SUITABILITY OF COMMERCIALLY AVAILABLE LABORATORY CRYOGENIC REFRIGERATORS TO SUPPORT SHIPBOARD ELECTRO-OPTICAL SYSTEMS IN THE 10 - 77 KELVIN REGION

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ABSTRACT

The primary development of cryogenically cooled infrared systems was accomplished by the Air Force for its various FLIR (Forward Looking Infrared) systems designed for airborne, passive night vision. Essential to the development of these FLIR systems was a family of closed cycle refrigerators which had to meet a limited envelope requirement, utilize a nonlubricated compressor module, and be light in weight. These refrigeration systems proved not only costly but also were characterized by a rather short meantime before maintenance interval. Although commercially available closed cycle refrigerators accomplished the same cooling function, they use modified oil-lubricated reciprocating compressors which are limited in their axis of orientation to an angle of approximately 15-20 degrees maximum from horizon. This restriction quickly eliminated them from being considered for use aboard naval vessels for passive infrared systems.

Recently, manufacturers of commercial cryogenic refrigeration systems initiated product lines featuring oil-lubricated, rotary type compressors which, as a result of preliminary tests, indicate an acceptable tilt tolerance of up to 45 degrees.

INTRODUCTION

Over the past 15 years considerable emphasis has been put forth by various agencies within the United States Government to develop closed cycle refrigeration systems for the cooling of infrared and optical devices. The primary application has been Forward Looking Infrared Systems (FLIR) which operate on the principal of cooled (sub-77 Kelvin) infrared sensors operating in a passive mode.

Primary emphasis on developing closed cycle refrigeration systems has been undertaken by the U.S. Air Force for airborne FLIR systems and the Army for ground-based mobile vehicles. Both users share the common requirement for a miniature, dry-lubricated compressor module with a lifetime of approximately 1,000 hours and the capability of being field maintainable.

It is the purpose of this paper to introduce the concept of utilizing commercially available laboratory cryogenic systems to support and sustain the longterm operation of electro-optic systems over the temperature region of 10 - 77 Kelvin for shipboard use.

CURRENT STATE OF MILITARY TECHNOLOGY FOR ELECTRO-OPTIC SYSTEMS

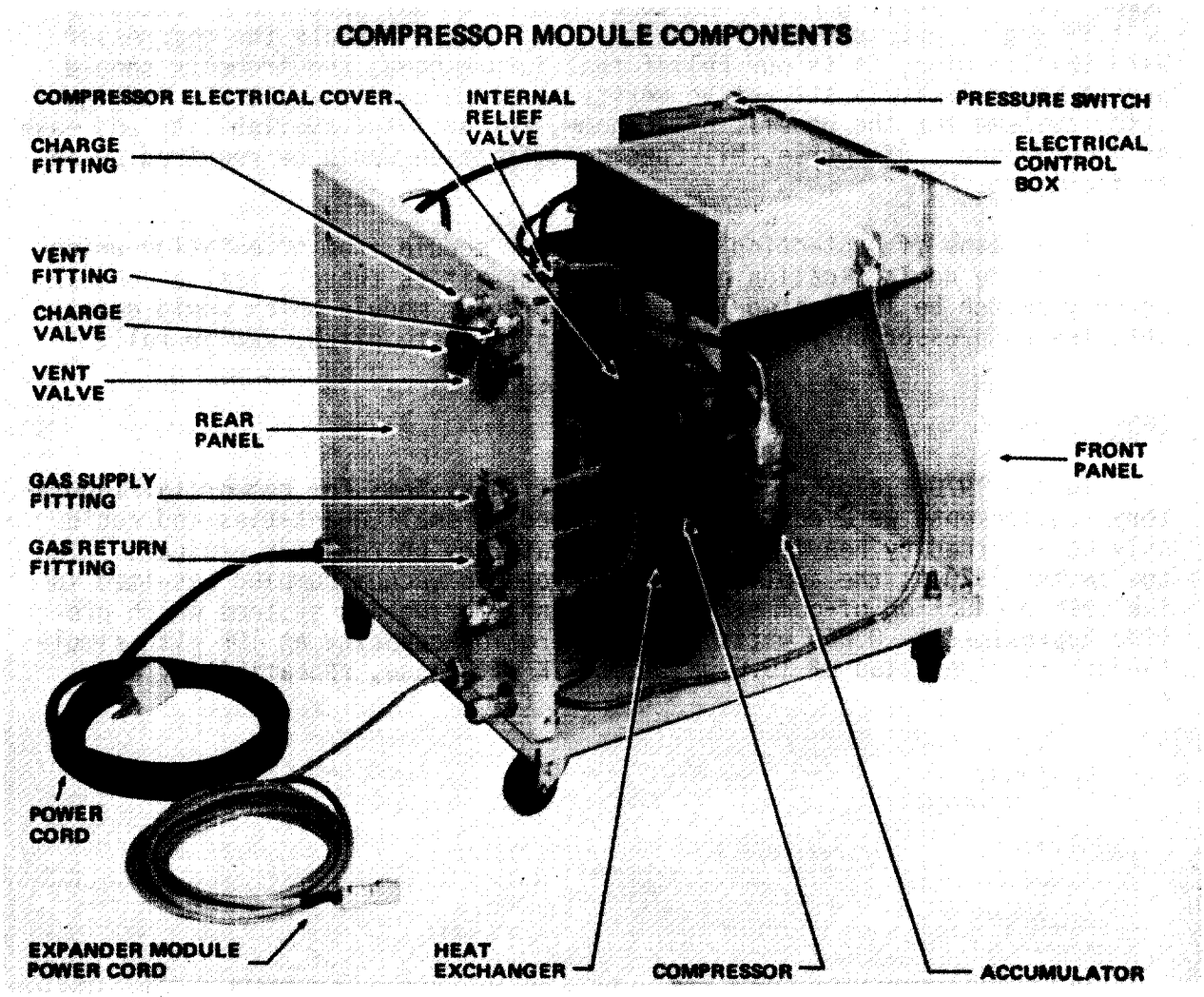
In an effort to provide commonality for the defense requirements, attempts were made to establish a common mod refrigeration system which would be interchangeable within various service requirements. This system, however, was designed for compact mobile use with size, weight, and nonrestrictive orientation being paramount design considerations. With this in mind, dry-lubricated compressors, of small size and short lifetime, have been utilized. Although they perform their intended function and have greatly enhanced the capabilities of our airborne and ground-based military forces, it is our opinion that naval requirements can use less sophisticated, although highly reliable, closed cycle refrigerators to support shipboard electro-optic systems with appreciable savings in economy and downtime for maintenance.

LABORATORY CRYOGENIC SYSTEMS

To perform the necessary cooling function for a variety of laboratory cryogenic sample cooling needs, a typical system comprises a compressor module, interconnecting ambient temperature gas lines, and a cryogenic expansion head (more commonly referred to as a cold head assembly). Commercially available, these systems have specifications of 10,000-20,000 hours of operating time before maintenance interval with projected meantime before failure of 25,000 operating hours. Additionally, the cold head assembly can be separated from the compressor module by as far as 100-200 feet by utilizing rigid plumbing for the supply and return of ambient temperature gas to the expansion module from the compressor.

Although the refrigerator cold head assembly presents no design constraints other than that of size, the typical laboratory system provides long term cooling with temperature stabilities of $\pm$ 0.01K over the temperature range of 10K to 77K.

The compressor module is the primary area of concern for shipboard



Air Products & Chemicals Model 1RO2W Rotary Compressor.

applications. The compressor is an oil-lubricated compressor which may be of reciprocating or rotary design with a weight of approximately 90 kg and may be oriented in up to a 14-20° list on reciprocating type compressors and 45° on rotary type compressors. This factor was established by elevating an Air Products and Chemicals, Inc. Model 1RO2A rotary compressor in such a manner as to allow the unit's orientation to be positioned at varying angles and the compressor's performance monitored on the inlet and outlet helium pressure gauges. Results indicated that orientation changes of up to 45° were tolerable to the compressor's function with no adverse effects in performance.

The changes in orientation were for five (5) minute duration and were accomplished in both the X and Y axis. After these tests, the compressor was operated for 1 1/2 hours. Should further testing on the part of the authors be undertaken, it would be our intent to monitor the compressor's temperature at varying positions to determine if any specific orientation or tilt angle restricts oil lubrication and thus overheats the compressor. With this in mind, it is our belief that future naval requirements should pursue the relatively attractive merits of commercially available refrigeration systems for the benefit of economy, reliability, availability and ease of maintenance. Of course, Mil-Spec certification would be required prior to fleet use.

As a means of protecting the compressor module from orientation which would provide nonlubrication of moving parts, it is thought that a conical mercury switch be integrated into the compressor module which would deactivate the compressor during times of excessive list, pitch, yaw or roll.

CONCLUSION

In the 1970's closed cycle refrigeration systems for commercial laboratory requirements were costly, manufactured in small quantities and could only be afforded by heavily endowed laboratories or research projects. In the latter 1970's, the application of cryogenic vacuum pumping resulted in the mass production of commercially available cryogenic systems which provide approximately 0.250 watts of refrigeration capacity at 10K with simultaneous refrigeration of 10.0 watts at 77K with ease, repeatibility and economy.