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Workshop summary report on
TARGET ENGINEERING

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The 21 presentations in the target engineering workshop covered a very wide range of topics ranging from facility design via safety issues, materials problems and designs of mercury targets all the way to the spallation target facility at the MMF in Troitsk and ADS Studies including the MEGAPIE project at PSI.

Design of new facilities.
There are many similarities in the general layout and design of the three new facilities presented in the workshop, namely SNS (USA), JSNS (Japan) and ESS (Europe). All of them chose horizontal beam injection into a liquid mercury target, which can be moved to a hot cell located downstream of the proton beam line. There is a physical separation between the experimental floors on both sides of the target block from the high bay area above the target block reserved for operations and manipulations of target system components (shutters, moderators, reflector units, etc.), which is not the case in existing facilities. According to the different phases the three projects are in, the degree of detail in the presentations varied, with SNS (2MW beam) being most advanced and ESS still looking at several R&D issues that need to be resoved to demonstrate the feasibility of their ambitious goal of a 5 MW_b short pulse target. These issues mainly relate to the consequences of the thermal shock generated in the target during the pulse. A considerable amount of thought has been given to remote handling issues by the JSNS team, who presented a complete procedure for the target shell replacement. New ideas were developed by the SNS group in the design and handling of beam shutters as they successfully developed a concept to incorporate neutron-optical components into the targe shielding up to about 1 m from the moderators. Moderator systems located above and below the horizontally extended targets use either ambient temperature water or supercritical hydrogen. Much work has been reported by the JSNS team in optimizing moderator geometry and premoderators to make optimum use of the neutrons generated in the target.
Conforming with the spirit of ICANS, presentations were generally very open and existing difficulties and open questions were discussed intensely. Of these the question of the beam window separating the target atmosphere (vacuum) from the accelerator vacuum is a common concern. This window must be intensely cooled and hence be double walled. The walls must be strong enough to withstand the water pressure. Inconel 718, which seems to be the preferred choice for SNS and JSNS causes a lot of beam scattering, which is undesirable. Good experience with the water cooled target shroud made from AlMg3 at SINQ may point towards a way to ease this problem.

Safety issues

A careful analysis presented by the JSNS team confirmed that the radiological hazard potential of a mercury target is intrinsically small. A spill of all target material after 30 years of full time operation with a spread over 55 m^2 at the peak temperature in the target was found to result in an exposure of the public which amounts to no more than 0.2% of the natural exposure. Similar conclusions were arrived at by the SNS group. An increased risk would result from an external heat source that could lead to substantially enhanced evaporation. This is why the SNS design incorporates a 2 hours fire resistant enclosure and an effort will be made to limit of burnable material in the experimental hall such that no fire of 2 hours duration can be sustained. This may affect the allowed shielding materials along neutron beam lines and around instruments.

Materials problems

Predicting the change in materials properties in and around a spallation target is still an issue. Although the materials data base is growing as a result of the examination of the APT-irradiation in Los Alamos and of spent components from accelerator facilities, experiments in truly prototypical environments are still scarce. Materials examined from these components are: austenitic 304L stainless steel, martensitic DIN 1.4926 low nickel steel, Inconel 718 and high purity tantalum (ISIS target)

High purity Ta is the surprise and clearly deserves more attention: after 13 dpa the material taken from the ISIS target still showed more than 15 % ductility, while its strength had nearly doubled. (These 13 dpa were calculated from the proton beam load; including the damage from fast neutrons would probably double this figure.)

There is hope that he current irradiation program in the SINQ target should increase the data base considerably. Nevertheless, some conclusions may be drawn from a workshop held in Schruns (Austria) in October 2000:

- Data obtained from fission and fusion related research is relevant also for spallation, when scaled on a dpa (displacement per atom) basis, as long as increased gas production plays no role. Much of this data is, however, in a temperature range higher than relevant for (mercury) spallation targets.
- Helium per se starts to play a role at concentrations above 1 at%, which will hardly be reached in the target container.
- He seems to act as trapping centers for H, preventing the diffusion of H out of the material. This mechanism and its consequences of this are not yet understood.
- No indications could be found that beam pulsing would affect radiation damage in steels in one way or the other.
- Measured heat transfer coefficients between 316L and mercury seem to indicate good thermal contact (wetting).
- Corrosion in static and flowing mercury is not a problem at temperatures up to 200°C.
- The fatigue life of 316L stainless steel seems not to be affected by mercury in the absence of radiation
- Nothing is known on the effect of radiation on these phenomena. An experiment to investigate this problem in PbBi is in preparation at PSI (LiSoR-experiment). First data should become available in 2001.
- Evidence for liquid metal embrittlement of T91 martensitic steel by lead was reported in one instance.

Designs of mercury targets

While ESS, SNS and JSNS all plan to use flat mercury targets, the tree designs differ in detail. The need for cross flow (perpendicular to the proton beam and parallel to the window) to cool the window is generally acknowledged. Different solutions are examined by ESS, SNS and JSNS. The initial ESS design provides for three channel inlet flow with window cooling by the flow through the bottom channel. SNS has separate window cooling by mercury flowing between two windows. JSNS is investigating horizontal cross flow in whole target volume. Two configurations are being examined. The problems to watch out for are:

- The maximum temperature in the fluid should be less than 200°C to have sufficient margin against local boiling (cavitation)
- The combined stress on the walls from all sources must be well below the endurance limit.
- Wall temperature fluctuations should be minimized to reduce the risk of thermal fatigue.

As yet the problem of pressure wave effects on the wall at power levels above some 50 kJ per pulse remains unresolved. This concerns convincing experimental verification of calculated stress levels as well as mitigation methods and the possible role of cavitation.

Spallation target facility at the Moscow Meson Factory (MMF) in Troitsk
The Institute for Nuclear Research (INR) of the Russian Acedemy of Science has become a new member of ICANS. It is in the process of commissioning a spallation neutron source at its meson factory in Troitsk. Construction of the MMF facility was started in 1975, at that time incorporating a number of new ideas in particular in the accelerator (RFQ an DW structure). The full length of the accelerator structure for 500 MeV has been installed and successfully tested, but, due to lack of klystrons, operation is only at a reduced energy of 160 MeV (up to 365 MeV). Present funding difficulties restrict operation to only for 2x2 weeks per year for isotope production funded by Los Alamos. This allows 1 week of extra operation for facility development.
MMF offers interesting possibilities in the context of source development: The beam stop in the straight through position could be converted into a radiation effects test facility also for use with liquid metal (cf. proposal made at ICANS XIV).
In order to increase the power dissipation capability of their slowing down spectrometer (isotope production by resonant capture), INR is interested in installing a coolant free target, which should be liquid metal (PbBi) to transport the heat by convection.
The second target pit in the shielding monolith is not very suitable for neutron scattering instruments but could be used, e.g. to test and develop the coupling between a spallation target and a multiplying assembly. (ADS)

ADS Studies and the MEGAPIE project at PSI.
Studies to use spallation neutrons to transmute long lived nuclear waste from fission reactors are going on in Japan and Europe (also the US and elsewhere). In Japan such studies are one of the missions of the joint KEK-JAERI High Power Accelerator Facility, which will also host JSNS.
Actinide transmutation requires a very hard neutron spectrum, i.e. liquid metal or gas cooling in the core. Actinides are fissionable under these conditions but have a small delayed neutron fraction and almost no Doppler effect. Since reduces the control margin for critical reactors For this reason, driven systems with an "external" (spallation) neutron source are being considered. (Accelerator **D**riven **S**ystems, ADS).
Virtually all ADS concepts chose PbBi as the preferred choice target material and, in several concepts, also for core coolant. The concepts, however, are mostly in an early stage of technical design and often reflect a lack of experience of the design teams. Research

spallation neutron sources clearly can serve to substantiate these designs in many respects. One example is the MEGAPIE project presently under development in Europe.
MEGAPIE_(**MEGA**watt target **PI**lot **E**xperiment) is an initiative started in 1999 by CEA (F), FZK (D) and PSI (CH) to demonstrate the feasibility of a liquid PbBi target for the beam power regime of 1 MW. It will be carried out in the SINQ facility starting in March 2004 and aims at a total proton fluence of 6000 mAh (1 year). The Collaboration has since been joined by CNRS (F), ENEA (I) and SCK_CEN (B), with JAERI being in the process of joining. Interest has also been expressed by KAERI, IPPE and LANL.
The goal is to design, build, run, post irradiation examine and dispose of a well researched and extensively instrumented target, thereby contributing as much as possible to the design data base of future high power targets in Accelerator Driven Systems, and at the same time help PSI to decide whether a liquid metal target should be used in the future in SINQ, since a gain in neutron flux pf about 50% is expected over the target presently in use.