhp_1 = (rpm_2 / rpm_1)^3$

512-2.2.9.1 These fan laws are mathematical equations that express the relationships between fan performance variables for any series of fans that are geometrically similar. The performance variables include fan wheel speed (rpm), airflow volume (cfm), total pressure (tp), and power consumption (bhp). The first fan law states that fan airflow volume varies directly with fan wheel speed. The second fan law states that fan total pressure varies with the square of fan wheel speed. The third fan law states that fan power consumption varies with the cube of fan wheel speed. The fan laws apply only to a series of geometrically similar fans at the same point of rating on the performance curve. The fan laws can be used to predict the performance of any geometrically similar fan when the test data of a fan of the same series is available. Figure 512-2-9 illustrates the application of the fan laws for fan wheel speed change. Using the fan laws, curve PV2 can be computed from the base curve PV1. For example, point E (1300 rpm) is computed from point D (1200 rpm) as follows:

At point D, cfm = 6000 and tp = 4.5

Using fan law 1 at point E, cfm = 6000 x 1300/1200 = 6500

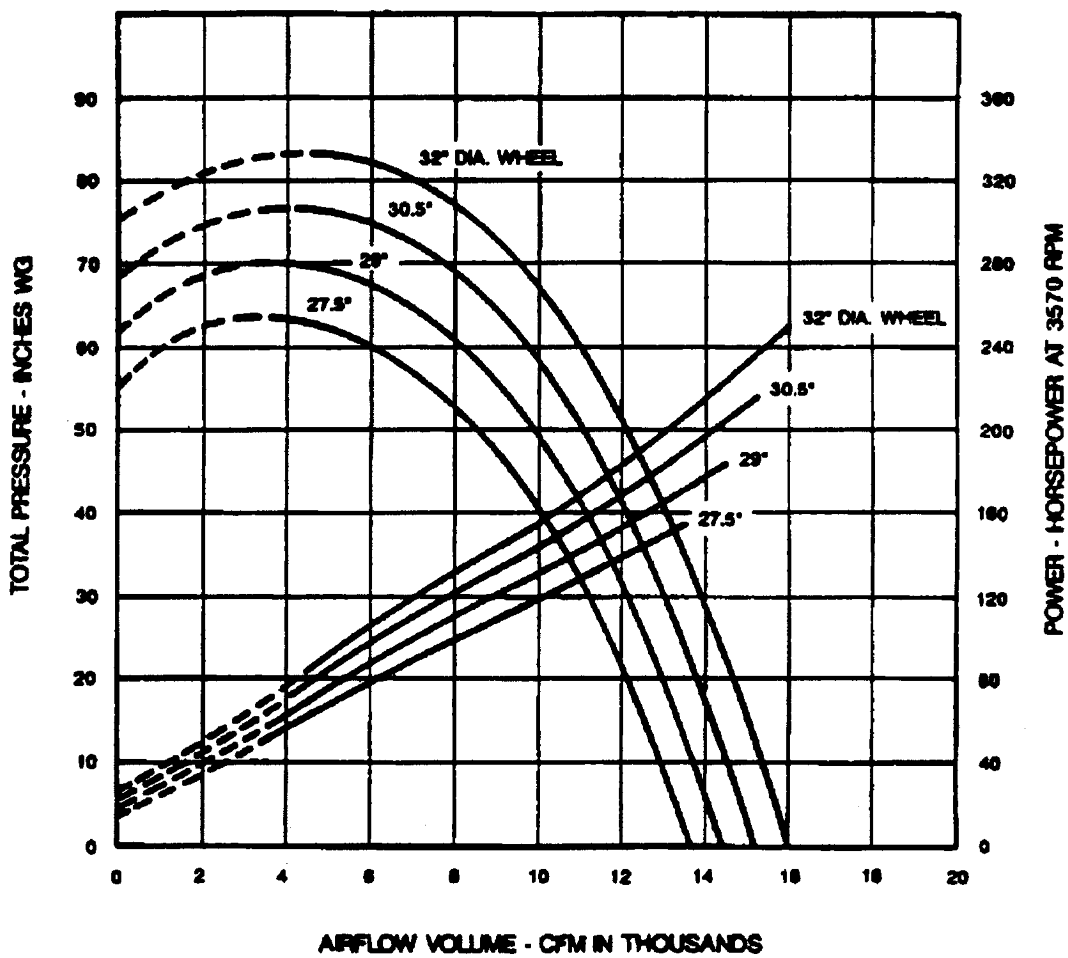
Using fan law 2 at point E, tp = 4.5 x (1300/1200) = 5.3

512-2.2.9.2 The complete fan performance curve PV2 can be generated by computing additional points from the base curve PV1 such as point G from point F. Each point of the base curve determines only one point on the computed curve. For example, point H cannot be calculated from either point D or F. Point H however is related to some point between these two points on the base curve, and only that point can be used to locate point H. Furthermore, point D cannot be used to calculate point F on the base curve. The fan laws cannot be used to calculate the base curve. Baseline fan performance can only be established by testing.

512-2.2.10 DUCT SYSTEM CHARACTERISTICS. Duct system characteristics, though largely independent of fan performance characteristics, have a direct impact on fan performance. Consequently, it is necessary to understand the nature of duct system characteristics which can be described by the statement, ″at a given airflow volume (cfm) through a particular duct system, the system has a specific total pressure (tp) associated with that airflow volume. If the airflow volume is changed, the total pressure will vary approximately as the square of the change in airflow volume.″ This relationship is expressed by the following equation:

$$tp_2 / tp_1 = (cfm_1 / cfm_2)^2$$

If the total pressure associated with a given airflow volume is known for a particular duct system, then the above relationship can be used to construct a duct system characteristic curve as shown graphically in Figure 512-2-10 for that particular system. For example, for a particular duct system it is known that an airflow of 10,000 cfm produces a total pressure of 3 inches wg (i.e., point A). Substituting these values into the equation above, point D and subsequent points are calculated, enabling the construction of curve A. If the duct system is modified such that its resistance is changed, then curve A is no longer applicable and a new curve is defined. In other words, if the duct system resistance is increased such that an airflow of 10,000 cfm produces a total pressure of 4 inches wg (i.e., point B), then curve B would be defined. Similarly, if the duct system resistance is reduced such that an airflow of 10,000 cfm produces a total pressure of 2 inches wg (i.e., point C), then curve C would be defined. It should be noted that duct system characteristic curves B and C shown in Figure 512-2-10 result from changes to the duct system itself and are independent of fan performance or operation. Duct system changes could be a result of design changes, an accumulation of dirt in the ductwork, orificing, misalignment of dampers or splitters, ductwork airflow leakage, or the presence of foreign objects in the ductwork.



Performance curves shown are for largest size (size 8E) blower. Performance curves for smaller blower sizes are available from fan manufacturer.

Figure 512-2-8 Typical Avionics Shop Fan Performance Curves

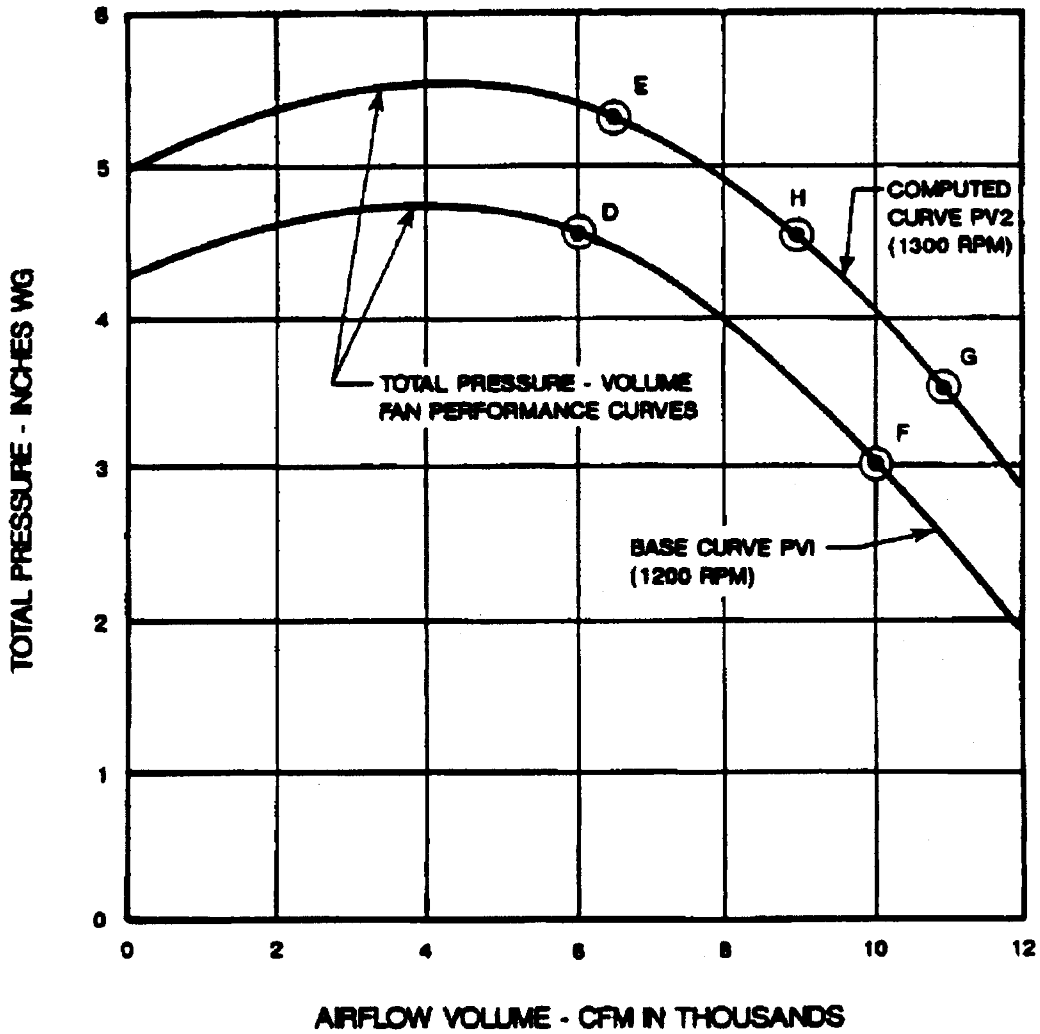


Figure 512-2-9 Effect of Fan Wheel Speed Change on Fan Performance Curve

512-2.2.11 DUCT SYSTEM EFFECTS ON FAN PERFORMANCE. Ductwork connected to the inlet and discharge of a fan have a significant impact on fan performance. Good inlet and discharge connected ductwork should provide uniform airflow without spin into the inlet of the fan and efficient pressure recovery on the discharge of the fan. Poor inlet connected ductwork can severely reduce fan performance, especially near free airflow volume delivery. An abrupt change in cross-sectional area (a converging taper not exceeding 15° is considered to have little effect) causes turbulence and non-uniform airflow at the fan inlet. A change in direction of airflow such as at an elbow, especially if it is not fitted with turning vanes, can cause the airflow to enter the fan with a spin. A spin in the same direction as the fan wheel rotation reduces the pressure-volume performance of a fan depending upon the amount of spin. A counter-rotating spin at the fan inlet slightly increases the pressure-volume performance of a fan but it also substantially increases the power consumption of the fan. Poor outlet connected ductwork, such as an abrupt change in cross-sectional area or change in direction within several duct diameters of the fan discharge, also seriously degrades fan performance by hindering pressure recovery in the fan outlet duct. For good pressure recovery, a uniform velocity profile should be established in the fan outlet duct as shown in Figure 512-2-11 before any changes in direction or cross-sectional area are made.

512-2.2.12 FAN SIZING CONSIDERATIONS. For best overall performance, fans should be sized so that they operate at maximum efficiency as shown in Figure 512-2-12. When operating at maximum efficiency, fans generate minimum noise (see Figure 512-2-12). Fan sizing should also include stable operation by eliminating aerodynamic stall. Aerodynamic stall is a fan operating condition that occurs when the fan reaches its peak total pressure point and further system pressure is imposed on the fan. This causes the fan to operate in the stall region of its performance curve. As shown in Figure 512-2-13, the fan's stall region is located to the left of the fan's peak total pressure point on the fan's performance curve. Fan operation in this region is accompanied by high noise, low efficiency, unpredictable airflow volume, excessive heat and vibration, and excessive total pressure and airflow pulsations. To prohibit fan sizing in the stall region, Navy standard fan performance curves include only the fans' stable operating ranges from their nominal rated airflow delivery volume to their approximate free airflow delivery volume. Another consideration regarding fan sizing for Navy application is that the number of available Navy standard fan sizes to select from is limited compared with commercial applications. In commercial applications, fan airflow delivery volume and total pressure can be tailored to suit a particular duct system by fan wheel speed control. For Navy applications, duct systems must be designed to suit the fan performance characteristics provided by the family of available Navy standard fans.

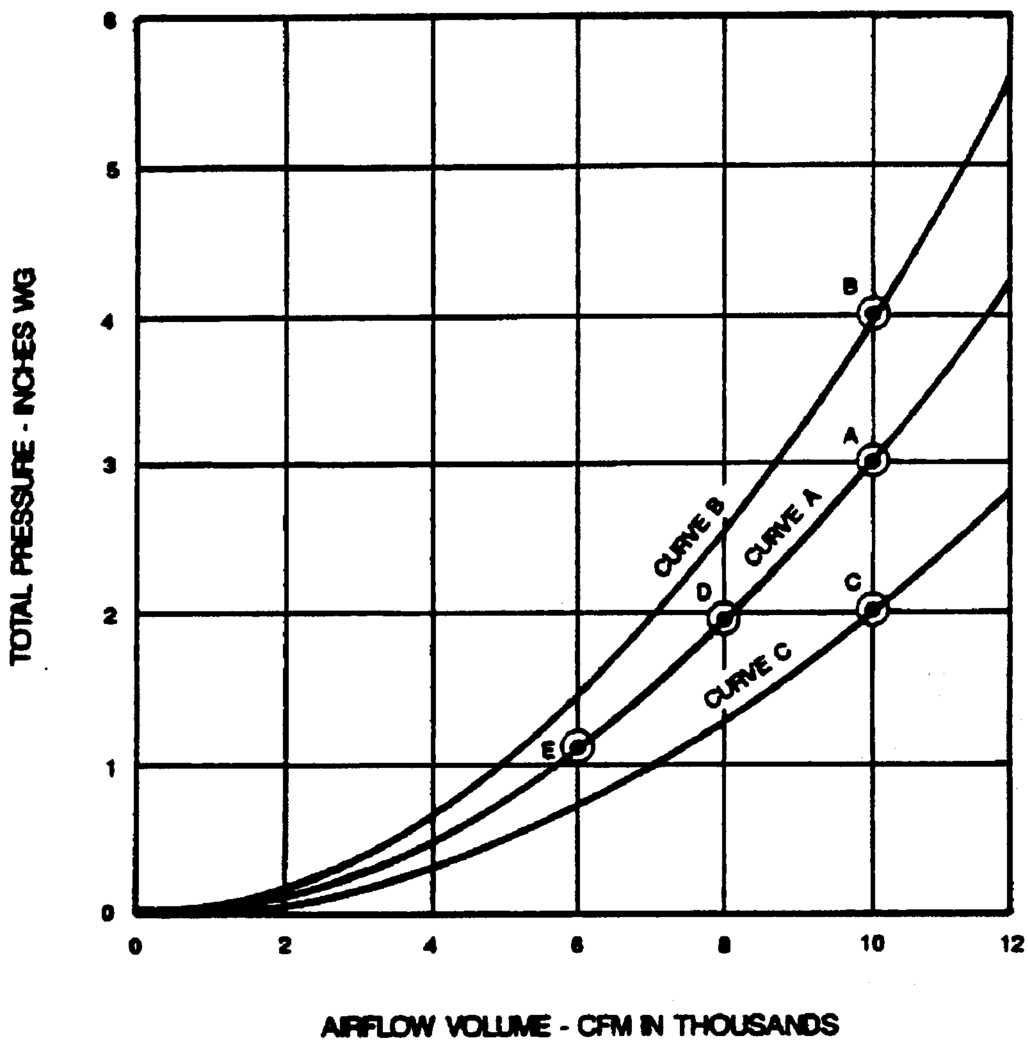
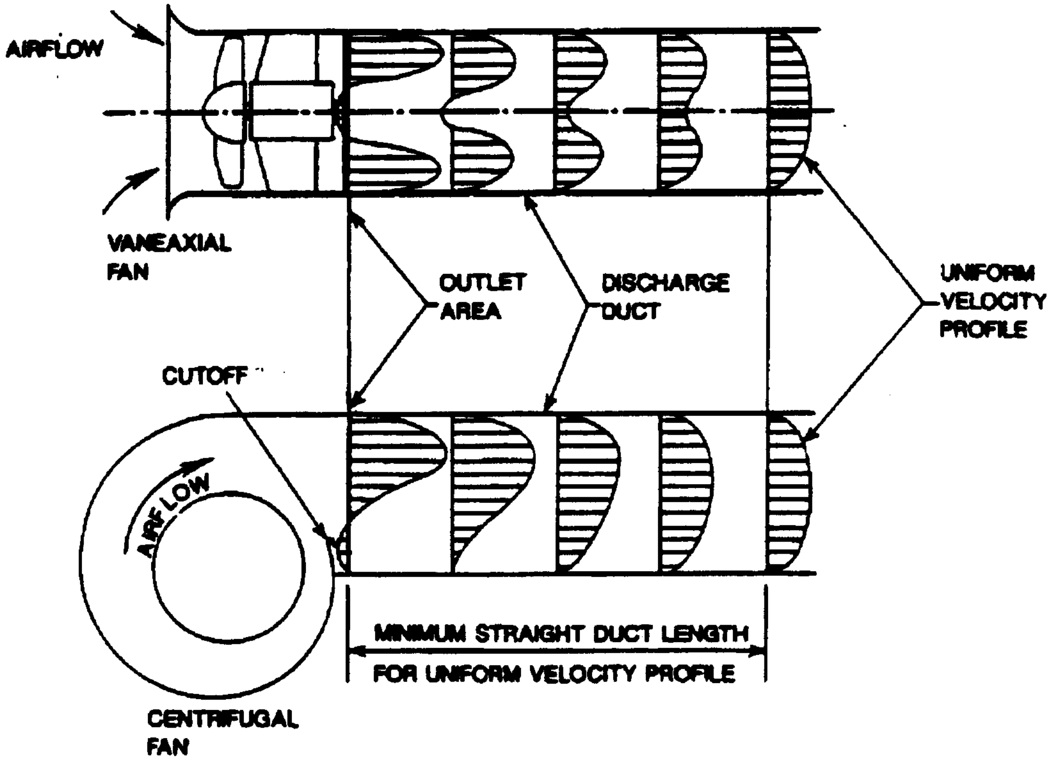


Figure 512-2-10 Duct System Characteristic Curves



Establishment of a uniform velocity profile in the fan outlet duct can be achieved with a straight length of duct at the fan outlet. The length of this duct is directly related to the fan discharge velocity and is determined as follows:

a. For fan discharge velocities of 2500 fpm or less, the minimum duct length should be 2.5 times the fan outlet duct diameter.*

b. For fan discharge velocities greater than 2500 fpm, add one duct diameter for each additional 1000 fpm.

For example, for a 3500 fpm fan discharge velocity, the minimum length of straight duct is 3.5 times the fan outlet duct diameter.

***The equivalent duct diameter of a rectangular duct with dimensions of h and w is $\sqrt{4hw/\pi}$.**

Figure 512-2-11 Establishment of Uniform Velocity Profile in Fan Outlet Duct

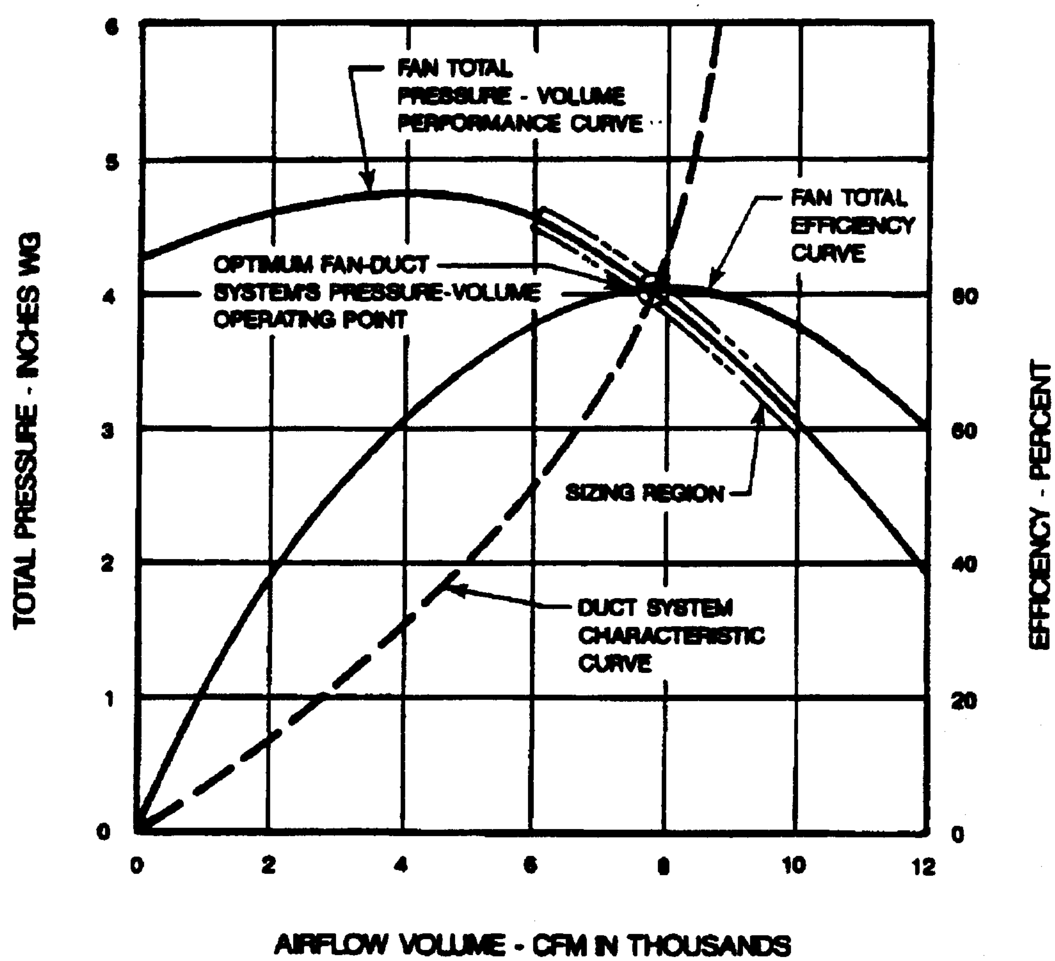
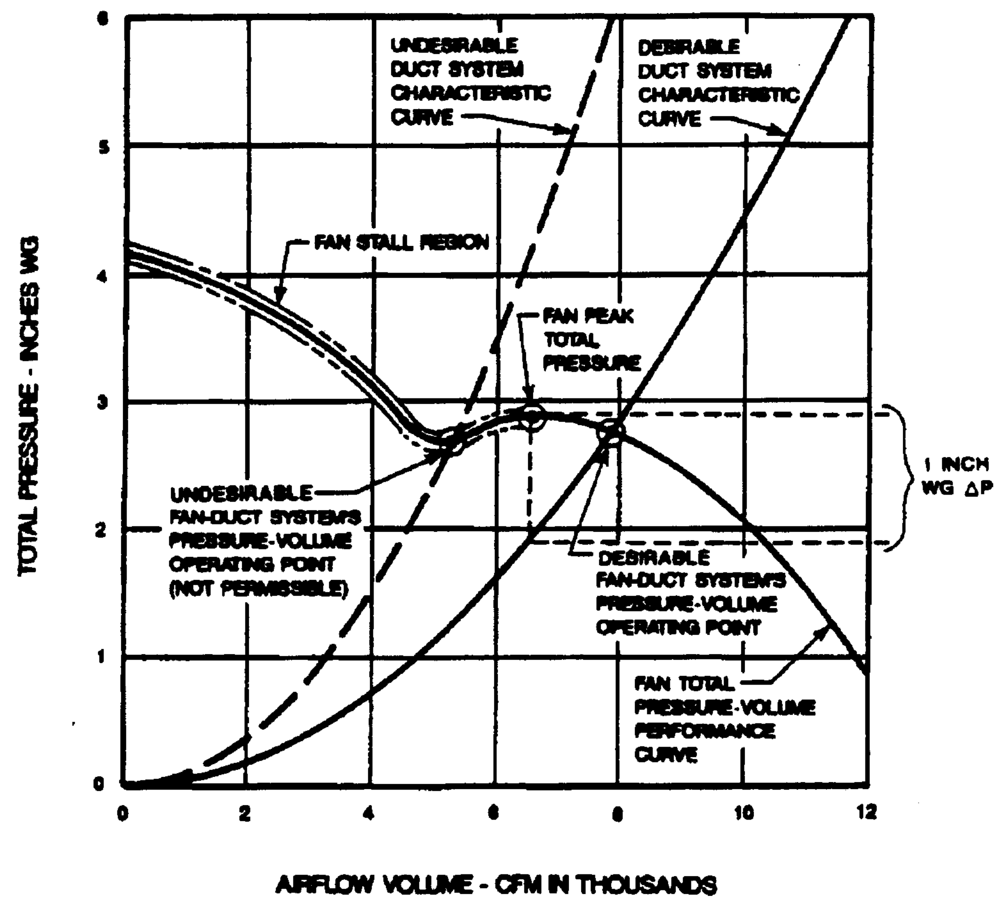


Figure 512-2-12 Optimum Fan Sizing



NOTE: THE DESIRABLE FAN-DUCT SYSTEM'S PRESSURE-VOLUME OPERATING POINT IS THE MAXIMUM PRESSURE AT WHICH THE FAN IS TO BE OPERATED. PERFORMANCE CURVES SUCH AS SHOWN IN FIGURE 512-15 ARE BASED ON THIS CRITERION.

Figure 512-2-13 Fan Stall Region on Fan Performance Curve

SECTION 3.

MAINTENANCE AND REPAIR

512-3.1 GENERAL

512-3.1.1 Recommended maintenance and repair practices included in this section are minimal for two reasons. First, they are intended to be typically applicable to Navy standard fans. Second, they are intended to be used to add to already established planned maintenance system (PMS) programs. Comprehensive maintenance and repair coverage used in PMS programs is provided in applicable maintenance requirement cards (MRC) such as:

MRC A46XBMN Inspect and operate motors being idle 30 days or more

MRC A46XBSN Inspect and clean dc motors

MRC A46XBVN Inspect and clean ac motors

MRC C5G16UN Inspect and resistantcheck motor windings

MRC C5W71NN Inspect fan mounts

MRC C5X51HN Inspect and clean fan housing and impeller (fan wheel)

MRC C5Y54LN Inspect ground straps

MRC 756XBDN Inspect and clean controllers

and specific maintenance coverage by technical manuals or publications such as:

NAVSHIPS 0941-LP-049-0010: Propulsion GTM enclosure cooling fan

NAVSHIPS 0961-LP-065-7010: Generator GTM enclosure cooling fan

Table 512-3-1 is a general operational trouble diagnosis guide typically applicable to Navy standard fans and is intended to be used in conjunction with maintenance prescribed herein.

512-3.2 MAINTENANCE PRACTICES

512-3.2.1 ROUTINE MAINTENANCE. The following practices, applicable to both axial and centrifugal fans, are considered to be within the capability of ships' force and should be conducted in conjunction with planned maintenance on a routine (time directed) basis as established by planned maintenance systems.

WARNING

When a fan is secured, its fan wheel may continue to rotate due to natural draft. Certify condition before using your hands.

a. Check fan wheel for freedom of rotation. After prolonged shutdown or after repairs, rotate the fan wheel manually to ensure freedom of rotation. Check fan installation for proper airflow direction through fan and for proper fan wheel rotation.

b. Check fan during start-up. When starting a fan, observe whether acceleration to full speed is rapid and without any unusual noise. Failure to accelerate rapidly is caused by mechanical interference or electrical deficiency, or both. Mechanical interference in axial fans is the result of reduced clearance between the fan wheel blade tips and the casing. Reduced clearance is caused by the casing being distorted, or having hardened deposits requiring wire brushing or light abrasive cleaning. The fan wheel blade tips of axial fans shall never be filed other than to remove burrs. In centrifugal fans, mechanical interference is the result of incorrect axial positioning of the fan wheel on the motor shaft or excessive shaft end play (clearance), or both. If the fan has a dc motor, inspect the motor to determine the degree of sparking between the commutator and the brushes and the usable length of the brushes. More frequent observation is required as brushes wear close to their minimum length. Periodic inspections should be made to conform with brush life experience on the ship. Dc motors used with Navy standard axial flow fans have transparent ports in their front bracket, and the fans also have corresponding transparent ports in their casing for inplace viewing of their brushes and commutator. Electrical deficiencies that cause slow acceleration are identified in following items c. and d. and Table 512-3-1.

Table 512-3-1. OPERATIONAL TROUBLE DIAGNOSIS GUIDE

Operational Trouble	**Cause**[1]	**Cure**[2]
Motor will not start	1. Electrical power circuitry open not supplying power to power contacts of fan contactor in fan controller.	Close electrical power circuitry (fuse, switch, breaker, or open wiring).
	2. Electrical control circuitry open not allowing control voltage to be applied to fan contactor operating coil in fan controller.	Close electrical control circuitry (fuse, manual reset switch, limit switch, or related system interlock).
	3. All motor windings open.	Remove and overhaul or replace motor.
Motor trips off electrically	1. Motor has locked rotor.	Eliminate mechanical interference (inadequate clearances between fan or motor components, or foreign object in fan or motor).
	2. Fan controller has overload heater coils that are deficient or are undersized (have too low a current rating), or tripping device is deficient.	Replace overload heater coils or tripping device.
	3. Electrical phase imbalance (excessive power circuitry resistance, or open or shorted motor windings).	Eliminate excessive power circuitry resistance, or overhaul or replace motor.
	4. Motor overheats	See items a, b, and c below.
	a. Electrical power supply voltage fluctuates, or is too high or low.	Provide corrected electrical power supply voltage.
	b. Motor overloaded (system resistance less than original design, or undersized motor).	Check for and correct alterations that would decrease system total resistance, or replace motor with larger motor.
	c. Insufficient airflow for motor cooling (system total resistance greater than original design, fan may be operating in the stall area of its performance curve).	Check orifices, dampers, and splitters and position properly. Check for and correct alterations that would increase system total resistance. Clean fan and duct system. If fault remains, check total system design.
Fan has excessive noise and rough operation	1. Reversed fan installation or rotation of fan wheel, or both.	Reverse fan installation to provide correct airflow direction through fan, or reverse any two motor electrical power connections at fan controller or motor terminal connection box for that speed to provide correct direction of rotation of fan wheel, or both.
	2. Dirty fan blades or fan interior, or both.	Clean fan blades and fan interior.

Table 512-3-1. OPERATIONAL TROUBLE DIAGNOSIS GUIDE -

Continued

Operational Trouble	Cause[1]	Cure[2]
	3. Worn or defective bearings or bearing housings, or both.	Check bearing housings and repair as necessary, and replace bearings.
	4. Loose fan wheel nut, or loose motor or fan mounting bolts, or both.	Tighten all hardware.
	5. Mechanical imbalance.	Check for bent motor shaft and straighten or replace. Balance motor rotor and fan wheel.
	6. Excessive system total resistance (see 4c under motor trips above).	Same as for 4c.
Fan has reversed airflow delivery	See 1 under excessive noise and range operation above	Same as for 1.
Fan has low airflow delivery	See 1, 2, and 6 under excessive noise and rough operation above.	Same as for 1, 2, and 6.

[1]**NSTM Chapters 300, Electric Plant General,** and **302, Electric Motors and Controllers,** for more detailed coverage of electrical deficiency and cure guidelines.

[2]**NSTM Chapter 244, Bearings** , for more detailed coverage of bearing trouble diagnosis and replacement guidelines.

c. Check fan motor winding resistance (see paragraph 512-3.2.2 item f). If a fan electrically trips offline or is slow in accelerating to full speed, check the motor electric power circuitry resistance for phase balance and grounding. If a fault is found, the motor should be tested for insulation resistance. If resistance is below 1.0 megohm for an ac motor or below 0.5 megohm for a dc motor, remove the motor and have it overhauled or replaced.

d. Check fan motor controller. Inspect electrical connections for tightness and electrical contacts in fan controller for pitting and wear (see **NSTM Chapter 302, Electric Motors and Controllers**). Inspect all heater coils installed in fan controller overload relays to verify that their current rating matches the motor full load current. Ships' records should indicate that heater coils in all fan controllers are the proper size. To confirm this, installed heater coils should be inspected and their current ratings verified. Fan motors are destroyed when faulty overload relays do not protect a motor from overload because of over-sized or faulty heater coils. Since ships' force does not have facilities for testing overload relays, a relay that is suspected of being deficient should be replaced and tested when shipyard or tender facilities are available. When an overload relay opens on a fault, the overload relay heater coils should be replaced since fault current can damage the heater coils, preventing proper operation on a future fault.

e. Check each operating fan for rough operation or unusual noise. These symptoms imply reversed fan installation (reversed direction of airflow through fan) or reversed rotation of fan wheel or both, a dirty fan or duct system, motor bearings in need of replacement, a loose fan wheel due to a loosened shaft nut, or a fan operating in the stall area of its performance curve, or any combination of the above. A recently overhauled fan may be out of balance.

f. Check fan interior and fan wheel for dirt and clean if dirty. When cleaning the fan wheel and the fan interior, use a rag moistened with a solution of water and detergent, NSN 7930-00-282-9699. For most cleaning operations 1/4 to 1/2 ounce of detergent in a gallon of water, preferably hot, is sufficient. Very heavy cleaning may require an ounce of detergent. If a duct is attached to the inlet of an axial fan, clean the fan interior through the access opening in the inlet duct, making sure that the fan wheel blades are cleaned thoroughly. The fan wheel of a centrifugal fan is cleaned through the access opening in the fan housing. Cleaning of the housing interior requires removal of the fan wheel (see paragraph 512-3.3.2). The importance of cleaning cannot be overemphasized, especially for vaneaxial fans where the high speed fan wheels are very sensitive to slight imbalance. Smoother operation, lower noise, and longer bearing life are characteristics of clean fans. Ships' force can play an important part in combating excessive noise by maintaining clean fans and duct systems, and by not obstructing the inlets of plenums and fans by using the free area around inlets as storage areas.

512-3.2.2 OVERHAUL MAINTENANCE. The following practices, applicable to both axial and centrifugal fans, should be conducted during each ship's overhaul period.

a. Check mounting bolts of all fans for tightness. Tighten if loose.

b. Check rubber-mounted fans for freedom of movement. Repair as necessary.

c. Check fan wheel (see paragraph 512-3.2.1 item a.). After prolonged shutdown or after repairs, rotate fan wheel manually to ensure freedom of rotation.

d. Check and clean fans if work was not done by ships' force (see paragraph 512-3.2.1 item f).

e. Check each controller and related fan and observe fan acceleration and operation (see paragraph 512-3.2.1 items b and d).

f. Check fan motor winding resistance. Test each fan motor in-place for insulation resistance by direct connection to loosened motor leads in the motor terminal connection box. If resistance is below 1.0 megohm for an ac motor or below 0.5 megohm for a dc motor, remove the entire fan and motor from the duct system and transport to the electric shop for overhaul. Motor overhaul consists of rewinding, dipping the winding in insulation varnish and baking, and bearing replacement. Motors are to be rewound using the manufacturer's specification as shown in the motor drawing. Whole sizes of round wire or standard rectangular wire, available from General Stores, are used for the windings of all Navy standard fan motors.

g. Check dc fan motors. On fans with dc motors, inspect commutator for circumferential surface grooves, loose commutator segments, and high mica between commutator segments. If faulty, take to the electric shop and make repairs. Replace worn brushes using brush grade and size as specified by the manufacturer's motor drawing.

h. Check the overload heater coils and trip device in each controller for tripping capability and tripping time. This will require disconnecting motor leads, and applying a load by means of a portable tester with variable resistance elements. If the overload heater coils of all fan motor controllers cannot be checked during an overhaul period, a record should be kept of those tested. Remaining heater coils plus any new heater coils installed in the interim should be checked during subsequent overhauls. This test procedure is especially applicable to vaneaxial fan motor controllers in view of the labor required to remove the fan from its duct system and transport it to the electric shop in the event of motor winding failure.

i. Check new or overhauled fans. If new or overhauled fans are installed during the overhaul period, check the fan installation for correct direction of airflow through the fan and for correct rotation of the fan wheel. Remove the lowest condensate drain plug from the fan motor in accordance with paragraph 512-1.5.3. Provide a ground connection in accordance with paragraph 512-1.5.2.

j. Check fan wheels for cracks. If a foreign object has passed through the blades or other damage is discovered when checking the cleanliness of the fan, inspect the fan wheels for cracks and repair or replace. The ends of axial fan blades shall never be filed to reduce the diameter or to remove sharp edges at the tip. Slight knicks in blade edges may be repaired by filing to remove burrs and blend the area with adjacent surfaces. Repainting is not advised unless extensive bare metal is observed. Slight contact of blade tips with the casing of an axial fan following painting is acceptable if due solely to paint and not to nonconcentrical fan wheel positioning, and if a locked rotor condition does not occur. After fan wheel repairs, balancing is required. On axial fans, balance is accomplished by removing metal from the fan wheel hub in the area indicated in the fan manufacturer's drawing.

512-3.2.3 REMOVAL AND REINSTALLATION. Removal and reinstallation practices included in this section are intended to be used as guidelines to supplement axial and centrifugal fan removal and reinstallation instructions provided in applicable MRCs and other manuals or publications used in PMS programs.

WARNING

Do not attempt to remove fans without accessing applicable mechanical and electrical documents for securing, removal, and reinstallation instructions. When a fan is secured its fan wheel may continue to rotate due to natural draft. This requires the fan motor to be ″electrically bumped,″ either forward or reversed, by the fan controller to completely stop fan wheel rotation. Certify that the fan wheel is not rotating and that all electrical power to fan and controller are secured before placing hands near the fan wheel.

CAUTION

If a vaneaxial fan is set down on its end, ensure that the fan wheel end is at the top to avoid possible damage to the nose piece.

a. Fan removal

1. With the fan operating, determine the direction of airflow through the fan and the direction of fan wheel rotation. Mark the directions on the duct adjacent to the fan. The direction of airflow through the fan can be determined at the fan intake or discharge. The direction of fan wheel rotation can be determined by viewing the fan from the fan intake/discharge or through the access opening in the fan while momentarily energizing the fan after it has been completely stopped. The direction of fan wheel rotation should be verified for all fan speeds to ensure that the fan has not been wired incorrectly. Airflow and rotation directions should be the same for all fan speeds and should also agree with the fan identification plate and fan/duct system label plates. Any discrepancies should be resolved prior to continuing with these instructions.
2. Turn the fan motor **OFF** at the fan controller and tag the controller out of service.
3. Turn the fan circuit breaker **OFF** at the main electrical power panel and tag the circuit breaker out of service.
4. Label the electrical motor and power line leads at the fan motor terminal connection conduit box, if they are not already labeled, and write down which leads are connected together to ensure correct reconnecting.
5. Disconnect all electrical power line lead connectors to the fan motor leads at the fan motor terminal connection conduit box and tag out of service.
6. Attach sufficient rigging for fan removal.

7. Provide a 1/2-inch flange alignment V-notch on the fan wheel end fan flange and its adjacent duct flange to facilitate correct fan orientation for reinstallation. Disconnect the fan from the duct system, by removing the flange nuts and bolts from around both inlet and outlet fan flange connections.
8. Move the fan away from the duct system and lower it to the deck. If the fan is a vaneaxial fan, be certain that the fan wheel end is at the top to avoid possible damage to the nose piece.

b. Fan reinstallation

1. Attach sufficient rigging for fan reinstallation and lift the fan into position between the duct flanges being certain that the fan wheel end flange is next to the duct flange alignment notch.
2. Align the flange alignment notches (if the same fan is used) and bolt holes with those of the adjacent duct system and connect the fan by installing both inlet and outlet fan flange connection gaskets (if used), bolts, and nuts.
3. Remove and stow the rigging.
4. Connect all electrical power line leads connections to the fan motor leads at the fan motor terminal connection conduit box and remove the out of service tag.
5. Turn the fan circuit breaker **ON** at the main electrical power panel and remove the out of service tag.
6. Remove the out of service tag from the fan controller. **Start** the fan, checking the direction of airflow through the fan and the direction of fan wheel rotation for each fan speed to verify that the fan was correctly installed and electrically connected. If a new fan is being installed, the fan wheel end shall be next to the 1/2-inch duct flange alignment V-notch and the direction of airflow through the fan shall be as shown on the duct adjacent to the fan. The correct direction of fan wheel rotation may be clockwise or counterclockwise depending upon the manufacturer and shall be in accordance with the fan label plate furnished by the fan manufacturer.

NOTE

If the correct direction of fan wheel rotation is uncertain for any reason, it may positively be determined by viewing the fan wheel blades from the fan wheel end of the fan. For axial fans the correct direction of fan wheel rotation is when the leading edge (edge closest to viewer) of the concave side of the blades cuts into the airstream. For centrifugal fans correct direction of fan wheel rotation is in the same direction as the fan scroll-shaped housing volute spiral. Incorrect fan wheel rotation for a given fan speed can be corrected by reversing any two electrical power line leads to the fan motor leads for that speed.

512-3.3 REPAIR PRACTICES

512-3.3.1 AXIAL FANS. Repairs, except for cleaning fans, will require removal of the entire fan from the duct system. The entire fan is transported to the electric shop with motor intact.

CAUTION

If a fan is set down on its end, ensure that the fan wheel end is at the top to avoid possible damage to the nose piece.

a. Disassembly.

1. If the fan wheel is a one piece casting, remove the shaft locknut and shaft lockwasher, or the castellated nut and cotter pin.
2. If the fan wheel has a separate nose piece, remove the screws around the periphery of the nose piece, then remove the shaft locknut.
3. Remove the fan wheel, exposing the heads of the motor mounting screws.
4. Disconnect the electrical motor leads and conduit from the fan casing (see following NOTE).

NOTE

The conduit arrangement and the sequence of installation varies with different fans (see the manufacturer's fan drawing for proper arrangement).

5. If there are rod supports for the motor, stand the fan on its inlet flange being careful that there are no loose bolts or debris under the fan which could cause a problem or damage. Remove the external nuts on the outside casing end of each rod. Back off the internal nuts at the motor end (if provided, see following NOTE) and at the casing end of each rod, then unscrew the rods from the motor frame, and remove the rods with their hardware from the discharge end of the fan casing.

NOTE

Some fans have nuts on the motor end of the rods. Some fans also utilize a band of vibration isolation material cemented around the motor frame periphery for a secondary mounting (see the manufacturer's fan drawing for proper arrangement).

6. Turn the fan on its outlet flange end with the inlet (fan wheel) end up. Place blocking under the motor to prevent it from dropping when the motor face mounting screws are removed.
7. Remove the motor face mounting screws, taking care that the motor is adequately blocked, then lift off the fan casing exposing the motor.
8. Make necessary motor repairs (see **NSTM Chapter 302, Electric Motors and Controllers** for general motor and controller repair requirements). It is imperative that the manufacturer's motor drawing be on hand if the motor is to be rewound. Each ship's force should ensure that the applicable drawing for each installed fan motor is available in ship's files.

b. Reassembly.

1. Block the motor on its end with its shaft end up.
2. Back off the inner nut on the casing end of the conduit, insert the motor leads into the conduit, then screw the conduit into the motor boss and tighten the inner nut against the casing (see note in step 11).
3. Place the serrated gasket on the motor face with the mounting holes aligned.
4. Carefully lower the fan casing vertically, ensuring that the edge of the gasket bends around the motor face rabbet (to vibrationally isolate motor from the fan casing).
5. Insert a bushing into each motor mounting hole.
6. Assemble a split lockwasher, a flat washer, and a vibration isolation washer onto each motor mounting screw. Insert screws in mounting holes and tighten.
7. Install the fan wheel on the motor shaft, pressing it on carefully to avoid damage to motor bearings. Use no hammers for heavy hitting as this will damage motor bearings. It is acceptable to heat the fan wheel to 250°F, but this will not be necessary if the shaft is in good condition since there is a 1/2-mil loose fit. If the fan wheel has a separate nose piece, do not install the nose piece at this time.

8. Check clearance between the blade tips and the casing to ensure that the fan wheel is centered. This is accomplished using the following procedure.

   (a) **Blade tip clearance measurement procedure:** The fan blades shall be in stationary position for the entire measurement. Inspect by eyes to locate an apparent maximum clearance (radial clearance) from the blade tip to the inside of fan casing. Measure this apparent maximum clearance and move the measurement to three different locations at 90, 180, and 270 degrees relative to the apparent maximum clearance. Compare the four measurements to determine the true maximum blade tip clearance. This maximum clearance shall not exceed 1/4 of 1 percent of the casing inside diameter. If the fan wheel is not centered, remove the fan wheel and consult fan manufacturer's drawings for slightly repositioning the motor. After slightly repositioning the motor reinstall the fan wheel and repeat clearance checks. Each ship's force should ensure that the applicable drawing for each installed fan is available in ship's files.

9. Assemble the shaft locknut and lock washer, or the castellated nut and cotter pin. Install and tighten.

10. If there are rod supports for the motor, stand the fan on its inlet flange being careful that there are no loose bolts or debris under the fan which could damage the fan wheel. Assemble a nut, a lock washer, a flat washer, and a vibration washer on the fan casing end of each rod and a nut on the motor end of each rod (if originally provided, see following NOTE). Insert each rod from the end of the fan casing and screw it fully into the motor frame. Tighten each motor end nut (if provided) against the motor and tighten each casing end nut against the inside surface of the fan casing, being careful not to cock the motor and thus destroy the fan wheel tip clearance. Assemble a grommet, a vibration washer, a flat washer, and a lock washer on the outside casing end of each rod and secure with a nut.

NOTE

Some fans have nuts on the motor end of the rods. Some fans also utilize a band of vibration isolation material cemented around the motor frame periphery for a secondary mounting (see the manufacturer's fan drawing for proper arrangement).

11. Carefully align the conduit through the hole in the fan casing, and secure the conduit with a locknut inside the conduit box.

NOTE

The conduit arrangement and the sequence of installation varies with the different fans (see manufacturer's fan drawing for proper arrangement).

12. Install nose piece if the fan wheel has a separate nose piece.

13. Reinstall the ground connection (see paragraph 512-1.5.2) and remove lowest condensate drain plug (see paragraph 512-1.5.3).

512-3.3.2 CENTRIFUGAL FANS. Fan wheels are cleaned through the access opening in the fan housing. Cleaning of the fan housing interior requires removal of the fan wheel which is accomplished, if there is no inlet duct, by removing the two set screws in the fan wheel hub then removing the fan housing inlet assembly and pulling the fan wheel from the motor shaft. If the motor shaft extension in the fan housing hampers cleaning of the interior of the fan housing, or if motor repairs are required, the motor may be detached by removing its four mounting foot-bolts and disconnecting its electrical leads and conduit connections. If there is an inlet duct, the motor and fan wheel are removed without breaking the duct connections as follows:

a. Install blocking under the fan housing.

b. Remove the nuts (a multiple of eight) near the outside edge of the drive-side plate. These nuts are on bolts attached to the side of the fan housing.

c. Disconnect the motor electrical leads and conduit connections and remove the four base mounting bolts which secure the motor sub-base to the ship’s structure.

d. Withdraw intact as a unit, the motor sub-base, the motor, the drive-side plate, and the fan wheel. The fan housing interior is then cleaned through the drive-side plate access hole and the fan wheel is cleaned while intact with the motor shaft. If motor repairs are required, the components may be disassembled.

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.