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SUMMARY OF THE WORKSHOP ON BOOSTERS AND NEW CONCEPTS.

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Our session was yesterday morning. We had three contributions on Boosters and New Concepts, and although there were only three contributions, there was plenty of discussion during and after and we easily filled the time available. We had two contributions on boosters, one from Jack Carpenter on the IPNS booster target and one from Dave Picton on the possibilities of enriching Target-I for ISIS, and then some discussion on these two papers. Finally, Walter Fischer presented a description of the ASTOR project.

The first paper was a very comprehensive review of progress on the IPNS enriched uranium booster target. Its basic design requirement was to fit within the existing space and to match the available cooling power of about 100 kW from the cooling system. The reason why they are interested in a booster is because of the limited proton intensity from the IPNS synchrotron (about 20 μA). This limit of a fairly low intensity is an important point in the philosophy of the design of boosters.

The basic operational parameters are: a K_{eff} of 0.8, a power gain of about 7 (which brings the total power to about 90 kW), the neutron production is increased by a factor of about 5 on the existing depleted uranium target and the moderator flux (the thing that really matters) is increased by a factor 3. The water cooling system provides 90 US galls/min and the target centre line temperature is $527°F$ ($275°C$), which is quite modest and a very good number to have. Those characteristics are calculated on the assumption of 500 MeV, 20 μA and a 3 cm FWHM beam spot. It turns out that they have, apparently, about a 30% tolerance on their available cooling capability. That sounds rather low to me, but, in fact, there are built-in tolerances and so it's not too bad. The target itself is uniformly enriched, with half inch disks at the front increasing to one inch at the back (as the energy deposition falls off). Short pulses are, of course, required and obtained by using a cylindrical decoupler (of boron) with a cut-off energy of about 100 eV; it's obtained by using a very interesting B-Cu composite.

As part of the complete and rather detailed survey of the performance of the target, some thermal-hydraulic stress analyses were done. The second disk from the front is the most highly stressed. Nevertheless, the fatigue life on the cladding (assuming 10 cycles per day) is about 27 years, which is rather comforting. In fact what rather more impressed me was the expectation of only 10 cycles per day of gross temperature changes; that sounds quite a good accelerator!

There was some heat transient analysis shown, where the classic accident scenario - you lose the coolant on the target and you ask yourself what happens - was examined. The target temperature rises to about 980°C after 5400 secs (ie still about two hundred degrees below the melting point of uranium) so basically, the target is safe as far as the outside world is concerned. That is a very important point. Activation was also considered; the worst case releases were still about 2% within the US guidelines, so again it sounds quite good. A number of safety studies were done which considered several possible configurations of the assembly; in all cases K_{eff} did not exceed about 0.93. We are told that K_{eff} about 0.95 is the value where the safety people really become very concerned. So it all sounded very encouraging and things are going quite well.

But we discovered there was a little dark cloud. That is, due to the casting process that was done by ORNL, the uranium shows texture (large grains and an anisotropic distribution). What one would like is small grains in a random orientation, because of the problem of radiation growth. Now, with the grain sizes that were found, predictions were made of target lifetime of somewhere between 1.3 and 2.1 years; the two numbers depend on whether one considers shrinkage in the radial direction, because of the preferred orientation of the grains, or axial growth. ANL would like 5 years. But those are the predicted numbers; there are some things which can be said about them which could be comforting but are not quantitative.

The target is expected to increase the thermal neutron current by about a factor of 3 to the experiments. Clearly because it is a heavily enriched target, there is a problem due to increased background from delayed neutrons and the delayed neutron fraction increases to about 3%. We heard from Kent Crawford, in another session, about the experimental steps that can be taken; but on the whole, the folk at Argonne must learn how to handle this increased background and then we will find out how serious it is.

We heard one or two things about the licensing and security; not too many, because, as the paper itself states, "Security" will not tell you too much about security. Jack painted a picture of armed guards, moats and alligators (it would be really quite pretty to have that around the Rutherford lab. as well).

Some other numbers have impressed me, considering the amount of effort which has gone in so far. I think over the last 3 years (when things have been done in earnest) a total of about 30 man-years effort has gone into designing and building the target. And the cost is 1.5M$. *[A comment was made by J Carpenter that the 30 man-years is somewhat an overestimate. He had 10 people working, but only part time, for a period of about 3 years.]* The target should be in by the end of 1986; it depends on how things go with the textured uranium. I think we should all like to say Good Luck to Argonne in this task. We at ISIS and at LANSCE will be watching you and are very concerned to see how well it goes as we have a great deal to learn from you.

The next paper was by Dave Picton, on some of the possibilities of enriching the ISIS Target-I. There are again similar types of constraints as at IPNS. That is, we have to satisfy still the basic shape of the target assembly and the power density (about 0.75 kW/cc). In fact, that limiting power density doesn't give much scope for uniform enrichment, because we are already at this peak value at the front of the target. There are three options: one is axial enrichment only, second to combine that with annular enrichment and third, to turn cicular plates into rectangular ones which could be variably enriched in either direction. The variations with the cylindrical target were all done at 9 cm, which is the present target material diameter. For the slab type target, a 10 by 20 cm^2 slab was considered. In all cases a homogeneous mixture of target material and coolant was used. One of the main aims was to flatten the power distribution, because we are near the acceptable peak power density at the front end of the target already.

We were presented with a large number of graphs, but I will do my best to reduce them to a small number of results. The first case was for an axially enriched target where a "semi-practical" distribution of enrichment in four 7.5 cm long zones was used; zero for the front quarter, second quarter 20%, then 50%, then 90%. The gain was quite small, a little more than unity for the front and a little more than two at the back end. The corresponding slab type target gives a similar gain for about half the enrichment. In some ways that would be a step forward, but in either case they are rather complicated devices, technically difficult to realise.

Another possibility was to vary the enrichment in both directions, axially and radially, and allow the power to go up to the maximum sensible available on the present target system of about 1.5 MW. Again, gains were a little greater than one at the front end and a little more than two at the back. An interesting and rather surprising result shown was that, in this assembly (which was "semi-realistic" and included decoupler, Be-reflector and D_2O coolant), the gain in thermal neutron current from the moderators was almost identical to the gain in fast neutron production. This is because in our case the Be-reflector is a moderating reflector and softens the spectrum of the neutrons reflected into the moderators.

There was a developing theme in the discussion associated with both presentations and which came through strongly during the second, that already even at relatively modest intensities, as for IPNS and the still modest intensity of ISIS, the users are becoming very concerned about backgrounds. Background is dominating discussions, as we have heard in all today's summaries. Put this into target terms: if the beam intensity is very low, then it's worth having a booster (as the Argonne have done) and because the proton beam intensity is low there is plenty of technical scope to do so and actually improve the thermal neutron current. However you do get a penalty of increased background. We heard from ANL, that there are things we might do and things we might do experimentally, but one still has to learn how to handle the increased background. If, however, the proton intensity is high, so already you are using a large fraction of the available technical limit on the target power density and heat flux (within the target itself), then the gains available by enriching the target are small. The gains must be measured against the technical complexity and of course the penalty of increased backgrounds. So it really does divide those things up and is leading to us to, we hope, clear conclusions about the way ISIS should go.

The last presentation was from Walter Fischer, on ASTOR. This is an accelerator and storage ring, an SIN "update". The reference design is for an energy of 2.2 GeV with a mean current of about 300 μA. It is based on the isochronous cyclotron so that one might well achieve a beam loss of 0.1% (which he called a conservative design but clearly at these energies and intensities is a very necessary design criterion if a difficult thing to achieve). The motivation for this work is essentially particle physics - especially neutrino studies - but clearly it's a potential neutron source (and I was going to say good neutron source but that may not be a properly qualified expression!). It has a high pulse repetition frequency (of about 2 kHz) with a pulse length of 150 to 300 nsec. It is possible to reduce the repetition frequency but the mean current goes down at the same time. Because of this high repetition rate, it is a system that would be good for the high epithermal region, 3 to 10 to 50 eV. There is scope for eV spectroscopy but, one must find good science against competition from synchrotron light sources, for example. Questions were asked about moderators and the possibilities of metal hydrides were recalled, which we at ISIS had looked at in the past but had discarded. Decouplers for high epithermal energies will be a problem, because the intent would be to take out the complete thermal part of the neutron spectrum. There were remarks that the spectrometers will be hard and we got back to the question of background.

We are always back to the problem of background these days!