Status of the ISAC-II cryogenic system

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ISAC-II is an upgrade of the ISAC radioactive beam facility that includes the addition of 43 MV of heavy ion superconducting accelerator. A first stage comprising a 500W class LHe refrigerator and distribution to five cryomodules is scheduled for installation by early 2005. The paper will present the design and status of the Phase I installation including a description of the distribution piping, details of the refrigeration system, and a summary of the helium storage and gas recovery.

INTRODUCTION

The ISAC-II superconducting accelerator is now under construction at TRIUMF[1] (Fig. 1). A first stage includes the installation of 20MV of accelerating structure is expected to be completed before the end of 2005 with a second equal stage due for completion ~3 years later. The new building is to accomodate the ISAC extension is now complete.

The refrigerator system will be installed in two equal stages. The first stage includes a 500 W helium refrigerator with associated compressors, oil removal system (ORS), helium buffer tank, helium dewar, room temperature piping, helium distribution transfer lines, and nitrogen distribution network.

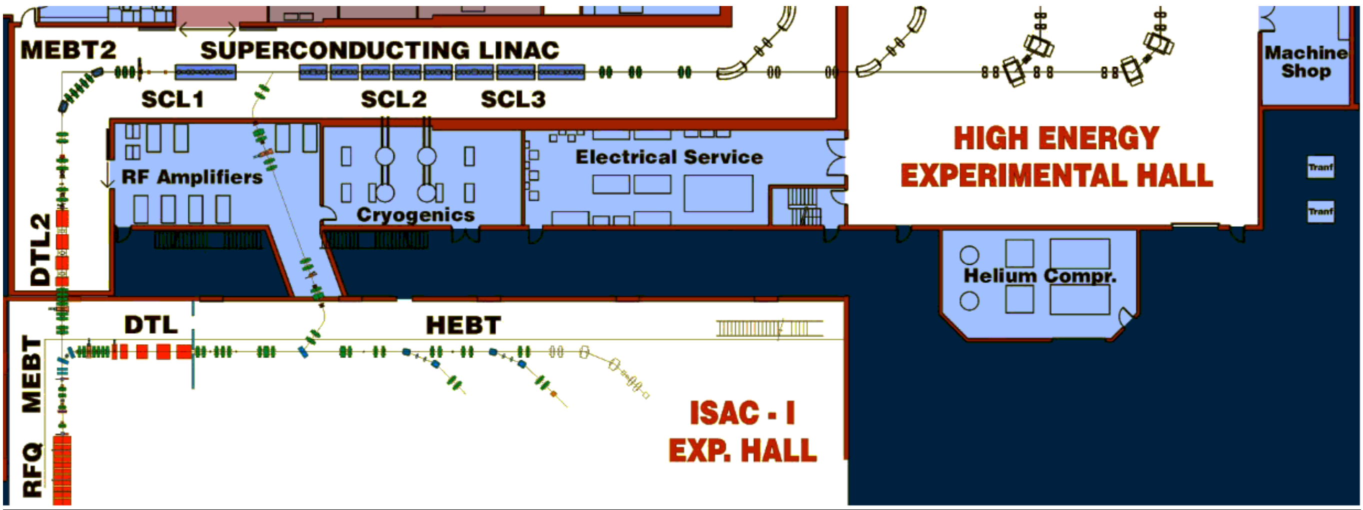

Figure 1: ISAC-II addition showing new superconducting linac, cryogenics (refrigerator room) and helium compressor building.

OVERVIEW OF THE ISAC-II CRYOGENIC SYSTEM

The ISAC-II phase I cryogenic system supplies 4.5K helium to five medium beta cryomodules[1] and to two high beta cryomodules. The refrigerator cold box delivers LHe to a main supply dewar located in the cryogenics (refrigerator room). The main supply dewar supplies LHe to the main distribution trunk line with a moderate push pressure. The ISAC-II cryomodules (CMs) are fed in parallel (Fig. 2) from the main distribution line with U-tube transfer lines. Each cryomodule has two associated female bayonet cans one for the delivery bayonet and one for the cold return bayonet. There is also a main warm return line that takes warmer gas (>20K) from the CM back to the suction side of the main compressor during cooldown.

There is also gas from the solenoid power leads and for cooling of the stack that is valved into the warm return line through throttle valves.

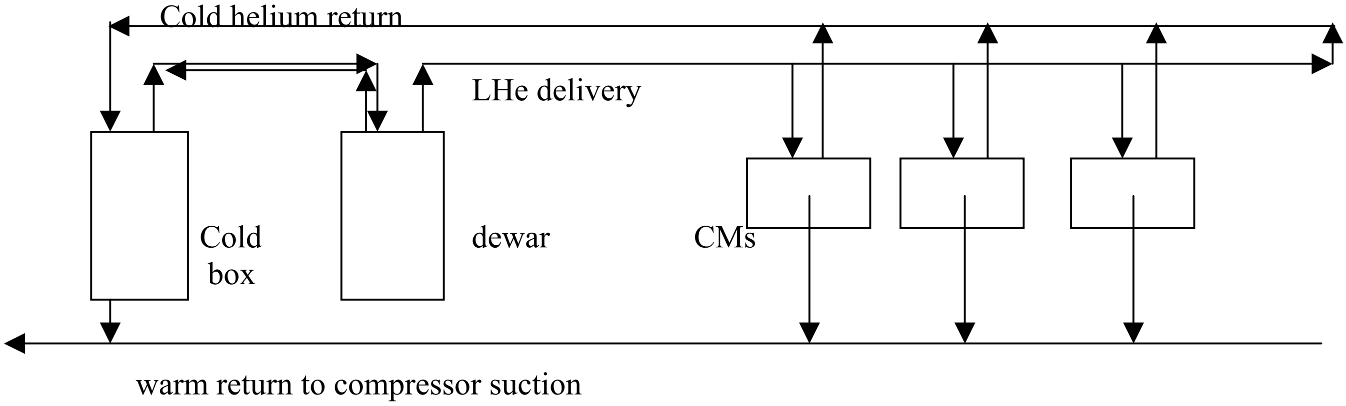

Figure2 : Schematic of the parallel flow concept to the cryomodule's.

The cryomodules contain a LN2 cooled thermal shield consisting of a ½" copper tube soldered to a copper box. Liquid nitrogen is supplied to the cryomodules via a parallel distribution scheme from a local nitrogen dewar/phase seperator. The dewar is fed LN2 from an external 9000 USG nitrogen tank via existing nitrogen vacuum isolated piping. A separate LN2 circuit is used to cool the vacuum jacketed cold distribution system.

During normal operation the linac will be cold and the rf will be on to accelerate the beam. The total expected cryogenic load for phase I is 390W. This can be broken down into 192W of static losses and 198W of active rf loss. The static loss budget is split half and half with 96W for the cold distribution system and 96W for the cryomodules. This assumes static losses of 13W and 14W for the medium and high beta CM's respectively. The liquification loss from the cryomodule power leads is expected to be 0.7gm/sec. There will be times where a cryomodule or cryomodules will have to be cooled down from room temperature. A flow of 6 liquid liters/hour of 100% liquid nitrogen will cooldown the medium-beta cryomodule LN_2 shield in ~24 hours. The bulk of the cold mass will cool by radiation to ~250-K. Cold tests indicate that a flow of 20 liquid liters/hour of helium is a sufficient flow to pre-cool the cavity from 250-K to 4-K in about four hours. The medium beta cryomodules require 100ltr/hour and the high beta modules 150ltr/hr for efficient cooling. The CM's are cooled one at a time and each filled cryomodule is topped up periodically as the cold mass thermalizes.

REFRIGERATION SYSTEM

The phase I refrigeration system has been purchased from Linde Kryotechnik AG, Switzerland. Refrigerator. The refrigerator-liquefier on order is the Linde TCF50 with liquefaction rate of about 5.2 g/sec and refrigeration rate of of 530 Watts at 4.5 K with simultaneous liquifaction rate of 0.71 g/sec.

The vendor supplied system consists of a cold box/liquifier, a main and recovery compressor, as well as oil removal and gas management systems. TRIUMF will supply helium gas storage tanks (170 m^3 per phase), the main LHe dewar and warm and cold piping. In addition TRIUMF will supervise the installation to Linde's specifications and Linde will commission the system to the supply dewar. In the near future a gas analyzer and gas purifier system will be added.

The compressor room will house the main compressors and recovery compressors, oil removal system and gas management system. A cryogenic room will house the cold box/liquefier and liquid helium dewar. This room is adjacent to the accelerator vault.

Helium Gas Storage Tanks

The total inventory of helium must be able to be stored as a gas before the system can be operated and also at any time the refrigeration system is shut down. Two 114 m^3 horizontal tanks will be provided to achieve this for phase 1; an additional tank will be added for phase 2. These will be located outside the experimental hall close to the compressor room. They will be stacked 3 high on a steel support frame. They will operate when full at 14 bara (203 psia, a safety pressure relief valve is set at 220 psig). It has been found that standard 30,000 USG (114 m^3) propane storage tanks can be utilized for this application and modified for additional penetrations plus thoroughly cleaned inside to avoid helium contamination.

Compressor Room

The compressor room will house 2 compressors for phase 1 and an additional 2 when phase 2 is added. The main compressor is a Kaeser ESD441SFC direct drive screw compressor of 268 KW producing a compressed helium flow of 79 g/s at 14 bara pressure to be delivered to the cold box/liquefier in the cryogenic room via the warm piping. The main compressor has a variable frequency drive option allowing part load performance during normal operating modes depending on the active load from the accelerator. The second compressor is a recovery compressor allowing the helium gas inventory to be recovered and compressed into the storage tanks. It is a Kaeser BSD62 screw compressor of 37.5 KW producing a compressed helium flow of 12 g/s at 14 bara pressure. The compressor room ventilation system controls the compressors cooling air inlet temperature by directing all the air out of the room in hot weather and partially in colder weather. The main compressor also utilizes water as well as air for cooling. The main compressor and the recovery compressor do not operate at the same time.

The gas management system manages helium flow to keep the main compressor inlet pressure at the correct level and to redirect flow, when the main compressor is shut off, to the recovery compressor. It also provides an oil absorber for oil removal from the helium gas. There is provision for the installation hook up of a helium gas purifier and gas analyzer in the near future.

Refrigeration System Piping And Installation

Installation will be done by a local refrigeration contractor up to completion, upon which a First Certification is issued allowing operation of the system. As part of the specification to do this work TRIUMF is providing Process and Instrumentation Drawing as well as complete 3D Installation Drawings and Bills of Material. Linde will be providing special installation instructions for their equipment. The refrigeration contractor will provide labour and the required piping to the requirements of Safety and Refrigeration Codes that are applicable.

Cryogenic Room

The cryogenic room will house the cold box/liquefier, control system rack and the liquid helium dewar. A duplicate system will be installed for phase 2 at a later date. The room lies adjacent to the accelerator vault and the transfer line runs from the dewar to the vault distribution system through an opening in the wall. The helium vapour return and cool down warm gas return also run through this opening.

The TCF50 cold box is capable of delivering a continuous stable pure liquefaction rate of 5.2 g/s and a continuous stable refrigeration rate of at least 530 watts at 4.5 K with a simultaneous liquefaction rate of 0.71 g/s. It will be capable of continuous stable operation with loads varying from 270 W to 530 W depending on the accelerator mode of operation. Linde will also be supplying a cryogenic transfer line to transfer the liquid helium to the adjacent dewar. Liquid nitrogen will be supplied to the cold box through an existing LN_2 distribution system.

Liquid helium is supplied to a 1000 litre dewar adjacent to the cold box (phase 2 will require another) through a Linde supplied transfer line; dewar helium vapour also returns through this transfer line. The liquid helium will exit the dewar through a TRIUMF supplied distribution system transfer line. A spare port is provided for possible hook up to an adjacent dewar. Two level probes will be provided in the dewar – one active, one spare, to monitor level information for the control system. Two replaceable heaters will also be provided – one active, one spare, to control liquid level when required and also it will be used during refrigeration system commissioning prior to the linac accelerator installation.

Gas Purifier and Analyzer

During commissioning Linde will provide this equipment. Connections on the gas management package allow for their installation. Maintaining gas purity to <5 ppm of contaminants is essential to the proper operation of the system and TRIUMF will be purchasing their own purifier and analyzer in the near future.

Control System

The control of the refrigeration system is done by a local Siemans controller supplied by Linde. The system will be monitored by the standard ISAC EPICS control system via Prophi-bus communication. Initially alarms and status will be passed to EPICS while in the future it is planned that some process control will be available. The control of the distribution system and cryomodule interface will be implimented by TRIUMF via PLC with the ISAC EPICS interface.

LIQUID HELIUM DISTRIBUTION SYSTEM

The liquid helium distribution and vapour return system will be a parallel flow system from common trunk lines running parallel to the linac. Current thinking embraces the idea of a transfer 'U' tube between the cryomodule and a bayonet box associated with a proportional valve on the supply and standard valve on vapour return. These transfer 'U' tubes would not be liquid nitrogen cooled but would employ vacuum jacket with super insulation. The rest of the distribution system would be vacuum jacketed and cooled with liquid nitrogen. A separate line would also run from each cryomodule in a non-vacuum jacketed but insulated line for the return of warm helium during cool down which gets sent back to the compressor.

The entire distribution and return piping system will be contracted to a supplier of this type of specialized equipment.

Distribution and return piping will run parallel to the linac at an elevation to accommodate the 'U' tube bayonet box and valve. It will be supported by a steel framework that will also serve as an access walkway for cryomodule maintenance and 'U' tube removal in the event that a cryomodule would require removal from the linac for internal maintenance. In this case it can be valved off and removed and replaced with a beam tube allowing continued operation of the linac.

STATUS

The compressors are expected at TRIUMF towards the end of this month. Installation will commence in June. The cold box is expected by the end of July. Specifications for dewar procurement will be issued this month with an order expected to be placed in June for delivery in August 2004. The order for the phase 1 buffer tanks should be placed this month. Commissioning of the refrigerator system to the main dewar is expected before year end. The distribution system has been delayed for cash flow reasons. The plan is to complete the specifications by Oct. 2004 with delivery and installation scheduled for early 2005.

An initial medium beta cryomodule has just been undergone the first cryogenic tests[3]. Both static load and LN2 consumption are within specifications. The first cold rf test is expected in June 2004. First beams from the linac are scheduled for Nov. 2005.

REFERENCES

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