



Society of Automotive Engineers, Inc.

TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

AEROSPACE INFORMATION REPORT

AIR 992

Issued 8-1-69

Revised

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 refurbishing 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.

- 1.4 **Controlling Design Factors:** The controlling factors must be weighed in order of relevant importance and listed in sequence for each GSE design. As the relative importance of each controlling factor changes, complete revision of the GSE design may be required. None of these factors are unique in themselves. As their importance is listed in sequence, a picture of how the design will progress is obtained. The supervisor is cautioned that shifting of emphasis from one of these factors to another will completely revise the designer's attitude toward his task.
- A. **Schedule:** Since man's life span is limited, all his activities are scheduled. The importance of schedule on any design for GSE must be evaluated. A balance must be maintained between the completion of the design, drawings and specifications, and the schedule for this completion. It may be mandatory that less detail be included in the original design in order that the scheduled release may be met. Freezing of design concept at an early stage in the schedule should be a prime objective. The design reviews possible are limited by the schedule and its relative importance to the rest of the design factors.
 - B. **Reliability:** Reliability of the GSE equipment is more critical as the launch schedule becomes limited. More exotic payloads tend to reduce the available launch window. A balance between reliable components and redundancy in system design must be maintained. Reliability is increased by qualification testing, proof testing, and quality control during the manufacturing of the air conditioning units.
 - C. **Cost:** The cost is an influencing factor of all systems designed for use on any project. The balance between cost and available funds (sometimes called "motherhood") must be maintained by the design engineer. Project life and initial funds available will control the design of the GSE from light duty to heavy duty equipment.
 - (1) **Initial Cost:** The initial cost of the GSE air conditioning system is a small portion of the overall cost of the system when operated on a continual basis. Intermittent operation may dictate lower initial cost and use of light duty equipment.
 - (2) **Operation and Adjustment:** Light duty equipment may require continual operating inspection and adjusting. The cost of this surveillance may exceed the initial cost of the unit. The balance between the maintenance cost and initial cost is controlled by the allocation of funds for the project.
 - (3) **Repair and Maintenance:** In general, heavy duty equipment will reduce the frequency at which repair and maintenance must be performed on the air conditioning equipment. The cost of major repairs on a long life program may be large for this type of equipment and must be balanced against continual repair and replacement required by light duty equipment.
 - (4) **Reapplication:** The adaptability of GSE equipment for reapplication may be a controlling factor on the cost of the initial equipment. A more flexible design may increase the cost of the unit but allow its use for later projects. The readaptability consideration is more critical for the payload air conditioning unit. Unit requirements vary from payload to payload, whereas the basic missile air conditioning requirements may remain unchanged. Modular design is attractive when applied to air conditioning for widely varying payload units.
 - D. **Power Consumption:** GSE air conditioning design is closely related to the power available at the complex since a major portion of the power required is supplied to the air conditioning system. The use of standby power must be considered when reliability is of major importance. If standby power is required, the type and amount available will have a great influence on the unit design. The operating duty factor of the GSE air conditioning unit will be a major factor in the use of power at the complex.

- E. Hazards: The safety hazards at the missile complex will dictate many of the controlling factors in GSE air conditioning design. Propellant leakage may cause an explosive safety hazard and thus dictate that the air conditioning unit be designed explosion proof. Inert gases may be required as a flow media in the air conditioning system in order to eliminate explosive hazards within the vehicle. Hazardous atmosphere warning equipment and automatic switchover to an operation with inert atmosphere may be required. In all systems in which inert atmosphere is used, its hazards, as related to operating personnel, must be considered.
- F. Weight and Space Limitations: Weight and space limitations for GSE air conditioning are related to transportability for the most part. Certain applications, such as silo installation, may impose weight and space limitations on the GSE design.
- G. Sterilization: Sterilization of the spacecraft is a GSE design function. It becomes more critical with an advance in the payload design. Sterilization methods may require the use of poisonous gases, high temperature (135 C) soak for 36 hours or more, or bacteriological filters to prevent the entrance of bacteria into the spacecraft prior to flight. Some method for maintaining pressure on the system after sterilization must be included in design. This is necessary to prevent recontamination.
- H. Maintainability and Time Between Servicing: Designing "maintainability" into the equipment is a difficult and challenging responsibility. It will include provisions for panel removal, flanging of components, ease of lubrication, and ease of removal of components from exterior points. Consideration of the removal of any item within the unit must be accomplished in the initial design stage.
- I. Transportability: Prior to design of the air conditioning system, the method by which the components or units will be transported from the vendor to the launch site must be determined. The State and Interstate transportation laws governing railway transportation and other shipping methods must be kept in mind when determining the space envelope for the air conditioning unit. If the unit is to be transported by air, size, weight, tie-down requirements, and aircraft vibration must be kept in mind. Location of the airfield and local roads over which the unit must be transported must be evaluated.

The following is an example of design loading for frame, supports and brackets when the unit is to be transported on the highways.

<u>CONDITION</u>	<u>VERTICAL</u>	<u>AXIS SIDE</u>	<u>HORIZONTAL</u>
Maximum Vertical Inertia	Minus .5g To Plus 2.5g	0	0
Maximum Side Inertia	Plus 1.5g	$\pm 1.0g$	0
Maximum Longitudinal Inertia	Plus 1.5g	0	$\pm 1.5g$

The load factors as shown are applied load factors for the individual masses at their respective centers-of-gravity for structural substantiation. Where two loads are listed they are considered to be acting at the same time.

- J. Flexibility: The flexibility of the air conditioning system must be kept in mind in the initial design phase. Such items as remote control, remote restart and remote readout for instrumentation must be coordinated with the blockhouse control design groups.

Flight: Flexibility must be considered for various missile requirements related to the flight mission of the vehicle. A shift in conditions may be necessary during the countdown phase. As cryogenics are tanked into the vehicle, the air conditioning system may be required to shift to an inert atmosphere. Hazard protection and remote warning system may be required with a manual or automatic switchover to an inert gas supply. During the static and checkout phase, the missile air conditioning may be required to accomplish reheat of the components after checkout. Hazard protection during the launch abort phase may be a design requirement.

- K. Operating Life, Idle Life: The anticipated operating life and idle life of the air conditioning system has an effect on the design of the system and may affect its use at the complex. The length of the program and the weather protection of the unit must be considered. Checkout and adjustment requirements as well as the maintenance program must be set up on the equipment. Prior to periods of idle life of the machine, pump-down and storage conditions, including valve shut-off and drain-down, must be initiated. Warning procedures for start-up should be included.
- L. Spare Parts (Interchangeability): The spare parts program for missile air conditioning is a major part of the cost of the system. Spare parts should be set up for the life of the program. Interchangeability of the parts in the various air conditioning systems will aid in reducing the cost of the spare parts program. In designing a new GSE air conditioning unit, the reliable existing component should be used whenever possible. It is advantageous to set up a preferred parts list for use within the company's air conditioning design section.
- M. Simplicity: The simplicity of the system is the most desirable feature in designing any GSE air conditioning unit. The simpler the system is, the easier it will be to maintain it at the complex. The manuals to support this equipment will be easier for the maintenance personnel to understand and use when simplicity is the prime objective of the design. In order to design simplicity into a system, extensive design analysis and component evaluation is required. Elimination of components and the use of one component to accomplish several tasks should be considered. Moving parts should be held to a minimum. Special test and adjustment tools and equipment should be avoided unless the system or procedure is simplified by their use.
- N. Dependability: The dependability of the system seems to go in hand with the simplicity of design. Quality control and redundancy may be required to increase the dependability. As more critical and complicated systems are designed, the dependability becomes a critical problem.
- O. Radiation (Radioactive): As atomic powered missiles and systems develop, radiation considerations as related to the air conditioning system will become more of a design problem. Baffles may be required, waste elimination equipment and extensive filters may become basic components within the air conditioning system.
- P. Redundancy (Or number of failures; i.e., single, double): The system for missile conditioning should be designed for protection against single failure causing loss of air conditioning. As the firings of manned space vehicles become more frequent, double failure analysis must be considered. When designing equipment for use with space launch boosters launching manned space vehicles, redundancy in the system becomes more important. Redundancy in the system must be analyzed as to its relation to the cost (funds available to the program) and nature of the mission. In general, redundancy is more applicable to the missile system rather than the GSE; however, the shorter the launch window, the more critical the GSE systems become. Redundancy may also be required where the safety of the missile is related to the operation of the air conditioning system. Loss of sterilization which would cause recycling of the payload through costly processes may require consideration of a backup system.

- Q. Corrosion Resistance: The corrosion resistance within the air conditioning system is especially important in moving parts and critical components. Salt spray atmosphere must be considered when the system will be operated in areas adjacent to oceans; i.e., Western Test Range and Eastern Test Range. Wind and dust must be considered when designing the equipment which will be operated in desert atmospheres such as White Sands Proving Grounds, Edwards Air Force Base, etc. Components such as coils, condensers, filters, dampers, valves and blowers should be analyzed for corrosion resistance. All components should be evaluated. Fungus resistance must be considered in cooling towers and electrical components when the system will be operated in tropical areas. Dissimilar metal contact must be considered in all design where moisture will contact the metal. Dielectric difference should not exceed 0.25 volts E. M. F.
- R. Backup: As a launch window becomes smaller and the time at which the missile is to be launched becomes more critical, backup systems for the air conditioning may be required. If the air conditioning system cannot be shut down for maintenance and repair without losing support of the missile on the pad, backup air conditioning systems should be considered. The cost of a complete backup unit, as compared to the critical nature of a pad shutdown for lack of air conditioning, must be evaluated. If short periods of downtime are allowed, a good spare parts program should be initiated in lieu of complete backup unit.
- S. Noise Level (Operating): The noise level of the operating air conditioning system is not critical for most GSE. As the noise level produced by the equipment exceeds 120 db, the psychological effect on the maintenance and operating personnel must be considered. Equipment emitting excessive noise may be difficult to check out. Operating personnel will shy away from making adjustments during the normal running cycle. If a high noise level is anticipated, the effect of this on surrounding equipment must be evaluated. Special consideration must be given to missile guidance and control components. Background electrical noise and interference must be considered and is usually controlled by military specifications (Ref. 14).
- T. Vibrations and Wind Loadings: Design of GSE air conditioning systems must take into account operating vibration, shipping vibration and wind loading.
- (1) Transportability: Transportation vibrations are a major cause of new equipment repair at the launch site. Design evaluation must be made in order to reduce the number of failures and the cost of repairs encountered. Wind loading during transportation is a contributing factor to interface damage on GSE air conditioning units. The method of transportation will control the wind loading factors imposed on the housing design. Protrusions that can be broken or damaged in shipment should be eliminated in the design of the unit. It is recommended that the units be shipped in enclosed van type trucks when possible.
- If the unit is to be shipped by rail or flat bed truck, it must be designed for 120 mph wind loading as listed in paragraph 1.4 I. In addition, the crating and cover must enclose all protrusions and be capable of sustaining the drop loading expected when setting it down with a crane. The drop loading will vary based on size and weight but will not be less than dropping a side or end from the height of one (1) inch.
- (2) Operating: In order to reduce the damage of components by operating vibration, design must include flexibility and consideration should be given to shock mounting of component. Vibration eliminators in the refrigeration lines should be installed parallel to the axis of the rotating shaft. Delicate controls may be rigidly mounted, provided vibrating equipment is shock mounted (compressors, blowers, fan and pumps). Equipment for use in areas subject to hurricanes may require special wind loading design and tie-down capabilities.
- U. Missile Interface: The major design coordination problem of GSE is the missile interface. Some method must be devised which will make certain that the airborne changes are coordinated and the GSE design is alerted. Time motion studies must be made at the interface. The angle of disconnect and wind loading must be considered in designing the disconnect assembly.

- (1) Connection: Size, number and location of the connections must be determined prior to design of the air conditioning ducting. Disconnect design must be coordinated for compatibility. Lanyards and special operating equipment may be required to effect proper disconnect. Space limitations in this area are critical. Extreme care must be taken in design to make certain that cross connections are not possible.
- (2) Airborne system requirements: The airborne system requirements must be determined as the first item prior to start of design of GSE air conditioning system. A continual check and coordination of these requirements is necessary throughout the task. Large changes in the airborne requirements may result in complete revisions to the design concept. Some changes can be handled by the flexibility of the initial design for the GSE unit.

V. Radio Interference: Initial design of the air conditioning system must consider the radio interference created by the system. Each electrical component and the system as a whole must be evaluated and, if possible, tested for radio interference. In most cases, interference can be eliminated by the use of filters or substitute components. Make/break contacts and controls should be held to a minimum during normal operation. In some cases, major components may be rechosen or redesigned in order to eliminate their interference with radio communications. Military specifications for control of radio interference are listed in Reference 14.

2. DEFINING DESIGN LIMITS

The following design limits must be determined prior to designing ground air conditioning systems. A major portion of the design engineer's time may be expended in defining the design limits. Many of the design errors or changes in design could be eliminated if the engineer had been more diligent in defining the limits to which he must design.

- 2.1 Interface Locations for Intake and Discharge: Prior to design of the installation for ground support air conditioning, the interface location must be determined. Proper choice of interface locations may eliminate many redesign problems. Interface incompatibility may be avoided or held to a minimum through proper space allocation and control by the assignment of this task to one design group.
 - A. Umbilical Location: The orientation and elevation of the umbilical, with respect to the missile, must be accurately determined. Allowable weights and forces against the missile may be critical. An allowance must be made for missile movement and clearance envelopes defined. Platforms and other service support equipment may be required for connecting and disconnecting the air conditioning lines.
 - B. Distribution Duct Location: The routing of the air conditioning ducting at the Complex should be considered in designing the controls for the air conditioning system. In choosing the location of the final control elements, line losses in heating or cooling may become a major design problem. Space allocation for the duct routing should include sufficient space for repair and replacement, as well as for the thickness of the insulation on the piping. Method of supporting and support spacing may be critical. Non-hygroscopic insulation is required for all cooling lines and should include a vapor tight seal with a rigid service coating to eliminate physical damage. Location of check points and readout transducers should be determined in the initial design phase. Flexibility must be designed into the ducting system to allow for expansion and contraction with changes in temperature. The use of insulated flexible ducting should be limited to temporary installations or sections that are expendable and replaced after each flight. Hoses are prone to wear and leaks. They must be continually checked and will require frequent maintenance.
 - C. Supply to Unit (Inlet): The location of the unit on the launch pad may require special consideration for the supply air or make up media for the air conditioning unit. Location of hazardous propellants in relation to the intake may require special ducting to obtain fresh, uncontaminated air. Care should be taken that the supply to the air conditioning system does not receive the impact of "flame wash" during launch. Flexibility in the connections must be considered in design where the air conditioning system is expected to vibrate. This will eliminate the transmission of vibrations into the ducting and upsetting of the control transducers which may be installed at the intake.

- D. Supply to Airborne (Outlet): Flexibility must be designed in the connection of the unit to the rigid ducting in order that vibration not be transmitted into the ducting during operation. The major control elements are usually located in the outlet of the unit and must be guarded against damage when making these connections, or during operation.

2.2 Airborne System Fluid Requirements: Evaluation of fluid requirements of the missile air conditioning must be made relative to time. If shifts in conditions must be made, a method of accomplishing these shifts must be chosen in the initial design phase. These requirements may vary from missile to missile and readjustments of the unit control must be as simple as possible. Override or adjustments from the blockhouse are desirable and should be considered for all critical requirements.

- A. Fluid Requirements: The fluid requirement must be determined relative to time and specified by type, conditions required and quantity. The preferred method for specifying the quantity is in pounds per minute; however, cfm, scfm, or the metric system, may be used. Flow requirements are related to pressure in the circulation system.
- B. Temperatures: Temperatures are normally specified in degrees fahrenheit with the adjustment range. Different temperatures may be required during the prelaunch phase, than those required during the checkout phase prior to launching of the missile from the pad.

The designer should know:

- (1) The nominal and tolerance limit during the checkout and prelaunch phase of operation.
 - (2) The design limits of all equipment supported and the conditions to which each component was subjected during qualification testing.
- C. Humidity: The preferred method for specifying humidity is the dewpoint of the flow medium. Grains of moisture per pound of dry air or relative humidity may be used; however, caution must be used when specifying moisture content as relative humidity. The temperature at which the relative humidity is required must be defined. Humidity is usually specified as a maximum allowable moisture content. If a fixed humidity is required, humidification equipment, as well as dehumidification equipment, must be designed into the unit.
- D. Pressure: The pressure is usually specified in inches of water; however, psi may be used. The pressure will vary with variations in the flow rate. Some method must be designed within the unit to control or adjust the discharge pressure. All pressures are related to flow rates. The two conditions must be specified together in order to determine design conditions.
- (1) Nominal tolerance limits.
 - (2) Maximum design capabilities. Caution must be exercised in the choice of the blower as flow rates are reduced in order to eliminate surging.
- E. Cleanliness Required: Minimum cleanliness requirement of the air conditioning system is that required to keep the cooling coil, heating strips, and drain lines free of clogging material. Intake filters must be chosen to accomplish this requirement. Final cleanliness of the air system is accomplished by the final filter. Its minimum efficiency, when clean, must be coordinated with the missile requirement. Cleanliness is usually specified with maximum particle size and concentration in parts per million.

The designer must know the following:

- (1) Particle size and minimum filter efficiency. _____
- (2) Maximum pressure drop allowed. Clean _____
Dirty _____
- (3) Media Flow Rate _____ Nominal and tolerance when
designing his filter. + _____ - _____

- 2.3 Ground System Requirements: The ground system requirements are related to the location at which the air conditioning unit will be used and the facilities available at that location. General design ambients are printed in the ASHRAE Guide (Ref. 1). GSE design should use the 1% or better design criteria. It is an accepted practice to design a GSE unit with a 20% pad over nominal requirement. This allows for a reduction in capacity as the compressor, coils, condensers, and other equipment as they degrade with use in the field. The design of the system must be such that the unit will operate from full load to no load without cycling.

Design requirements, calculation data and formulas are listed in References 1, 2, 6, 7, 8, 10, and 11. The GSE air conditioning data sheet (Fig. V) is included as an aid in obtaining the complete load and requirements data. When testing of the designed and fabricated system is required, a test requirements directive must be written. A test requirements sheet (Fig. IV) will aid in setting up this document. A load calculation guide sheet is included (Fig. VI) to aid in including all the design requirements and loads in the engineer's calculations.

- A. Design Ambients (i. e., temperature, pressure, humidity): The complete list of design ambients can be obtained from ASHRAE Guide (Ref. 1). Government weather reports for a particular location may also be used to verify validity of the design ambient chosen. Additional data is found in the Carrier Corporation's design manuals (Ref. 10).
- B. Facilities Available: The installation pad for the air conditioning unit and foundations required, including hold-down capabilities, should be coordinated with the facility. Electrical grounding locations, drain locations, water supply, and facility power interface must be coordinated. The location of "white rooms" and guidance alignment requirements must be considered as facilities which may require GSE air conditioning.
- C. Power Available: The phase, voltage, and total power available for use by the air conditioning system must be determined. The control voltage for remote control and restart must be determined and coordinated with the design of the GSE unit. All electrical design should meet the requirements of the National Electrical Code (Ref. 15.).
- D. Standby Emergency Power: If standby power is to be used, a complete analysis of the compatibility of the air conditioning system is required.
- (1) Type
 - (2) Capability
 - (3) Switchover requirements
 - (4) Regulation: Regulation is critical when standby power is used for air conditioning because of the large power requirements and cycling nature of the air conditioning control system. Its use for air conditioning may upset the operation of the standby power generation equipment.
- E. Fluids Available: Capacity of the support systems, such as domestic water supply, ambient air, and inert gases supplied, must be evaluated as to quantity and temperature. The use of glycol in "closed-loop" circulated cooling system will require make-up facilities. When systems are critical for support of missile flight, back-up fluid systems may be required.
- F. System Requirements (Schematic Layout): Preliminary layouts and schematics must be made in the initial design stage to aid in determining location for the air conditioning equipment and ducting and aid in space control. Continual upgrading of the schematics must be carried on along with the system design.
- G. Interface Definition: All interfaces must be determined as closely as possible. Flange location and orientation and duct transitions must be pinpointed. Location of the bolts, holes, and tie-down facilities must be adequately determined. Pipe sizes and thread dimensions should be spelled out.
- H. Remote Blockhouse Control and Reset Capability: Voltage, number of conductors, and shielding required for the reset capability must be coordinated. Terminal strips are recommended for these connections.

- I. Equipment Location: The location of the air conditioning system will determine the design requirements for the housing of the unit. Outdoor design and weather proofing is normally used. If the equipment is to be located in a shed or building, general purpose electrical equipment may be used. Requirements for foundations, sheds, and blast-shields must be considered. Service lighting and panel lighting design will vary with location. Sufficient room around the air conditioning system must be allocated for maintenance and service of the equipment. Removal of large components, such as the compressor, may require the use of a crane or a fork-lift truck. Space must be allocated to allow the use of this equipment.
- J. Explosion Hazard and Design Limits: The allowable limits of hazardous materials can be obtained in the Industrial Ventilation Guide by the American Conference of Government Industrial Hygienists (Ref. 4). Missile propellants and the location of the air conditioning unit with respect to the propellant tanks and piping will control the design requirements for explosion proof electrical equipment. Corrosive propellants may dictate additional requirements for explosion proofing. The temperature, flash point, concentration limits in the propellants, should be known. Care must be taken so that the air conditioning units are not located under propellant lines which may develop leaks. Most missiles have a hazardous limit radius, depending on type of propellant. It is desirable to locate the air conditioning system outside of this radius. (See 1.4E).
- K. Toxic or Smothering Effects of Fluid: When inert gases are used in the air conditioning system for explosive protection, care must be taken in designing the relief areas in the missile for the cooling media. Use of "white rooms" in enclosing the payload area may require elaborate warning systems to eliminate suffocation or asphyxiation of workmen.
- L. Produced Interferences: An evaluation should be made of electrical communication equipment adjacent to the air conditioning unit to determine the component, which may be subject to radio interference.
- Missile equipment and telecommunication equipment, if upset by the operation of the air conditioning unit, may cause extensive redesign of the air conditioning control section. (Reference 14 lists these requirements and methods for testing the units.)
- M. Filtering Required: The installation location at the complex of the air conditioning unit will determine what filtering is required in the make-up area.
- (1) Location of grain fields, large trees, etc., may require special filters to eliminate the clogging of the intake filter during the Fall and Spring seasons. If the unit is to be located in desert areas, protection must be designed for dust storms.
 - (2) Radio suppression filters may be required to eliminate interference communication by the electrical control.
 - (3) Discharge filter requirements must match missile requirements.
- N. Maximum Limits of Transfer Losses: The length of the duct installation between the air conditioning unit and the missile together with the heat leak to the insulation must be calculated. Allowable pressure loss and temperature variation will determine the line sizes and the insulation thickness required. If the losses cannot be compensated in ducting design, the control circuit must be designed to compensate for these losses. The vapor sealing and protection against physical damage may be a critical design problem for cooling ducts. The ducting installed adjacent to the missile must be designed for blast protection at missile rise, or considered expendable and replaced after each flight. Methods for calculating these losses (and tables) are included in the Carrier Corporation data (Ref. 10).