AD/RHIC-25

Accelerator Development Department

Brookhaven National Laboratory
Associated Universities, Inc.
Upton, New York 11973

RHIC Technical Note No. 25

RHIC HELIUM REFRIGERATOR SYSTEM PERFORMANCE TESTS

D. P. Brown
R. J. Gibbs
A. P. Schlafke
J. H. Sondericker
K. C. Wu

May 14, 1987

RHIC HELIUM REFRIGERATOR SYSTEM PERFORMANCE TESTS

Two acceptance tests for the RHIC refrigerator system were conducted during 1985 and 1986.

Compressor station performance was demonstrated in an acceptance test conducted on 25 April 1985. The plant normally utilizes all 20 installed first stage compressors and four second stage compressors to supply 4400 g/s of helium at 16.4 atmospheres. One additional compressor is for redundancy and it can be employed as either a first or second stage unit.

The plant capacity during the test measured to be 4403 g/s at 16.4 atmospheres using eighteen first stage and five second stage compressors. The isothermal efficiency was calculated to be 57.01%.

A post refrigerator acceptance test observation is that the compressor station mass flow has been consistantly somewhat less than measured during the test. These later observations were made using a Venturi flowmeter acquired after the compressor station tests but prior to the start of refrigerator acceptance. The flowmeter associated with the compressor station is the Annubar type and its measurement values are typically 2 to 5% higher than the Venturi meter. This discrepancy is being investigated. A five percent flow reduction would reduce the calculated isothermal efficiency to 54.3%.

The refrigerator acceptance tests spanned the period between July 1985 to early March 1986 with five cooldown runs during that period. The refrigerator tests were timed to fall between AGS running periods to minimize the demand rate charges for electric power. Intervals between runs were used for considerable work on adjustments to the turbo expander machinery and completion of unfinished work by BNL. Two major problems with the turbo expanders were that the shafts of the colder expanders were operating too close to critical speed and that too brittle a steel (17-4 PH) was employed for inlet vane shafts and control element pins. These conditions resulted in failing labyrinth seals, shaft bearings, shafts and damaged impellers. The former defect was caused by an increase in designed shaft overhang to further reduce heat leak without a thorough check for effects on shaft critical speed. Installation of larger shaft diameters and heavier bearings eliminated these problems.

An initial run took place on July 10 to July 12, 1985 to test control and operation of the turbine machinery. The BNL supplied process control computer performed well from the outset in such tasks as speed control of four series turbine expanders and in interlock protection of the machine. However, seal gas and lubricating oil return systems for the close coupled turbine expanders required extensive oil skid piping changes by the manufacturer to eliminate control interactions.

The first cooldown run was from August 22 through August 24. The run ended when failure of many labyrinth shaft seals occurred for reasons described earlier.

A second cooldown from Nov. 15 to Nov. 18 ran well initially and a temperature of 5.3 K was reached on the morning of Nov. 16. However, gas contamination forced a shutdown. A warmup and a thorough gas cleaning was initiated.

The third cooldown ran through Nov. 18 and 19. Liquefaction was achieved after ten hours of operation. Stable control of the plant was obtained throughout cooldown and operations. Temperatures down to 3.5 K were reached using the cold compressors of the system. The circulating loop compressor flow rate went high enough, at times, to exceed the flowmeter range ($\sim$5000 g/s). During this run it was possible to conduct thermodynamic analysis of the process. Shutdown occurred for scheduling reasons.

The fourth cooldown run was performed during the period of Feb. 13 through Feb. 17, 1986. In the forenoon of Feb. 14th the cooldown was interrupted by a piping faiure in cold box 4. The refrigerator was warmed, the damaged section removed, and a new section installed together with a new expansion loop in the circuit. Cooldown resumed early on Feb. 16. Cooldown was interrupted again by a cracked shaft of turbo expander 5. Expander 5 is the final unit in the train of expanders and operates with its inlet at 6 K. However, cooldown continued for another twenty hours using Joule-Thompson effect via a valve in parallel with expander 5. The reason for continuing was to have liquid in the low and intermediate pots to obtain preliminary performance data on the cold compressors. Approximate measurements of the plant capacity in the J-T mode were also obtained.

The fifth cooldown, which became the acceptance run, commenced on Feb. 27 with expander 5 operational. Three incidents of a mechanical nature occurred during the cooldown but had only small effect on the cooldown rate. The first of these, about 3 hours after starting, was the disabling of expander 3A by failure of the inlet vane mechanism and destruction of its impeller. The redundant expander string 3B/4B was brought on stream and the run continued. The speed control of expander 5 was lost after an interlock shutdown. The unit was warmed, disassembled, checked and reassembled without finding any cause and was placed on stream without further speed control problems. Heat exchangers 1B/2B fouled with ice. Redundant heat exchangers 1A/2A were cooled for about 12 hours and then placed in service. Exchangers 1B/2B were then put through a deriming cycle.

On March 3rd, during a period of eight hours, refrigerator capacity was measured at steady-state full load conditions. Performance data was also obtained on expanders, cold compressors and heat exchangers. Analysis of data revealed that the refrigerator produced 23.1 kW of low temperature refrigeration capacity and 55 kW of shield cooling at RHIC operating conditions. Further fine tuning of turbo expanders and cold compressors was not attempted because the scheduled operating period expired.

Since the capacity of the refrigerator is more than sufficient to meet RHIC requirements, it was agreed with the contractor that BNL would accept the system at reduced cost to cover the expense of modifications to some of the cold rotating equipment. The refrigerator will be run in the future, as funding becomes available, to train personnel and to fine tune the operating parameters of the system.