SUMMARY OF THE ACCELERATOR SESSIONS

M.K. Craddock
Physics Department, University of British Columbia
and TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C. Canada V6T 2A3

The nine accelerator sessions were attended by about 30 delegates, who heard 26 papers covering both development of the existing sources and design considerations for future ones. Unfortunately, only the highlights can be mentioned in this brief summary; for full details the reader is referred to the individual papers.

From the existing sources (Table 1) some remarkable progress was reported since the last ICANS meeting. At ISIS the beam current has been doubled to over 200 μA, and the machine availability has also been increased. The extra intensity is the result of a number of improvements, in particular doubling the number of rf power tubes, incorporating feedforward compensation, and rapid programming of the betatron tunes and closed orbit. Plans are now being laid to raise the current towards 300 μA with the help of higher harmonic cavities. LANSCE has also made major strides, the beam current being raised to 80 μA. The beam loss mechanisms seem now fairly well understood, one novel form of injection loss being due to H^0 atoms emerging from the stripping foil in certain unfavourable excited states. The current-limiting instability is now fairly firmly identified as an electron-proton instability, the electrons apparently being supplied chiefly by secondary emission from the foil; remedial measures are under way.

The proposals for new sources are listed in Table 2 (adapted from ref. 1). Two of these (AUSTRON, to be built near Vienna, and IREN, at JINR Dubna) offer capabilities similar to those of existing sources but to new user communities. The others all aim at much higher powers in the 1-5 MW range, and come in a variety of shapes, sizes and energies, though all can be reduced to the formula of linac+ring(s). The major design question is whether the ring should be an accelerator or a (fixed energy) compressor; this choice is correlated with that of top energy, accelerator rings being associated with high-energy and low-current designs and compressor rings with low-energy and high-current designs.

The major design considerations for these sources are minimizing the beam spill and minimizing the cost. It is the first of these that leads to the correlation mentioned above; assuming that the activity produced by beam spill is roughly proportional to the power loss, then to maintain the present activity levels in accelerators operating with an order of magnitude higher beam power, the fractional beam current spill must be reduced by an order of magnitude. What sources of beam spill are most important? The answer to this question is a major factor in steering the designer towards either the higher-energy accelerator or lower-energy compressor ring options.

Experience shows that the greatest current loss in a ring occurs during injection and trapping. Since many features of H^- injection (e.g. transport, painting, momentum ramping, and foil damage) get harder or worse at higher energies, it is desirable to keep the ring injection energy as low as possible. This logically leads to the lower-energy linac+accelerator ring option, as exemplified by the Argonne, Brookhaven and European RCS (rapid cycling synchrotron) and FFAG designs. (The historic term FFAG is misleading, for although the Field is Fixed, modern designs do not use Alternating Gradient but sector edge focusing; a better term would be ring synchrocyclotron, by analogy with the sector ring cyclotrons at PSI, Indiana, RIKEN, etc.).

Beam loss occurring during acceleration in a ring is intrinsically more dangerous than at injection because of the higher energy. Since the circulating currents will be an order of magnitude higher than at present, and the acceleration time will be around 10 ms compared to 1 ms for a compressor, a synchrotron may be much more difficult to operate than a compressor. These considerations have led Rutherford and Los Alamos designers to choose the full-energy linac+ compressor ring option.

The problem here is that to reach 5 MW with a reasonable current in the compressor ring its energy must be at least 2 GeV. This would make a conventional linac very expensive to build and extremely expensive to operate. For this reason the design of superconducting proton linacs is being actively pursued both in Europe and North America. The Santa Fe Workshop last February concluded that a superconducting linac looked very promising for a neutron source from both technical and economic points of view. At this meeting, however, it was pointed out that the duty cycle had incorrectly been assumed to be 10% rather than 3.3% and that the power required to pulse the linac cavities had been neglected, casting some doubt on the earlier conclusions. These questions will perhaps be resolved at the Superconducting Workshop to be held at Wuppertal next week.

An alternative approach, avoiding the need for either a very high energy linac or an accelerator ring, and providing some redundancy, is to use multiple compressor rings. Both Rutherford and Los Alamos have proposed options using three compressor rings with an 800 MeV linac for a 5 MW source.

I. Gardner[1], reviewing the choice of top energy, pointed out that the while high energies required only low average currents, the peak current requirement remains more or less the same, the difference lying in the duty cycle or the number of rings. His conclusion was "USE LOWEST POSSIBLE ENERGY, HIGHEST POSSIBLE INTENSITY".

Which of the above options is most cost-effective must await a detailed design and cost study. Meanwhile I can provide some guidance -- or perhaps fan the flames of controversy -- by proposing two speculative inequalities regarding accelerator costs C based on common prejudices:

1. For the same top energy, repetition rate and beam current

$$C(\text{FFAG}) > C(\text{synchrotron}) > C(\text{compressor})$$

2. For the same energy gain and five years' operation

$$C(\text{warm linac}) > C(\text{SC linac}) > C(\text{synchrotron})$$

Finally, I would like to thank the organizers for the opportunity to participate in this meeting and also to demonstrate a famous tradition of Abingdon, the Mayor's distribution of bread from the roof of the County Hall. In doing so I may have become the first speaker ever to throw buns at his audience -- rather than the other way around -- and I'm grateful that they resisted the temptation to respond in kind.

References

1. I.S.K. Gardner *"Accelerator Considerations for the Choice of Proton Energy"*, these proceedings.

Table 1: PRESENT SPALLATION NEUTRON SOURCES[1]

Facility	Energy	Rep. Rate	Beam Power Avg.	Beam Power Peak
KENS (Japan)	500 MeV	20 Hz	2 kW	2 kW
IPNS (US)	450 MeV	30 Hz	6 kW	7 kW
LANSCE (US)	800 MeV	20 Hz	40 kW	60 kW
ISIS (UK)	800 MeV	50 Hz	145 kW	160 kW
PSI (CH)	570 MeV	cw	1 MW	

Table 2: PROPOSED ACCELERATOR NEUTRON SOURCES

	Linac	Ring(s)		Beam Power
JINR (e^-)	0.2 GeV	--	Pu Booster	0.06 MW (eqvt.)
LBL	1.0 GeV	--	Indn. Linac	5.0 MW
AUSTRON	0.07 GeV	1.6 GeV	RCS	0.1 MW
ANL	0.4 GeV	2.2 GeV	RCS	1.0 MW
BNL	0.6 GeV	3.6 GeV	RCS x 2	5.0 MW
ESS	0.8 GeV	3.0 GeV	RCS	5.0 MW
INR	0.6 GeV	45.0 GeV	K Factory	5.0 MW
ESS	0.46 GeV	1.6 GeV	FFAG	5.0 MW
KEK/NEA	1.5 GeV	1.5 GeV	Comp x 1	3.0 MW
ESS	2.4 GeV	2.4 GeV	Comp x 1	5.0 MW
"	1.2 GeV	1.2 GeV	Comp x 2	5.0 MW
"	0.8 GeV	0.8 GeV	Comp x 3	5.0 MW
LANL	2.2 GeV	2.2 GeV	Comp x 1	5.0 MW
"	0.8 GeV	0.8 GeV	Comp x 1	1.0 MW
"	0.8 GeV	0.8 GeV	Comp x 3	5.0 MW