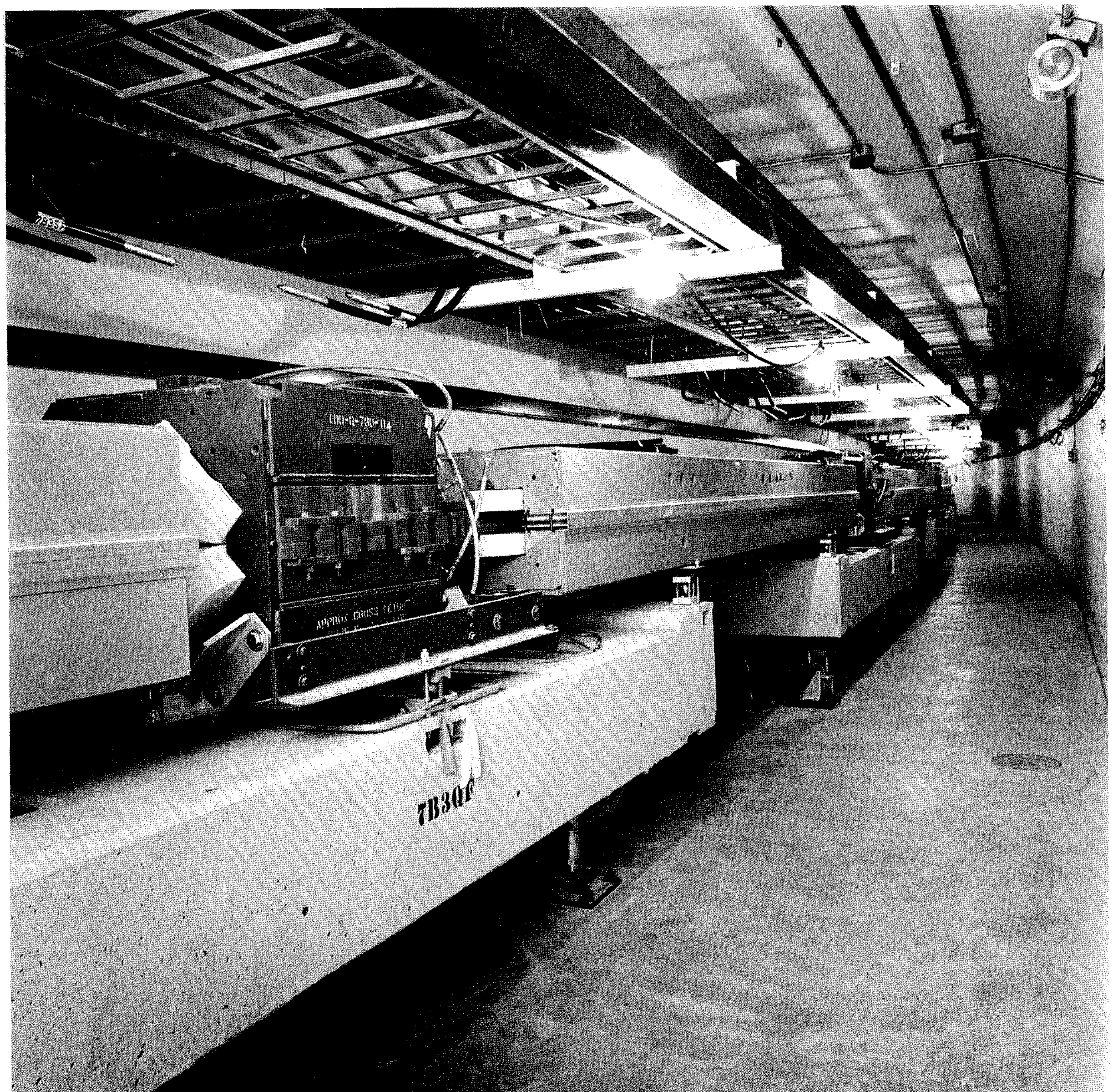
# SLAC BEAM LINE

*There is no excellent beauty that hath not some strangeness in the proportion.*—Francis Bacon

*Volume 10, Number 7* *July 1979*



This month's cover photo, by Joe Faust, shows a portion of the PEP storage ring tunnel in which the installation of technical components is nearly complete. PEP is now expected to begin colliding-beam operation in December of this year. The article on pages *2-5* of this issue takes the reader on a tour through some of PEP's conventional facilities.

In This Issue

# A TOUR OF PEP

The present PEP construction schedule calls for first injection of an electron beam into a portion of the PEP ring in early October of this year. It is expected that the first full operation of the ring, with colliding electron and positron beams, will occur in mid- or late December. Recently, PEP's new Chief Engineer, Vish More, took *Beam Line* reporter Bill Ash and photographer Joe Faust on a tour of the PEP tunnel and buildings to see the progress of the work. The following article includes Ash's description of the tour and Faust's photographs of several of the areas that were visited.

---

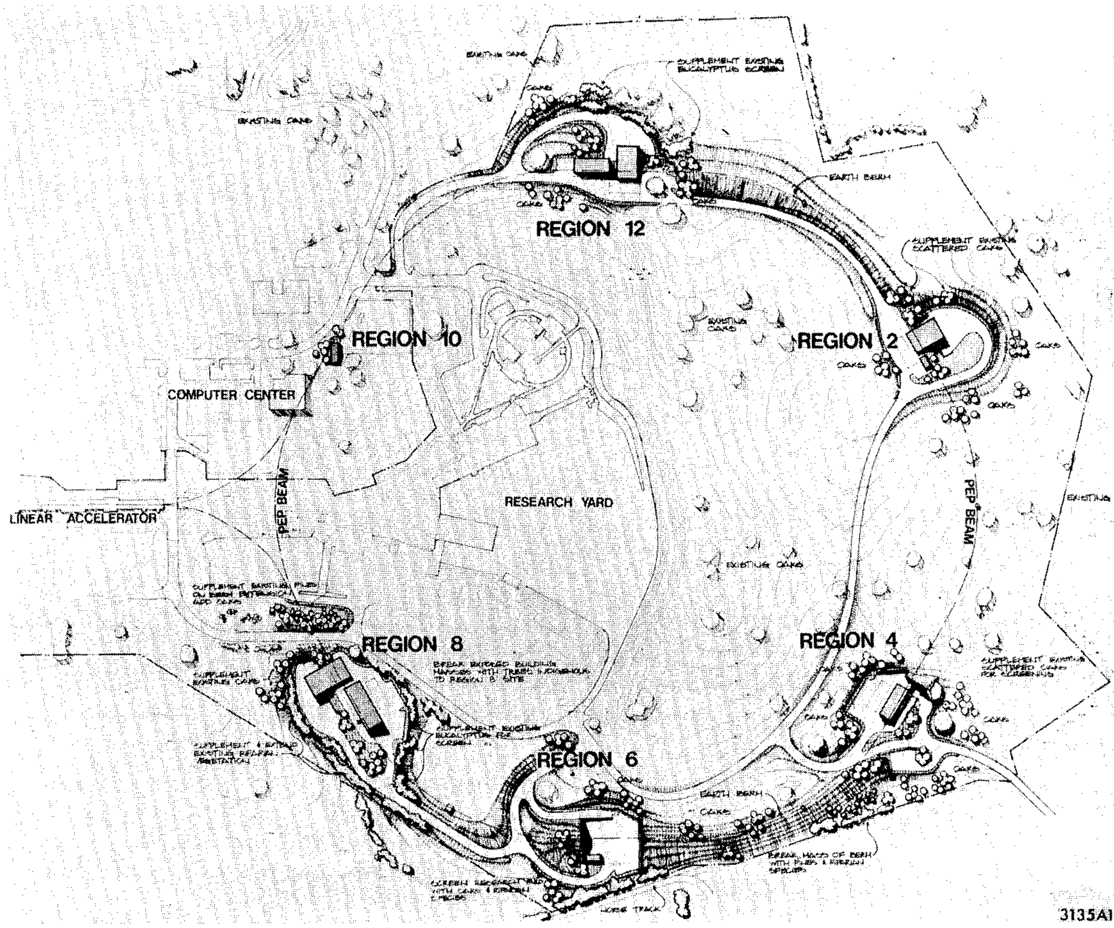
Vish Moré talks, gestures a lot, and gets things done. Here are some of the things that Joe Faust and I learned from Vish on our recent tour of PEP.

The tidy way to build a storage ring would be to have the tunnel first bored, then mechanically finished; then install the power and other utility services; then follow with the installation of the magnets, vacuum system and control equipment. But this strict sequential system would be unacceptably slow, so the approach used with PEP has been to have each phase of construction follow the previous one as soon as it has moved a ways down the tunnel. So at the present time you can see just about every phase of building going on depending on where you happen to be standing around the circumference of the ring.

The most primitive phase of digging and building the tunnel was completed early this year. The next phase of construction, that of installing the electrical and mechanical services, will be completed within the next few weeks. This activity is presently going on around Region 8 of PEP.

*Hotting Up*

We began our tour at the big electrical substation near the Sector 30 gate, where transformers convert the AC power from 60 kV to 12 kV for use at PEP. We traced the 12 kV line from the substation over to the Region 8 pad at PEP, from which point it continues around the PEP ring. Two weeks ago this high-power loop was turned on ("hotted up"), tested and approved. The transformers at Region 8 share the pad with three heat-exchanger systems that provide cooling water for the PEP vacuum, RF and magnet systems in the ring below. The water-pumping power is prodigious, with three 125-hp motors driving



pumps that can handle a few hundred gallons a minute through the automatic filter and quality control systems. The pad at Region 8 is built like a shallow concrete boat and is filled with crushed rock. It is designed to catch any water or oil spills, one of the many requirements of the EPA that must be met.

*Mechanical Trees*

Leading from the pad to the top of the beam-interaction point in Region 8 is a line of mechanical "trees"—tall poles with cross arms that carry cooling water, electrical conduit, control and telephone cables, nitrogen, air, and utility water. Right now these trees simply look rusty, but Vish points out that the trees are built from the type of structural steel that naturally weathers to a respectable appearance.

The PEP Control Building at Region 8 is now finished from the point of view of general contracting, and we have taken beneficial occupancy. The benefit is that SLAC people can now get in to begin installing all of the equipment that will make PEP work. Most of the first floor of this building is taken up by the power supplies and controls for the large klystrons that will feed RF power down through the floor to the accelerating cavities in the ring below. This area is similar to a short section of the SLAC klystron gallery.

We then entered the PEP Control Room itself, which already features a red carpet, orange racks, blue panels, a white ceiling, and a high level of activity. The equipment racks are significantly taller than those commonly used at SLAC—tall enough, in fact, that there was a minor problem during installation which required dismantling the door jamb.

Up the stairs from the Control Room is a mezzanine which includes offices, some lab space, and an interesting view. Vich noted that the glass used here is double insulated to conform to new building standards. This is just one of the many details that someone has to worry about, along with roof insulation, smoke and fire detectors and sprinklers, paint color, height of drinking fountains, sealing tunnel leaks . . . and so on. And of course there are the bigger details like megawatts of electrical power, and the torrents of water needed to take all those megawatts away. Vish's job as Chief Engineer consists partly of keeping track of all the people who worry about these things. "It's a fantastic challenge," he says. "I learn something new every day." Vish is with the LBL side of the PEP project. Before coming to PEP four years ago, he had been in charge of LBL's Plant Engineering Department.

*Experimental Area*

From the Control Building at Region 8 the road drops down to the level of the experimental hall and the PEP ring itself. The view out is of the coastal range of hills, but the view down at present is of a ditch that will carry the irrigation pipe for the planting of trees and shrubs that will go in after the heavier work is done. More details to worry about. By the side of the road, a diesel-electric generator chugs along, supplying the temporary power that is needed for

Vich More, left, and Bill Ash in the PEP Control Room at Region 8.

the ongoing work.

Half of the experimental hall is built with thick concrete walls designed for strength and radiation protection, while the other half is lighter, steel-framed construction that will be used as a staging area. When PEP is running, the two halves of the hall will be separated by a thick concrete shielding curtain that can be handled by an overhead crane. Inside the hall at Region 8, we see that the crane and shielding curtain are in place, and that work has begun on a support pad and an electronics counting house for one of the scheduled PEP experiments.

A passage built into the side of the experimental hall at Region 8 will allow access to the large detector without taking apart the shielding wall. At the end of this passage is the bottom of a utility shaft that will carry the cables and piping down from the mechanical trees located on the upper level.

*Dark Places*

Both ends of the vertical shaft will be fenced off as a part of the personnel protection system that keeps people away from dangerous places at PEP. This system of barriers, monitored gates, keys and interlocks is a small project in itself. At present, this unlighted shaft area isn't a desirable place to be anyhow. By walking with a shuffle, we managed not to trip over any wires or loose debris, but the hard hat I was wearing came in handy when I looked up the shaft and smacked my head against a wall.

Across the hall from the shaft area, we entered the ring tunnel itself and began walking clockwise toward Region 10. The magnets, vacuum chambers and other technical components have been installed in more than half of the PEP ring by this time, but not yet in the particular regions through which we were walking. (See the cover photo of this issue for the appearance of the ring where installation is nearly completed.)

As we proceed, Vish stops to talk with one of the contract management people about a problem with the installation of the fire-protection system. He has had conversations with each group of workers we have passed so far on the tour. A short time later, there is another pause to inspect some expansion joints and the welding that is going on nearby. "I know about 90% of the people working on the job," Vish says. "That's the key thing, knowing the people."

At the mid-point of Region 9, we pass under the beam switchyard area at the end of the SLAC linac, which is about 30 feet above our heads. One of the more interesting problems at PEP has been to work out the design of the two beam-injection systems that must curve downward from the linac to meet the PEP ring at the ends of Region 9. We come eventually to the North injection tunnel's junction with the ring. This area was carved out by a tunneling machine working underground, and it has left a high vaulted ceiling. All of the components in the North in-

Looking up the utility shaft at Region 8.

jection line have been in place for some time, and in fact an electron beam from the linac has already been transported through this injection line nearly to the PEP ring itself.

Beyond the junction point, we are informed that we won't be able to get past Region 10 without boots. A minor mixup has resulted in a water hose left running, and the area ahead is now ankle deep in water. Vish ventures into the flooded area on some boards, then returns mostly dry and gets someone to begin working on fixing the problem. Apart from this mixup, the PEP tunnel is now drying out nicely. The sprayed concrete walls do tend to sweat a bit, but this will be cured by the regular ventilation system and by the heat generated by the magnets and other equipment in the tunnel. The actual leaks in the tunnel facing have been pretty much located and plugged with a material called Zypex. This is a powder that is applied at the wet spots and that grows like a crystal, covering the leaks and sealing them.

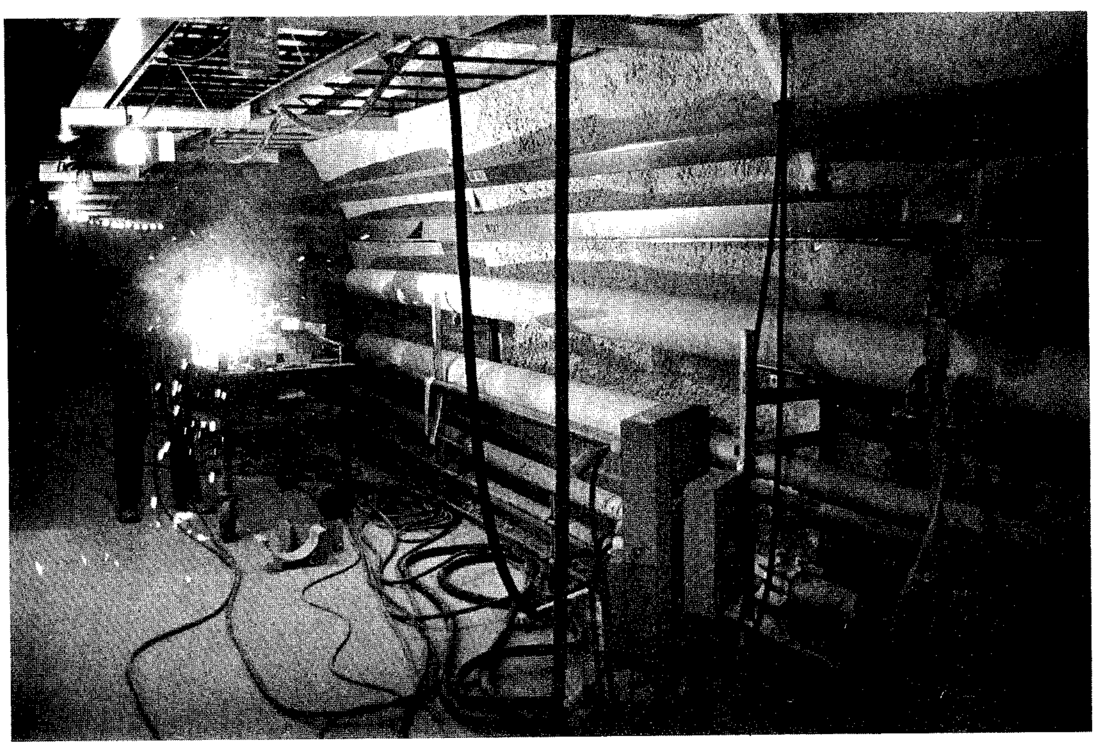
On our way out of the tunnel, Joe Faust is overtaken by one of the workers who wants to discuss cameras. A technical discussion about Joe's Leica follows, and the guy offers Joe either $900 or a brand new Olympus with two lenses if he'll trade. High finance 60 feet under the SLAC Computer Building.

We finished our tour by taking a drive around the ring road at PEP and quick looks at the other experimental areas. At Region 12, one of the tunnel-exhaust ports is visible from roadside. These vent shafts have an L-shaped section below in order to avoid any line-of-

sight radiation problems. Since someone took the trouble to wonder about any possible problems with the tunnel ventilation system in the event of an otherwise minor grass fire on the surface, there are now fire-protection sprinklers for the surface area around the ring. More details.

"We got a lot of ideas from everybody," Vish tells us. "Getting here took quite a bit of listening." And quite a bit of doing, too.

—Bill Ash



## ERCOLE W. CRONE

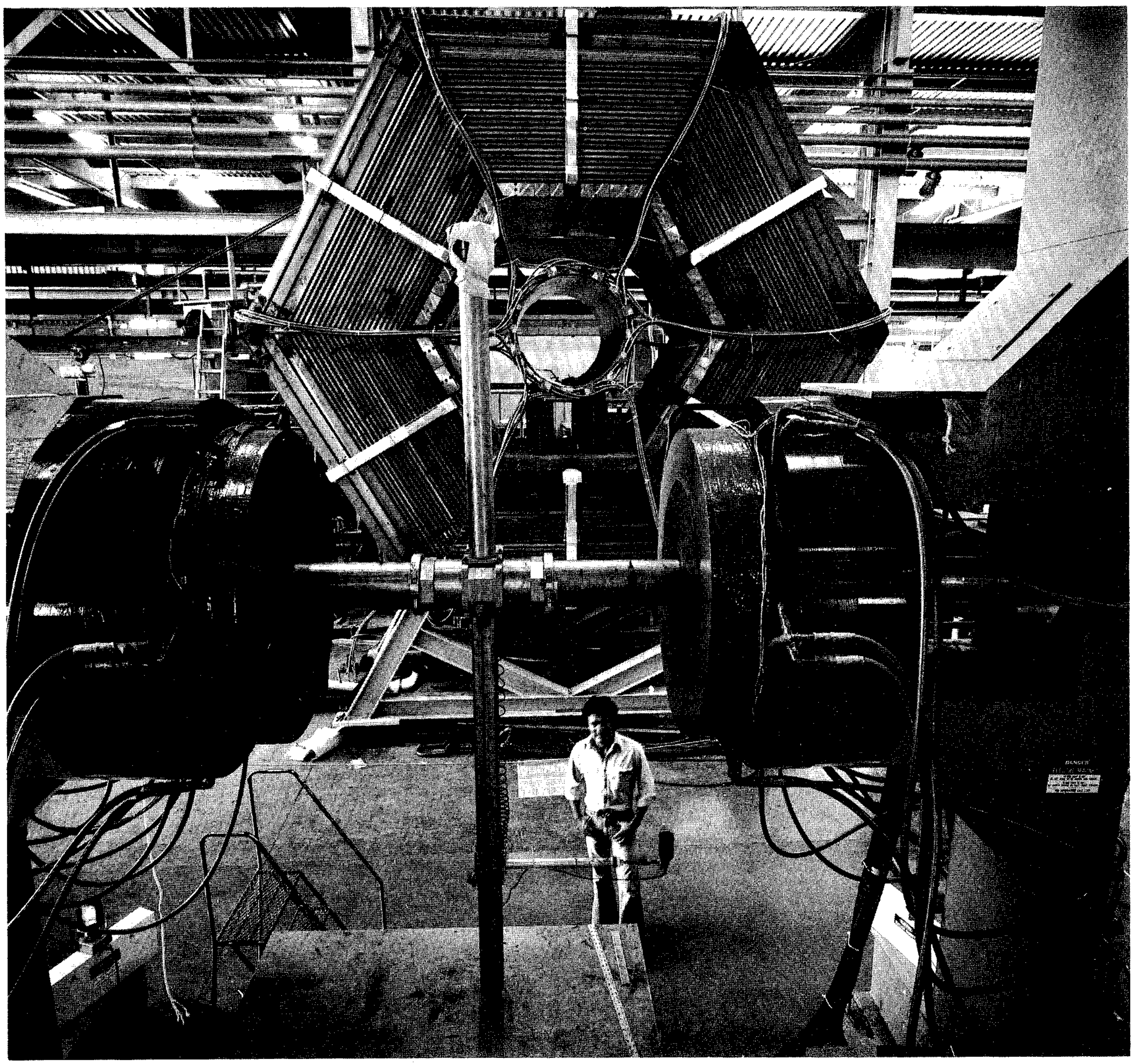
Ercole Crone, a machinist in the Light Machine Shop at SLAC, suffered a heart attack and passed away on the first of June, 1979. Ercole had been a machinist for 25 years, and prior to his employment at SLAC, in 1976, he had been with Ampex Corporation in Redwood City.

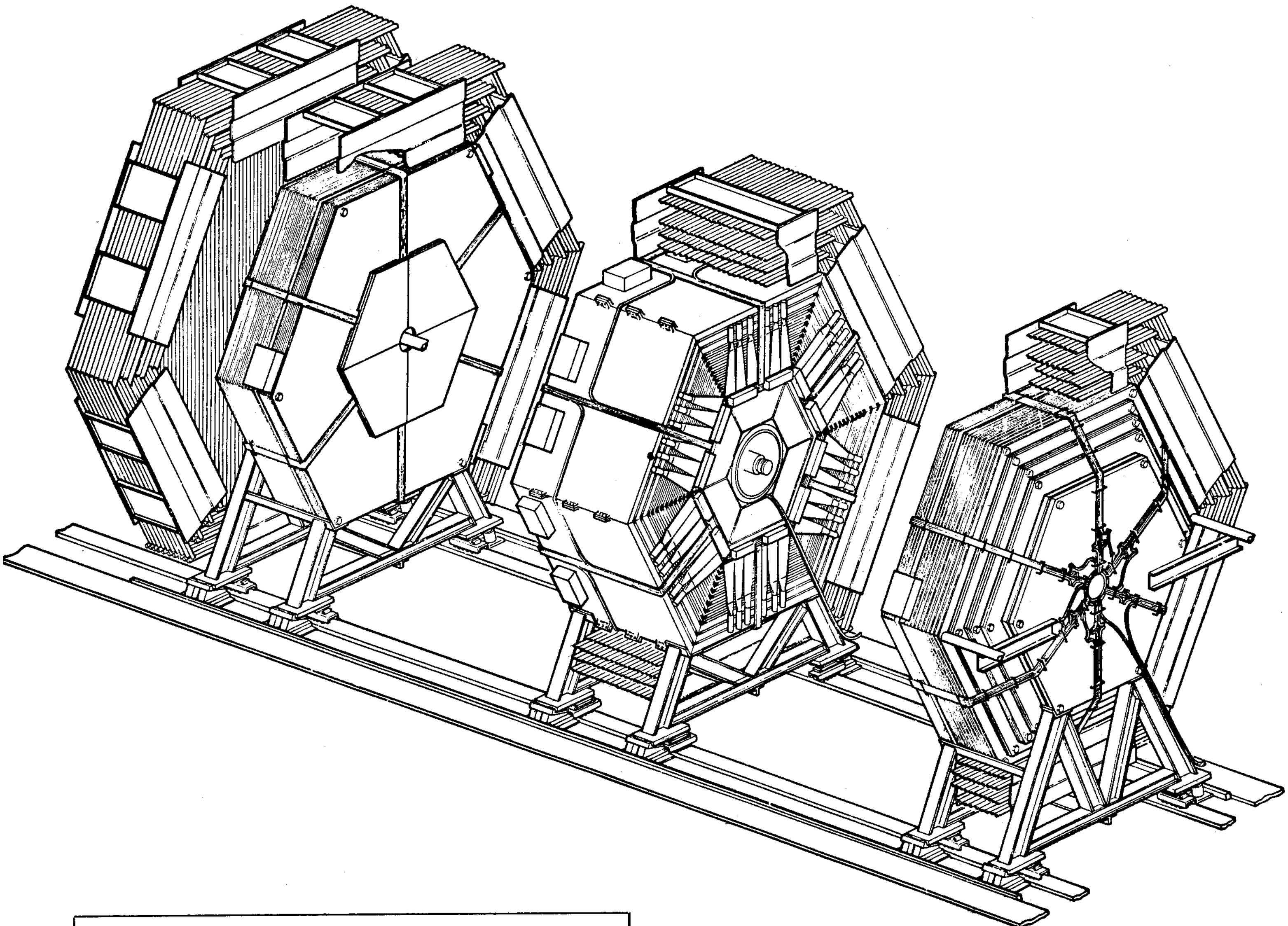
He was a veteran of World War II, having served two years in the Marine Corps. He was well-liked and respected by his fellow employees here and SLAC. We shall miss him.

He is survived by his wife Clara, a resident of Santa Clara.

—Marion Adams

Joe Faust's photograph shows a part of the open magnet structure of the DELCO detector in the foreground, and the central section of the MAC detector in the background. Both of these large particle-detection systems will be used during the initial round of experiments at PEP. The MAC magnetic calorimeter is shown in more detail in the sketch on the next page.





M.A.C. - P.E.P. 6
MAGNETIC CALORIMETER
VIEW LOOKING SOUTH
DRAWN BY AUDREY KENNEY
ENGR ROGER COOMBES
DATE NOV. 1978

## THEORETICAL SOFTBALL

During the 20-odd years in which the Annual SLAC softball game between experimental and theoretical physicists has been played, it has become traditional that one side or the other will squeeze out a narrow win by a typical score of something like 17-16, or 21-20. After this year's game, held on June 10, a damnable rumor began to spread that the experimentalists had won by a score or 18-5, or 21-5, or some such ridiculous margin. Anyone with the least grounding in statistical mechanics will immediately recognize this as a wildly improbable result. We urge that this factitious datum be completely discounted as a test of any gauge theory that purports to represent the real world.

—SLAC Theory

## CERN—THE NEXT 25 YEARS

The European Centre for subnuclear physics—CERN—celebrates its 25th anniversary next week. But it is time for Europe to look forward, not back. Robert Walgate reports.

[Reprinted from *Nature*, 21 June 1979]

American high energy physics laboratories—there are three major ones—have generated one or two Nobel prizes, and much spectacular physics. On the other hand CERN, the European Centre for high energy physics, has discovered 'neutral currents' (a new kind of weak interaction), but nothing else with the feel of a Nobel prize. (The one for neutral currents hasn't been awarded yet.) CERN has been much praised for the quality of its work; but sometimes this has felt like being patted on the back for trying hard. However, all this seems about to change.

Burton Richter, an American who won a Nobel prize for discovering the J/psi (indirectly a discovery of the charmed quark) agreed last week that in the last 25 years the greatest discoveries have been American; but in the next 25, he said, "Europe will become the senior partner." And according to Leon Lederman, also a man of spectacular discoveries (he recently found the next quark, bottom, in a 9.5 GeV particle called upsilon), "the US is going to have a rather hard time competing."

However "it's nonsense," says Lederman, to say that CERN was too concerned with quality and missed the spectacular results. "Anyone can get spectacular results." The reason the US got most of the big discoveries was partly the statistics of small numbers—luck. "Plus we had a heritage of experience. We had accelerators running in 1951." CERN's first, the SC [SynchroCyclotron], started up in 1957. And now he envies the quality of CERN engineers. "The European engineering education is better based in mathematics and physics and ideally suited to accelerators."

Lederman should know, for it is, in some sense, his job to compete: he has been appointed director of The Fermi National Accelerator Laboratory (Fermilab) in Chicago, America's nearest equivalent to CERN. But he says "we're undermanned by a factor of 2 or 3; we don't have the people or the money." The previous director, Robert Wilson, resigned over a question of funding.

But CERN isn't going ahead simply because the US is falling behind. It has three adventurous plans on the books: one approved and building; one on the verge of approval; and one very ambitious scheme yet to be put to the political test.

The first (the antiproton collider) should generate physics from the collisions of protons and antiprotons within the present 500 GeV accelerator ring towards the end of 1981. There's probably a Nobel prize in it through the discovery of the 'intermediate vector boson' (a particle as important to modern physics as the structure of DNA was to 1950s biology). The second (LEAR) should use stored antiprotons for unique experiments in low energy nuclear physics. And the third (LEP) would generate 200 GeV collisions between electrons and positrons (presently the cleanest way of investigating the fine structure of matter) towards the end of the next decade. There are probably a few Nobel prizes in that.

A firm and unanimous proposal for LEP, the result of the deliberations of hundreds of physicists throughout Europe in the technical panels of ECFA (the European Committee for Future Accelerators), should go to CERN Council on 9 November this year. LEP is CERN's future for the late 1980s and 1990s; it is up to governments to decide if CERN can have it. (The clash between Germany and CERN over the siting of LEP has died down; CERN will have it, while Germany's national Hamburg laboratory DESY will add protons to its electron rings; at least that's the physicists' plan.)

Hamburg, too, is ahead; experiments are underway there on what is presently the world's highest energy electron-positron machine, PETRA, with the American equivalent, PEP, coming on in November about a year later because of funding delays.

But America hasn't given up. According to Lederman, "I think Fermilab is going to cause CERN a lot of grief." Fermilab is building—and had been building for some time—a ring of superconducting magnets (the 'energy doubler') to join the normal magnets in its 500 GeV proton accelerator tunnel, and these magnets will give Fermilab the capability of reaching beam energies of 1000 GeV to collide with a target, or making collisions between 1000 GeV protons and 1000 GeV countermoving protons. Lederman hopes to phase in physics on the colliding beams by 1982; and on fixed target by 1983. This would give Fermilab the highest energies in the world. "The doubler is the only way we can get ahead," says Lederman.

(Ultimately the USSR should overtake Fermilab with UNK, a 10,000 GeV—10 TeV—machine.)

Furthermore at Hamburg there have been problems in reaching design collision rates (which determine whether an experiment can be done in months or years) because of a complicated acceleration system which will not trouble PEP. Richter says "I've laid a number of bets that within two weeks of first injection we will be at 10% of design luminosity." PETRA has been sitting around 1%, and although this figure is rising fast there will be a lot of physics left for PEP to do.

A few years ago such competitiveness was justified in terms of repeating experiments: if Fermilab discovered something, then CERN ought to check it. There was an example of that recently, when an anomaly in neutrino interactions was checked—and discounted—in a more sophisticated experiment at CERN.

Sharing unique facilities

But the future seems to be one of sharing unique, continental facilities and no overlap.

So a number of physicists—particularly American ones—foresee a period when there will have to be increased international cooperation, even going so far as a transatlantic pooling of funds on projects such as, for example, the energy doubler at Fermilab. But according to the chairman of ECFA, Marcel Vivargent, this is impossible at present; CERN funds are very rigidly controlled by the member states and must be spent only for Europe. "But if LEP is accepted" said Vivargent last week, "we will have to discuss cooperation."

Leon Lederman, Fermilab director, raises an interesting issue: there are presently 26 European groups working at Fermilab, he says, who have come through the usual selection procedure by merit. "We have no way of assessing where a proposal comes from . . . but the energy doubler is going to raise a question of discrimination." With their (disputed) better funding the European groups will have better equipment for their experiments, he says, and without discrimination this would leave the Americans in the cold. There seems to be a possibility here that if competition does not ease, it will increase. No sharing of funds, no sharing of experiments, may be a new threat from the US to Europe.

Leon Van Hove, research director-general of CERN, feels that the normal exchange of groups (evidenced by the 26 European groups at Fermilab) will suffice; and that although exchange is increasing, no new procedure or institution (to match groups and laboratories) is necessary. The International Committee for the Future of Accelerators (ICFA) under the International Council of Scientific Unions (ICSU) would be sufficient to discuss the matter, he feels.

Burton Richter, on the other hand, believes that the old ways will not suffice, because of the large and increasing cost of the apparatus that must be built up around an accelerator to do a particular experiment. A single detector at LEP would cost about $20 million, he estimates; who is going to pay for the apparatus, the group or the laboratory?

And how should the operating costs of the accelerators be divided? According to Lederman, Fermilab's electricity bill is presently $7 million, and may rise to $10-12 million next year (though the superconducting energy doubler, used not to double beam energy but to save accelerator power, could cut the costs 70%). And LEP, according to some estimates, if it used conventional magnets, could consume 500 MW of electrical power. (But that estimate is sensitive to the assumed radius, and to the energy of the machine. The consumption rises as the fourth power of the beam energy.) With costs and consumptions such as these, intercontinental cost-sharing may be necessary.

Whatever agreements may prove necessary on this level, there is a definite feeling both in Europe and the US that Europe now has the initiative. In the short term the US has PEP, which will be competitive with PETRA; in the long term, the American future depends on the technology of superconducting magnets, which Fermilab is still wrestling with. (Another US machine for the 1980s, Isabelle, a high energy East Coast machine to collide protons with protons, also needs superconducting magnets.) Lederman says Fermilab is about to go into a 1,000 magnet production run (they have produced 200 in various batches so far) but CERN cynics say they have heard that before; the technology is proving very difficult.

(If LEP needs superconducting accelerating cavities to save power costs and reduce that 500 MW to something manageable, it will face a problem of even greater magnitude. But test cavities are already in construction at Karlsruhe in West Germany for trial at DESY.)

Is there a simple reason why Europe appears to have taken the lead? According to Lederman, funding has a lot to do with it. "In the early 50s we were better funding, but somewhere in the 70s the budgets crossed." In CERN, it is not felt that Europe has much more money to spend—rather that the US is stretching its resources across too many projects. "If we had the energy doubler, PEP, and Isabelle, I wouldn't say we were badly off," said one CERN physicist. And according to Leon Van Hove, "to run three big labs on a small budget is trying to square the circle."

Delayed advantage

Also, the delay in building the 500 GeV super proton synchrotron (the SPS) at CERN may, in retrospect, have been an advantage. While the US committed a large fraction of its funds to Isabelle, which many now see to be an outdated machine, it became clear that a major way forward in physics was to collide particles with their antiparticles (electrons with positrons, or protons with antiprotons). Hence when the SPS was built, European physicists were free to use their new experience in allocating the potential European budget to the antiproton collider and to LEP.

Furthermore there appears to be a new mood in CERN. It used to be accused of being very strong on engineering—accelerator design—but unadventurous on physics. There was a strong division between the accelerator people who wanted a beautiful machine, and the users who wanted physics quickly. Now that divide is being bridged, and the accelerators are really being designed to suit the physicists, while the physicists are becoming more aware of the real constraints of design. LEP is certainly benefitting from this, and so is the antiproton collider.

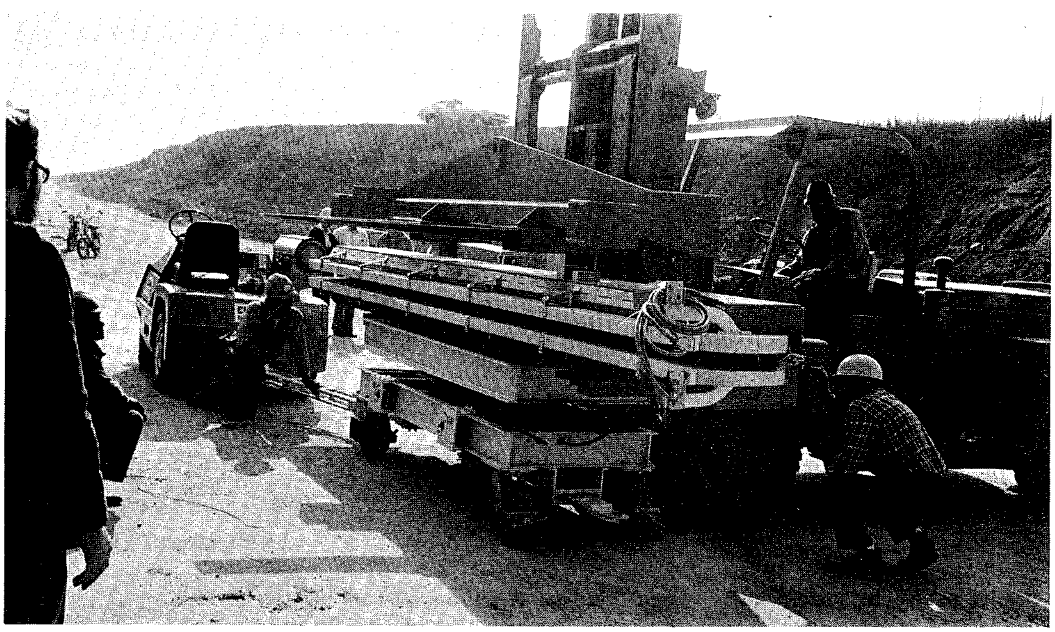
That particular project is very instructive. An Italian with Italian temperament and American determination, Carlo Rubbia, who had been doing experiments at Fermilab and making a few discoveries (dimuons, events now connected with charm, and the anomaly later discounted at CERN), decided that the Fermilab and CERN accelerators could be used to make the intermediate vector boson (this latest holy grail of physics) if antiprotons could be injected into them the wrong way round. Simple in principle, but difficult in practice; but Rubbia was enough of an accelerator engineer to make some sensible proposals. He made them, to CERN and Fermilab, around 1976, and from then on the labs were in competition.

Then a number of interesting events occurred. First, it became clear that the vacuum in the Fermilab machine, at $10^{-7}$ Torr, while good enough for the accelerator, would not do for day-long storage of intense beams (beams were lost in 30 minutes); while the SPS, over-designed to some American tastes at $10^{-8}$ Torr and in easy reach of $10^{-9}$ Torr, could do the job it had not been designed for.

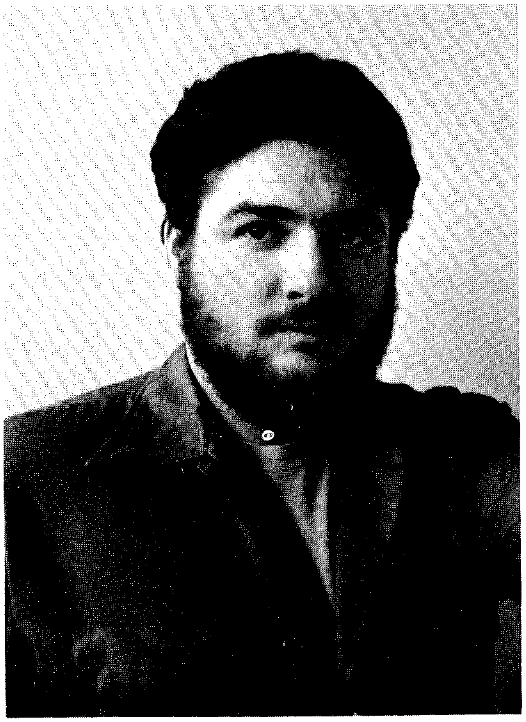
Second, the CERN team in charge of future projects rejected the scheme, which involved creating antiprotons, catching them and 'cooling' them into a confined beam, as impractical—so the project was taken on directly by people who were in favor of it. "There were people at CERN who were determined not to be beaten again" said one member of Rubbia's group. "They'd lost the J/psi and the upsilon to the US and they were not going to lose the IVB [intermediate vector boson]." There was, in fact, a kind of breakthrough by radical elements, greatly assisted by the persuasive powers of the antiproton advocate, Carlo Rubbia.

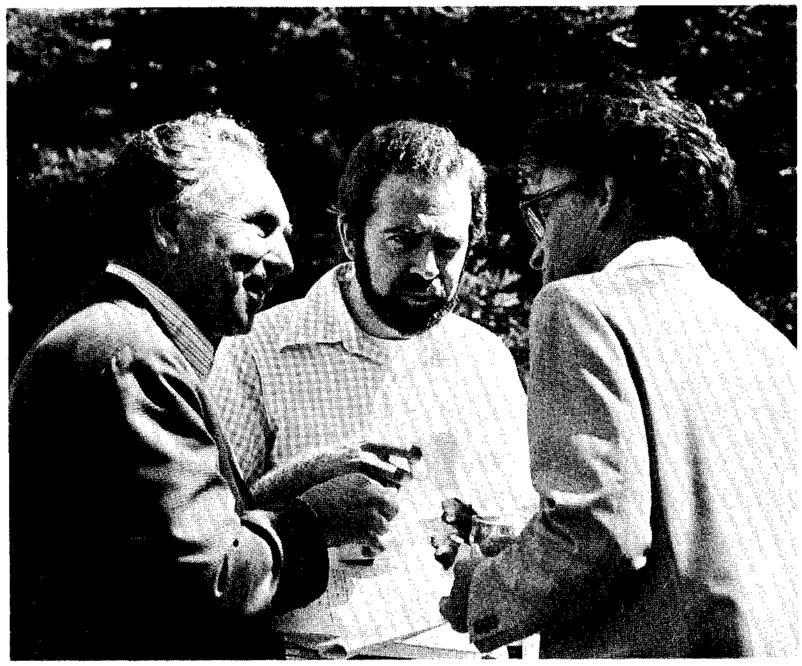
Third, the CERN directorate swung wholeheartedly behind the scheme (in fact they had a choice between two radical proposals, one involving electrons; it's arguable which was best) and put a good deal of CERN money into it.

And finally, the CERN accelerator physicists and engineers moved rapidly in reaching the solution of a very difficult technical problem, and proving it in a beautiful experiment, the initial cooling experiment (ICE). The project drew on all available CERN expertise, but decisions were taken sequentially as step after step was proved. There are still two years and many problems to go, but the antiproton project appears to be CERN at its very best—using not only its skills, but also a large dash of imagination. Yes, Professor Lederman, it's going to be a very difficult combination to beat.

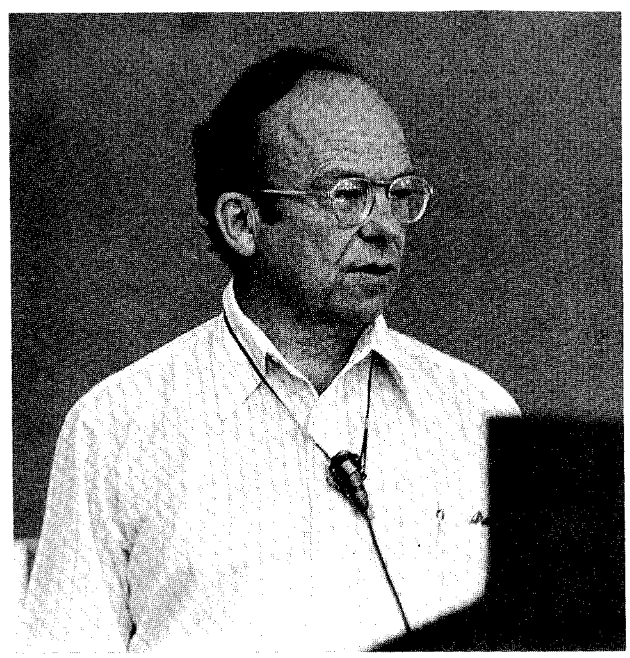


A forklift places one of the PEP bending magnets on a dolly for transport to the PEP ring. This is one of about 700 magnets that will make up the complete magnetic guide field of PEP.





*Some Faces Seen At SLAC*
*Photos by Joe Faust*



## RED CROSS BLOODMOBILE

The Red Cross Bloodmobile will be making its way to SLAC on Friday morning, August 10. Appointments will be scheduled at 15-minute intervals. For an appointment, please phone Nina Adelman at ext. 2351 or 2719.

Many SLACers are regular donors through the Red Cross Center, as well as other local programs. The Red Cross Bloodmobile will be coming to SLAC every three months with hopes of obtaining regular donations and recruiting new donors. If it is time for you to donate, why not walk over to the Auditorium breezeway—and bring a friend or co-worker.

Stanford University Medical Center is famous for difficult and specialized surgery. The Red Cross Center supplies not only Stanford with a portion of their blood needs but also 29 other hospitals within Santa Clara, Santa Cruz, San Benito and Monterey counties. These needs require 375 blood units per day from our region.

Donating blood at SLAC is a convenient way to help those in our community who need it. It is also an opportunity to learn what your blood type is and to receive a mini-physical: pulse, temperature, blood pressure and the level of hemoglobin in your blood.

Last August, SLAC had 27 on-site donors; in November, 30. Out of approximately 1200 SLAC employees, we set a goal of 35 productive donors for April. Out of 35 attempted donations, 27 were successful at that time.

If you have thought about it but have not yet taken the time, please contribute to your community. If you regularly donate at another location, consider the convenience of having the unit come to you. If you are unable to donate blood, perhaps you could talk with other people in your work area. Each time we have the Bloodmobile unit come to SLAC, many people have claimed afterward that they did not hear about it. Let's attempt to spread the word this time!

For anyone who is unsure about making the commitment, please give me a call, or else call the Red Cross directly with any specific questions. Their number is 493-1363.

As responsible people living and working in this area, it is obvious that there are many ways to help others in the community who are less fortunate. Take an hour to make a truly life-giving contribution to others. Come out on the morning of August 10 to the Bloodmobile.

--Nina E. Adelman, ext.2351/2719

## TECHNICIAN CERTIFICATION EXAMS

Civil, electrical/electronic, and mechanical technicians will have an opportunity on November 17 to obtain certification from the National Society of Professional Engineers. NSPE certification is the only national recognition of technician ability, achievement and professionalism. It is considered to be equivalent to a bachelor's degree in engineering technology.

The 6-hour certification exams follow the completion of 14-week preparation courses offered by the Professional Engineering Institute. There are 3 different courses, one each for civil, electrical/electronic, and mechanical technician examinations.

All 3 courses meet from 7:00 to 10:00 PM on Tuesday nights starting August 14. The last class meeting is November 13, just prior to the certification examinations. Cost of the courses, which are held at Menlo College in Menlo Park, is $115. All materials are included in the course fee. To obtain a brochure describing the certification process or the courses, call (415) 593-9731, or write to: Professional Engineering Institute, P.O. Box 911, San Carlos, CA 94070.

The Professional Engineering Institute is a non-profit educational organization specializing in licensing of engineers and certification of technicians.

*SLAC Beam Line*
*Stanford Linear Accelerator Center*
*Stanford University*
*Stanford, CA 94305*

**Published monthly on about the 15th day of the month. Permission to reprint articles is given with credit to the *SLAC Beam Line*.**

**Joe Faust, Bin 26, x2429** — ***Photography***
**Crystal Washington, Bin 68, x2502** — ***Production***
**Dorothy Ellison, Bin 20, x2723** — ***Articles***
**Herb Weidner, Bin 20, x2521** — ***Associate Editor***
**Bill Kirk, Bin 20, x2605** — ***Editor***

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Beam Line Distribution at SLAC Total: 1629* | 0-3 | 7-2 | 13-54 | 23-28 | 34-4 | 52-9 | 61-21 | 67-10 | 73-13 | 81-61 | 87-14 | 95-43 |
| | 1-24 | 8-4 | 14-2 | 24-18 | 40-120 | 53-47 | 62-40 | 68-11 | 74-7 | 82-10 | 88-22 | 96-20 |
| | 2-6 | 9-3 | 15-4 | 25-2 | 45-10 | 55-42 | 63-15 | 69-50 | 75-3 | 83-6 | 89-14 | 97-95 |
| | 3-7 | 10-2 | 20-65 | 26-21 | 48-7 | 56-11 | 64-17 | 70-2 | 78-36 | 84-8 | 91-4 | 98-32 |
| | 4-17 | 11-18 | 21-4 | 30-47 | 50-20 | 57-14 | 65-32 | 71-26 | 79-86 | 85-27 | 92-2 | |
| | 6-17 | 12-117 | 22-19 | 33-24 | 51-60 | 60-19 | 66-10 | 72-3 | 80-8 | 86-6 | 94-19 | |