

A Discussion Paper for the Exploitation of the New Harwell  
LINAC for Condensed Matter Studies

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**Summary**

In December, 1974, Harwell obtained approval for the construction of a new electron LINAC able, to give improvement factors of around an order of magnitude over the present LINAC. The project was funded by Nuclear Physics Division but shared use, as on the present LINAC, is envisaged with the electron beam multiplexed between nuclear physics targets and a new condensed matter cell having some 18 beam holes. The project and its time scale is described, and figures detailed for the expected fluxes at the spectrometer positions assuming 50% multiplexed use. We show here that, for epithermal neutron energies (0.2 to 1.0 eV), both calculation and extrapolation from experimental results on the present LINAC suggest that the performance of spectrometers on these holes can exceed that from hot source holes at the ILL, or indeed that from any other source at present operating or approved in the western world. We therefore conclude that provision should be made for a substantial portfolio of instruments on the new LINAC. We present here a possible portfolio of 9 instruments to be installed over 10 years, the scientific programmes that would be possible with them, and their approximate costs of construction (or moving from their existing positions), and installation. We also give outline information and approximate costs of an appropriate experimental hall, and of the laboratory and office accommodation needed. We emphasise that the plans outlined merely form a basis for discussion and call for comments from the community of neutron beam users.

The references quoted are contained in the collection of references on Condensed Matter Research Using Pulsed Neutron Sources, D. F. R. Mildner and G. C. Stirling. RL-75-095.

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**Introduction** 1. The advantages of using a pulsed electron LINAC as a thermal neutron source for diffraction experiments were realised during the fifties (Egelstaff, 1953). Compared with a reactor neutron beam pulsed by a conventional rotor system, they give a relatively high epithermal neutron flux, relatively short pulse times, allowing short flight paths, and relatively large pulsed beam areas. The intrinsic neutron background should be less because the g and fast neutron contributions come as a "flash" essentially when the LINAC fires and scarcely exist between pulses when the slow neutron signal is being counted.

2. The present Harwell LINAC was installed in 1959 largely for nuclear Physics purposes, but since 1967 there have been a number of condensed matter experiments. Initially the programme was one of exploiting the techniques possible using the LINAC, including neutron moderation (Day and Sinclair, 1969 and Sinclair 1968) and spectrum calibration (Day, Johnson and Sinclair, 1969). Later work in the nature of demonstration experiments was performed on single crystal  $Mn_5Ge_3$  (Day and Sinclair. 1970) and on inelastic molecular spectroscopy (Day and Sinclair, 1971). In 1971 the work acquired new impetus with the commissioning of the Total Scattering Spectrometer (TSS). This spectrometer rapidly acquired an appreciable joint SRC/Harwell programme in the field of structure factor measurements from liquids and amorphous solids at high scattering vectors  $Q$ . The programme was reviewed by an NBRC Working party chaired by Dr Clark in 1973 (NBR p. 201). This group recommended further improvements in the counter assembly and in data handling which have now been implemented. The present programme has been recently reviewed (Sinclair et al, 1974). Experiments have been performed on the gases nitrogen and oxygen (Page and Powles 1975), the liquids nitrogen and oxygen (Clarke et al, 1975), heavy water, phosphorus, bromine (Clarke et al, 1975). gallium and carbon disulphide molten polymer polytetrafluoroethylene, the amorphous materials silica and germania (Wright and Sinclair, 1975) as well as several powder spectra. The nitrogen work is gratifying in giving possibly the first published example of a problem where measurements to comparable accuracy and resolution have not been possible on any reactor including the Grenoble reactor with its hot source.

3. There has also been successful experimental programmes on other electron LINACS of comparable power. These include the Rensselaer Polytechnic institute, USA, LINAC where several inelastic experiments have been performed (e.g. Kironac et al, 19670;Pan and Webb, 1985), the Tohoku LINAC in Japan where there exists a complex of 8 beam holes covering both elastic and inelastic spectrometers (Euratom 1973), and a smaller inelastic programme at Toronto, Canada (Egelstaff et al, 1975).

4. We must also review the status of other projects for the production of pulsed neutrons other than by the electron LINACS (see Hobbis 1974). Other processes which might be used are fission, proton spallation and fusion. All these

methods have the intrinsic advantage that they produce less target heat to be dissipated per neutron produced. The heat produced from electrons, fission, protons and fusion are respectively 2000, 100, 40 and 17 MeV per neutron produced. The fission process may be exploited either in a pulsed reactor or a sub-critical neutron booster. The pulsed reactor IBR 30 at Dubna, Russia, has operated for some years (Alberquerque, 1969) and has a peak thermal flux of  $10^{14} \text{ns}^{-1} \text{cm}^{-2}$ . However its long pulse time of 90 mseconds has meant the use of very long flight paths with consequently reduced count rates, not to mention instrumental costs. The project IBR 2 should give an impressive x100 performance with  $10^{16} \text{ns}^{-1} \text{cm}^{-2}$  peak thermal fluxes.

These long pulse-times are avoided by the sub-critical boosters as existing for a nuclear physics programme on the LINAC at Harwell (Poole and Wiblin, 1958). Used on the new Harwell LINAC a booster giving a multiplication factor of order 50 can be constructed without damaging pulse lengthening or background from delayed neutrons between pulses. Such a project is being discussed at Oak Ridge as part of the ORELA electron LINAC. Larger multiplications are possible using mechanically modulated boosters as in the "Super-booster" project (Poole, 1967) but at much greater cost and complexity.

Proton spallation sources give short intense neutron pulses with less problems in heat dissipation. The ZING project proposed by Argonne National Laboratory in 1972 (Carpenter and Marmer 1972) would have provided  $10^{15} \text{ns}^{-1} \text{cm}^{-2}$  peak fluxes. This proposal has now been superseded by a more ambitious project, IPNS, which will use the new proton synchrotron to give peak neutron fluxes of  $10^{16} \text{ns}^{-1} \text{cm}^{-2}$  (Carpenter and Price, 1975). Already, prototype ZING-P experiments have been carried out at Argonne with peak fluxes of around  $10^{13} \text{ns}^{-1} \text{cm}^{-2}$ . Elastic experiments on several powder and amorphous samples (Beyerlein et al, 1974, Beyerlein et al, 1975), and inelastic measurements on molecular vibrations in hydrogenous compounds (Mildner, Private Communications) have been completed with results showing great promise for the larger machines. Laser fusion sources are necessarily pulsed and have the desirable characteristic of relatively long periods between pulses. Their progress must be awaited eagerly in any consideration of an ultimate pulsed source.

## The New Harwell LINAC Project

5. The project for a new LINAC at Harwell obtained its impetus from the Nuclear Physics Division. They wished to replace the existing one with one representative of the best technology of proven reliability that was available "off the shelf". The machines considered were L-band (1300 MHz) LINACS built by Radiation Dynamics of Swindon, which are available in modular form in up to four modules. The machine originally considered was a 2 module machine capable of delivering an electron power of order 40 KW to a target. Assuming a 50% multiplexed use for condensed matter use this would have given a mean flux gain of around 5 over the present LINAC,

6. The proposal was considered in detail by the LINAC working party chaired by Dr. Hobbs (NBR/LRG/75, P.7). This considered the experimental programme possible with LINACS, the likely portfolio of spectrometers which could be justified, and attempted the complex task of making fair comparisons between LINAC and reactor performance. It appeared that in the field of epithermal energy neutrons (0.2 - 1 eV) where the fast pulse times from the LINAC could be exploited, even the present LINAC was competitive with reactors (LIWP/P.8). In the case of liquid studies where back scattering can be exploited, the existing LINAC actually out-performed the hot-source at Grenoble at short wavelengths  $< 0.5 \text{ \AA}$ , (LIWP/P.9). Studies for a high resolution ( $Dd/d = 0.03$ ) Back Scattering Powder Spectrometer (LIWP/P.4) and an inelastic rotor spectrometer (LIWP/P.3) appeared feasible using the present LINAC and programmes to implement these spectrometers have now gone forward (NBR/LRG/75/P.4, HNBFC/73/P.2). It was felt that in some respects the Harwell proposal was over-modest and that appreciable SRC investment should centre around a more powerful LINAC.

7. The proposal finally approved by the treasury in December 1974 was for a four module LINAC giving 90 KW beam power which in 50% multiplexed use would give order of magnitude gains in the condensed matter counting rates. The time-scale for the project is outlined in figure 2. The new LINAC is expected to be operational in the Spring of 1976. By phasing the building construction it was possible for the present LINAC, including condensed matter work on cell II, to be continued until the end of 1976. Of the major components noted, the condensed matter target cell is the most critical

and has to be defined by the end of May 1975. This is being done through a discussion group of present users held at Harwell. The LINAC, the target cells and targets are being funded solely by Harwell. This part of the work is under the control of the Project Officer, Dr. Eric Lynn of Nuclear Physics Division, with the help of a Project Management Committee (LAPMC) and a Technical Advisory Committee (LATAC). The target hall of the condensed matter facility, the instrument portfolio and their associated support facilities have not yet been defined or funded.

### **The Specification of the New LINAC**

8. The general arrangement of the new LINAC is shown in figure 3. It fires from the north side at right angles to the existing LINAC so that the existing Nuclear Physics booster and its associated flight tubes might remain unchanged by bending the electron beam by 90° and slightly downwards to join the beam line of the existing LINAC. Down the new LINAC beam line in the position formerly occupied by cell III would be a Fast Neutron Target for nuclear physics use and the Condensed Matter Cell. A Low Energy Cell would be placed after 2 LINAC sections for 7-30 MeV electron irradiation work. 

9. The detailed specification of the new LINAC has been given in LATAC/75/ P.2. Its minimum performance as given by the acceptance tests is only slightly inferior. Run in an "open circuit" condition with negligible beam power, the accelerator gives its full electron voltage of 136 MeV. At the higher beam powers needed for condensed matter research the output voltage drops following the "load line" given in figure 4. The acceptance test confirming this important curve is that for 0.75A pulse current the voltage should be at least 72 MeV. within the constraint of the load line there is considerable flexibility in choice of pulse repetition frequencies and pulse times. Standard pulse repetition frequencies are 150, 300, 600 and 1200 p.p.s. and standard pulse lengths for condensed matter use of 0.4, 1, 2 and 5 mseconds.

10. Linac pulses can be switched or multiplexed between the booster, the low energy cell and either the fast neutron cell or the condensed matter cell. (Provision for multiplexing between these two cells can be made at a later date). Pulse length modulation is possible so that short pulses to the booster and long pulses to the condensed

matter cell are feasible. At present pulse current modulation is not possible so that the low pulse currents appropriate to the long pulse condensed matter experiments will embarrass multiplexing with the very short pulses required by the low energy cell and fast neutron cell who could use much higher currents of order 6A. Because of these points non-multiplexed sole usage is expected during the fast neutron cell operation.

11. Some of the multiplexed modes of operation which are envisaged for routine use have been given by Lynn in LATAc/75/P.4. The most important for condensed matter usage are as follows.

-	Multiplexed Cells	Frequency	Pulse Current	Pulse Length	Electron Energy	Power
-	-	p.p.s.	A	msec	MeV	KW
(a)	Condensed Matter Cell	150	1	5	60	45
-	Booster	150	1	0.1	127	-
(b)	Condensed Matter Cell	300	1	2	60	36
-	Booster	300	1	0.1	127	-
(c)	Condensed Matter Cell	100	1	5	60	30
-	Booster	100	1	0.1	120	-
-	Low Energy Cell	100	1	5	20	-
(d)	Condensed Matter Cell	600	1	2	60	72

The choice of operating mode will always be a compromise between longer wavelength users who can use long electron pulse lengths matching their longer neutron thermalisation time and also require long periods to prevent frame overlap, and shorter wavelength users for whom the reverse considerations apply. In practice most of the present interests use neutrons in the range 1 to 0.5 AMS (a four-fold energy range) over which the neutron thermalisation time varies between 7 and 35 msec. Thus mode (a) above with 5 msec pulses is well matched to these times. Mode (b) would be suited to experiments between 0.5 and 0.3 A. It will be noted that the reduced pulse time in general compensates the increased pulse repetition frequency to leave the mean power, and hence the count-rate, largely unchanged. Case (d) involving safe use of the LINAC gives doubled beam power and might be advantageous for a few experiments where short

counting times were essential. In general it gives no advantage over a multiplexed run (b) of twice the running time.

### The Expected Neutron Fluxes at the Moderator Surface

12. When electrons of energy greater than around 30 MeV energy are stopped in a natural uranium target fast ( $\sim 1$  MeV) neutrons are produced essentially instantaneously from  $e^- \rightarrow g \rightarrow n$  reactions. The fast neutron flux produced is proportional to power

$$n_{\text{fast}} = 4.12 \text{ ns}^{-1} \text{ KW}^{-1} \dots \quad (1)$$

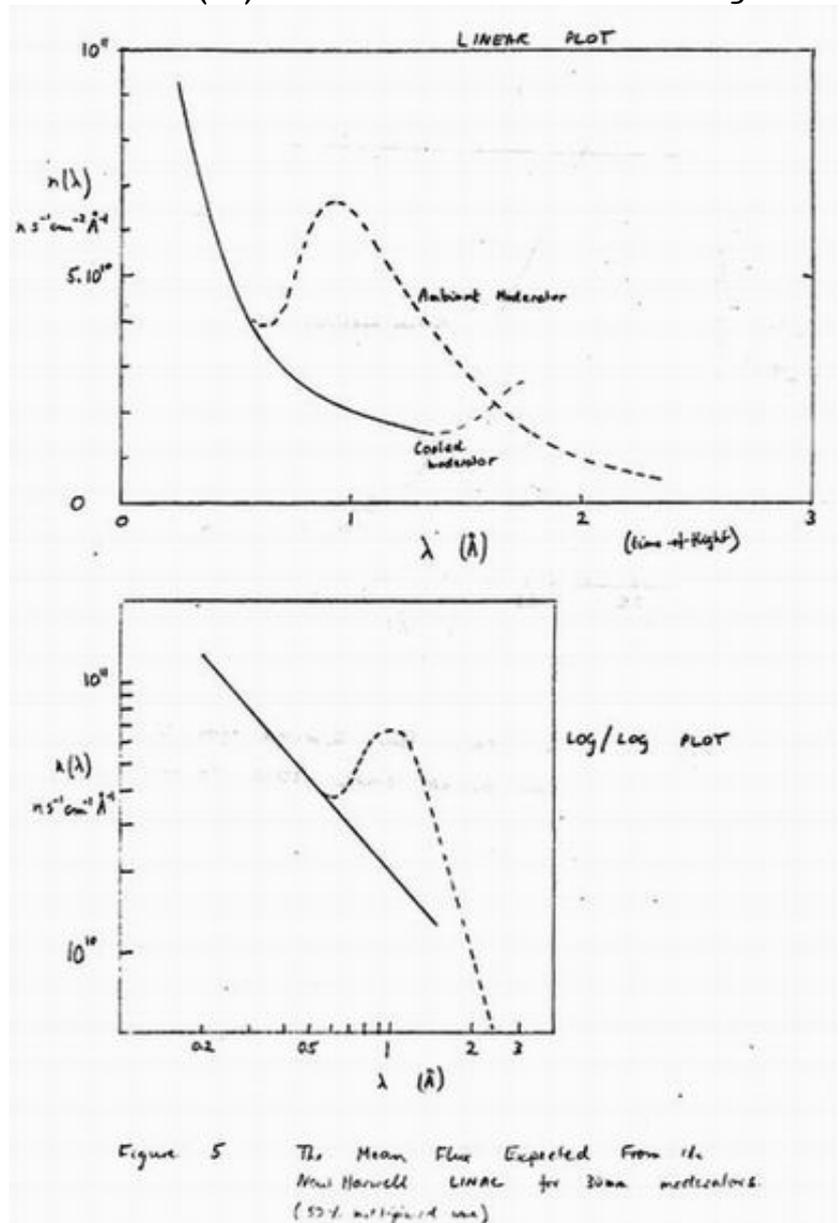
13. For condensed matter studies these neutrons must be moderated. This process has been extensively studied (see Mildner's references).

For a simple 30 mm. thick slab of polyethylene close to the target the flux of slow ( $>0.3$ AMS) neutrons produced is again proportional to power with the mean thermal flux at the surface of the moderator being of order

$$n_{\text{thermal}} = 1.10^9 \text{ ns}^{-1} \text{ cm}^{-2} \text{ KW}^{-1} \dots \quad (2)$$

This number is not very meaningful since it depends somewhat arbitrarily on the lower wavelength limit chosen, and since the spectrum is grossly non-Maxwellian cannot be directly compared with reactor fluxes.

14. The wavelength dependent flux calculated for the new LINAC by scaling from measurements made on the existing LINAC is sketched in figure 5. Here we have assumed a 30 mm thick polyethylene target at ambient temperature running in



the multiplexed mode (a) of §11 where the beam power is 45 KW just 10 times the beam power during multiplexed operation on the present LINAC. The figure shows the roughly 1/l dependence of the flux for epithermal neutrons with the typical Maxwellian peak becoming significant above 0.6AMS. The mean flux in the epithermal region may be expressed in round figures as

$$n_{\text{mean}}(l) = 2 \cdot 10^{10} / l(\text{\AA}) \quad n \text{ s}^{-1} \text{ cm}^{-2} \text{\AA}^{-1} \quad \dots (3)$$

This figure is derived from the flux curve given in LIWP/73/P.2 where the flux is given per (eV) on the epithermal energy range for the old LINAC as

$$n(E) = 1 \cdot 10^9 / E \quad n \text{ s}^{-1} \text{ cm}^{-2} \text{ eV}^{-1}$$

In practice the spectrum shape is found to be a proportional to  $E^{-0.82}$ , but we ignore the difference for the present purpose. The relationship between flux per AMS and flux per eV is given by

$$n(l) dl = n(E) dE \cdot (dl/dE) \\ = n(E) \cdot (2E/l) dl$$

$$= (1.0/E) \cdot 10^9 \cdot (2E/l) dl = (2 \cdot 10^9 / l) \cdot dl$$

The general relationship between fluxes in AMS and eV units is

$$n(l) = n(E) \cdot 7 E^{3/2}$$

The relationship between energy and wavelength being

$$l = 0.286 / E^{1/2}$$

15. The actual utility of these neutrons depends critically on the pulse length of the moderated neutrons. This moderation time has again been well discussed in the literature (Fluharty et al. 1969). For the present purposes we shall simply take the observed pulse widths as measured on the present LINAC. Again for 30 mm polyethylene and in the epithermal region we obtain

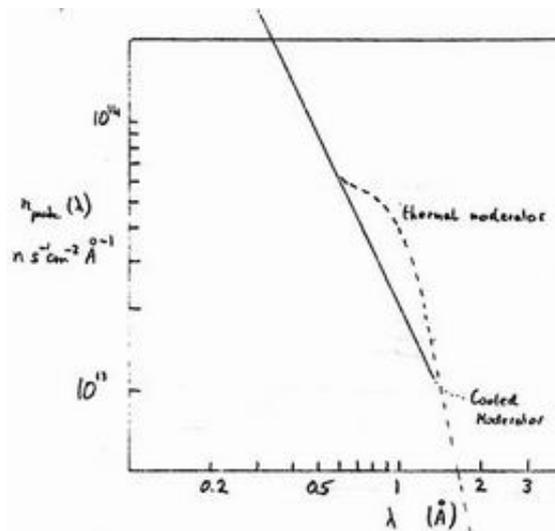


Figure 6. The Peak Flux Expected from the New Harwell LINAC (50% Multiplexed use)

$$DT_{\text{mod}} = 7 \left( \frac{\lambda}{\text{\AA}} \right) \text{ ms} \quad \dots (4)$$

This dependence of the pulse time on wavelength is of fundamental importance in understanding the performance of LINAC experiments. It has the simple physical interpretation that as the neutrons slow down by inelastic collisions within the moderator, the number of collisions required and hence the time spread is proportional to the wavelength.

Within the Maxwellian region of the spectrum, the pulse times are much longer, around double, because of the large number of nearly elastic collisions suffered by the neutrons before being lost from the moderator. The pulse shapes also become very asymmetric with a slowly decaying tail.

16. The pulse times and flux distribution associated with the epithermal wavelength range can be extended into the thermal wavelength range by preventing the build-up of the Maxwellian in this region. This can be done by homogenous poisoning of the moderator by neutron absorbers (Day and Sinclair, 1969), or by heterogeneous poisoning using a "cadmium sandwich" technique to decouple a very thin thermal

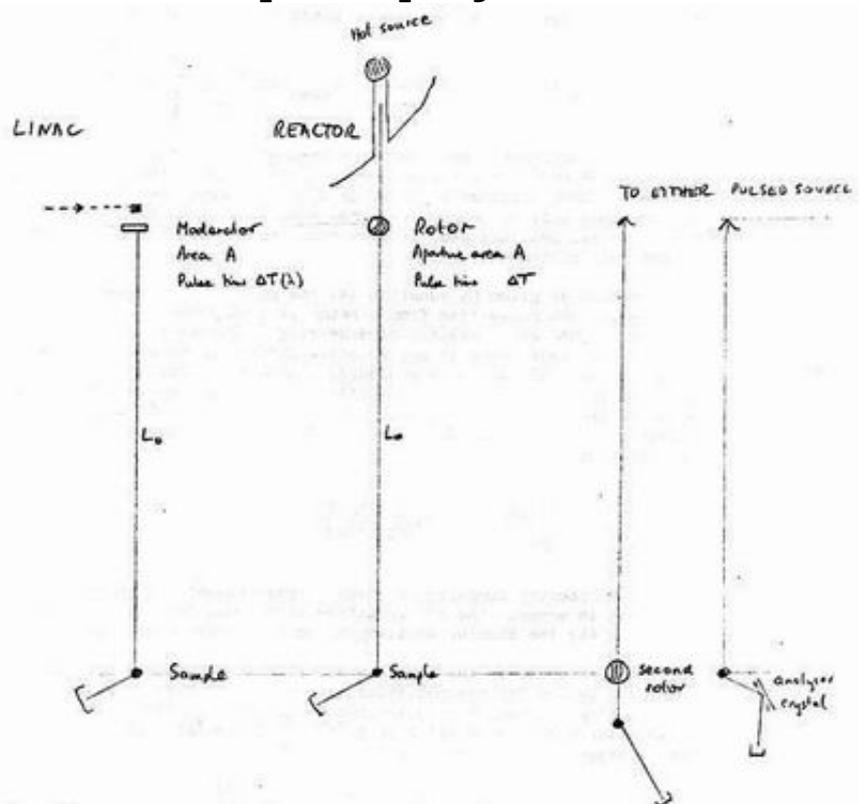


Figure 7.  
The suggested comparison between reactor and LINAC configurations.

moderator from a much thicker epithermal reflector layer. Both these methods produce some reduction in the epithermal flux. The best method which avoids this disadvantage is to cool the moderator so that the Maxwellian peak is shifted to the long wavelength end of the spectrum. A liquid nitrogen cooled slab of polyethylene is sufficient to extend the epithermal performance through the  $1\text{\AA}$  region, and such a moderator will be installed on the present LINAC this year.

17. Assuming the presence of such a cooled moderator for thermal studies on the new LINAC we may take relationships 2

and 3 above to hold over the whole range. The peak neutron flux may then be calculated assuming a pulse repetition frequency  $f = 150$  p.p.s. as in multiplexed use system (a) to be given by

$$n_{\text{peak}}(l) = [n_{\text{mean}}(l)] / [f D t_{\text{mod}} \sqrt{2}] = 2.10^{13} / l^2 (\text{\AA})^{-1} \quad \text{n s}^{-1} \text{ cm}^{-2}$$

Here we have assumed that the moderation pulse time is in all cases matched to the electron pulse time so that the true pulse time is of order  $\sqrt{2}$  times the moderation time. This relationship is plotted in figure 6 together with dashed lines showing the more complex relationships existing within an ambient and cooled moderator Maxwellian.

### The Expected Neutron Fluxes at the Specimen Position

18. The peak fluxes given up are still not comparable with reactor fluxes because the LINAC pulse has greater utility, being of larger area and angular divergence than say the chopped beam transmitted by a rotor. The valid comparison with reactor situations is between fluxes at the sample position for configurations of comparable resolution, as suggested in figure 7. By sample position in this connection, we generalise to refer to the position of the next component of the instrument, be it a real sample, a rotor, or a monochromating crystal.

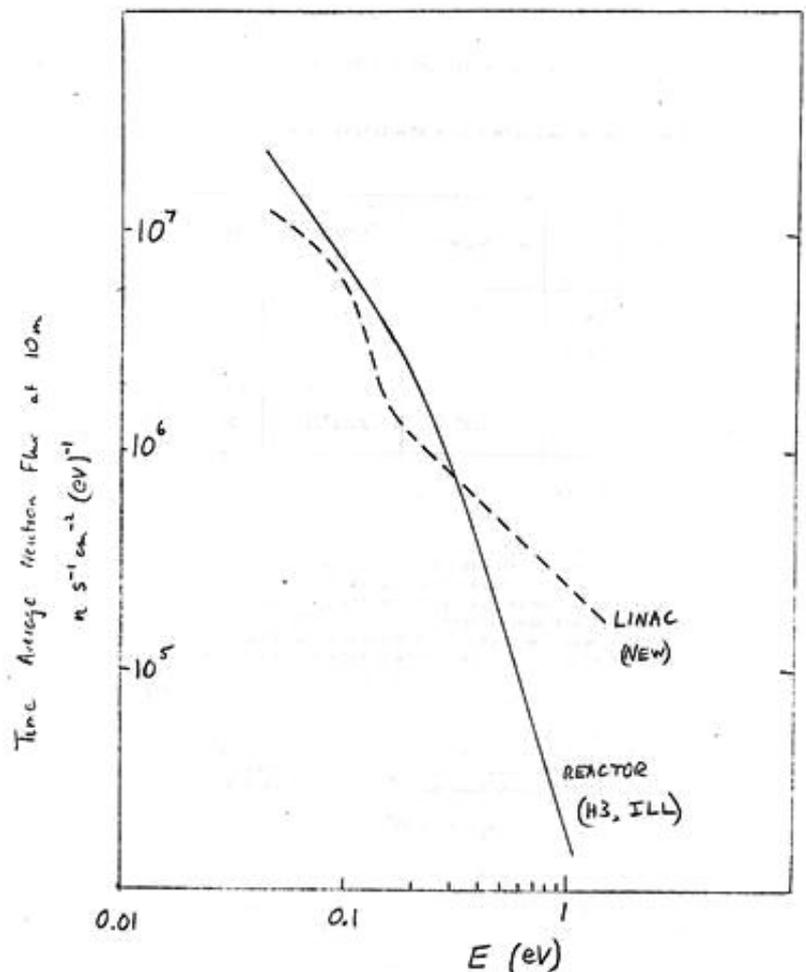


Figure 7a: The flux 10m from the new LINAC moderator (assuming 50% multiplexed use) compared with that from a single rotor time-of-flight spectrometer with the same pulse length, and incident flight path.

If the LINAC or rotor time pulse length is  $DT$ , its effective area  $A$  and the required wavelength resolution over the

incident flight path  $L_0$  is

$$R = D/l = DT/T \quad \dots (6)$$

Then the incident flight time ( $T_0$ ) defines the flight path  $L_0$  from

$$L_0 = (h/ml) T_0 = (h/ml) \cdot DT/R \quad \dots (7)$$

The time average flux at the sample position is therefore

$$\begin{aligned} N_{\text{sample}}(l) &= n_{\text{mean}}(l) [A/4pL^2] \\ &= n_{\text{mean}}(l) [m^2 l^2 R^2] / [4ph^2] \cdot [A/DT^2] \quad \dots (8) \end{aligned}$$

This is an important result, and the bracketed part may be said to define a "figure of merit" for pulsed sources. Short pulse times improve fluxes at the specimen position at least as  $DT^{-2}$ . In practice it is often more extreme than this as long pulse times also imply long flight times  $T_0$  giving frame overlap problems and, of even more importance, the expense of long flight path instruments.

19. Because as given by equation (4) the pulse time increases proportionally to  $A$ , while the pulse time from a rotor is independent of  $A$ , the comparison between a LINAC and a reactor time-of-flight spectrometer will always suggest  $1/l^2$  dependence in any relative difference between LINAC and reactor. Thus the new LINAC may have a moderator area  $A = 20000 \text{ mm}^2$  ( $\sim 15 \times 15 \text{ cm}^2$ ) and an overall pulse time  $AT = 10(x8) \text{ S}$ . A typical Harwell rotor as used on 6H in DIDO has a rotor aperture  $A = 1000 \text{ mm}^2$  (1" x 2" with 75% transmission), and a pulse time  $DT = 20 \text{ mS}$ . The relative figure of merit is therefore

$$n_{\text{LINAC}}/n_{\text{reactor}} = (20000/1000) \cdot (20/10)^2 = (80/l\text{\AA})^2 \quad \dots (9)$$

$$N_{\text{sample}}(l) = n_{\text{mean}}(l) [A/4pL^2]$$

Thus LINAC/reactor comparisons based on peak fluxes can be two orders of magnitude in error. The  $l^{-2}$  variation also shows the inherent advantage of LINACS for the shorter wavelength end of neutron beam science.

20. We next evaluate the time average flux at the sample

position given the above values for the moderator area A and the overall pulse time AT, and assuming the mean flux distribution given by equation 3. Substituting in equation 8 and remembering that

we obtain for the time-average flux at the specimen position

$$\sim (2.10^{10}/l) R^2/l^2(\text{\AA}) \quad n \text{ s}^{-1} \text{ cm}^{-2} \text{\AA}^{-1} \quad \dots(10)$$

At the same time, the flight path L is given from equation 7 as

$$l_0 = [4/l]. [10l/R] = 40R \text{ mm}, \quad \dots(11)$$

and the incident beam collimation  $\alpha_0$  is given by

$$\alpha_0 = A^{1/2}/L_0 \text{ rad} = 200R^0 \quad \dots(12)$$

In many cases it is more meaningful to discuss the mean flux per wavelength resolution element D l. This is related to the flux per  $\text{\AA}$  through

Then the incident flight time ( $T_0$ ) defines the flight path  $L_0$  from

$$n_{\text{res}}(l) = d(l).dl = n(l).Rl = 2.10^{10}R^3 \text{ ns}^{-1}\text{cm}^{-2}$$

In the table we tabulate these quantities as a function of resolution.

R	$L_0$ (m)	$\alpha_0$ ( $^\circ$ )	$n_{\text{sample}}(l)$	$n_{\text{res}}(l)$
-	-	-	$\text{ns}^{-1}\text{cm}^{-2}\text{\AA}$	$\text{ns}^{-1}\text{cm}^{-2}$
0.01	4	$2^\circ$	$2.10^6/l$	$2.10^4$
0.006	6.7	$1.2^\circ$	$7.10^5/l$	$4.10^3$
0.003	13	$0.6^\circ$	$2.10^5/l$	600
0.001	40	$0.2^\circ$	$2.10^4/l$	20

It should be noted that the flight path length and incident collimation do not depend on wavelength and hence can be uniquely determined as a function of resolution. In terms of the suggested sizes of the new LINAC target cell and building, we may note that the 1% wavelength resolution length of 4m lies within the cell wall (but could be employed using the loose block hole 10 in figure 9). The 0.6% resolution distance of 6 m occurs conveniently 1.5 m

from the proposed cell wall and will give a most convenient spectrometer position. The 0.3% resolution distance of 13 m occurs near the edge of the proposed building. The 0.1% resolution distance of 40 m would necessitate a separate spectrometer building. However for certain of the proposed holes (e.g. number 4) there is no obstruction preventing flight paths even up to twice this figure.

21. For very long flight paths, the use of neutron guide tubes must be considered. These have the great advantage of giving good (>50%) transmission over many tens of metres, but at the expense of an angular collimation angle  $\alpha$  determined by the guide tube material and the wavelength. For nickel guides ... (13)

Thus the guide transmission is proportional to  $\lambda^2$  and favours long wavelengths rather than the short wavelengths at which LINACS give their best performance relative to reactors. For a guide tube configuration, the analogue of equation 8 for the time average flux at the sample position is

$$n_{\text{guide}}(l) = n_{\text{mean}}(l) (a_g^2/4p) = 2 \cdot 10^{10} / (4pl) \cdot (0.2l/57)^2 = 2 \cdot 10^{41} n \text{ cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1} \dots (14)$$

Thus the time average sample flux is now independent of flight path and increases relative to the simple geometry at a given distance as  $\lambda^2$ . However for 1 $\text{\AA}$  neutrons the gain only occurs for flight paths greater than about 40 m. For cold neutrons with  $\lambda = 2\text{\AA}$  the guide tube has the useful collimation of 0.4° and begins to show a nett gain even for 0.2% resolution at a 20 m flight path. From equations 14 and 12 it may be seen that the

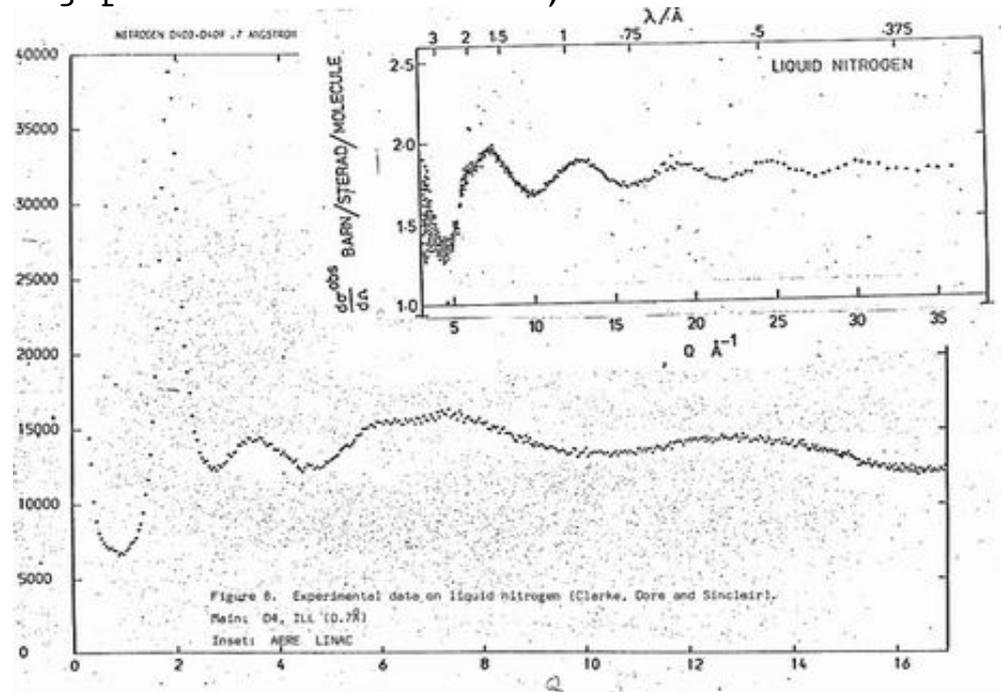
$$l > 10^3 \text{ \AA} \dots (15)$$

### Comparisons with Reactor Performance

22. It must be said that comparisons between LINAC and reactor performance are never easy, and are subject to many uncertainties. The best comparisons are between individually optimised spectrometers attempting to measure in the same range with the same resolution. Such a comparison is described in §14 but the completely different methods employed mean that the results are less applicable to any general comparison between the neutron sources. A second

type of comparison, more valid, is a general comparison in which LINAC time-of-flight experiments are compared with rotor time-of-flight experiments using a reactor. Such comparisons are quite sensitive to the details of the rotor system employed. There are two philosophies, neither of which are satisfactory, One is to take the parameters from routinely running rotor systems, often optimised for other wavelength ranges. The other is to design the required rotor and assume that it can be made routinely operational. (An important point of confusion here is to compare plausible LINAC rotors with those required on reactors where  $g$  and fast neutron stopping power are essential).

23. We now review and update a discussion paper LIWP/73/P.8 which attempted the comparison between LINACS and rotor systems on reactors sketched in figure 7. It was assumed that to keep resolution and



constructional details comparable a rotor would be available giving a pulse time  $\Delta T$  comparable with the moderation time 71 mS from a LINAC. A standard Harwell rotor system was assumed using 10" rotors spinning at 400 c.p.s with multislotted rotors having a separation between slats of 1/8" for strength reasons. Rotors giving comparable pulse times to the LINAC moderation times of 5 mS at 0.2 eV can be constructed but tend to have low transmissions of order 30%, and have slits so fine. that their transmitted angular divergence is only of order 0.3°. Figure 7a shows the flux calculated at a 10 m sample position for the new Harwell LINAC (assuming a factor 10 increase in useful flux over the old LINAC) compared with measured fluxes from the H3 hot source hole at the ILL. It is seen that the new LINAC gains over the ILL for energies over 0.3 eV, (0.5 Å). It remains within a factor of two of the ILL over the whole range appropriate to the hot source.

24. We next review the direct comparison made between the

elastic diffractometer D4 on the hot source and the Total Scattering Spectrometer on the old Harwell LINAC by Clarke LIWP/73/P.9. The two spectrometers have very different configurations but were both designed to measure elastic structure factors at high scattering vectors. D4 employed a zinc monochromator and scanned against scattering angle at constant wavelength. The TSS employed a white neutron beam and scanned against wavelength at a constant scattering angle of  $150^\circ$ . Resolution was comparable at high  $Q$  values. The mean counting rates recorded for the same 6 mm diameter vanadium rod are as follows.

Spectrometer	Wavelength range ( $\text{\AA}$ )	$Q$ range ( $\text{\AA}^{-1}$ )	Background ( $n^{-1}$ )	$n_{\text{res}}(l)$
TSS (Harwell)	4 - 0.4	3 - 36	140	40
D4 (ILL)	0.7	3 - 17	85	31
D4 (ILL)	0.35	3 - 33	4	2

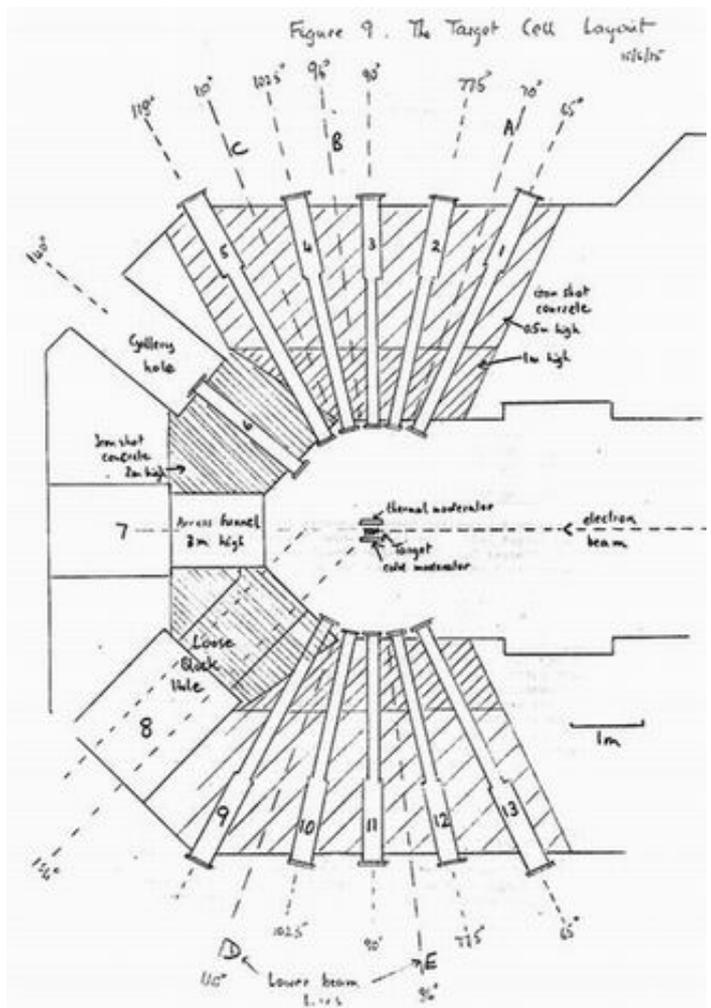
Figure 8 shows the measurements on liquid nitrogen performed in the same manner. It is clear from the figure and the recorded count rates that for  $Q$  values of order  $15\text{\AA}^{-1}$  even the present Harwell LINAC has comparable performance to the ILL hot source. For  $Q$  values of order  $30\text{\AA}^{-1}$  the advantage is overwhelmingly on the side of the LINAC. The reasons for this exceptionally good performance compared with our rotor comparison of the previous paragraph lie in the poor reflectivity ( $\sim 10\%$ ) of all monochromator crystals at these wavelengths and even more in the back scattering geometry which allows very relaxed angular collimations in both incident and scattered beams. Exceptionally good performance has also been noted in back scattering powder patterns. There is no doubt that the ability to exploit the back scattering configuration is a major advantage of pulsed sources.

### **The Condensed Matter Target Cell**

25. Figure 9 shows the planned general arrangement of the Condensed Matter Target Cell. The layout shown had been designed and approved by a small "Target Cell Discussion Group" convened by D. H. C. Harris representative of the principle SRC and Harwell LINAC users.

26. The cell is constructed from poured concrete of at least 3m thickness. This was judged from published calculations and overseas experience to be the minimum allowable. It is

expected that this wall thickness will reduce radiation levels within the experimental hall to permissible working levels. With a target room width of order 3 m this gives maximum flight paths of order 4.5 m. The target cell would be constructed largely of conventional poured concrete. However a band of concrete loaded with iron shot would be included in the plane of the beam tubes to compensate for the shielding loss caused by the beam tubes themselves. This would be +/- 0.25 m. high near the outside of the cell (two fast neutron scattering lengths), 1 m high up to one metre from the inner wall of the cell, and 2 m high in the region of the short flight path holes.



27. The target would be of natural uranium, water cooled, and built to handle 100 KW of beam power. Targets handling up to 60 KW are in routine use on ORELA but detailed design of a 100 KW target was still in progress. It will probably be necessary to install a tungsten target in the first instance to test the target window and cooling system. This would give around half the flux of a uranium target but would minimise the dangers from any target melt-down. The target will be remotely lowered into a service duct and moved out of the cell to the target service building when necessary.

28. Allowance for the provision of a booster project further down the electron beam line has dictated the general arrangement of the moderators and flight tubes. A new 6 m wide concrete tunnel could be constructed on the flat face on the left of the cell in figure 9, linking the new booster cell with the existing electron beam line. When the booster was in operation the existing target would be lowered allowing the electron beam to be transmitted to the booster cell. Hole 7 in figure 9 is therefore of large size and will

also provide access to the target room for bulky components. This arrangement will allow booster development to continue in parallel with use of the existing cell experimental programme, with relatively rapid change of electron beam path.

29. The beam tube layout has the general form of two horizontal fans of tubes from two moderators on either side of the target. It is envisaged that one of these moderators would be cooled to liquid nitrogen temperatures allowing epithermal neutron performance to extend through the  $1 \text{ \AA}$  wavelength region. The other would be a conventional thermal moderator appropriate to higher energy neutron experiments.

Both these moderators would be in line with the beam hole as sketched in figure 10. This arrangement gives the largest thermal flux since the moderator accepts the maximum solid angle of fast neutrons from the target. However it means that the g and fast neutron flash from the target is transmitted down the beam tubes giving a radiation level in the beam of order 500 R/h comparable with that from a reactor tubes.

30. The radiation problem is reduced by employing a through moderator offset from the target line, and it has been decided to use the space above the target for the future installation of such a moderator (the space below the target is required for target services). As shown on figure 10 this is placed to intercept only a small solid angle from fast neutrons from the target, A fast neutron reflector is therefore required to feed fast neutrons into the moderator. To avoid pulse broadening effects it is then necessary to line the reflector with a "de-coupling" layer to absorb any neutrons moderated to thermal energies in the reflector. Much work on this type of moderator has been recently done in connection with the ZING project where the high proton energies make an on-line moderator out of the question (Carpenter and Marmer ANL-SSS-72-1, Argonne Report). We have therefore positioned a second array of horizontal beam holes 400 mm above the electron beam height.

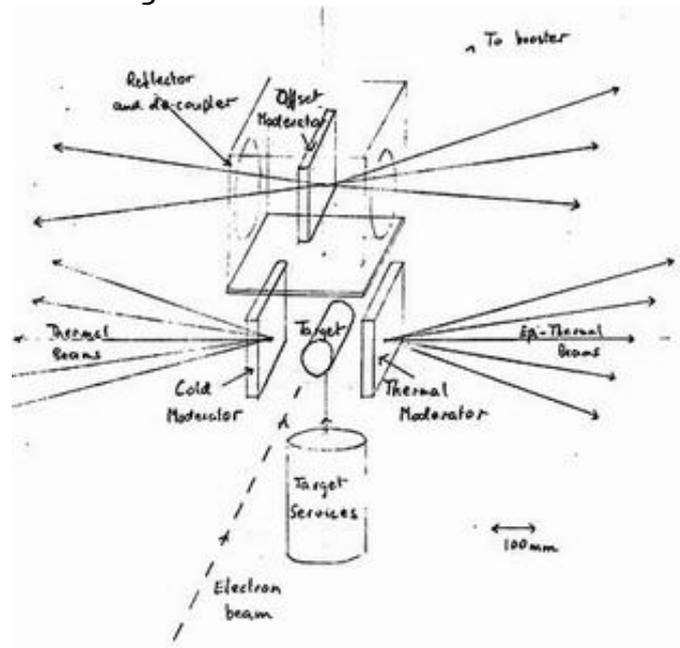


Figure 10 The arrangements of 4 Moderators

31. There are 18 beam holes in the proposed layout. This number being dictated by a requirement that holes on the same plane be spaced at around 1 m at the cell face. This is a smaller spacing than permissible on a reactor because only a few of the instruments need be situated close to the cell face, and because there is no problem of reactivity loss. The 18 holes are subdivided as follows;

- a) 5 standard holes on the ambient moderators
- b) 5 standard holes on the cooled moderator.
- c) 1 short flight path "gallery" hole.
- d) 1 large rectangular aperture leaving flexibility for experiments requiring rotating collimators, off-set holes for crystal monochromator or rotating crystal spectrometers, or guide tubes.
- e) 5 standard holes looking at the through moderator.

32. The standard holes (a) to (e) above will be of stainless steel tube of 200 mm smallest inside diameter with a step to a 250 mm size near the face. These will initially all be filled with resin and lead shielding. As each hole is brought into use, they will be fitted with internal collimators and evacuated. Remotely controlled beam shutters located in the target cell will also have to be fitted at this stage if permissible reactivity levels for work on these spectrometers are to be reached during operation of the cell. It is envisaged that the funding of these items will be done in association with the individual spectrometers, as it is expected that the holes will be brought into use as required over a period of years.

### **The Experimental Hall**

33. The building to house the condensed matter cell and its associated spectrometers is not at present decided or funded. Construction would ideally occur after the completion of the target cell scheduled for July '77 and be completed by the end of 1977 to allow adequate time for the installation of spectrometers before the LINAC start-up scheduled for May '77 (see figure 11). Local design should be complete by January '76 to meet this schedule. The hall has already been considered by the Target Discussion Group who recommended consideration of the 14 m x 25 m building

outlined in figure 11. The detailed positioning is dictated largely by constraints from the rest of the project. The 14 m width down the electron beam direction is relatively narrow compared to the length to minimise the interaction with the proposed booster. The 10m maximum flight path allowed on ambient moderator side is imposed by the long nuclear

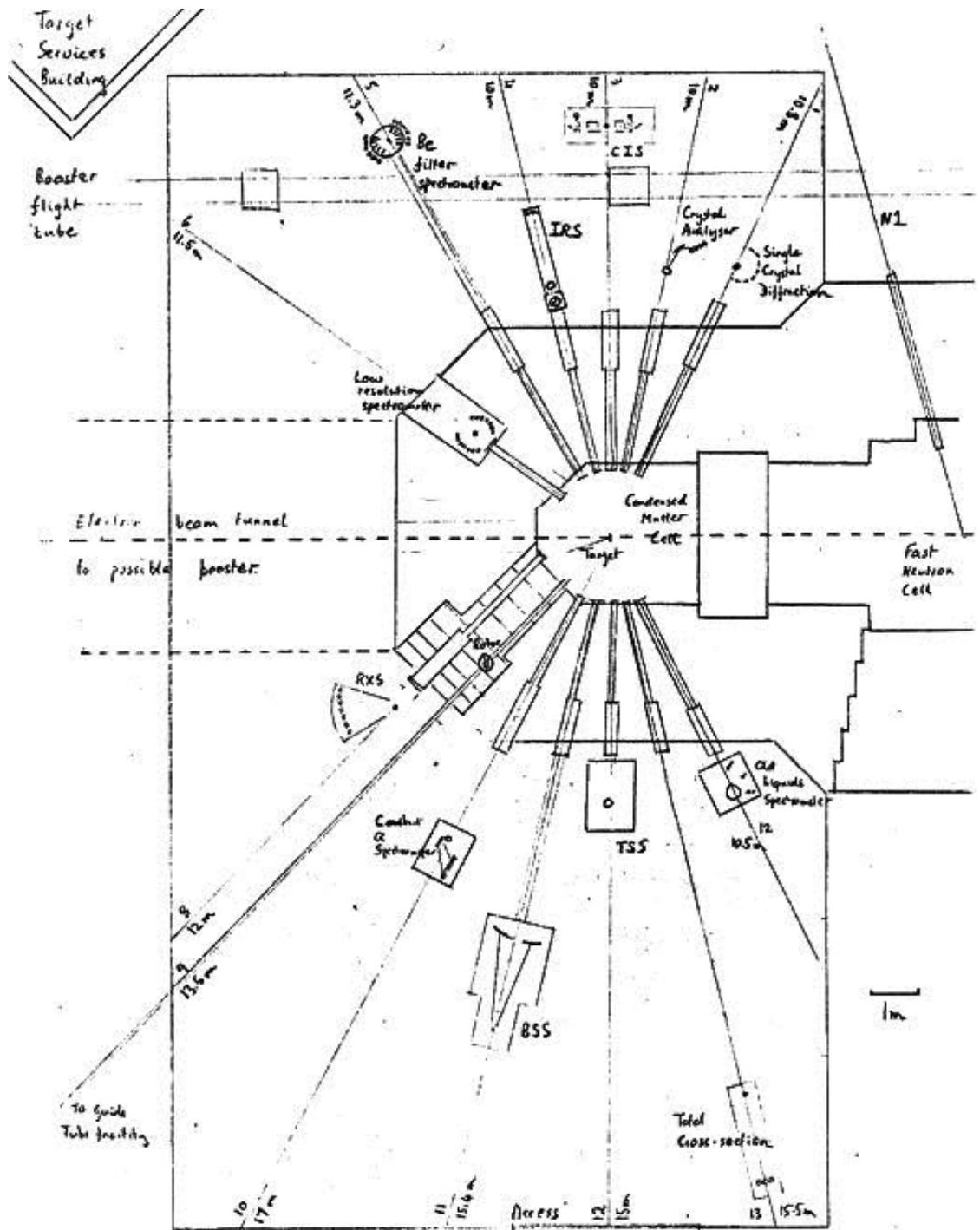


Figure 11. A Proposal for the Condensed Matter Experimental Hall.

physics flight path N1 and by the target service building. There are no restrictions on the cooled moderator size where longer flight paths are more likely to be required. The loose block hole 10 which would be suitable for the installation of guide tubes points to the corner of the proposed building allowing flight paths of 17 m. The Discussion Group also recommended a 10 ton overhead crane and vehicle access for the building to permit rapid moving of spectrometers and ad hoc shielding.

The suggested building has an area of 350 m (3200 sq. ft.) and priced at £25/sq. ft. would cost £80K.

34. The experimental facilities proposed would put acute pressure on the laboratory and office accommodation of the existing LINAC, building 418. The Discussion Group advised the provision of a substantial building giving office accommodation for about 30 people, 6 laboratories for cryogenic work\* simple preparation and counting rooms. A 2,000 sq. ft. building at £35/sq. ft. would cost 870K.;

### A Possible Choice of Instrumental Priorities

35. The appendix contains a list of possible LINAC instruments, their present status of development, their scientific objectives and performance, and an approximate Installed cost. The rate at which the new LINAC beam holes can be exploited must be severely limited by manpower and financial resources and we give here a possible choice of instrumental priorities. The objectives being to produce an instrumental portfolio which is most complementary to the existing reactor portfolio, which exploits the favourable epithermal flux available from a LINAC, and which enables us to utilise our existing hardware and experience.

#	Instrument	Status	Field	Year	Cost
1.	Total Scattering Spectromete	Exists	Structure factors	1977	£10K
2.	Back Scattering Spectromete	Will exist	Powder Diffraction	1977	£10K
3.	Inelastic Rotor Spectromete	Prototype exists	Molecular vibrational	1977	£100K
4.	Crystal Analyser Spectromete	Has existed	at low Q. Magnetic scattering	1978	£30K
5.	Cross-Section Spectromete	Has existed	Nuclear data	1978	£20K
6.	Costant Q Spectromete	Prototype exists	Phonons/magnons	1978	£50K
7.	Chemical Inelastic Spectromete	-	Inelastic spectrometry (large Q)	1979	£40K
8.	High Pressure Spectromete	-	Low resolution diffraction	1979	£50K
9.	Beryllium Filter Spectromete	-	Inelastic large Q	1970	£60K

26. Data collection and display for the 1977 instruments would be from the dedicated computers, and a simple existing hard wired time-of-flight analyser (LABAN) for the Inelastic Rotor Spectrometer. As the number of time-of-flight

instruments installed increased it would seem desirable to combine certain functions such as display, hard copy and data transmission facilities. Initially it would be practicable to use one of the existing GT40 computers for this purpose, but by 1978 this would become impracticable. It is therefore suggested that a "hub" computer such as PDP11/45 at around £50K should be purchased in 1979.

27. The funding programme including moderator, buildings and spectrometers might therefore resemble at December 1974 prices;-

Year	Items	Total Cost (£K)
1976	Cold moderator (20K)	20
1977	Experimental Hall (80K), Spectrometers (120K)	200
1978	Laboratories (70K), Spectrometers (100K)	170
1979	Tangential Moderator (20K), Spectrometers (150K), Computer (50K)	220
1980 ->	Booster construction	-

### A1. The Total Scattering Spectrometer (TSS)

#### Status

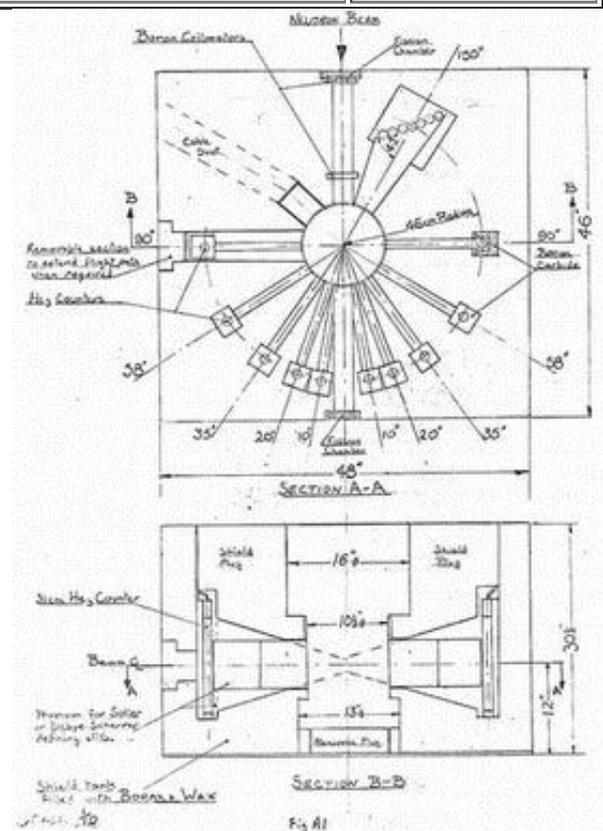
Under construction. Expected commissioning December 1975. Planned to transfer to the new LINAC.

#### Purpose

The spectrometer is designed to measure the structure factor  $S(Q)$  as a function of  $Q$  from 0.5 to  $60 \text{ \AA}^{-1}$ , Measurements can be done on liquids, particularly molecular liquids where structure extends to large values of  $Q$ , on amorphous solids and on crystalline solids.

#### Construction (see Figure A1)

The machine is constructed with a 5.5 m incident flight path and has 6 counter banks at angles of  $150^\circ$ ,  $90^\circ$ ,  $50^\circ$ ,  $35^\circ$ ,  $20^\circ$  and  $10^\circ$ . Each of the counters are at a scattered flight path



of 0.46m and are designed with curved slits of appropriate curvature to follow the Debye Schorrer cones.

There are monitor counters before and after the specimen, allowing some estimate to be made of the absorption.

The sample region diameter is 27cm allowing sufficient room for both cryostats and furnaces. Sample size is up to 50 x 50 mm.

A 6 position sample changer is available allowing simultaneous acquisition of sample, can, vanadium and empty cell spectra.

Data acquisition is by an on-line dedicated GT40 system. This allows display of the data while accumulating, and immediate subtraction and normalisation of spectra. A hard copy graph and numerical output is provided by a printer/plotter.

### Resolution

With a cooled or poisoned moderator the 150° bank gives a resolution  $DQ/Q$  of 0.010 independent of  $Q$ . Other banks have slightly inferior percentage resolution of order 0.02 → 0.05.

### Intensity

The time average intensity per resolution element at the specimen is  $2 \cdot 10^4 \text{ ns}^{-1} \text{ cm}^{-2}$ .

### Problems and Papers

Nucl. Inst. and Meths., 117 (1974), 445, Sinclair, Johnson, Dore, Clarke and Wright.

Nucl. Inst, and Meths., 114 (1974), 451, Sinclair and Wright.

Mol. Phys. 29 (1975), 561, Clarke, Dore and Sinclair.

Mol. Phys. 29 (1975), 1287, Page and Powles.

Mol. Phys. 26 (1973), 1325, Powles.



## **A2. The Back-Scattering Spectrometer (BSS)**

### Status

Operational. Planned to transfer to the new LINAC.

## Purpose

The spectrometer is designed to measure the diffraction pattern in the range of  $Q$  between 7 and  $60 \text{ \AA}^{-1}$  with 0.3% resolution. Measurements can be done on powdered crystalline samples, when the profile fitting technique may be used for analysis, and also on liquids or amorphous solids when better resolution than available with the TSS is necessary.

## Construction (see Figure A12)

The machine is constructed with an 11 m incident flight path and has two counter banks at a scattering angle of  $170^\circ$ . Each covers the range of angles from  $165^\circ \rightarrow 175^\circ$  using a time focussing geometry and give a total solid angle of .05 ster. The sample to detector distance is  $\sim 2$  m. The counter box, sample region and exist beam pipe are evacuated to eliminate air scattering.

There is a monitor before the specimen allowing background subtraction and absolute normalisation.

The sample region diameter is 50 cm to provide room for furnaces, cryostats and pressure cells. Sample size is up to  $50 \times 25$  mm. A 5 position sample changer is available; it may be operated at ambient temperature or at liquid nitrogen temperature.

Data acquisition is by an on-line dedicated ET44 system (subject of final approval). This allows display of data while accumulating and immediate subtraction and normalisation of spectra. A hard copy graph and numerical output is provided by a printer plotter.

## Resolution

With a cooled or poisoned moderator the spectrometer gives a resolution  $DQ/Q$  of 0.003 independent of  $Q$ .

## Intensity

Time average flux on specimen  $700 \text{ ns}^{-1}\text{cm}^{-2}$  per resolution element.

## Problems and Papers

The main problem is one of frame overlap. This will be tackled either by an overlap filter, unscrambling the

spectra or reducing the repetition frequency.

SB 72/74

LIWP/73/P4

HNBFC/73/P1



### A3. The Inelastic Rotor Spectrometer (IRS)

#### Status

Prototype in construction. Operational summer 1975 - proposal for an engineered version.

#### Purpose

The spectrometer is designed to measure  $S(Q, \omega)$  in the energy transfer range from 50 to 500 meV at medium  $Q$  values. Measurements can be made on incoherently scattering molecular samples to observe optical and internal molecular modes of excitation.

#### Construction (see Figure A3)

The machine is constructed with a 5 m incident flight path and ~1 mm from the sample the beam. is chopped with a spinning rotor which is phased to the source pulse. Scattering is observed in banks of detectors at scattering angles of  $5^\circ$ ,  $10^\circ$  and  $15^\circ$  placed 3 m from the sample. There are two monitor counters before and after the sample allowing background normalisation and measurement of the incident energy.

The sample region is evacuated and allows cryostats to be used without their normal outer containers. The sample size is 50 x 25 mm.

Data acquisition will initially be by hard-wired time-of-flight analysis. Subsequently it would be hoped to use a small dedicated mini-computer system which would transmit data to a larger computer for examination, preliminary analysis, etc.

#### Resolution

$$DE_0/E_0 = 2\% \text{ when } E_0 = 300 \text{ meV}$$

$$D\omega_0/\omega_0 = 3\% \text{ when } \omega_0 = 100 \text{ meV}$$

$$DQ/Q > = 5\% \text{ when } E_0/E_1 = 1.5$$

## Intensity

Time average flux at the sample (when  $E_0 = 300$  meV) =  $10^4$  ns<sup>-1</sup> cm<sup>-2</sup>.

## Problems and Papers

HNBFC/P., 2. Sinclair.

Neutron Thermalisation and Reactor Spectra, 1, p.389. -IAEA Vienna (1967).

G. J. Kironac et al,



## A4. The Crystal Analyser Spectrometer (CAS)

### Status

Prototype in operation on cell 2 until 1971. Proposal only.

### Purpose

The spectrometer is designed mainly to measure  $S(Q, \omega)$  in the region of high energy transfer ( $\omega$ ) and 'low' momentum transfer  $Q$ . Measurements can be made on molecular systems to study the internal modes. A second area of research is the study of high frequency excitations in magnetic crystals. Measurements can also be made at high  $Q$  values in order to study recoil effects.

### Construction (see Figure A4)

The machine is constructed with a 5 m incident flight path and energy analysis of the scattered beam is accomplished by a curved crystal analyser of total, flight path length  $\sim 1$  m. The crystal is made up of oriented CuBe crystals (or Be equivalent) cut to reflect (331) plane 100 meV neutrons into a phase detector. Time focussing on the analyser allows a large solid angle through the analyser without spoiling the incident beam resolution determination. The geometry allows very high energy transfer to be observed without contamination from scattering to the (662) at 400 meV,

A monitor in the input beam allows normalisation of the results for background subtraction.

Data acquisition is based on a small mini-computer that is linked to a larger computer for data examination and preliminary analysis.

## Resolution

$DE_0/E_0 = 0.02.$

## Intensity

Time average flux at the sample  $2^4 \text{ ns}^{-1}\text{cm}^{-2}$  (per resolution element).

## Problems and Papers

J. Chem. Phys. 55, 2807 (1971). Day and Sinclair.  
Research Applications of Pulsed Nuclear Systems. IAEA  
Vienna, 1967, p169, PorlimKi et al.  
Argonne Solid State Science Division, Research Surwn.  
October - September 1974



## **A5. Cross-Section Spectrometer (CSS)**

### Status

Existed up till March 1975 on cell III. Proposed for the new LINAC.

### Purpose

The facility is designed to measure removal cross-sections in the energy range between .005 eV and 10.0 eV. Measurements can be done on scattering samples in order to determine parameters for multiple scattering correction and on special samples in order to derive total scattering cross-sections. These can be used to estimate incoherent cross-sections, to derive mean Kinetic energy values or may be needed for reactor design purposes.

### Construction (see Figure A5)

The machine is constructed with a 5 m incident flight path and a flight path for the transmitted beam of 2 m. Converging-diverging geometry is used and gives an adjustable sample size of -10 mm diameter. A monitor before the sample allows normalisation for background and transmission determination.

Two sample changers each with 3 positions allow the sample to be oscillated and filters for background determination to be inserted in the beam.

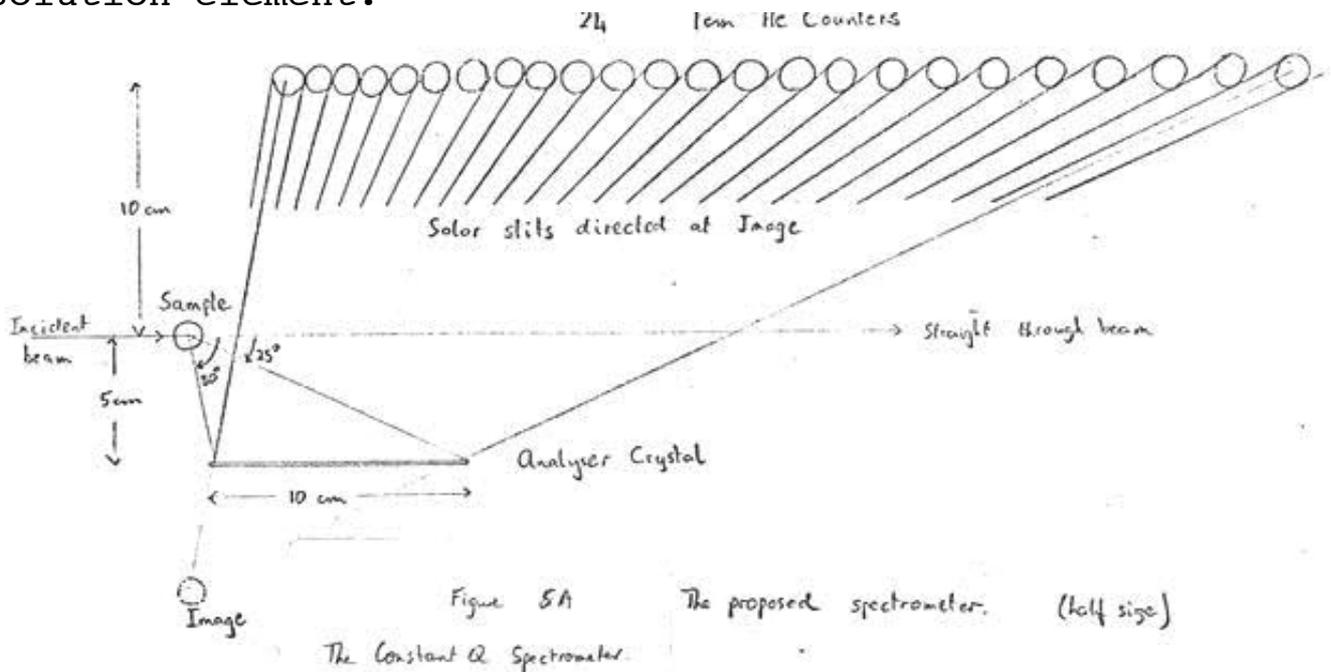
Data acquisition is by a small dedicated mini-computer which transmits data to a larger computer for examination, preliminary analysis, etc.

### Resolution

$DE/E = 0.01$  for  $0.025 < E < 1.0$  eV.

### Intensity

The open beam intensity at the detector is  $\sim 10^4$  per resolution element.



## A6. Constant Q Spectrometer (CQS)

### Status

Simple single counter prototype in operation. Projected for the new LINAC.

### Purpose

The spectrometer is designed to measure coherent inelastic scattering from single crystal samples.  $S(Q, \omega)$  is observed over a wide range and the geometry of the experiment allows constant  $Q$ , scans to be obtained in chosen crystal directions. Measurements can be made on optical phonons, internal modes in molecular crystals, and on magnon modes. Its absence of a crystal monochromator gives it a relatively large incident flux at epithermal energies.

### Construction (see Figure A4)

The machine is constructed with a 5 m incident flight path and has a large area single crystal as analyser placed close to the sample. Neutrons reflected from the analyser are detected by a bank of 24  $^3\text{He}$  counters, (or by a position sensitive counter) as in a MARX spectrometer. Each position channel must be recorded as a function of time-of-flight and the constant  $Q$  locus derived by interpolating between positional and time channels. Statistical accuracy in the constant  $Q$  scan would be optimised by appropriate averaging over positional and time channels according to the calculated resolution function. Thus a small dedicated computer with Fortran capability would be highly desirable. The sample angle should be computer controlled for the automatic sequencing of constant  $Q$  scans. Sample and analyser orientation should be remotely controlled but need not be computer controlled.

### Resolution

Incident energy resolution (8m)  $\Delta E/E = 0.02$ . ( $\sim 2$  meV)

Incident angular resolution (8m)  $\sim 1^\circ$

Scattered angular resolution ( $2\theta = 90^\circ$ )  $\Delta E/E = 2\cot\theta \Delta\theta = 0.04$ .

### Intensity

Flux incident on specimen ( $\lambda = 1\text{\AA}$ )  $10^8 \text{ ns}^{-1} \text{ cm}^{-2} \text{\AA}^{-1}$ .

Flux on specimen per time resolution element  $\Delta l = 0.01\text{\AA}$   $10^4 \text{ ns}^{-1} \text{ cm}^{-2}$

### Problems and Papers

A range of analysers with diverse  $d$  spacings is needed if constant  $Q$  scans over a range of energies and scattering vectors is to be achieved. C. G. Windsor, HNBFC/74/p

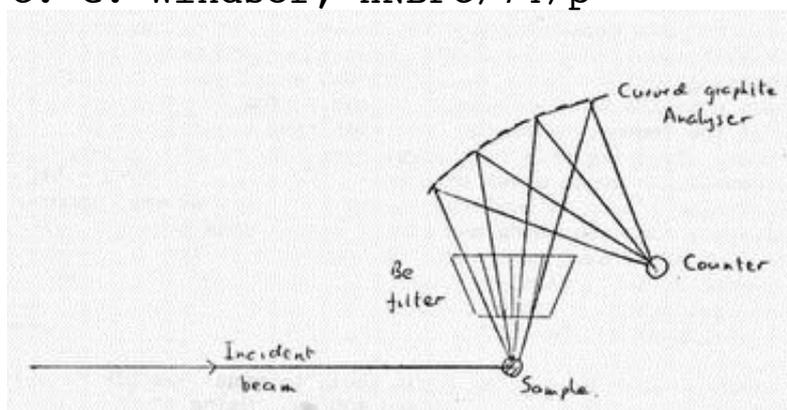
## A7. Chemical Inelastic Spectrometer (CIS)

### Status

Proposal only.

### Purpose

The spectrometer would measure inelastic scattering from hydrogenous compounds. The  $Q$  range of the measurements may



be varied in the high to medium range by using low or medium analyser energies. Construction

Construction (see Figure A7)

The spectrometer is constructed with an incident flight path of 5 m and energy analysis of the scattered beam is accomplished by a curved graphite crystal analyser combined with a Be filter. Data acquisition is based on a small mini-computer that is linked to a larger computer for data examination and preliminary analysis.

**A8. High Pressure Spectrometer (HPS)**

Status

Proposal only

Purpose

The spectrometer would be designed to measure the diffraction pattern in the range of  $Q$  between 1.5 and 20  $\text{\AA}^{-1}$  with around 5% resolution.

Measurements would be possible, on gases, liquids, glasses and crystalline powders. We calculate a count rate of order  $10^4 \text{ ns}^{-1}$  per resolution element allowing 1% statistics to be achieved each second from a 10% scatterer

covering the full beam. This would allow studies of the time-dependence of reactions and phase changes. It should also be possible to study adsorbed gases on surfaces and other minority phase problems in chemistry, and metallurgy.

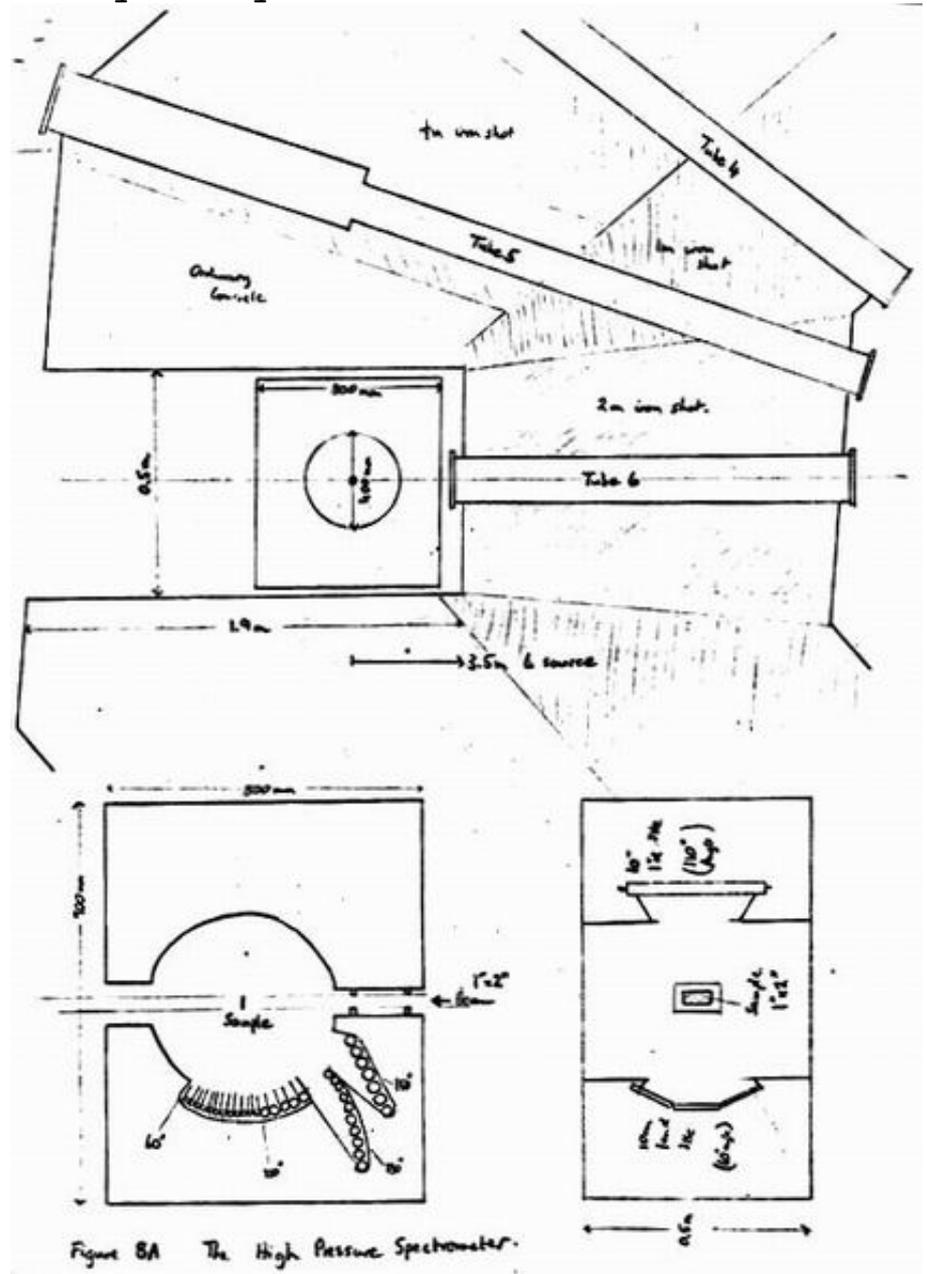


Figure 8A The High Pressure Spectrometer.

Construction (see Figure A4)

The spectrometer would-be built around the "gallery" hole allowing a 3.5 m. flight path from moderator to specimen. The 1.7 m. iron shot loaded concrete wall should permit satisfactory background levels for the spectrometer if not for personnel. (Access would almost certainly be limited to periods when the beam shutter is closed). The 45° moderator take-off and the use of the thermal moderator mean that time resolutions of around 3% would occur. Matching this to a large area counter bank giving a 4% resolution would give an overall resolution of  $DQ/Q = 5\%$ . For the highest intensity work it would be feasible to have several counter banks each employing time focussing and placed along Debye-Scherrer circles. Neutrons counted by each bank could be processed on-line to remove channels contaminated by the y flash or the booster peak, and sorted into bins representing steps in  $Q$  commensurate with the resolution. Thus data from all the counters could be presented as a single diffraction pattern when desired.

A large counter bank solid angle would be made feasible by using short scattered flight paths between 250 and 400 mm. Using 1"  $^3\text{He}$  counters and a 30 mm diameter specimen this would give a scattered beam divergence of 5 degrees allowing the required resolution to be achieved for scattering angles above  $100^\circ$ . Using a 10 mm diameter specimen and counters would allow the 5% resolution requirement above  $60^\circ$  scattering angle.

A specimen surround of 400 mm and a head-room of 1.5 m. could be provided giving ample-space for cryostats, furnaces or pressure rigs.

### Resolution

Overall resolution requirement  $DQ/Q = 0.05$ .

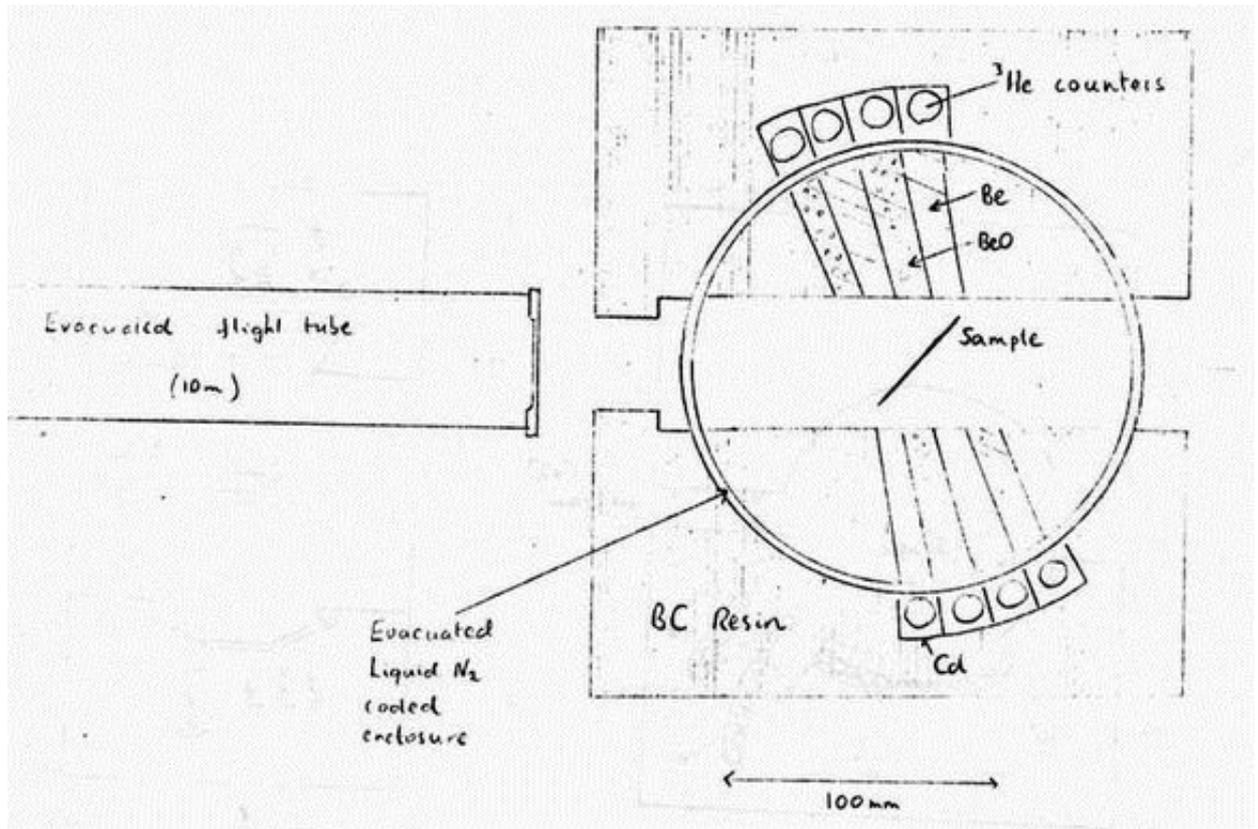
### Intensity

Total pulsed flux at the specimen position  $(2.6/l) \cdot 10^6 \text{ n s}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$

Flux at the specimen per resolution element ( $l=0.05\lambda$ )  
 $= 1.3^5 \text{ ns}^{-1} \text{ cm}^{-2}$ .

Scattered flux per resolution element for 20 mm<sup>2</sup> area specimen and 10% scatterer  $2.6^5 \text{ ns}^{-1}$

Count rate per resolution element for 1 radian<sup>2</sup> accepted solid angle  $(2 \cdot (160-60) \cdot 45.50/100) \cdot 1.8 \cdot 10^4$



### A9.beryllium Filter Spectrometer (BFS)

#### Status

Preliminary measurements performed by R. Sinclair (unpublished) in 1970. Proposal only.

#### Purpose

The spectrometer (like its reactor analogue) would measure inelastic vibrational scattering from hydrogenous molecular compounds. The small scattered wavevector ( $k' < 1\text{\AA}^{-1}$ ) means that inelastic spectra are recorded at relatively large values of the scattering vector  $Q$ . For  $90^\circ$  scattering:  $Q \sim k_0/\text{SUB} = \sqrt{E(\text{meV})}/2.07$ . The reason for duplicating the technique on the LINAC stems from its higher expected count rates for energy transfers above 200 meV.

#### Construction (see Figure A4)

The performance of the spectrometer depends critically on reducing the sample/counter distance, since the time spread of the scattered neutrons depends on the velocity spread of the slow  $\sim 5\text{\AA}$  neutrons transmitted by the filter. The design indicated achieves this by encasing sample, filter and beam shield within a single liquid nitrogen cooled cryostat.

Large scattered beam solid angles are then possible. It would also be possible to employ the Be, BeO difference technique to improve time and energy resolution.

### Problems and Papers

Bajonik et al. Inelastic Scatt. of Neutrons (IAEA Vienna), 1965, 2, p.519.

Pan. Web. Yeater Nucl. Inst. and Meths. 42, p.197 (1966).

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