500,000 Miles Without an Overhaul

Thomas J. Peterson

A helium expansion engine, manufactured by Koch Process Systems, Inc., extensively modified by technicians in the Cryogenics Department of the Accelerator Division, and installed in the Fermilab Main Ring, has been operating for more than a year without an overhaul.

Liquid helium used to cool the superconducting magnets of the TEVATRON is produced by 24 satellite refrigerators in conjunction with the Central Helium Liquefier. Each satellite refrigerator has one "wet engine," a machine whose purpose is analogous to that of the expansion valve in a household refrigerator. It expands the coolant (helium in this case, rather than freon), which cools at it expands. The wet engine is much like any other piston-type engine in that high-pressure gas in its cylinders pushes on a piston which is connected to a crank and drive shaft.

The wet engine drives a small electric generator, but that is just an incidental benefit. What we really want is its exhaust, liquid helium (hence the name, "wet"). Even the helium entering the engine is so cold that all other gases except helium are frozen solid. Valves in these engines can be damaged by solid particles of frozen air if the helium is contaminated with air. Lubricants, of course, would also be frozen solid, so none can be used in the cold parts of a wet engine.

Each engine has two pistons and four valves, which typically go through about 120 cycles per minute, over a million cycles per week. Valves and piston seals must remain leak tight, but eventually, parts wear and fail and must be replaced.

Although expanders similar to these have been used for making liquid helium since the 1960s, reliability has always been a problem. Even in the late 1970s when prototype satellite refrigerators began operating, some similar engines did not last 48 hours without breaking. Six to twelve weeks before failure was typical.

But during the last Collider run, which ended in May of 1987, our 24 wet engines averaged more than 5000 hours (over six months) without failure. Most were overhauled as a part of scheduled maintenance, but a few were let go to see how long they last. One has now exceeded one year without major repairs.

The author, with the Fermilab Accelerator Division Cryogenics Department at the time of this writing, is currently with the Accelerator Division Mechanical Support Department.

A car averaging 50 miles per hour would have gone almost 500,000 miles in that time, with only oil changes and tune-ups.

The reasons for this success include design improvements made here at Fermilab, years of testing and data collection from operating engines to check performance of newly designed components, and skilled technicians assembling and maintaining these engines. A great many people have been involved in this effort, including people at the Bubble Chamber and others in Research Division Cryogenics as well as in the Accelerator Division. The purity of the helium in the cryogenic system is also a key factor affecting lifetime.

(Fermilab photograph 87-432-11)

Expansion-engine crew, Cryogenics Department, Accelerator Division. Left to right: Steve Dochwat, Jeff Spencer, Dan Freeman, Jim Thompson, Tom Peterson (now with the Mechanical Support Department), and Mark Gilmore. Not pictured: Joe Savignano and recent full-time expansion-engine people Ralph Afanador, Ann Eighorn, Carl Pallaver, Ernie Ramirez, and Ted Roberts.

Institutions and companies using similar helium liquefiers have called us for advice regarding these engines. Among these users who have contacted us are the University of Washington, Kansas State University, GA Technologies, and General Electric. We have cooperated with Koch Process Systems in communicating to them our experience, design changes, and suggestions. Helium liquefiers which Koch markets for magnetic resonance imaging devices include expansion engines which incorporate many features based on experience at Fermilab.

[The Friends of Fermilab, Inc., is a frequent and welcome guest to the pages of Fermilab Report *(see* Fermilab Report *November 1983, September 1985, February 1986, April/May 1986, October 1986, and July/August 1987). The following article, to be published in slightly different form in the proceedings of the Federal Laboratory Consortium semi-annual meeting (November 3-5, 1987, Sacramento, California), provides an overview of Friends programs, most of which were unique at the time of their inception. These programs have placed the Friends of Fermilab at the forefront of the effort to help build an educational foundation for this country's scientific future. - Ed.]*

Precollege Education Programs at Fermi National Accelerator Laboratory

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Introduction

Most precollege science education programs at Fermilab are sponsored by the Friends of Fermilab,Inc., a not-for-profit corporation founded in the State of Illinois in 1983. The Friends of Fermilab's mission is "to provide support for endeavors extending Fermilab's mission of research in fundamental physics to its social responsibilities in science education." Today, the Friends sponsors a number of programs at Fermilab for elementary and secondary students and teachers. It has raised close to $1 million from private and public sources and continues to develop and conduct programs in direct response to the needs of the education community. Friends of Fermilab program reports and "how-to" manuals are shared with other institutions interested in implementing similar programs.

In this presentation we will describe the organization and the program development process based on Friends experience. The Summer Institute for Science Teachers (SIST) will then be used as an example of a model program. Finally, an overview of other Friends precollege programs at Fermilab will be given.

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Organization and Program Development

During the past four years of its existence, Friends of Fermilab has developed a successful working format for program development and implementation. The process starts with the appointment of a program committee consisting of educators (teachers, school administrators), Fermilab physicists, and the program director for the Friends. The program committee conducts a Needs Assessment Workshop to identify the current needs in science education that could be addressed at Fermilab. Based on the goals set by the workshop, the Program Committee drafts a proposal for consideration and approval by the Friends of Fermilab's Board of Directors. The board, which consists of Fermilab, civic, business, and education community leaders, approves the proposed programs and proceeds to seek funds from private and public sources. When the funds become available, the program committee hires a project director who is fully responsible for the conduct, evaluation, dissemination, and writing of the program reports.

The involvement of master teachers from the inception of a program is the most important element in the success of Friends of Fermilab programs. The project director and most of the program staff are drawn from local schools. In many cases, the project director and the key staff personnel are teachers who participated in the needs assessment and therefore had a part in the program's design. Scientists from Fermilab and other laboratories and universities are the program lecturers and consultants with very little, if any, administrative responsibilities. Friends of Fermilab is responsible for management and prudent use of funds.

Another important element is a carefully developed program budget that provides the project director with well defined working parameters. Program funds are dedicated funds. This provides each program with complete budget autonomy and independence.

Curriculum development and participant selection are the responsibility of a committee of program staff members, teachers, and scientists. It is very important to recognize that teachers are most sensitive to what type of teacher or student will benefit most. The correct combination of the course content and participants assures a successful program.

Formal and informal evaluations of a program are conducted by the staff and the participants. The program reports are written by the project director. Subsequently, based on these reports, Friends staff develops how-to manuals for use by others. The curriculum materials developed by the program activities, if any, are also made available.

Summer Institute for Science Teachers: A Model Program

Most of the processes described above evolved through the experience of the Summer Institute for Science Teachers program. In response to Fermilab's interest in providing support for high-school science teachers, the Friends of Fermilab conducted its first Needs Assessment Workshop in 1982. Secondary schools, universities, community colleges, private industry, and research institutions were represented at the workshop. Discussions began in four small groups where individuals were asked to suggest objectives. Each group reached a consensus on five or six priorities which were presented to the entire group. After considerable discussion, the participants recommended five objectives. This advice was invaluable in developing the program. The five objectives, which are *not* ranked, include:

- Targeting successful and lively teaching techniques for existing materials, including laboratory preparation and techniques, and computer applications.
- Improving the teaching of problem-solving skills.
- Enhancing teachers' backgrounds in basic subject matter.
- Exposing teachers to current developments in scientific research, and basic objectives and problems in modern science.
- Strengthening the awareness and teaching of contemporary relations among science, technology, and society.

Based on these objectives, the Program Committee drafted the proposal that has successfully raised funds for five consecutive Summer Institutes for biology, chemistry, and physics teachers. In 1987 the institute was expanded to include a section for mathematics teachers. Using the proposal, and later the how-to manual, several other institutions conducted programs modeled after the Summer Institute.

High School and Junior High School Programs

Over the past four years, the Friends has sponsored, or co-sponsored with Fermilab, 15 education programs for elementary and secondary school students and teachers. Some of the programs are described here.

Beauty and Charm at Fermilab - An Introduction to Particle Physics

A week-long particle physics curriculum for the junior-high classroom was developed. Teachers attend workshops to become familiar with the curriculum, including several simple hands-on experiments that demonstrate concepts such as "How Small is Small?" and "How to Measure What We Cannot See." The teachers are provided with a "kit unit" which includes all the materials needed for the classroom experiments, a manual outlining the day-to-day conduct of the curriculum, and audio-visual materials to supplement the curriculum. After teaching the classroom unit, the teachers may accompany their students on a visit to Fermilab to tour working areas and meet with a Fermilab physicist.

DOE High School Honors Research Program in Particle Physics

The objective of this program, which is sponsored by the U. S. Department of Energy, is to expose gifted high school students to the research done at a world-class particle-physics laboratory. Participants join groups of physicists and graduate students doing particle-physics research. The program includes lectures by Fermilab staff physicists, lab tours, and tutorial sessions, as well as on-the-job experiences. Students spend two weeks working and studying at Fermilab. They are under the supervision of master high school physics teachers and are boarded at the Illinois Mathematics and Science Academy. Students in this program come from the 50 states, the District of Columbia, and six foreign countries.

Target: Science and Engineering - An Apprentice Research Program

Gifted minority high school students are nominated by their schools and selected by a committee composed of Fermilab Equal Opportunity Office personnel, Fermilab scientists, and area educators. The selected students, the majority of them from Chicago schools, spend six weeks in the program. Mornings are spent working side-by-side with a scientific, engineering, or technical mentor at Fermilab. During the afternoon, students attend classes taught by high school teachers and receive assistance in the preparation of an individual or group research project, which is generally based on some aspect of the morning work. The students receive a combination of salaries and a stipend for their participation in the program. The program is in its eighth year at Fermilab, and is co-sponsored by Fermilab and Friends of Fermilab.

Physics West and Chemistry West

Friends of Fermilab sponsors Physics West and Chemistry West, network organizations for area teachers. The objective of these programs is to prolong the

beneficial effects of the SIST for institute "graduates" and other science teachers. Each group meets monthly in a local school or college in order to share skills, strategies, and materials for the high school science classroom.

These and other Friends programs have generated a variety of classroom materials such as Standard Model charts and the Big Bang poster (available from Friends of Fermilab, P.O. Box 500, Batavia, Il 60510, at $6.00 for both or $4.00 each; the charts are 2 ft x 3 ft in size) which are used by science teachers nation wide. The Friends of Fermilab is currently developing materials that can be directly incorporated into existing physics curricula. This program, "Topics in Modern Physics," is under the direction of six master physics teachers. The *Resource Manual*, including material on particle physics, symmetry, relativity, accelerators, detectors, and cosmology, will be tested in 50 classrooms across the country by participants in the 1986 Conference on the Teaching of Modern Physics which was held at Fermilab. Later, other teachers will be trained to merge the *Resource Manual* material with existing physics textbooks.

The vitality, versatility, and high quality of the precollege programs at Fermilab are due in large part to Fermilab scientists and their commitment to science education. Through Friends of Fermilab, the intellectual resources of Fermi National Accelerator Laboratory have been utilized to "extend Fermilab's mission of research in fundamental physics to its social responsibilities in science education."