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The IRIS 4.2 K Cold Graphite Analyser Design.

M.A. Adams , J.J.P. Balchin , T.A. Broome , C.J. Carlile , D.A. Cragg ,J. Tomkinson , C.N. Uden
ISIS Facility , CLRC Rutherford Appleton Laboratory , Chilton , Didcot , Oxfordshire , UK , OX11 0QX
Tel: + 44(0)1235 821900
Fax: +44(0)1235 445720

Abstract:

Summary.

This presentation describes a new Cryogenic Cooling system for the IRIS Graphite Analyser on the ISIS Spallation Neutron Source. The paper includes a brief description of the scientific requirements, the concept behind the cooling system, reference to an increase in the area covered by the analyser using a mixed array of the original Le Carbonne and new Atomgraph Pyrolitic Graphite crystals, design layouts supporting the new proposed design and CAD 2-D & 3-D views showing the current design status.

The requirements of the new graphite analyser cooling system are:

1. To cool the Graphite Analyser Crystals to 5 Kelvin or below.
2. To increase the area covered by Crystals both Longitudinally & Latitudinally.

Background:

The IRIS instrument graphite analyser is located within a vacuum vessel some 36.5 m from the liquid hydrogen moderator on the ISIS pulsed neutron source. The cylindrical vessel, 2.0 m in diameter & 0.6 m in height contains two crystal analyser banks, Muscovite Mica & Pyrolitic Graphite, arranged in inverted geometry close to back scattering. Each analyser consists of a spherical surface reflecting scattered neutrons to an array of scintillation detectors below the sample position. The precise crystalline structure of each analyser material provide peak neutron reflection intensities (Bragg angle scattering) for discrete neutron energies from different atomic planes. Using a series of beam choppers to select different energies allows the instrument to measure d-spacings for a range of materials within several ranges of instrument resolution.

The present graphite analyser is cooled to 25 Kelvin using a 2-stage gaseous Helium closed cycle refrigerator circulating through a pipe brazed to the rear of the analyser mounting plate. The Helium refrigerator & cooling head, liquid Nitrogen feed pipework & storage vessel near the main vacuum vessel are linked to it via insulated lines. Operation at this temperature reduces background neutron scattering caused by the effect of Thermal Diffuse Scattering (TDS) & is caused by neutron interactions with phonons within the graphite. Measurements conducted on the IRIS instrument suggest that reducing the analyser temperature produces a proportional reduction in TDS. An improvement in instrument signal background up to a factor of four is achievable by a four fold reduction in Thermal Diffuse Scattering. Cooling the graphite to 5 Kelvin using liquid Helium is expected to improve the instrument signal background from 1250:1 to 5000:1. Further reductions in TDS may be achievable by reducing temperatures still further if pumping on the Helium reservoir takes place (this is not covered here but may be incorporated at a later date).

In order to achieve this temperature a cryostat design is required which will connect to the IRIS vacuum vessel. This will supply liquid Helium to an analyser support surrounded by a radiation heat shield cooled to liquid Nitrogen temperature, 77 Kelvin. The current cooling installation will be retained for improved cryopumping of the instrument vessel. The graphite analyser crystals, together with Cadmium shielding plates will be secured to a new cooling loop within the vessel in a manner to provide good heat transfer characteristics and the required back scattering geometry.

In parallel with the installation of the cryostat, a new analyser plate is required to increase the graphite analyser coverage. Latitude angles are increased by 5.4° for low & high angle scattering, together with an increase in the solid angle subtended by the analyser in the longitudinal axis from 4.2° to 11.2°.(Subject to modifications to the collimation / beryllium filter assembly). The design mixes the original Le Carbonne & new Atomgraph crystals to give a uniform resolution function.

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THE IRIS INSTRUMENT

The IRIS Spectrometer incorporates two Analyser arrays. An ambient temperature array of Muscovite Mica Crystals and a Pyrolitic Graphite Crystal array cooled to 25 Kelvin using a gaseous Helium CCR cooling system. Each array is arranged to a geometry suitable for near backscattering experiments. A cooling system is proposed to further cool the Graphite Analyser array to a temperature of 4.2 Kelvin to produce an improved instrument Signal : Background ratio of 5000 : 1. This reduces the Thermal Diffuse Scattering effects of the analyser material. It is also proposed to increase the Graphite area coverage x 3 to improve the neutron flux at the detectors.

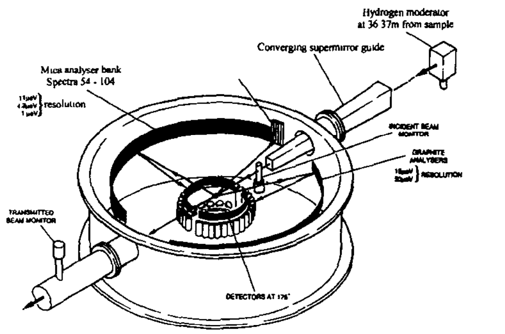
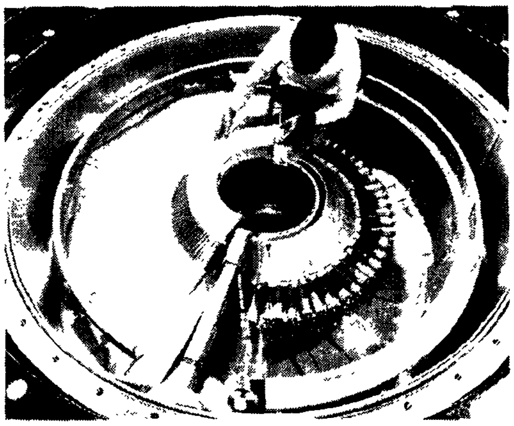


FIGURE 1 - IRIS INSTRUMENT VACUUM VESSEL



GRAPHITE (LHS) MICA (RHS)

THE IRIS COLD ANALYSER CIRCUIT

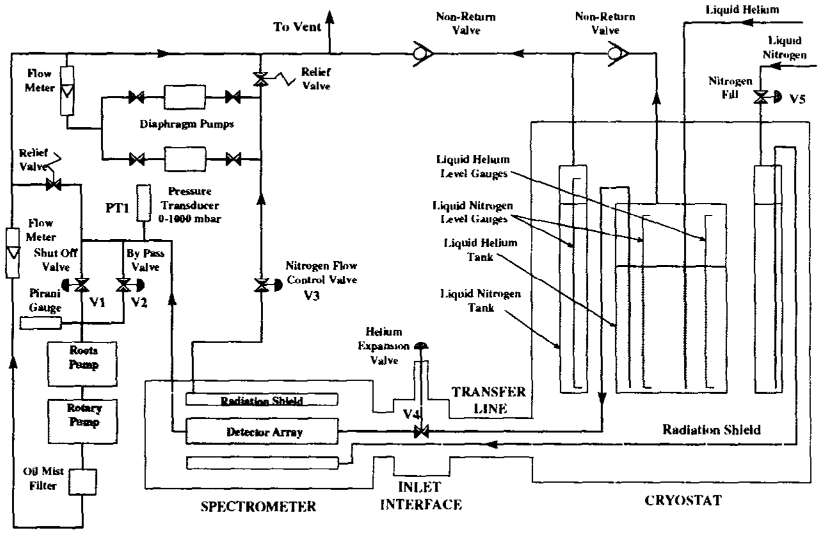


FIGURE 2. IRIS SPECTROMETER CRYOGENIC CIRCUIT

A continuous flow cooling system is proposed, supplied from a Custom designed and built Helium Storage Vessel. To reduce Helium losses the storage vessel is designed to incorporate a Liquid Nitrogen jacket which also provides a balanced feed to the Nitrogen cooled radiation shield and a supply for pre-cooling of the Analyser to 77 Kelvin prior to base temperature cool-down. Both Helium and Nitrogen cryogens are pumped through a heat-exchange coil on the rear of the analyser mounting / radiation shield respectively. To ensure optimal heat transfer a square wall tube is used for each coil, electron beam welded to the component being cooled. The analyser and transfer lines are instrumented for temperature and pressure to allow automated operation

THERMAL DIFFUSE SCATTERING (TDS)

Thermal diffuse scattering originates in a temporal variation of d-spacing of the analyser crystal at elevated temperatures. The vibration of atoms either side of the crystal lattice position results in a spread in the Bragg scattering angle akin to chromatic abberations in optical systems.

In an instrument without collimation this results in low energy neutrons being lost to adjacent detector modules. This increases the background noise of the instrument. As a result the resolution of the instrument tails off as energies decrease.

By lowering the temperature the atomic vibration is lowered and the scatter of low energy neutrons can be reliably detected above the noise floor of the instrument. Both the instrument operating bandwidth and signal-to-noise ratio are improved.

FIGURE 3. IMPROVEMENT IN TDS OF GRAPHITE AS A FUNCTION OF TEMPERATURE

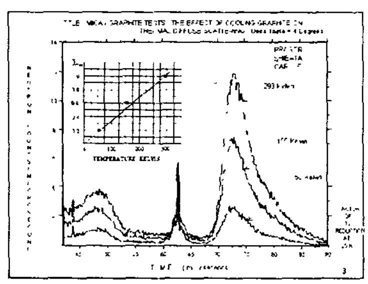
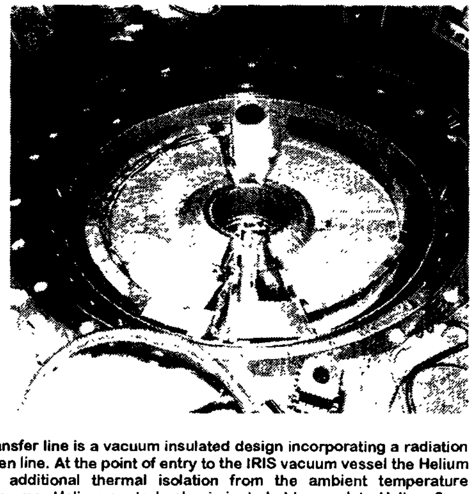


FIGURE 5. THE IRIS CRYSTAL ANALYSERS :- GRAPHITE (LHS) & MICA (RHS)



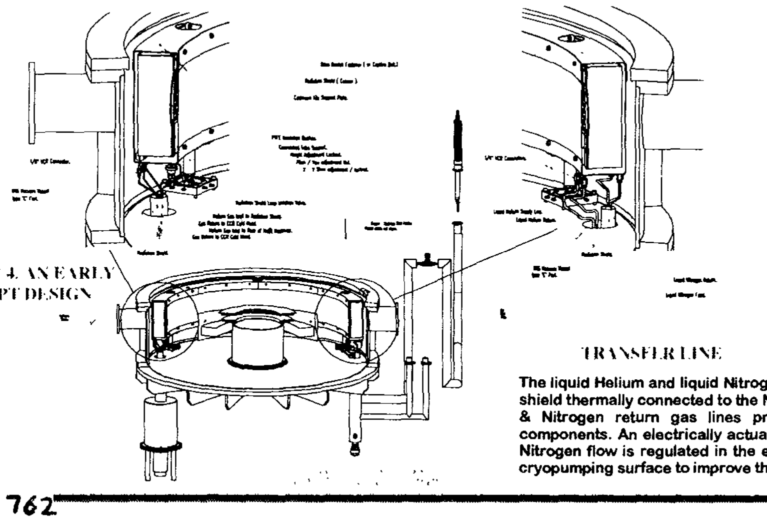


FIGURE 4. AN EARLY CONCEPT DESIGN

TRANSFER LINE

The liquid Helium and liquid Nitrogen transfer line is a vacuum insulated design incorporating a radiation shield thermally connected to the Nitrogen line. At the point of entry to the IRIS vacuum vessel the Helium & Nitrogen return gas lines provide additional thermal isolation from the ambient temperature components. An electrically actuated Kammer Helium control valve is included to regulate Helium flow. Nitrogen flow is regulated in the exhaust line. The existing CCR cold head will be retained to provide a cryopumping surface to improve the vacuum in the instrument.

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FIGURE 7: THE GRAPHITE ANALYSER

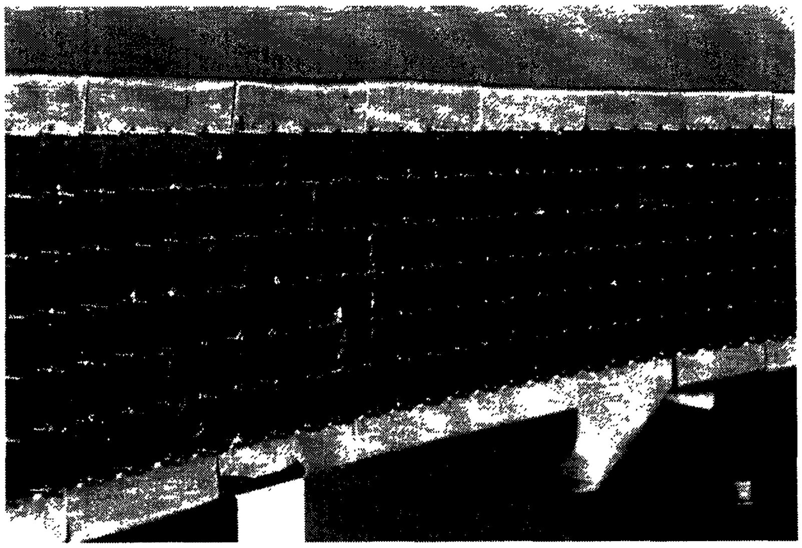
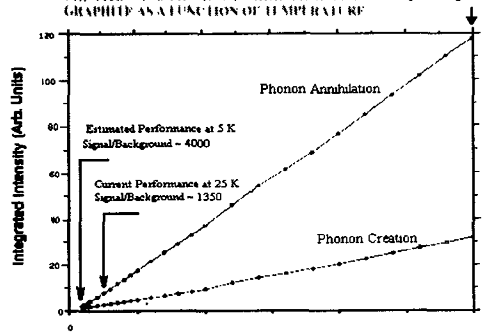


FIGURE 8: THE INTEGRATED INTENSITIES OF PHONON CREATION AND PHONON ANNIHILATION PEAKS IN GRAPHITE AS A FUNCTION OF TEMPERATURE



THE IRIS COOLING SYSTEM INSTALLATION

This shows the layout of the LN2 storage vessel, Intermediate storage vessel, transfer line, IRIS & OSIRIS Instruments, helium & nitrogen exhaust lines , heat exchangers and associated pumping & flow control equipment within the IRIS blister in Hall 3. All the equipment within Hall 3 is located at floor level beneath the IRIS platform to allow for later modification to a transfer line connected to analysers in the OSIRIS instrument.

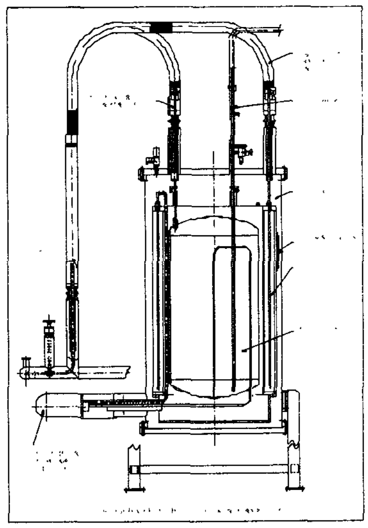


FIGURE 9: THE INTERMEDIATE STORAGE VESSEL.

This vessel is sited outside ISIS Hall 3, within the IRIS liquid nitrogen storage compound. It is supplied via a fill line, from 200 l helium dewars, and via a permanent transfer line, from the existing nitrogen storage vessel. A central 214 litre capacity helium reservoir is enclosed within a circumcircular 163 litre capacity nitrogen reservoir. Phase separation tanks prevent impurities entering the transfer lines. The outer shell of the vessel includes an evacuated radiation shield with superinsulation. Future installation of a lambda plate to pump superfluid helium within the helium reservoir is envisaged.

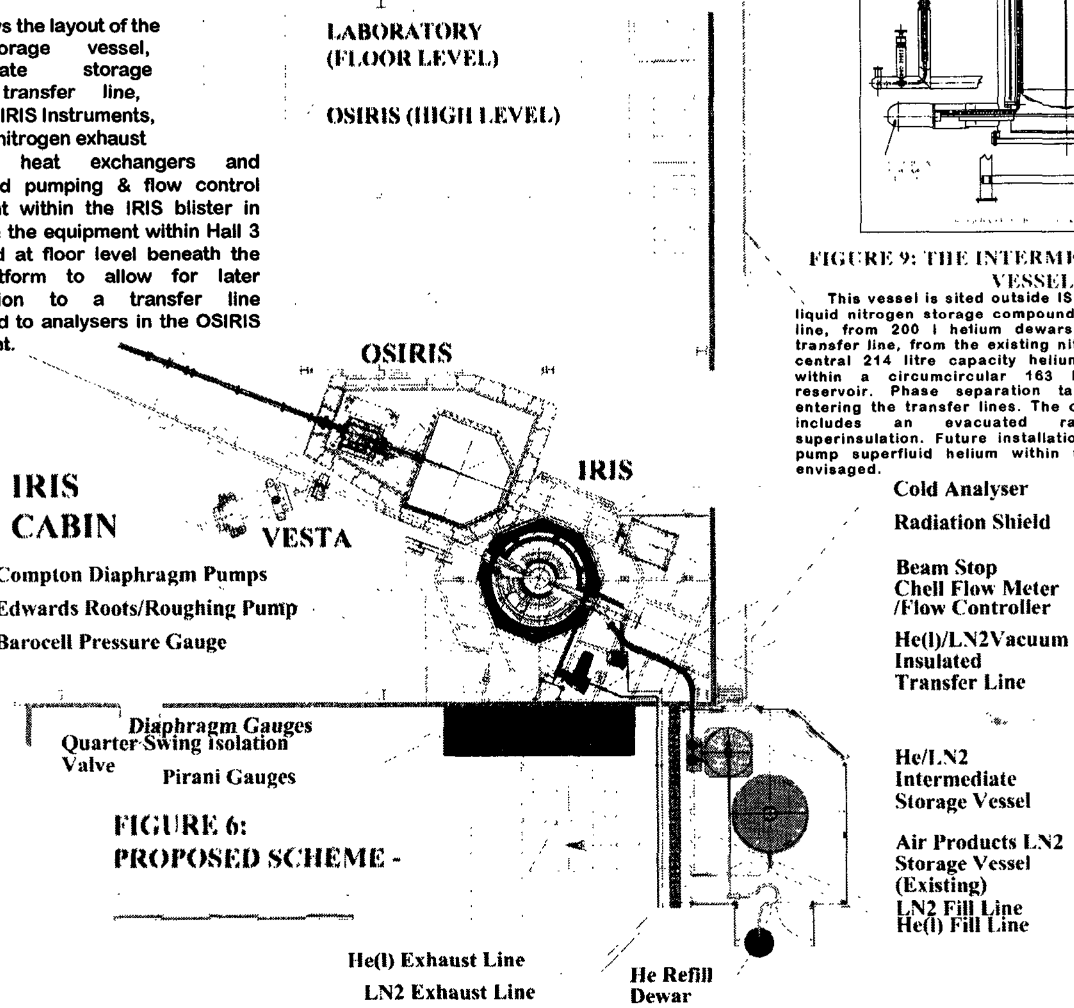


FIGURE 6: PROPOSED SCHEME -