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A Review Paper on Design of HVAC System for Human Cabin in Space Craft

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Abstract: This project aims at “Design of HVAC system for human cabin in spacecraft”. A complete air conditioning was designed to control the human cabin environment conditions like temperature, humidity, pressure etc., in an economical way. In this project HVAC system for human cabin design was done by using the AUTO CAD software and the calculations were done as per ASME(American Society of Mechanical Engineers) manually. After taking the plan and load calculations results like total heat, mass flow rate of refrigerant of evaporator and mass flow rate of refrigerant of condenser, power of compressor, volume of evaporator and volume of condenser. Based upon the obtained results length and diameter of condenser coil, evaporator coil and r.p.m of the shaft. With this the capacity of equipment was estimated and selected for the installation. Total data was shown in document.

Keywords: Auto cad software, Evaporator, Condenser, Compressor, ASME

I. INTRODUCTION

From Manned spacecraft and space shuttle to the scale of space station, the technology of manned spacecraft has been developing. The astronauts have to work and live in the cabin for much longer time. Therefore, the spacecraft environmental control and life support systems is not only asked to control the cabin environment parameters within a certain range, but also to ensure the cabin environment with high thermal comfort which can meet the physical and psychological needs of astronauts, also improve the efficiency of equipments, structural components in the manned space System. The ventilation, air conditioning problems and the air flow arrangement of the cabin directly affect the environmental parameters controlling and the thermal comfort of the cabin environment. So, it has an important significance to research the ventilation, air quality, thermal environment and comfort of the astronauts in the cabin under the microgravity condition. There is $10^{-3} \sim 10^{-6}$ -g₀ level of micro-gravity ($g_0=9.8 \text{ m}^2/\text{s}$) inside the cabin of spacecraft or the space station. At this point, the phenomena which are common with ground gravity such as natural convection, static pressure differential and sedimentation are greatly reduced. Therefore, forced ventilation is crucially essential to achieve the exchange of matter and energy in cabin under the micro-gravity conditions. With changes of the mission and flight time, improvement of air ventilation system in the manned spacecraft cabin determines the comfort of astronauts. The way of ventilation in such confined spaces like small cabin should give priority to the centralized air supply system. The environment inside of the space station is similar to a building on the planet. It is quite necessary to solve the design problems of air-conditioning of cabin in order to meet the astronauts' requirement of comfort when they live and work in the space station or the spacecraft, and moreover variety of spacecraft equipments, structural components and the organisms in spacecraft are unable to withstand large temperature fluctuations. In order to ensure equipments working in the normal environment and improve their performance, it is required that the spacecraft thermal control system not only ensures the maintenance of normal temperature, but also provide a constant temperature environment for some equipments. Therefore, temperature and humidity as well as the conditions of ventilation ensure the operating efficiency of equipment, structural components in the spacecraft.

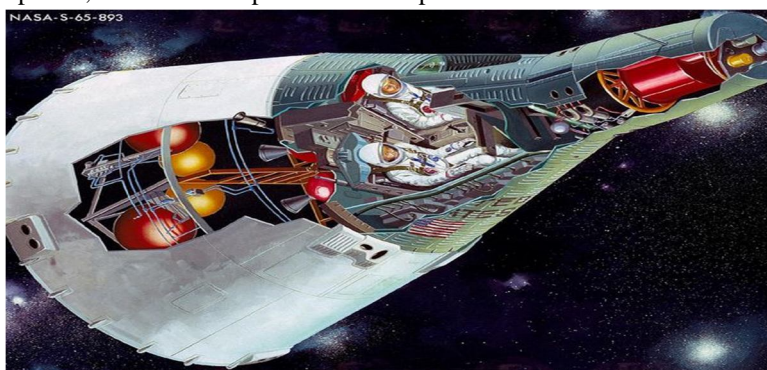


Fig. 1 Gemini spacecraft

II. LITERATURE REVIEW

- A. M. Hegar et al. examines a test method for determination of energy consumption of bus HVAC unit. The energy consumption corresponds to a bus engine fuel consumption increase during the HVAC unit operation period. The HVAC unit energy consumption is determined from the unit input power, which is measured under several levels of bus engine speeds and at different levels of testing heat load in the laboratory environment. Since the bus engine fuel consumption is incrementally induced by powering an HVAC unit, the results are subsequently recalculated to the unit fuel consumption under the defined road cycles in terms of standardized diesel engine, where the vehicle diesel engine is used as primary source of energy.
- B. Paul Maina et al. examined that natural refrigerants are environmentally benign. When other refrigerant qualities are considered, especially those relating to toxicity and flammability, carbon dioxide emerges as the best among the natural refrigerants. However, carbon dioxide based refrigerants are not without drawbacks. Even though the use of R744 – a carbon dioxide based refrigerant gas – has solved the direct effect of emissions on the environment, studies to investigate the indirect effects of these systems are needed. As a result of its superior properties, especially concerning refrigeration, we believe R744 will be a dominant refrigerant in many applications of the refrigeration technology in the future.
- C. Xiangli li et al. The design of ventilation and air conditioning system is not big but more complex, and the requirements of reliability is much higher than that of civil air-conditioning, noise and fan energy consumption is also should be strictly controlled. So it is necessary to optimize and adjust the pipeline network after the preliminary design and actual working condition simulation are finished. Before simulation optimization, deviation of some pipe flow is large. The deviation of pipe flow and design flow can be greatly reduced through adjustment of the fan model and part of the pipe diameter. A study shows that, the fan pressure head after optimization is nearly 10% less compared to the total head loss of the most unfavorable loop.
- D. H. K. F. Ehlers et al. The described measuring system proved to be valuable not only for verifying required test conditions, but also for detecting abnormal and characteristic test article or chamber conditions by assisting in leak detection, leak localizing, simple gas analysis (condensibles and noncondensibles), analysis of pumping system performance, and analysis of events (operations of valves, doors, life support systems, water boilers, and waste water dumping). Improvements could be made by the use of: a) pairs of gages supported by rotatable mounts which would permit the same gage to read, in short sequences, the gas flows in one and then in the opposite direction; b) metal-tubulated ion gages provided with instruments to measure gage temperatures; c) small mass spectrometer tubes (replacing some of the ion gages) for measuring partial pressures and for analyzing gas types; and d) power supplies for the gages providing automatic range switching and range recording.
- E. J. D. Clement et al. The scattering amplitude function has an important effect on thermal radiation transport through particle clouds, especially if the particles are highly scattering. As was reported by Stockham and Love²⁴ regarding their Monte Carlo solution for a cylindrical particle cloud, "The results obtained indicate that anisotropic scattering plays an important role in heat transfer in this geometry. While Rayleigh scattering may still be closely approximated by isotropic scattering, the anisotropic scattering results may differ greatly from those assuming isotropic scattering."
- F. Tzu-Ping Lin et al. conducted a field experiment involving simultaneous physical measurements and a questionnaire survey, collecting data from 2,129 respondents, that evaluated thermal comfort in short- and long-haul buses and trains. Experimental results indicate that high air temperature, strong solar radiation, and low air movement explain why passengers feel thermally uncomfortable. The overall insulation of clothing worn by passengers and thermal adaptive behaviour in vehicles differ from those in their living and working spaces.
- G. A. G. Buckingham et al. This paper has shown that COGGS should be able to perform the slewing, pointing control, and momentum dumping functions for the ATS-F&G mission. Its mechanical design is such that it can be constructed with conventional hardware and construction techniques. It has low power requirements and will function in an elliptical orbit as well as circular orbits with a single boom that does not have to be perfectly straight. It permits the pointing direction to be varied as desired using an onboard sensor, astronaut, or ground command.
- H. A P Narayan et al. have developed and discussed the design and implementation of an accurate and intelligent contaminant monitoring system for the space station. The use of advanced CFD techniques in tracking the air flow greatly increases the accuracy of the results. We use a three-dimensional implicit Kalman filter for the state prediction and discuss the tracking performance in the presence of uncertainty. We found that a time step of about 30 s results in real-time performance of the tracking system, given our current computational power. Further mathematical development should give rise to an efficient and accurate real-time tracking system for contaminants and match the advanced technology requirements of a tracking time interval of 15 s.

- I. Charles.B.king et al. Using current technology and existing structures, a concept for outfitting the Space Shuttle external tank at Space Station Freedom for use as a 12-man lunar habitat is presented. The addition of a resource node, an air lock, and an ECLS module to the Space Station Freedom minimizes EVA in the assembly of the habitat. Conceptual design as a lunar habitat. Post landed operations require erection of the thermal rejection system, installation of a power system, and use of lunar regolith for radiation shielding prior to manned occupancy.
- J. Eric L. Strauss et al. Ablative heat shields were designed for Space Tug aerobraking trajectories involving 2 and 30 perigee passes. The tug configuration was a 14-ft-diam cylinder with a 2:1 elliptical dome. Both a low drag and a high drag configuration were studied. High drag would be achieved by attaching a 60° retractable flare at the aft end of the cylindrical body. Silicone-base ablators ranging in density from 15-55 lb/ft³ were selected for evaluation. Flat-face ablator models were tested in a plasma arc under conditions simulating stagnation point heating for 2-pass and 30-pass entry modes.
- K. Abdul Afram et al. This work presents a literature review of control methods, with an emphasis on the theory and applications of model predictive control (MPC) for heating, ventilation, and air conditioning (HVAC) systems. Several control methods used for HVAC control are identified from the literature review, and a brief survey of each method is presented. Next, the performance of MPC is compared with that of other control approaches. Factors affecting MPC performance (including control configuration, process type, model, optimization technique, prediction horizon, control horizon, constraints, and cost function) are elaborated using specific examples from the literature. The gaps in MPC research are identified, and future directions are highlighted.
- L. K. Luck et al. The main focus of this paper is a literature review of analyses of high-performance indoor environments which aid in the design of appropriate energy efficient Heating-Ventilation Air Conditioning (HVAC) systems. In the past, investors planned and built interiors primarily according to economic considerations. Aspects of performance-oriented interior spaces were not taken into account. Yet, to meet growing expectations and requirements, it is necessary to combine thermal comfort features and energy efficient HVAC systems. A huge amount of electricity is necessary for the operation of these systems. Overall, one-third of the final energy is consumed by the provision of space heating and hot water in Germany. More than 95% of this demand is met through the use of fossil fuel. There is, however, a great potential to reduce CO₂ emissions. Forward-thinking planning includes both the careful use of resources and the optimization of performance promoting rooms.
- M. Jamal Khodakarami et al. The authors have found a reasonable amount of literature in thermal comfort in hospitals. This paper presents a literature review on thermal comfort in hospitals. From the review, the paper concludes that it is important to undertake original studies in the relationship between thermal comfort conditions and productivity for hospital staff. The study finally concluded that it is important to find some solutions to reconcile the different thermal comfort conditions required by different occupants in hospitals. These solutions could be used whenever patients and the attending caregivers have to stay in one room for a long time compulsorily.
- N. S. Wright et al. This paper presents a focused literature review to understand the common problem of fouling of air-conditioning heat exchangers aboard aircraft, with the academic consideration to employ electrostatic precipitation to remove airborne particulate matter. Particulate matter suspended in air, is carried through the matrices of aircraft environmental cooling systems. The deposition and build up of such contaminants affects the thermal performance of cooling systems and leads to component failure, expensive repairs and loss of service of an aircraft.
- O. Nayeff Najjar et al. This paper addresses the issue of fault diagnosis in the heat exchanger of an aircraft Air Conditioning System (ACS). The heat exchanger cools the air by transferring the heat to the ram-air. Due to a variety of biological, mechanical and chemical reasons, the heat exchanger may experience fouling conditions that reduces the efficiency and could considerably affect the functionality of the ACS. Since, the access to the heat exchanger is limited and time consuming, it is preferable to implement an early fault diagnosis technique that would facilitate Condition Based Maintenance (CBM). The main contribution of the paper is pre-flight fault assessment of the heat exchanger using a combined model-based and data driven approach of fault diagnosis.
- P. Pietro Mazzei et al. This paper, on the basis of the main literature indications, deals with moisture control in buildings during the summer season; so, the dehumidification of the air is analysed. Dehumidification is considered as a key feature of HVAC systems for thermal comfort. Initially, the principles of mechanical and chemical dehumidification are shown. The first one utilises mechanical means—compression refrigeration systems—to cool the air and so to dehumidify it; the latter removes the water vapour from the air by transferring it towards a desiccant material (adsorption or absorption). In the mechanical dehumidification field, a proper control of ambient temperature and humidity can be obtained by means of an air handling unit (AHU) which treats outside air alone, while recirculating air is treated by a simple cooling coil.

- Q. Pei Huang et al. Heating, ventilation and air-conditioning (HVAC) systems are widely equipped in modern buildings to provide indoor thermal comfort and guarantee indoor air quality. In this paper, a prototype of HVAC system design under uncertainty is proposed, which is able to take uncertainty directly in the design, and most importantly it can assess the performance of a design at the design stage in term of multiple performance indices and the customers' requirements and preferences, i.e. the new design method falls in the framework of multiple criteria decision making. Case studies are used to illustrate the design procedure, and the result is compared with that of a conventional design method.
- R. Peng Zhao et al. This paper has four primary goals: First, it provides the theoretical support and states the need for using HVAC systems to provide FR. Second, it proposes two methods of using HVAC systems for providing FR – a direct method and an indirect method; these two methods are developed as models and tested in simulation. Third, it addresses the challenges of using commercial building HVAC systems for FR; this motivates the development of a new supervisory control method to support the HVAC system for providing FR service. Fourth, it evaluates the simulated results based on the performance based regulation (PBR) rules proposed by the PJM regional transmission organization; thus, it provides the reference for the future field-testing.

III. CONCLUSION

From this review paper it can be concluded that to maintain a suitable environment inside the spacecraft cabin the temperature and pressure should be maintained according to the altitudes. In order to do that equipment such as heat exchangers, evaporators and condensers with full capacities should be installed to survive such conditions and to keep the passengers safe from any emergency situations as well as for an effective space time without any disturbances.

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