SURFACE VEHICLE INFORMATION REPORT

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Bleed-Air Pneumatic Systems for Gas Turbine Equipped Marine and Amphibious Craft

RATIONALE

J1775 has been reaffirmed to comply with the SAE five year review policy.

1. Scope—This HIR provides a description of bleed-air pneumatic system elements and identifies parameters required to define the requirements for a detailed specification. Specific design requirements are dependent on the application and should be incorporated in a detailed specification.

1.1 Purpose—This Hydrospace Information Report (HIR) is intended to provide basic design considerations with respect to bleed-air pneumatic systems for marine craft equipped with gas turbine propulsion engines or gas turbine service power units with compressor bleed-air capability. It is not considered within the scope of this HIR to cover the equipment driven by this bleed air or other sources of pneumatic power such as power driven compressors.

1.2 Classification—This report is applicable to marine surface craft, air cushion vehicles, captured air bubbles, surface effect ships, hydrofoils and other advanced marine craft, such as small water area twin hull (SWATH), equipped with gas turbine propulsion or gas turbine power units.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE ARP 699 D—High Temperature Pneumatic Duct Systems for Aircraft
Familiarization with this document is of utmost importance
SAE ARP 735 (cancelled)—Aerospace Vehicle Cryogenic Duct Systems
SAE ARP 1796—Engine Bleed Air Systems for Aircraft

2.1.2 MILITARY PUBLICATIONS—Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robins Avenue, Philadelphia, PA 19111-5094.

MIL-S-901—Shock Tests, H.I. (High Impact), Shipboard Machinery, Equipment and Systems, Requirements for (Navy)
MIL-STD-167—(Ships), Mechanical Vibration of Shipboard Equipment
MIL-STD-740-1—Airborne Sound Measurements and Acceptance Criteria of Shipboard Equipment
MIL-STD-740-2—Structure Vibratory Acceleration Measurements and Acceptance Criteria of Shipboard Equipment
MIL-STD-777 (SH)—Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships

3. Bleed-Air Pneumatic System—System elements and design parameters are identified and discussed in this section. Careful consideration must be given to bleed air system efficiencies and penalties. These factors are discussed only briefly in this HIR and the designer should consult the gas turbine manufacturer and other sources to ensure that a bleed air system is appropriate for that particular application.

3.1 Bleed Airflow—The term "bleed-air" identifies the airflow used to drive pneumatic systems and that is available from a gas turbine used as propulsion or auxiliary power unit and is used to drive pneumatic systems. Bleed airflow limitations are specified in the gas turbine specifications and are normally to 5 to 10 percent of the total airflow through the engine. To minimize the use of the bleed-air flow is important so as to avoid adverse affects on fuel consumption and useful power. The reduction of bleed-air extraction can be attained by proper selection of the driven equipment, a suitable distribution system and controls, and the appropriate management of the power available, like scheduling and/or intermittent duty cycle. Some gas turbines require surge avoidance valves to vent a portion of compressor airflow during certain engine operating conditions. The requirements of this surge avoidance bleed system are independent of the pneumatic system bleed. The surge avoidance vents must be discharged overboard to avoid adverse effects to the local environment and adjacent equipment.

3.2 Pressure—Bleed-air pressure level is dependent on engine power setting. The pressure is minimum at idle and maximum at full power. The distribution system should be designed to withstand a proof pressure of 150 percent of the maximum engine bleed port pressure, with the component at the associated temperature for the most adverse pressure and temperature condition that occurs during operation. Distribution system components should be designed to withstand a burst pressure of 250 percent of the maximum engine bleed pressure, with the component at the associated temperature for the most adverse pressure and temperature condition that occurs during normal operation.

3.3 Temperature—Bleed-air temperature level is dependent on engine power setting; it increases with higher engine power settings. Bleed-air temperature levels of marine gas turbines approach 1000 °F (538 °C). The use of heat exchangers to limit the bleed-air temperature to the specified system temperature becomes a requirement. The maximum temperature level must be compatible with the controls and equipment of the system and, most important, it must be maintained below that limit to avoid critical effects on other systems (fuel, hydraulic and lube) and accessories. The safety devices selected must be of the redundant and fail safe type.

3.4 Ducting—Ducting includes runs, joints, control components and supports. The geometry of the system, as well as the type of craft in which the system is used, dictates the type of supports: rigid or elastic to minimize dynamic interaction between the primary and secondary structure of the craft and the ducting; i.e. the hot air ducting must be structurally independent of the ship or craft structure. A thorough analysis is recommended, economic and operational factors should be brought together to arrive at the selection of system or systems. The use of insulation could be mandatory in some areas, and the selection must be based on safety and repairability.

3.4.1 MATERIALS—The high temperature and the marine salt-air environment significantly increases the corrosion susceptibility of the material selected. In the case of amphibious craft, the erosive effect of the sandy environment must be added to the important parameters considered when selecting the materials. The selection of fastener type and material is as important as the selection of materials for the ducting and supports.

The gas turbine bleed-air section of MIL-STD-777 may be used as guidance in the selection of piping and component materials. ARP 699 presents very useful information concerning the materials available for design of the ducting and some components. The U.S. Navy is currently using AISI 347 and 321. The introduction of nitrogen-strengthened stainless steel has brought a variety of materials that have demonstrated higher corrosion resistance and much higher strength than the usual austenitic stainless steel without impairing the actual handling of the materials. The materials are available under different AMS and ASTM specifications and commercially are identified as the nitronic series by Armco, nitrogen-strengthened stainless steel by Carpenter, and in general the U.N.S. designations: S21904, S28200, S20910 and S21800. It is also suggested to explore the use of precipitation hardened grades considering the corresponding heat treatment. The most common are U.N.S. S15500, S17400, S36200, S45000, S45500, S13800, and S17700.

3.4.2 LOADS—The effect of thermal expansion, duct end loads, deflections due to ship or craft motions, undue accelerations, and linear and angular misalignment are paramount in the design and installation of the distribution system. A clear understanding of the ship or craft motions at different attitudes and operational modes is mandatory for the proper evaluation of the loads that is additive to airflow, pressure, temperature, vibration and shock-induced loads.

3.4.2.1 *Vibration*—The vibration criteria established in MIL-STD-167 should be considered as part of the loading system. Vibration induced by high velocity flow in metal bellows should be considered for the selection of flow liners and the determination of the dynamic system of loads.

3.4.2.2 *Shock*—For combatant vehicles, shock loads outlined in MIL-STD-901 should also be considered in the analysis of the design loads.

3.4.2.3 *Fatigue*—The combination of pressure—temperature and marine environment demands a thorough study of material fatigue and cycling of the system. All components must be properly qualified to this respect. Concerning the actual system, the number of thermal cycles must be determined and specified. The physical and mechanical properties of the materials selected must be in agreement with loading and temperature effects on stress levels and endurance, fracture properties and galvanic coupling. Special attention must be rendered to joints, supports and geometrical changes due to temperature. The question of external loads due to shock and vibration must be well identified and the proper dynamic loading must be superimposed, if anticipated. Provisions must be established in the maintenance instructions to inspect those areas or components of the overall system that are susceptible to initiate any kind of failure, and also to schedule replacement of those items that are part of the system and whose safe and useful life is defined.

3.4.3 LEAKAGE—Duct connections, control and components interfaces must be sealed to eliminate the leakage of hot air to the environment and adjacent components.

3.4.4 SUPPORTS—As mentioned in 3.4 above, the supports could be of the rigid or elastic type, and they must be located as close as practicable to fittings, control components, vents, etc., to minimize overhang. Dynamic analysis must be performed especially in high speed craft when dynamic coupling can be of significant meaning.

3.4.5 MOISTURE—All ducting should be installed such that accumulated moisture can drain to drain ports or be vented through dedicated equipment. A centrifugal air/water separator or other device for water removal should be installed downstream of each heat exchanger. Desiccators should be considered for moisture protection of sensitive equipment only if they will not pose a maintenance burden.

3.4.6 LOCATION—Components should be located for ease of access to inspect, adjust and repair when necessary. System should be designed to allow removal and replacement of sections of ducting and components without requiring removal of the remaining ducting or components. Ducts should be routed to minimize any maintenance support requirements. Components susceptible to freezing should be installed where collection of moisture can be avoided or they must be equipped with drains.

3.4.7 DAMAGE PROTECTION—When bleed-air ducting is routed, maximum care should be taken such that leakages of high-temperature air from ducting and components could not cause damage to structure and to adjacent components. If this leakage could result in fire and explosion hazards, provisions to detect bleed-air leakage must be installed. Where dual ducts used to provide redundancy, their routing should be fully independent of each other to attain that redundancy. Advantage should be taken of structural components to isolate ducting from potential hazards and battle damage. Main shutoff valves should be installed in the duct system as close to the bleed-air source as practical to permit shutdown in the event of system rupture. If the valves are remotely activated, they should be designed to return to the closed position upon failure. If the system serviced by bleed-air is critical to the ship's operation or safety, a signal should be provided to the ship's or craft's control station to indicate the shutoff valves are closed to aid in determining the operation.

3.4.8 BRANCH CIRCUITS—Systems with branch circuits to supply airflow to various subsystems should include isolation shutoff valves to separate failed circuits.

3.4.9 COMPARTMENT ISOLATION—Penetrations of bleed-air ducting through watertight bulkheads should be appropriately sealed and isolated on each side by an isolation shutoff valve. The valves can be manual or automatic with a manual override.

3.4.10 NOISE—Airflow noise generated in relief valves, vents and ducting should be considered. To eliminate the possibilities of airborne noise, induced structure-borne noise and vibrations, the components must not be installed in or near where high flow vibrations exist.

3.4.11 PERSONNEL SAFETY—Personnel safety is of paramount importance. It must be remembered that access to the system while in operation is possible and the use of safety devices must be fully understood to avoid accidents and injuries when exercised.

3.5 Insulation—Minimizing the loss of bleed-air energy due to heat transfer to the surrounding areas should be a system design consideration. Insulation should be used to prevent overheating of compartments and ship structure. Wherever there is a possibility of combustible fluids contacting or being absorbed in the insulation, the surface temperature should be limited to a level below the auto-ignition point of the fluid. Insulation should be constructed of materials that are nonflammable or self-extinguishing. Insulation surfaces, edges, cutouts, and seams should be effectively sealed to prevent the entrance of combustible fluids. Insulation external temperature limits should normally be limited to 145° F (63° C) and should not exceed 160° F (71° C) in manned spaces. Insulation materials that use binders which could precipitate acids from moisture condensation should not be used.

3.6 Pressure Losses—Pressure losses in the pneumatic distribution system should be minimized to limit the loss of power. Duct airflow velocities should normally be limited to maintain the "Mach Number" (M) below 0.25. Velocities in flexible metal bellows without flow liners should be limited to M = 0.20.

$$\text{Mach Number} = M = \frac{V}{a} = \frac{V}{C\sqrt{T}} \qquad \text{Dimensionless} \qquad \text{(Eq. 1)}$$