A SAFETY SYSTEM FOR DYNAMIC VACUUM LIQUID NITROGEN PIPELINE

For World Class Manufacturing Operation in Semiconductor Industry

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Abstract: Liquid nitrogen is a colourless, odourless, extremely cold liquid and gas under pressure. It can cause rapid suffocation when concentrations are sufficient to reduce oxygen levels below 19.5%. Contact with liquid or cold vapors can cause severe frostbite. One volume of liquid nitrogen will expand to produce 696.5 equivalent volumes of gas. With this background Ln2 is being used in Semiconductor industry especially in testing operation. The cold tests are taken on products at a temp up to -40C to -60C. The Ln2 is used in testing machine to reduce test handler chamber temp. The chamber temp is required to maintain at -40 C with allowance of + or – 3C to get accurate results. So this paper describes how Dynamic Vacuum ln2 pipeline system can be maintained smartly to get maximum benefits with minimum unscheduled shutdown in semiconductor industry. This paper also gives the details about the safety system developed at SPANSION Thailand limited for handling of ln2 through Dynamic vacuum ln2 pipeline system.

1 INTRODUCTION

In semiconductor industry Ln2 is handled in two ways. 1) PLC (Portable liquid cylinders) is filled from main cylinder and then PLC is moved from filling station to tester machine. 2) Direct Ln2 pipeline system from main cylinder to Test chamber. There are many advantages of direct pipeline system over PLC, provided the ln2 requirement is more than 100KCum./month. Filling of PLC cylinders from main tank involves loss of Ln2. The liquid turns into gas. There are handling issues like weight of PLC, quality of vacuum at PLC so on. So it is always better to transfer Ln2 through piping system, provided usage is more than 100KCum./month . Or if the manufacturing requires to fill more than 15 PLCs /day with 200Kg /PLC. The Ln2 is handled in various ways. The boiling point of ln2 is -195.8C. So, it is very difficult to handle Ln2 in a liquid state. In cold testing operation the handler chamber required to get Ln2 in a liquid state. If ln2 is provided in a gas state there is no heat absorption at test chamber and it is considered as a loss of ln2. So there are various methods of supplying of ln2. The first and oldest type of supply system used simple copper or stainless steel pipe wrapped with wood insulation. Wood was later replaced by mica, then shortly after polyurethane foam. Foam insulation is highly inefficient and cumbersome, much of the liquid nitrogen traveling through the pipe turns to gas and pipe diameters with insulation are often over 8 inches. These large, bulky, inefficient piping systems were relatively cheap to install, but the loss of liquid nitrogen makes them to be very expensive in the long run. Vacuums are one of the best ways to eliminate heat conduction, so finally a dynamic vacuum piping system was developed. This piping system uses a pipe inside a pipe. To maintain a thermo-arresting vacuum, the ultimate insulator, between the two layers a vacuum pump is attached to the line. The vacuum pump works continuously twenty four hours seven days a week.

The dynamic vacuum piping system dramatically decreased heat loss, and therefore was a much more

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efficient system. While the dynamic system is much more effective than foam, materials and installation cost much more, and the time and maintenance required for the pumping system is highly cost ineffective due to electricity consumption.

Table 1: HAZOP table.

Guide Word	Deviation	Ln2 line needs to stop?	Consequences	Causes	Suggested Action
More	120psi Pressure at PG1	No need	Alarm will be at 120 psi	VENTS are off no handler ON	Start handler , check VENT

There are four principal areas of hazard related to the use of
Ln2. These are: flammability, high pressure gas, materials, and personnel. All categories of hazard are usually present in a system concurrently, and must be considered when introducing a Ln2 system or process The high pressure gas hazard is always present when ln2 is used or stored. Since the liquefied gases are usually stored at or near their boiling point, there is always some gas present in the container. The large expansion ratio from liquid to gas provides a source for the build-up of high pressures due to the evaporation of the liquid. The rate of evaporation will vary, depending on the characteristics of the fluid, container design, insulating materials, and environmental conditions of the atmosphere. Container capacity must include an allowance for that portion which will be in the gaseous state. These same factors must also be considered in the design of transfer lines and piping systems A very brief contact with ln2 at -195.8C temperatures is capable of causing burns similar to thermal burns from high temperature contacts. Prolonged contact with these temperatures will cause embitterment of the exposed members because of the high water content of the human body. The eyes are especially vulnerable to this type of exposure, so that eye protection is necessary.

1.1 Designing Safety System for Dynamic Vacuum Pipeline

The HAZOP study is done for Dynamic vacuum pipeline system but it is done before installation of pipeline. HAZOP: It is a hazard and operability study. The Hazops procedure involves taking a full description of a process and systematically questioning every part of it to establish how deviations from the design intent can arise. Once identified, an assessment is made as to whether such deviations and their consequences can have a negative effect upon the safe and efficient operation of the manufacturing plant. If considered necessary, action is then taken to remedy the situation. This study helps to design the safety system required for Dynamic vacuum ln2 pipe line system. An essential feature in this process of questioning and systematic analysis is the use of keywords to focus the attention of the team upon deviations and their possible causes. These keywords are divided into two sub-sets:
Primary Keywords which focus attention upon a particular aspect of the design intent or an associated process condition or parameter. Secondary Keywords which, when combined with a primary keyword, suggest possible deviations. The entire technique of Hazops revolves around the effective use of these keywords, so their meaning and use must be clearly understood by the team. Examples of often used keywords are listed below. Primary words: Incase of Dynamic vacuum pipeline system is Pressure, Vacuum, Temp, and Flow etc. Secondary words: More, less, In the HAZOP study we have to write a report on Purpose, Objective, and Scope of study, Team members, and Data collection by team members in following format. Showed in Table 1.
But it has been observed that the users do not install sufficient safety system while installation of Dynamic vacuum pipeline system. For long term success of Dynamic vacuum pipe line, it is very clear that control over vacuum, and pressure are very important. Usually, the manufacturers design Dynamic vacuum pipeline system with many safety release valves (SRV) to stop over pressurization. Usually these valves are present at both sides of any ln2 valve. Typically SRV operates at 120PSI, 170PSI as per requirement. But it is a one kind of breakdown maintenance. It means, if the pressure goes more than 120PSI the SRV fires. But one important point is ignored and that it the firing of SRV happens inside production floor. The ln2 gets fired with smoky jet with loud cranking noise. It is big disturbance to all operators around the line. It also may decrease the percentage of O2 in atmosphere. So, the operators need to go away from work place causing production disturbance. Any production disturbance can cost thousands of dollars. So it is required to control the pressure with different perspective. The Dynamic vacuum line should have an additional safety system which should alarm on over pressurization. The SRV is needed but that should be the last choice. The control over vacuum

is also very important. Usually the manufactures gives vacuum meters to monitor vacuum in the line. But additional alarm system should be there to get an alarm as soon as the vacuum is out of control. Usually the vacuum slowly reduces if there is failure of sealing. The gaskets or sealing fails over time because of wear and tear. The user can make necessary arrangement by controlling vacuum zone valves. To describe a safety system let consider a Dynamic vacuum pipe line system. The typical picture is shown.

1.2 Designing of Dynamic Vacuum Pipeline System

A typical Dynamic vacuum system fig1 is designed to illustrate. The main tank is located at A, ideally there should not be any pressure regulator on the Dynamic vacuum pipeline; the pressure regulator either expands or restricts the area of cross-section and creates gas from liquid. Our main aim is to provide 100% liquid nitrogen to test chamber. It can not be 100% but we should tray to design a system which can capable of supplying approximately 100% liquid. There is a main valve at A. The VENT 1 is installed to remove gas from liquid. The main cylinder can not be a reservoir of 100% Ln2. So, VENT1 is used to remove gas from liquid when liquid flow from main tank to test chamber. Sub main valves B and C are pneumatic actuated valves. These vales can be opened and closed with N2 gas supply ON and OFF. There are two more sub main valves at F and D .These valves are installed to get maximum flexibility. The flexibility of pipeline is explained at the end of this article.

These are manual. VENT3 and VENT2 are connected at the end of each line to achieve closed loop pipe line. All generated gas in pipe line is thrown away. PG1, PG2, PG3 are the pressure which are installed just before end of line. They must be installed just before end of line so that you can get

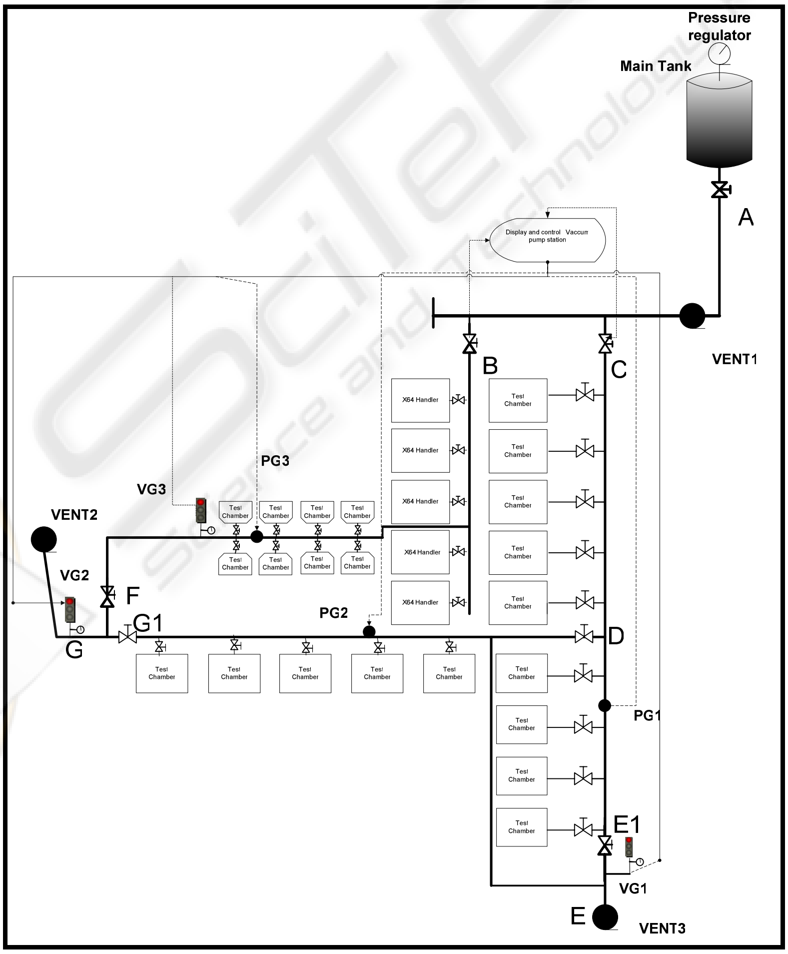

Figure 1: diagram of Dynamic Vacuum ln2 direct line.

normalized pressure of that pipe section.VG1, VG2, VG3 are installed at the end of pipeline so that we can get a minimum vacuum achieved at the end of line. It ensures that the recorded vacuum is certainly present in that pipe section. The computerized control
system is installed to control pneumatic valves at B and C. It also monitors the signals from pressure gauges and vacuum gauges.

2 SAFETY CONTROL SYSTEM

The safety control system has three parts A) Monitoring and evaluation B) Audit review and improvement and C) Emergency plan. To satisfy all three requirements, two types of safety control systems should be installed after installation of Dynamic vacuum ln2 line. 1) Monitoring and evaluation: It means the Dynamic vacuum system should be real monitored for vacuum and pressure parameters along the pipeline. The monitored results should be compared or evaluated real time with set limits. If there is any gap appropriate alarm system should be ON real-time automatically. 2) Audit review and improvement: For audits the old data is required. So, the safety system should be capable of producing the old data. There must be secured data base and all vacuum and pressure parameters must be stored real-time for future reference. Audits must be done; Process capability index like Cpk must be calculated automatically. C) Emergency plan: The system should stop the supply of Ln2 from the main tank in case of emergency. The emergency limits must be evaluated and set with control system.
With this requirement the two kinds of safety systems must be there along with Dynamic vacuum pipeline system.

Analog control and alarm system. Shown in fig2; As we know pressure and vacuum are the key parameters; so, hardware should be selected in such a way that it gives analog and digital signal. Usually vacuum or pressure probe senses the pressure; it is then collected by a meter which creates digital and analog signal. Now let consider figure for the the Dynamic vacuum pipeline system mentioned in fig3. VG1, VG2, VG3 are the vacuum meters which send analog and digital signal to control panel. The signal transfer is explained in fig. We can set two limits in vacuum meter lower and upper. So let us consider a Dynamic vacuum pipeline whose vacuum is controlled at 1mtor. The vacuum meter is set at 15mtor to give lower alarm and 30mtor to give upper alarm. In normal working condition vacuum meter should show reading 1mtor with some allowance. But if there is any problem and vacuum decreased to 15mtorr then vacuum meter sends analog signal to control panel to activate lower alarm. If the vacuum further decreased to 30m tor the vacuum meter sends an upper alarm.
The control panel is equipped with relay circuit as shown in fig 2. If it receives lower alarm then it will make buzzer ON and a yellow light will start blinking. If vacuum meter gets upper alarm it actuates circuit to get Buzzer ON, red light starts blinking it shuts off the solenoid valve which is operated on gas .The valve shuts down. If you see figure 5 and if VG1 senses the upper alarm then the corresponding signal will go to controller; the controller will actuate the signals to solenoid valves at B and C. It will shut down the flow of Ln2 to all Dynamic vacuum pipe line.

Digital Computerized Alarm and Control System. Incase of digital control system see figure 3 & 4. The vacuum and pressure meters give corresponding digital signal. The signal comes by RS232. But usually the computers are placed at controlling room far from production floor. So we need to convert signal from RS232 to RS422 to achieve better accuracy. RS232 can be used when the computer is not more than 50m away from vacuum or pressure sensor. In above case RS422signal again converted to RS232 at computer. The computer is installed with multi COM cards. So a computer is capable of receiving 15 signals from vacuum or pressure meters.

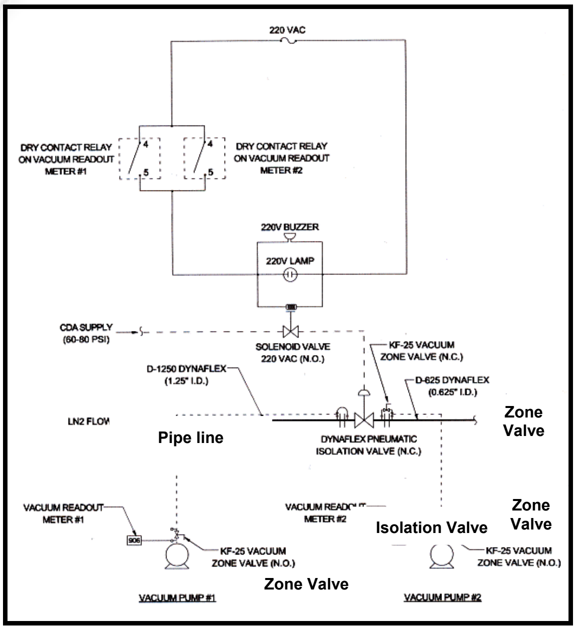

Figure 2: Analog control system.

Now in above case customized software is designed and developed which is capable of capturing the data at COM ports. The data is stored in a secured data base for future reference. So the software is capable of sending and receiving data from sensors. The Cpk is automatically calculated to get online process capability index. The software is capable of plotting real time data on statistical process control charts. It is shown in the fig4

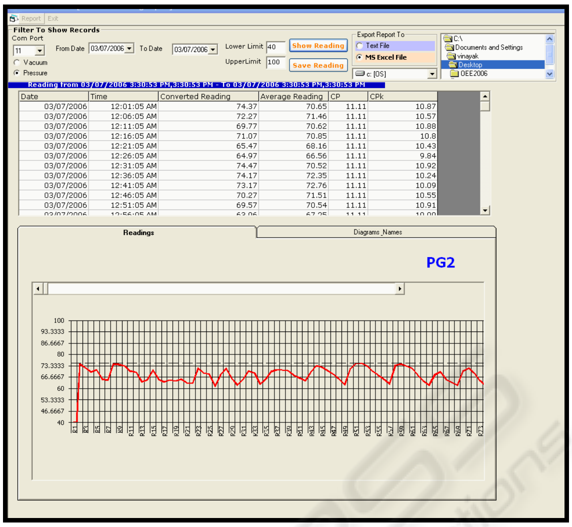

Figure 4: UI digital monitoring and data storage.

3 FLEXIBILITY OF DYNAMIC VACUUM PIPE LINE

This is one more concept which must be taken into consideration while designing of Dynamic vacuum ln2 line. It is little costly to design a flexible line but in long term it gives a lot of benefits. This concept is especially useful when the manufacturing requires zero down time. If the line is flexible, we can use the line partially, avoiding total 100% shutdown.

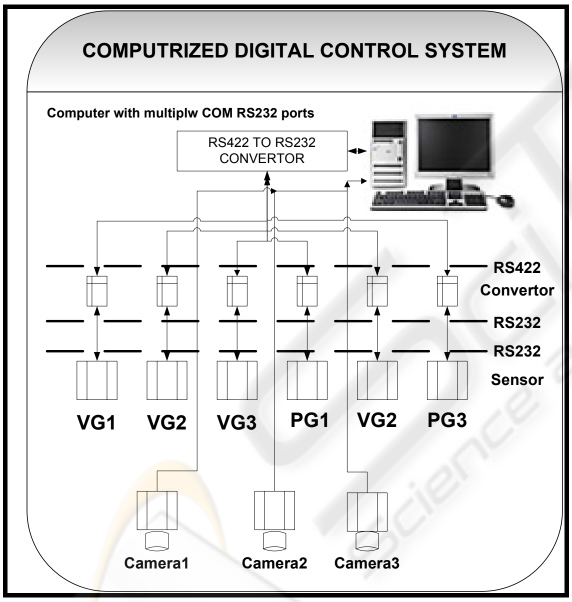

Figure 3: Digital control safety system.

So, if the above Dynamic vacuum pipeline is considered shown in fig 1. The pipeline is divided into three parts Part A.

Table 2: Flexibility of Dynamic Vacuum line.

Sr . No	Part of Dynamic vacuum line	Number of Outlets	Flexibility
1	Part 1-B to F 13	13	If problem is in part1, then close valve at B and F; Part 2 and 3 will get Ln2 from Valve C with closed
2	Part 2 – C to D to E 9	9	If problem is in Part 2 , Close the valves at C and E1, D. The ln2 will come to Part 1 and 3 from valve B to F to E giving closed loop.
3	Part 3-D to G 5	5	If the problem is in Part3, Close the valve at D, G1 still part 1 and 2 will work as closed loop pipeline.

4 RECOVERY ON BREAKDOWN OF DYNAMIC VACCUUM LN2 PIPE LINE

In semiconductor industry the breakdown of any utility system is a big crime. The testers are highly expensive so, utilization of machines is very important. Now if we consider break down of Dynamic Vacuum system then it is more troublesome as the Dynamic Vacuum ln2 line can not be started unless the vacuum is back to normal level. So normally it takes 8 to 9 hrs for a section of pipe of 100 feet by three vacuum pumps. In SPANSION Thailand this problem is solved by experimenting with Dynamic Vacuum line. In SPANSION Thailand the vacuum pumps and vacuum zone valves are arranged in such a way that the 100 feet Dynamic Vacuum line can be vacuumized by three pumps within 2 hrs. It is achieved as follows.

a) N2 gas supply is arranged at four points along Dynamic Vacuum line.
b) Three vacuum pumps at three equal distances along 100 feet are suitable installed. Vacuum zone valves are directed in such a way that all pumps will pump approximately 33 m of 100feet Dynamic Vacuum line.
c) At starting, make all three pumps ON and we have to purge N2 gas at liquid line and vacuum line for 15 mins to remove humidity.
d) Stop purging N2 gas at vacuum line and pump vacuum for another 30 mins .
e) Stop N2 gas purging at liquid line and open Ln2 to make all line cold enough to close all micro holes along 100 feet Dynamic Vacuum line for five mins at pressure 70psi.
f) The liquid is very cold and closes all micro holes, the vacuum pumps gives very good performance as there is no humidity.
g) Now pump for another 1 hr 10 mins , vacuum with partial ln2 in liquid line and vacuum line with no humidity .
h) We can achieve vacuum at desired level of 50 to 60 mtorr in two to three hours. Now we can open a liquid line fully to give ln2 to handlers.

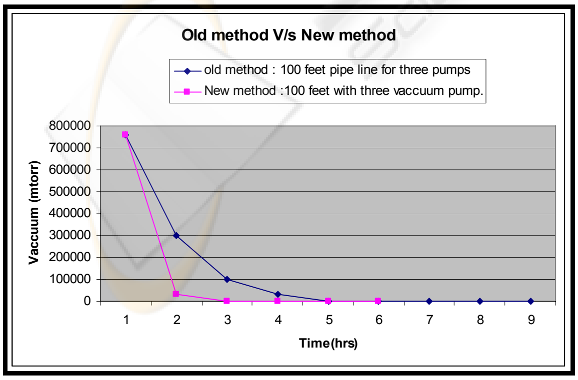

Figure 5: Recovery on Breakdown.

5 CONCLUSION

We can say that Dynamic vacuum pipeline system is the best choice if requirement of Ln2 is large at manufacturing. Secondly the user must install or invest sufficient money in customized development of safety systems. The vacuum and pressure control are the key elements .The two kinds of safety systems must be installed, analog and digital. Both systems give a lot of benefits in maintaining a Dynamic vacuum ln2 line 24 hours 7 days week ON without any accident. Analog system should be set at two levels of alarm system. The first alarm is precautionary alarm and the second alarm is for system shut down. Digital system must be equipped with good database design, customized user interface, real time system for monitoring the signals. The pressure at throughout Dynamic vacuum line should be maintained as low as possible. It should be controlled at main tank with tank mechanism. The pressure regulators are loss making devices so, should be avoided. The line should flexible enough so that there will not be total shutdown of system. In semiconductor industry recovery from system breakdown should be in minimum time so proper contingency plan and Dynamic Vacuum system must be installed accordingly.

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