Application of RGA as Leak Detector in ADITYA Tokamak Vacuum System

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ABSTRACT

Residual gas analyzer (RGA) is used to measure partial pressure of various gases in a vacuum system. For leak detection in vacuum system, mass spectrometer helium leak detector (HLD) is the basic device to perform the operation to detect helium leak rate. After initial leak detection of the vacuum system, helium leak detector is disconnected from the system. HLD is not operated daily in routine for leak detection of a vacuum system. The HLD operation is time-consuming work. Therefore, the user avoids to use it for daily routine operation. Alternatively, RGA already installed on the system for partial pressure measurements, is useful as a handy tool for leak detection. It fulfills the necessary leak detection on regular basis and also identifies air leak and virtual leak. The large ADITYA vacuum vessel is installed inside a complex Tokamak structure. Many diagnostic sub systems are connected to the ADITYA vacuum vessel through gate valves and other isolators like ceramic, glass windows, feed-throughs etc. During plasma discharges, the vacuum vessel experiences forces due to complex pulsed magnetic field. Therefore, the probability of leak generation is relatively high compare to normal vacuum system. In ADITYA vacuum system, a remotely operated RGA is used for leak detection, as and when required in a short time. The RGA is calibrated with standard HLD to estimate the helium leak rate. In this paper, the calibration of RGA installed on ADITYA Tokamak, with a helium leak detector is described. We also present its application as an in-situ air leak detector.

INTRODUCTION

Calibration of Residual gas analyzer (RGA) with Helium leak detector (HLD) in any vacuum system must be carried out to solve leak related queries immediately at any time.

➢Once RGA is calibrated with HLD to get helium leakrate in any vacuum system, there is no need of HLD to find out leaks for pressure below to 1 x 10^{-4} mbar (Due to RGA's operating pressure starts below 1 x 10^{-4} mbar).

➢But, Differential pumping system (DPS) is the solution to detect leak using RGA for pressure greater than 1 x 10^{-4} mbar in vacuum system. The DPS can provide enough operating pressure to RGA to get sampling data from actual process vacuum chamber.

➢RGA provides very useful information of Air leak in vacuum system for round the clock. When air leak occurs at any time, the ratio of mass 28 (nitrogen) and mass 32(oxygen) indicates as 4:1 (as atmospheric contain) with constant intensity.

➢RGA also solves virtual leak problem in vacuum system using standard pump down records of particular system. The virtual leak dominates mostly due to trap volume, system contamination of oil, water, solvent, material outgassing etc.

ADITYA vacuum system has torus shape with 2 m^3 volume and 60 cm x 60 cm cross section. This system has 48 nos. main ports and four quadrant joints. There are many diagnostic sub systems connected using sub ports (more than 100 nos.) through gate valves and other isolators like ceramic & glass windows, feed-throughs, foils etc.

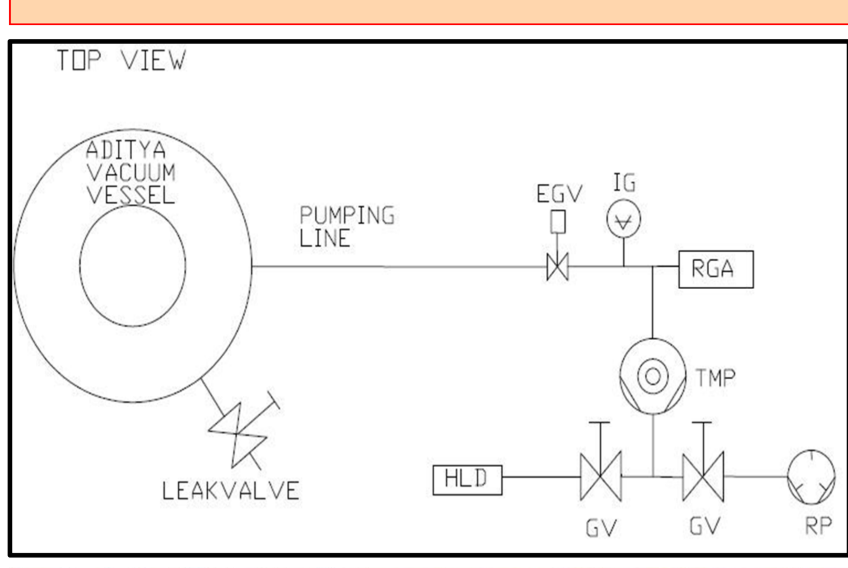
➢The leak generation probability is high in the ADITYA vacuum system at any time due to the complex design and high temperature plasma discharges. During plasma shots, the vacuum vessel experiences forces due to complex pulsed magnetic field.

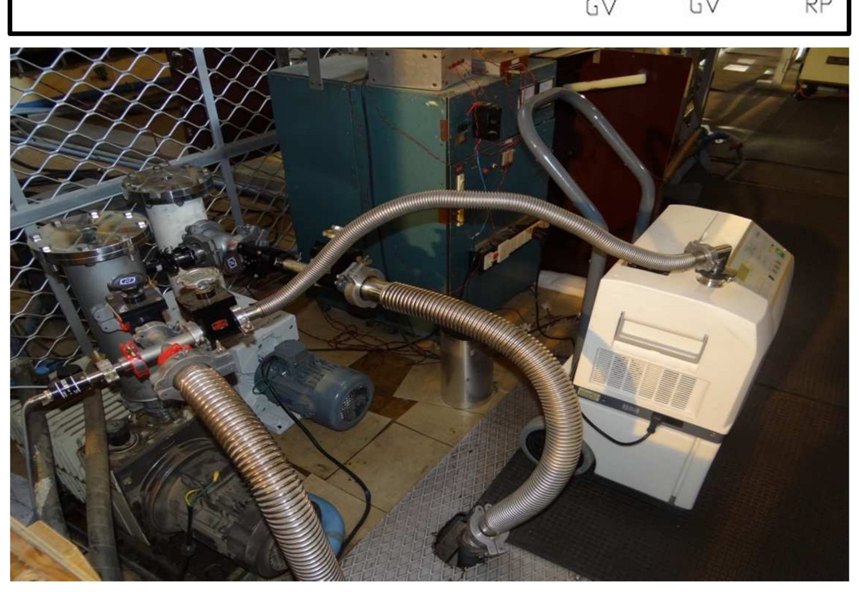
➢Continuous monitoring & recording of air leak using RGA is easy solution of this leak generation problem.

➢In ADITYA vacuum system, RGA (SRS make RGA200 model) is also calibrated to get helium leak rate using HLD (Alcatel Adixen make ASM142 model).

➢Here, Experimental results of air leak and RGA calibration in HLD are explained to study of RGA as leak detector in ADITYA.

EXPERIMENTAL SETUP





EXPERIMENTAL OBSERVATIONS

Table: 1 Experimental data of RGA calibration for leaktest with Standard Setup* of HLD in ADITYA

Pressure (IG) (Torr)	Helium pressure (Peak value) (RGA) (mbar)	Helium leakrate (Peak value) (HLD) (mbar.l/s)	Calculated Helium leakrate (RGA) (mbar.l/s)	Remarks
6.8E-07	6.0E-09	4.2E-09	NA	Base pressure of vac. System
7.3E-07	1.0E-08	6.6E-06	1.5E-05	(Leak Generate using Leak valve w.r.t. IG pressure as reference)
7.9E-07	1.4E-08	1.4E-05	2.1E-05	
1.0E-06	2.8E-08	4.0E-05	4.3E-05	
2.8E-06	1.3E-07	1.9E-04	2.0E-04	
4.0E-06	2.1E-07	2.9E-04	3.2E-04	
5.6E-06	3.2E-07	5.0E-04	4.9E-04	

** In standard setup, HLD is connected as back pump of Turbo pump (or diffusion pump) using roughing valve to get actual helium leakrate data*

Table:2 Experimental data of RGA calibration for leaktest with Throttle Setup* of HLD in ADITYA

Pressure (IG) (Torr)	Helium pressure (Peak value) (RGA) (mbar)	Helium leakrate (Peak value) Throttle setup (HLD) (mbar.l/s)	Calculated Helium leakrate for Standard setup (HLD) (mbar.l/s)	Calculated Helium leakrate (RGA) (mbar.l/s)	Remarks
7.0E-07	7.0E-09	4.0E-09	3.2E-08	NA	Base pressure of vac. System
7.3E-07	9.9E-09	4.0E-07	3.2E-06	1.5E-05	(Leak Generate using Leak valve w.r.t. IG pressure as reference)
7.9E-07	1.3E-08	1.5E-06	1.2E-05	2.0E-05	
2.8E-06	1.3E-07	2.5E-05	2.0E-04	2.0E-04	
5.6E-06	3.5E-07	6.7E-05	5.4E-04	5.3E-04	
7.0E-06	4.1E-07	8.0E-05	6.4E-04	6.2E-04	
8.4E-06	5.2E-07	1.0E-04	8.0E-04	7.9E-04	
2.4E-05	1.9E-06	2.9E-04	2.3E-03	2.9E-03	
3.4E-05	2.2E-06	4.7E-04	3.8E-03	3.4E-03	
6.4E-05	3.2E-06	8.7E-04	7.0E-03	4.9E-03	

** In throttle setup, HLD and Back pump, both are connected simultaneously with Turbo pump (or diffusion pump) using roughing valves. Here standard calibrator is used for conversation of throttle setup to standard setup to get actual helium leakrate data.*

➢ Throttle setup is also used to find out high leak rate data of HLD due to increased pumping speed of Turbo's back pumps (Rotary & HLD) and Helium flow distribution in both back pumps.

➢There is no difference in RGA data in Standard and Throttle setup due to constant pumping of Turbo pump. So, Throttle setup gives actual picture of RGA as leak detector. (Because After calibration, HLD can be removed from back pump and RGA data dependent on Turbo's pumping speed)

Table: 3 Experimental data of RGA with Air Leak generated in ADITYA Vacuum system

Pressure (IG) (Torr)	Mass 28 (mbar)	Mass 32 (mbar)	Ratio of Mass 28:32	Remark
6.4E-07	5.6E-07	7.4E-08	7.6	Base Vacuum
1.0E-06	1.0E-06	2.2E-07	4.5	Air Leak generated
5.0E-06	6.8E-06	1.6E-06	4.3	
1.0E-05	1.5E-05	3.6E-06	4.2	
5.0E-05	5.5E-05	1.3E-05	4.2	
9.0E-05	6.0E-05	1.6E-05	3.8	

In Atmosphere, Nitrogen (Mass 28) is 78% and Oxygen (Mass 32) is 21%. The Ratio of Mass 28 to Mass 32 is approximate 4:1, which is indicated in above experimental data on air leak generation

CALCULATION

➢Conductance(C) up to RGA Head (for long tube in Molecular Flow region)

Formula: Conductance (C) = $3.81(T/M)^{1/2}(D^3/L)$

Where L= length of pipe up to RGA head= 85 cm, D=Diameter of pipe =25cm, M= Mass of helium=4, T=Room temperature in Kelvin…..Conductance $C_{(He)}$ = 5994.18 liters/sec

➢Effective pumping Speed ($S_{eff\,(He)}$) of Helium at RGA Head calculation

Formula: $1/S_{eff\,(He)} = 1/Sp_{(He)} + 1/C_{(He)}$

Where $S_{p\,(He)}$ = Turbo pump speed for helium= 2050 l/s (Turbo model: Hipace2300 of Pfeiffer)

$S_{eff\,(He)}$ = 1527.57 liters/sec

➢Calculated Helium Leakrate using Helium partial pressure of RGA

Formula: Helium leak rate $Q_{l\,(He)} = P_{(He)} \cdot S_{eff\,(He)}$

Using Experimental data of generated Leak as Pressure (IG): 1e-6 Torr (Table: 1) with RGA indicated $P_{(He)}$ =2.8e-8 mbar **than get Calculated helium leak rate $Q_{l\,(He)}$ *= 4.3e-5 mbar.l/s, while HLD indicated as 4.0e-5 mbar.l/s***

(Other data indicated in table: 1)

➢Calculation of Throttle setup to Standard setup of HLD connected in vacuum system.

(Standard calibrator of range **3.8 e-6 mbar.l/s** has been used for this calibration.)

HLD data with Std.calibrator connected at leak valve in ADITYA vacuum system:

In standard setup, helium leak rate as **3.2e-6 mbar.l/s** and in throttle setup as **4e-7 mbar.l/s**

Now, Calculated helium leak rate of standard setup (Using Throttle setup data) at generated leak as pressure (IG): 2.8e-6 torr (Table: 2)

In Throttle setup experimental value of helium leak rate is: 2.5e-5 mbar.l/s

Converted in standard setup helium leak rate: 2.5e-5 x3.2e-6/4e-7= ***2.0e-4 mbar.l/s, while RGA's calculated helium leak rate value is also same as 2.0 e-4 mbar.l/s (table: 2)*** *(Other data indicated in table: 2)*

ADVANTAGES of RGA as LEAK DETECTOR in any VACUUM SYSTEM

❖Huge Difference in Cost, RGA's value approximately 70% less than standard helium leak detector.

❖Once RGA is calibrated in helium leak rate with standard HLD in any vacuum system, the vacuum system doesn't require HLD to find out helium leak rate.

❖Detect Air leak in vacuum system.

❖Detect Virtual leak in vacuum system.

❖Easy accessible for round the clock in active vacuum system.

❖Take minimum equipment space in vacuum system.

❖Other species can be set for leak detection. i.e. Argon, volatile liquid etc.

❖For more than 1e-4 mbar pressure of vacuum system, DPS (Differential Pumping System) is designed to solve leak and process related queries using RGA.

❖Most of high vacuum system is equipped with RGA, which can be calibrated for Helium leak rate to solve leak related problems at any time as well as improve system efficiency

CONCLUSION

➢In ADITYA tokamak vacuum system, Calibrated RGA (Residual Gas Analyzer) in helium leak rate is performed the role of standard helium leak detector (HLD) in vacuum mode. Air leak and virtual leak application of RGA also improves the active vacuum system efficiency for round the clock.

➢For any vacuum system equipped with RGA, must be calibrated for helium leak rate to fulfill the requirement of helium leak detector without connected it.

PSSI-2011