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DESIGN GUIDE FOR AEROSPACE GROUND AIR CONDITIONING

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INTRODUCTION

The rapid pace and continually changing state-of-the-art today makes it difficult for the engineer to complete his design and obtain tested equipment before the design becomes obsolete. Design of ground air conditioning to support flight missiles has been accomplished by numerous design groups with varied experience, the designers in many cases being unaware of some of the problems associated with aerospace requirements. This design must go beyond the state-of-the-art required for normal building and equipment air conditioning.

Basic equipment components which are standard and can be universally purchased are usually employed in order to keep the cost of the system competitive.

In preparing this report, the author was assisted by members of the General Dynamics Convair, Air Conditioning Design Group, with support from representatives of The Martin Company and Lockheed Missiles and Space Company. Review and editing was accomplished by SAE Committee SC-9, Spacecraft Environmental Control & Life Support Systems.

The material is arranged in the following sequence: 1) orientation of the designer in the subject; 2) presentation of specific problem areas of design; and 3) presentation of basic arrangements and check lists to aid the designer in completing his task.

PURPOSE

This guide is intended to aid the Aerospace GSE Air Conditioning Designer in accomplishing his task; and it will hopefully become a useful tool for design group supervisors who must review the designer's product and verify compliance with design parameters.

SCOPE

The guide acquaints the designer with problems which are unique to ground support equipment design, points out critical design areas, and presents a brief outline of the unlimited volumes of design data, equipment manuals and manufacturers' catalogues which he must use in order to accomplish his assignment. This document is written as a supplement to these publications; design is broadly discussed in the guide, while the referenced manuals in each case give adequate details, formulas, discussion and direction for the designer to accomplish his task.

A basic approach to the design task is outlined. This approach is applicable to any new design, but is more critical in the design of aerospace GSE equipment.

Some of the "pros" and "cons" of using basic types of equipment components are discussed. A few design problems of each type are pointed out.

A design check list is included which will aid the designer in ascertaining that his design is as complete as possible.

"Ground support air conditioning" is defined as any non-airborne process control used for supplying conditioned fluid to a space vehicle and its associated equipment for environmental control (temperature, humidity, gaseous envelopes, pressure, etc.), while the vehicle is on the ground.

This equipment is classified as Ground Support Equipment (GSE). A list of the specifications of qualified equipment is presented in the U.S.A.F. Handbook (Ref. 13). The listed units are designed and qualified to MIL-S-8512 Support Equipment Specification (Ref. 5).

1. DESIGN CRITERIA

The following criteria must be defined prior to designing GSE air conditioning systems.

1.1 Missile Type: Basic classifications of the missiles are required in order to determine the requirements of the air conditioning system. As these classifications change, the air conditioning requirements vary and may require redesigning or extensive modification of the ground air conditioning unit(s).

A. Number of Stages: Each stage of the missile is unique in itself and has its own support requirements. The number of stages requiring air conditioning will determine the number, location and size requirements for the umbilical connections. The requirements for the stages may vary and must be determined independently. The variation in individual compartment requirements will affect the design of the overall air conditioning system. If the requirements for the individual stages vary extensively from each other, a single system may become impractical. Individual systems for each stage, because of the increasing number of components required to make up these systems, tend to become less reliable. In some missile installations, modular interchangeable sections are designed to allow build-up of flexibility to meet varying requirements.

B. Type of Propellants: The type of propellants used in the space launch vehicle for the individual stages will control the type of media supplied to the vehicle for air conditioning. As more critical propellants are used, the requirements for air conditioning become more closely related to pad safety requirements. Cryogenic propellants usually create a requirement for heating of missile components in the engine compartment. Volatile propellants, which are explosive in an oxygen atmosphere, may create a requirement for an inert air conditioning atmosphere.

C. Type of Construction: Vehicle construction will control the type of ducting and interface connections for the air conditioning system.

(1) Pressurized: Balloon type construction must be pressurized at all times while in transport or on the launching site. As the air conditioning supply is changed in temperature and impinges on the balloon tank, pressure control must be maintained. Because of the inherent fragility of the balloon type construction, heat transfer from the air conditioning system into the propellant tank has a great effect on the propellant during tanking and storage prior to flight. During the flight, the reverse is true where the heat from the electronic equipment is readily absorbed by the cryogenics in the tanks.

(2) Rigid: Rigid missile construction lends itself better to insulation. When the missile has greater strength in the structure, more insulation is possible in the areas adjoining the air conditioned compartments. Disconnects and ducting mounted within the missile are not as critical a design problem as those on the pressurized missile. Because the rigid missile is not pressurized, the air conditioning system has little or no effect on the maintenance and operation of the missile while the air conditioning system is being checked out.

1.2 Missile Mission: The type of mission of the missile will govern the time the missile and equipment is subjected to atmospheres other than those encountered on earth. The type of environmental control chosen is controlled by the time, power and equipment which is in operation during checkout and through powered flight to burnout of the missile propellants.

A. Recoverable

(1) Suborbital: Missiles for suborbital missions are generally short life in flight. The air conditioning required for this type of mission is related to the power supplied and equipment operating temperature limits. The use of the equipment housing and structural supports as an equipment heat sink is a general cooling method used for these missions. The structural heat sink method requires limits for the component temperatures at lift-off. The flight time has only a limited effect on component cooling or heating, as related to GSE operation; although it may dictate lift-off temperature and thus may require different conditions during checkout than those required at lift-off.

The GSE air conditioning for the ballistic missile is in this category. In most cases, a standard cooling coil, operating with leaving air of 40 F is adequate to supply the conditions required at lift-off.

(2) Orbital: The air conditioning requirements for an orbital mission vary with the payload and time. The interface between the ground air conditioning system and airborne environmental control system becomes more critical with increased mission time. For short duration orbital missions, storage of the cooling medium has an attractive weight advantage. As the duration is increased, active systems must be employed for airborne environmental control. In all orbital missions, surface coating must be employed to aid in the control of the temperature within the vehicle. Maintaining the surface clean and free from dust, dirt, discoloration and icing, prior to flight, may be some of the critical and difficult requirements of the GSE air conditioning system. Special filters, inert or dry gases, or other special requirements may be imposed on the GSE designer. The GSE air conditioning for orbiting two-burn mission boosters is in this category. In the case of the Centaur missile, air is used for air conditioning during checkout. Dew point is held below 40 F during this phase. During cryogenic tanking, the air in the air conditioning unit is completely replaced with dry nitrogen. The engines are purged with helium to maintain the dry conditions. Frost formation in all areas is critical as it affects the weight of the missile at lift-off and the temperature of the electronic and other equipment exposed to space conditions after a frost layer has formed adjacent to it. Frost formation changes the reflection of the sun and earth's albedo and this changes the surfaces that the components are looking at in space.

(3) Escape

a. Interplanetary: Design of the air conditioning system for interplanetary missions is the most difficult of the air conditioning design problems to date. For small instrument payloads, control of the absorptivity and the emissivity of the spacecraft surface may suffice. All other payload types will require extensive design using active systems. The compatibility of the airborne system with the GSE system must be maintained. Solar flares and micrometeorites, as well as planetary atmospheres encountered by vehicles, will affect the vehicle system design.

Special component coatings may require special humidity control. When soft insulation is used to stop meteorites and is installed around components which must be air conditioned, it may completely change the design concept for conditioning those components. The relation of these special structural requirements should be investigated if considered critical. Where changes in the GSE will simplify vehicle system design, it may be advantageous to complicate the GSE system in favor of simplicity in the vehicle.

b. Deep Space: The environmental control requirements for deep space recoverable missions has not yet been determined. Extensive research in this area will be required to formalize any air conditioning design.

B. Non-Recoverable: Non-recoverable flights are expected to be of long duration and, therefore, require airborne environmental control systems. GSE air conditioning systems for these missions are expected to have little effect on the vehicle other than during the injection phase.

(1) Orbital: Non-recoverable orbital missions will require environmental control in flight depending on the equipment operating. GSE air conditioning related to this equipment is only effective during the injection phase of the mission. The interface between the GSE and the airborne equipment is a major design problem. If the surface coating method of airborne temperature control is employed, the GSE air conditioning must not deface the surface of the spacecraft.

(2) Escape: Non-recoverable escape mission GSE air conditioning requirements are related to the direction of the mission as well as the equipment operating in the payload. GSE air conditioning has a minimum of effect on the operation of the system in flight, and major problems exist only at GSE to airborne interface, when airborne environmental control is employed.

1.3 Missile Payload: As more exotic payloads are designed and injected into space, the air conditioning to support the vehicle becomes more complex. The interface requirements may branch out from just supplying cooled or heated air to include dehumidification filtering in the air, switch to GN_2, sterilization of air, hazard sensing with warnings or automatic switch of conditions, cooling liquids, such as glycol or freons supplied to disconnects or many other undefined requirements. Separate systems for air conditioning payloads become more attractive. Interface problems between the operating GSE and the airborne system are the main design problems. The interface is defined as the disconnect or separation point for the GSE and airborne systems at lift-off. It includes self-sealing valves, doors on the missile, lanyard releases, backups and signal releases, such as squibs, solenoids or pneumatic signals. Compatibility of the two systems, at this point, is the prime objective.

A. Mechanical-Electronic Equipment: The guidance equipment for each stage of the multi-stage missile falls in this category. Air conditioning is required for ground operation and checkout in the guidance equipment. Payload electronic equipment will vary from mission to mission, thus changing the requirement for GSE design. As the time increases for the operation of this equipment in space, the effect of the GSE air conditioning on the vehicle becomes a minimum.

B. Life Support: The GSE air conditioning for a payload which includes a life support system must support all operation during the checkout and launch phase. The major problem is the interface between the two systems. It is helpful if these systems can be designed as a single system working together to accomplish the task. Duration of the spacecraft flight will control many of the requirements of the GSE design. The use of cryogenics, super-critical storage, or pressurized storage of the atmospheric gases for life support modifies and enlarges the GSE air conditioning design problems.

(1) Vegetable: Because life support on earth (man's first operating space vehicle) requires a balance between the life of plants and animals to maintain the proper atmosphere, similar conditions must be maintained in the spacecraft. If the payload contains living vegetable material, such as mold or eatable plants, the gases and waste products from the animal life must be supplied to the spacecraft by simulation unless man occupies the same compartment. CO_2, solar energy and water must be supplied, together with food for the plants. The storage and refurnishing of this material while the vehicle is on the ground may be a requirement fulfilled by the GSE air conditioning system.

(2) Animal: As the order of animal life in the payload varies from microorganisms to the high level of animals, such as the chimpanzee, the air conditioning system must more closely simulate that of the earth's atmosphere. Gaseous products produced on earth by the plant life must be simulated in the air conditioning of the spacecraft. Oxygen must be stored or converted for use by the animals. As flight missions increase, dual or multi-use of materials must be sought by design to reduce the weight of the spacecraft. Recovery and reuse of materials for animal life is difficult unless nature's methods of plant and animal balance is maintained. Purification of waste products is the major challenge and one of the controlling factors of airborne systems. GSE systems supporting closed systems must be evaluated for contamination possibilities. Pressure compatibility is a critical area. As more vacuum insulation and absolute pressure references are used, doubling of the normal operating pressures can be expected during ground atmosphere checkouts. The designer must be aware of these checkout requirements and design for them.

(3) Human: The life support system in the payload of a missile which is to carry human life must contain all the elements supplied for that life on earth. Simulated conditions will be controlled by the length of time of the mission. Compatibility of the GSE system with its multitude of interfaces becomes a major design problem. During checkout, the air conditioning system may be required to handle air supply, water, and CO_2 removal, waste removal, contamination removal, as well as the heating or cooling of the cabin area or space suit which is designed to maintain these conditions.

(4) Missile Refrigeration: When cryogenics are used to supply the requirements of a life support system, refrigeration and environmental control systems of the spacecraft must be operated while the vehicle is on the ground. This interface with the GSE air conditioning is difficult and will require extensive system analysis prior to designing equipment.