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POWER FOR THE FERMILAB TEVATRON HELIUM LIQUEFIER

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Abstract

The paper describes the electrical power installation for the central helium liquefaction plant at Fermilab. The system includes three 4000 horsepower motors for the helium and nitrogen compressors, complete with the necessary motor starting and auxiliary equipment. Details are given also on the associated interlocking and monitoring equipment.

Introduction

The Tevatron helium liquefier is a central helium plant for the Fermilab Tevatron magnets.[1,2] The plant consists of one nitrogen compressor and two helium compressors (Fig. 2), together with all the peripheral equipment necessary to liquify helium for the Tevatron magnets.

Power Systems

Electrical power for the liquefier plant is supplied from the Laboratory's master substation as indicated in the single line diagram of Fig. 1.

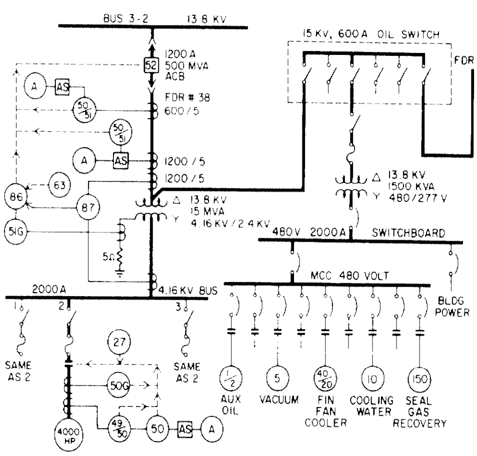

Fig. 1. Single Line Diagram

The three main compressors derive their power through feeder #38, a 15 MVA transformer and a 5 kV motor starter assembly. Each compressor is driven by a 4000 horsepower motor.

The auxiliaries and building services are powered through feeder #47, an oil switch and a 1500 kVA substation. A connection from feeder #38 to the oil switch allows operation of the building power and auxiliaries with feeder #47 out of service.

15 MVA Transformer

The 15 MVA, outdoor, station type oil filled transformer has the following abbreviated specification:

15 MVA, 55/65 °C rise

3 phase, 60 Hz

5.75% impedance

13,800 V primary, delta, 110 kV BIL

4,160 V secondary, wye, resistance grounded neutral, 75 kV BIL

The transformer was purchased on May 1, 1977, for $75,200.

Materials from Surplus

The synchronous motors, starters and excitation equipment, and compressors of 1952 vintage were available from government surplus.

5 kV Motor Starters

The question whether to reuse the old starters and rotating excitation equipment was seriously investigated. A number of facts became soon apparent:

1. Reconditioning would cost about $60,000.
2. The old-style equipment would need about four times as much floor space as new equipment.
3. Availability of future spare parts could not be guaranteed.
4. A considerable amount of engineering time would have to be spent due to lack of drawings.

The logical decision to buy new, across-the-line starters, was made and an order was placed on December 27, 1976, for $57,384.

The starter line-up consists of three fused ac 600 A magnetic airbreak contactors and solid-state synchronizing and excitation equipment, one incoming line compartment and one metering compartment, totally measuring 280" w. x 100" h. x 30" d. No incoming main breaker was used in order to reduce cost and size. The starter line-up requires only front access and is mounted against a wall.

4000 HP Compressor Motors

The three motors are each rated as follows:

Capacity:	4000 HP synchronous
Voltage:	4160 V line-to-line
Phases:	3
Frequency:	60 Hz
Service Factor:	1.15
Synchronous Speed:	277 rpm
Power Factor:	1.0
Full Load Line Current:	444 Amps
Locked Rotor Line Current:	1776 Amps
Field Current:	146 Amps at 125 Vdc
Acceleration Time:	2 seconds
Temperature Detectors:	6 embedded RTD's each 10Ω at 25°C.

The rotors are of the salient pole construction with 26 poles. The rotor OD is 7 feet. All motors were in a neglected state, but it was found more economical to recondition them. The plan was to clean, bake, and re-varnish them. When the work started it was found that there were a large number of shorted field poles, bad bearings, and one motor with a sawed-

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through stator winding. Repair of the field poles proved frustrating but was successful. Attempts were made to replace the sawed-off stator winding. It was not successful. Good old stator coils adjacent to the one being replaced would fail upon subsequent testing. These coils apparently could not withstand the removal required to insert a new coil. It was decided to rewind this stator completely at a cost of $25,413. The total cost of rebuilding three rotors and three stators was about $62,000.

The old stator windings were high potential tested at 8000 Vdc, the new stator windings at 9000 Vdc. The rotors were subjected to 120 V, 60 Hz drop tests and 1000 Vdc megger tests. Stator leakage currents were in the order of 2 μA at 8000 Vdc. The average rotor leakage current was 30 μA at 1000 Vdc. Tests and performance indicate that the repair was successful.

Auxiliaries

The auxiliary systems include:

Compressor for seal gas recovery system.
Instrument air compressor.
Auxiliary oil pumps.
Vacuum pumps.
Fin fan motors.

The fin fan motors are part of the outdoor water-to-air heat exchangers. Large 14-foot diameter fan blades provide forced air cooling. The fan blades are driven by dual speed, constant torque motors. The motor speeds are 1760/885 rpm. A gear reducer with a ratio of 7.556:1 is connected between motor and fan blades. The auxiliary systems are powered off the 480 volt, 3-phase power through a motor control center. The combination starters are remotely controlled from the control room. All interlocks are routed through the control room.

Controls

The controls are centralized at an interface for future computer control. At present a TI-5 logic ladder sequencer is in control of compressor and motor instrumentation. Pressure, temperature, and flow interlocks are summed into a permissive which will either prevent the motors from starting or trip them off. Parameters for the permissive can be readily changed via adjustable trip levels. Logic in the TI-5 is in random access memory and can be optimized for safe operation.

Interfacing

The remote control uses dc logic. It was, therefore, necessary to install an ac-to-dc interface between the starters and the remote controllers. Solid state relays were used for this purpose.

AC power and control cables have been carefully separated to prevent power line noise interference. The motor starters were designed for local control using 120 Vac control power. Trip relay contacts such as overcurrent and ground fault were wired in parallel.

Starter fault indications are separately transmitted to the remote controller via toroid coils added to the starter relay circuits. This approach provides good electrical isolation, and does not interfere with existing starter wiring.

An LM-311 comparator in the toroid circuit is used to provide a high level dc output voltage (24 Vdc) compatible with the sequencer. Motor currents and voltages are displayed at the remote control point. These signals are taken from existing potential transformers, current transformers, and the field circuits in the starters. Signal processing amplifiers provide isolation for control room displays and hi/low alarm signals.

Operator Console

The operator console has a 3' x 6' graphic display board showing a flow diagram of the compressors. All control devices are displayed. Flashing lights indicate warning, steady lights indicate tripped condition and unlit lights indicate ready status. The compressor permissive is controlled via the TI-5 sequencer.

Motor start, stop, and lock out are all manually controlled by the operator. The same is true for all of the other rotating machinery in the plant. Compressor trips are routed through the sequencer located in the console. Faults detected by the sequencer, drop out the motor permissive.

The sequencer is monitored by an independent watchdog timer. Some sequencer hangups have occurred, though rarely. An alarm is sounded in the event of a sequencer reset failure. The operator can then start a manual plant shutdown.

Operation

Essentially all three compressors are independent. Any combination can be operated. Compressor loading is a manual operation. Pressures and temperatures are, or will be, automatically controlled to set levels.

The two helium compressors are now operational, including all of the auxiliary systems. Full load operation of these compressors corresponds with the following measured motor data:

Motor voltage:	4160 Volts
Motor current:	230 Amperes
Field voltage:	104 Volts
Field current:	147 Amperes
Stator winding temperature:	70°C.

The stator thermal protection has been set to trip at 80°C.

Orange colored sparks were observed at different positions around the air gap during initial start-ups of the motors. This is a normal occurrence after a motor has been reworked. It is caused by the voltage induced in the damper winding rods. Sparking-to-ground occurs while the damper rods are relocating to a solid ground position.

References

[1]H. R. Barton, Jr., G. A. Hodge, J. A. Hoover, and R. J. Walker; "Nitrogen Detector and Process Control System for the Tevatron Liquefier"; to be presented at the 1979 Particle Accelerator Conference.

[2]R. S. Ahlman, J. E. Harder, M. E. Price, R. K. Rihel, R. J. Walker, and D. M. Wilslef; "The Central Liquefier for the Fermilab Tevatron"; to be presented at the 1979 Particle Accelerator Conference.

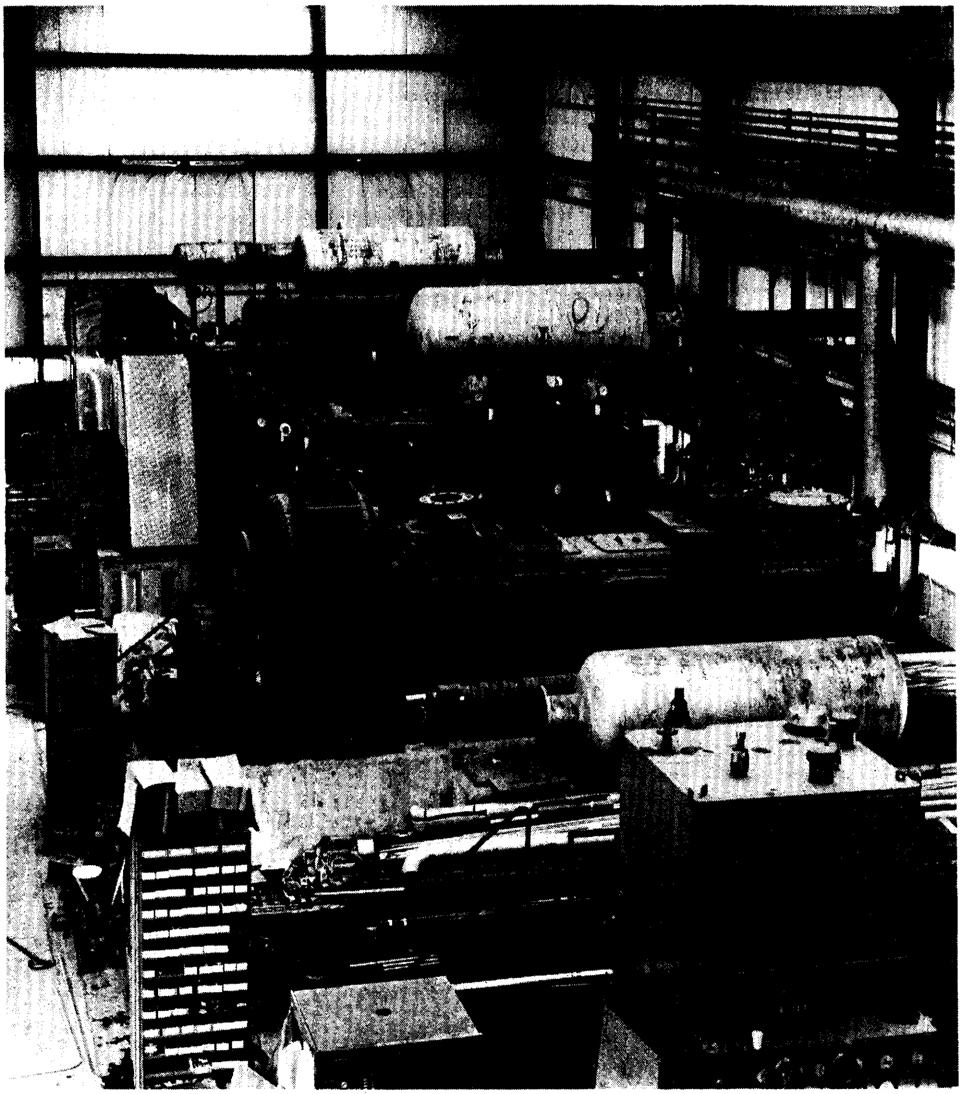

Fig. 2. Central Helium Plant Compressors