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FERMILAB SATELLITE REFRIGERATOR COMPRESSORS WITH THE OIL AND MOISTURE REMOVAL SYSTEMS

J. A. Satti and R. A. Andrews

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John A. Satti, Richard A. Andrews

Fermi National Accelerator Laboratory*
P.O. Box 500
Batavia, Illinois 60510

INTRODUCTION

We have designed and tested a helium purification system for the Energy Doubler and the experimental areas. A purification system is installed after each screw compressor in the satellite refrigerators. The purification system removes oil mist, oil vapor, water vapor, and particulate from the compressed helium. The units were designed with consideration of modularity and necessary redundancy (i.e. guard purification). Test results which led to the final configuration are presented, along with achieved performance of the oil removal in the operating system.

COMPRESSOR SYSTEM DESCRIPTION

There are twenty eight Mycom Compressors installed around the Main Accelerator Ring in seven locations. Four compressor skids are installed per building with each having an independent oil and moisture removal system. Five compressor systems are installed in the experimental areas with three more to follow.

The Mycom skids each consist of an oil injected screw compressor of 58 g/s capacity with a 350 hp motor, oil pump, oil cooler and oil separator. Helium gas returning from the low pressure gas header is compressed from 1 atm to 20 atm in the compressor. The compressed gas in then passed through the purification system where oil mist, oil vapor, water vapor and particulate are sequentially

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removed. The end product of this system (compressed and purified helium gas), ready to be cooled to cryogenic temperatures, is injected into a high pressure gas header.

General Description of Compressor Skid

The entire system is contained on a single, fabricated steel base skid and is arranged for ease of installation, operation and maintenance. A typical Mycom process gas compressor system consists of the compressor, direct drive motor, lube oil reservoir, lube oil pumps, lube oil cooler, oil filters, oil removal system, compressor inlet strainer, aftercooler, local control panel and controls. Oil is supplied to the compressor and subsequently separated from the discharge gas by an intregrated fluid management system. Local and panel mounted instruments are provided to allow monitoring of all important system parameters. Fig. 1 shows a photograph of the skids installed in the FØ compressor building.

The compressor is a two stage, positive displacement, oil flooded screw compressor utilizing unsymetrical rotor profiles. Capacity control is accomplished by a slide valve which moves parallel to the rotor axis and changes the area of the opening in the bottom of the rotor casing. An unloader indicator is connected

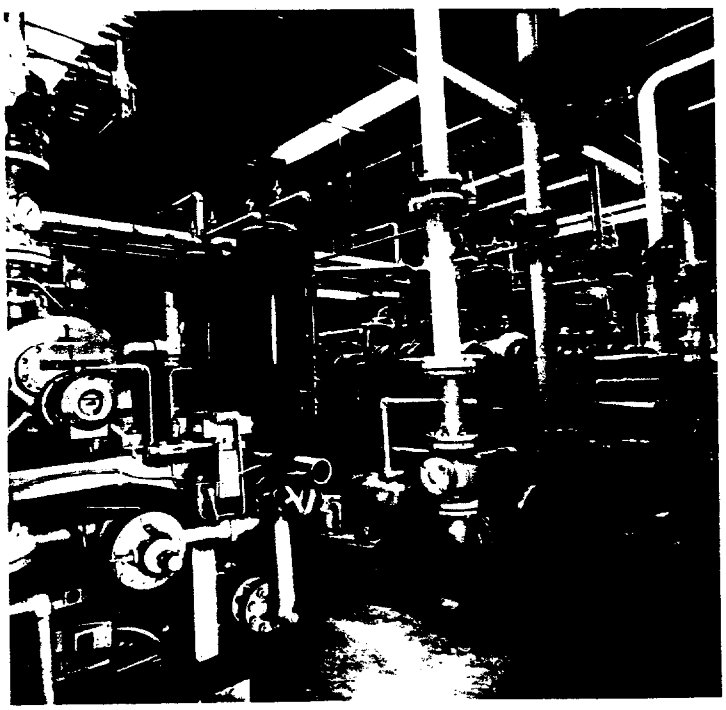

Figure 1. FØ Compressor Skids Installation

to a potentiometer, and the slide valve position is transmitted to the Control Room Console.

The oil separator is a horizontal vessel that also serves as the reservoir for 300 L of oil. Gas delivered by the compressor contains mist as a result of contact with the injected oil. This oil is removed to a level of ~ 2500 ppm by weight by the action of a de-mister element installed in the separator shell which is an integral part of the reservoir. An ASME pilot operated relief valve set at 2240 kPa (gage) is installed from the top of the oil separator vessel to protect the compressor system. The discharge of the valve is connected to the 10 cm suction pipe. The valve is designed to relieve 3.8 times normal compressor capacity with back up pressure up to 1034 kPa (gauge).

Instruments and Controls

Instruments and controls necessary for operation of the compressor system are installed on the skid. Manual local operation is possible by switching the capacity selector switch to the "MAN" position and selecting "LOAD" or "UNLOAD" as desired by using the selector switches for the low stage and high stage capacity controls. The local automatic capacity controls have been disconnected and replaced by the Microprocessor Based Control System. Operation is possible from the Accelerator Main Control Room and the following capabilities are available:

1. Remote compressor starting and stopping
2. Automatic capacity regulation
3. Remote capacity regulation
4. Remote analog and digital readback
5. Remote alarms

OIL AND MOISTURE REMOVAL SYSTEM DESIGN AND OPERATION

The purification system removes oil mist, oil vapor, water vapor, and particulates from the compressed helium. It is designed with consideration of modularity reliability, and necessary redundancy.

The system was developed by matching the available technology of industry with a performance specification developed at Fermilab. The heart of this system is the oil mist removal (or oil coalescer) which was competatively procured, tested, (results in Table I) and tailor designed to the compressor equipment and space available. The test results showed that two stages of oil were necessary to reduce the oil carryover to < 0.1 ppm_w. To insure reliable accelerator operation the design incorporated three identical stages of oil coalescer vessels connected in series. The third stage acts as a "guard filter", insuring that any subsequent failure (resulting

Filter elements	(1) Velocity through filter	Critical velocity on filter side	(2) Average oil cont. after 1st. stg.	Average oil cont. after 2nd. stg.
(5) 15 elements 7 cm OD x 24.4 cm lg.	.008 m/s	1.50 m/s	(3) 250 ppm (4) 43 ppm	(3) 5 ppm (4) .020 ppm
(5) 18 elements 7 cm OD x 24.4 cm lg.	.007 m/s	0.50 m/s	(3) 30 ppm (4) 43 ppm	(3) .020 ppm (4) .015 ppm
(6) 1 element 26.6 cm OD x 61 cm lg.	.090 m/s	at exit pipe 3.44 m/s	(3) 275 ppm (4) 275 ppm	(3) 8 ppm (4) 8 ppm
(6) 1 element 30 cm OD x 107 cm lg.	.038 m/s	0.24 m/s	(3) 40 ppm (4) 40 ppm	(3) .024 ppm (4) .024 ppm

(1) Helium gas flow 58 g/s for all tests
(2) Oil contamination 2500-3000 ppm from compressor
(3) Start-up after overnight shut-down
(4) Steady stage after 16 hr of running
(5) Pressure drop across vessel ΔP = 7 - 11 kPa
(6) Pressure drop across vessel ΔP = 3 kPa

Table I. Oil Mist Coalescing Test Results

in unusually high oil carry over) will not contaminate the cryogenic system. This concept works only if regular testing of the coalescer's performance is done. The third stage coalescer is mounted in a skid along with a charcoal adsorber, molecular sieve, and a final filter. These units respectively remove oil vapor, water vapor and particulate from the helium gas. Fig. 2 shows a block diagram of the Helium Gas Purification System.

Oil Coalescer

The coalescer vessel is 46 cm in diameter and 140 cm high. A single filter element (30 cm OD x 107 cm long), made by Monsanto Enviro-Chem Systems Incorporated, is permanently installed in the vessel and the vessel is then welded together. Periodically (~ 6 months) differential pressure readings are taken across the coalescer vessels with full compressor flow. Normal differential pressure

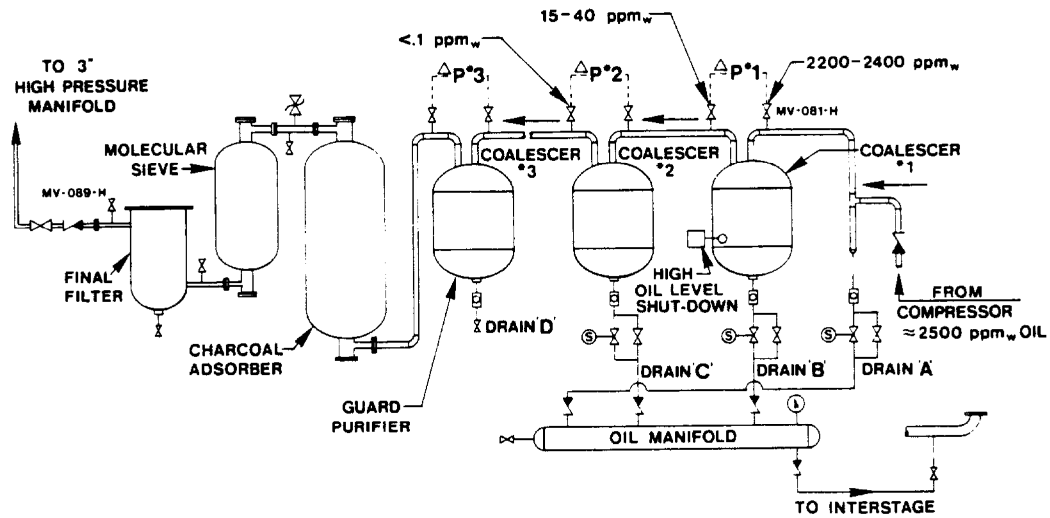

Figure 2. Helium Gas Purification Systems

readings are as follows: (refer to Fig. 2)

No. 1 Coalescer ΔP#1 = 2.0 - 3.5 kPa
No. 2 Coalescer ΔP#2 = 0.5 - 1.0 kPa
No. 3 Coalescer ΔP#3 = 0.5 - 0.7 kPa

Including the adsorber skid package, the differential pressure across the purification system is 8.7 kPa (between valves MV-081-H and MV-089-H). Fig. 3 shows a photograph of the typical first two coalescers installed on the compressor skid.

Oil contamination of 15-40 ppm_w is typically measured downstream of the No. 1 coalescer. This measurement is accomplished by extracting a gas sample from a small tube placed at the center of the process pipe with its opening normal to the flow. Before each reading, the tube is purged for one minute to remove any contaminant. A "Balston Oil Check Kit" is used to measure this level of oil contamination. With this instrument a fixed volume of gas is sprayed onto a treated slide through a controlled orifice. The exposed slide is then placed under an ultraviolet light where the size of the oil spot is compared to a similar spot on a standard slide. This method gives us a good day-to-day comparison of oil carried over after the first coalescer.

After the second coalescer, oil contamination of < 0.1 ppm_w is typically measured. We take this data with an "Aerosol Monitor C-20a" made by PPM Incorporated. The monitor is a microprocessor based electro-optical instrument. The range of the unit is from 0-0.8 ppm_w, and should only be used in regions where the contamination levels are < 2 ppm_w. Therefore, oil contamination is always checked with the treated slide first.

The coalescer No. 1 has a High Oil Level Shut-down switch to protect the oil removal system from drain malfunction . The No. 1 coalescer removes about 91% of the oil from the helium gas and 8% is removed by the 5 cm pipe with the remaining 1% from the No. 2 coalescer.

Oil Drain

The first oil collection is just a 5 cm pipe at the bottom of a "T" fitting branch. Oil mist is separated from the gas by the inertial impaction of the oil on the side of the "T" fitting. Three solenoid valves automatically drain the oil from the pipe and the two coalescer vessels. The solenoid valves are energized by a programmable process controller to open every 15 minutes and stay open for 30 sec. The controller is programmed to open the valves in sequence to minimize gas bypass. Pressure differential flows the oil back to the compressor's interstage pipe. Each solenoid valve has a manual bypass valve. A glass sight gauge is used to visually check oil drain conditions. Normally at Drain B, from the No. 1 coalescer, the sight gauge is full with oil. Opening the bypass valve, the oil normally drains in less than 20 seconds.

Adsorbent Beds

The charcoal adsorbent vessel is installed to remove the oil vapor from the helium gas. The vessel was designed for a maximum

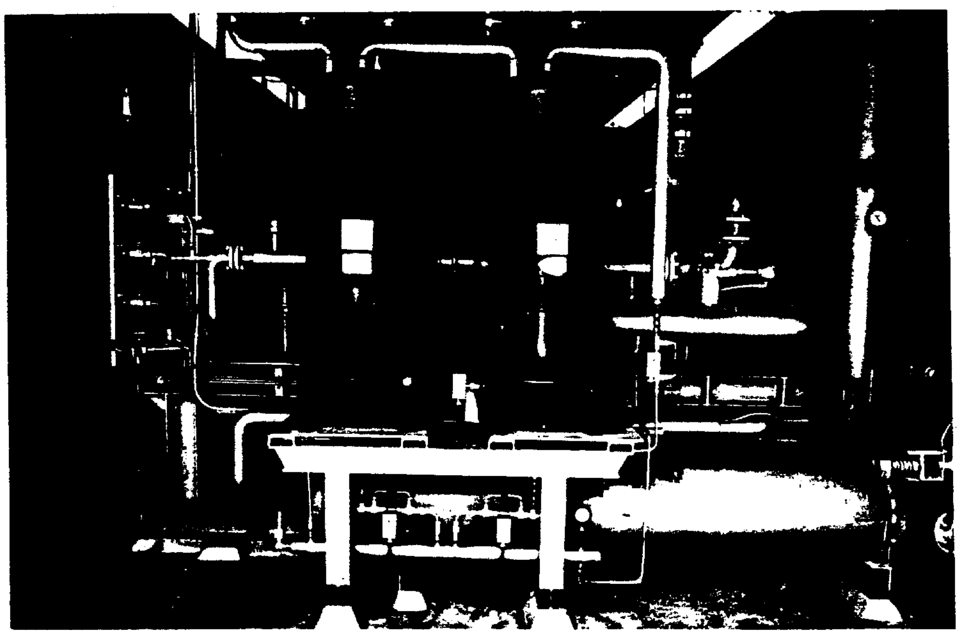

Figure 3. CØ Coalescers and Drain System on Compressor Skid

surface velocity of .005 m/s with an upward flow. The gas velocity is conservatively low to prevent any channeling effect and fluidization of the top layer. The normal designed contact time for the gas required to traverse the depth of the activated charcoal bed is 28 sec. We have purchased and installed two types of activated carbon adsorbents (Union Carbide JXC and American Norit Sorbonorit B4). The charcoal vessel is 0.6 m O.D. and 2.7 m tall. It contains 270 KG of carbon pellets. The carbon as delivered from the vendor, contains 2% of moisture. After the carbon is installed in the vessel, the moisture is removed by purging the bed with 533 K nitrogen gas until the nitrogen coming out of the vessel (463 K) has a dew point of ~213 K. This charcoal dehydration usually takes about 1.5 days.

The molecular sieves vessel is installed downstream of the charcoal bed. Type 4A molecular sieve is used to adsorb water vapor left in the helium gas. The vessel is 0.45 m in diameter and 1.8 m high. The molecular sieve vessel is filled with 128 kg of pellets. The flow in the bed is downward with conservatively low velocity. At 20 atm pressure the bed has the capacity of retaining 5.5 Kg of water with < 1 ppm_v effluent contamination.

Adsorber beds for oil vapor and water vapor removal were sized and designed at Fermilab with some adsorbent performance data provided by the manufacturers. Fig. 4 is a photograph of the typical adsorbent bed skids installation. A few of the adsorbent vessels were built with ports on the vertical side to measure the Mass Transfer Zone (MTZ) wave propagation. The MTZ is the band in which adsorption is taking place. Some measurements have been taken on the molecular sieve beds. We learned that the stabilities of dew point sensors are very critical for the low moisture level we are working with (< 1 ppm_v). We have purchased field calibration systems and more data will be required. We take measurements of the effluents, and when they exceed 2 ppm_v, the beds are changed.

Final Filter

The final filter is installed downstream of the adsorbent pellets material to retain any particle of 1 micron and larger. The Dollinger Corporation makes the filter assembly which consists of a 0.22 m O.D. x 0.61 m high vessel with a single filter element. The gas flow is from the outside to the inside of the filter. The radial fin-pleating design of the filter gives the element collapse pressure of 345 kPa.

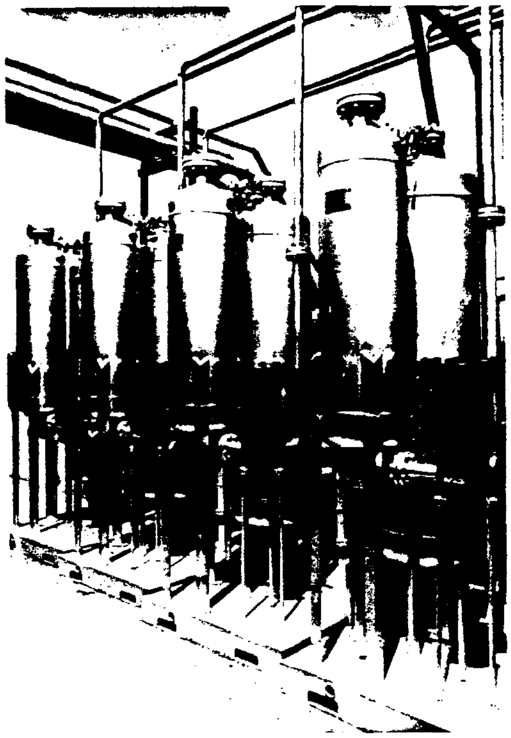

Figure 4. CØ Adsorbent Bed Skids

CONCLUSIONS

Oil mist removal to < 0.1 ppm_w has been measured after the second stage of the coalescing filters. From several months of testing different types of commercially available oil mist removal systems, a critical gas velocity of 0.5 m/s was observed to prevent oil re-entrainment from the wet surfaces. More data on the adsorbent beds are required.

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