

Acknowledgment

With great feeling and immense pleasure I would like to express my thanks and gratitude to my project supervisor Prof. Sunil Kumar Sarangi, Mechanical Engineering, NIT Rourkela, who spared a great amount of his valuable time for giving me guidance, help and encouragement over the last one year.

I express my sincere thanks to Prof. K.P.Maity, HOD, Mechanical Engineering, NIT, Rourkela for providing me the necessary facilities in the department. I am extremely grateful to Prof. R.K.Sahoo, for his help in purchasing the equipment and timely advice in various occasions.

My heartfelt thanks to Prof. V.V. Rao, IIT Kharagpur for the support and help extended while doing the Laboratory experiments.

A special thanks goes to my class mate, Trilochan Penthia, who has been working with me during the entire one year in helping to purchase and assemble the equipment.

I take this opportunity to thank all research scholars for being very helpful and especially to Mr.Rvindra Vutukuru for his cooperation and assistance.

For many technical as well as mechanical helps, I must thank workshop and lab instructors for being kind enough to help any time during this period.

Shihabudeen PS

ABSTRACT

This project deals with study, design, construction and installation of Vacuum laboratory apparatus including preparation of lab manual for Vacuum Laboratory which is being set up under Refrigeration and Cryogenic Engineering Centre in NIT Rourkela.

The Vacuum laboratory, a part of first year M.Tech (Cryogenics and Vacuum Technology) curriculum in Mechanical department, consists of twelve experiments in which six experiments will be designed and installed under this project. The proposed laboratory will help both the graduate and under graduate students of our institute to conduct different experiments under vacuum environment.

Two experiments using rotary pump [1] namely; Pumping speed measurement and conductance measurement of different piping analogy need to be set up. For which we designed a vacuum chamber [3] with suitable capacity first, decided pump down time allowable to get ultimate vacuum level of a rotary pump in accordance with the total lab hrs assigned to each sessions, and finally we calculated pumping speed [2] required for the pump. The same rotary pump set up will be used for conductance measurement too, but with different piping analogy. Conductance of each pipe is calculated using relations and are compared with experimental results in series and parallel connections.

For high vacuum application a turbo-molecular pump [4] experimental set up is designed. Pumping speed calculation as well as leak detection test may be carried out in this set up. For roughing and backing, a suitable rotary pump is fitted with this pump.

Since Mass spectroscopic leak detection [5] is most commonly used leak detection method in vacuum systems, we proposed one MSLD with turbo-molecular pump. Bill of material for the turbo pump is also prepared and handed over to department.

Oil-free vacuum atmosphere can also be created in our lab by using sorption pump [6] for medium range vacuum applications. A small capacity sorption pump's design is carried out and drawings are prepared.

Keywords: *Cryogenics, Turbo-molecular pump, Sorption Pump, Mass spectroscopy*

Contents

Certificate	
Acknowledgement.....	i
Abstract.....	ii
Contents.....	iii
List of Figures.....	vi
List of Tables.....	iii
Introduction.....	1
List of Experiments.....	1
1. Pumping Speed Measurement of Rotary Pump.....	2
1.1 Mechanical Pump.....	3
1.2 Classification.....	3
1.3 Theory of Operation.....	3
1.4 Rotary Vane Mechanical Pumps.....	4
1.5 Design.....	5
1.5.1 Vacuum Vessel Design Parameters.....	5
1.5.2 Evacuation of Chamber in the Rough Vacuum Region.....	7
1.5.3 Evacuation of Chamber in Medium Vacuum Region.....	8
1.5.4 How to Determine Pump Size.....	9
1.6 Vacuum Vessel.....	10
1.6.1 Thickness.....	10
1.6.2 Validity Check for End Plate Thickness.....	12
1.7 Rotary Pump Experimental Setup.....	13
1.8 Item List- Rotary Pump Set up.....	14
1.9 Pumping Speed by Constant Volume Method.....	15
1.9.1 Procedure.....	15
1.9.2 Tabulation.....	16
2. Conductance Measurement.....	17
2.1 Conductance in a Vacuum System.....	18
2.2 Configuration of Conductance.....	18
2.3 Conductance Calculation in different flow regime for air.....	19
2.3.1 Viscous Flow.....	19
2.3.2 Molecular Flow.....	19

2.4	Conductance values for other elements	20
2.5	Conductance of High Vacuum Lines.....	20
2.6	Conductance of Rough Vacuum Lines.....	20
2.7	Average Pressure Limit of Piping for different flow regime	21
2.8	Experimental Set up.....	21
2.9	Procedure.....	22
2.9.1	Tabulation.....	23
3.	Turbo-molecular Pump	24
3.1	Principle of Operation.....	25
3.2	Operational Aspects of Turbo-molecular Pumps.....	26
3.3	Applications for Turbo-molecular Pumps.....	27
3.4	Characteristics.....	28
3.4.1	Gas loads.....	28
3.4.2	Critical backing pressure.....	28
3.4.3	Compression ratio.....	28
3.4.4	Pumping speed.....	29
3.4.5	Specific Pumping speed.....	29
3.5	Evacuation of a chamber in the high vacuum region.....	30
3.6	Determination of a suitable backing pump.....	30
3.7	Item List-Turbo-molecular Pump.....	32
3.8	Design.....	32
3.9	Technical details of Turbovac 361.....	33
3.9.1	Maximum permissible Leak rate to get ultimate pressure.....	33
3.9.2	Selection of Backing Pump.....	34
3.9.3	Experiment Procedure.....	35
4.	Sorption Pump.....	36
4.1	Introduction.....	37
4.2	Principle of Operation.....	37
4.3	Design.....	39
4.4	Construction and Working.....	40
4.5	Experimental Setup-Sorption Pump.....	41
4.6	Item List- Sorption Pump.....	42
4.7	Experimental Procedure.....	42

5. Leak Detection.....	43
5.1 Introduction.....	44
5.2 Leak Rate.....	46
5.3 Sources of leaks.....	46
5.6 Leak Detection Methods.....	47
5.6.1 Pressure rise method.....	47
5.6.2 Tracer gas method.....	47
5.7 Mass Spectroscopic Leak detection.....	47
5.7.1 Test methods.....	47
5.7.2 Operating methods.....	48
5.8 Working of Helium Leak Detection Cell.....	49
6. Result & Conclusion.....	50
6.1 Result & Conclusion.....	52
6.2 References.....	52

List of Figures

Fig.1.1: Constructional Details of Rotary Pump.....	5
Fig. 1.2: Dependency of dimensionless factor σ on pressure.....	8
Fig.1.3: Nomogram.....	10
Fig 1.4: Deflection of circular end plate, uniform load, edges clamped.....	12
Fig 1.5: Rotary Pump Experimental Setup.....	13
Fig.1.6: Pumping Speed Characteristics.....	16
Fig.2.1: Series Connection.....	18
Fig.2.2: Parallel Connection.....	19
Fig.2.3: Conductance Measurement System	21
Fig.2.4: Conductance of piping for viscous flow.....	22
Fig.2.5: Conductance of piping for molecular flow	22
Fig.2.6: Dependency of Diameter and Pressure on Type Flow.....	23
Fig.3.1: Cross Sectional View of Turbomolecular Pump.....	26
Fig.3.2: Blade Geometry	29
Fig.3.3: Specific Turbopump pumping speeds.....	30
Fig.3.4: Turbo-molecular Pump Experimental Set up.....	31
Fig.3.5: Pumping Speed Characteristics- Turbo Pump.....	34
Fig.3.6: Pumping Speed Characteristics-Rotary Pump	34
Fig.3.7: Pumping Speed Varies with Molecular Weight	35
Fig.3.8: Pumping Speed Vs Inlet Pressure.....	35
Fig.4.1: Pumping Behaviour of Zeolite as a function of Pressure	38
Fig.4.2: Sorption Pump Details.....	40
Fig.4.3: Sorption Pump Experimental Setup.....	41
Fig.4.4: Line diagram of Sorption Pump.....	42
Fig.5.1: Variation of Pressure in an isolated system	45
Fig.5.2: Leak detection of Vacuum Vessel by Tracer Method.....	48
Fig.5.3: Leak detection Pressure Vessel using detector method.....	40
Fig.5.4: Leak Detection Counter Flow method.....	49
Fig.5.5: Working of He Leak Detection.....	49

List of Tables

Table 1.1: Vacuum Vessel Pipe details.....	13
Table 1.2: Item List-Rotary Pump.....	14
Table 2.1: Average Pressure Limit of piping for different flow regime.....	21
Table 2.2: Conductance of piping.....	21
Table 3.1: Item List-Turbo-molecular Pump.....	32
Table 3.2: Technical Data-TUBOVAC 361.....	33
Table 4.1: Item List –Sorptions Pump.....	42