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LANSCE '90: The Manuel Lujan Jr. Neutron Scattering Center

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ABSTRACT

This paper describes progress that has been made at the Manuel Lujan Jr. Neutron Scattering Center (LANSCE) during the past two years. Presently, LANSCE provides a higher peak neutron flux than any other pulsed spallation neutron source. There are seven spectrometers for neutron scattering experiments that are operated for a national user program sponsored by the U.S. Department of Energy. Two more spectrometers are under construction. Plans have been made to raise the number of beam holes available for instrumentation and to improve the efficiency of the target/moderator system.

When I spoke at the last ICANS meeting in 1988 [1], LANSCE was struggling with low beam availability and a proton beam current that was less than a third of its design value. Construction of a large experimental hall had been completed and desert dust was hanging over the construction site of our new office and support building. A user program had been started and 399 days of beam time were requested for the 1988 run cycles. Occupancy of the ER-1 experimental hall during beam delivery had been achieved but relied heavily on fail-safe instrumentation to detect proton beam spills and prevent large radiation doses close to the spectrometers. The neutron powder diffractometer (NPD) and the reflectometer (SPEAR) were being commissioned: a chopper spectrometer (PHAROS) and a back-scattering machine were but concepts in the minds of their designers. We were contemplating a neutron guide for the back-scattering spectrometer but had not even decided whether it should be straight or curved.

The scene has changed in the past two years. Construction of the office/support building was completed early in 1989, on time and within the budget prescribed by the Department of Energy. Two months after we moved into our new building, the LANSCE facility was dedicated to Manuel Lujan Jr., a long-time New Mexico congressman and supporter of scientific research who is currently serving as Secretary of the Interior.

Thanks to the support and commitment of Los Alamos Laboratory management, we have been able to improve substantially the performance of the Proton Storage Ring (PSR). In recent months the proton current extracted from ring has usually been between 75 μA and 85 μA whenever beam has been delivered to the LANSCE target, averaging 75 μA with a beam availability of 74% during the most recent run cycle. During the same cycle, the

LAMPF linear accelerator was available for 84% of the time, so less than half of our lost time was due to breakdown of the PSR and beam transport systems. A beam current of 95 μA at a 20 Hz repetition rate was achieved for a shift or so last week, demonstrating that there is no fundamental technical obstacle to reaching our ultimate goal of 100 μA. For the moment however, the beam losses at 100 μA are larger than we are willing to tolerate because the activation caused by these losses is inconsistent with the Laboratory policy of reducing radiation doses received by employees In his talk later in this meeting Bob Macek will tell you what magic he worked to achieve the present PSR performance and what modifications he expects to make to achieve 100 μA on a regular basis. We are still committed to this goal, even though the present performance of PSR gives LANSCE a peak neutron intensity that is 50% higher than that of our closest rival.

The social environment in which research facilities are operated is changing rapidly in all of the industrialised nations. It is becoming increasingly clear that society will not tolerate facilities that it perceives to be unsafe or to cause environmental insult. Of course, this gives spallation sources an inherent political advantage over competing reactors, in addition to the technical advantages that are becoming increasingly apparent. Nevertheless, most of the existing spallation sources were not designed to achieve the level of safety that is now demanded. For that reason, we at LANSCE have expended a great deal of time and money over the past two years improving radiation and other safety systems. Over 800 tons of steel shielding was installed in a layer 750 mm thick on the floor of the proton transport tunnel to shield the experimental room (ER-1) that is under the tunnel from the effects of beam spill. The attenuation factor of about 100 provided by this steel substantially reduces our dependence on instrumentation for safe occupancy of the experimental hall. During our studies of radiation safety, we discovered a weakness in the shielding of the proton transport system where it passes under a road between LAMPF and the PSR. In order to deliver beam under acceptable conditions during 1990 we had to divert this road, fence off part of a parking lot and install fail-safe instrumentation to interrupt the proton beam in the event of a major spill. Such reliance on instrumentation is uncomfortable and we will install additional shielding in our road during the 1990-91 shutdown. By next year, we will have spent between $4 million and $5 million on additional shielding and instrumentation for radiation protection in a three year period.

Neutron spectrometers at most spallation sources have been designed so that access to neutron beams is prevented during beam delivery, a safety feature which is absent from all research reactors that I have ever visited. The system installed at LANSCE interlocks the door to a spectrometer cave with the shutter that prevents neutrons reaching the spectrometer. Even though this system has worked well, we have concluded that its lack of redundancy is a drawback. Accordingly we will incorporate radiation monitoring devices in our spectrometer interlock systems during the 1990-91 shutdown.

The previous paragraphs describe only two of the many safety related actions that we have taken or planned during the past year or so. There have been many others, ranging from an almost complete refurbishment of our chemistry laboratory to collaboration with the video club at our local high school to tape a comprehensive safety briefing for users of the facility. Even though I expect safety to be of continuing concern, I doubt that we will need to spend as much money on this activity as reactor centers. Nor do I anticipate that it will be necessary to interrupt research at spallation sources for safety related reasons.

Early this year we completed four new penetrations of our bulk shield. This task had to be accomplished with precision because there was very little space between the new holes and existing penetrations of our crypt. Once the holes had been bored through magnetite concrete and iron, liners were installed and welded to the crypt. The latter task proved to be highly non-trivial and it is a testament to the perseverance of Harold Robinson and his crew that the welding was completed before the run cycles began in May. If any of you ever have to install additional beam lines at your facilities I encourage you to contact Harold: he learned many lessons the hard way. The new beam lines will eventually allow us to install four "new" spectrometers in our large experimental hall. In fact, at least two of these spectrometers (a Single Crystal Diffractometer and a Filter Difference Spectrometer) already exist and will be upgraded only in minor ways when they are moved. Unfortunately we cannot yet provide neutrons for our new beam holes. To do so requires new moderators to be installed as part of an upgrade in which we expect to increase the neutron flux to all spectrometers. Whether we will be able to obtain the $1 million or so needed for this upgrade remains to be seen.

The user program at LANSCE has expanded each year since its inception in 1988, in part because of the addition of new spectrometers. In 1988, users requested 399 days of beam time on four spectrometers. This year, 145 proposals asked for a total of 592 days on six instruments. Because funding for LAMPF has been limited, less than 50 days of beam time could be offered to users on each spectrometer, resulting in an average overload factor of 2.1. This number is close to the canonical value of 2 that seems to pertain at almost all successful neutron scattering centers, regardless of the number of spectrometers or the fraction of time during which the facility operates. Of course, it would be sensible to increase the operating time for LANSCE from five months to about nine months of each year but I doubt that this can be achieved under present budget constraints in the U.S.

The two spectrometers that were being commissioned in 1988 (NPD and SPEAR) are now an integral part of our user program. Even though we expect to upgrade the performance of both instruments by installing position-sensitive detectors during the next two years, both are already producing high quality data and are popular with users.

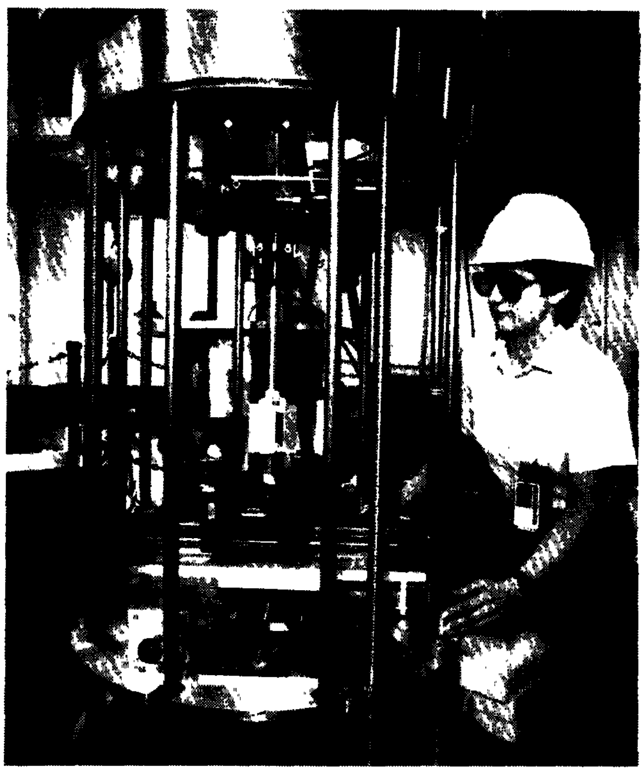

Figure 1:Joyce Goldstone with the equipment she helped design to position samples and collimate neutron beams for residual stress measurements on NPD

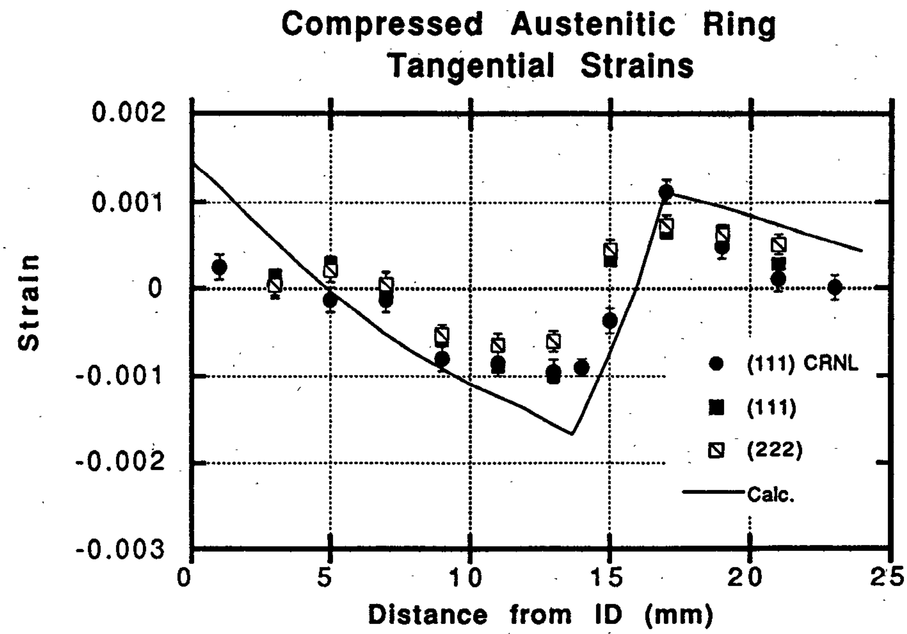

Figure 2:Tangential strain in a plastically deformed, austenitic steel ring. Measurements made at Chalk River and Los Alamos are compared with a finite-element calculation made by Elane Flower of Lawrence-Livermore Laboratory.

A system (c.f. figure 1) for positioning samples and collimating both the incident and scattered beams was installed this year on NPD to permit accurate studies of residual stress in engineering materials. To check this equipment, Joyce Goldstone and Mark Bourke, in collaboration with Tom Holden from Chalk River, remeasured the stress in a plastically deformed austenitic steel ring that had previously been examined at Chalk River [2]. Agreement between the two results was very good (c.f. figure 2). It seems that, with PSR running at 75 μA, it takes about 6 times longer to measure a single Bragg peak to a given statistical accuracy on NPD, with a resolution that is almost twice as good as that of the spectrometer used at Chalk River. Of course, the advantage of the pulsed source is that many Bragg peaks can be recorded simultaneously at two scattering angles (+90° and -90°), providing information about the anisotropy of residual stress and perhaps the density profile of stacking faults. A series of Bragg peaks would have to be recorded consecutively at a reactor to provide the same information, more than cancelling the time advantage of the reactor for measurement of a single peak. Additionally, the time-of-flight method ensures that the gauge volume within which residual stress is sampled is the same for each Bragg peak recorded. The principal disadvantage of spallation source instrumentation seems, at this stage, to be the time-consuming procedure needed for sample alignment. However, I expect this situation to improve as more experience is gained.

The LANSCE reflectometer (SPEAR) has been designed to use neutrons with wavelengths between 1 Å and 32 Å in two equal frames. This permits reflectivities to be measured for a large range of wavevector transfers perpendicular to a surface, without changing the grazing angle. Because the spectrum of incident neutrons decays rapidly at large wavelengths, the signal measured on the reflectometer only changes by a factor of a hundred or so over the 32 Å wavelength range, even though the reflectivity drops by five or six orders of magnitude. In 1990, a linear, position-sensitive detector was installed on

SPEAR. This device simplifies measurement of the scattering angle because both reflected and undeviated beams can be recorded without moving the detector. In addition, diffuse scattering can be measured, giving rise in some cases to interesting Rorschach-like patterns that we are now trying to understand. With its PSD, SPEAR is able to measure specular reflectivity at the 10^{-6} level, about an order of magnitude above the best value achievable with a well collimated and shielded single detector. It is our belief, substantiated to some extent by calculations performed by Devinder Sivia [3], that a complete reflectometry program requires both neutron and x-ray measurements. For this reason we have installed at LANSCE a conventional SCINTAG x-ray powder diffractometer that can also be used as a reflectometer. By next year, a Langmuir trough (the design of which was generously communicated to us by Jens Als Nielsen) and a single-crystal quartz cell will be available for reflection studies of liquid surfaces as well as solid-liquid interfaces.

Ancillary equipment has been added to other spectrometers. A computer controlled sample changer has replaced midnight manipulations by haggard LANSCE scientists on the Low-Q Diffractometer (LQD) and such a device will be added to NPD and SPEAR next year. A shear cell, designed by Gerry Straty of the National Institute of Standards and Technology (NIST) in Boulder, Colorado, was recently tested on the LQD. It is anticipated that both quartz and beryllium stators and rotors will be provided so that neutron and x-ray measurements can be made with the same sheared sample. As a first step towards implementing a capability for high-pressure powder diffraction, a test experiment was performed this year on the High Intensity Powder Diffractometer (HIPD) with a 49 milligram sample of $CaGeO_3$, contained in a platinum capsule and previously pressed at 65 kbar by John Parise of Stony Brook. Bob VonDreele has a poster about this work later this week.

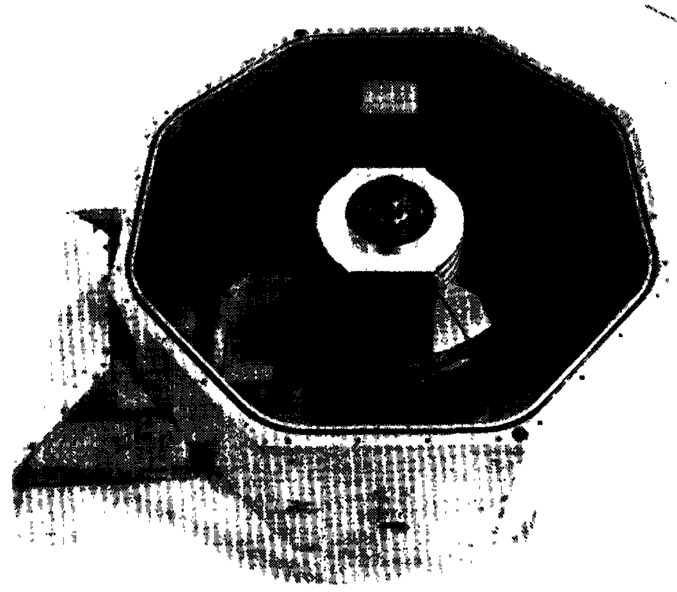

Figure 3: The T-zero chopper used on SPEAR to eliminate the "flash" of high energy neutrons and gamma rays produced when the proton beam strikes the neutron production target. The heavy nickel-alloy rotor turns 20 times per second and is synchronised with the beam delivery system.

A great deal of progress has been made on the chopper spectrometer PHAROS, which will have an incident-energy resolution of 0.5 % as well as a Brillouin scattering capability that will eventually achieve scattering angles down to 0.65 degrees. The engineering design of the spectrometer is essentially complete and most of the 20-metre incident flight path has been installed, along with a T-zero chopper (c.f Figure 3) and much of the secondary spectrometer for Brillouin scattering. Pressure tests were successfully carried out to validate the design of the window in the tank containing the large angle detectors. The tank will allow almost uninterrupted angular coverage from -10° to +140° scattering angle with a secondary flight path of 4 metres. We are now able to phase the PHAROS monochromating chopper to an oscillator signal with an accuracy of ±20 μsec. By using the chopper to fire the PSR, each neutron pulse can be phased to the chopper with a FWHM error of ±0.25 μsec. PHAROS will rely heavily on 10-atmosphere ^3He, linear position-sensitive detectors that are 1 m long and 25 mm in diameter with 25 mm resolution. Since the commercially available, time-of-arrival electronics for such detectors is expensive, we have chosen to develop a charge division scheme that we believe will cost ten times less per detector. This project has proved much more difficult than we thought. The main problems have been variation of discriminator levels, temperature drift of the position calibration by as much as 10 mm, and noise in the charge division circuits. The first two problems have now been overcome but new, faster amplifiers may be needed to eliminate noise. John Sandoval, the electronics engineer in charge of the PSD's is hopeful that the detectors will be available when PHAROS is turned on next year.

The neutron guide that will provide neutrons for the back-scattering spectrometer has been ordered from Silas in France. Delivery and installation of the in-shield rotating shutter is expected in spring 1991. The guide specifications call for a 60 mm-square, 20 metre-long straight guide coated with ^{58}Ni. At the end of the guide there will be a 2-metre converging section coated with appropriate supermirror that will reduce the beam to a 30x30 mm^2 cross section at the sample. The guide will be interrupted close to the shield wall by a T-zero chopper and further out by a light, disk chopper that will define the wavelength band of neutrons transmitted. We have decided to test silicon crystals grown by the Czochralski method and annealed at high temperatures as analysers. Schneider and co-workers [4] have demonstrated that the annealing process produces domains of oxygen defects that strain the crystals and greatly enhance their reflectivity without introducing a mosaic structure. The annealed silicon crystals can be produced with a variation of d-spacing of $\Delta d/d \sim 5 \times 10^{-4}$, an ideal value for our back-scattering spectrometer. In designing the spectrometer we will make use of recent theoretical work performed at LANSCE [5] which has shown how the resolution of the primary and secondary spectrometer should be chosen to derive the greatest benefit from the asymmetry of the neutron pulses produced by a spallation source.

I am sure that Gary Russell will tell you in detail about the recent failure of our hydrogen moderator. As figure 4 shows, replacing the liquid hydrogen in this moderator by room temperature water had an enormous effect on the intensity of long wavelength neutrons used by both the LQD and by SPEAR. Nevertheless, we had no choice but to make this replacement. When the hydrogen moderator vented at the end of the first cycle this year, we found that a leak of about 0.1 mm in diameter had developed between the hydrogen transfer lines and the vacuum jacket surrounding them. Worse, there was a leak of 1.6 mm diameter into the same vacuum jacket from the crypt, which is usually maintained at a pressure of 2 torr. These leaks could have allowed small amounts of hydrogen to leak into the transfer jacket at the same time as oxygen was cryo-pumped into the same space from the crypt. Prudence dictated that we not run the hydrogen moderator under these conditions, even though the leak rates were small. Thus, for two cycles we used water and several canisters of automobile radiator sealant instead of liquid hydrogen. Repairing the hydrogen moderator is the most important task that we will undertake during the up-coming shutdown. Unfortunately, when the present targets, moderators and reflectors were installed in 1985, the pressure of funds and deadlines did not allow sufficient thought to be given to repair operations. Accordingly we are not well equipped with remote handling tools, so the various components cannot be removed or replaced easily. The lesson to be drawn from this experience is rather obvious.

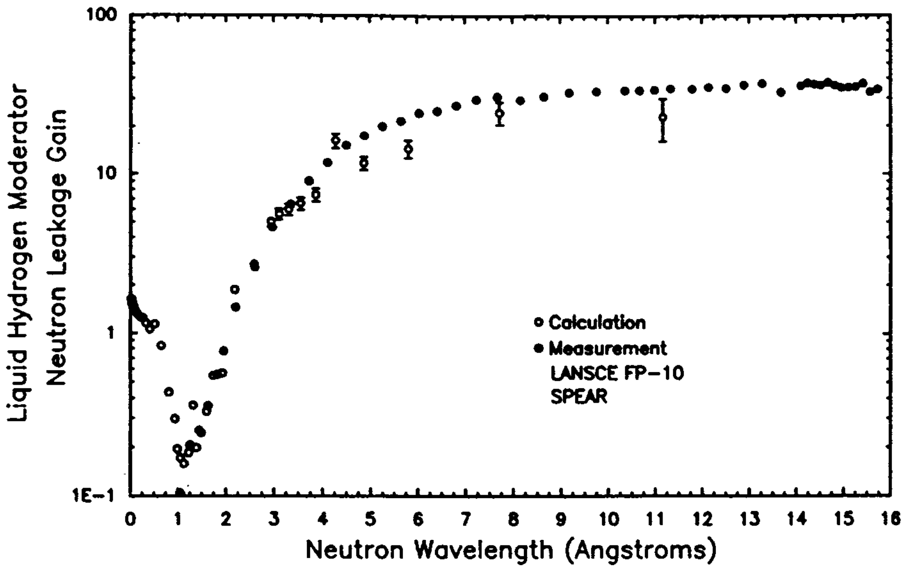

Figure 4: Comparison of the neutron spectra obtained with liquid hydrogen and water in the LANSCE "liquid hydrogen moderator". The measurements were made on SPEAR and LQD and the calculations were done by Gary Russell using the Los Alamos Monte Carlo codes.

There is a general consensus among neutron scatterers who use both spallation sources and reactors that the former provide "the big picture" while the latter are preferred for "surgical strikes". While one can debate the virtues and vices of each of these features, it is certainly true that the large dynamic range offered by most spallation source spectrometers inundates the user with more information than is easily comprehensible. The need for on-line data reduction and, above all, for display and manipulation of data in graphical form is obvious. To standardise this type of operation and to achieve a modular system capable of responding to various user needs, we have purchased a commercially available graphics and image enhancement system called PV-Wave [6]. This system uses a Pascal-like language capable of expressing sophisticated manipulations of data arrays, such as plotting, Fourier transforming, filtering and so on, in a single line of code. Commands can either be issued sequentially from a workstation or can be accumulated as a program. Windowing and menu organisation are straightforward and the system has been robust enough to convince several of our users to write their own data analysis protocols. The paper by Greg Smith and Bill Hamilton later in this conference demonstrates the way in which PV-Wave has been used on SPEAR.

I have believed for several years that neutron scatterers are lagging behind other experimental scientists in learning how to extract information from their data. For this reason, we have been fortunate to have Devinder Sivia at LANSCE for the past two and a half years to educate us in the mysteries of the Maximum Entropy method and Bayesian logic. Several of the results he has obtained in collaboration with other LANSCE staff have been quite spectacular. His two-channel entropy method has been used successfully to separate background from sharp signals in data obtained with the constant-Q spectrometer [7]; MaxEnt is now used routinely on the Filter Difference Spectrometer (FDS) to extract information with the best possible resolution; and an application to small angle scattering data obtained with cylindrical micelles showed that the lengths of these particles was quantised [8]. Finally, application of Bayesian methods to the very difficult problem of inverting data obtained with reflectometers led Devinder to suggest a new way of performing such experiments, dubbed neutron speckle holography because of its similarity to a technique applied in astronomy [9].

LANSCE is a very different place now than it was when the last ICANS meeting was held there in 1988. At that time, LANSCE was struggling to find its place: beam current was low and unreliable, buildings were temporary and many spectrometers were not well engineered. In the two years since ICANS X, all that has changed. The main emphasis now is not on building machines but on science. I fully expect that, in the two years before the next ICANS meeting, our users will produce scientific results that justify the effort that has gone into building LANSCE.

Acknowledgements

I would like to acknowledge the LANSCE staff whose efforts have made possible the outstanding progess that has been made during the past two years. The Manuel Lujan Jr. Neutron Scattering Center is supported by the U. S. Department of Energy under contract number W-7405-ENG-36 with the University of California.

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Q(P.A.Egelstaff): Intensity of liq-H_2 relative to H_2O at short wavelength?

A(J.M.Carpenter): Before conclusions are drawn about relative intensities, the pulse widths must be definitively compared. Of course in principle H2O should provide shorter pulses than liq-H_2 simply because of proton density differences.

Q(N.Watanabe): I understand that time averaged proton current of 75μA was achieved at 20Hz. Do you have any program to increase the repetition rate?

A(R.Pynn): No, we believe that would be a step backwards because the performance of many instruments depends on peak neutron flux, so one does not want to increase average current by increasing repetition rate.