**Title**
ESCAR HELIUM REFRIGERATOR FACILITY



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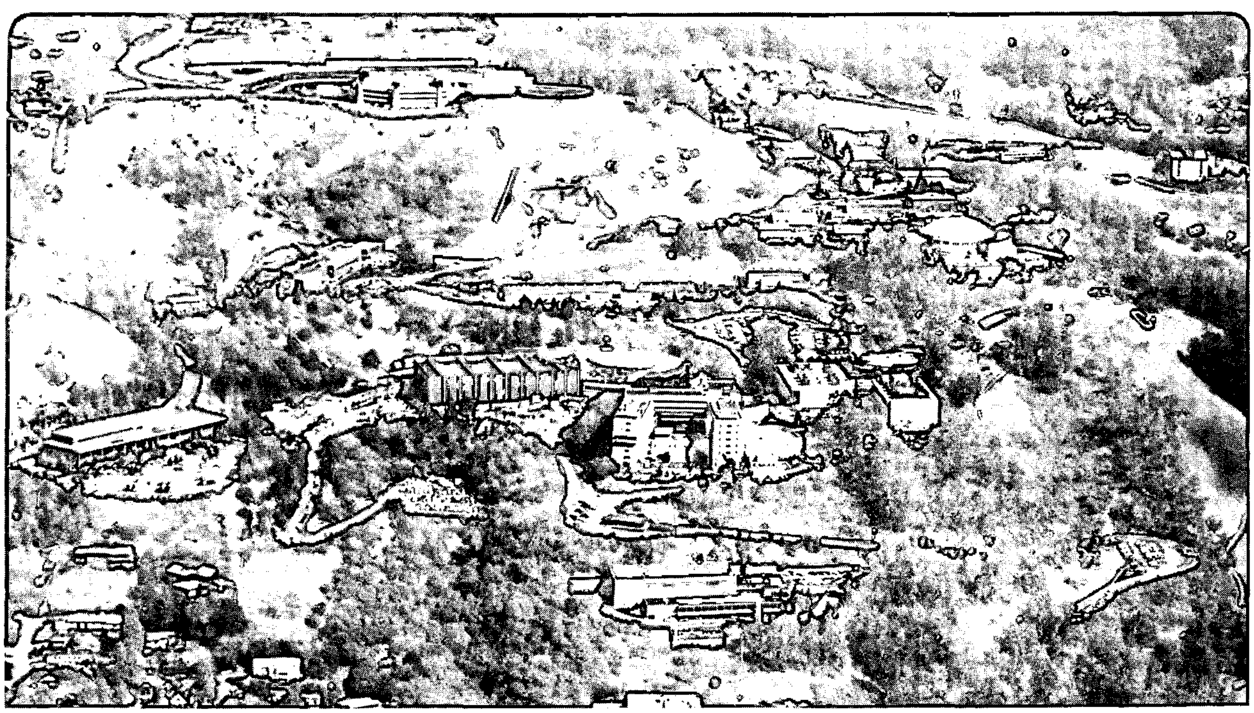
**Publication Date**
1980-06-01

# Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

## Engineering & Technical Services Division







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| LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA ENGINEERING NOTE | | CODE ES 0501 | SERIAL M4852 | PAGE 1 OF 8 |
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| AUTHOR R. Byrns, T. Elioff, M. Green | DEPARTMENT Mechanical Engineering | LOCATION Berkeley | DATE July 31, 1974 | |
| PROGRAM — PROJECT — JOB ESCAR HELIUM REFRIGERATOR FACILITY | | | | |

## Introduction

An experimental plant facility is proposed in order to conduct investigations pertaining to the development and testing of medium-size helium refrigeration systems for present and future cryogenic programs. The building structure and base facility will be utilized over a projected 2.5 year development period for experimentation in the area of advanced helium compressors. At the conclusion of these experiments the facility is expected to be utilized by other laboratory cryogenic programs such as cryopumping for the Hilac-Bevalac complex, helium refrigeration for the Superconducting Magnet Test Lab and for the ESCAR project, and providing liquid helium for various laboratory research projects. The rotary screw compressor appears to have numerous advantages for us in relatively large helium refrigerator/liquefier systems, and a development program is proposed to realize these potential advantages.

This project will have significant bearing on cryogenic accelerator projects at this Laboratory as well as others. Examples include: PEP-II (SLAC-LBL), ISABELLE (BNL), and the energy doubler (NAL). Apart from accelerator projects, other programs with projected cryogenic utilization may also benefit. Examples include electric power transmission and CTR programs.

The experimental results obtained from this development will provide clear specifications for refrigeration systems that can be used in future projects with a high degree of reliability. In addition, it is believed that the proposed experimental system, if successful, should result in considerable cost savings for future projects; this includes both capital and operating-maintenance costs. Prototype operational systems will be tested and evaluated under realistic conditions providing liquid helium to ESCAR (Experimental Superconducting Accelerator Ring) and a variety of other laboratory programs requiring cryogenics. Thus, in addition to the longer range projected benefits, the system can be tested and utilized with immediate laboratory programs.

## Cryogenic Facility

The proposed facility will consist of a helium refrigerator/liquefier of approximately 1500 watts capacity at $4.2^{0}$K or 400 liters liquid helium/

hour, or combination thereof. The major items will be the cold box, expanders, and a building enclosure (~30' x 30') with appropriate support pads and hoist equipment. The cold box, 8 ft dia. x 12 ft high, with high-vacuum insulation, will contain the heat exchangers and expanders. Controls and instrumentation will be sufficient for manual operation.

The size of the refrigerator plant is selected to realistically model future projects. While multiple units of this size are required for systems such as PEP II and the NAL energy doubler, the present ESCAR project at LBL is well matched for a single 1500 watt unit. As ESCAR is a development to build and test the world's first complete superconducting accelerator system, it will provide the most appropriate and comprehensive tests of the proposed cryogenic facility with full-scale operating requirements.

The cold box meeting the technical requirements of the proposed system is potentially available from several manufacturers, will form the basic facility, and will be capitalized with plant funds. The evolution of the compressor system may involve the trial, development, and testing of a number of units as described below. Due to the various modifications, unknown reliability of the first compressor units, and the "wear and tear" they will be subjected to in the development and testing phases, it is unlikely that the compressor system will be of any value at the end of the experimental period. This development will be supported by operating funds.

## Justification of Need

A significant improvement in the state-of-the-art of medium-size liquid-helium refrigerator systems is required for future cryogenic accelerator systems. This development is important for future projects such as PEP II, which would utilize six or more systems of the size proposed here. Programs at other laboratories also project similar systems. Moreover, a meeting was held at LBL on May 21-23, 1974, to discuss the needs of the AEC's national laboratories for helium refrigerator systems in the proposed size range. Representatives from BNL, LASL, Oak Ridge, NBS, HEPL, and EPRI attended this meeting and expressed their desire for a system in this size range for their future projects. All in attendance agreed they would like a standard "off the shelf" system which would run on almost a turn-key basis thereby eliminating the need to have to engineer refrigerators as well as the basic experiment. Smaller systems in the range of 75 watts at 4 deg. K are currently available as a standard manufactured package and have been used at many Labs with great success. It is this sort of arrangement that everyone wants, only in the larger size.

Systems of greater reliability than the few custom designed and built units now in operation are required. Increased reliability will result in considerable improvement in machine operations, as well as substantial savings in operational costs which are essential in the realization of programmatic goals. Therefore, the laboratory is undertaking a development program to advance the state-of-the-art significantly in order to have the necessary advanced technology for future high-energy physics proposals.

<u>Compressor Development Program</u>

<u>Summary</u>. It is proposed to develop a rotary screw compressor system to supply the refrigerator with 190-200 g/s of pure helium gas at a pressure of about 18 bar. This requires 750-800 HP of compressor capacity.

Although conventional reciprocating compressors are available in this size range, they are massive and bulky, and their reliability leaves much to be desired. In the last few years, a new line of rotary screw compressors has been developed, which are much smaller and potentially more reliable. These compressors are positive displacement dual-screw compressors. While rotary screw compressors are available from some vendors, they have not been used for helium, as dry helium for cryogenic refrigeration is a particularly difficult gas to pump. Screw compressors offer a number of advantages over their more conventional counterparts, and initial cost estimates are quite favorable.

<u>Background.</u> Historically, the standard laboratory, intermediate or large size cryogenic refrigerator/liquefier has been assembled with reciprocating, positive-displacement compressors. The reciprocating compressor has many disadvantages, especially in the areas of capital, installation, and operation costs as well as complexity. The large size required by multiple cylinder layouts, the high shaking loads and the difficulties in lubrication, oil removal and wear rates create particular problems for many special cryogenic applications. Now with the incipient growth and application of superconducting devices in many areas, incentives are

increasing for the development of an inexpensive, reliable, compact (even semi-portable) compressor system.

With the standard reciprocating compressor, the designer has two choices--lubricated or non-lubed. The lubed system can be operated for long periods between maintenance, but it requires an absolute oil-removal system. Also, the oil-injection must be carefully adjusted for the proper balance between rapid ring wear and flooding the clean-up system. For the non-lubed case, one can select filled Teflon (fluorcarbon) seal rings with their frequent maintenance periods or labyrinth seals with their high-leakage rates.

Rotary-type compressors have the potential for compactness, simplicity, and high reliability, minimal vibration and relatively low cost. In the rotary group, centrifugal compressors are unique because they create pressure by velocity increase. They are not positive displacement, and hence subject to much slippage. This is their primary disadvantage, especially in the cryogenic application. Centrifugal machines can offer the advantages of oil-free gas and no wearing parts in the process stream, but for low-density gases they require many stages to reach the higher pressures, and very high-tip speeds, with highly stressed and precision-balanced rotors.

In the rotary positive-displacement compressor group, various types are available: rotary screw, lobe or Roots-type, water-ring and sliding vane. All of these machines have similar performance curves to those of reciprocating compressors: fixed capacity with variable back pressure. The water-ring isolates the process gas from the rotating metal parts and provides excellent cooling but introduces other problems with water vapor removal and potential heating malfunction. The sliding vane type requires oil lubrication and has high-wear parts in the process stream. The lobe or Roots and the rotary screw type seem the best of the group because they can deliver oil-free gas and have no wear parts in the stream. The design gives them a through-put capacity much larger than reciprocating units without pulsation problems.

Advantages of the Rotary-Screw Compressor. The rotary-screw compressor is the most attractive system for development because of the following advantages:

1. High Efficiency: The efficiency characteristics curve is relatively flat with excellent operation over a wide range of conditions. The efficiency does not decrease with time because there are no wearing parts to reduce the through-put.

2. Mechanically simple - High reliability: Few working parts result in a design for long,continuous operation. The screws are very rugged, lightly stressed and insensitive to shocks and overload.

3. Low maintenance: Elimination of wearing parts such as valves, rings, cylinders and liners extends life and minimizes maintenance costs.

4. Oil-free delivery: The machine has the potential for oil-free gas delivery; however, for helium, this will depend on the results of the development program.

5. Compact, light weight: The small size and low weight result in reduced building and foundation costs. Skid mounting is feasible for flexibility.

6. Minimum vibration: Free of unbalanced forces, and high amplitude vibration eliminates the need for heavy foundations, and does not damage surrounding piping and instruments.

7. Stable performance: Positive displacement allows the unit to operate over a wide range in compression ratio, speed and gas density with stable discharge and without the pulsation of reciprocating units or the surge of centrifugals. This stability permits easy operation with other compressors in parallel or series.

8. Drive flexibility: Adaptable to high-speed electric motors, gas or diesel engines, gas or steam turbines. Direct drive and vari-speed

8. (Continued)

is possible. The adaptability over a wide range of speed and performance makes the machine especially desirable for a development and research study in an expanding technology.

9. Cost Savings: Relative to reciprocating units (1500 watt size-range), capital cost reductions of ~ \$150,000/unit are estimated. As 10 to 25 units are projected AEC wide for various projects in the next few years, this can amount to \$1.5 - 4 million in capital savings alone. With minimization of wear and optimized reliability, operating and maintenance cost savings can easily approach or exceed the above capital cost savings. Also, the flexibility of a semi-portable skid-mounted compressor permits minimal redundancy and standby units for widely separated cryogenic stations.

Experimental Program. The steps in the experimental program development are outlined below:

1. Manufacturer and Trade Survey. Discussion and study with rotary screw compressor vendors and users. The screw compressor is a rather recent (10 years) development and has not been developed for helium systems of the size required here.

2. Compressor Design Study. The gases used for low-temperature work--hydrogen and helium--create problems because of their low density (high leakage, slippage, low oil entrainment for lubrication) and high specific heat ratios. This means that for helium, if the compression ratio is too high, the heating can be severe and adequate cooling must be provided. A design balance must be reached between number of stage and balanced cooling of components. A number of variations will be considered.

3. Purchase of First Model for Helium Conversion. This will be a full-scale unit, large enought for 1500 watts refrigeration at $4^{o}K$ (or

3. (Continued)

dependent on system and redundancy design purchase of 50% compressor capacity). Whereas some preliminary work could be done with small models, anything less than a full-scale final test of the complete system could only furnish incomplete information subject to challenge. Subsequent units may be required, depending on the experimental results.

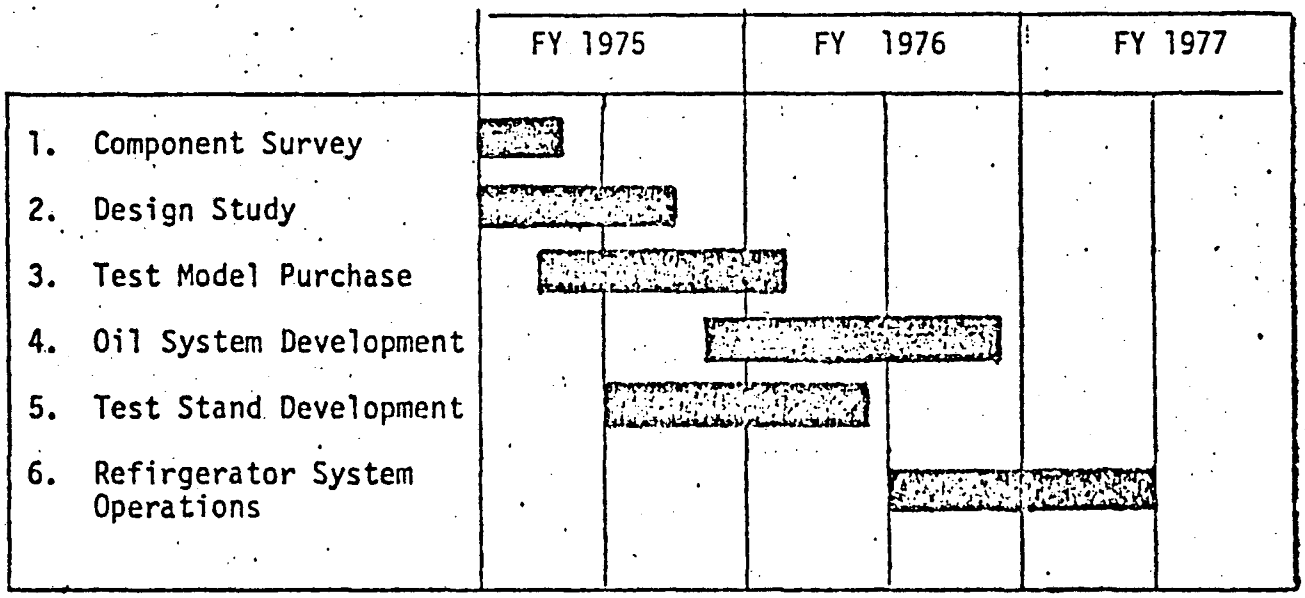
4. Oil/Coolant System Development. Some industrial techniques are available, but overall system will require design, assembly, testing and evaluation. One technique, used for small commercial units, injects cooled oil directly into the process stream, cools it, removes it completely downstream, and returns it to the closed cycle. This technique permits a closer approach to isothermal compression and provides full ring and cylinder lubrication. Ideally, it would be best to eliminate oil completely from the process stream; but if that is not possible, then a satisfactory clean-up system must be developed. Various techniques will be investigated.

5. Test Stand Development: Operation on closed-loop system with full flow and load (and overloads). Operation without process stream oil or other fluid (kerosene, $H_2O$) contaminant if possible. Depends greatly on gas slippage, number of stages, and heating.

6. Incorporation of Compressor Operation with Helium Refrigeration and Loads. This would involve operation of the complete system, compressor(s), refrigerator and loads (e.g., ESCAR) and would constitute a final examination and proof of the system. Unattended, continuous operation of something like 6000-8000 hours will be the objective.

Schedule & Costs

A project schedule for the development is as follows:




Estimates for the capital and developments costs are shown in Table I and II. Operational costs for Test Stand Development and refrigeration system operations of course depend on the success of various stages of the initial development program,and the best estimates for FY 76 and FY 77 are provided.