Docket No. 1117

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ABYC Standard P-1, Recommended Practices For Exhaust Systems, 6/4/93

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ABYC®

Setting Standards for Safer Boating

P-1, Recommended Standards and Practices for Exhaust systems

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P-1 INSTALLATION OF EXHAUST SYSTEMS FOR PROPULSION AND AUXILIARY ENGINES

Based on ABYC's assessment of the state of existing technology and the problems associated with achieving the requirements of this standard, ABYC recommends compliance with this standard by August 1, 1994.

1.1 PURPOSE

These voluntary technical practices and engineering standards are guides for the design, installation and selection of materials of exhaust systems for marine engines.

*NOTE: **Some jurisdictions require noise abatement compliance. Exhaust system design should comply with the noise level limits.***

1.2 SCOPE

These voluntary technical practices and engineering standards apply to the exhaust systems of all boats equipped with inboard or stern drive engines or permanently installed auxiliary engines, from the exhaust outlet of the engine, or the turbocharger if used, through the terminus where the exhaust gases are discharged.

*EXCEPTION: **Stern drive installations which exhaust through the drive system.***

1.3 REFERENCES

1.3.1 SAE - Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096. (412)776-4841.

1.4 DEFINITIONS

Accessible - Capable of being reached for inspection, removal or maintenance without removal of permanent boat structure.

Dry Exhaust - A system in which exhaust gases are kept separate from the cooling medium and are discharged from the boat as gases.

Exhaust Riser - A section in the exhaust system which uses an elevation to prevent water from flowing back into the engine. (See Figures 2 and 3).

Exhaust System - A means by which exhaust gases discharged from the engine are conducted to an outboard terminus and released.

Flexible Section - A non-rigid section of an exhaust system installed to minimize the transmission of engine vibration and motion to an exhaust pipe and its supports, and to the hull terminus.

Readily Accessible - Capable of being reached quickly and safely for effective use under emergency conditions without the use of tools.

Silencer - An exhaust component designed for the purpose of noise attenuation.

Waterlift Exhaust - A wet exhaust system incorporating an accumulating chamber in which the cooling water collects before being expelled by exhaust gas pressure via a riser.

Wet Exhaust - A system in which water is mixed with the exhaust gases and discharged from the boat as a mixture of gases and water.

1.5 REQUIREMENTS - IN GENERAL

1.5.1 The exhaust system shall be gas-tight to the hull interior.

1.5.2 The exhaust system shall be designed so that the back pressure does not exceed that specified by the engine manufacturer.

1.5.3 If included in an exhaust system the installation of an exhaust silencer shall comply with all applicable sections of this standard.

1.5.4 All fittings, joints, clamps and supports of an exhaust system shall be accessible for inspection and repair.

1.5.5 A separate exhaust system shall be provided for each engine installation.

1.5.6 Exhaust system piping and components shall be independently supported to minimize failure from vibration, shock, expansion and contraction.

1.5.7 All supports, hangers, brackets or other fittings in contact with uncooled exhaust carriers shall be non-combustible and constructed so that the temperatures transmitted to the supporting materials will not cause combustion.

1.5.8 Protective guards, jacketing or covers shall be provided wherever persons or gear might come in contact with the exhaust system where the temperature exceeds 200°F (93°C). Engine maintenance or engine repair may make the temporary removal of this protection necessary.

1.5.9 The exhaust system shall be designed and installed to prevent cooling water, rain water or raw water from entering the engine through the exhaust system under all normal operating conditions. The exhaust system design shall consider the drop height of the manifold above the waterline and a provision for downward slope for the exhaust system.

1.5.10 No additional discharges other than cooling water may share the exhaust gas passage.

1.5.11 Exhaust systems shall be designed so that reverse operation cannot force water into the exhaust manifold of a non-operating auxiliary engine such as a generator.

1.5.12 Provision shall be made for draining all exhaust system components that can trap or retain exhaust cooling water, rain water, raw water or condensation, if the component can be damaged by freezing of the water or chemical action accelerated by the presence of the water when the system is out of service.

1.5.13 Exhaust System Integrity Test - Boats with an accommodation space(s) and gasoline engine(s) for propulsion, electrical generation or auxiliary equipment shall be tested from the exhaust terminus to the connection at the engine. The system shall evidence no leakage under testing checked at a minimum of five minutes after the application of a test pressure of 4 psi.

1.6 *MATERIALS*

1.6.1 Materials shall be selected from those listed in Table I.

1.6.2 Materials used in a marine engine exhaust system shall be resistant to saltwater corrosion, shall be galvanically compatible (see Table II: the closer in the table the more compatible, the further apart the less compatible) and shall be resistant to exhaust products.

NOTE: Diesel exhaust contains high sulfur content which produces sulfuric acid and will corrode certain copper alloys.

1.6.3 *Pipe Size* - Threaded pipe and fittings for the engine exhaust(s) should be at least schedule 80 pipe or equivalent.

1.7 *WET EXHAUST SYSTEMS (See Figures 1, 2 and 3)*

1.7.1 To minimize the backflow of gases from a gasoline engine(s) into the cockpit or boat interior, the exhaust terminus(i) shall be located in the proximity of the intersection of the hull side and transom:,

1.7.1.1 on the side of the boat, or

1.7.1.2 in the bottom of the boat, or

1.7.1.3 in the transom positioned as far outboard of the centerline as practicable.

1.7.2 An indicator shall be provided that is effective at all helm positions to indicate loss of exhaust system cooling water supply. This indicator shall be independent of the engine block temperature indicator(s).

1.7.3 A wet exhaust system shall have a continuous source of cooling water. The cooling water may be:

a. engine cooling water,
b. raw water from a heat exchanger,
c. raw water, or
d. a combination of these.

1.7.4 The introduction of additional cooling water shall not cause the system to exceed the engine manufacturer's back-pressure recommendations.

1.7.5 Hose used in wet exhaust systems shall comply with the performance requirements of SAE J2006 or UL 1129. All other exhaust system components shall meet the performance requirements of UL 1129.

1.7.6 The wet exhaust system shall be capable of conducting the gases and cooling water at all normal engine operating conditions without exceeding the temperature limitations of all exhaust system materials and the engine manufacturer's back-pressure limitations.

1.7.7 Water for cooling a non-water-jacketed exhaust shall be injected in a manner that minimizes the possibility of cooling water entering the engine through the exhaust manifold.

1.7.8 The section of the exhaust system extending from the engine manifold to the point of water injection shall be constructed the same as a dry exhaust system.

*EXCEPTION: **If the section is water jacketed.***

1.7.9 If a water diverting or by-pass system is used it shall be regulated by:

1.7.9.1 controlling the size or height of the plumbing, or

1.7.9.2 utilizing a valve to control the flow of by-passed water. Once the proper flow has been determined the valve shall be secured and labeled indicating that it is a cooling water valve and that its setting shall not be changed.

1.7.10 *Flexible Exhaust Hose Connections*

1.7.10.1 Every exhaust hose connection shall be secured with at least two clamps at each end to produce a secure, liquid and vapor tight joint.

1.7.10.2 Clamps used for this purpose shall be entirely of stainless steel metal. The bands shall be a minimum of 1/2 inch (12 mm) in width.

1.7.10.3 Clamps depending solely on spring tension shall not be used.

1.8 *WATERLIFT EXHAUST SYSTEMS (see Figure 5)*

1.8.1 The waterlift system may be used on boats if the engine (either main propulsion engine or auxiliary engine such as a generator) is very close to or below the heeled waterline. In this case the exhaust line must lead upward to a high point which minimizes the possibility of the inflow of raw water under the vessel's operating conditions, whether the engine is running or not.

*NOTE: **The engine's cooling raw water is discharged into the exhaust system to achieve cooling which permits the use of non-metallic hose leading downward to a waterlift chamber which must be at the low point of the system. The waterlift chamber may be of metal, plastic, fiberglass or synthetic rubber. The chamber is primarily to catch the water present in the exhaust system. From the chamber the cooling water is pushed up to and over the high point of the system by the exhaust gas pressure. The process makes the chamber an effective silencer.***

1.8.2 *Waterlift Chamber* - The total volumetric capacity of the accumulating waterlift chamber shall be sufficient to prevent engine cooling water from backing up into the cylinders through the exhaust valves during normal cranking, starting and stopping cycles and while the engine remains stopped.

1.8.2.1 The chamber inlet shall receive the exhaust hose connection from the engine. The inlet shall be higher than the normal operating water level in a chamber.

1.8.2.2 The discharge or outlet connection from the chamber shall pick up from, or very close to, the low point of the chamber so that most of the accumulated water will be evacuated by the pressure of the exhaust gas.

1.8.2.3 The chamber shall be fitted with an accessible drain at the low point of the chamber.

1.8.2.4 Minimum burst pressure for reinforced thermoset plastic (fiberglass) mufflers. Fiberglass waterlift mufflers shall be designed and manufactured to withstand the following test:

1.8.2.4.1 The muffler shall be sealed and immersed in water,

1.8.2.4.2 the internal pressure shall be increased at the rate of three pounds per square inch per second to a maximum pressure of (690 KpA) 100 pounds,

1.8.2.4.3 the muffler shall maintain that 100 pound pressure for three minutes.

*EXCEPTION: **Mufflers that exceed 1000 cubic inch internal volume designed for diesel installations only.***

1.8.3 The waterlift system shall be designed to prevent siphoning through the raw water pump when the engine is stopped. If this is accomplished through the use of a siphon break device it shall be installed at the top of a loop which shall rise high enough to assure that the high point where the siphon break device is installed will always be above the water level surrounding the boat. Depending on the design of the boat, the condition of its loading and the sea conditions encountered, this loop may be 30 to 45 cm (12 to 18 inches) above the waterline at repose. The loop shall be between the water pump outlet and the point of injection of cooling water into the exhaust system.

*NOTES: 1. **In auxiliary power in sailboats, it is best to locate the siphon break on the boat's centerline. If it cannot be on the centerline, additional height is required to keep the break above the waterline at the maximum expected heel and pitch.***

*2. **Some siphon break devices that are available require periodic maintenance to maintain their intended effectiveness. One problem encountered is the formation of salts or the products of corrosion which prevent the device from operating.***

1.8.4 *High Point in the System* - In boats characterized by extremes of roll and pitch the exhaust must lead as directly as practicable from the waterlift chamber to a high point in the piping, as near to the boat's centerline and as high as practicable to minimize the possibility of raw water flooding the exhaust during heavy weather when the engine is not running.

1.8.5 *Dry Exhaust Systems (see Figure 4)*

1.8.5.1 Vertical dry exhaust systems shall be designed and installed to arrest sparks.

1.8.5.2 If insulating material is used on a dry exhaust system to achieve the requirements of section P-1.5.8, the insulation shall be capable of withstanding the temperatures involved, without failure to perform as intended, and shall prevent the exposed surfaces from exceeding the temperature stated in P-1.5.8.

1.8.5.3 Metallic connections shall be flanged, threaded or welded.

1.8.5.4 Flexible exhaust sections, where used, shall be of seamless, stainless steel.

TABLE I - MATERIALS IN ALPHABETICAL ORDER

	GASOLINE ENGINES		*DIESEL ENGINES*	
Components	*Wet Exhaust*	*Dry Exhaust (11)*	*Wet Exhaust*	*Dry Exhaust*
Exhaust Pipe	Brass Pipe (6)	Aluminized Steel (11)	Copper -Nickel (4)	Aluminized Steel (11) (12)
	Copper-Nickel (4)	Carbon Steel (9)	Fiberglass (10)	Carbon Steel (9)
	Copper Tubing (7)	Nickel-Iron-Chrome (1)	Galvanized Steel	Nickel-Iron-Chrome (1)
	Enameled Steel	Nickel-Iron-Chrome (2)	Galvanized Wrought Iron (12)	Nickel-Iron-Chrome (2)
	Fiberglass (10)	Stainless Steel (8)	Nickel-Copper (3)	Stainless Steel (8)
	Galvanized Wrought Iron (12)		Nickel-Iron-Chrome (1)	
	Nickel-Copper (3)		Nickel-Iron-Chrome (2)	
	Nickel-Iron-Chrome (1)		Stainless Steel (8)	
	Nickel-Iron-Chrome (2)		Synth. Rubber Hose*(5)	
	Stainless Steel (8)			
	Synth. Rubber Hose*(5)			
Silencer Or (Wet Exhaust) Waterlift Chamber	Cast Iron	Aluminized Steel (11)	Cast Iron	Aluminized Steel (11)
	Copper	Carbon Steel (9)	Enameled Steel	Carbon Steel (9)
	Enameled Steel	Nickel-Iron-Chrome (1)	Fiberglass (10)	Nickel-Iron-Chrome (1)
	Fiberglass (10)	Nickel-Iron-Chrome (2)	Nickel-Copper (3)	Nickel-Iron-Chrome (2)
	Nickel-Copper (3)	Stainless Steel (8)	Nickel-Iron-Chrome (1)	Stainless Steel (8)
	Nickel-Iron-Chrome (1)		Nickel-Iron-Chrome (2)	
	Nickel-Iron-Chrome (2)		Reinforced Plastic (10)	
	Reinforced Plastic (10)		Stainless Steel (8)	
	Stainless Steel (8)		Synth. Rubber*(5)	
	Synth. Rubber*(5)			
Engine Flexible Section	Copper (7)	Carbon Steel (9)	Copper-Nickel (4)	Carbon Steel (9)
	Copper-Nickel (4)	Nickel-Iron-Chrome (1)	Nickel-Copper (3)	Nickel-Iron-Chrome (1)
	Nickel-Copper (3)	Nickel-Iron-Chrome (2)	Nickel-Iron-Chrome (1)	Nickel-Iron-Chrome (2)
	Nickel-Iron-Copper (1)	Stainless Steel (8)	Nickel-Iron-Chrome (2)	Stainless Steel (8)
	Nickel-Iron-Chrome (2)		Stainless Steel (8)	
	Stainless Steel (8)			
	Synth. Rubber Hose*(5)			
Pipe Connection	Synth. Rubber*(5)	Flanged, screwed or welded (12)	Synth. Rubber*(5)	Flanged, screwed or welded (12)
	Flanged, screwed or welded (12)		Flanged, screwed or welded (12)	

*This classification is for rubber-like flexible materials.

(1) 40. Ni., 21. Cr., 31. Fe., 3. Mo., 1.75 Cu., 0.60 Mn., 0.40 Si., 0.05 C.

(2) 29. Ni., 20. Cr., 44. Fe., 2. Mo. (min.), 3. Cu. (min.) 0.75 Mn., 1. Si., 0.07 C.

(3) 70. Ni., 30. C.

(4) 70. Cu., 30. Ni., 0.75 Fe. or 90. Cu., 10. Ni., 1.5 Fe.

(5) See ABYC P-1.7.10 "Flexible Hose Connections"

(6) 85. C., 15. Zn.

(7) Minimum recommended: Type M copper.

(8) Type 316 L (low carbon)

(9) For temperatures below 482°C (900°F).

(10) Shall meet the test criteria 94V-0 when tested in accordance with 8.20 mm of UL 94 "Tests for Flammability of Plastic Materials for Parts in Devices and Appliances".

(11) For temperature below 677°C (1250°F)

(12) Threaded pipe and fittings should be at least schedule 80 pipe or equivalent. See P-1.6.3.

TABLE II - GALVANIC SERIES OF METALS IN RAW WATER

(Raw water flowing at 8 to 13 ft./sec., temperature range 50°F (10°C) to 80°F (26.7°C) - except as noted)

NOTE: Metals and alloys are listed in the order of their potential in flowing raw water as determined in tests conducted by a nationally recognized corrosion research laboratory.

Metals and Alloys	Corrosion-Potential Range in Volts (Half-Cell Reference Electrode) Silver-Silver Chloride
(Anodic or Least Noble-Active)	
Magnesium and Magnesium Alloys	-1.60 to -1.63
Zinc	-0.98 to -1.03
Galvanized Steel or Galvanized Wrought Iron	NA
Aluminum Alloys	-0.76 to -1.00
Cadmium	-0.70 to -0.73
Mild Steel	-0.60 to -0.71
Wrought Iron	-0.60 to -0.71
Cast Iron	-0.60 to -0.71
13% Chromium Stainless Steel, Type 410 (active in still water)	-0.46 to -0.58
18-8 Stainless Steel, Type 304 (active in still water)	-0.46 to -0.58
Ni-Resist	-0.46 to -0.58
18.8,3% Mo Stainless Steel, Type 316 (active in still water)	-0.43 to -0.54
78% Ni - 14.5% Cr - 6% Fe (Inconel) (active in still water)	-0.35 to -0.46
Aluminum Bronze (92% Cu - 8% Al)	-0.31 to -0.42
Naval Brass (60% Cu - 39% Zn)	-0.30 to -0.40
Yellow Brass (56% Cu - 35% Zn)	-0.30 to -0.40
Red Brass (85% Cu - 15% Zn)	-0.30 to -0.40
Muntz Metal (60% Cu - 40% Zn)	-0.30 to -0.40
Tin	-0.31 to -0.33
Copper	-0.30 to -0.57
50-50 Lead - Tin Solder	-0.28 to -0.37
Admiralty Brass (71% Cu 28% Zn 1% Sn)	-0.28 to -0.36
Aluminum Brass (76% Cu 22% Zn 2% Al)	-0.28 to -0.36
Manganese Bronze (58.5% Cu 39% Zn 1% Sn 1% Fe 0.3 MN)	-0.27 to -0.34
Silicone Bronze (96% Cu Max, 0.80 Fe, 1.50 Zn, 2.00 Si, 0.75 MN, 1.60 Sn)	-0.26 to -0.29
Bronze-Composition G (88% Cu - 2% Zn - 10% Zn)	-0.24 to -0.31
Bronze-Comp. M (88% Cu - 3% Zn - 6.5% Sn - 1.5% Pb)	-0.24 to -0.31
13% Chromium Stainless Steel, Type 401 (passive)	-0.26 to -0.35
90% Cu - 10% Ni	-0.21 to -0.28
75% Cu - 20% Ni - 5% Zn	-0.19 to -0.25
Lead	-0.19 to -0.25
70% Cu - 30% Ni	-0.18 to -0.23
78% Ni - 13.5% Cr - 6% Fe (Inconel) (passive)	-0.14 to -0.17
Nickel 200	-0.10 to -0.20
18-8 Stainless Steel, Type 304 (passive)	-0.05 to -0.10
70% Ni - 30% Cu Monel 400, K-500	-0.04 to -0.14
18-8, 3% Mo Stainless Steel, Type 316 (passive)	-0.00 to -0.10
Titanium	-0.05 to -0.06
Hastelloy C	-0.03 to -0.08
Platinum	+0.19 to +0.25
Graphite	+0.20 to +0.30
(Cathodic or Most Noble - Passive)	

FIGURE 1 - TYPICAL WET EXHAUST SYSTEM

(ADEQUATE ENGINE HEIGHT ABOVE WATER LINE)

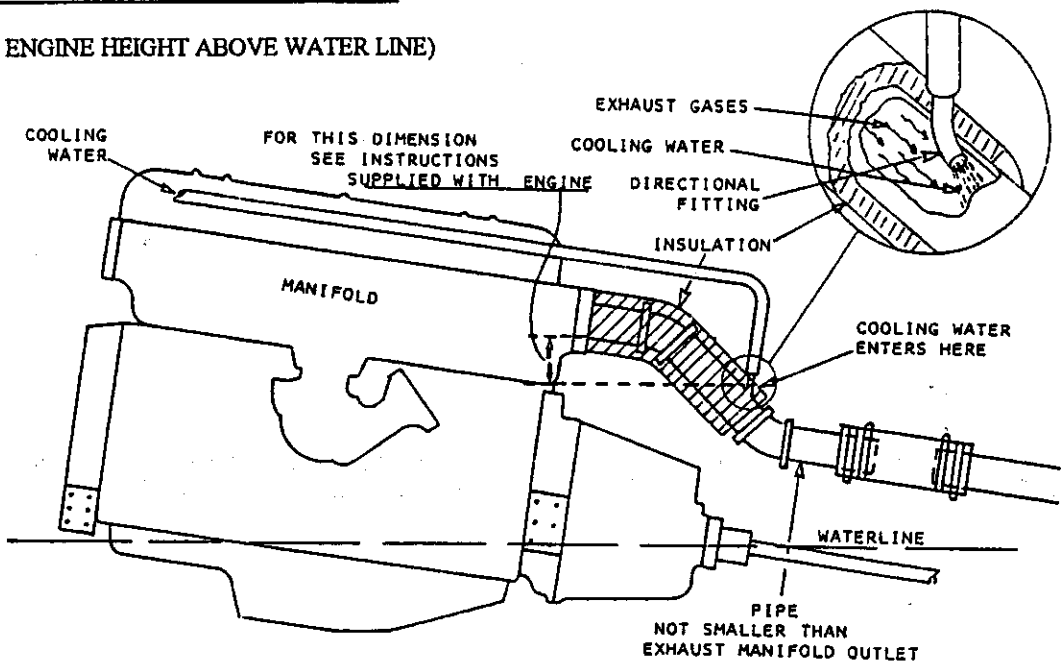


FIGURE 2 - TYPICAL RISER SYSTEM

(ENGINE LOCATED LOW IN REFERENCE TO WATERLINE)

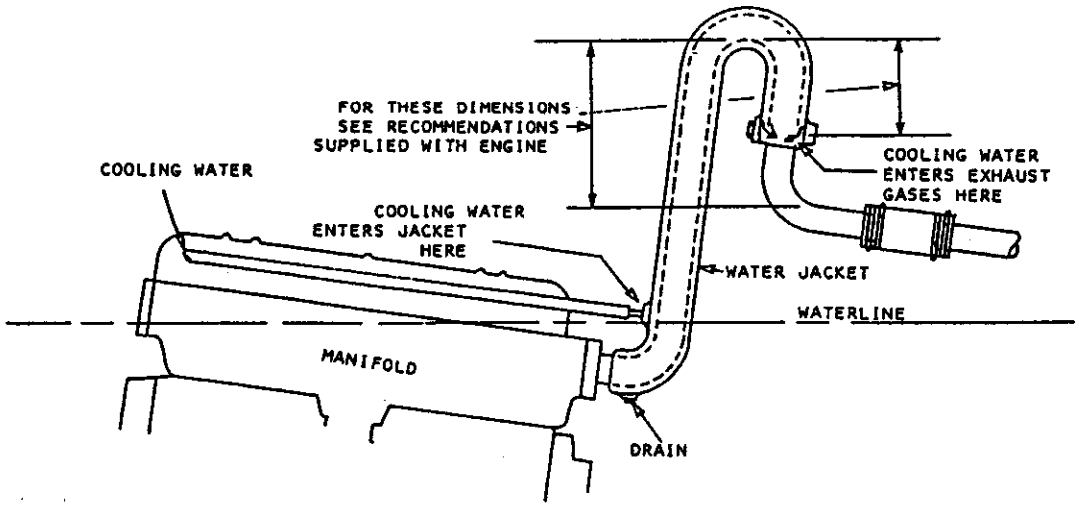


FIGURE 3 - TYPICAL EXHAUST RISER

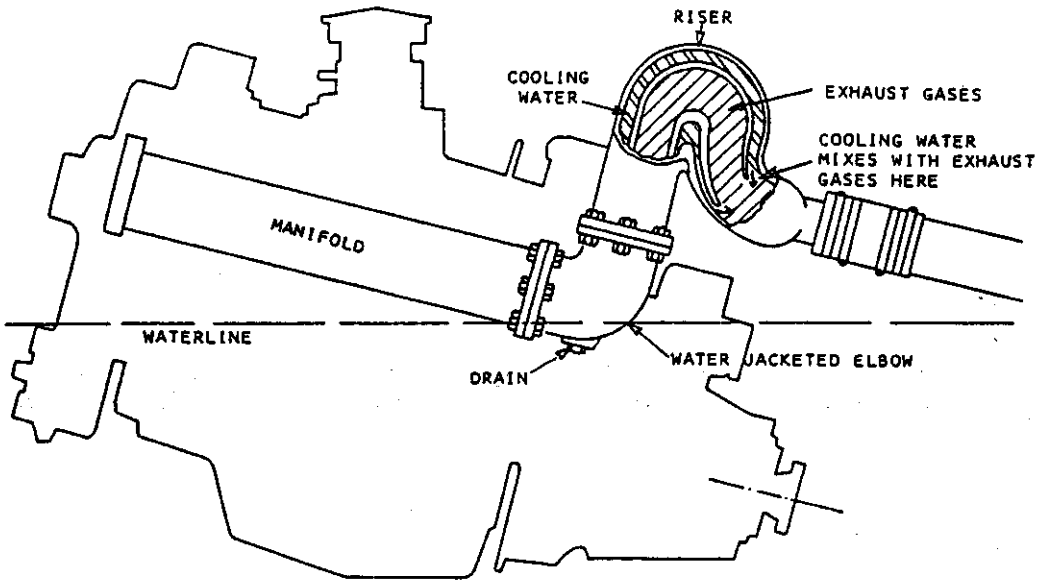


FIGURE 4 - TYPICAL DRY EXHAUST SYSTEM

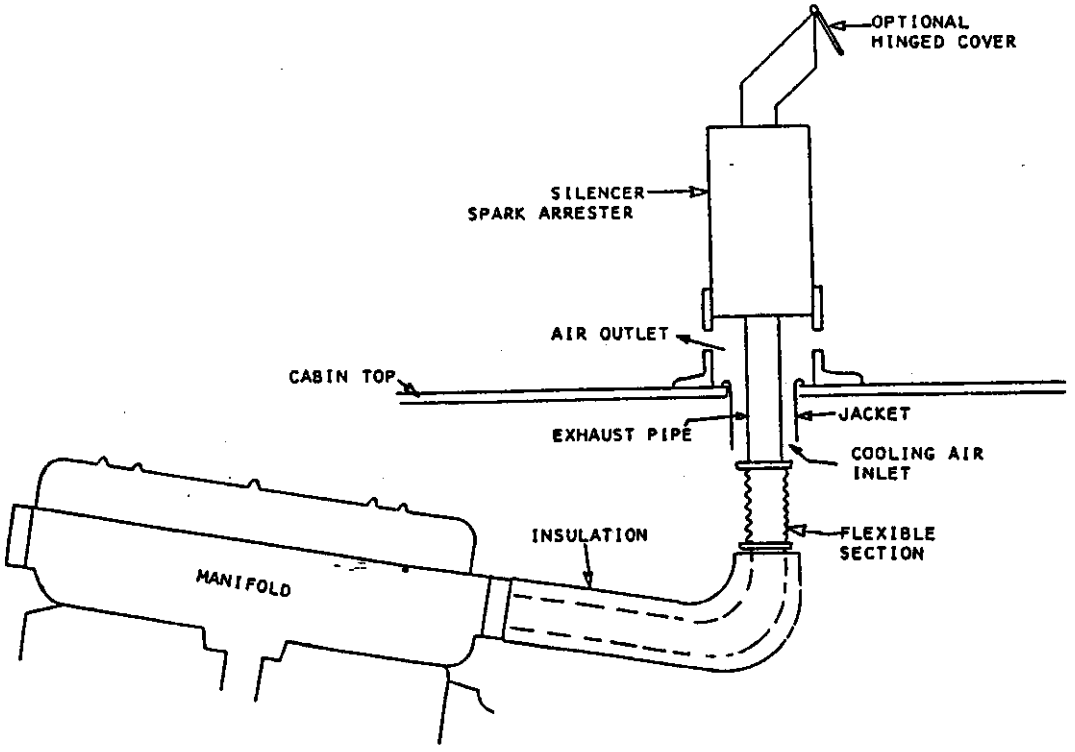
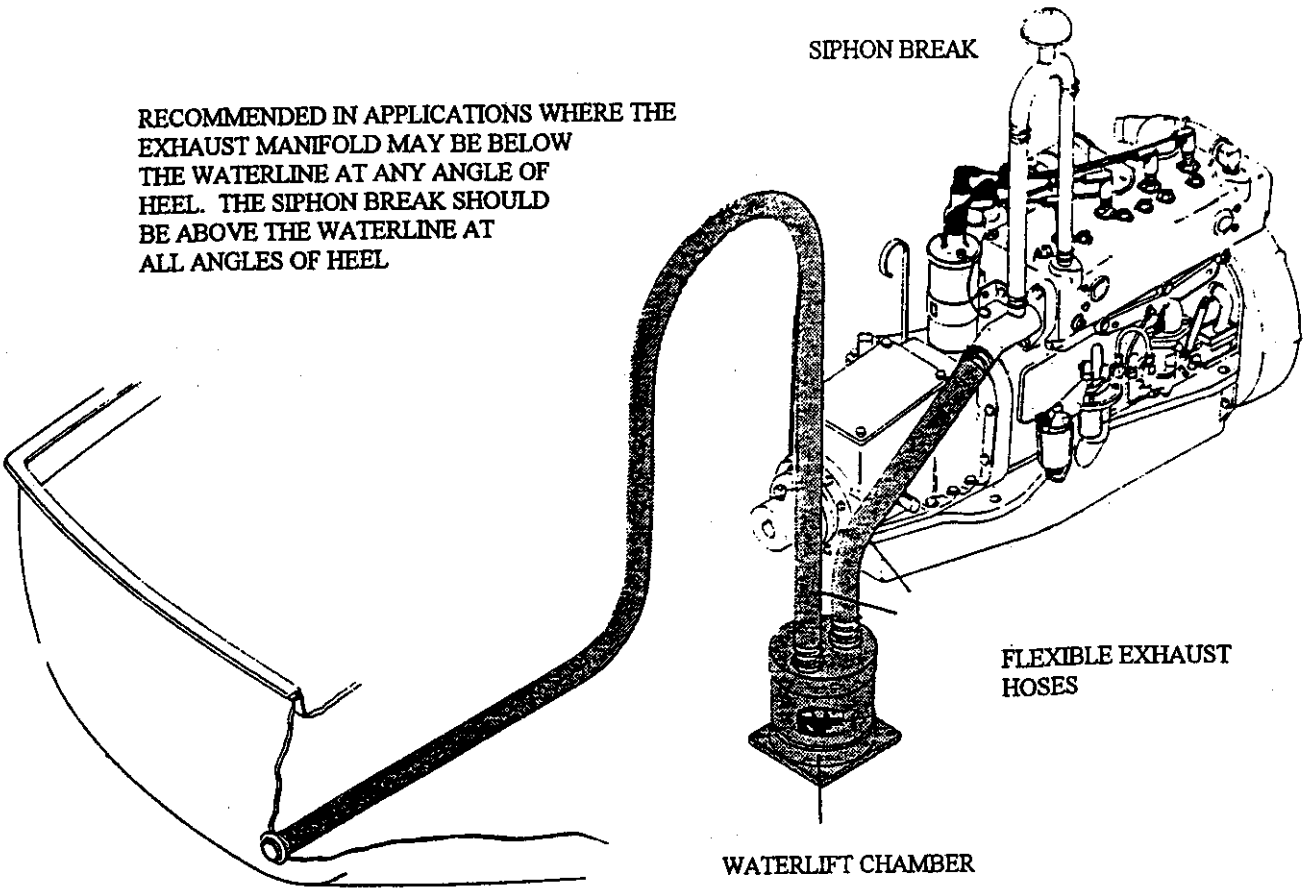


FIGURE 5 - TYPICAL WATERLIFT EXHAUST SYSTEM



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