AD-A171 756 DEVELOPMENT OF A LOW NOISE 10K J-T REFRIGERATION SYSTEM 1/1
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W A LITTLE ET AL. 15 AUG 86 N00014-86-C-0301

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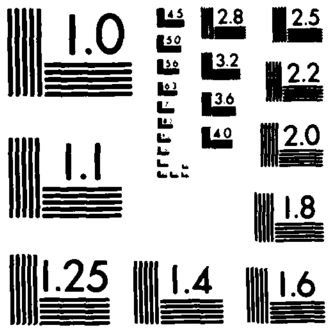

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Item No. 0001AA

Technical Progress Report

Development of a Low Noise 10K J-T Refrigeration System

August 15,1986

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Contract No. N00014-86-C-0301

ABSTRACT

The Purpose of this Contract is the development of a low noise , closed cycle, Joule-Thomson refrigeration system for10K operation. This report summarises the general plan of attack, what problems are likely to come up, and what work has been completed in the first 30 day of the Contract.

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1.0 INTRODUCTION

This report summarises the work done to date, in the first 30 days, ~~of Contract No. N00014-86-C-0301~~ on the development of a low noise, Joule-Thomson, microminiature refrigeration system designed for 10K operation. Previous work on the development of this system had been done under Contract No. N00014-85-C-0428. That was completed in February 1986 and the results obtained were summarised in the Final Technical Report 0001AC of that Contract. The new contract has an effective start date of July 15,1986. The first few weeks since then have been spent reviewing the work done under the previous contract and, because of the break in funding, bringing new personnel up to speed on the work done earlier. Dr C.R. Wolfe, who had previously played a lead role in the develpment of the refrigerator, has taken a position at Lawrence Livermore Laboratories, and is no longer available to the project.

The plan of attack for the present contract has three major parts to it: first, the development of the three stage refrigerator; second, the development of a suitable compressor to provide the gases and thirdly, the development of an effective gas cleansing sytem.

1.1 Refrigerator Design

Preliminary results obtained earlier, on the first two stages of the refrigerator, showed that the argon stage had an excessively high pressure at the boiler. This gave an anomalously high temperature, in excess of 100K, for this stage. In addition, it was found that the flow through the hydrogen stage was excessively large. This tended to overload the argon stage and raise that temperature still further. The entire heat exchanger calculation was redone and the various channel dimensions recalculated taking in to account what had been learned from the firing profile which was necessary to obtain proper sealing of the laminations of the refrigerator. Some significant changes in channel dimensions were found to be necessary, and these are being incorporated in the next build of the refrigerator.

1.2 Digitizing of Refrigerator Layout

One of the most costly aspects of the design of a new refrigerator, particularly one involving several stages, is the repeatitive, re-design and layout of the various heat exchanger sections. This is an iterative process because of the poorly understood factors which go in to the firing of the refrigerator and which affect the roughness of the channels and hence the heat transfer and flow characteristics of the refrigerator. Until now the layout has been done on Rubylith by hand. With the availability of Laser printers and the Macintosh™ computer it is now possible to develop the design on the computer screen and subsequently to print the image on vellum and then have the image reduced photographically to the size for the mask. This process, by which the design can be manipulated on the computer, reduces greatly the amount of labour necessary to make modifications to the refrigerator design. We are now in the process of digitizing the layout of each of the heat exchanger sections so that the design can then be manipulated in software. This will allow us to make the minor corrections to the hydrogen heat exchanger which our calculations indicate are necessary.

1.3 Theoretical Study of Gas Mixtures

Some years ago we had studied the use of various hydrocarbon-nitrogen gas mixtures in our microminiature refrigerators and obtained the interesting result that certain of these mixtures could give a cooling efficiency a factor of 5 to 10 times that of nitrogen alone, yet allowed operation at temperatures close to 80K. It was also found that efficient operation could be obtained at operating pressures below 1000 psi in a properly designed refrigerator. It occurred to us that the use of such a gas mixture instead of argon in the first stage of the three stage, 10K refrigerator would simplify the design of the first stage compressor, permit larger hydrogen flow rates in the same refrigerator and provide much faster cooldown. However, to do this and obtain optimum results, a much better understanding of the gas mixtures would be required. In particular, the phase diagrams of the various mixtures would be needed containing both isobars and isenthalps. These have only been determined experimentally for a few selected mixtures. However, it has been known for many years that it is possible to model the entire phase diagram of most gases using one of several empirically determined equations of state. In particular, an equation of state developed by Benedict, Webb and Rubin in the Journal of Chemical Physics, 8, 334 (1940) has been shown to describe to high accuracy the behaviour of pure hydrocarbons over the entire range from the gaseous to the liquid state. In addition, it has been successfully applied to mixtures of these gases. At the time this was done computing facilities were rather primitive, it is now possible to handle all the necessary calculations for the determination of the properties of arbitrary mixtures on a PC, very much more easily and quickly. We have begun a study of these mixtures using this equation of state and have been able to reproduce the phase diagram, fugacity and the isothermal variation of the enthalpy for the pure components and have begun to map out the coexistence curves between liquid and gas. A recently graduated student from the physics department at Stanford University, Al Nash has joined the project for the summer and has participated in this study. We believe we will be able to get a good physical understanding of the factors which give these mixtures their high cooling efficiency and will be able to determine which would be most suitable for use in the first stage of the refrigerator. We will then study their use experimentally in the refrigerator.

Empirically we had noticed earlier that small changes in the composition of these gas mixture gave dramatically different results at the lowest temperatures. This needs to be studied further and the above theoretical analysis can be expected to provide the means to do this.

1.4 Helium stage test fixture

As pointed out in our earlier studies, the one problem which can be expected to be most troublesome in the design of the helium stage of the three stage refrigerator is the heat transfer between the two gas streams in the helium stage through the glass interlayer. The poor thermal conductivity of the glass is the limiting factor in this stage. In order to study this problem experimentally we need a simple test fixture which would allow us to check the heat transfer at hydrogen temperatures. It is too expensive in time and money to use the complete refrigerator for these tests at this time. We have designed a simple fixture which will allow extensive tests to be made on prototype designs of the heat exchanger at temperatures between about 25K and 19K or below, in order to address these problems before completing the design of the three stage refrigerator. This will be based on a simple, straight, argon stage refrigerator, similar in design to a standard MMR product refrigerator; and to this will be fused a simple hydrogen refrigerator. Use of this will give us some experience in the operation of the hydrogen stage and of the filtration system.

1.5 Filter Design

We have completed design of a small zeolite filter, which will be used to trap condensible impurities in the hydrogen and helium gas streams. For laboratory tests this will be cooled in liquid nitrogen but for space applications it will be radiantly cooled. This is a stainless steel filter chamber, filled with zeolite and sealed by welding it closed. The inlet and outlet lines are connected with Swagelock fittings.

2.0 Compressor design and fabrication

In the next month we plan to examine in detail the seals and cylinder walls of the hydraulically actuated, single gas, prototype compressor, which we built and ran for 500 hours under the earlier Contract. We have replaced the hydraulic cylinder which had developed a hydraulic fluid leak, with one designed for higher pressure operation, and have tested it successfully with the compressor operating at 2000 psi.

We are in the process of re-designing the pistons on both stages of this compressor so as to be able to operate with three sealing rings instead of one. One is suitable for tests on accelerated wear but the final compressor will need back-up rings to ensure a longer operating life. Mr G. Doda, who had been responsible for much of the design of the details of this compressor has taken a position with another company and will no longer be associated with the project. Mr Edman, design engineer who will be replacing Mr Doda, is presently reviewing the compressor design and the drawings of the different components. Based on the conclusions we draw from these studies certain modifications will be made in the piston design and the new designs will be fabricated and tested. If these prove satisfactory we will proceed with the fabrication of the three gas,W compressor.

3.0 Summary

Each of the three areas of study have been started in this first month of funding. The refrigerator is being re-designed and is being reviewed in the light of new developments in cooling with gas mixtures; the compressor is being examined for the effects of wear and the design modified so as to incorporate three sealing rings in each stage piston. Finally, a design of a filter has been completed and will be fabricated and used to determine if adequate gas purity can be obtained with it for continuous operation of the refrigerator at hydrogen and later, at helium temperatures.

6.0 Persons participating in project.

W.A.Little	Senior Scientist
H. Edman	Engineer
M. Stewart	Production supervisor
M. Dubois	Technician
A. Nash	Physicist.

Respectfully submitted : WALittle

W.A.Little (Chairman)

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