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Operational Experience of Helium Gas Management System at TIFR Mumbai

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Abstract

The Low-Temperature Facility (LTF) of the Tata Institute of Fundamental Research, (TIFR) Mumbai, India, is one of the largest facilities in India under the R&D sector and has been operating and maintaining cryogenic plants more than five decades. LTF provides liquid helium and liquid nitrogen along with the cryogenic support services to many facilities and laboratories of the institute. LTF helium gas management system handles more than 1300 high-pressure helium gas cylinders. LTF low-pressure helium gas recovery network is one of the largest among such similar facilities elsewhere in India. This commands unusual type of safety and monitoring control systems as parameters such as pressure, purity, leak checking, gas accounting needs to be continuously monitored for appropriate actions. The operational strain in managing such a complex helium gas managements is attempted successfully with the help of computer automation. This paper presents the in-depth details about the helium gas management systems implemented at LTF along with sharing the operational experience.

1. Introduction

The Low-Temperature Facility (LTF) of the Tata Institute of Fundamental Research, (TIFR) Mumbai, India, is one of the largest facilities in India under the R & D sector and has been operating and maintaining cryogenic plants for more than five decades (since 1962). LTF provides liquid helium and liquid nitrogen along with the cryogenic support services to many facilities and laboratories of the institute. To cater these large demands of cryogens, this facility handles huge numbers of high-pressure helium gas cylinders and large network of low-pressure helium gas recovery piping. The paper is intent to explain the safety and monitoring control systems implemented at LTF using computer automation

2. Liquid Helium Production and Distribution

Since May 2008, the facility operates and maintains the Linde L280 helium Liquefier [1]. The photo of the present helium liquefier at LTF is given in Figure 1. The average annual, liquid helium consumption is about 125000 liters, which is one of the largest consumption by similar such facilities in India. LTF works round the clock in shifts and mostly in unattended operation mode. The annual liquid helium consumption is mentioned in Figure 2.

Figure 1. *Linde L280 Helium plant at LTF.*

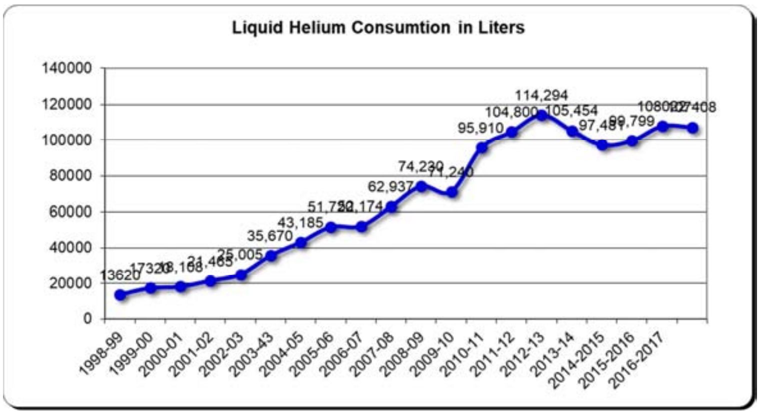

Figure 2. *Annual liquid helium consumption at TIFR.*

LTF supports various facilities and equipment with the uninterrupted supply of liquid helium to users on an "on-demand" basis. User dispensation is automated through an interactive touch-screen based software system integrated with data logging and dewar tracking facilities. The list of important facilities catered by LTF is listed in Figure 3.

Figure 3. *Facilities supported by LTF.*

LTF handles large number of cryogenic dewars to support the above facilities and systems with the uninterrupted supply of liquid helium. Presently, LTF handles a total of 30 liquid helium dewars of capacities ranging from 60 to 200 liters. 18 of these are 100-liter capacity, lightweight transportable aluminum-alloy dewars. Figure 4 shows the dewars maintained by LTF.

Figure 4. *Liquid helium dewars at LTF.*

On an average, LTF dispenses about 90 dewars every month (mostly the 60 & 100 liters), with an annual average dispensation of about 930 dewars. Figure 5 shows the total dewars (annual) filled with liquid helium

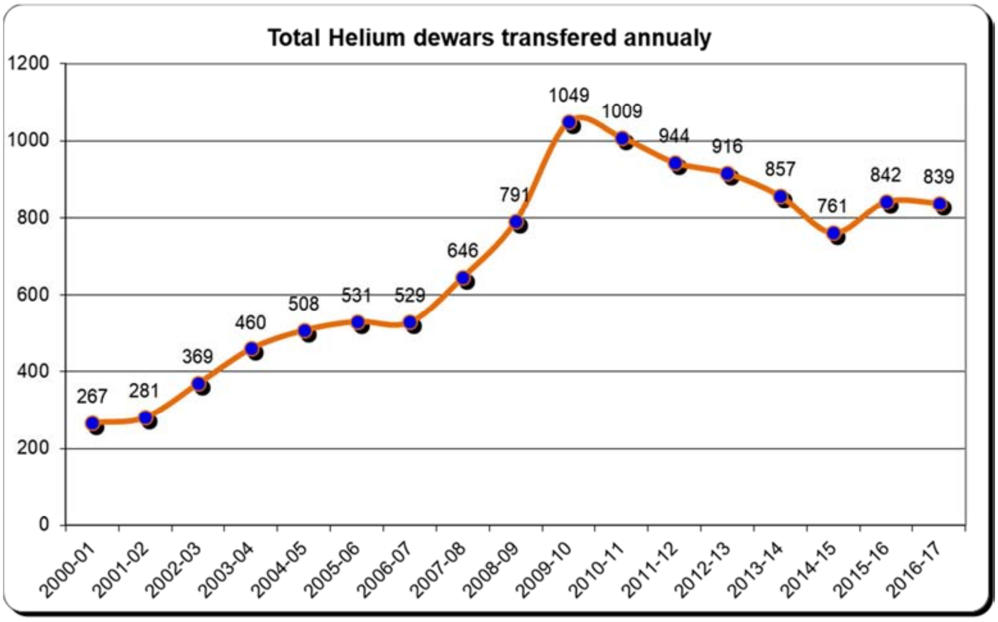

Figure 5. *Graph showing the total Dewars filled annually.*

3. Helium Gas Recovery

After the use of liquid helium at various laboratories in the institute, the boil-off gas is recovered back for re-liquefaction. LTF's helium gas recovery system handles a large quantity of boil-off helium gas sent by various laboratories through the large network of recovery lines from the various blocks within the Institute, through lines with an approximate length of 1.75 km. The user end of helium gas recovery piping is of 1 Inch diameter copper piping, which connects the header piping of 3 Inches diameter steel pipeline. The helium gas recovery pipeline and connected laboratories are schematically represented in Figure 6, as helium gas recovery network map.

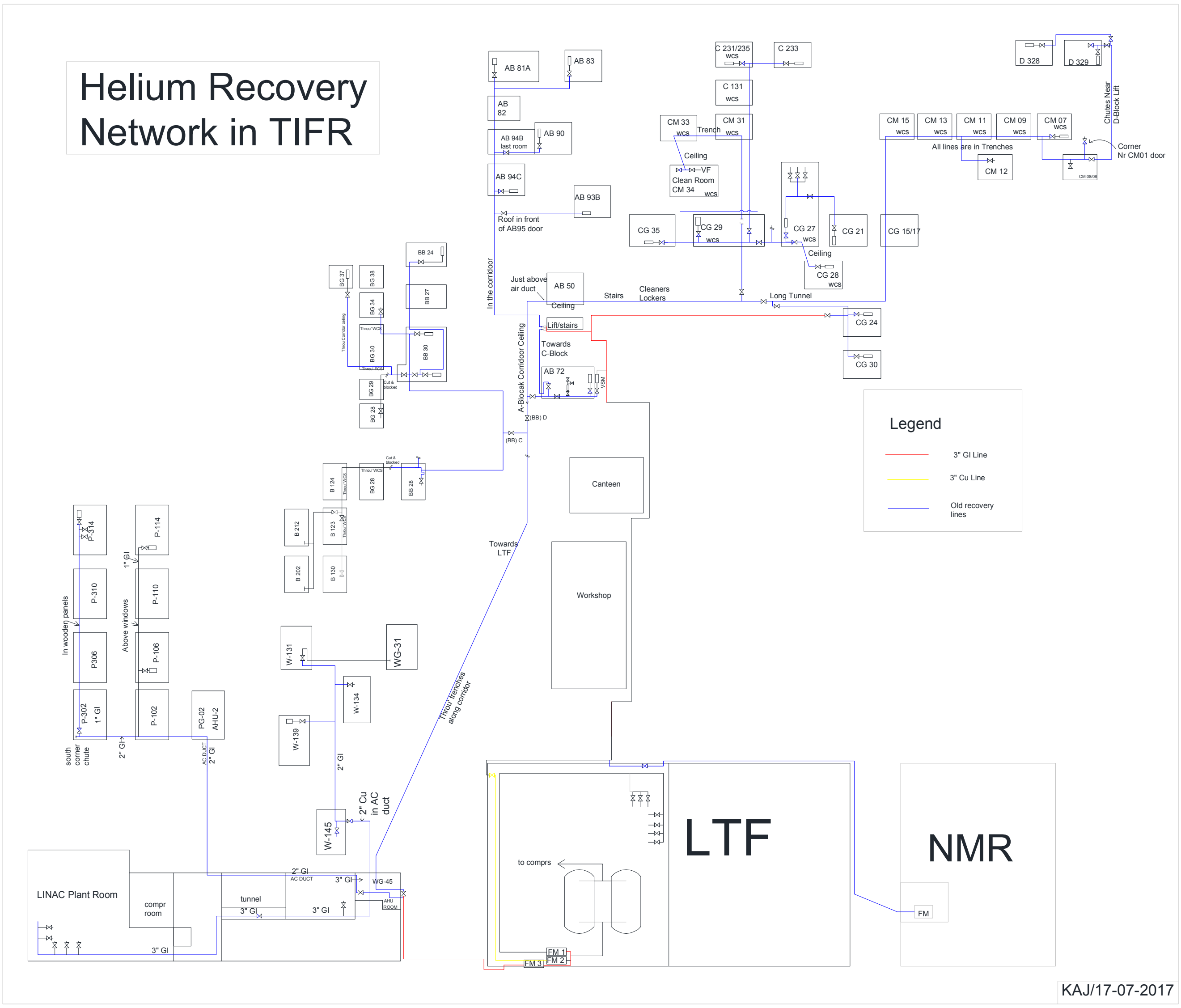

Figure 6. *Helium gas recovery network map.*

Figure 7. *Helium gasbag & high pressure compressor.*

The recovered low-pressure, impure helium gas from the above mentioned laboratories are collected in the recovery balloons at LTF using two sets of gas balloons. The recovered gas from these balloons is compressed with the help of high-pressure recovery compressors. The final delivery pressure at 200 bar is passed through the regenerative filters to remove the moisture and hydrocarbon before storing in cylinders. The gasbag & recovery compressor used in LTF is shown in Figure 7.

Considering the long, helium gas recovery line, which connects more than 45 active helium users through 32 helium gas flow integrators, fitted in various user locations, it is highly essential to monitor the en-route gas recovery and to identify the leak zone as & when required. To facilitate this, the helium recovery network was diverted through five major clusters as shown in Figure 8.

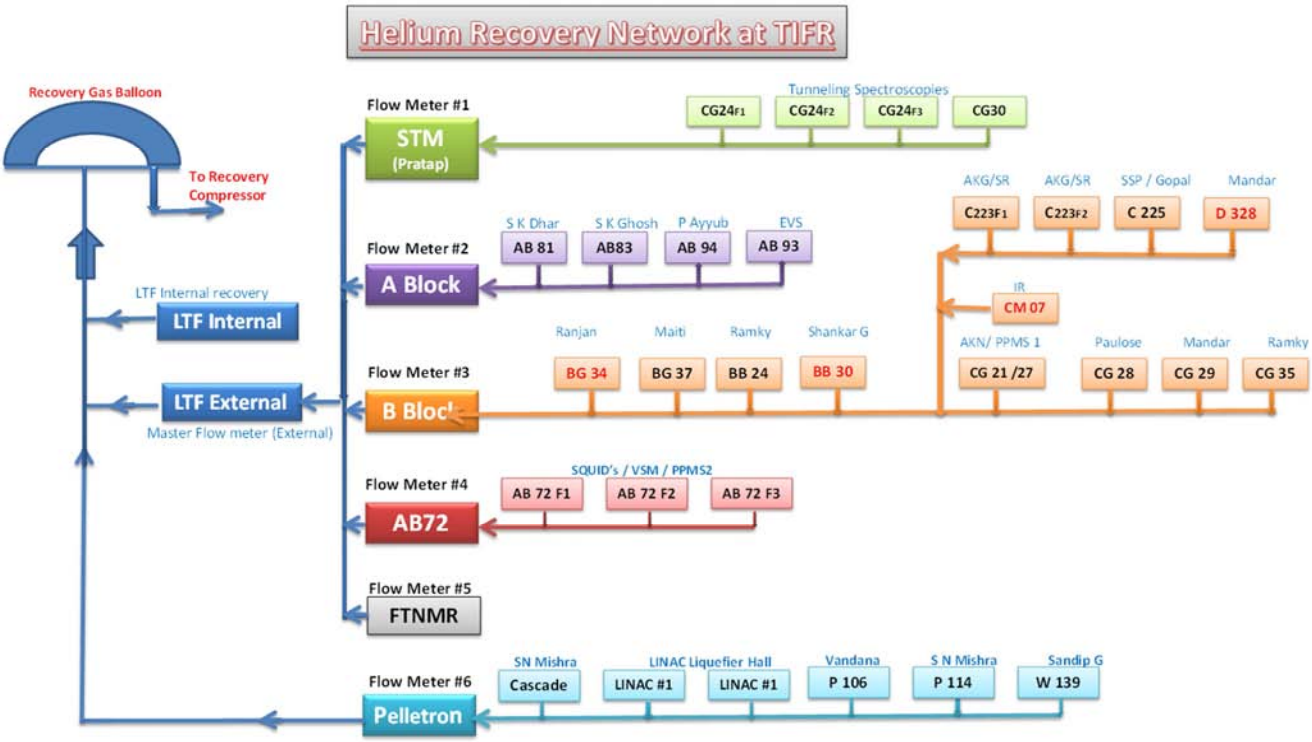

Figure 8. *Cluster-wise helium gas recovery piping layout.*

Helium gas recovery is cross checked with the collected helium gas quantity at LTF on a daily basis, along with the overall gas inventory on a weekly basis, lab wise gas accounting on every dewar usage etc were some of the activities to keep the helium gas loss & gas quality under control. The typical impurity level of the recovered gas is about 2 to 5% and the average measured helium gas loss is around 13 % of the quantity liquefied.

4. Cylinder Banks / Frame (QUAD)

Conventionally helium gas is stored in cylinder banks tied in a steel frame work structure, which is also called as gas QUAD. LTF facility handles a total of about 1300 high-pressure helium gas cylinders packed in about 25 gas quads structure, for storing the pure and recovered impure helium gas at a operating pressure of 200 bar.

The typical TIFR's gas Quad specification is as below.

Individual cylinder size	: dia 232 mm X 1465 mm long
Water capacity of cylinder	: 50 liter
Working Pressure	: 200 bar
No. of cylinders in Quad	: 54
Cylinder matrix	: 6 rows by 9 cylinders

The typical construction of helium gas Quad is shown in figure.9 and layout of helium gas quads at TIFR is shown as Figure 10.

Figure 9. *Helium Quad with interconnecting manifold.*

Figure 10. *Helium gas Quad layout at TIFR.*

A. Safety in cylinder usage

Gas Cylinder Rules (GCR) 2004 of Petroleum and Explosive Safety Organization (PESO) is the governing document for high-pressure gas cylinders in India. All these high-pressure gas cylinders are mandatorily tested periodically by Hydrostatic Stretch Tested (HST) for safe and continuous usage [3]. Retest period for different gas applications is defined in IS 8868 [4] and for helium gas cylinder it is 5 years. The above periodic inspection comprises visual examination, measurement of wall thickness, internal cleaning, weighing and HST for conforming the permanent elongation. The cylinders which do not meet the following criteria is to be condemned under the intimation to the cylinder owner and the statutory authority.

B. Cylinder Hydrostatic Stretch Testing

During this test, the cylinder is pressurized up to the standard test pressure for 30 seconds and the total volumetric expansion is measured. The pressure is then released and permanent expansion is measured. For a safe validation, the permanent expansion must be less than 10% of the total volumetric expansion [5]. There are two methods for carrying out the cylinder testing methods, the water-jacket volumetric expansion (can be levelling burette or fixed burette) method and the direct expansion method by which these cylinders are tested. Water-jacket testing is widely used, on the count of safety and accuracy. In the water-jacket method for hydrostatic testing the water-filled cylinder is inserted into a sealed chamber called test jacket, which is also filled with water and is connected to a calibrated glass tube (burette) or any electronic expansion measuring system. The water-filled cylinder is then pressurized to its specified test pressure (usually 1.5 times the standard filling pressure). This test pressure is usually held for a period of thirty seconds. The cylinder is examined externally for any leak. Any reduction in pressure noticed during this test period or leakage / bulge /deformation is considered a case of failure in the test. The cylinder expands upon pressurizing and forces water out of the test jacket and up into the expansion bowl or burette. After the thirty-second test time has elapsed, the “total expansion” of the cylinder under test pressure, is measured in the burette, usually in milli-liters. The test pressure is then released and the cylinder "deflates". As the cylinder deflates to its approximate original size, water is allowed to drain back into the test jacket from the burette. Typically, the cylinder will not return to its original size, but will remain slightly stretched due to the pressurization process. This stretching is called the permanent expansion/elongation. The difference between the "total expansion" and the "permanent expansion" is called the elastic expansion. When the permanent cylinder elongation exceeds the predetermined limits, then the cylinder must be condemned and removed from further service. A higher value of expansion indicates that the metal of the cylinder has lost its elasticity, or that there has been excessive wear & tear leading to the thickness reduction of the cylinder wall, so that the cylinder is no longer safe for use. HST in India is carried out, in accordance with IS-5844 [4]. The typical setup for the water-jacket volumetric expansion fixed burette method is shown in Figure 11.

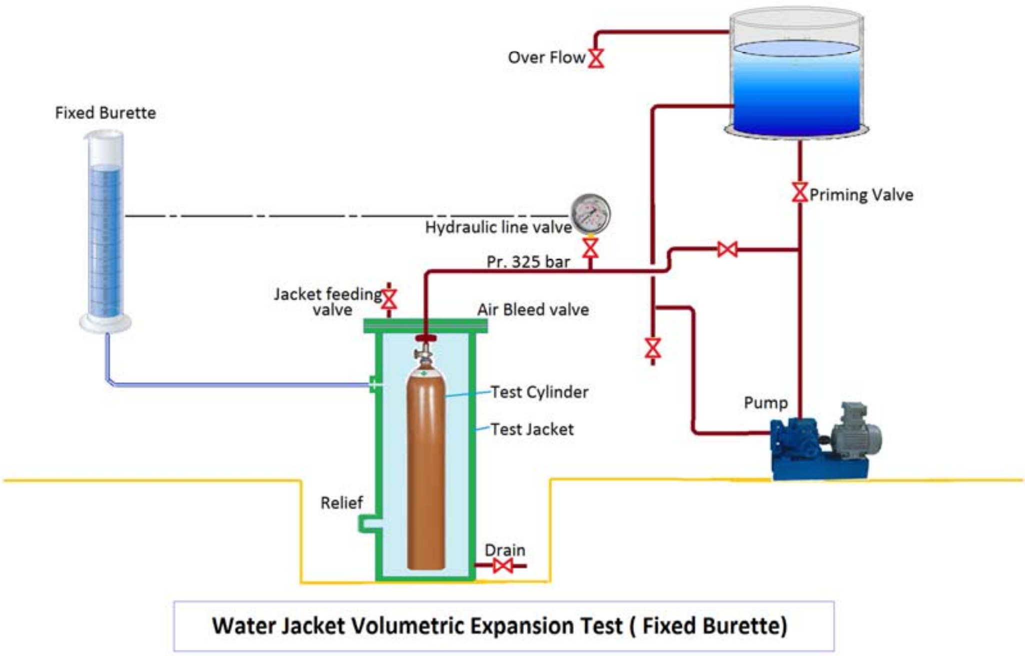

Figure 11. *Setup diagram of Water-Jacket Volumetric Expansion Method.*

After the hydrostatic stretch test, the cylinders are cleaned and painted using middle-brown color shade reference no. 411 as per IS 5 as per IS 4379 [6]. Test details are stamped on a neck ring which is fitted as impact fitment as per IS 8868. Test certificates for accepted cylinders are documented as per the guidelines given in Clause 42 of GCR 1981. Necessary filling permission certificates are issued for refilling these tested cylinders with helium gas. All the cylinders are regularly tested for its safe and continued usage, thus ensures that only tested and valid cylinders are in used.

5. Helium Gas Management System

The helium gas inventory needs special attention and it is necessary to keep a close watch on the losses, in view of the high cost of helium gas. Many automation works using programmable logic controller (PLC) and other modern electronic tools were implemented at LTF [7]. This automation system generates the online data logging, alarms through email & SMS for any abnormal helium gas loss and online helium gas accounting sheet. The architecture of the automation implemented is schematically explained as Figure 12 and the screen shot of the process graphical visualization screen is depicted as Figure 13. [8] [9]

Figure 12. *Architecture of automation.*

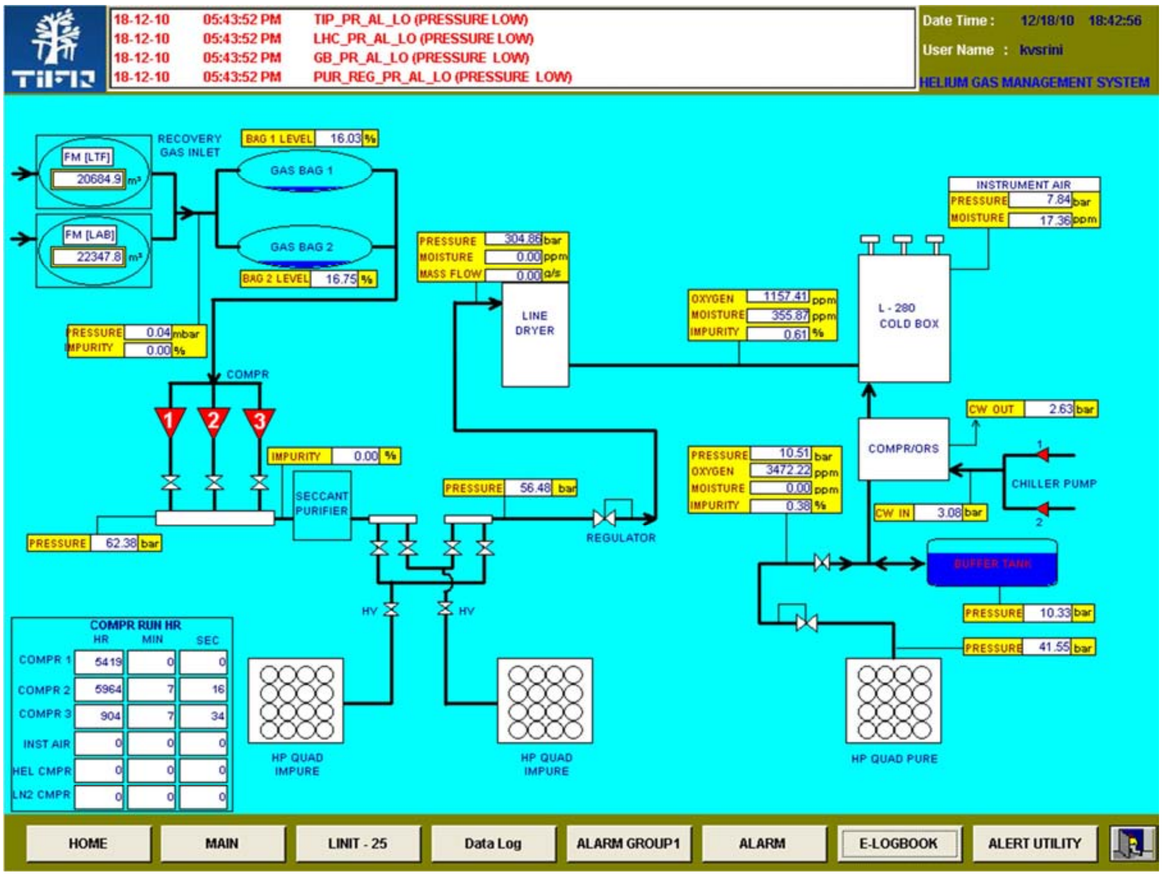

Figure 13. *Screenshot of the process visualization screen.*

Irrespective of many Liquid helium systems in operation at TIFR and with the increasing liquefied quantity, the average helium gas recovery rate is about 87% of the total gas liquefied. The annual helium gas loss against the liquefied quantity and the annual gas loss percentage against the liquefaction quantity are shown in figure. 14 & 15.

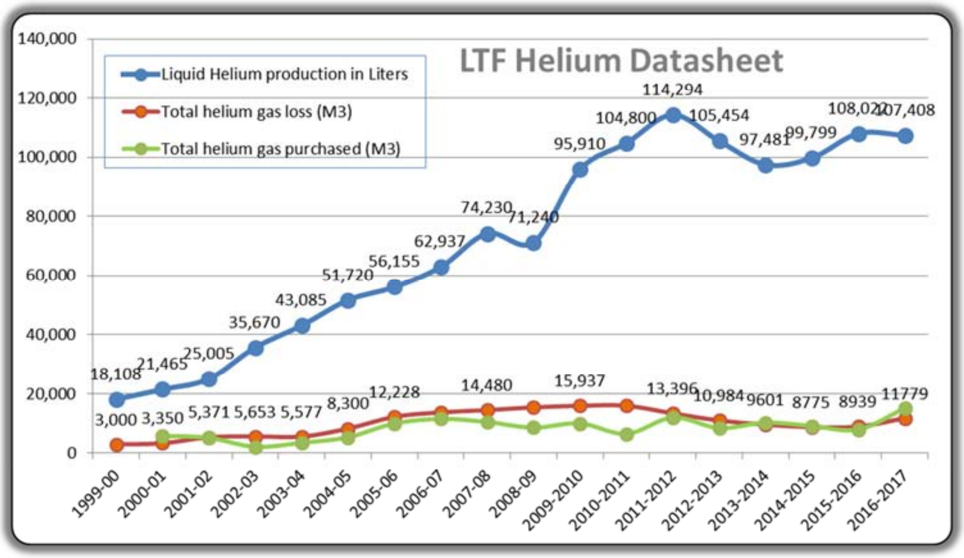

Figure 14. *Gas loss against liquefied quantity.*

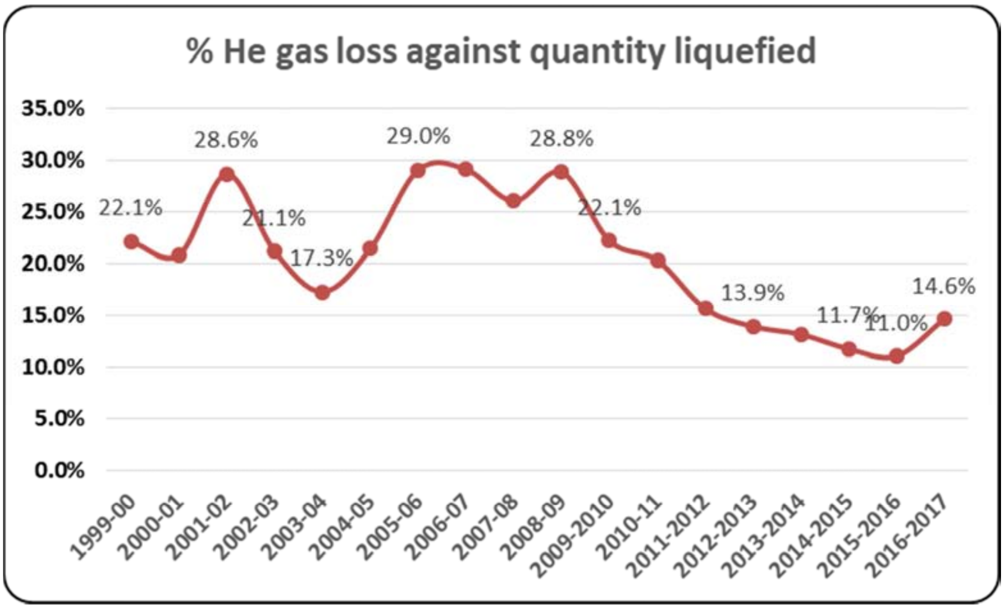

Figure 15. *Helium gas loss against liquefied quantity.*

Based on the monitoring system implemented and the observation, it is evident that the main source of helium gas loss is arising at the plant end in recovery compressors & high pressure relief valves [10]. Similarly at the users end the loss occurs due to the improper handling of transfer siphons, gas recovery valves, leakage while usage of vacuum pumps when pumping on liquid helium baths, untrained user in cryogen handling etc. Attempts are being made to curtail the leak rate to below 8% by incorporating the many actions like cluster level accounting, regular leak checks at plant and user ends with regular training on safe cryogen handling, online monitoring of purity at various segments, gas accounting at user end on every dewar usage, and additional automation

6. Conclusion

Management of such a large quantity of helium, multiple systems along with large set of high-pressure helium gas cylinders, long recovery network it is highly essential to incorporate suitable control system using computer automation. Adequate safety and automation based monitoring system resulted in identifying the areas of leakage, controlling the gas loss and safety in operation were successfully established at LTF. This resulted in controlling the helium gas loss substantially irrespective of increased liquid helium consumption, since its active implementation from the year 2008.

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