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ISIS STATUS REPORT

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ABSTRACT

Two years back, I reported at ICANS X [1] that ISIS was running regularly at 100 µA, 750 MeV, with 9 scheduled neutron instruments and one muon beam line. Overall efficiency, measured as a percentage of time beam on target, was about 72%, and our stated priority was to improve reliability at 100 µA current. Over the past two years, major improvements have been made to several component parts of the system, and reliability so far in 1990 is just below 80%. Regular running periods at 100 µA have been achieved, with 100 µA average current achieved over a period of over a week. On 3 November 1989 a record integrated current over 24 hours of 2571 µA hrs was obtained. Trip rates have been significantly reduced. Three more neutron instruments are now scheduled, bringing the total to 12 neutron and 1 muon instruments. Around 350 neutron experiments were run in the 7 cycles of 1989, and about the same number are expected to be run in the 6 cycles of 1990.

Detailed reports on ISIS in the two years to March 1990 are given in ISIS 89 [2] and ISIS 90 [3]. Annual integrated currents have continued to rise, with 1989 seeing 283,000 µA hrs in 28 weeks scheduled running for users. So far in 1990, nearly 240,000 µA hrs have been achieved.

1. REVIEW OF OPERATION

As reliability has improved, integrated currents produced for user runs have risen, as shown in Figure 1. The first 4 cycles of 1990 have already produced 217,000 µA hrs: even though only 6 cycles will be run in 1990 for financial reasons (7 were run in 1989), continued running at this efficiency will lead to the 1990 figure exceeding that of 1989. Figure 2 shows the integrated beam current delivered per completed cycle to date: since ICANS X in 1988, ISIS has produced over twice as much beam as in its previous history. Figure 3 presents ISIS average beam current per cycle, and illustrates both the fall in efficiency after a long shutdown and the overall improved performance with time. The record cycle 6 in 1989 (Figure 4) included both the record day (day 16) which delivered both 2571 µA hrs (average 107 µA) and champagne to the crews. It was also in this cycle that a 100 µA average was maintained over a 9 day period (days 12-20 inclusive). 110 µA currents were achieved routinely in the second half of 1989, while the equivalent of 130 µA has been achieved at base rate during machine physics.

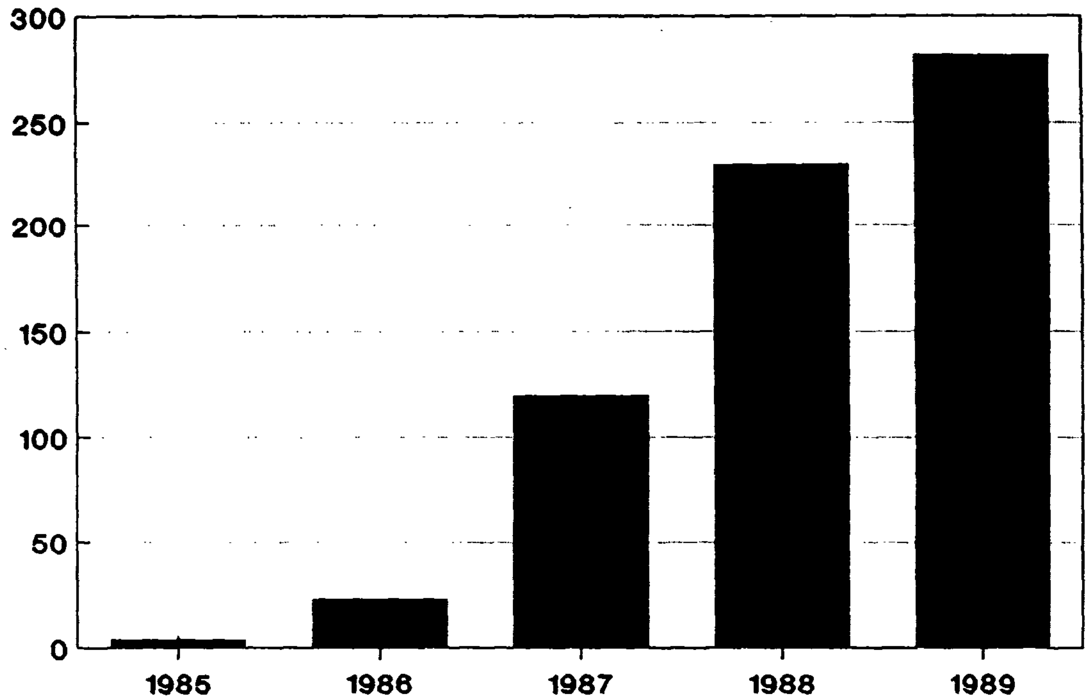

Figure 1. Integrated beam current produced by ISIS in each complete year from start-up in 1985 to 1989.

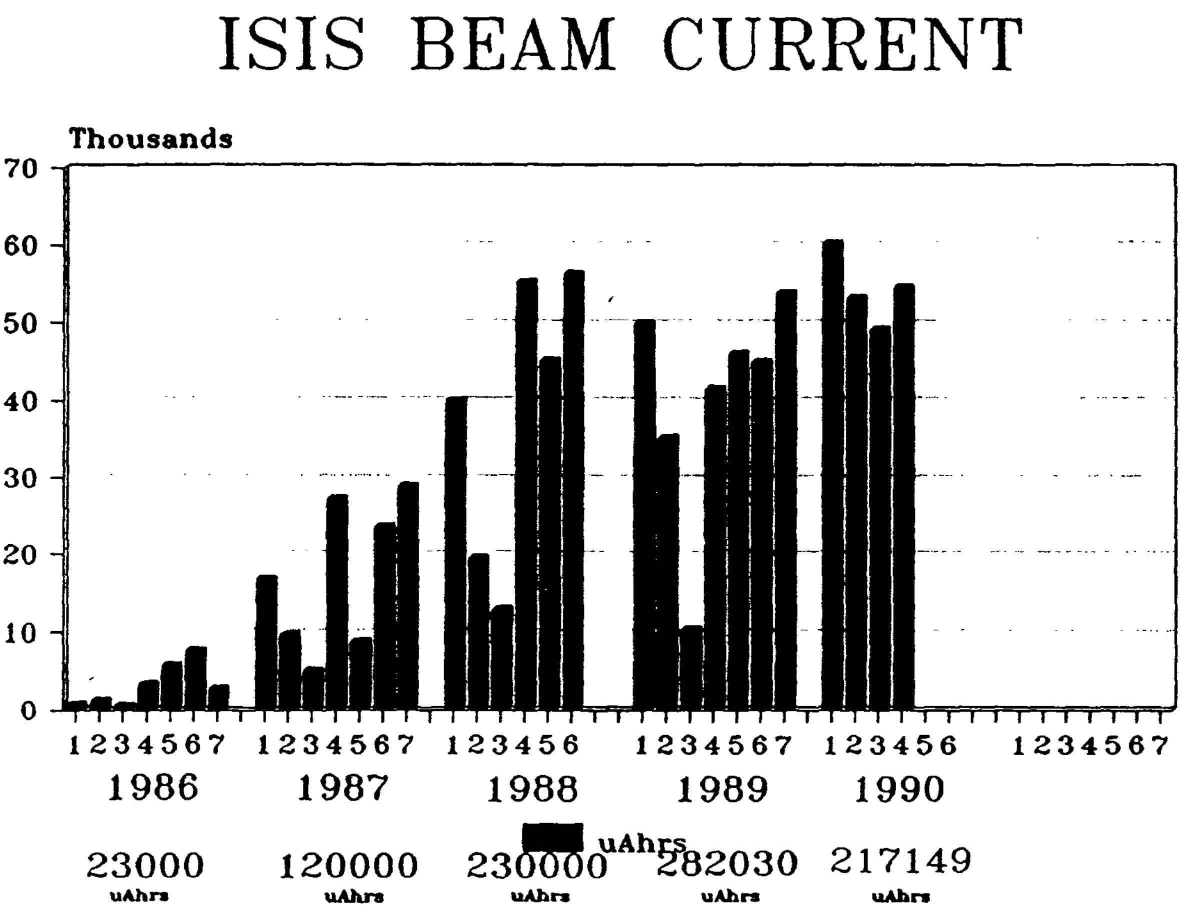

Figure 2. Integrated beam current produced by ISIS per cycle from 1986 to date.

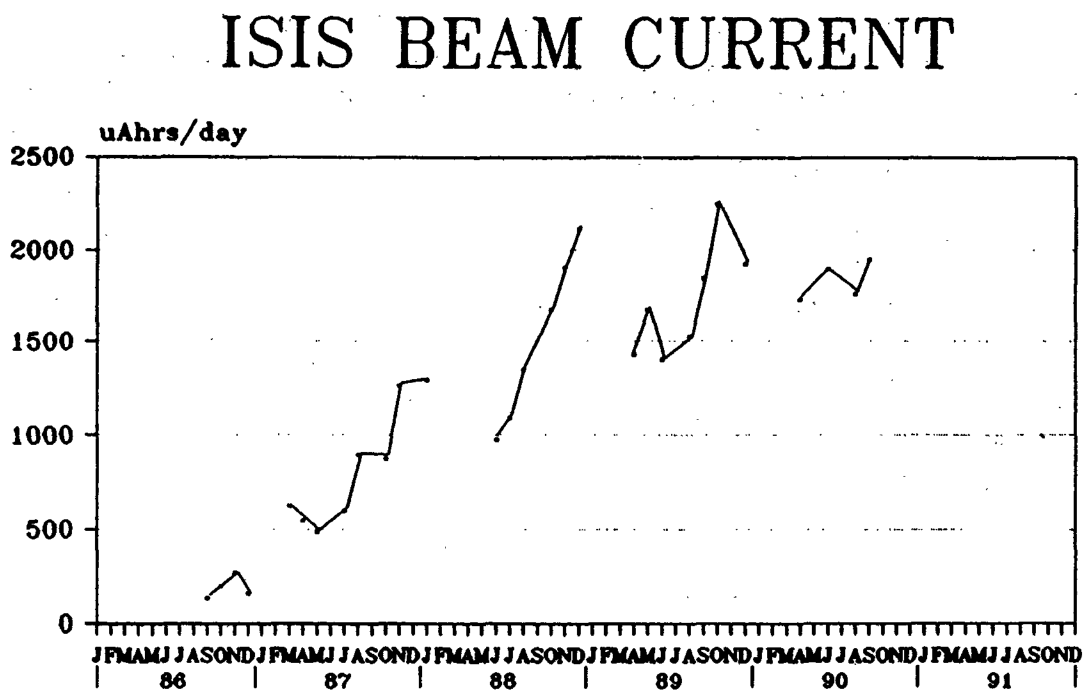

Figure 3. Average beam current per day for each cycle since 1986

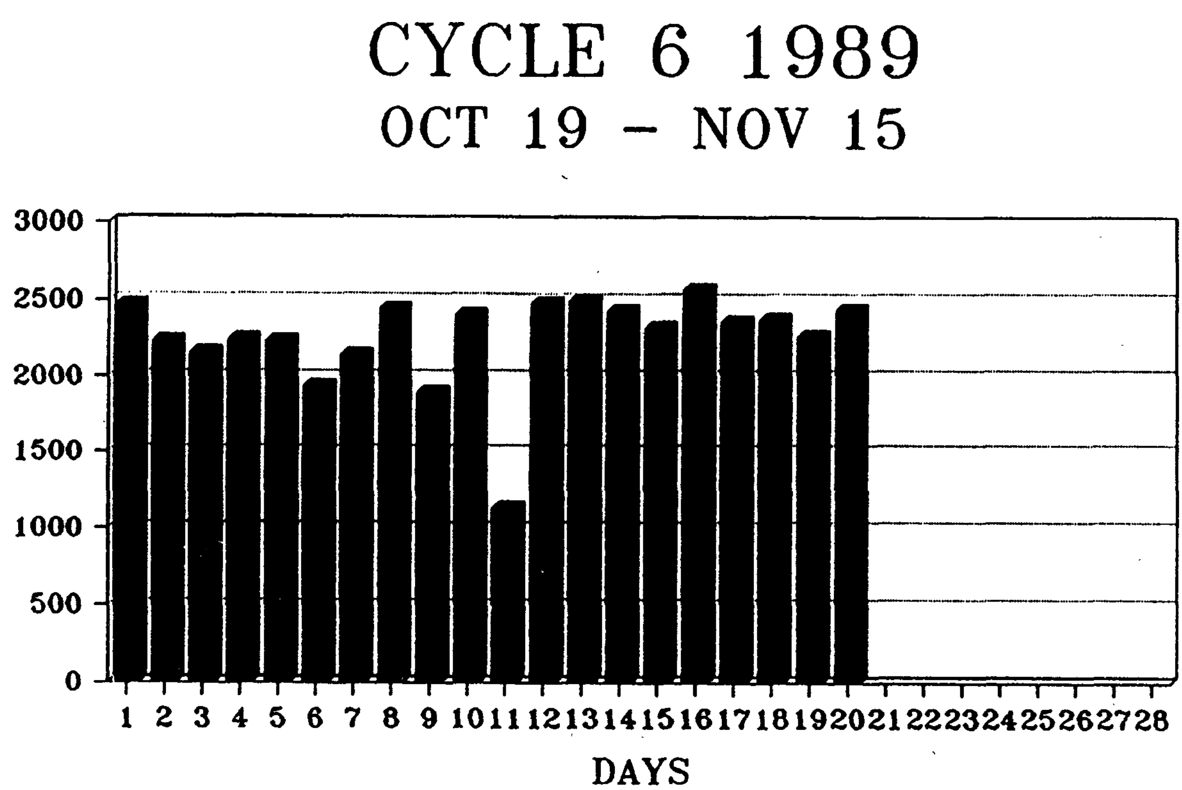

Figure 4. Beam production for each day in cycle 6, 1988. Over 100 μA was averaged for a continuous period between days 12 to 20 inclusive, with an all-time daily record of 107 μA on 3 November 1989.

Whereas in previous years, machine faults tended to come from a variety of sources and lead to short off periods, 1989 saw a shift to fewer but larger problems, with consequently longer off periods for repairs. The major failures in 1989 included the failure of a main dipole, overheating of power cables, sparking in a linac drift tube, and failure of the injection dipole power supply. Several of these problems stemmed from a major electrical storm. Some of these problems were tackled during the long shutdown between December 1989 and March 1990. A spare dipole was tested, the cable overheating problems were resolved by rerouting them, and the electrical insulation of the injection dipole magnets was improved. On the preinjector accelerating column, a modification to the electrodes was also introduced during the long shutdown to give better shielding of the insulators at the high voltage end of the structure. This has resulted in a significant reduction in the frequency of column breakdowns, and hence in the number of thermal quenches suffered by the neutron target. From an average of 68 per day in the last cycle of 1989, the trip frequency in late 1990 has fallen to 25 per day or less.

In addition to other major work, a new extraction kicker box is due to be installed in early 1991. In early 1989, it was observed that kickers 1 and 2 had been damaged by sparking, and that a large part of the copper conductor on kicker 3 had melted - although it still worked! The new kicker will allow the energy on extraction to be increased to the design 800 MeV.

At 100 μA (1.25 x 10^{13} protons per pulse), typical beam transfer efficiencies during routine running are :

Injection	98-99%	(98-99%)
Trapping in synchrotron	88%	(86%)
Acceleration	100%	(99%)
Extraction	100%	(99%)

The figures in brackets are those reported to ICANS-X, and demonstrate further improvement.

On the target station, new methane filters have been installed which last around 20,000 μA hrs. Uranium target number 3 failed in October 1988, after receiving 175,000 μA hrs of protons and experiencing 11,000 trips. The product of integrated current and number of trips was at 1.8 x 10^6 close to that for target 2: it is believed the failure mechanisms of the two targets were similar, namely swelling of the depleted uranium after repeated thermal shock. The tantalum backup target was then used for several cycles, and was found as expected to produce about 50% of the neutron yield of the uranium target. Interestingly, there was for the great majority of instruments no significant improvement in signal to noise ratio. There are thus no operational or scientific benefits apparent to offset the reduction in neutron flux. The fourth uranium target failed prematurely in August 1989: although no post mortem was carried out, a possible reason for the premature failure may have been the larger grain size of the zircalloy cladding compared to previous targets.

The asymetrically-poisoned ambient moderator, which gave rise to decay constants of 30 μs and 20 μs from opposite faces, was replaced in 1989 by a symetrically-poisoned one with 20 μs decay times from both faces. This modification was particularly beneficial in reducing the peak widths on the crystallographic instruments SXD and POLARIS. Substantial progress has also been made on the design of a system to allow the methane in the 100K moderator to be replaced as a liquid, thus removing the radiation damage products. This system, which will be essential for running at higher proton currents, will be installed in early 1991.

2. BEAM TIME DEMAND AND ALLOCATION

Seven cycles (equivalent to 28 weeks) were run for science in 1989, while financial considerations limited 1990 running to 6 cycles (24 weeks). Overall oversubscription of the instruments remained steady at around 2.5, despite the bringing on stream of new instruments. Some instruments were oversubscribed by factors of 4 to 5 or more. In 1990, 791 proposals requested 3576 instrument days, of which 403 (57%) were allocated the 1286 instrument days available. User demand from outside the UK continued to increase, and 34% of the available beam during 1990 was allocated to non-UK scientists. Figure 5 shows the distribution by country for Round 2, 1990.

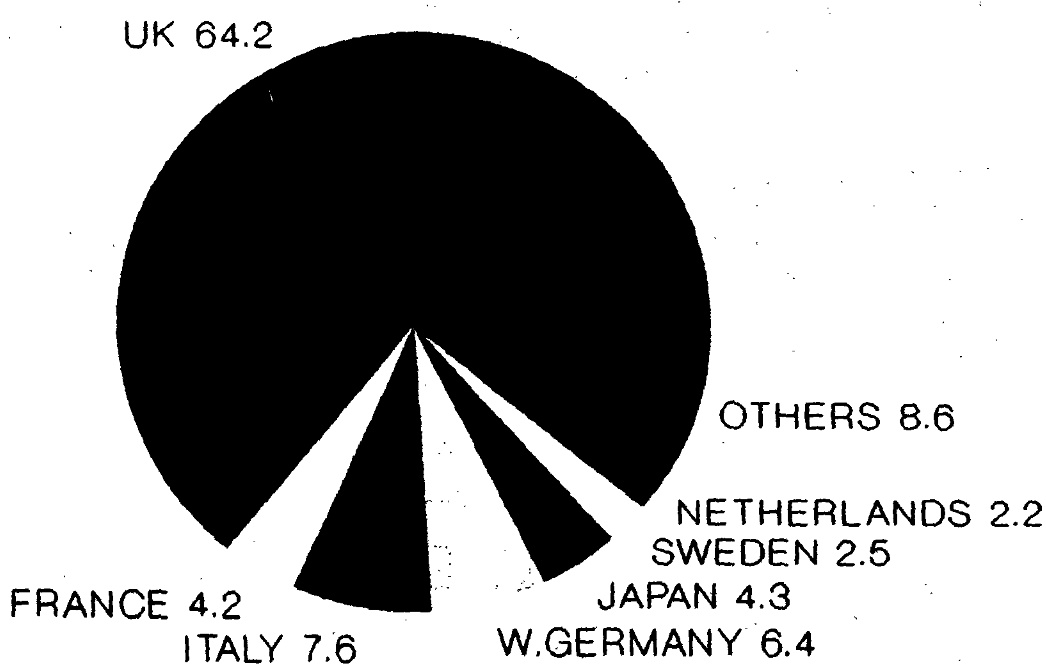

Figure 5. Allocation of ISIS beam for Round 2, 1990

3. NEW INTERNATIONAL AGREEMENTS

The agreements reported at ICANS-X as under negotiation have all been signed; as a result, agreements for the use of ISIS beams are now in operation with France, India, Italy, Japan, The Netherlands, Sweden and the University of Würzburg, Germany. In addition, a proposal to the Large Scale Facilities committee of the European Commission was approved, and consequently the present muon line will be split into three, considerably increasing the capacity of a very overloaded station. Furthermore, an important agreement was signed with the German BMFT which will provide funds to upgrade the accelerator towards its design current, and further improve reliability. Although primarily aimed at increasing neutrino production for the neutrino experiment KARMEN, this enhancement will benefit all users of the Facility. Finally, an agreement was signed with the Japanese Institute of Physical and Chemical Research (RIKEN) at the end of September 1990 for the construction of a further muon beam line and instruments on the opposite side of the muon target from the existing one. The characteristics of this line will be different from the present stopped muon line, and hence further extend the capabilities of muon science at ISIS.

4. INSTRUMENTS

Since ICANS-X, four further instruments have joined the scheduled user programme, making a total of 12 neutron instruments and 1 muon station. PRISMA - the ISIS spectrometer built by CNR Frascati, Italy - has demonstrated its suitability to perform overview measurements of dispersion curves in single crystals over an extensive range in energy and wavevector transfer. SXD - the single crystal diffractometer - joined the scheduled user programme in early 1990 and has already demonstrated the power of the time sorted Laue method, particularly in studies of disorder in crystals and magnetic satellites. SANDALS - the new generation instrument for liquids and amorphous materials designed to minimise troublesome inelasticity corrections - has just emerged from its commissioning phase. In addition to making new high quality measurements on water and silica, new science has emerged in studies of hydration of polar molecules (dimethylsulphoxide, ethylene glycol) and the tetramethylammonium ion, which appears to hydrate as a non-polar molecule.

Finally, MARI - the result of a strong collaboration with KEK, Japan - which saw its first neutrons in September 1989, has emerged from its commissioning phase and has already produced impressive results on e.g. crystal fields in ceramic superconductors, final state interactions in liquid ^4He, random network glasses such as vitreous silica, and antiferromagnetic spin waves in low dimensional systems. The instrument is clearly extremely successful, and is already in very strong demand. This is a fitting tribute to a very strong collaboration.

Papers are presented elsewhere at this meeting giving further detail on these new instruments.

Development work continues on eVS, ROTAX, and on progressing polarised neutrons at ISIS. The detectors on eVS were reconfigured to allow momentum distributions in single crystals to be measured in two mutually perpendicular directions simultaneously, and measurements on $KHCO_3$ have already produced the first unambiguous experimental evidence for the exploration of both potential wells by a single hydrogen-bonded proton.

The ROTAX principle was demonstrated on the test beam, and preparations are in hand for a test of a polarised chopped beam using the $SmCo_5$ filter developed earlier at ISIS. In addition, several instruments have been the subjects of major upgrades.

The table gives details of current ISIS instruments.

5. A CONCLUDING NOTE

ISIS produced its first neutrons at 19:16 on 16 December 1985. The occasion was marked by a 5th Anniversary celebration in and around the ISIS control room exactly five years later.

1990 was also notable for the retirement of Alan Carne, who was head of the Target Station and Muon Unit and contributed to the development and running of ISIS over many years, and also of David Gray, who was Head of Facility, and was central to the whole ISIS project from its inception. Both will be sorely missed, as will Bill Mitchell, who stood down at the end of September 1990 as SERC Chairman. Not only did the early discussions on ISIS take place in Bill's garden in 1975, but he remained a strong and sympathetic supporter of ISIS during his time in the hot seat.

INSTRUMENTS AT ISIS

Instruments commissioned since ICANS-X are underlined

Neutron Elastic

HRPD	High resolution powder diffractometer	Ab-initio structure determination, large unit cell structure refinement, phase transitions, mixed phases, line broadening, high-pressure studies.	$\Delta d/d \sim 5 \times 10^{-4}$ (backscattering), $\Delta d/d \sim 2 \times 10^{-3}$ (90° bank), guide: $\lambda^* = 0.98$ Å, minimum wavelength = 0.5 Å.
POLARIS	Medium resolution powder diffractometer	Magnetic structures, phase transitions, kinetic studies, small samples, high pressure work.	$\Delta d/d \sim 5 \times 10^{-3}$ (backscattering), $\Delta d/d \sim 8 \times 10^{-3}$ (90°), $\Delta d/d \sim 2.5 \times 10^{-2}$, (forward scattering).
<u>**SXD**</u>	Single crystal diffractometer	Reciprocal space surveying, study of structural phase changes and magnetic order, single crystal structure determination.	$0.2 < Q < 30$ Å^{-1}, $0.02 < \sin\theta/\lambda < 2.5$ Å^{-1}, 1.2–300 K accessible, position-sensitive detectors, Max. cell edge ~40 Å.
LAD	Liquids and amorphous diffractometer	Structures of liquids and amorphous solids, medium resolution powder diffraction.	$0.2 < Q < 100$ Å^{-1}, $\Delta Q/Q = 0.004$ (backscattering).
<u>**SANDALS**</u>	Small angle diffractometer for amorphous and liquid samples	Static structure factors of fluids, amorphous materials and biological systems.	Minimises inelastic corrections, $0.05 < Q < 50$Å^{-1}, $\Delta Q/Q \sim 0.01$–0.1.
CRISP	Pulsed source neutron reflectometer for surface studies	Surface structure, interfaces and surface magnetism.	Resolution 2–10% $\Delta\theta$, Q range 0.003–1.3 Å^{-1}, $0.5 < \lambda < 6.5$ Å, inclined beam for liquid surfaces.
LOQ	Low-Q diffractometer	Macromolecular, biological and other large scale structures.	$0.005 < Q < 0.2$ Å^{-1}, $\Delta Q/Q \sim 0.05$.

Neutron Inelastic

HET	High-energy transfer spectrometer	Magnetic and vibrational excitations, single particle motion in quantum systems.	Chopper incident energy 20-2000 meV, ϵ range 10-1500 meV, 1% energy transfer resolution.
<u>MARI</u>	Multi-angle rotor instrument	Dynamic structure factors of liquids and magnetic systems, excitations in crystalline, amorphous and disordered systems, molecular spectroscopy, momentum density.	Chopper incident energy 20-2000 meV, ϵ range 10-1000 meV, 1% energy transfer resolution, ϕ = 3-135°.
<u>PRISMA</u>	High-symmetry coherent inelastic spectrometer	Phonon and magnon collective excitations in single crystals.	16 independent crystal analysers and detector arms
eVS	Electron-volt spectrometer	Momentum density studies in low mass systems.	Resonance analysers in the range 1-20 eV, ϕ=30-130°
IRIS	High-resolution quasielastic and inelastic spectrometer	Rotational and translational diffusive motion in atomic and molecular systems, quantum tunnelling, crystalline electric field transitions and low lying inelastic modes.	Graphite analyser (002) reflection, 15 μeV resolution at E_a = 1.83 meV, Q = 0.25-1.85 $Å^{-1}$ (004) reflection, 50 μeV resolution at E_a = 7.2 meV, Q = 0.5-3.7 $Å^{-1}$.
TFXA	Time-focused crystal analyser	Inelastic scattering from magnetic and vibrational systems, molecular spectroscopy of hydrogenous systems.	ϵ range 2-2000 meV; ~ 1.5% energy transfer resolution, elastic line width 0.2 meV.

Muon beam

Muon Facility	μSR spectrometer and specialised equipment	Transverse, longitudinal or zero field pulsed μSR studies of magnetic materials, metals, semiconductors; muonium spectroscopy and muon catalysed fusion.	Incident momentum 20-26.5 MeV/c. Stopping range 30-90 mg/cm^2 Beam size 11 mm (v) x 20 mm (h) Intensity 5 . 10^4 μ^+/s Frequency response 100 kHz to 10 MHz

REFERENCES

1. D A Gray and J L Finney, Advanced Neutron Sources 1988, Ed D K Hyer, IOP Conf Series No 96, p11, 1989

2. ISIS 89, RAL-89-050

3. ISIS 90, RAL-90-050

Q(I.M.Thorson): I did not understand what you meant by "a three way split" in the muon beam. Could you please explain it?

A(J.L.Finney): The ISIS muon beam line accepts two sharp pulses 400ns apart every 20ms. The existence of these two pulses degrades the resolution of many μSR experiments. Currently, the new UPPSET device improves things by suppressing one of the two pulses. The EEC approved proposal will improve this situation considerably. One of the two pulses will continue to pass directly to what will be the central instrument of three. The other pulse will be split into two, with the two halves being kicked out to two experimental stations placed on either side of the central instrument. Muon capacity will thereby be increased by a factor of between 2 and 3.

Q(P.A.Egelstaff): Can you express your annual output in a convenient standard unit i.e. a 24 hour day at 100μA (2400μA hrs); in these units was your 1989 output 110 standard days?

A(J.L.Finney): Yes, of course. But the number will depend on your standard unit. Defining 2400μA hrs as 1 Egelstaff unit, ISIS in 1989 produced 118 Egelstaffs (!). We might prefer a rounder figure of 2000μA hrs, in which case 1989 produced 141 standard days.

Q(H.Tietze): Will a second target on ISIS have fully thermalized cold moderators?

A(A.D.Taylor): Probably yes.

Q(B.S.Brown): Can you say a few words about the plan and timetable for the upgrade to 200μA and 90%?

A(I.S.N.Gardner): The programme is designed to take 3years. Start of programme is 1990. The first step will be to increase the energy to 800MeV in 1991.