A STUDY OF PARTIAL STROKE TEST FOR METSO NELES EMERGENCY SHUTDOWN VALVE

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By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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Assoc. Prof. Dr Nordin bin Saad
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Dalila

Dalila binti Mohamad Idris

ABSTRACT

Partial Stroke Test (PST) is designed to perform diagnosis by slightly closing a valve during plant operation. Thus, it can be a good complement to Full stroke Test (FST) since it does not require process to be down. This report essentially discusses the basic understanding and details of the project entitled "A Study of Partial Stroke Test for Metso Neles Emergency Shutdown (ESD) Valve". Since this project is a collaboration between Universiti Teknologi Petronas (UTP) and PETRONAS Improvement Working Group (IWG) of Skill Group 14 (SKG14), discussion session is conducted once in a few months to compare the latest update of valves performance from three vendors, namely, FISHER, METSO NELES, and MESONEILAN that may be used in PETRONAS plants if satisfies the required standard. The Phase I of the project which is to conduct PST (Dry Test) for 90 days has been completed. Furthermore, valve performance and monitoring it automatically on a continuous, real-time basis using Neles ValvGuard and FieldCare software is also discussed. In addition, the function of Programmable Logic Controller (PLC) YOKOGAWA together with WideField2 software while conducting FST is also taken into discussion. While for Phase II, enhanced method for testing the valves which is called Testing with Real Flow Medium is planned to be performed. In relation to this, a mini plant has been designed with the requirements to have real flow to the valves. Scope of study of this project is to explore and verify PST and FST technology with the purpose to ensure ESD valve performance. The Dry Test conducted in Phase I covers three parts: first, to test whether the ESD valves close 20% as it required during PST (Valve Test), secondly to test spool valve condition that control ESD valve opening or closing (Pneumatic Test), and lastly to test whether the FST be able to bypass PST when emergency occurs (PST collides with FST). The outcome for the Dry Test is positive where both the ball and butterfly valves show very good performance and never fail to function to requirement.

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LIST OF ABBREVIATIONS

ESD	Emergency Shutdown
PST	Partial Stroke Testing
FST	Full Stroke Test
PLC	Programmable Logic Controller
SIL	Safety Integrity Level
DCS	Distributed Control System
RCI	Remote Communication Interface
μC	Microcontroller
HART	Highway Addressable Remote Transducer
PC	Personal Computer
LED	Light Emitting Diodes
PR	Prestage
SV	Spool Valve
FDT	Field Device Tool
UTP	Universiti Teknologi Petronas
IWG	Improvement Working Group
SKG14	Skill Group 14
PFD	Probability of Failure on Demand
λD	Dangerous Failure Rate
TI	Testing Interval

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Processing plants contain many valves that perform safety functions which one of them is the emergency shutdown (ESD) valve. It is always hope that these valves need never be used in earnest. Such use means that something has gone wrong and, at least, one plant system has to be shut down, with its associated disruption of operations. However, if ESD valves are called into use, they have to work reliably, because the consequences of failure will be far more serious than the disruption, when they work.

ESD valve Partial Stroke Testing (PST) is a method whereby a portion of the valve assembly is tested at a more frequent interval than the full test rate. In simple words, it is an accelerated (partial) proof test. In this project, Metso Neles vendor has been chosen. Metso has developed a digital valve monitoring device called Neles ValvGuard. This allows the valve performance to be tested and monitored automatically on a continuous, real-time basis since the operator can reliably test valve performance on-line at anytime, without disturbing the process.

Depending upon specific process needs and the potential for danger, an on-line testing sequence can be defined from many times a day up to once a year. [1] During this project, the valves will be closed about 20% which tests a portion of the valve failure modes with 0.05 bar pressure used. Apart from that, Full Stroke Test (FST) will also be done together with PST once, in order to ensure that the ESD valve is able to automatically shut-off if by chances any emergency occurs during the execution of PST onwards.

1.2 Problem Statement

For the past thirty years, the turnarounds were done every two to three years. Due to mechanical reliability and preventive maintenance program, the turnarounds have been extended to every five to six years whereby increased the production. The performance of ESD valve usually is demonstrated by the Full Stroke Test (FST) which is done at turnaround since it requires the process to down.

Experience has shown that, if ESD valves are not exercised, they can stick in one position. In fact, the general perception is that sticking is the main failure mode of ESD valve. Sticking may be caused by several factors such as dirt or corrosion. Thus, movement of the valves can reduce dirt build-up and can give an indication if corrosion is present for example stroking time is longer than specified. However, it is only possible to fully test these valves at scheduled turnarounds. [2] Therefore, PST is the best solution to be implemented since it can be done without stopping the production.

Given the trend in the process industry to follow the requirements of IEC 61508 and 61511 to preserve safety integrity levels (SIL), these long intervals between tests are often too long to show an adequately low probability of failure on demand (PFD). [3] This means, that in order to test an ESD valve's functionality at a rate commensurate with the PFD requirements of the design SIL, alternative arrangements need to be implemented for online proof testing.

It is an economic advantage if ESD valve can be tested for its functionality without having to fully shut down the plant. Therefore, PST is a very suitable alternative to replace FST for ESD valves since it does not require process to be down. PST will provide a measure of confidence that a valve is not stuck in one position and it will do so at short intervals, if required. This has a preventive and corrective aspect. The valve movement can dislodge any dirt build-up to help prevent sticking. If the valve is already stuck, the test will detect it and corrective measures can be taken. The system can be brought to an orderly shutdown to perform repairs, or, if repairs can be completed quickly, the valve may be temporarily by-passed.

1.3 Objective

There are several objectives that have been listed to be achieved in this project which are as follow:

1. To design equipments setup for Dry Test (Phase I).
2. To conduct Dry Test for 90 days based on PETRONAS requirements.
3. To analyze performance of ESD valves based on result obtained in Phase I.
4. To design a mini plant with real flow medium through the ESD valve during PST (Phase II).
5. To validate and verify that PST secures ESD valves to respond to true demand and target SIL can be maintained.

1.4 Scope of Study

Scope of study of the project is to explore Partial Stroke Test (PST) and Full Stroke Test (FST) technology that will be used in the project to ensure ESD valve performance. Three vendors are involved which are Metso Neles, Fisher and Masoneilan. For each vendor, different software is used to conduct testing which as follow, FieldCare (Metso Neles), AMS Valvelink (Fisher), and Valvue ESD (Masoneilan).

In this project, two types of ESD valve which are ball and butterfly type from Metso Neles are tested and their performances are monitored to ensure the valves can operate without error. Furthermore, software that is used to execute the PST is FieldCare software and for FST, Programmable Logic Controller (PLC) from YOKOGAWA together with the WideField2software. There are two type of testing which are Pneumatic Test which measures pressure change through spool valve and Valve Test which physically moves the valve by desired stroke size. [4]

CHAPTER 2
LITERATURE REVIEW

2.1 Emergency Shutdown Valve

Emergency shutdown (ESD) valves means it operates at 0 and 100% which it remains either fully open or fully close depending upon the process requirement. It is an actuated valve installed in a pipeline that isolates a process unit from an upstream or downstream (gaseous or liquid) inventory upon activation of the process unit alarm and shutdown system.[5] In this project, two types of valve are used which are ball and butterfly valve.

2.1.1 Ball Valve

Ball valve is a valve that opens by turning a handle attached to a ball inside the valve (*refer Figure 1*). The ball has a hole, or port, through the middle so that when the port is in line with both ends of the valve, flow will occur. When the valve is closed, the hole is perpendicular to the ends of the valve, and flow is blocked. The handle or lever will be in line with the port position letting the observer sees the valve's position. The ball valve is a part of the family of quarter turn valves.

Ball valves are durable and usually work to achieve perfect shutoff even after years of disuse, thus an excellent choice for shutoff applications. Ball valves are used extensively in industry because they are very versatile, pressures up to 10,000 psi, temperatures up to 200 Deg C. They are easy to repair, operate manually or by actuators. The body of ball valves may be made of metal, plastic or metal with a ceramic center. [6]

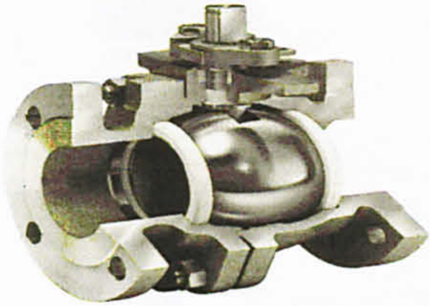


Figure 1: Ball Valve

2.1.2 Butterfly Valve

A butterfly valve is a type of flow control device, typically used to regulate a fluid flowing through a section of pipe. A plate or disc is positioned in the center of the pipe (*refer Figure 2*). The disc has a rod through it connected to an actuator on the outside of the valve. Rotating the actuator turns the disc either parallel or perpendicular to the flow. Unlike a ball valve, the disc is always present within the flow, therefore a pressure drop is always induced in the flow, regardless of valve position.

A butterfly valve is from a family of valves called quarter-turn valves. The butterfly is a metal disc mounted on a rod. When the valve is closed, the disc is turned so that it completely blocks off the passageway. When the valve is fully open, the disc is rotated a quarter turn so that it allows an almost unrestricted passage of the fluid. [7]

Figure 2: Butterfly Valve

2.2 Partial Stroke Test

The definition of Partial Stroke Testing (PST) is to close a valve partially, and after a few seconds, will return it to the initial position. Even the impact of the valve movement on process flow is negligible since it is so small but the movement is still sufficient to reveal several types of dangerous failure. PST is introduced to detect failures without disturbing the process, that otherwise require functional tests. [8]

PST can be used to replace Full Stroke Test (FST) as an alternative to reduce the FST interval required to achieve Safety Integrity Level (SIL). In order to implement PST, FieldCare Software is used which is developed by Metso Neles. Other than that, the Neles ValvGuard system also plays an important role where it automatically tests the valves based on programmed testing interval. The interval for the test stroke can vary from every minute up to once a year or more. In this project, for every testing period, six stroke tests will be done for each valve with 15 minutes interval for each stroke.

2.2.1 Safety Integrity Level (SIL)

Safety Integrity Level (SIL) is defined as a relative level of risk-reduction provided by a safety function, or to specify a target level of risk reduction. Four SILs are defined, with SIL4 being the most dependable and SIL1 being the least. Partial Stroke Test (PST) is one of the most effective techniques for enabling a single valve to achieve safety integrity level (SIL) 2 performance or possibly even SIL 3. The statistical measure of availability in an emergency is called the Probability of Failure on Demand (PFD).

PST improves the ESD valve performance, as measured by the Probability of Failure on Demand (PFD). The amount of the reduction is dependent on the valve and its application environment. The probability to fail on demand (PFD) can be calculated using the dangerous failure rate (λD) and the testing interval (TI).

The mathematical relationship, assuming that systematic failures are minimized through design practice, is as follows:

$$PFD = \lambda D * TI/2$$

The equation shows that the relationship between PFD and TI is linear. The longer testing interval (TI) yields larger PFD [9]. PFD calculations consist of two parts: on-line testing and off-line testing. When dealing with safety valves, the on-line diagnostics part relates to PST and the off-line part to periodic maintenance. With frequent on-line testing, better diagnostic coverage, shorter mean times for repair and good communication methods, it is possible to achieve lower PFD which is preferable.

2.2.2 Neles ValvGuard System

Neles ValvGuard will control the Emergency Shutdown (ESD) valve testing automatically. Whereas traditional systems require testing while the process is completely shutdown, but with Neles Valve guard the valve performance is tested and monitor automatically on continuous, real time basis, without disturbing the process. Furthermore, a clear signal will be given to control room showing the valve status (OK, testing, alarm). Based on information data, plant production can be optimized and predictive maintenance plans can be made if needed.

Neles ValvGuard system is able to check the condition of the whole valve package by partial stroke test conducted whilst the plant is running. In addition, ValvGuard performs a separate pneumatic test which verifies all components and the system integrity up to a change of air pressure in the actuator. Malfunctions and alerts are transmitted in real time to the Distributed Control System (DCS). Automated valve testing done by the ValvGuard system adds value by both lowering maintenance costs and increasing safety.

Neles ValvGuard comprises two components which are Remote Communication Interface (RCI) and ValvGuard (VG). In this project, VG800 is installed at butterfly valve while VG9000 is installed at ball valve. RCI is usually installed close to the control room and VG800/VG9000 is mounted on the field located at ESD valve actuator. The general arrangement is shown in Figure 3.

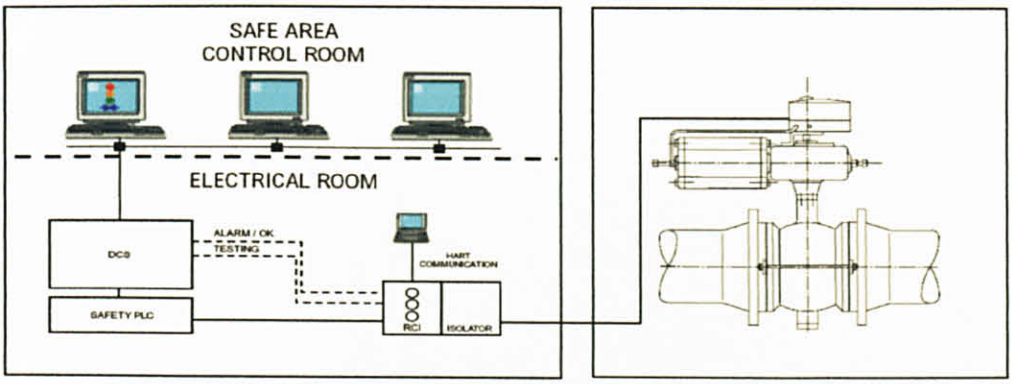


Figure 3: Neles ValvGuard System

Neles ValvGuard operates at two independent levels which are safety level and diagnostic level. For safety level, there is safety circuit, where the 0/24 Vdc output signal from plant safety-PLC is connected to the RCI within the cross connection control cabinet. The RCI output is wired through an isolator to the VG800 in the field using standard cabling. Within the VG800, a spool valve controls the air supply to the valve actuator. The spool valve is energized by the 24 Vdc which will open the ESD valve and is de-energized at 0 V which will close the ESD valve (*refer figure 8*).

While for diagnostic level, programming and data collection functions are controlled by the micro controller (μC). The μC takes its power from the normal state 24 Vdc supply. In the 0 V condition, the μC is inactive. μC functionality is configured remotely by a software package called Valve Manager. Certain functions can also be controlled locally by use of push buttons mounted within the VG800/VG9000 casing (*see Figure 4 and 5*). It is necessary to remove the cover of the VG800/VG9000 to do this.

2.2.2.1 ValvGuard VG800/VG9000

VG9000 (*refer Figure 5*) has the same function as VG800 (*refer Figure 4*) such as can conduct pneumatic and valve test but VG9000 has extensive safety valve testing capabilities and improved diagnostics data, hence, more data can be gathered. For VG9000 it has extra function such as it can conduct emergency trip test and the pneumatic test is also done differently where the spool valve will be de-energize and energize back in fast manner for sometime while for VG800 it only be done once. Another extra function that VG9000 has is that the device is powered during the trip and can collect diagnostics information and the speed and temperature of the valve is also known.

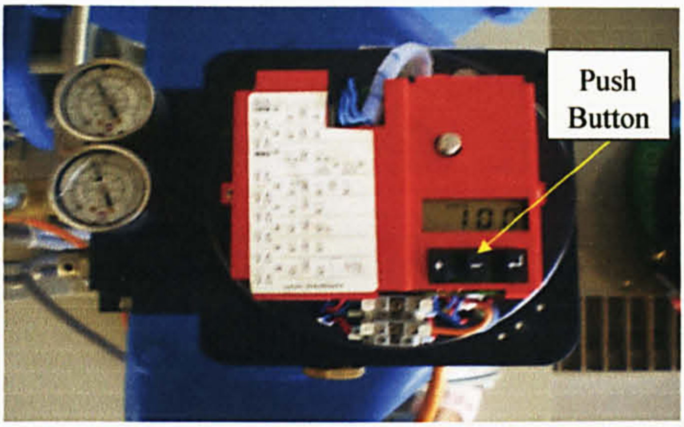


Figure 4: VG800

Figure 5: VG9000

2.2.2.2 Remote Communication Interface (RCI)

Remote communication from the control room with the VG800 is made via Highway Addressable Remote Transducer (HART) protocol and a Personal Computer (PC) fitted with a suitable modem wired to the Remote Communication Interface (RCI). There is a second real-time communication system which enables the μC to send messages to RCI and further on to the plant DCS system. The RCI *(refer Figure 6)* is mounted in the control cabinet of plant safety PLC and connected to its output. Nominal safety PLC output is 24 V but a 15 % variance on this is acceptable.

RCI has three functions, which are to transmit HART signals to and from the VG800/VG9000 field device and also filter the noise along the transmission (*refer Figure 7*). A suitable modem is connected between the PC and the RCI to facilitate this. Thirdly, the RCI function is to receive real-time signals from the VG800/VG9000 field unit. These signals are displayed on three Light Emitting Diodes (LED) mounted on the RCI casing. The RCI also has relay potential free contact outputs which correspond with the LED display. Three signals are given which Green indicates OK, Yellow indicates Test and Red indicates Alarm. (*Refer to Figure 6*).

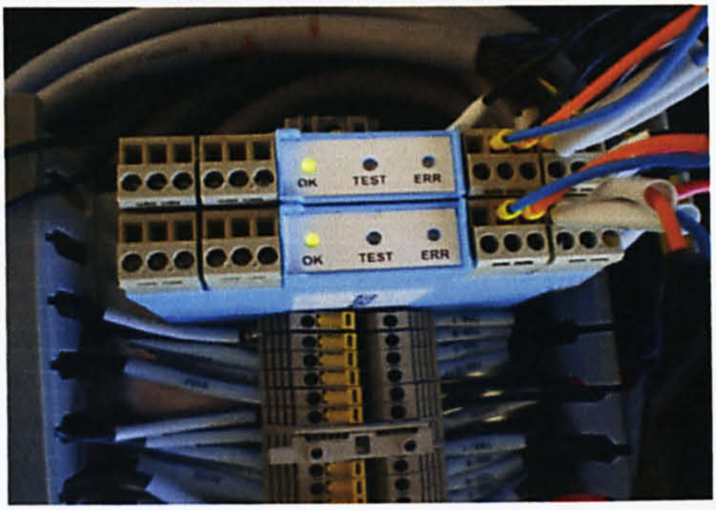


Figure 6: Remote Communication Interface (RCI)

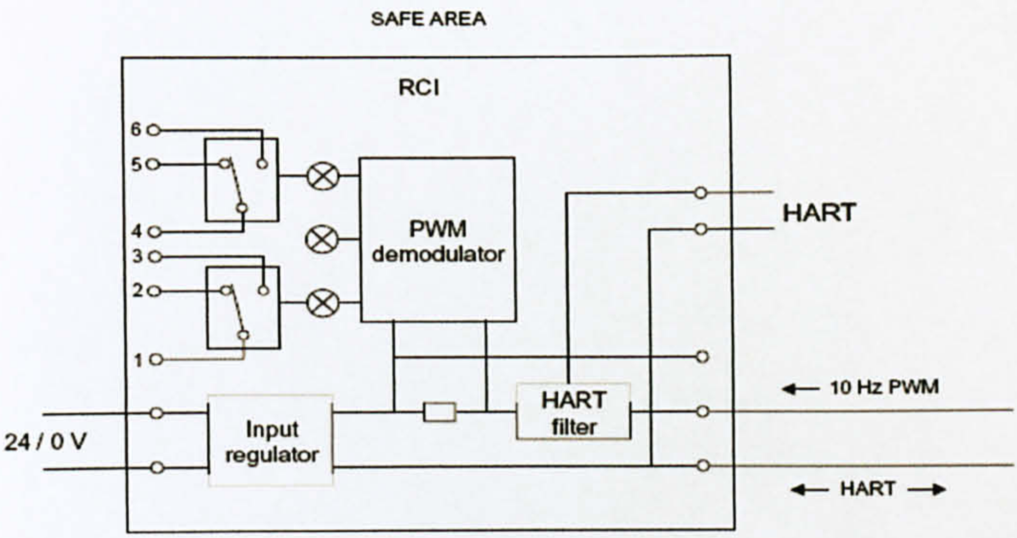


Figure 7: RCI Circuit Diagram

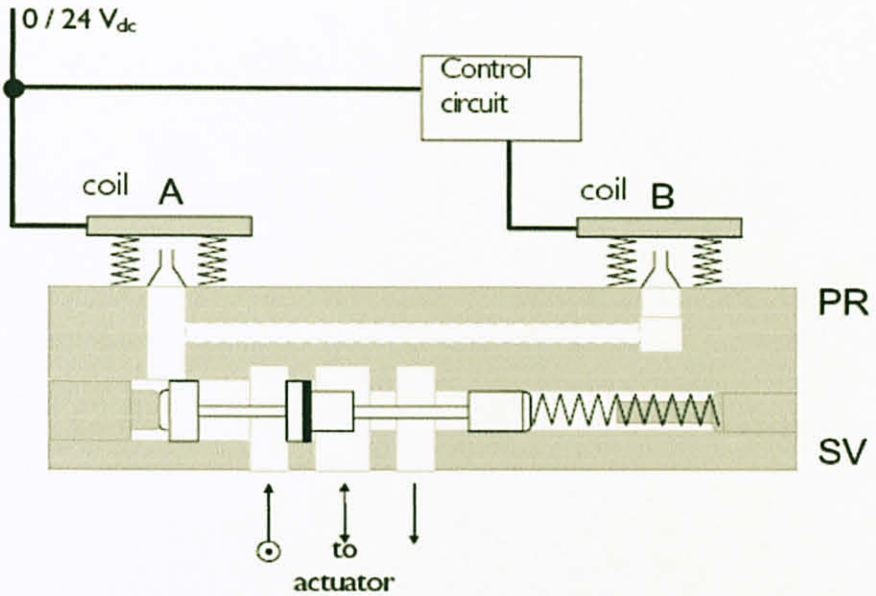


Figure 8: Prestage (PR) and Spool Valve

During service period the 24 Vdc supply powers the prestage (PR) redundant coils, A and B (*refer to Figure 8*) which control the air pressure on the spool valve (SV) in such a position that keeps the SV return spring compressed. The SV is arranged so that the actuator air supply is maintained on the actuator piston in opposition to the actuator return spring thereby keeping the ESD valve open.

When an emergency occurs, the power at the control room is switched to 0 v, this de-energizes both PR coils and vents the pressure on the SV causing the SV return spring to change the SV position to shut off the air supply and to vent the air above the actuator piston. The actuator spring then closes the ESD valve. When power is restored the PR coils are energized back and air pressure once more causes the SV to compress the SV return spring. Air supply pressure is again applied to the actuator piston which opens the ESD valve. [10]

2.2.3 *FieldCare Software*

FieldCare is a scalable field management tool for the configuration, diagnostics and condition monitoring of intelligent field devices. It is used for configuration and condition monitoring of VG800/VG9000 (*refer Figure 9*). Data collected during testing is automatically posted to a database, which can be accessed by authorized personnel. It is used to interrogate, configure and collect data when connected to VG800/VG9000. It provides real-time information under operational process conditions, and its ability to browse and store data makes prediction of device condition extremely accurate.

The information it provides supports predictive maintenance and can be used to plan regular maintenance activities, ensuring sufficient time to order spare parts and plan for service operations. It is universal Field Device Tool (FDT)-based software. FDT is an open software specification supported by major instrument and control system suppliers. It consists of an FDT frame application and Device Type Managers (DTM). It is independent of communication protocol. A DTM is a user interface for device operation that is developed by the vendor and can be used in any frame application. [11]

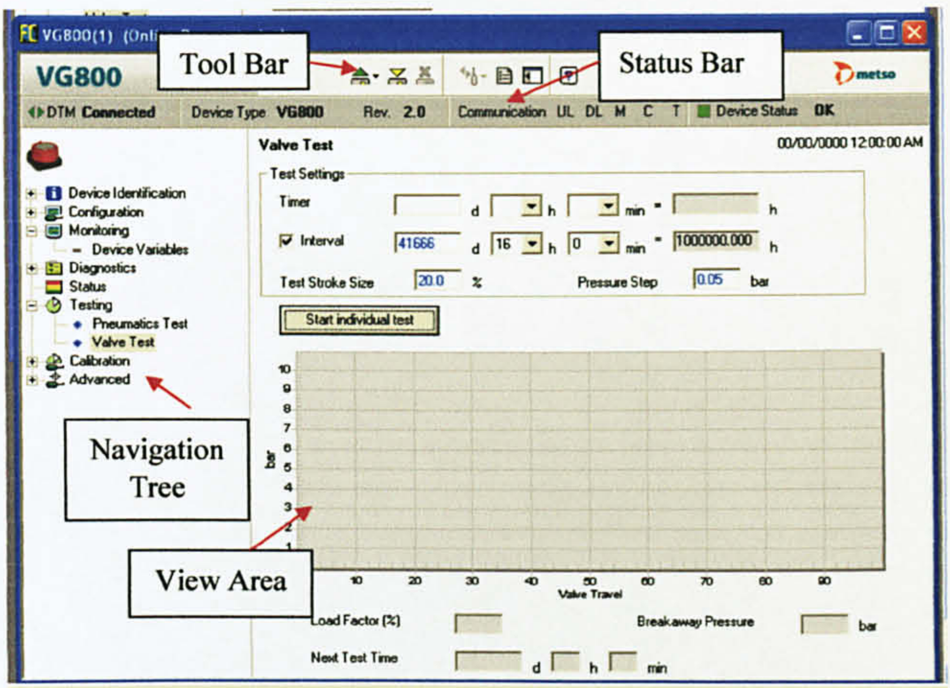


Figure 9: FieldCare software interface

2.3 Full Stroke Test

Full Stroke means whenever emergency happens, the valve will be forced to fully close. In order to control the Full Stroke Test, Programmable Logic Control (PLC) is used in the project together with the WideField2 Software (YOKOGAWA).

2.3.1 Programmable Logic Controller (PLC)

Programmable Logic Controller (PLC) is a digital operated electronics system, designed for industrial environment to implement specific functions such as logic, sequencing, timing, counting and arithmetic to control the outputs. The function of PLC is to continual scanning of a program which means running through all conditions within a guaranteed period. In this project, PLC is used is used for start-up and to control the Full Stroke Test (FST) execution which it is used to force the valve to fully open or close.

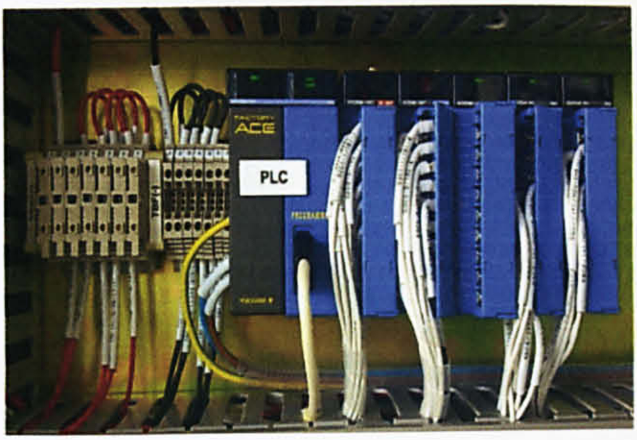


Figure 10: Programmable Logic Controller

For this Full Stroke Test, ladder diagram which is primarily used to develop software for PLC used in industrial control applications is taken into concern (*refer to Figure 11*). It is a programming language that represents a program by a graphical diagram based on the circuit diagrams of relay-based logic hardware is used to develop software for the PLC. The ladder diagram of PLC is developed by using WideField2 software.

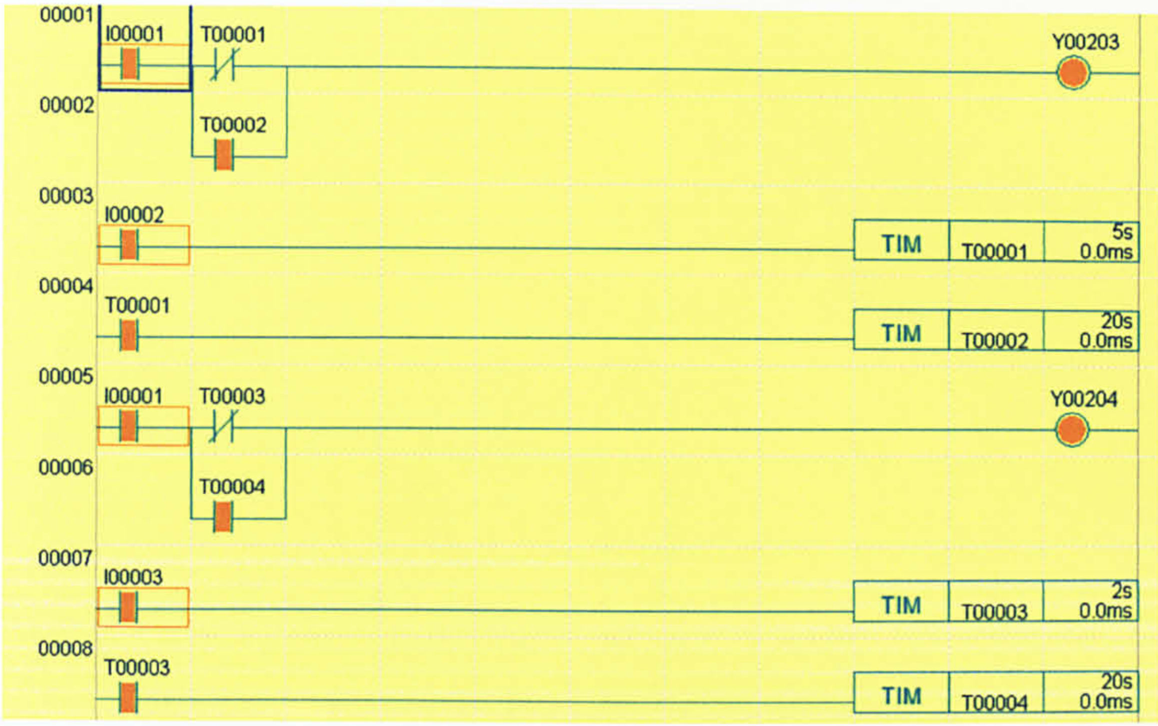


Figure 11: Ladder Diagram for Programmable Logic Controller

Ladder diagram can be thought of as a rule-based language, rather than a procedural language. A rung in the ladder represents a rule. When implemented in a PLC, the rules are typically executed sequentially by software, in a continuous loop (scan). By executing the loop fast enough, typically many times per second, the effect of simultaneous and immediate execution is relatively achieved to within the tolerance of the time required to execute every rung in the loop (the scan time). [12]

When Full Stroke Test (FST) is executed for ball valve, I00002 will send signal to Y00203 (ball valve) to respond to be fully close after 5seconds. There are timers involved which are T00001 and T00002. After 20 seconds, then the ball valve received another signal that gives command to it to respond to be fully open back.

On the other hand, for butterfly valve Full Stroke Test, I00003 will send the signal to Y00204 (butterfly valve) to respond to be fully closed after 2 seconds. Timers involved are T00003 and T00004 which are used to set the Y00204 to be fully close or open. After 20 seconds, the valve will receive another signal that asks it to fully open back. The orange colour indicates that there is connection between them.

Table 1: Ladder Diagram Description for Ball Valve

	DEVICE	NAME	DESCRIPTION
Ball Valve	Output relay, Y	Y00203	Represent Ball valve
	Internal relay, I	I00001	Used as a start-up signal for the both valves Forced Set I00001 in order to move both valves from fully closed to fully opened. PST can only be done when valve is in fully opened condition.
		I00002	Used to send FST signal for ball valve Forced Set I00002 to conduct FST on ball valve (valve will move to fully closed)
	Timer, T	T00001	After I00002 is forced set, T00001 will be triggered. Timer will be activated for 5 seconds before FST signal is sent to ball valve. Ball valve will be closed fully.
		T00002	T00001 signal will forced set T00002. Timer will be activated for 20 seconds before sending a signal for ball valve to move back to its initial position from fully closed to fully opened.

Table 2: Ladder Diagram Description for Butterfly Valve

	DEVICE	NAME	DESCRIPTION
Butterfly Valve	Output relay, Y	Y00204	Represent Butterfly valve
	Internal relay, I	I00001	Used as a start-up signal for the both valves Forced Set I00001 in order to move both valves from fully closed to fully opened. PST can only be done when valve is in fully opened condition.
		I00003	Used to send FST signal for butterfly valve Forced Set I00003 to conduct FST on butterfly valve (valve will move to fully closed)
	Timer, T	T00003	After I00003 is forced set, T00003 will be triggered. Timer will be activated for 2 seconds before FST signal is sent to butterfly valve. Butterfly valve will be closed fully.
		T00004	T00003 signal will forced set T00004. Timer will be activated for 20 seconds before sending a signal for butterfly valve to move back to its initial position from fully closed to fully opened.

2.3.2 WideField2 Software

WideField2 introduces new functions like program modularization, local devices, component macros and structures for defining structures of devices, to realize further modularization of programs and device structures. By using the software, PLC program which is known as ladder diagram is run during the testing period to fully open the ESD valves at the beginning of the testing and to conduct the FST.

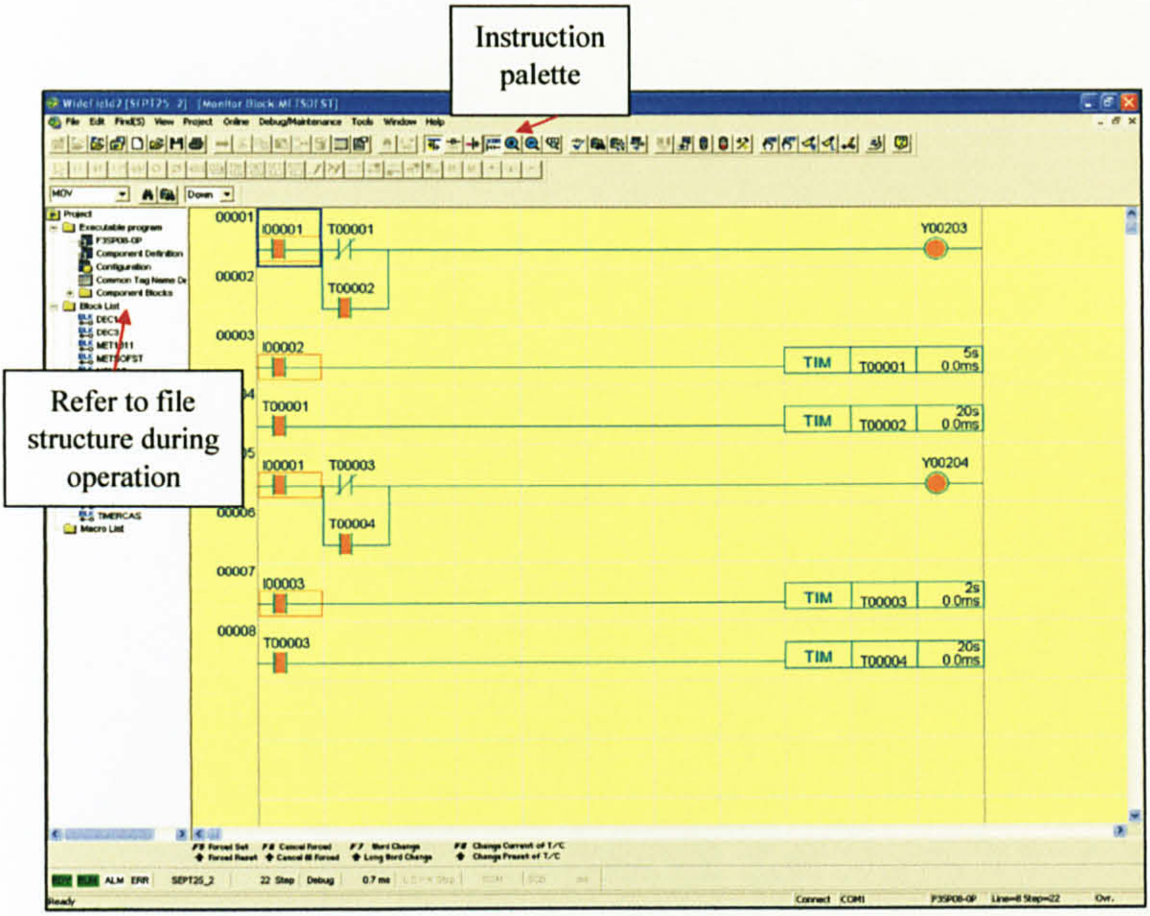


Figure 12: WideField2 Software (Programmable Logic Controller)

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

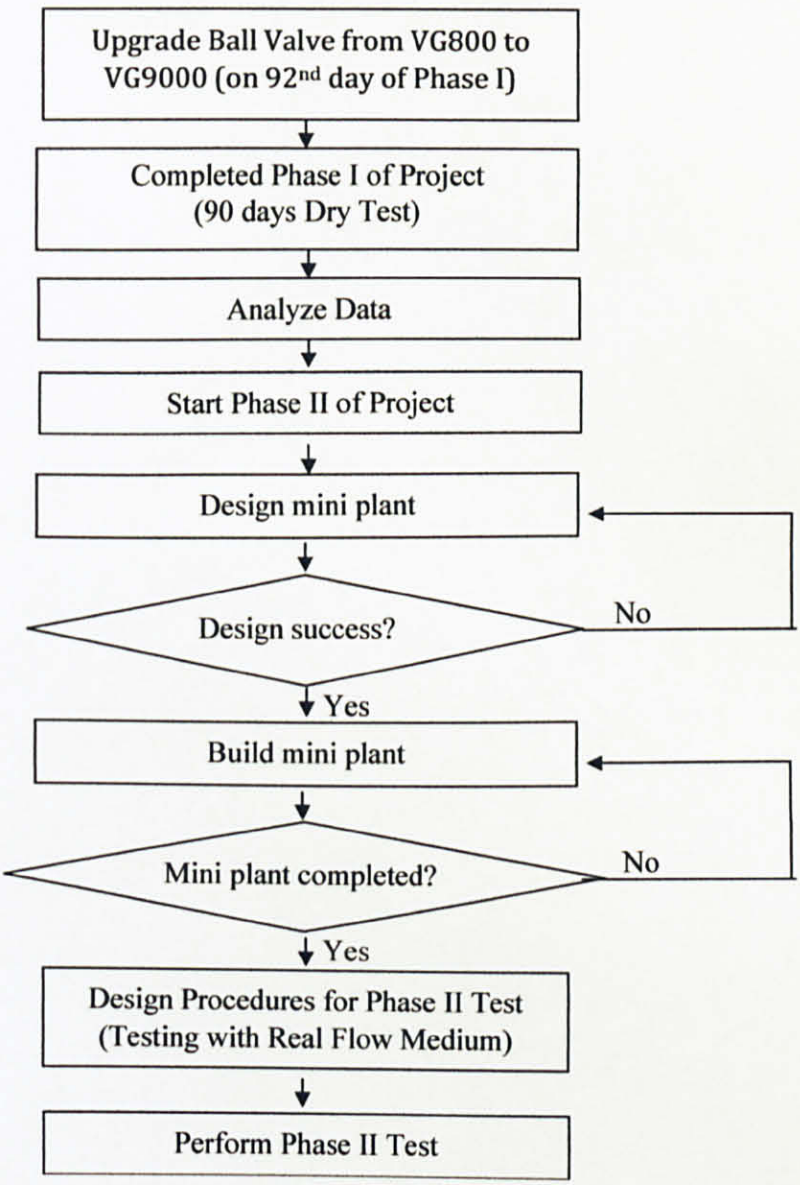


Figure 13: Project Flow Diagram

The project flow diagram (*refer Figure 13*) explains the project flow undertaken and plan to be undertaken throughout two semesters. Phase I of the project has been completed at the beginning of the semester. At this moment, the project has entered the second stage which is called Phase II and at this stage, mini plant is planned to be built. The draft of the mini plant has been made and has been brought into discussion with PETRONAS. While sketching the mini plant design, the safety matter and the cost involved were being considered.

3.2 Tools and Equipments

Several tools and software are required in order to implement this project which as follow:

- Emergency Shutdown Valves
  - There are two types of valve which are ball and butterfly from Metso Neles. Specifications of the valves are tabulated in *Table 3 and 4*.

Figure 14: Ball and Butterfly Valve from Metso Neles

Table 3: Ball Valve Specification

Positioner Information			
Device Type	VG800/9000	**Manufacturer**	Metso Automation
Device ID	1410103	**SW Revision**	2
HW Revision	1	**Final Assembly Number**	0
Device Serial Number	2008-02-9300	**Position Sensor Serial Number**	834550
Assembly Related			
Valve Acting Type	Rotary		
Rotation Direction to Fail Safe	Clockwise		
Fail Safe Action	Close		

Table 4: Butterfly Valve Specification

Positioner Information			
Device Type	VG800	**Manufacturer**	Metso Automation
Device ID	1410066	**SW Revision**	2
HW Revision	1	**Final Assembly Number**	0
Device Serial Number	2007-50-9201	**Position Sensor Serial Number**	834561
Assembly Related			
Valve Acting Type	Rotary		
Rotation Direction to Fail Safe	Clockwise		
Fail Safe Action	Close		

- Programmable Logic Control
  - It is used to control the Full Stroke Test, scanning of a program which means running through all conditions within a guaranteed period.

Table 5: Programmable Logic Controller Specification

Company	YOKOGAWA (made in Japan)
Model	F3SP08
SUFFIX	-OP
STYLE	S1
REV	15:02
SUPPLY	-
I/P	100 -240 V_{AC}
O/P	-
DATE	2007/07/04
NO	F7G041069

- VG800/VG9000
  - Enables programmable functions and communication between the control room and the ESD valve in the field

- WideField2 Software
  - It is develop by vendor YOKOGAWA for simulate Full Stroke Testing.

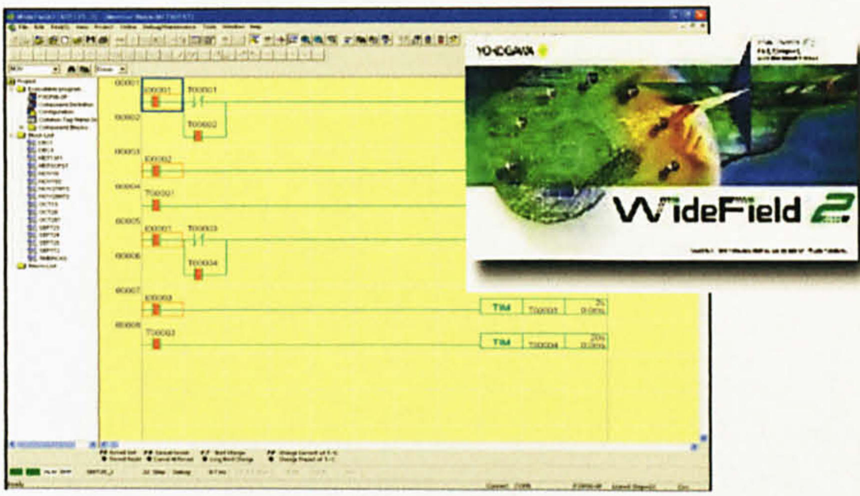


Figure 15: WideField2 Software

- HART Server
  - Allow the ESD valves to communicate with the PST Software.

- FieldCare Software
  - It is develop by vendor Metso Neles to perform Partial Stroke Test and collect diagnostics information.

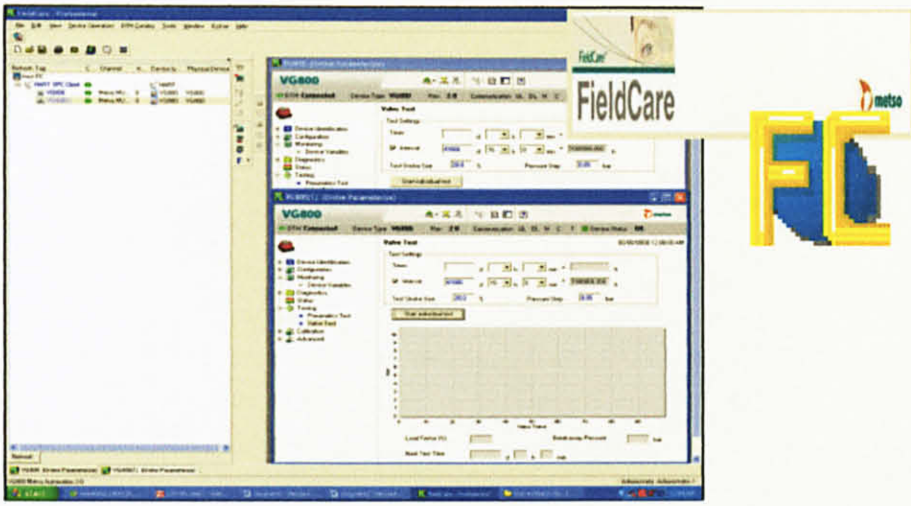


Figure 16: FieldCare Software

3.3 Phase I Testing Procedures

Testing procedures briefly explained in *Figure 17* were used during Phase I (Dry Test). The detailed testing procedures are attached in *Appendix D.* The testing is done every day and it takes approximately about one hour and a half since six strokes are executed for both valves and one stroke takes about 15 minutes. Before the test is started, first, an Excel file is open and the testing time is planned with 15 minutes intervals for each stroke. In the same Excel file, load factor and breakdown pressure is also recorded. The testing procedures for Phase II (Testing with Real Flow) are still in progress and will only be completed after the mini plant is successfully built.

For Phase I, three softwares must be set up which are WideField2, HART server and FieldCare software. FieldCare is used to conduct PST where VG9000 is means for ball valve and VG800 is for butterfly valve while for conducting FST, WideField2 is used. Briefly, the steps involved during the Phase I (Dry Test) are as follow:

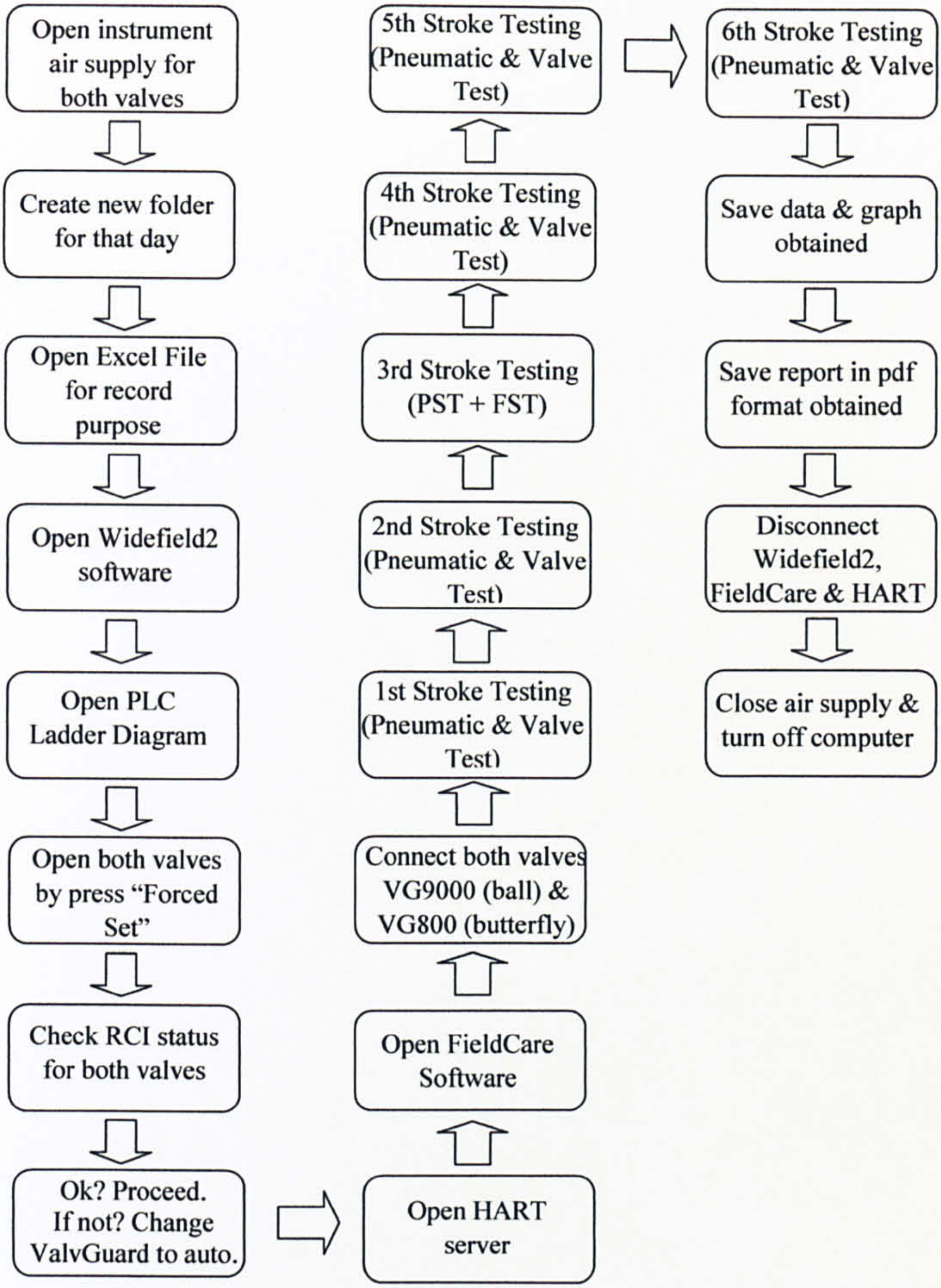


Figure 17: Phase I Testing Procedures

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Overview of Phase I Testing Criterion

Phase I of the project (Dry Test) has been completed at the beginning of the semester which is total of 104 of testing day with different conditions but has covered 90 days of testing that follow requirements given by PETRONAS which are 0.05 Bar pressure step and stroke size 20% closing. The testing condition involved is as follow:

Table 6: Testing Days with different conditions

Testing condition (Pressure step, Stroke size)	Days
0.05 Bar, 20% closing	**90**
0.05 Bar, 30% closing	4
0.005 Bar, 20% closing	10

For every testing day, six strokes of each valve are conducted in the interval of 15 minutes for every stroke. At every third stroke, FST will be performed to overwrite PST while for the remaining five strokes, PST is conducted solely. On 92nd day (75th day of testing based on PETRONAS requirement) , ball valve has been upgraded to VG9000 which yields different pattern of graphs compared to butterfly valve which is still continued using VG800.

There are several testing criteria that are taken into discussion. For the pneumatic test, only one graph is obtained named pneumatic test graph which shows the pressure drops and recover back. During pneumatic test for butterfly valve (VG800), the spool valve is de energized and energized back only one time but for ball valve (VG9000) it is done a few times which takes several minutes.

While performing partial stroke test for butterfly valve (VG800), three graphs are obtained that are valve signature, load factor and breakaway pressure graph while for ball valve (VG9000), five graphs are obtained which are two graphs for valve signature, load factor, breakaway pressure, and emergency trip test graph. For load factor and breakaway pressure, there are historical value captured in the graph which means it shows value from the latest result of testing to the previous time of result testing.

In this report, one set of test result for each valve are taken into discussion since the trends are the same. The samples of graphs are taken from 104^{th} testing day which equivalent to 90^{th} day for test that follow PETRONAS requirement (last day). The rest of the Phase I results are recorded in *Appendix C* with scale one sample for ten days hence for 90 days, nine set of test results are presented. Since both valves show a consistent trend of reliable results, therefore they show a good performance as emergency shutdown valve.

4.2 Pneumatic Test

Pneumatic test is done to test the spool valve condition inside VG800/VG9000. The spool valve acts like a limit switch which it control the opening and closing of valve since it controls the instrument air supply into the valve diaphragm. During the test, pressure is released from the actuator diaphragm by de-energizing the spool valve for a few seconds.

When the spool valve is been de-energized, the pressure will drop but not exceed the breakaway pressure to avoid valve from moving, and then it will be sensed by a pressure sensor located inside the VG800/VG9000 and an action will be taken to compensate the pressure drop which is by energizing it back in fast manner, then the pressure drop will recover. For VG800, it is done only once but for VG9000, it is done for several times (*refer figure 18 and 19*).

The time taken for the pressure drop to recover back is the main part during the test where the faster the time taken the better the performance of the spool valve because it shows that the spool valve is reliable since it can respond to any changes of pressure in fast response. Pneumatic test is done at every stroke before conducting valve tests due to safety purpose. Therefore for every testing, six pneumatic test graphs of are obtained for each valve type.

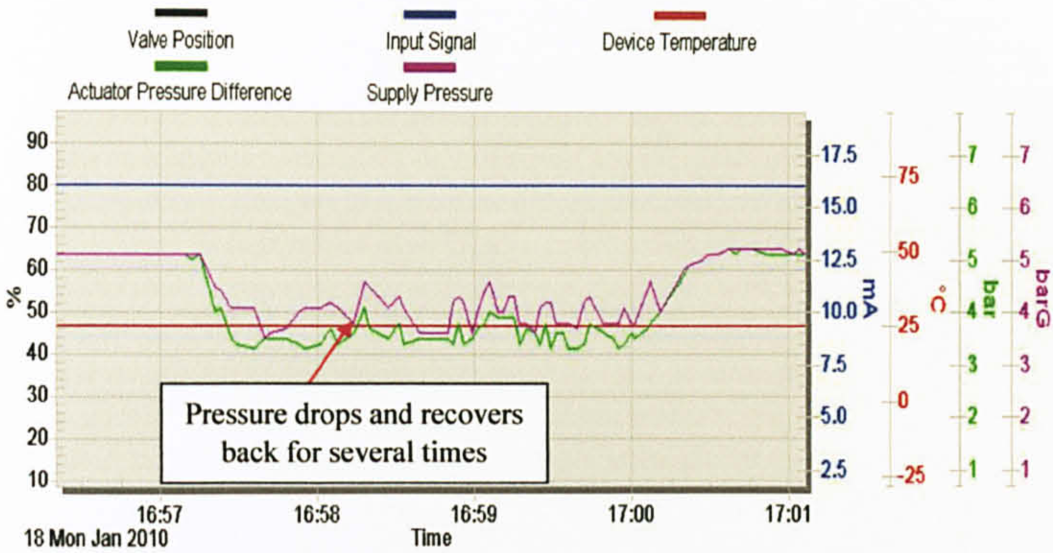


Figure 18: Pneumatic Test for Ball Valve

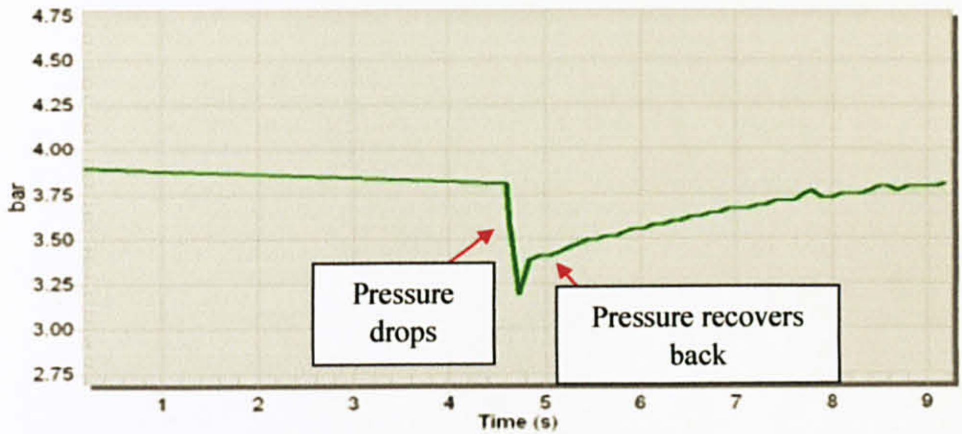


Figure 19: Pneumatic Test for Butterfly Valve

The graphs (*refer figure 18 and 19*) show that the spool valve for ball and butterfly valve are in good condition since the pressure will drop but not beyond the breakaway pressure when we de-energized the spool valve and when we energize back the spool valve then the pressure recovers back in fast response. Therefore, if any changes happen, the spool valve will take action to compensate the changes in fast manner that is very important to prevent danger when emergency occurs.

4.3 Valve Test (Partial Stroke Test)

Valve Test is referring to the Partial Stroke Test (PST) which is done six times for both valves, ball and butterfly type. The valve test is set to have 20% valve stroking with 0.05 bar pressure. Before the test is executed, the valve must be ensured to be at fully open condition because during the test, both valves will be stroked 20% which means 80% opening remains. However, during third stroke test for both valves, Full Stroke Test will be executed to overwrite the PST.

During valve test, for ball valve (VG9000) two valve signature graphs are obtained which is pressure difference versus position and position versus time while for butterfly valve only one valve signature is obtained which is pressure difference versus position (*refer to figure 20, 21 and 22*). From the graph, the testing criteria such as breakaway pressure and load factor can be observed.

The samples of graphs for ball and butterfly valve are attached below where the testing criteria are labeled. The value of breakaway pressure and load factor can be known by analyzing the valve signature. The samples of valve signature show that both valve have good performance since it can stroke 20% closing and then return back to the initial condition (fully open).

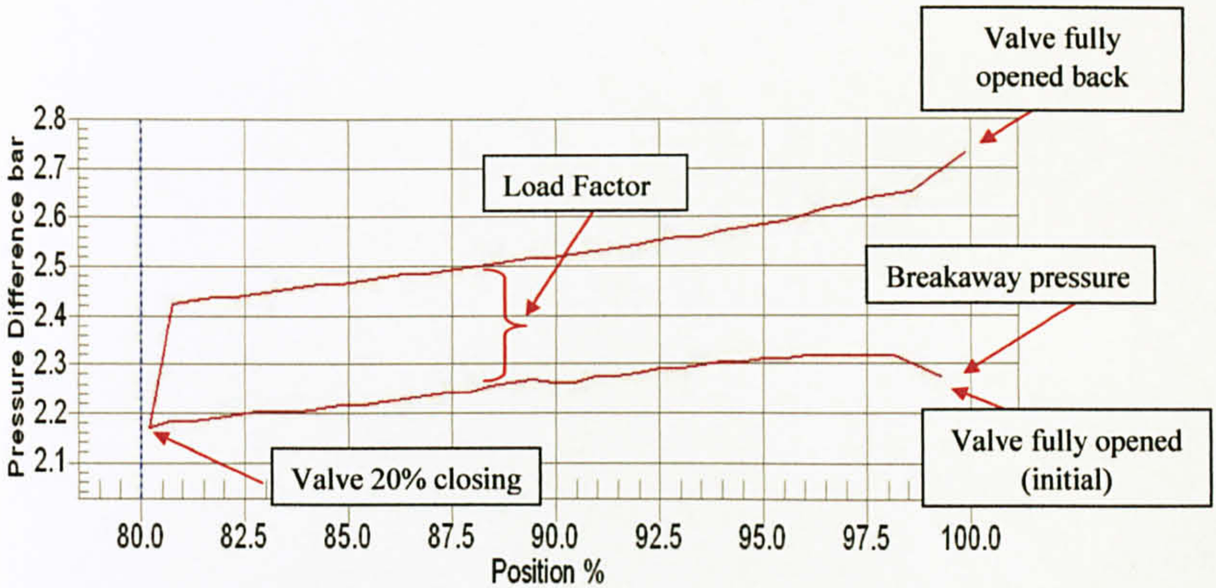


Figure 20: Valve Signature for Ball Valve (Pressure Difference versus Position)

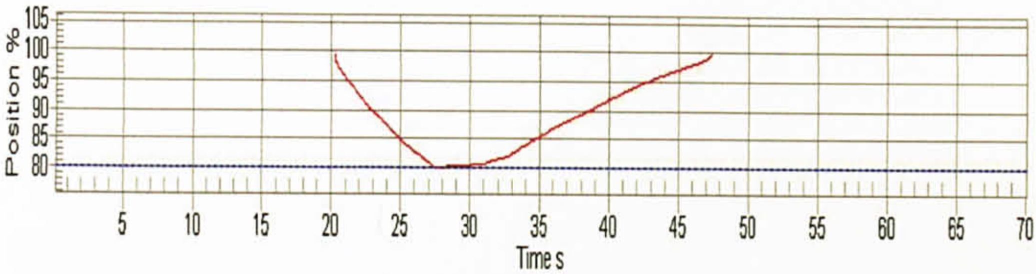


Figure 21: Valve Signature for Ball Valve (Position versus Time)

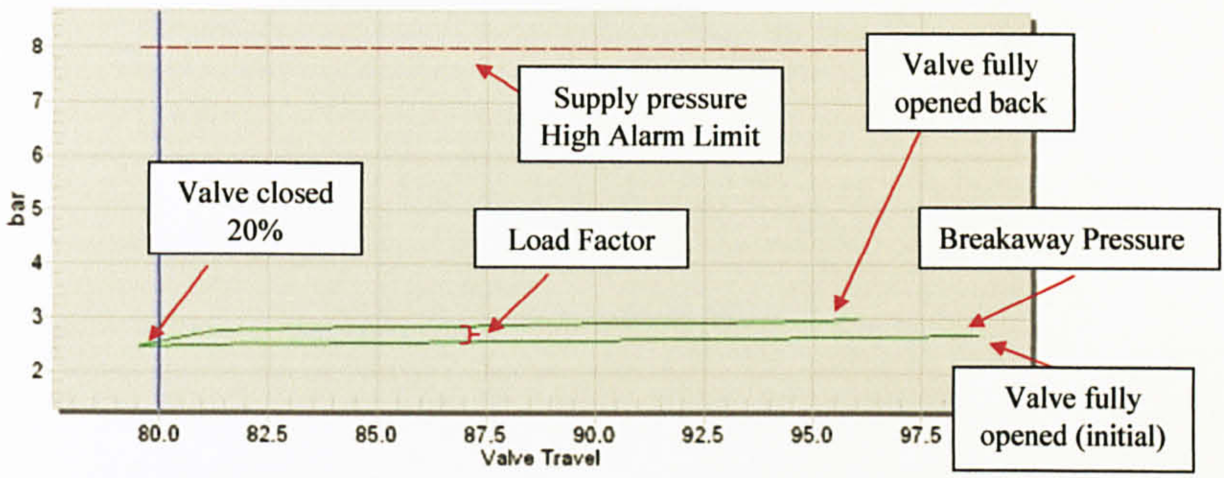


Figure 22: Valve Signature for Butterfly Valve

During this test, "Valve Signature" plot will be analyzed. This plot shows the integrity of the valve body and actuator assemblies. "Y" axis represents the input which is actuator pressure while "X" axis represent the output which is valve travel or valve position (%). By plotting the data in this fashion, any increase or decrease in force can be observed by a vertical change on the graph.

At the beginning, the pressure is lower because both ESD valves are air to open valve (fail-close type). It requires air in order to move the valve to open position. Since the valves are fail-close type, therefore when the partial stroke test starts, a few amount of pressure supply will be released and thus the actuator pressure will drop and reach breakaway pressure which is represented by the bottom green line. After it reaches breakaway pressure, then only the valve will start moving from fully open to 20% closing, then the pressure will increase back and the valve will move to its initial condition which is fully open.

4.4 Full Stroke Test

At every third stroke, Full Stroke Test (FST) will be executed to overwrite PST which means PST collides with FST. At first, the valve received signal from FieldCare software to do PST. Then, when the valve starts to close 20%, another signal is sent from Programmable Logic Controller (PLC) that gives command to valve to be fully closed to mock the situation that an emergency has occurred and the valve need to be fully closed to prevent danger. Based on observation, the valve will bypass the instruction given by FieldCare software and it follows PLC instruction to perform FST which means the valve will be fully closed.

In real life, that situation represents condition which, if during the time the PST is conducted then suddenly an emergency occurs, the ValvGuard will bypass the PST procedure and perform safety function which is move the valve to be fully closed immediately to prevent danger or any loss or damage to plant. The figures (*refer Figure 23, 24, 25*) show the errors by the FieldCare Software indicating that PST is failed and FST is done for Ball and Butterfly Valve respectively. The Full Stroke Test results are as follow:

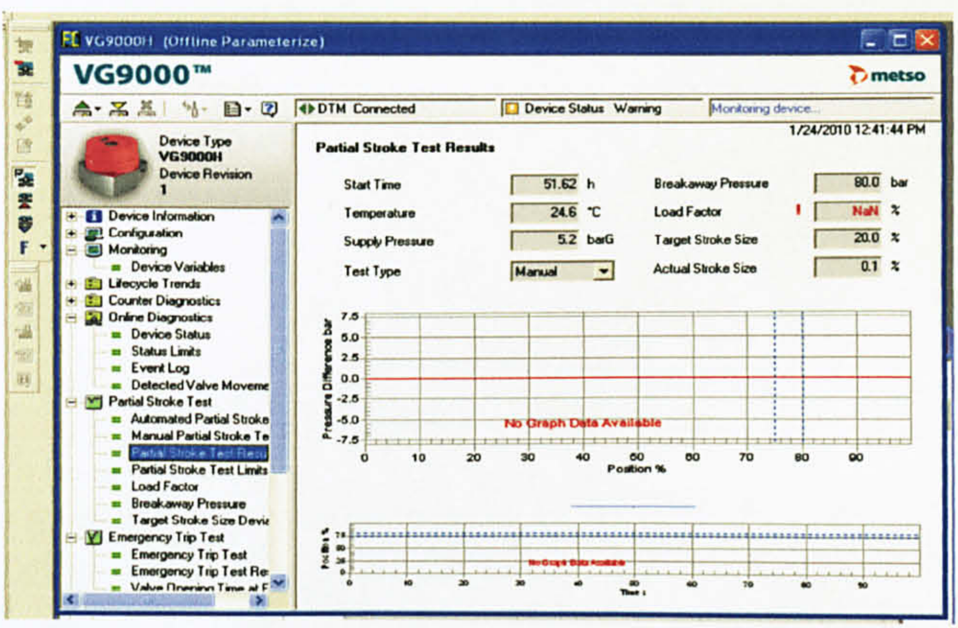


Figure 23: No graph is obtained since PST is interrupted for Ball valve

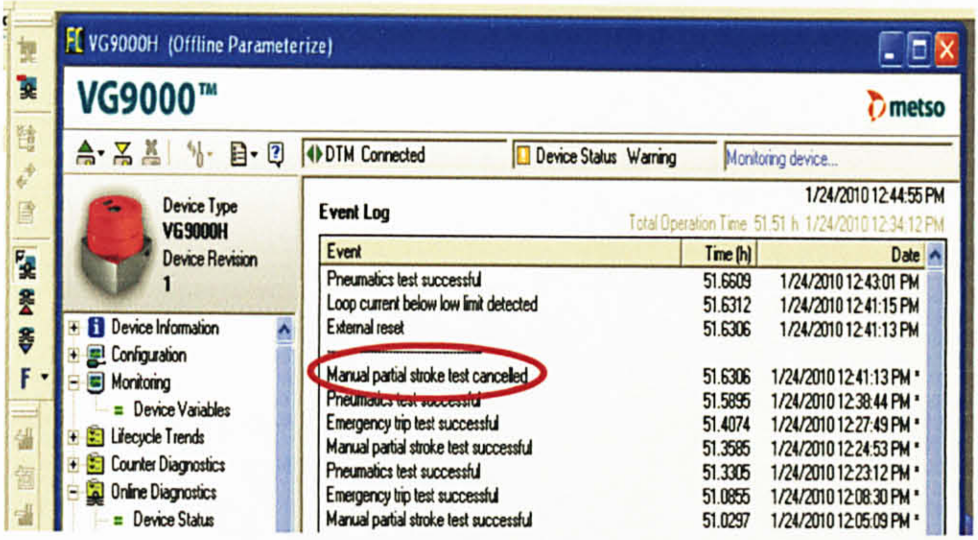


Figure 24: PST is cancelled for Ball Valve from Event Log

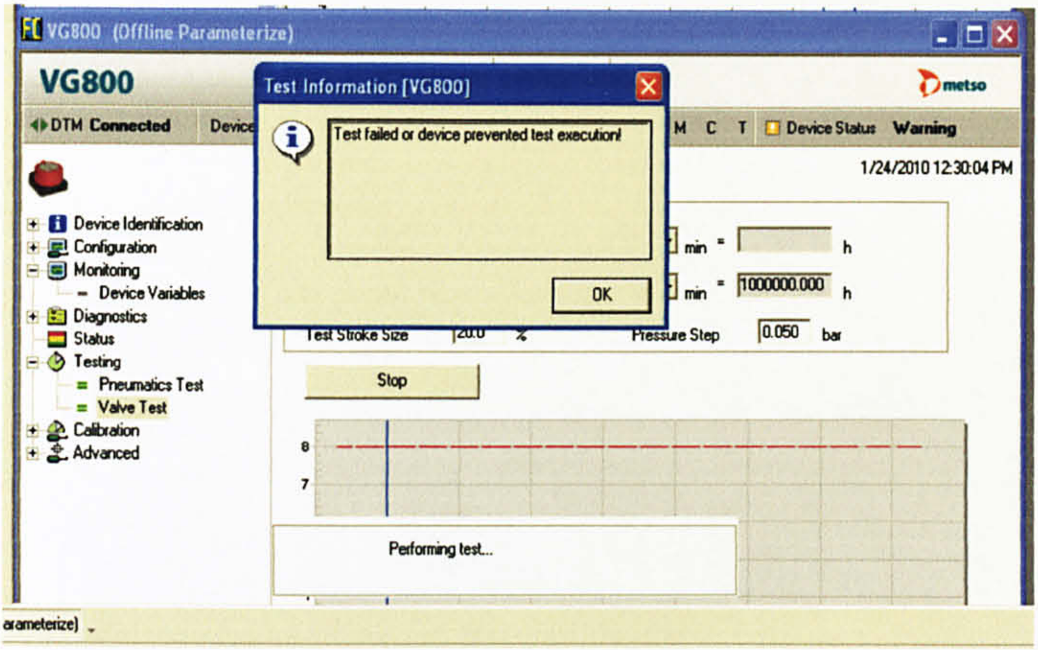


Figure 25: PST Failed for Butterfly Valve

4.5 Breakaway Pressure

Breakaway pressure indicates the pressure measurement level at which the valve starts to move during a valve test. The trend data is calculated and updated every time a valve test is performed. The trend can be used to analyze valve load changes and predict future behavior of safety valve.

The breakaway pressure for both valves is almost the same which is around 2 to 3bar which means it is the amount needed to be supplied in order for valve to start moving. *Figure 26 and 27* show historical trend of breakaway pressure for the valves and since it is almost constant, it determines that the valves are in good condition and do not have any wear and tear symptom or any leakage at the actuator diaphragm. The summary of the breakaway pressure for both valves is recorded for analysis purpose (*refer Figure 28 and 29*).

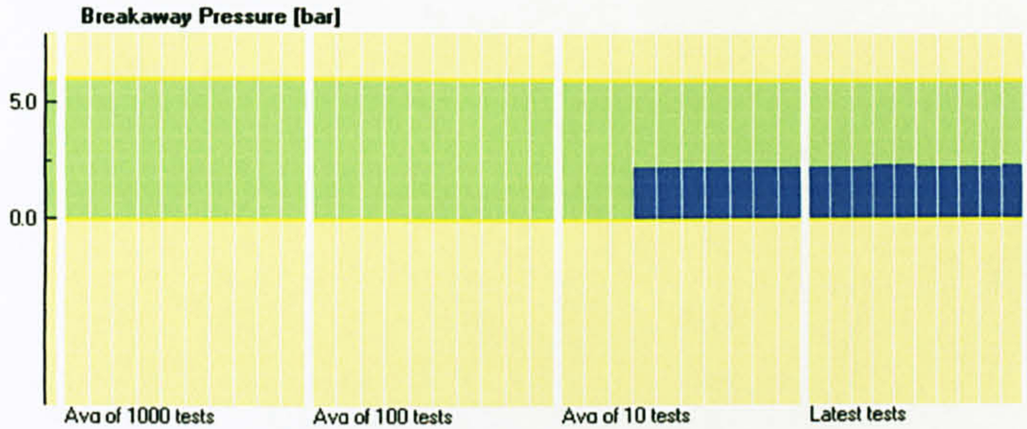


Figure 26: Breakaway pressure for Ball Valve

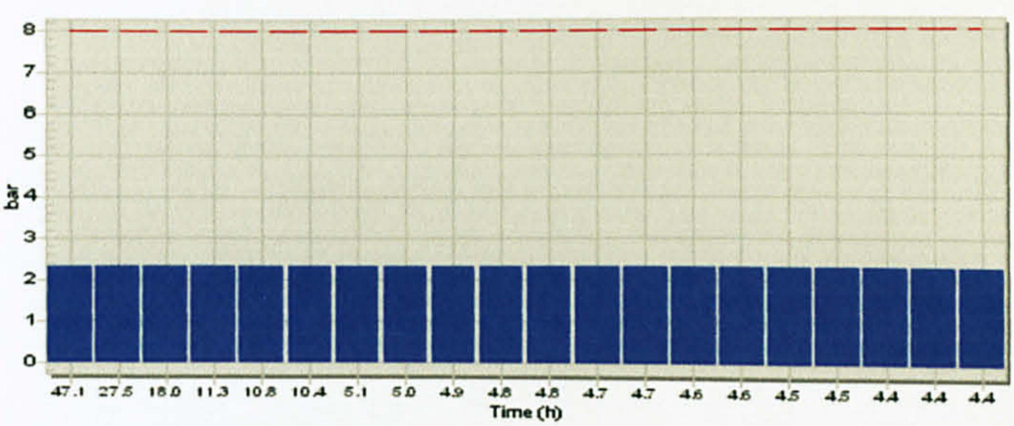


Figure 27: Breakaway pressure for Butterfly Valve

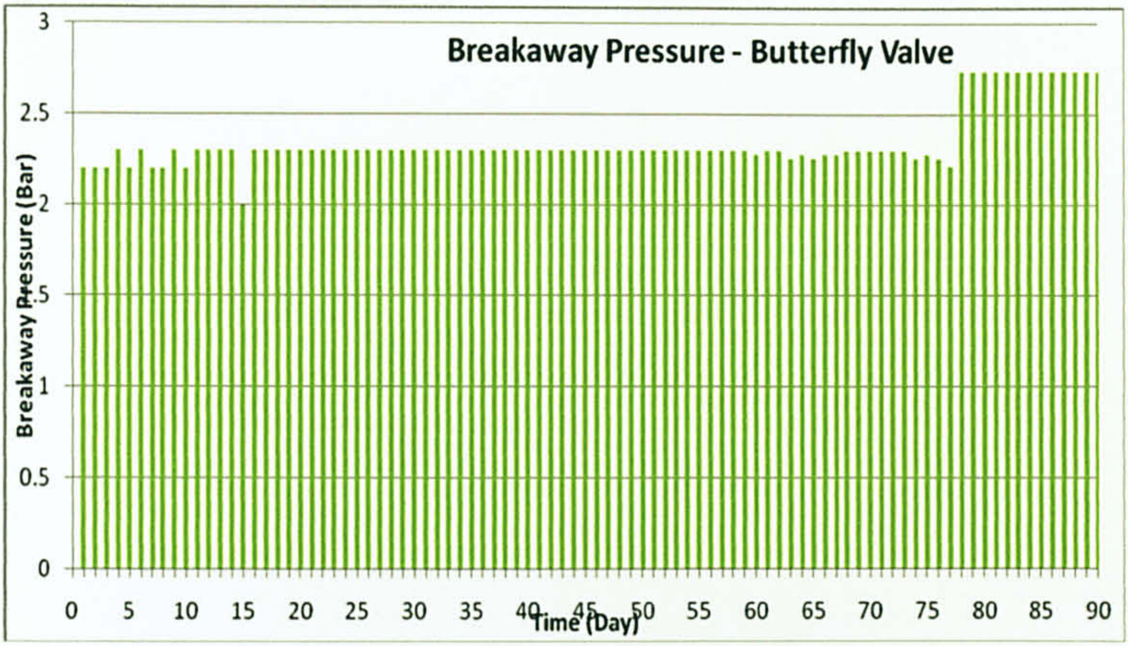


Figure 28: Summary for Breakaway Pressure (Butterfly Valve)

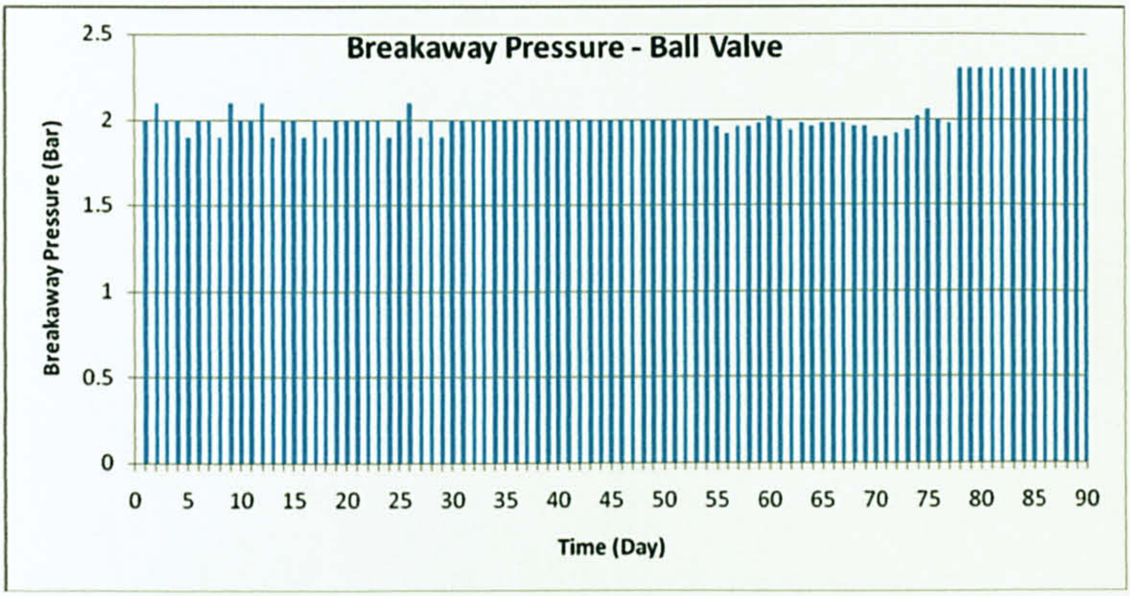


Figure 29: Summary for Breakaway Pressure (Ball Valve)

4.6 Load Factor

For ValvGuard, in addition to the valve position measurement, there is an actuator cylinder pressure measurement, which enables the operator to get the load factor trend graph retrieved from partial stroke test. Load factor (*refer to Figure 30, and 31*) is actually the percentage of the air supply needed or used to stroke a valve. The load factor is calculated from PST data, which indicates the friction changes of the valve. In this Phase I project, the load factor of the valves only started to be recorded on 56th day of testing which refer to testing day that followed PETRONAS requirement (*refer Figure 32 and 33*).

A high load-factor value means increased friction due to the structure of the valve. For example, a ball type consists of core and seat inside it, therefore at every time the valve moves, the core always has contact with the seat which caused more friction compare to a butterfly valve that consists of gate and seat inside it where the gate only has contact with the seat at fully close condition and when the valve starts to move it will no longer has contact with seat, therefore the friction is less.

Less friction leads to less load factor because less instrument air needed to move the valve. Because of that, the load factor for butterfly valve is lesser than ball valve (*refer figure 32 and 33*). This friction load is measured on every partial stroke test and stored to a historical trend, therefore comparison can be made between the current valve friction load to a long time history (when the valve was new).

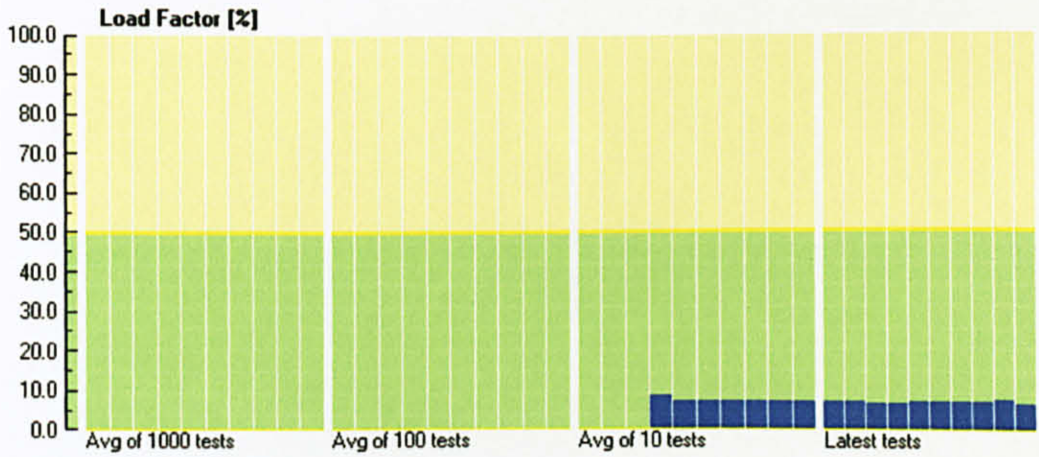


Figure 30: Load Factor for Ball Valve

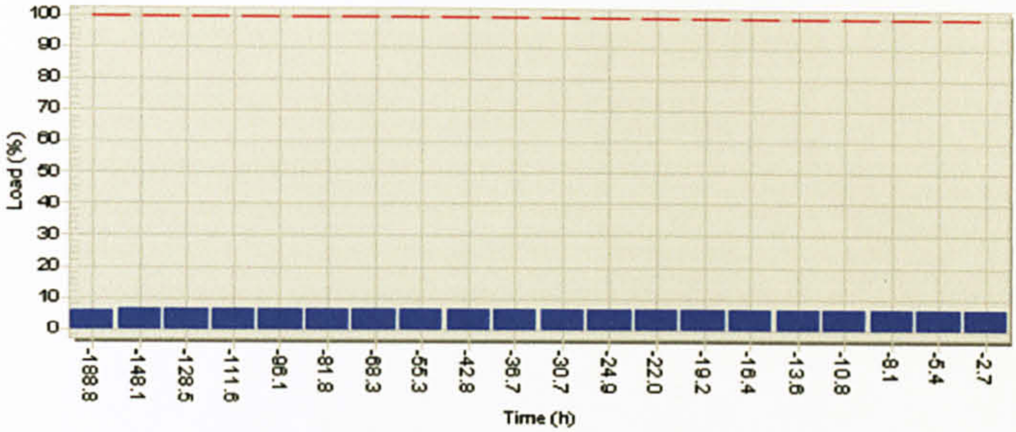


Figure 31: Load Factor for Butterfly Valve

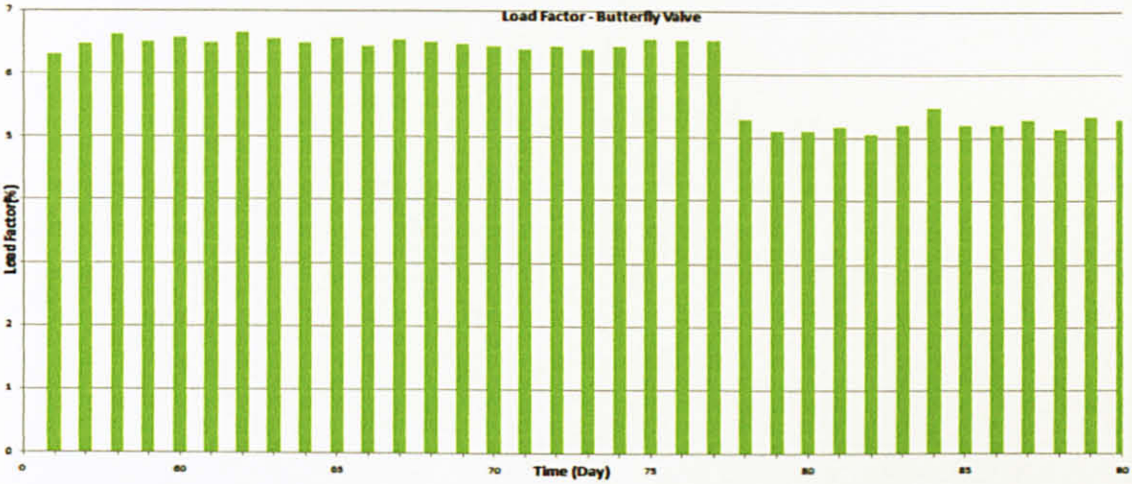


Figure 32: Summary of Load Factor (Butterfly Valve)

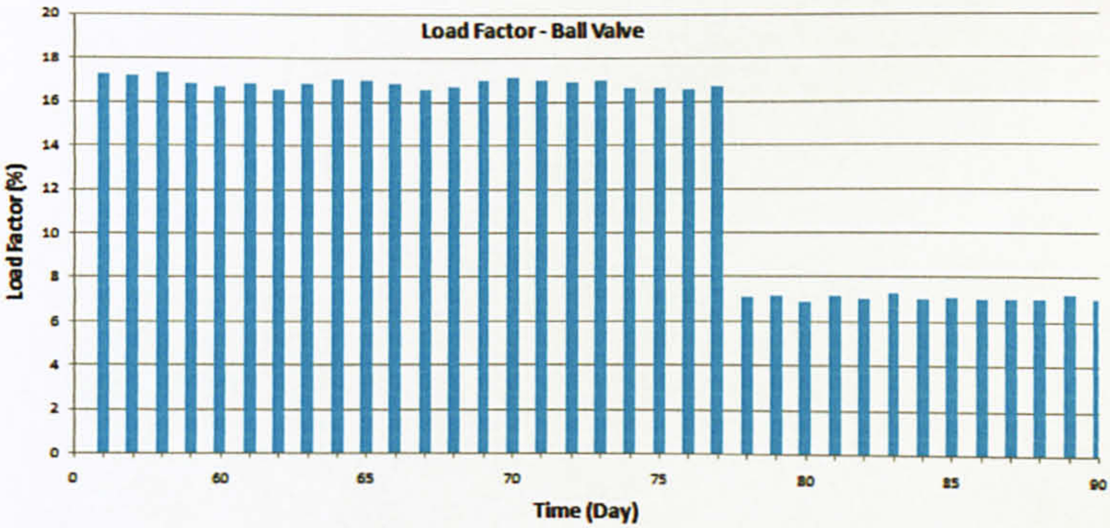


Figure 33: Summary of Load Factor (Ball Valve)

4.7 Reliability

During Phase I, the Dry Test has been conducted and completed and it gives a very good result which the system has never failed. Since both valves never fail to function to requirement for every testing day that has been done, therefore the reliability of the system can be calculated as follow:

Total testing days = 90 days

For every testing, 6 strokes were done which are 5 Partial Stroke Test (PST) plus 1 Partial Stroke Test (PST) + Full Stroke Test (FST).
5 PST + 1 PST & FST = 6 strokes

Thus, 90 days x 6 strokes = 540 strokes has been done successfully.

Normally, Partial Stroke Test is conducted in plant once in every three months. Therefore, this accelerated testing represents 540 x 3 months = 1620 months = 135 years of system reliability.

Based on the calculation, we can conclude that the test quantitatively shows that the system will be reliable for at least 135 years which means it should never fail within that period of time.

4.8 Extra Features of VG9000

Since VG9000 is an upgraded version of VG800, therefore, it has more features and function that can be used in testing the valve performance. For example, the valve opening and closing time at full speed (*refer Figure 36 and 37*), valve temperature (*refer Figure 34)* and target stroke size deviation (*refer Figure 35)* can be known which VG800 cannot give. Besides that, VG9000 also has extra function which is emergency trip test (*refer Figure 38)* that will full stroke the valve when requested.

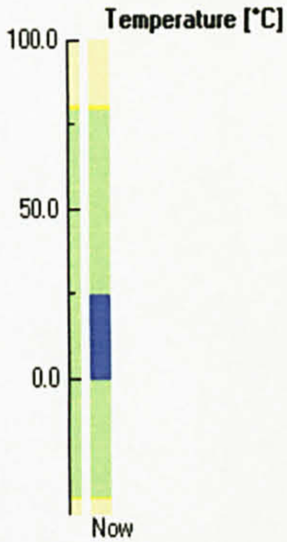


Figure 34: Ball Valve Temperature

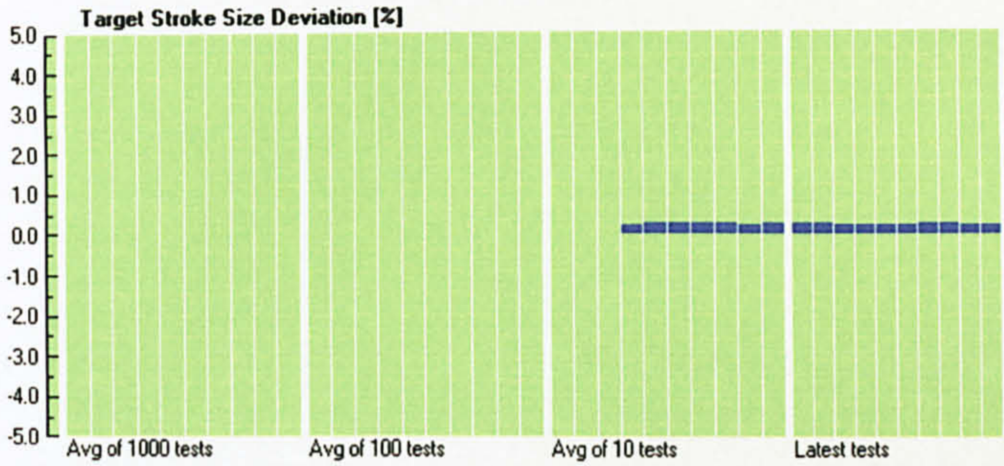


Figure 35: Ball Valve Target Stroke Size Deviation

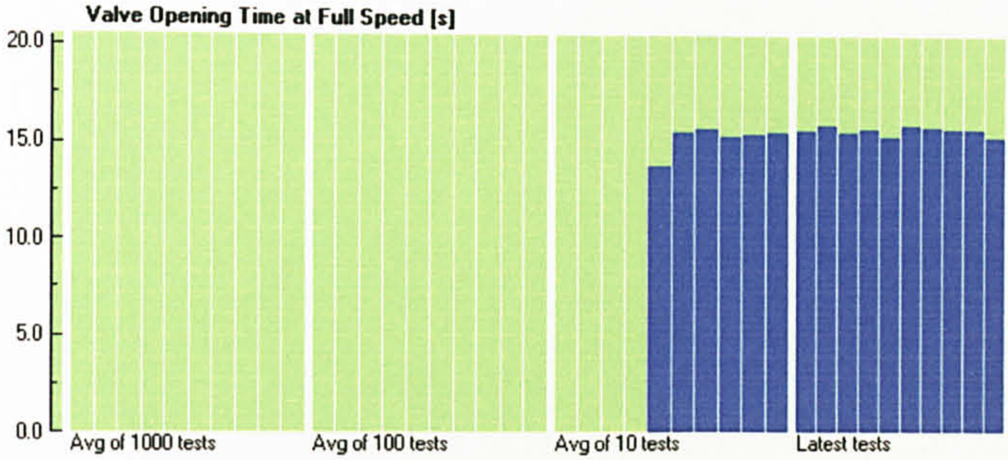


Figure 36: Ball Valve Opening Time

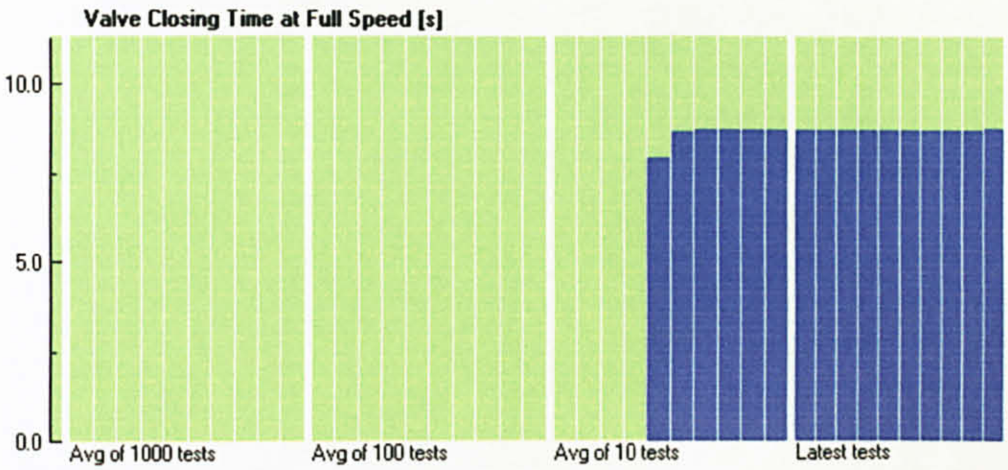


Figure 37: Ball Valve Closing Time

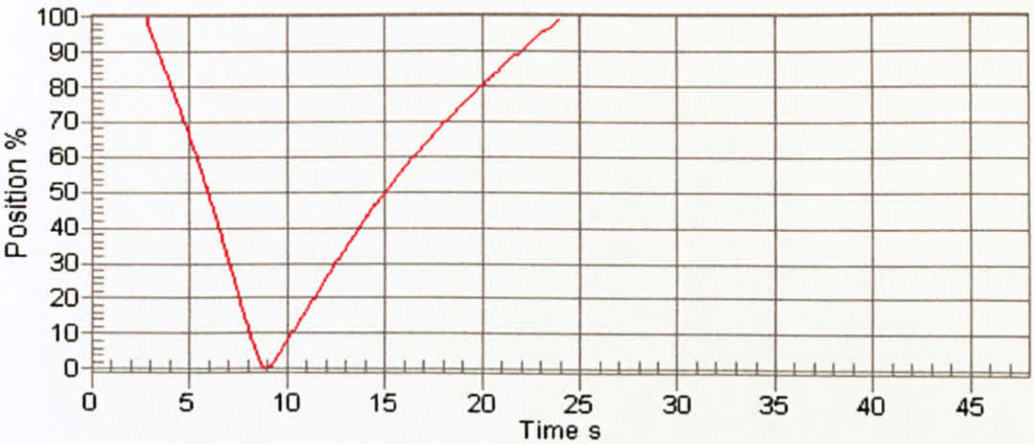


Figure 38: Ball Valve Emergency Trip Test

4.9 Problem Encounter in Phase I

During Phase I of the project, there was one problem occurred which are:

1. Wrong Connection of RCI

4.9.1 Wrong Connection of RCI

The problem occurred after the contractor has installed the cabinet for all the wiring and devices. HART server cannot detect ValvGuard (VG800) for both valve, thus there is no communication establish between computer and the VG800. While at FieldCare Software, it give error message indicate that the devices are not found. As a result, no testing can be done. This is caused by the wrong connection for RCI. So the VG800 cannot communicate with the HART Server. After the wiring connection is being corrected, the HART Server can detect both ValvGuard and testing can be done.

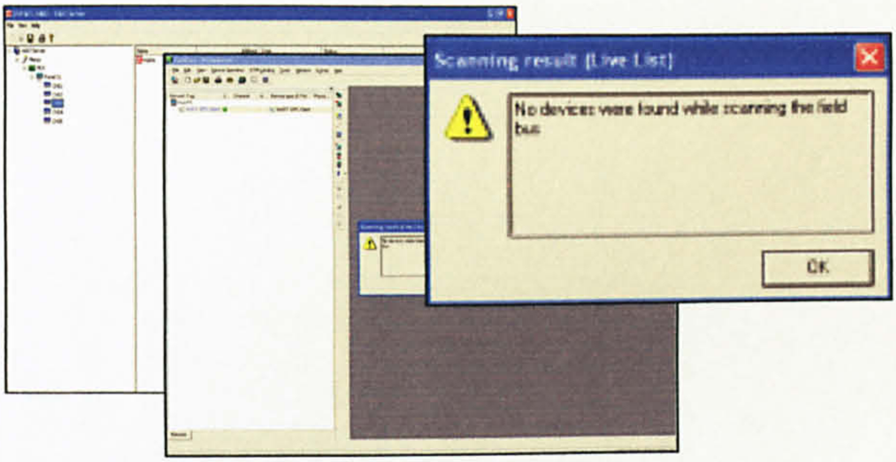


Figure 39: Error message

4.10 Design Mini Plant in Phase II

After completion of Phase I, the project started to enter the Phase II which is to perform Phase II Test (Testing with Real Flow Medium). In order to perform Phase II Test which is performing the partial stroke testing with real flow going into the ESD valve, a mini plant must be built. Therefore, at this moment the mini plant design which is needed in order to build the mini plant is in progress. The mini plant consists of eight ESD valves that are ball and butterfly type from Metso Neles, Fisher, Mesoneilan, and Rotork.

4.10.1 First Draft of Mini Plant

In the first draft of the mini plant, all eight ESD valves is planned to be located in one single loop (*refer Figure 42*) where four of them are at one side of the loop and another four ESD valves are located at the other side of the loop. A flow control valve is also needed to control the flow and to bypass the ESD valves if one of them has problem. Other than that, a water tank is needed to store water that will flow into the pipeline during the Phase II test and a pump is also crucial in order to increase the flow rate inside the pipeline.

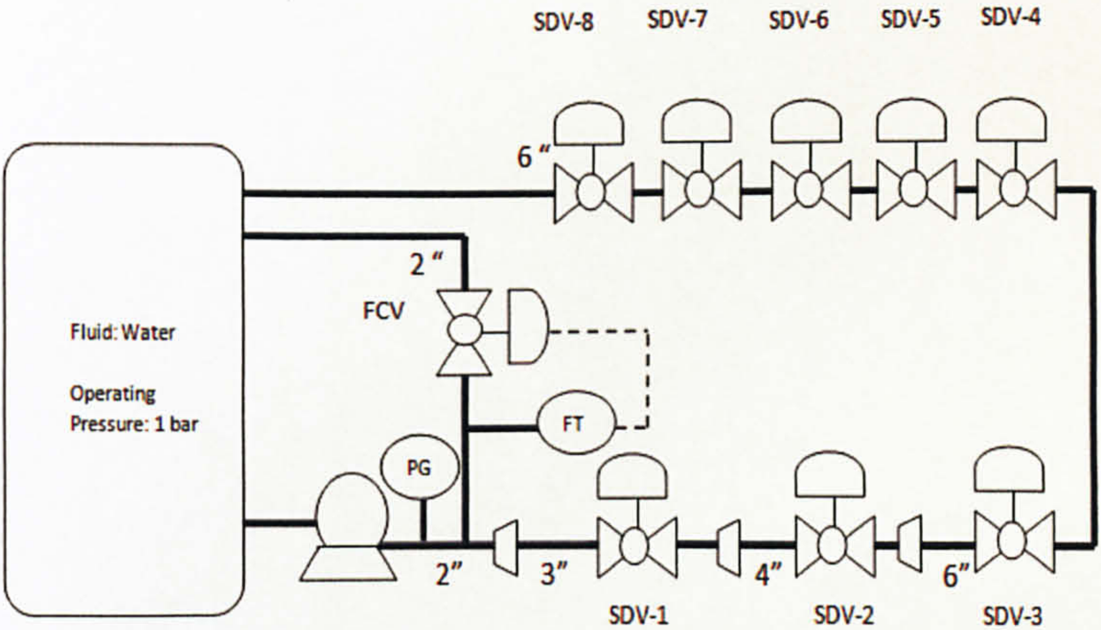


Figure 40: First Draft of Mini Plant

Size of the emergency shutdown valves is not the same from one vendor to another and the data is recorded in the table below:

Table 7: Size of Emergency Shutdown Valve

Brand	Ball Valve	Butterfly Valve
Fisher	6 inch	3 inch
Mesoneilan	6 inch	4 inch
Metso Neles	6 inch	6 inch
Rotork	6 inch	6 inch

The arrangement of the eight ESD valves in the first draft is based on increasing in size which starts from the smallest size that is 3 inches to the bigger size of valve and the biggest size is 6 inches. This arrangement is chosen because of the safety purpose where the pressure of flow will be increased step by step. Between the valves, reducer is used in order to increase the size of the pipeline. Apart from that, the size of water tank, length of the pipeline, output discharge of water pump, and the exact location of the mini plant are another crucial matter to be decided.

4.10.2 Second Draft of Mini Plant

After done more self study and having discussion with supervisor regarding the project, the second draft of the process design is initiated which is an improvement version of the first draft. Based on the previous design, the amount of pressure drop that may occurred in the pipeline is concerned since the water from the tank will flow through all eight ESD valves before it returns back to the water tank. This means that, more valves in the pipeline in one single loop, more constraint for the water flow and more pressure drop will happen which may lead to decrease in volumetric flow rate inside the pipeline when the water reaches at the end of the loop.

Therefore, in the second draft of the process design it is decided that only four valves will be in the operation at one time when the testing is conducted which means that the arrangement of the valves is designed to be four valves in one loop. This means that the plant will have two different loop s for the water flow to conduct the Phase II Test called loop A and loop B. If the valve to be tested is located in loop A, thus the water will only flow through loop A and at that moment loop B will be isolated from the process. The isolation process can be done by installing two hand valves for each loop which is located at beginning and ending of the loop.

In this second draft, some of the design criteria are also decided such as the pump rating is decided to be 45 ℓ / min equivalent to 0.045 m^3/ min which is possible to be purchased, the gap between each ESD valve is 1 m each and there are two size of pipeline which are 2 inch and 6 inch diameter pipe. The detailed measurement of the PST test rig is shown in *figure 43*.

The proposed size of the water tank is 0.1963 m^3 which it is 1 m in height and 0.25 m in radius. Detailed calculation has been done before determining the water tank size. From the calculation, it must be determined that those size of tank will be enough to store water to fill the pipeline of the longest testing path with water flow in order to conduct the testing or in other words the path used for testing the ESD valve located at the farthest location from the water tank. If that particular tank size is enough to supply water for the biggest volume of pipeline which means the longest testing path, thus, it should be more than enough to supply water for the smaller volume of pipeline loop which means the shorter testing path. This assumption can be made since only one valve can be tested at one time.

In the calculation, the biggest volume of the water flow in pipeline is calculated first as bench mark. Then, by taking into consideration the output discharge of water pump, the time taken for the water to fill the pipeline is calculated and the testing time is estimated. Next, the minimum volume of water tank required to sustain water to flow fully in the pipeline for that particular time is determined. After that, by using the proposed radius and height, the volume of the tank is calculated. Finally, comparison is made between the volume of tank and the minimum volume of water tank required. From the calculation, it is proven that the water tank size proposed is reasonable.

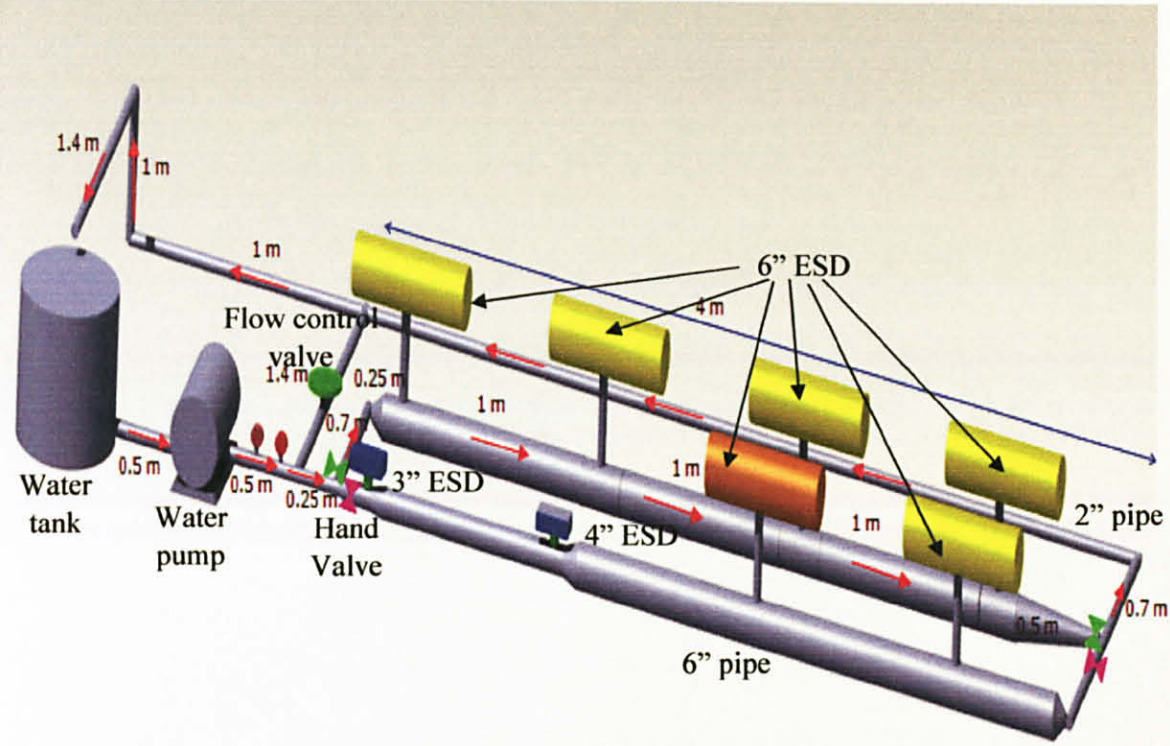


Figure 41: Second Draft of Mini Plant

The detailed calculation of the project is shown below:

Volume for 2" pipe diameter,

$r = 1" = 0.0254$ m

$l = 0.5 + 0.5 + 0.25 + 0.7 + 0.7 + 4 + 1 + 1 + 1.4 = 10.05m$

$A = \pi r^2 = \pi(0.0254)^2 = 0.00203m^2$

$V = Al = 0.00203x10.05 = 0.0204m^3$

Volume for 6" pipe diameter,

$r - 3" - 0.0762$

$l = 0.25 + 1 + 1 + 1 + 0.5 = 3.75$

$A = \pi r^2 = \pi(0.0762)^2 = 0.01824m^2$

$V = Al = 0.01824x3.75 = 0.0684m^3$

$V_{total} = V_{2"} + V_{6"} = 0.0204 + 0.0684 = 0.0888m^3$

The output discharge of the available pump is $45\,{}^{l}/_{min} = 0.045\,{}^{m^3}/_{min}$

$\therefore \textit{Volumetric flow rate}, \dot{V}$

$$\dot{V} = \frac{V}{t}$$

$$t = \frac{V}{\dot{V}} = \frac{0.0888}{0.045} = 1.97min = 118.4s \approx 120s$$

$$t_{testing} = 80s$$

Total time required = $t + t_{testing} = 120 + 80 = 200s = 3.333min$

$\therefore \textit{minimum volume tank required} = V_{piping} = 0.045\, m^3/min \times 3.333min = 0.15m^3$

By using hand valves at beginning and ending of each branch, the ***total time has been reduced*** since the flow is directed to either of the branches depending on the location of the valve to be tested. This is because only one valve will be tested at one time.

To re-check the volume of the tank with the specified *r* and *h*,

$$V_{tank} = \pi r^2 h = \pi \times 0.25^2 \times 1 = 0.196m^3$$

Thus, the size of the tank is valid because:

$$V_{tank} > V_{piping}$$

$$0.196m^3 > 0.15m^3$$

Therefore, the summary of the second draft is:

1. Minimum volume tank required = 0.15 m^3
2. Tank size = 0.196 m^3 (1 m in height and 0.25 m in radius)
3. Water pump rating = 45 ℓ / min = 0.045 m^3/ min

4.10.3 Final Draft of Mini Plant

For the final draft, the mini plant design is more or less the same with the second draft design but it has been decided to have lesser valves in one single loop. After having discussion with PETRONAS, the amount of valves which is four in one loop in second draft has been decreased to two valves in one loop for the final draft (*refer to Figure 44*). Thus, there are four different loops called Loop A, Loop B, Loop C, and Loop D in the final draft of the mini plant design. By having lesser valves in a single loop, we can decrease the constraint for the water flow thus lessen the pressure drop in the pipeline which will then decrease the percentage of having low volumetric flow rate inside the pipeline when the water reaches the end of the loop.

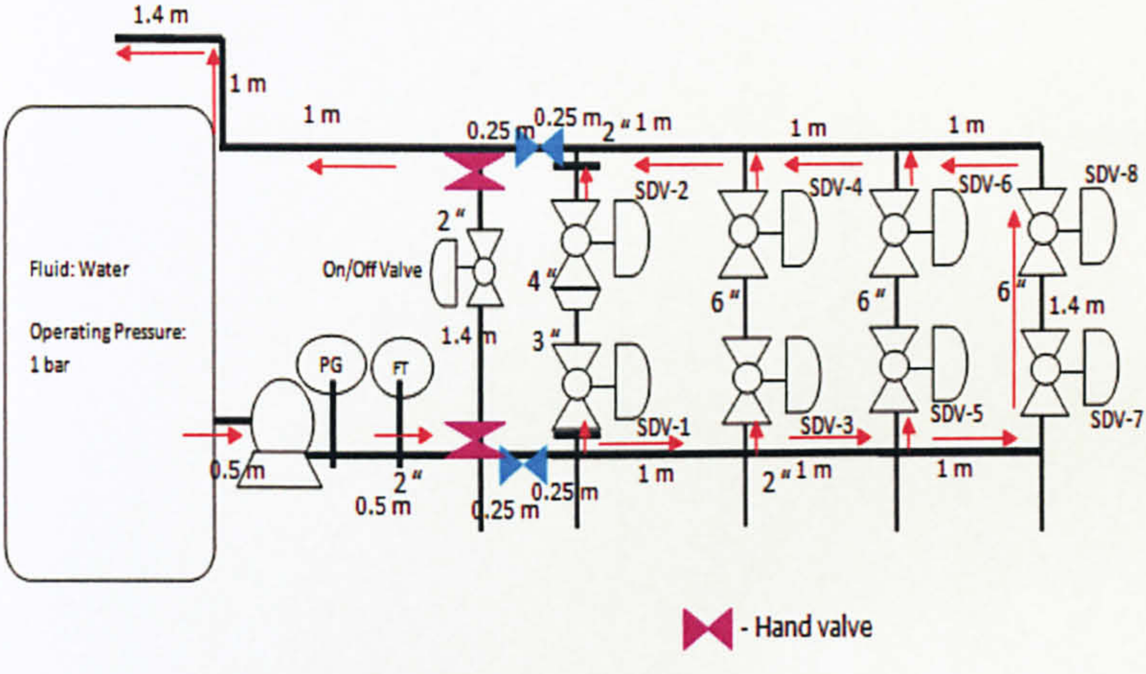


Figure 42: Final draft of Mini Plant

The same concept like in the second draft, at one operation time only one loop of valve will be operated, thus if one valve in that particular loop let say Loop A is having problem only another one valve's operation is affected which compare to second draft, if one valve is having problem in that loop it will affected another three valves operation. Therefore, by having the new design, the probability of one valve cannot be operated has been reduced.

For the final draft, same design criteria like second draft are used such as the pump rating is 45 ℓ / min equivalent to 0.045 m^3/ min which is possible to be purchased, the gap between each ESD valve is 1 m each and there are two size of pipeline which are 2 inch and 6 inch diameter pipe. The detailed measurement of the PST test rig is shown in *figure 44*.

The water tank size proposed is 0.1963 m^3 which it is 1 m in height and 0.25 m in radius and it is coincidentally the same with second draft. Detailed calculation for the final draft has been done before determining the water tank size and is shown below. While doing the calculation, the same concept is used which is the longest path used for the water to flow during the testing is taking into concerned since if the water in the tank is enough to test the valve located in the farthest location, it should be more than enough to supply water for valve located at closer location from the water tank. This assumption can be made since only one valve can be tested at one time.

First step in the calculation, the biggest volume of the water flow in pipeline which referred to the longest path taken by the water to flow in pipeline is calculated first as bench mark. Since we know the output discharge of water pump, the time taken for the water to fill the pipeline is then calculated and the testing time is estimated. The total time required is then estimated.

After that, the minimum volume of water tank required to sustain water to flow fully in the pipeline for that particular time is determined. Then, volume of water tank is calculated by using the proposed radius and height. Lastly, volume of tank obtained from calculation is compared with the minimum volume of tank required. From the calculation, it is proven that the water tank size proposed for the final draft is reasonable.

For safety purpose, a pressure gauge, a flow transmitter and an on/off valve (safety valve) will be installed in the loop. Whenever the pressure gauge senses any excessive pressure inside the impulse line, it will send signal to safety valve to open in order to avoid back pressure to the pump which can damage it. On the other hand, if the flow transmitter measure low flowrate in the impulse line, it will send signal to pump to stop pumping since if the pump is still pumping without any flow through it, it will also damage the pump.

The detailed calculation of the project is shown below:

Volume for 2" pipe diameter,

$r = 1" = 0.0254$ m

$l = 0.5 + 0.5 + 0.25 + 0.25 + 3 + 3 + 0.25 + 0.25 + 1 + 2.4 = 11.4$ m

$A = \pi r^2 = \pi(0.0254)^2 = 0.00203\text{m}^2$

$V = Al = 0.00203x11.4 = 0.023142\ \text{m}^3$

Volume for 6" pipe diameter,

$r = 3" = 0.0762m$

$l = (0.35m\ x\ 6) + 1.4 + = 3.5m$

$A = \pi r^2 = \pi(0.0762)^2 = 0.01824m^2$

$V = Al = 0.01824x3.75 = 0.06384m^3$

$V_{total} - V_{2"} + V_{6"} - 0.023142 + 0.06384 - 0.086982m^3$

The output discharge of the available pump is $45\ {}^{l}/_{min} = 0.045\ {}^{m^3}/_{min}$

$\therefore \textit{Volumetric flow rate}, \dot{V}$

$$\dot{V} = \frac{V}{t}$$

$$t = \frac{V}{\dot{V}} = \frac{0.086982}{0.045} = 1.933min = 115.98s \approx 120s$$

$t_{testing} = 80s$

Total time required $= t + t_{testing} = 120 + 80 = 200s = 3.333min$

$\therefore \textit{minimum volume tank required} = V_{piping} = 0.045\ m^3/min \times 3.333min = 0.14985m^3$

Re-check the volume of the tank with the specified *r* and *h*,

$V_{tank} = \pi r^2 h = \pi \times 0.25^2 \times 1 = 0.1963m^3$

Thus the size of the tank is valid because:

$V_{tank} > V_{piping}$

$0.1963m^3 > 0.14985m^3$

Therefore, the summary of the final draft is:

1. Minimum volume tank required = $0.14985\ m^3$
2. Tank size proposed= $0.1963\ m^3$ (1 m in height and 0.25 m in radius)
3. Water pump rating = $45\ \ell / min = 0.045\ m^3/ min$

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The reliability of emergency shutdown (ESD) service is very crucial since it is an important element in the safety loop and play big role in order to ensure the safety of the plant equipments and also the people working in that area if any emergency occurs. In order to ensure proper operation of ESD service, ESD valves must be actuated and to do so without interrupting processes, Partial Stroke Test (PST) is the best solution since it can reliably move an ESD valve between shutdowns. Therefore, it can improve ESD valve integrity and confirm availability.

Phase I of the project which is conducting Dry Test for 90 days has been completed and both ball and butterfly valve successfully passed the test. On 92nd day (75th day of testing based on PETRONAS requirement) of Dry Test, ball valve is upgraded from VG800 to VG9000 which has more features and extra safety function. As for now, we can conclude that both ball and butterfly valve have a very good performance as an ESD valve since they never fail to function to requirement, during every testing days. The trend of results that were obtained is similar and do not show any irregularity. Based on the reliability calculation, it can be concluded that the system is reliable for at least 135 years without failure.

At this moment, Phase II of the project which is to build a mini plant and later to perform Testing with real Flow has started. At this time, final draft of the mini plant design has been decided together with the detailed calculation. The final draft of the PST test plant has been sent to PETRONAS and feedback from them is waited. Once the design has been approved, the construction of the mini plant will be started. After the plant construction has been completed, Phase II test will be conducted.

5.2 Recommendations

First recommendation is that, the previous ESD valve trolleys are suggested to be re-used in building the PST test rig. It is planned that all the ESD valve that already located on the trolley be arranged side by side together with the trolley and the length measurement of it have been taken into consideration in the design calculation.

Second recommendation is that the availability of water pump with higher flowrate (current calculation used 45 litre per minute) output should be considered. If available, it should be a better choice to increase the volumetric flow rate of water inside the pipeline. Therefore, the time taken for the water from water tank to fill the testing pipeline can be reduced.

Third recommendation is that new way of basic tests that will be conducted in Phase II would be similar to the existing test, namely: valve test, pneumatic test, and PST collides with FST test. Hence, more realistic characteristic of the value performance can be realized. By having real flow through valves, the more accurate outcome can be obtained since it resembles the situation in the plant.

Forth recommendation is that, a mini plant may be built in open air condition in the future which it is exposed to environment to simulate the real conditions and allow more robust tests to be conducted and produces realistic test outcome.

The design has been done by mental calculation using realistic values. Thus next recommendation for further work is that, it will be useful to simulate the plant to investigate varies parameters like pressure at a specific location by using simulation tool, for example HYSIS, or other tools.

REFERENCES

[1] *Neles ValvGuard – partial stroke testing system for emergency valves* http://www.metso.com/Automation/valve_prod.nsf/WebWID/WTB-041120-2256F-9817F?OpenDocument

[2] *Partial-Stroke Testing Of Emergency Shutdown Valves.*
http://www.acm.ab.ca/uploadedFiles/003_Resources/Articles_in_ProcessWest/Partial_Stroke_Testing_of_Emergency_Shutdown_Valves.pdf

[3] *Partial-Stroke Testing Of Emergency Shutdown Valves.*
http://www.acm.ab.ca/uploadedFiles/003_Resources/Articles_in_ProcessWest/Partial_Stroke_Testing_of_Emergency_Shutdown_Valves.pdf

[4] *Improving Processing Plants Safety with Smart Emergency Valves and Web-Based Data Collection and Distribution.*

http://www.sipi61508.com/ciks/makinen1.pdf

[5] WikiAnswers.com
http://wiki.answers.com/Q/What_is_a_shutdown_valve&action=edit

[6] http://en.wikipedia.org/wiki/Ball_valve

[7] http://en.wikipedia.org/wiki/Butterfly_valve

[8] Mary Ann Lundteigen , Marvin Rausand., "Journal of Loss Prevention in the Process Industries", *Partial stroke testing of process shutdown valves: How to determine the test coverage,* Vol. 21, Issue 6, November 2008, pp. 579-588

[9] Angela E. Summers, "Partial Stroke Testing of Block Valves", Instrument Engineers Handbook, Vol. 4, Chapter 6.9,2006.

http://sis-tech.com/Technical%20Resources/Design%20&%20Implementation/IEH_-_Chapter_6-9_-_PARTIAL-STROKE_TESTING_OF_BLOCK_VALVES.pdf

[10] "neles ValvGuard System Series VG800Installation, Maintenance and Operating Instructions 9 VG 70 en ", Issue 1/02,pp.3-5

[11] http://www.metso.com/Automation/valve_prod.nsf/WebWID/WTB-041120-2256F-D0B79

[12] http://en.wikipedia.org/wiki/Ladder_logic

APPENDICES

APPENDIX A

GANTT CHART

Table 8: Gantt Chart for Semester 1

No	Activities / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
2	Data Gathering on Topic														
3	Submission of Preliminary Report														
4	Testing procedures and requirement identification														
5	Conduct testing (FST and PST)														
6	Submission of Progress Report														
7	Seminar														
8	Results Gathering														
9	Submission of Interim Report														
10	Oral Presentation														

Table 9: Gantt Chart for Semester 2

No	Activities / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Completed Phase I (Dry Test) and start preparation of Phase II (Destructive Test) which is designing process to build mini plant														
2	Logbook														
3	Continue to design process														
4	Submission of Progress Report 1														
5	Finalized Process Design and start to build mini plant														
6	Submission of Progress Report 2														
7	Seminar														
8	Perform Destructive Test														
9	Conclusion and Recommendation														
10	Poster Exhibition (Pre-EDX)														
11	Submission of Draft Report (softbound)														
12	Submission of Final Report														
13	Submission of Dissertation (hardbound)	25 June 2010													
	Oral Presentation	7 – 11 June 2010													

APPENDIX B
DEVICE CONFIGURATION

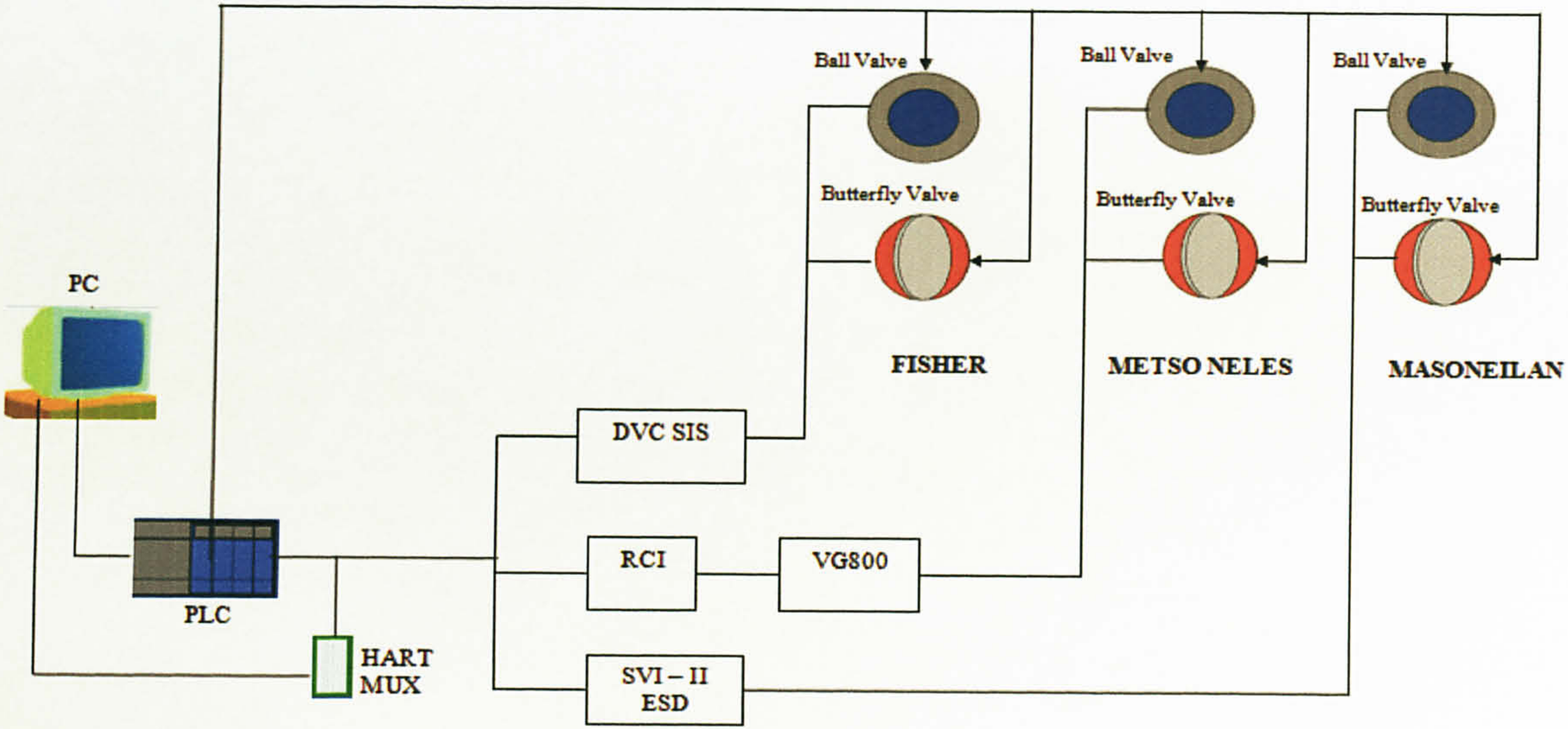


Figure 43: PST Project Device Configuration

APPENDIX C

LOOP DRAWING

i)
ii)

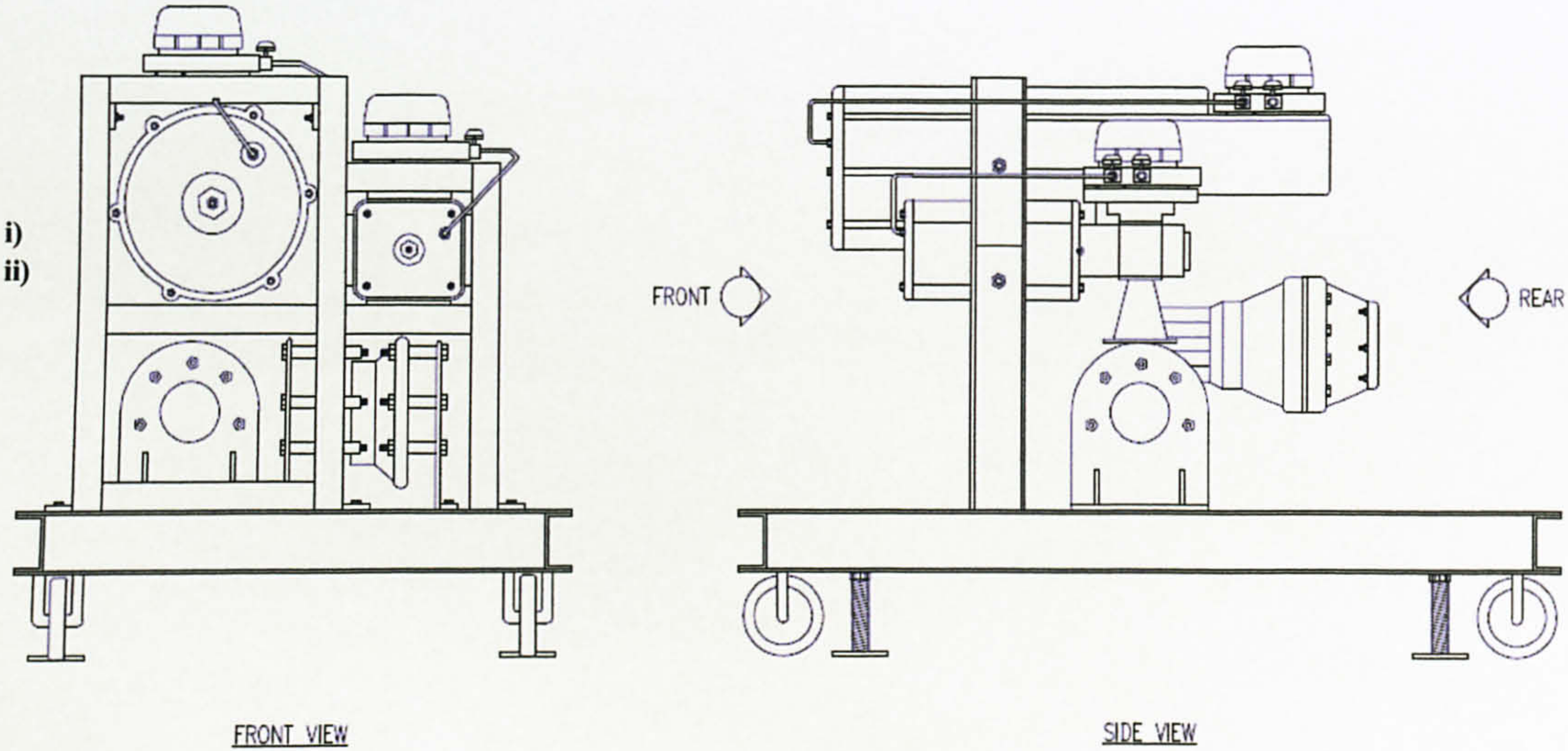
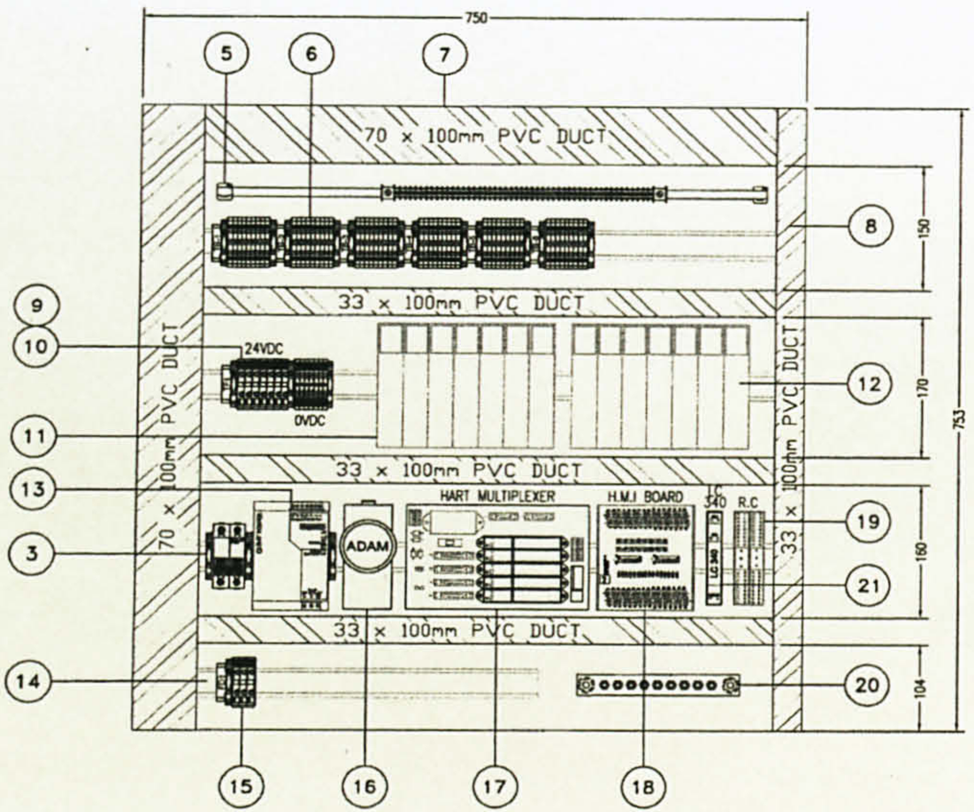


Figure 44: External Skid Trolley Layout



FRONT VIEW WITH OUT DOOR

BILL OF MATERIALS

ITEM	DESCRIPTION	PART/MODEL NO.	QTY
1	METAL ENCLOSURE (800(H) x 800(W) x 260(D))	CVS	1
2	ISOLATOR	MERLIN GERIN	1
3	MCB - 2P,6A	MERLIN GERIN	4
4	FAN	LOCAL	2
5	INSTRUMENT EARTH BAR	LOCAL	1
6	TB-1 to TB-6 - WDU2.5	WEIDMULLER	54
7	70MM x 100MM - TRUNKING (GREY)	KSS	2
8	33MM x 100MM - TRUNKING (GREY)	KSS	4
9	TERMINAL BLOCK (24VDC) - WSI6	WEIDMULLER	7
10	TERMINAL BLOCK (0VDC) - WTR2.5	WEIDMULLER	7
11	PLC	-	1
12	PLC (SPARE)	-	1
13	110-240VAC/24VDC POWER SUPPLY (10A)	PHOENIX CONTACT	1
14	DIN RAIL	LOCAL	4
15	TERMINAL BLOCK (INCOMING) - WDU6	WEIDMULLER	3
16	CONVERTER	ADAM	1
17	HART MULTIPLEXER	-	1
18	HART MULTI INTERFACE BOARD	-	1
19	REMOTE COMMUNICATION	-	2
20	SAFETY EARTH BAR	LOCAL	1
21	LC 340	-	1

NUFACTURER : ICPE Your Industrial Solutions — I. C. P. E SDN. BHD, 86, Jalan Harmoni 5, Taman Sungai Pinang, 42100 Klang, Selangor D. E.

REV	DATE	DESCRIPTION
1	04-08-09	PRELIMINARY PROPOSAL DRAWING
2	13-08-09	AS BUILT

CLIENT : UNIVERSITI TEKNOLOGI PETRONAS

DRAWN : ANIE
DESIGNED : MR
APPROVED : KHARUL
SCALE : N.T.S
PAPER SIZE : A4

PROJECT : PARTIAL STROKE VALVE CONTROL PANEL
TITLE : CONTROL PANEL DETAILS LAYOUT

PROJECT NO. : -
JOB.NO. : -
REV. NO. : 2
SHEET NO. : 10 OF 15
I. C. P. E SDN. BHD

Figure 45: Partial Stroke Valve Control Panel Layout

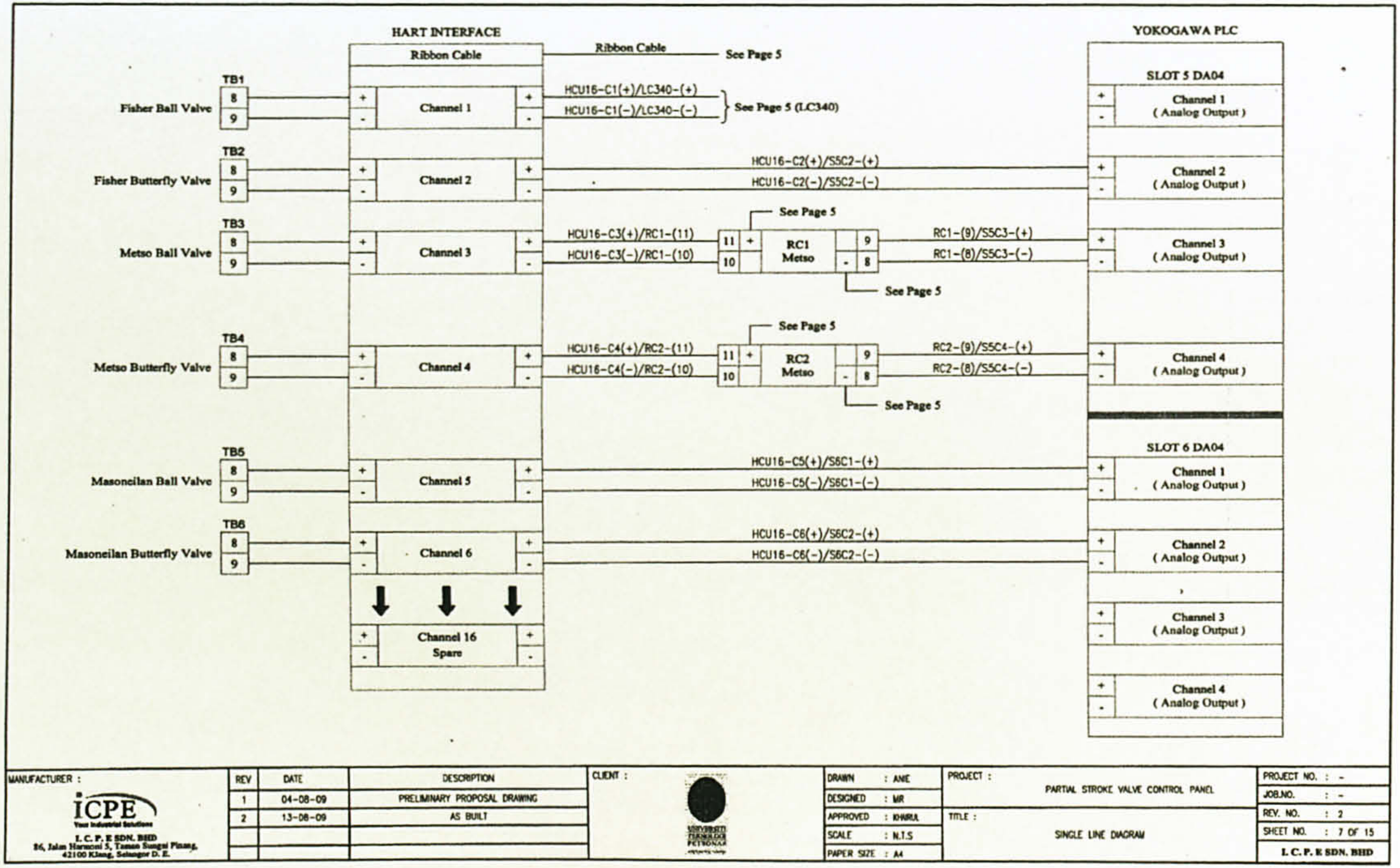


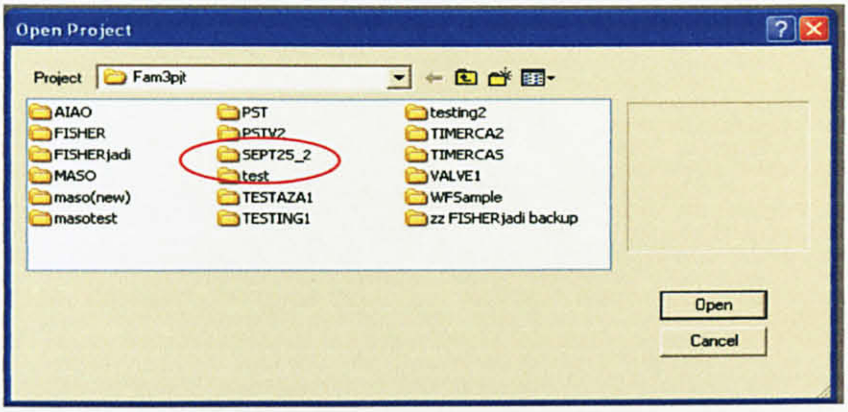
Figure 46: Single Line Diagram

APPENDIX D

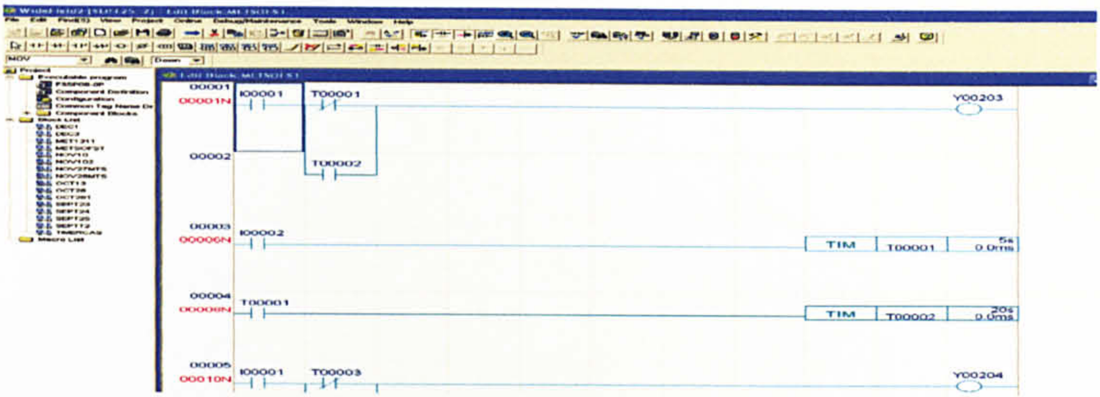
PHASE I DETAILED TESTING PROCEDURES

TO START EQUIPMENTS AND SOFTWARE

1. Open air supply
2. Create New Folder
3. Double click Widefield2 software > File > Open project > SEPT25_2 > SEPT25_2

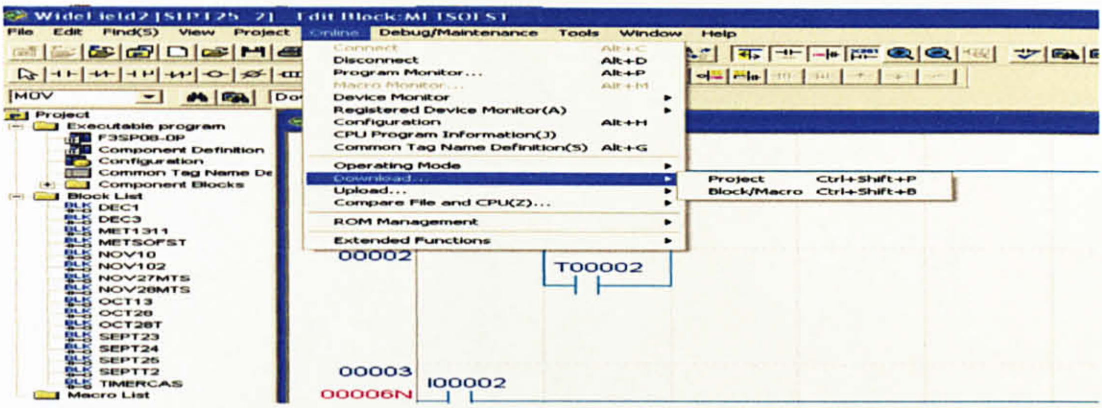


At left: Double click METSO FST



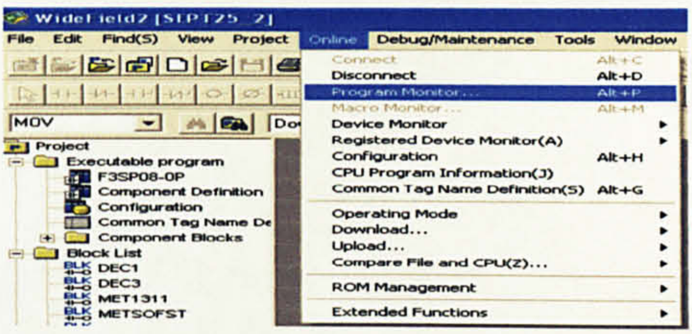
At top: Online > connect > yes

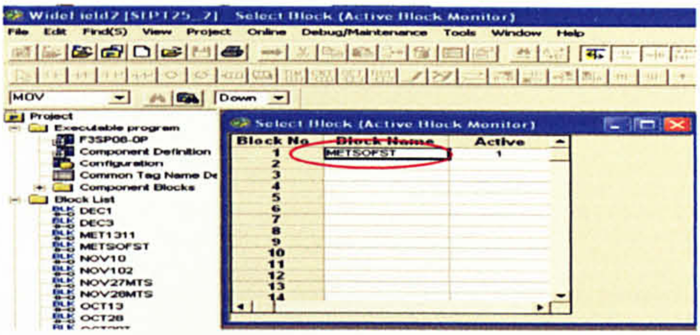
4. Online > download > project > yes > yes > yes. Then, close white window.

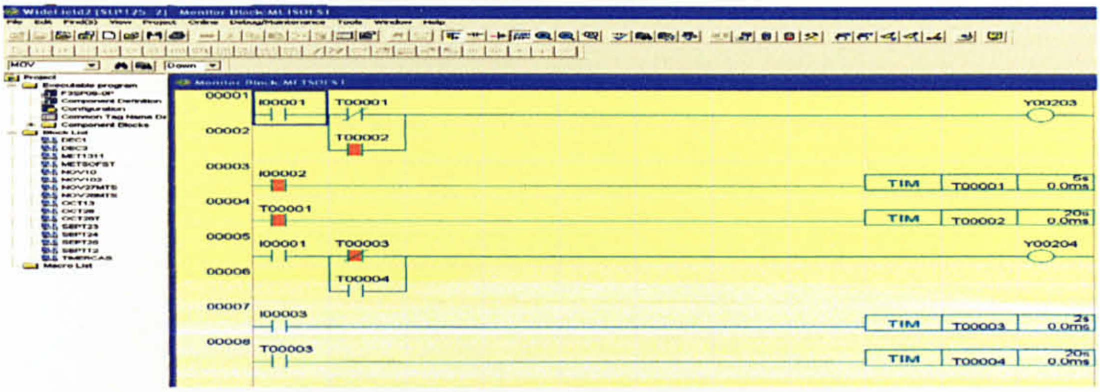


5. Click Online > Program Monitor

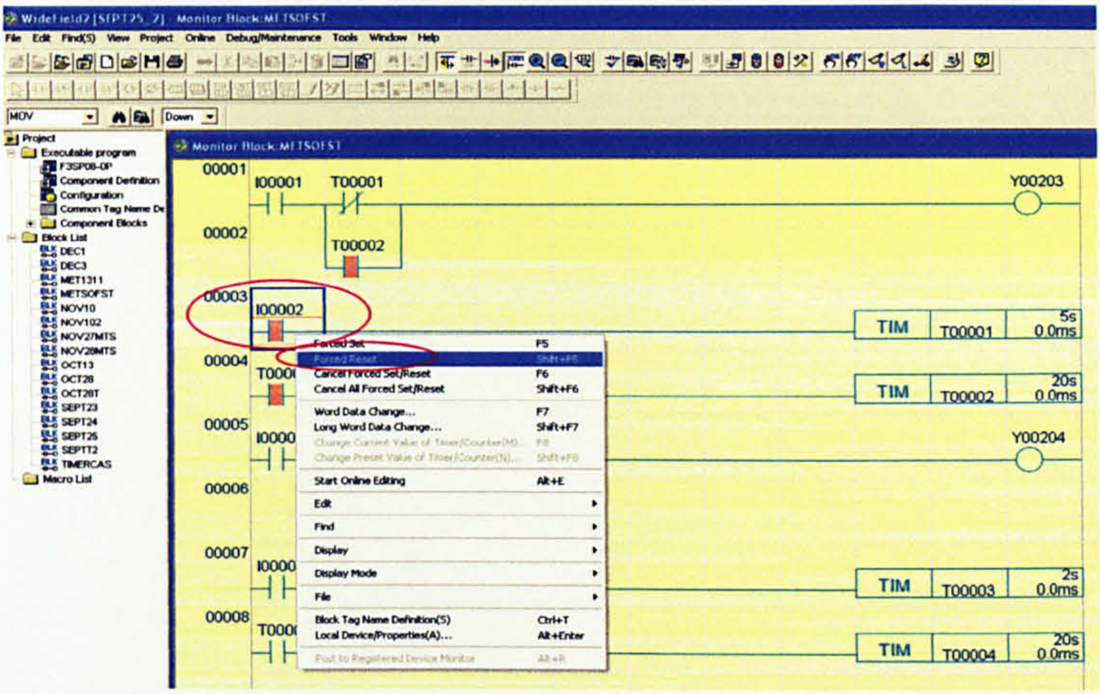
Double click METSO FST (ladder diagram layout appear)

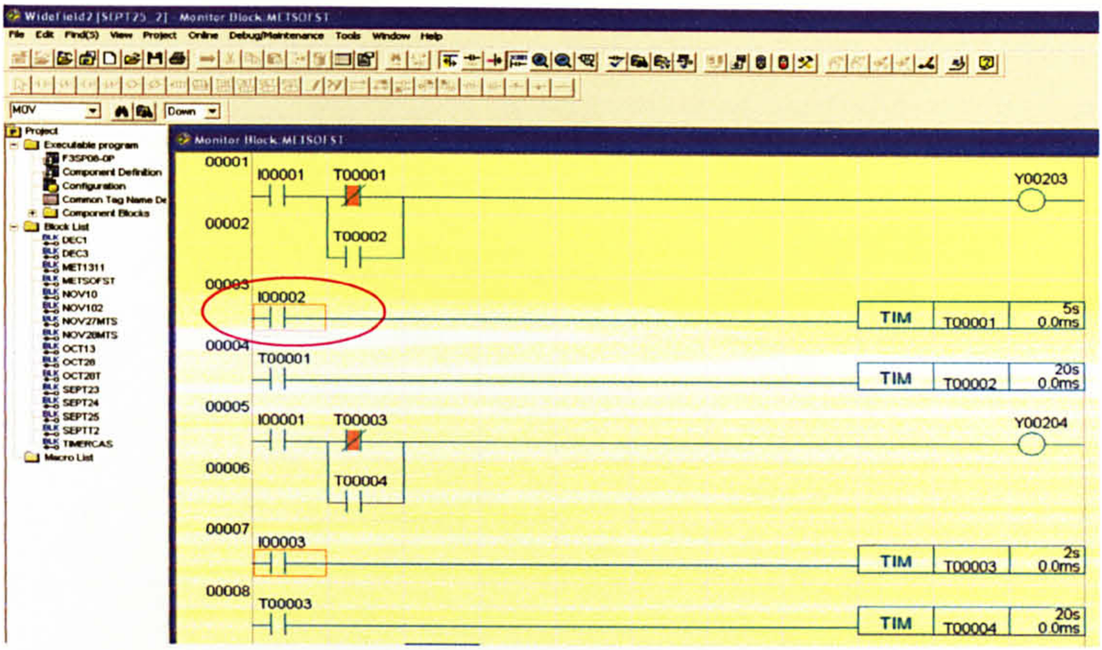




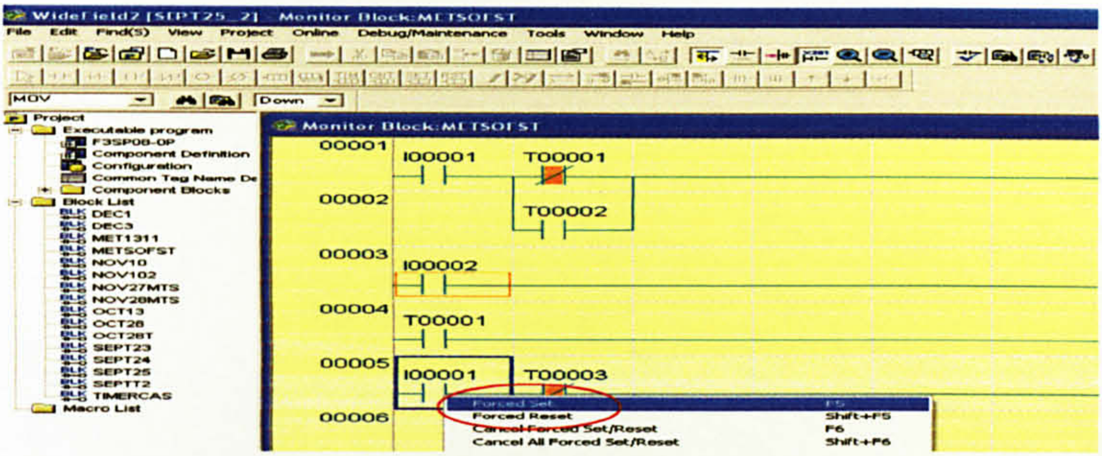


6. At ladder diagram:
I00002 (ball) & I00003 (butterfly) > right click > forced reset (because do not want any connection. If orange in colour means it has connection.)

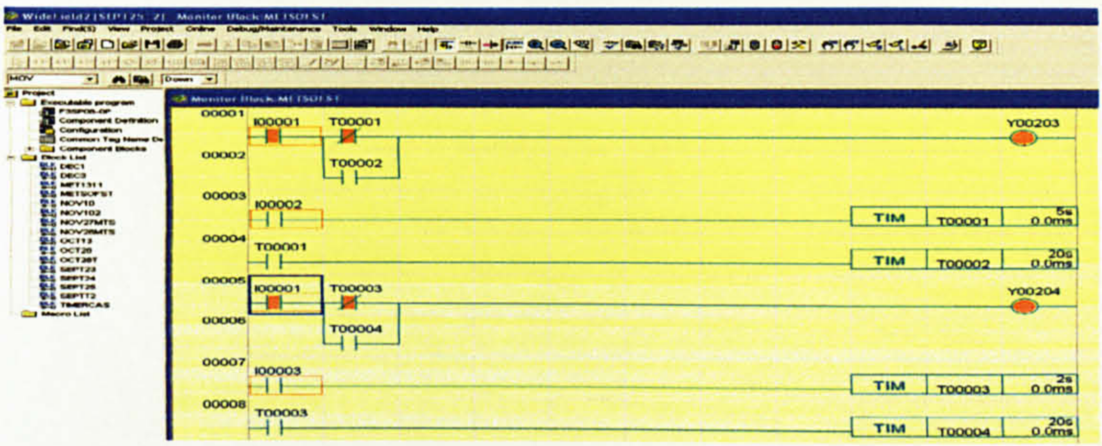




I0000I > forced set (to open valve)



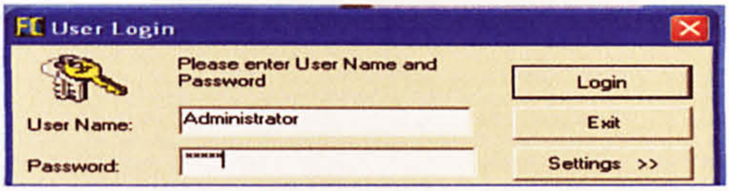
After forced set:



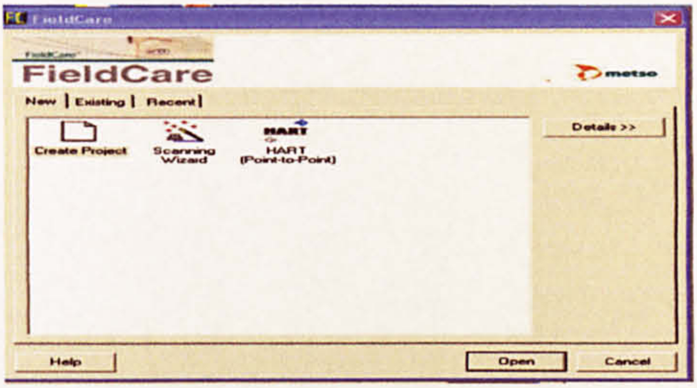
7. Check IS barrier (If has error, press + - symbol, choose mode with arrow (choose auto mode) press for a few second.

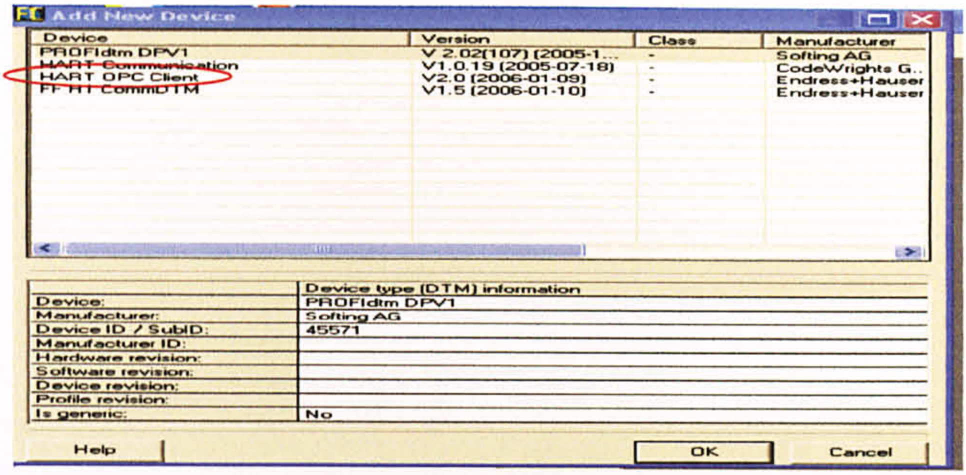
8. Start > Program > HART server > HART server (click)

9. Click FieldCare > user login > type: user - Administrator, p/word – Admin. Click login.

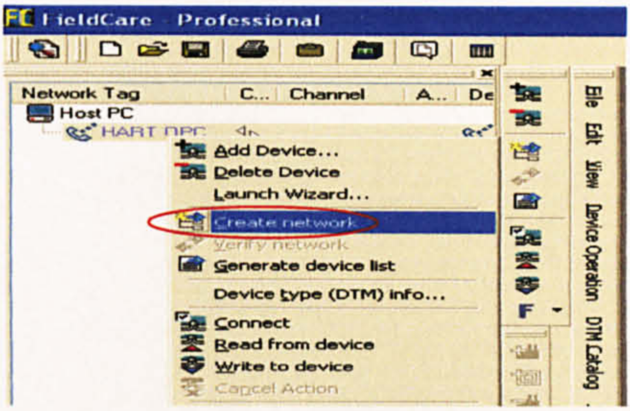


10. Create project (open) > HOST PC (right click) > add device > HART OPC Client > ok

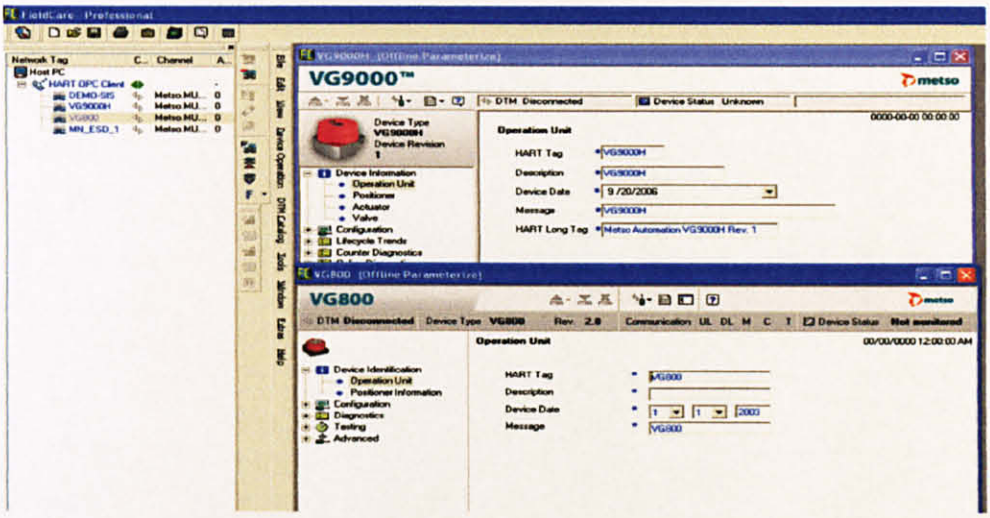




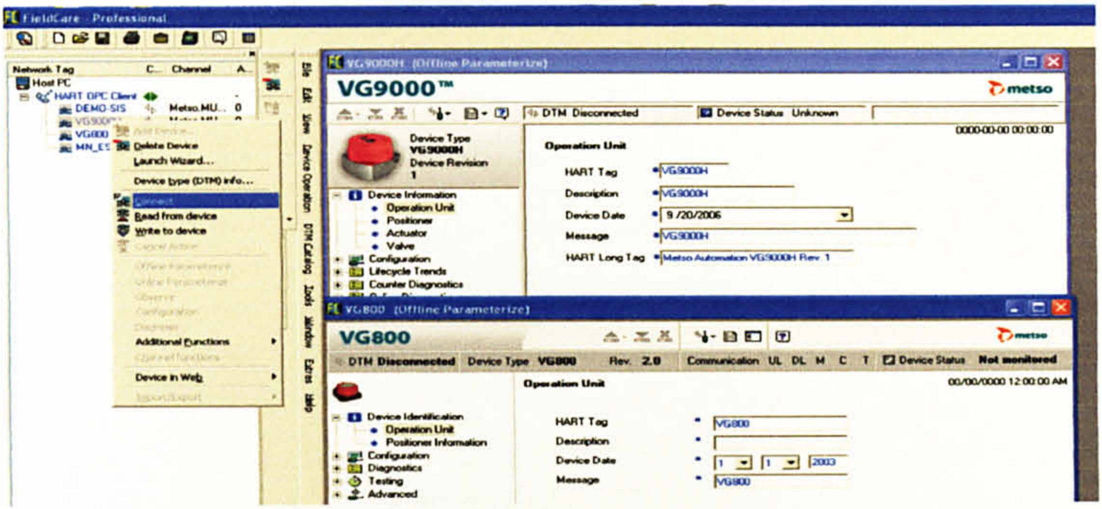
11. Right click at HOC > create network > ok > ok > ok

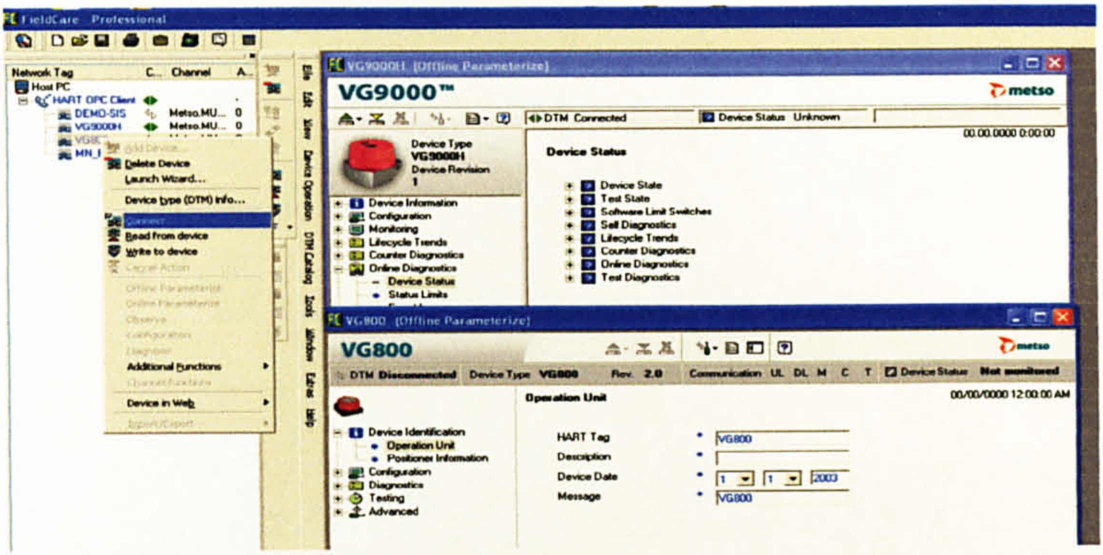


12. Double click VG9000H (ball) & VG800 (butterfly).



> Right click at VG9000H (ball) & VG800 (butterfly) > press connect



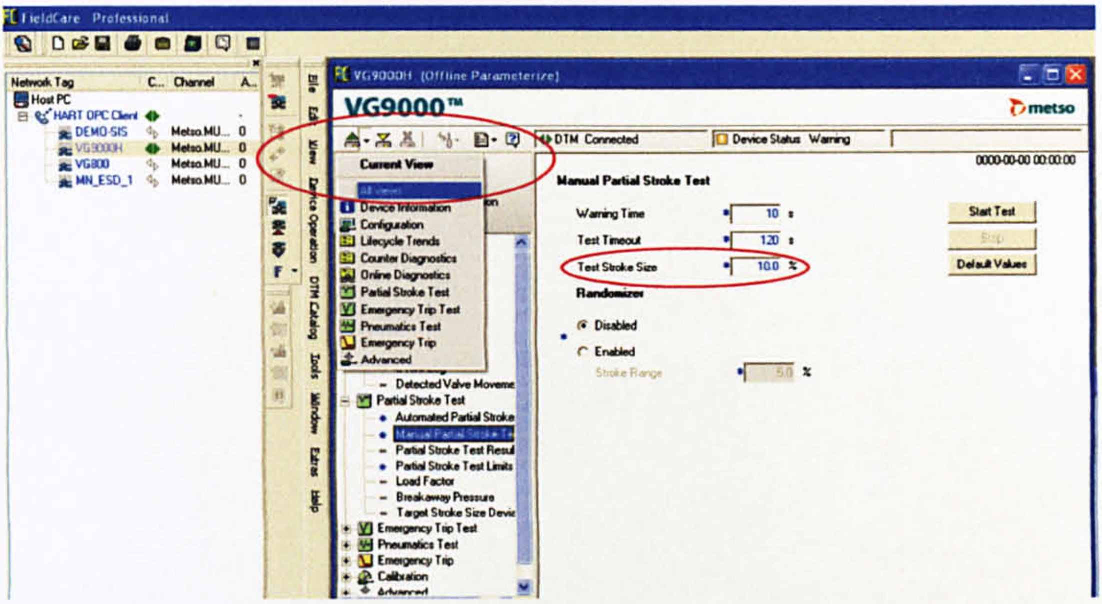


BALL VALVE (VG9000)

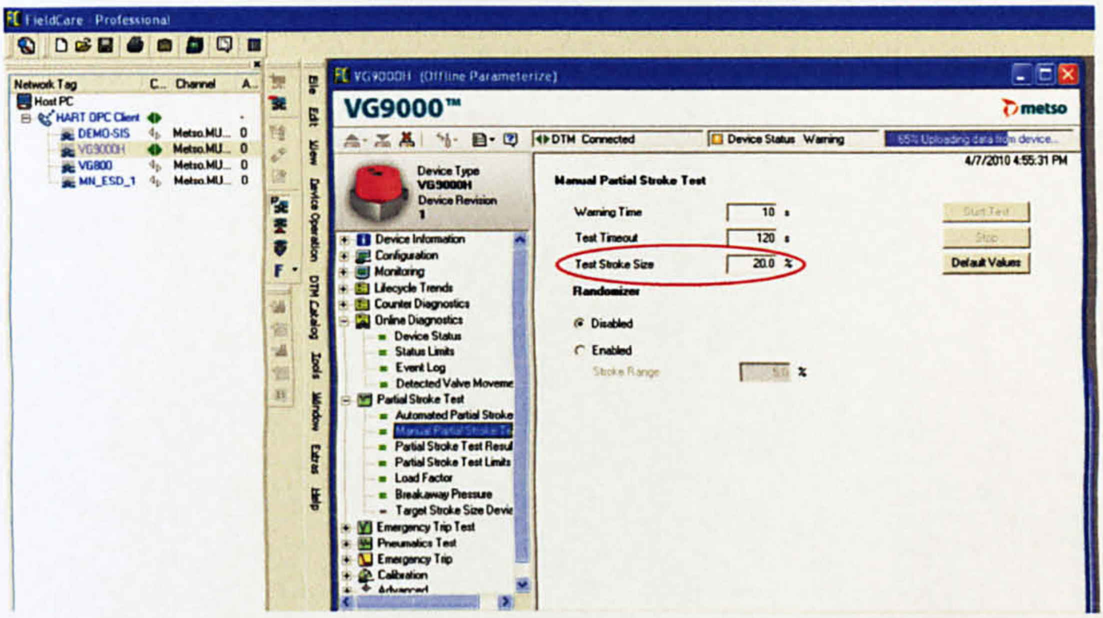
* test stoke size – 20%

1. Upload data (all views) – click arrow in green colour

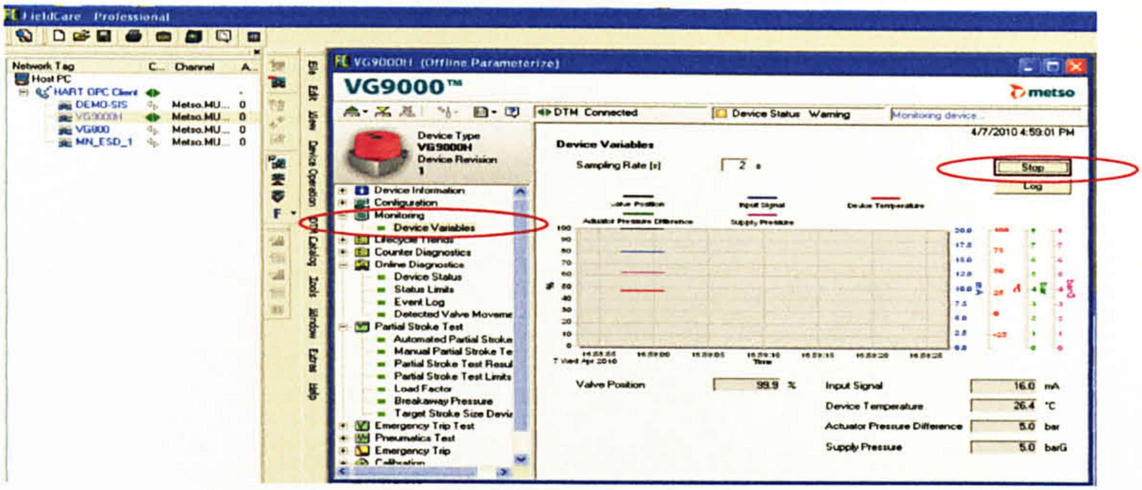
   Must be done to change the default stroke size from factory setting (10%) to our predetermined size (20%)



The stroke size will change to predetermined size. (20%)

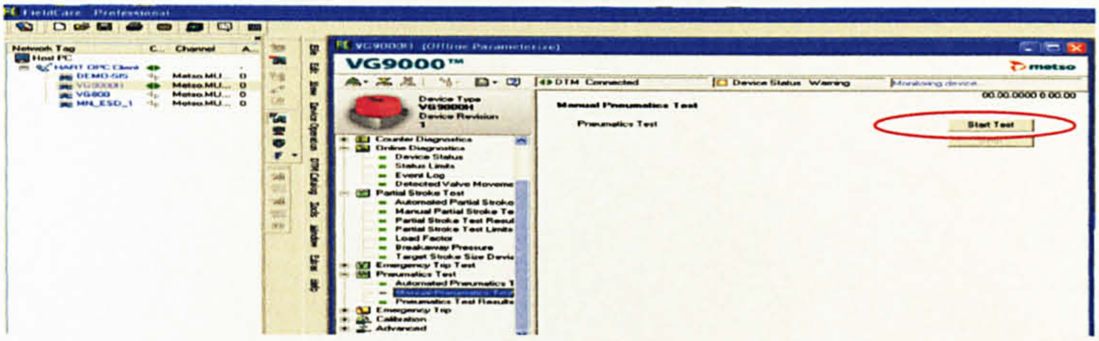


2. Click Monitoring > Device Variables > Start



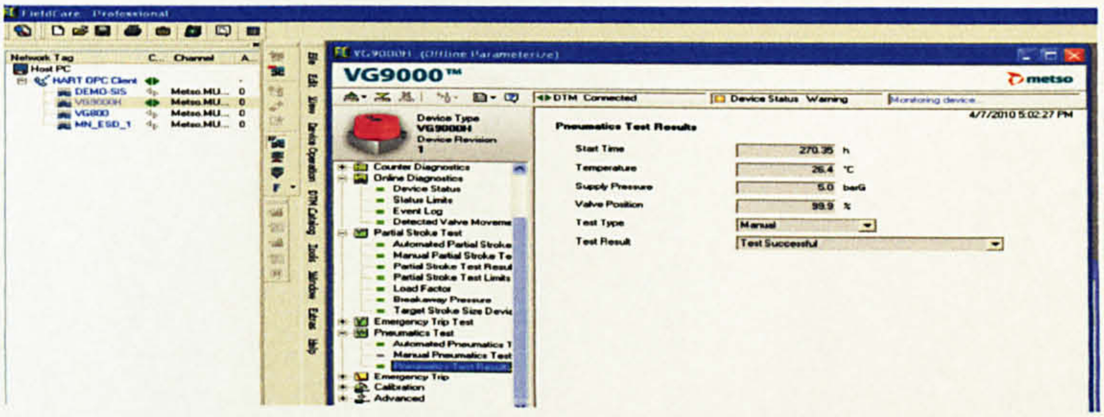
For PST only (1st, 2nd, 4th, 5th, and 6th stroke):

3. Click Pneumatic test > manual Pneumatic test > start test

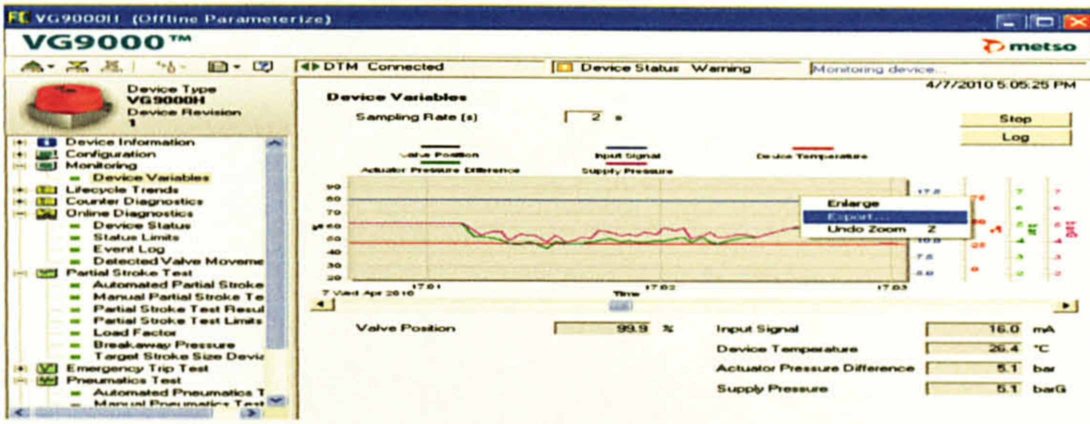


For record (Pneumatic test result):

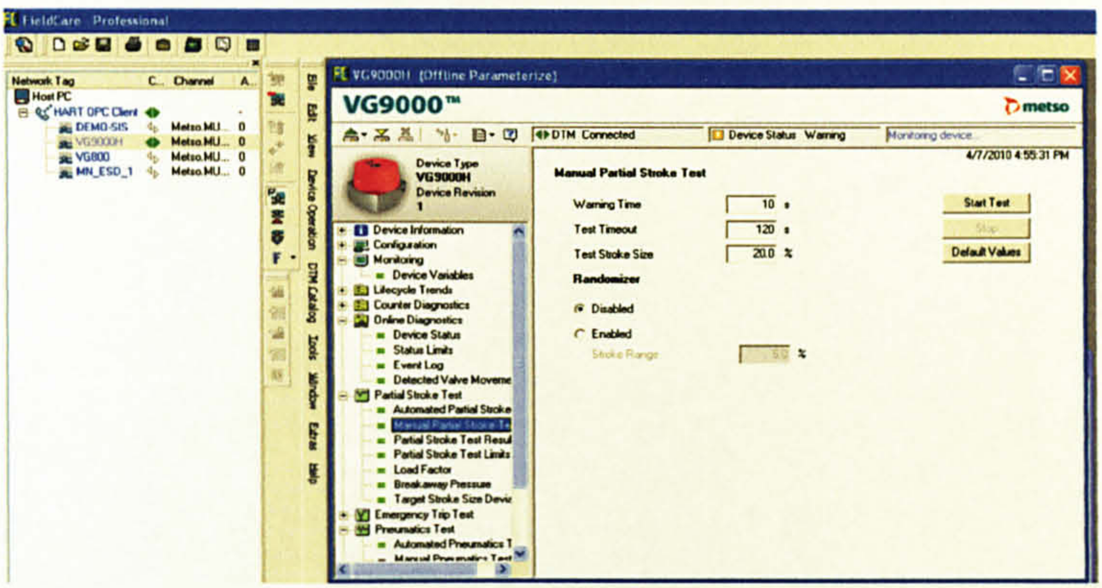
a. Print screen window pneumatic test result - test successful



b. Graph from online monitoring > right click > export > JPG > file > browse > "file name" > save > export

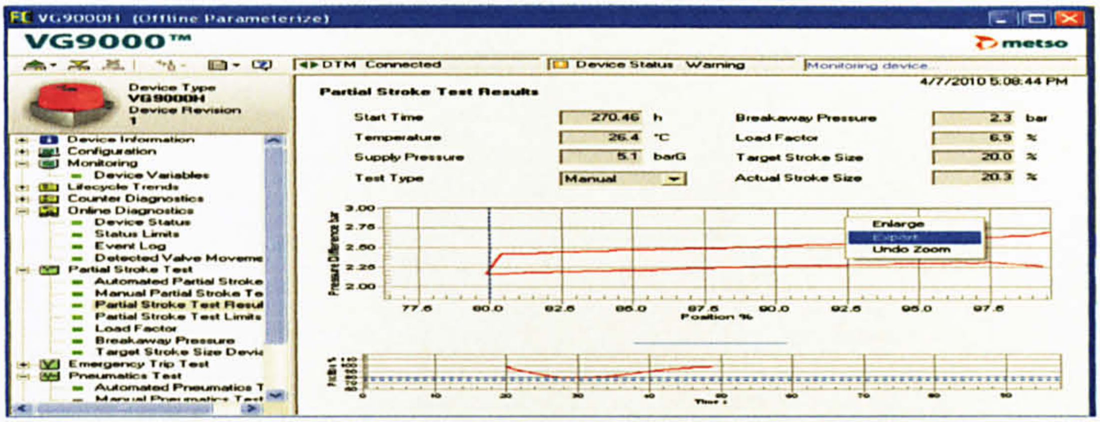


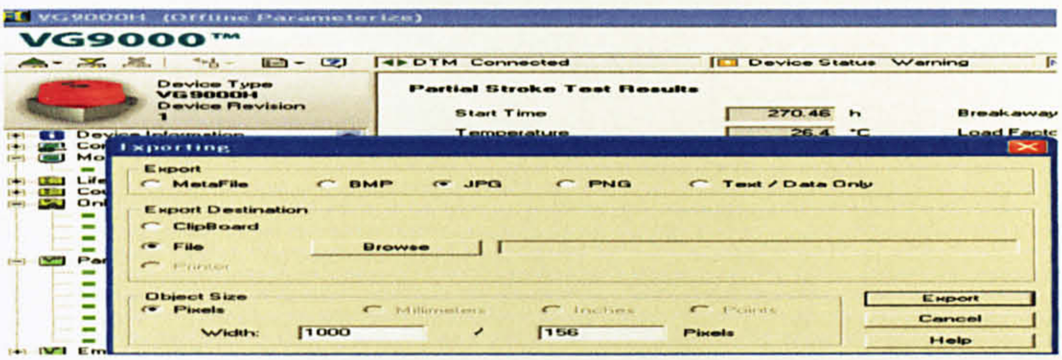
4. Click Partial Stroke Test > manual PST (stroke size =20%) > start test > ok



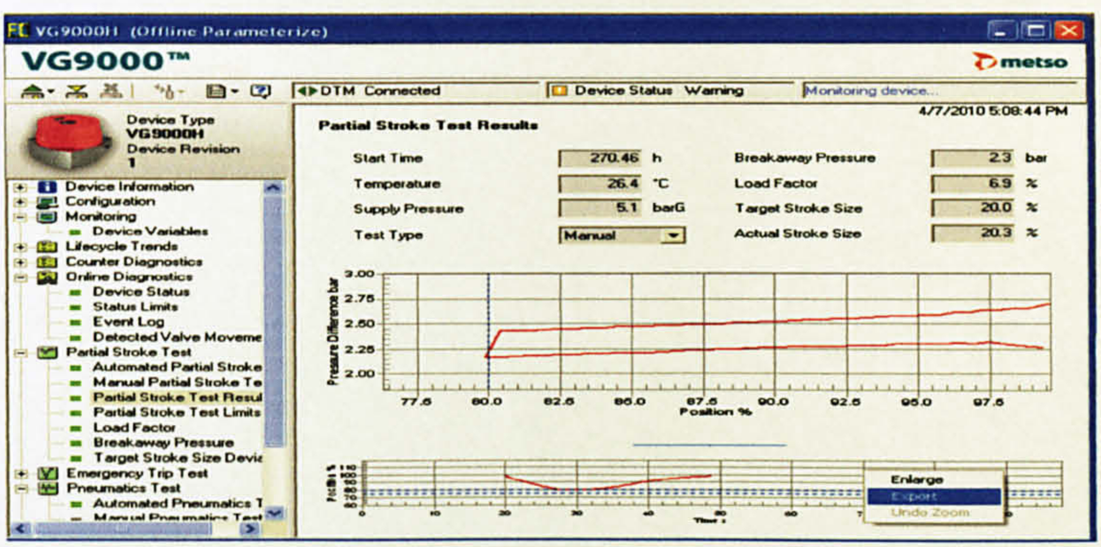
For record (PST result):

a. Graph pressure diff vs position > right click > export > JPG > file > browse > "file name" and where to save > save > export

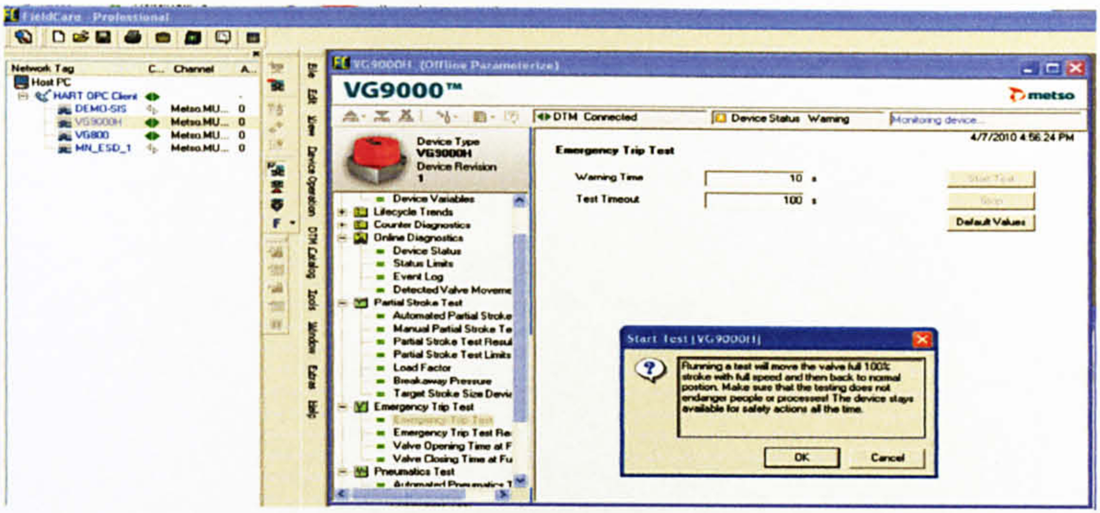


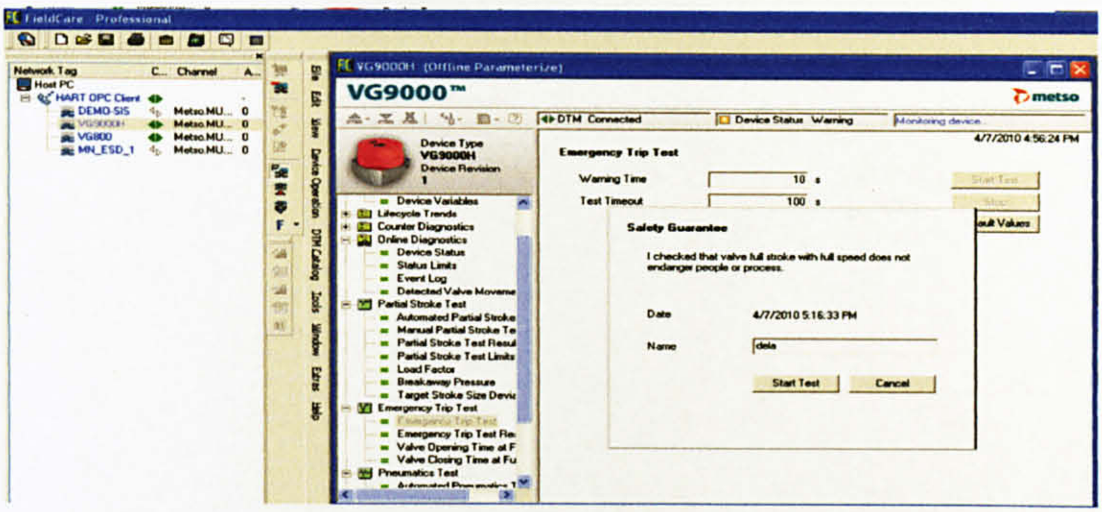


b. Graph position vs time > right click > export > JPG > file > browse > file name > save > export

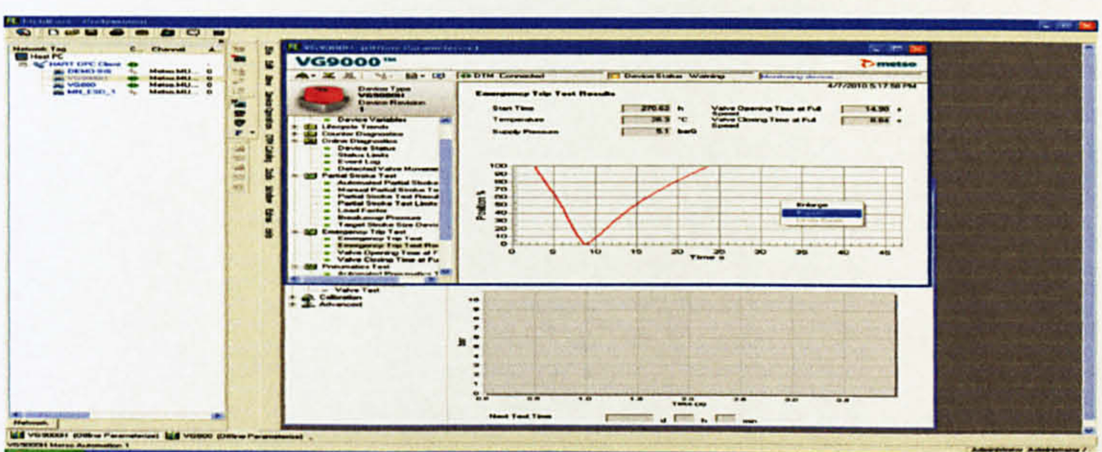


5. Click Emergency Trip test > start test > ok > safety guarantee - name

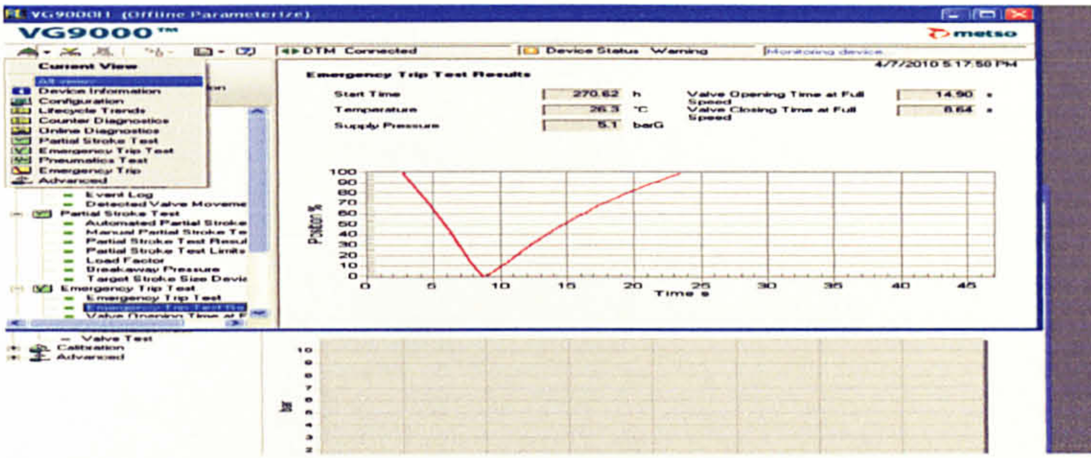




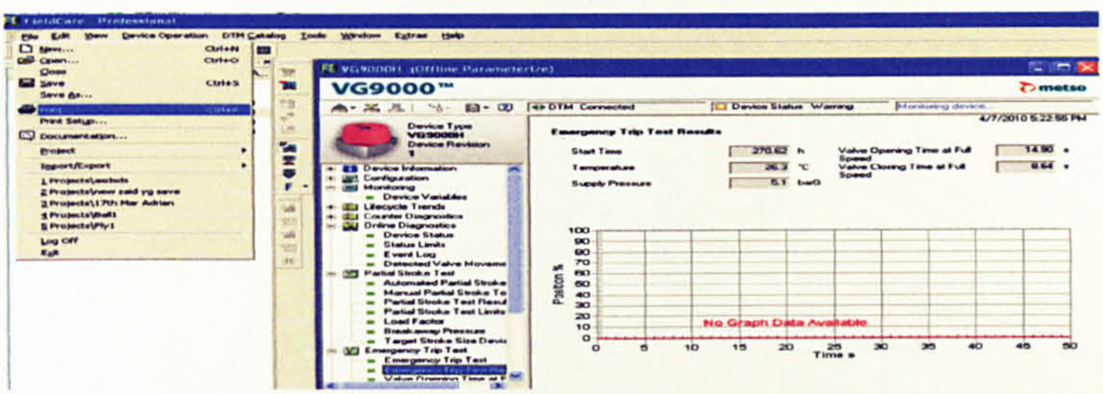
a. For record: graph position vs time > right click > export > JPG > file > browse > file name > save > export

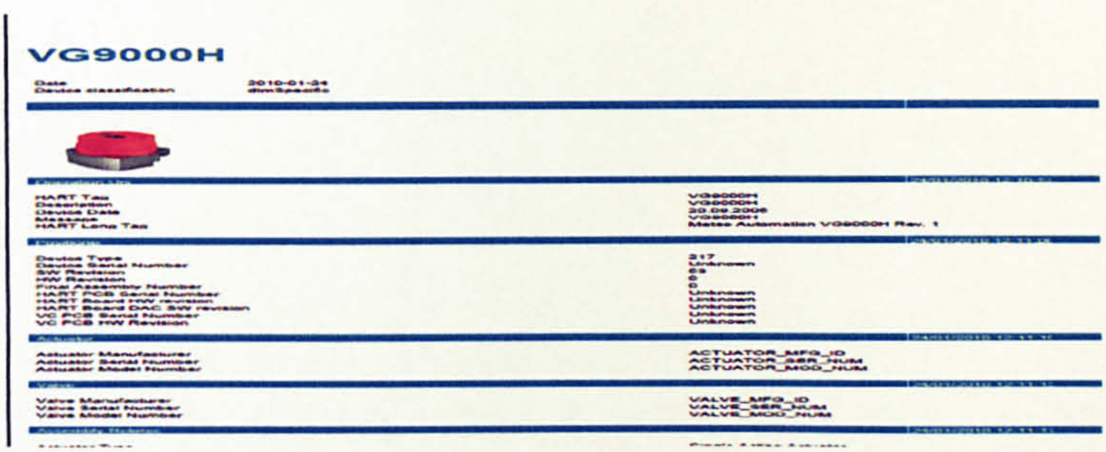


6. Upload all view.



7. File > Print > Save as > “file name” > save. (to get report in PDF format)





For PST + FST (3rd stroke):

8. Click Pneumatic test > manual Pneumatic test > start test

   For record (Pneumatic test result):

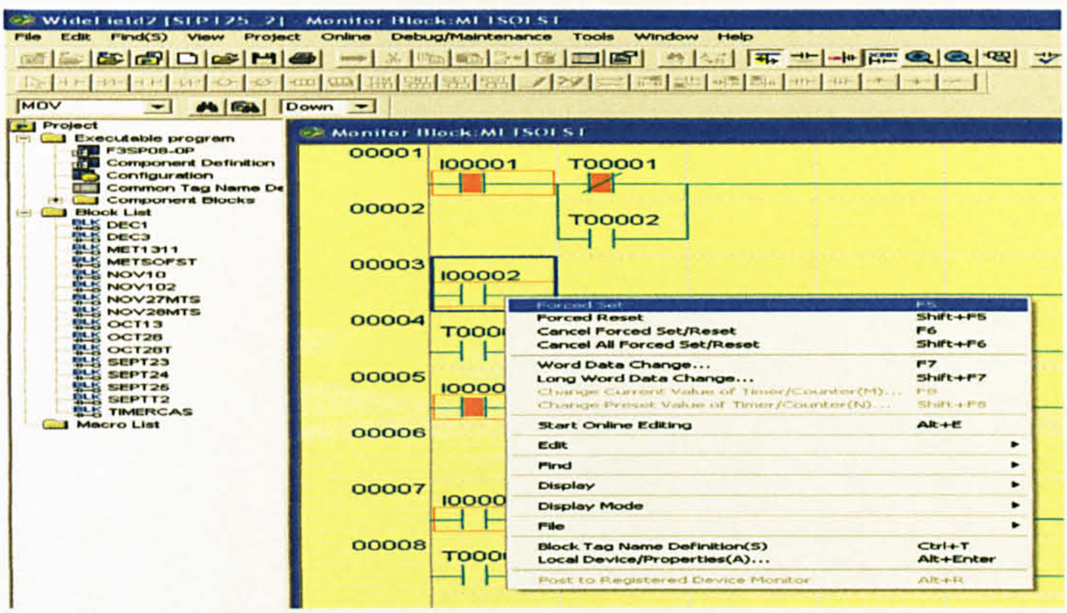
   a. Print screen window pneumatic test result - test successful

   b. Graph from online monitoring > right click > export > JPG > file > browse > file name > save > export

9. Click Partial Stroke Test > manual PST (stroke size =20%) > start test > ok

   BUT when heard sound of air been released, go to Widefield (ladder diagram),

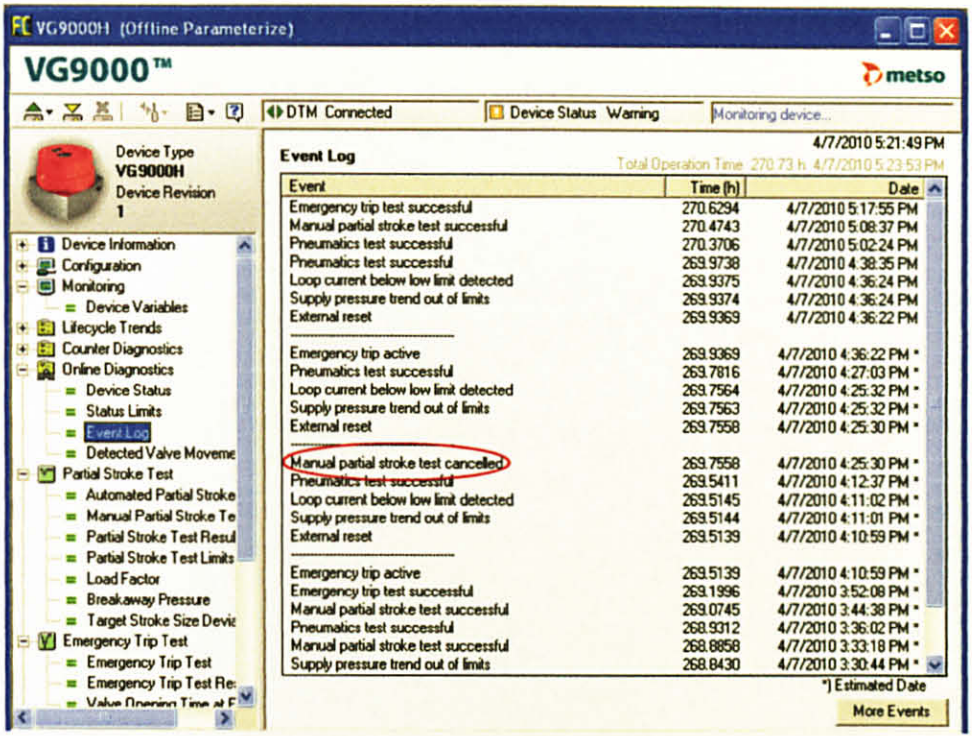
   Right click at I00002 (for ball valve) > click forced set



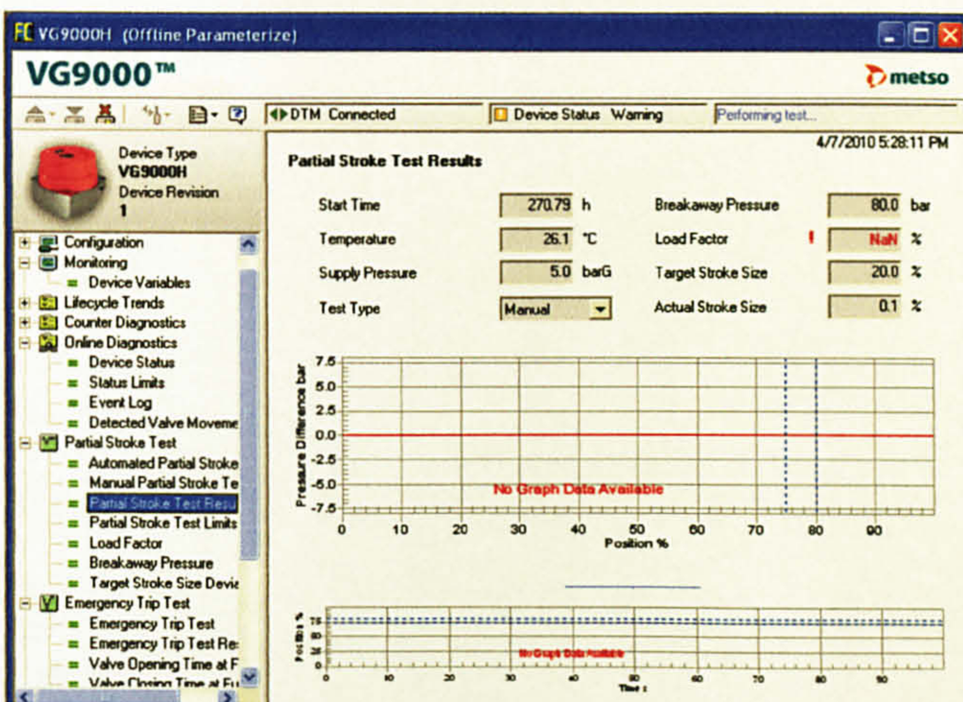
For record (PST + FST result):

a. Click green arrow button (Upload data) > all view

   Online Diagnostic > Event Log > Print Screen > Paste at word file



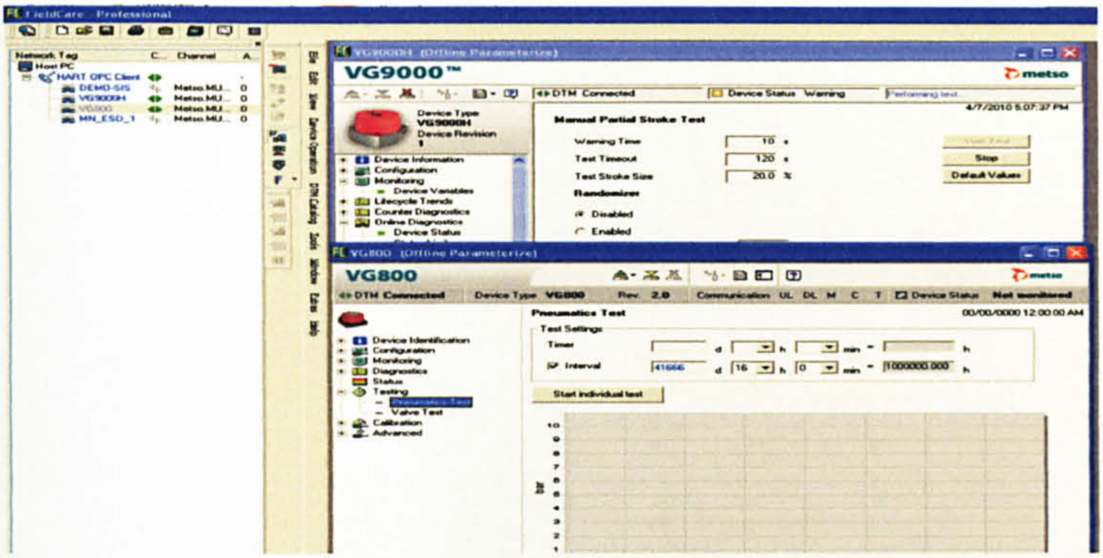
b. Print Screen PST window that indicate no graph (PST is cancelled)> Paste at word file



BUTTERFLY VALVE (VG800)

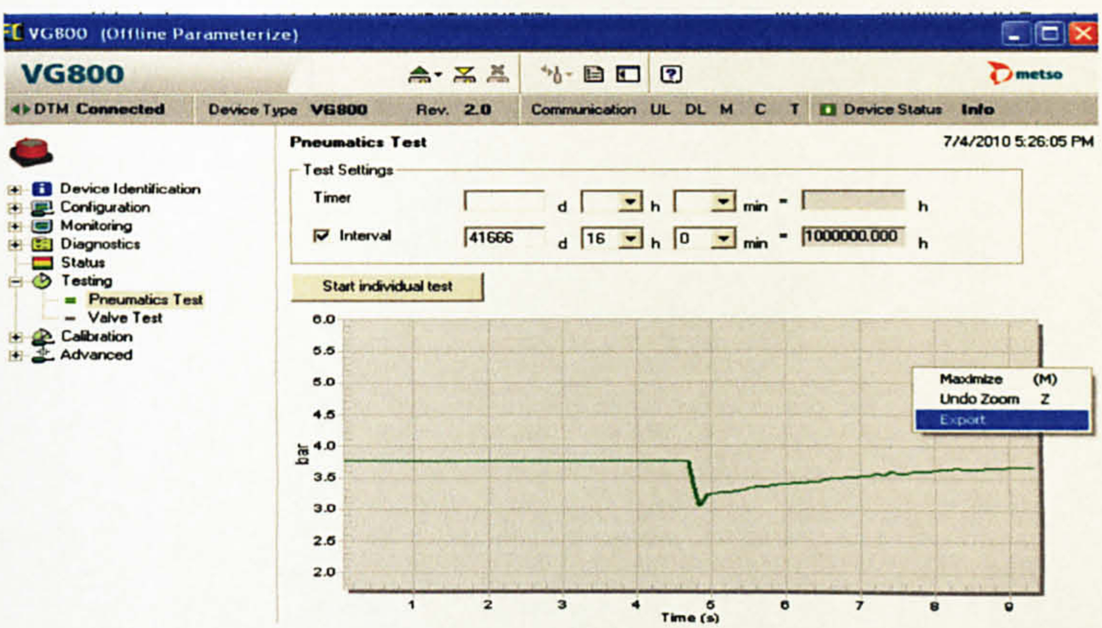
For PST only (1st, 2nd, 4th, 5th, and 6th stroke):

1. Click Pneumatic Test > manual Pneumatic test > start test

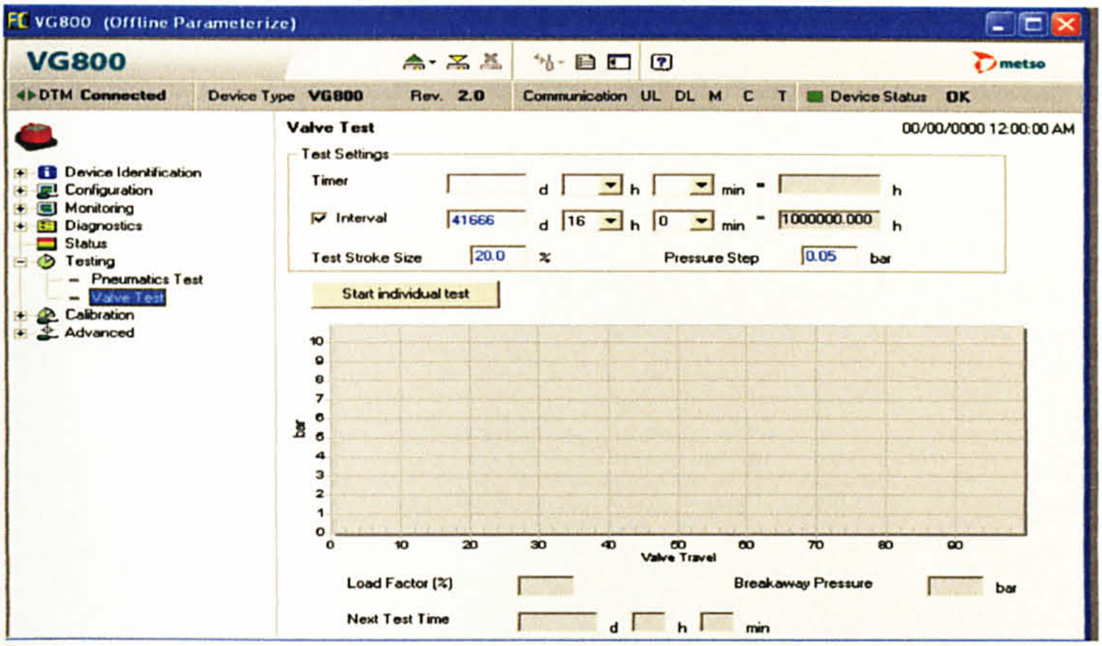


For record:

Pneumatic test graph > right click > export > JPG > file > browse > file name > save > export

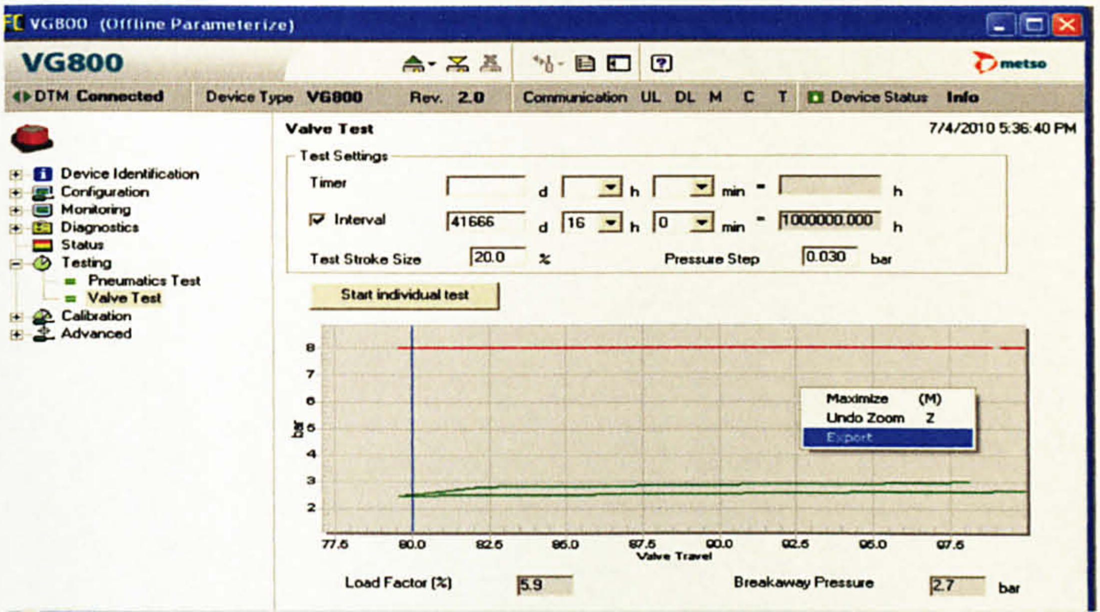


2. Click Valve Test > start



For record:

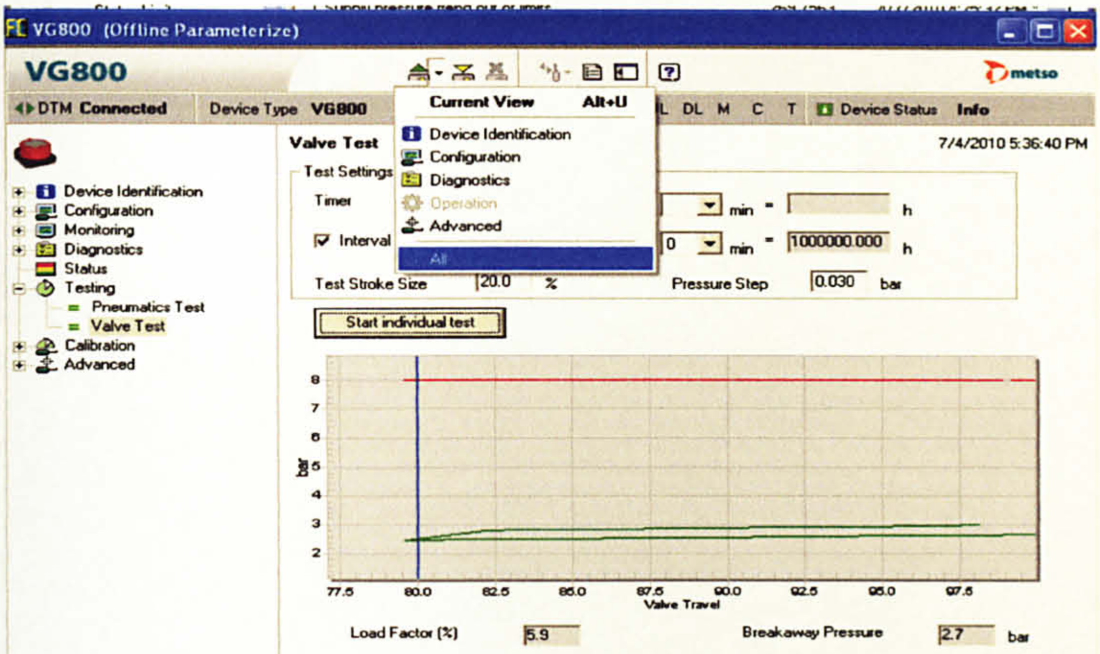
Valve test graph > right click > export > JPG > file > browse > file name > save > export



For record:

Save the load factor & breakaway pressure.

3. Upload view > all



File > Print > Save as > file name > save. (to get report in PDF format)

VG800

Date	2010-01-24
Device classification	positioner

Device Type	VG800
Manufacturer	Metso Automation
Device ID	1410103
SW Revision	2
HW Revision	1
Final Assembly Number	0
Device Serial Number	2008-03-0300
Position Sensor Serial Number	834550
HART Tag	VG800
Description	
Device Date	01.01.2003
Message	VG800
Power-up Mode	Automatic
Device Keyboard	Enabled
Valve Acting Type	Rotary
Rotation Direction to Fail Safe	Clockwise
Fail Safe Action	Close
Measurement Time (s)	0
Stabilizing Time (s)	0
Valve Dead Angle (%)	1
Valve Test Count	10
Pneumatics Test Count	10

For PST + FST (3rd stroke):

4. Click Pneumatic test > manual Pneumatic test > start test

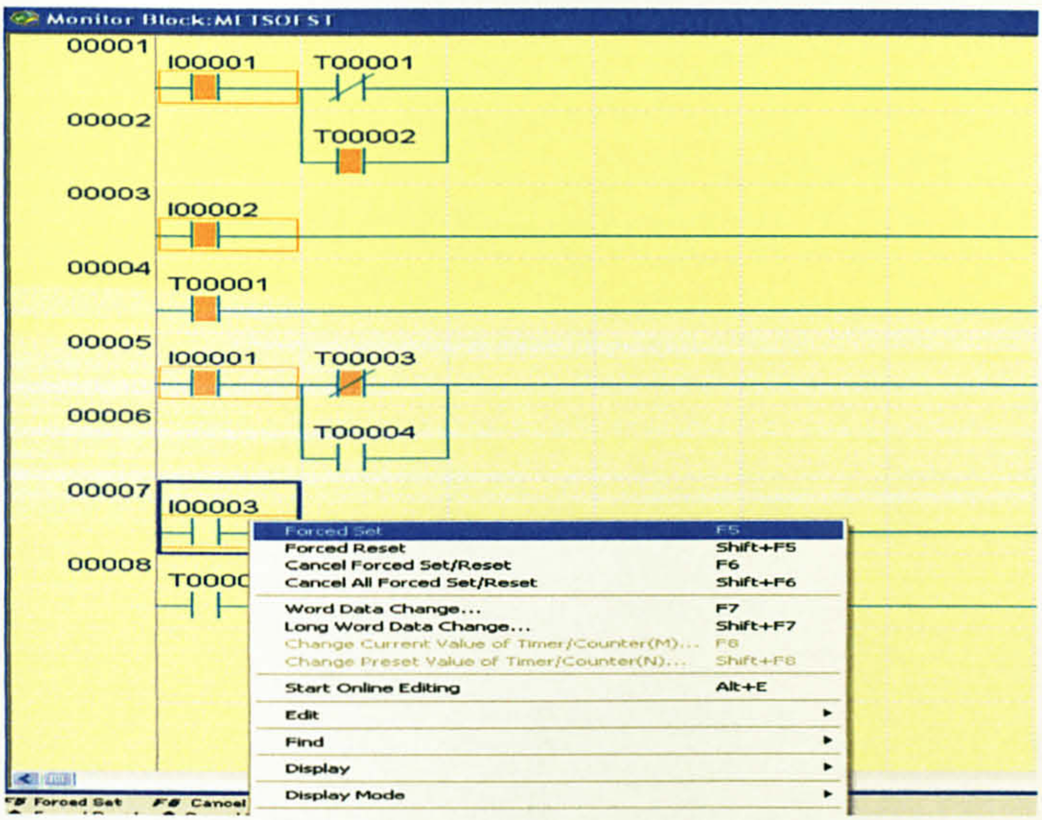
   For record (Pneumatic test result):

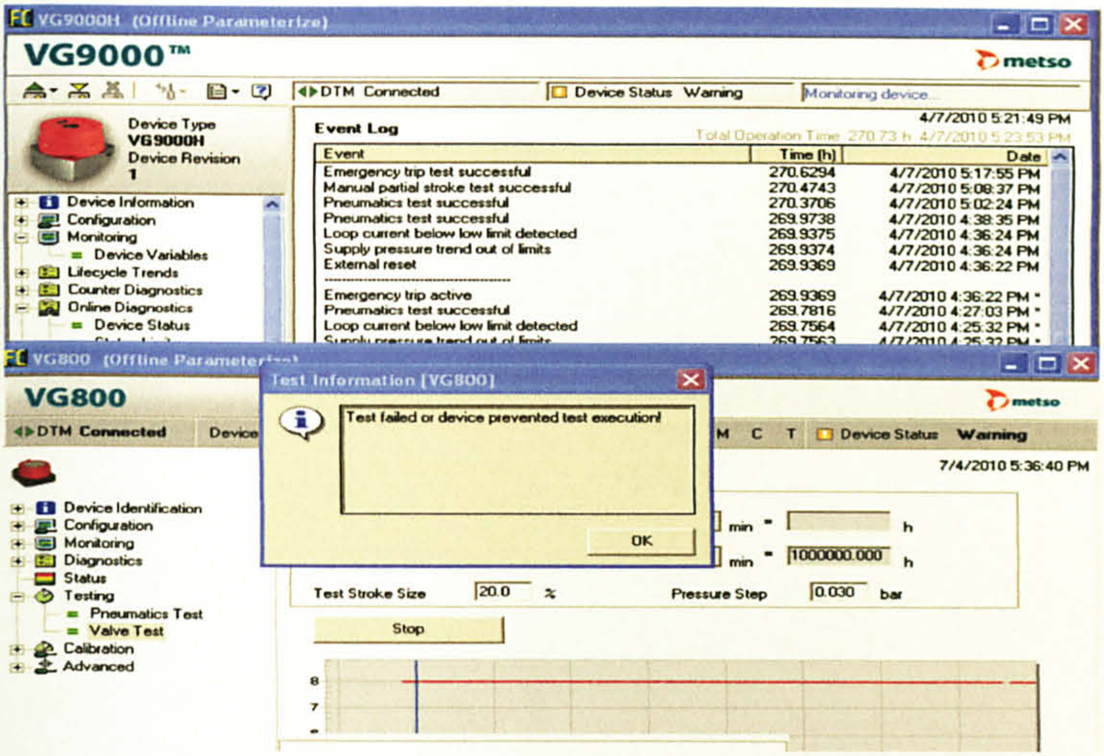
   a. graph> right click > export > JPG > file > browse > file name > save > export

5. Click Partial Stroke Test > manual PST (stroke size =20%) > start test > ok

   BUT when heard sound of air been released, go to Widefield (ladder diagram),

   Right click at I00003 (for butterfly valve) > click forced set





TO CLOSE EQUIPMENTS AND SOFTWARE

FieldCare > Right Click Hart OPC Client > Disconnect > press cross symbol > ok > Save Project? NO!

Widefield2 > right click I00001 > forced reset > press cross symbol > yes

HART > close

APPENDIX E

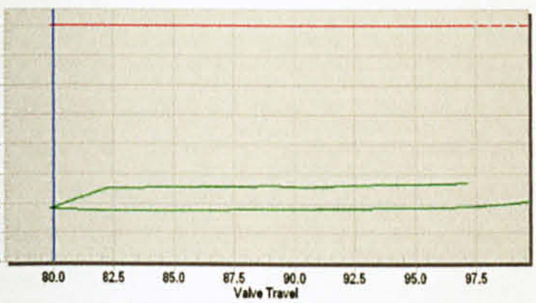
PHASE I RESULTS FOR BALL VALVE

Sample 1: Day 1

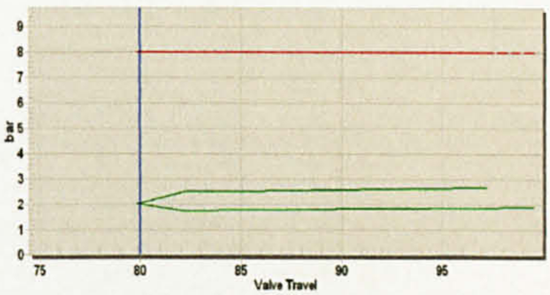
Test Date: December 22nd, 2008

Time : 10.20am – 11.35 am

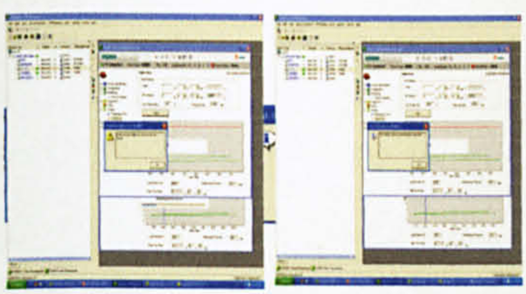
First Stroke:



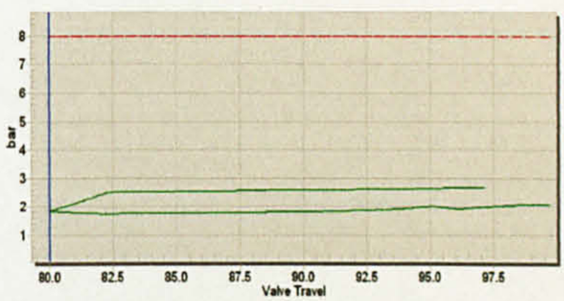
Second Stroke:



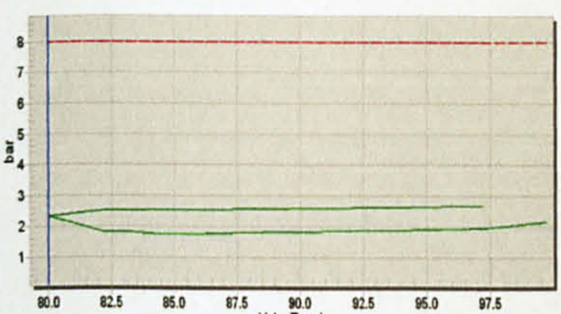
Third Stroke – PST + FST:



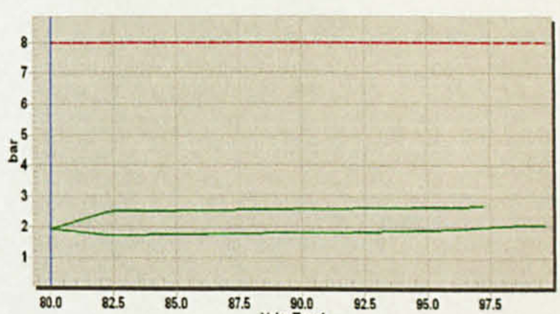
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

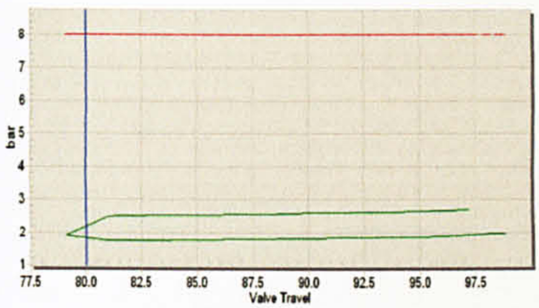


Sample 2: Day 10

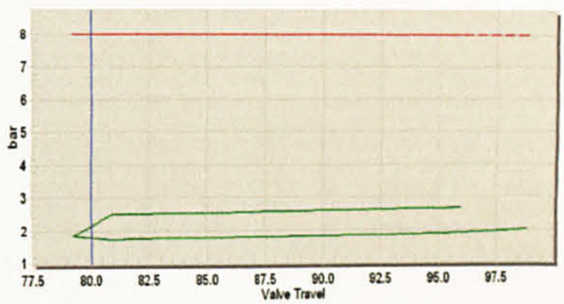
Test Date: January 14th, 2009

Time : 8:50 am – 10:05 am

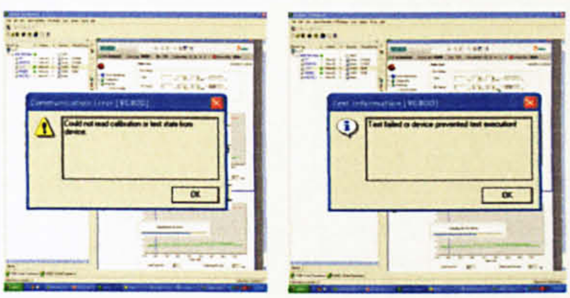
First Stroke:



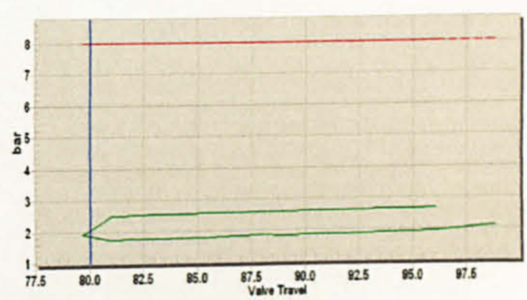
Second Stroke:



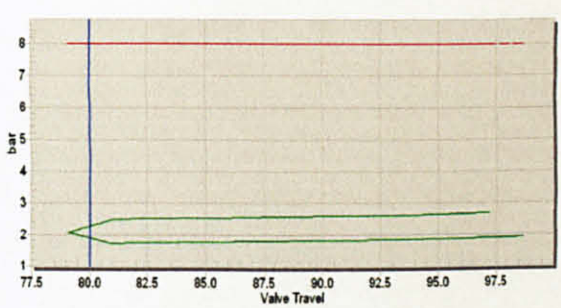
Third Stroke – PST + FST:



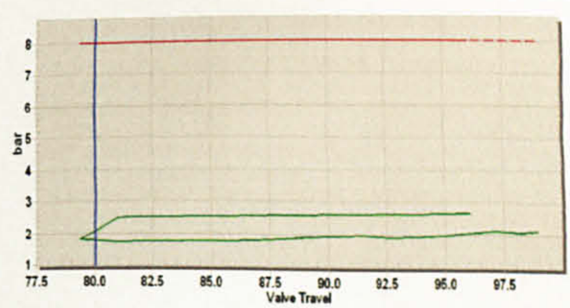
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

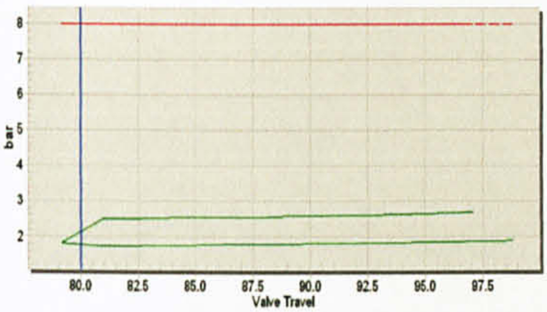


Sample 3: Day 20

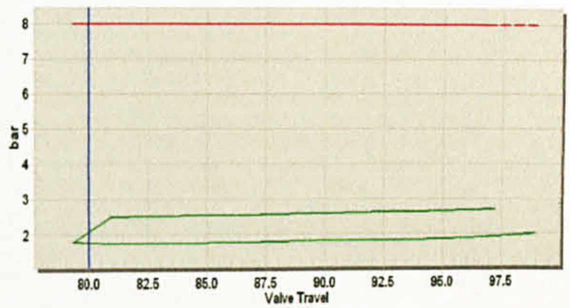
Test Date: January 24th, 2009

Time : 9:00 am – 10:15 am

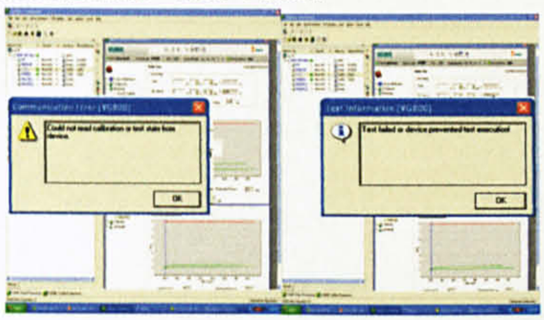
First Stroke:



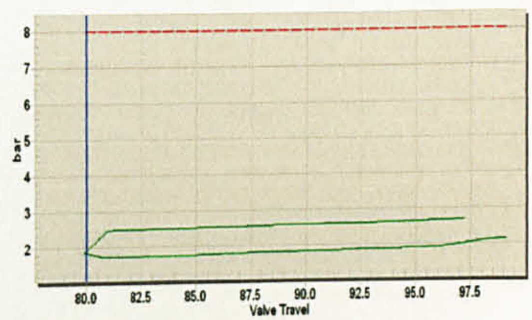
Second Stroke:



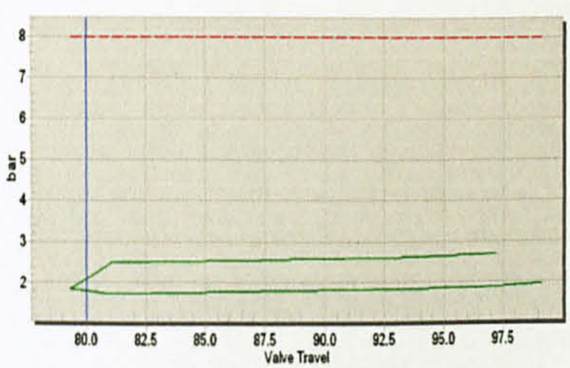
Third Stroke – PST + FST:



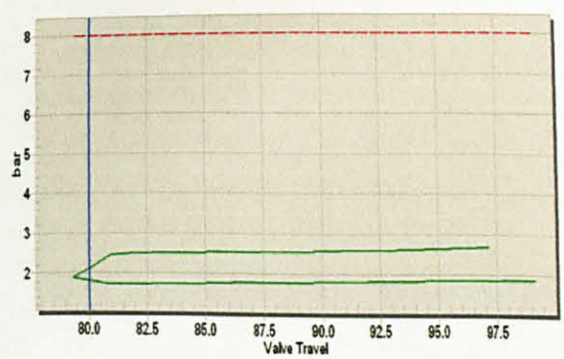
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

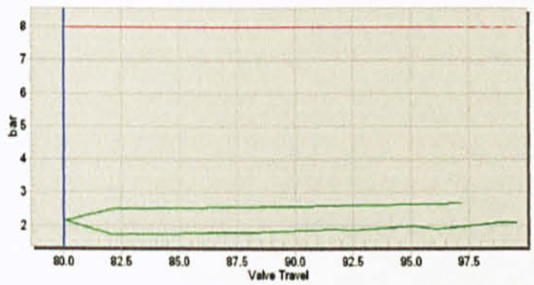


Sample 4: Day 30

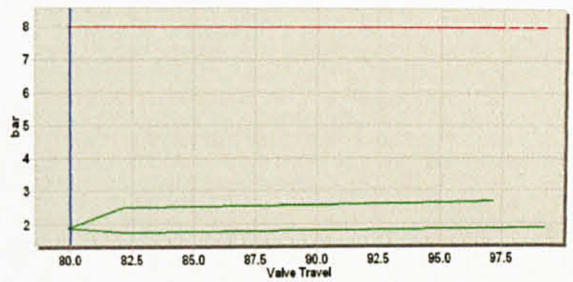
Test Date: February 12th, 2009

Time : 11:20 am – 12:35 pm

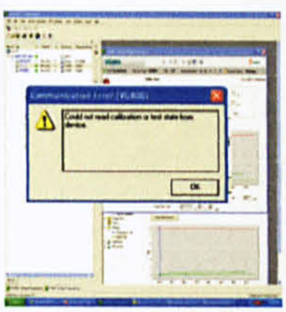
First Stroke:

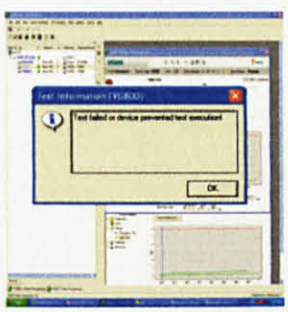


Second Stroke:

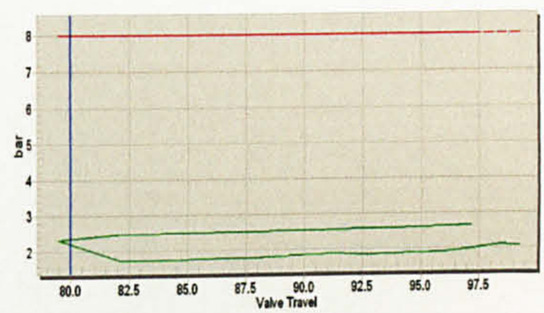


Third Stroke – PST + FST:

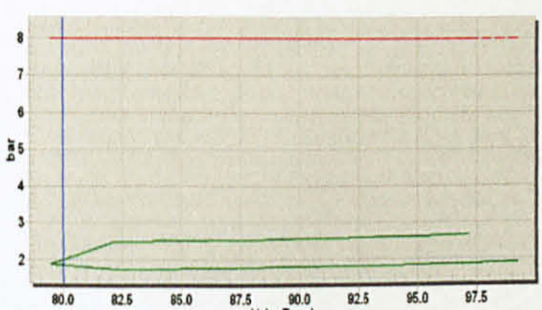




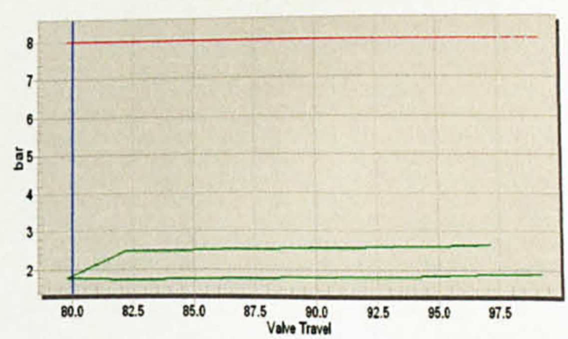
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

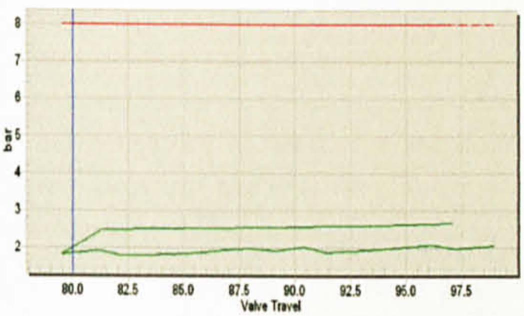


Sample 5: Day 40

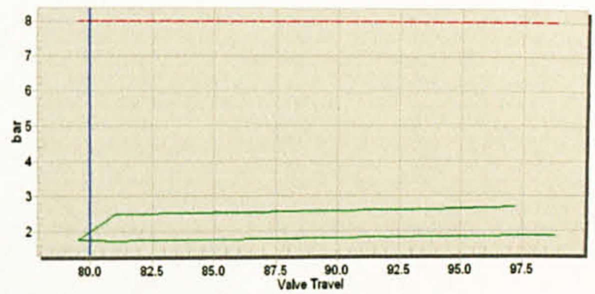
Test Date: February 28th, 2009

Time : 9:00 am – 10:15 am

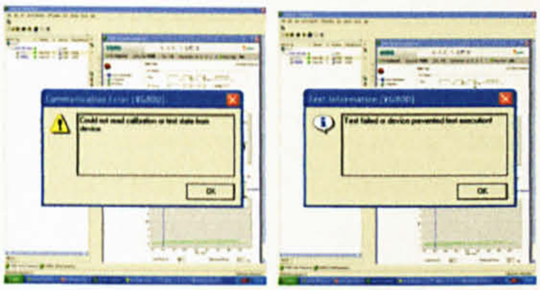
First Stroke:



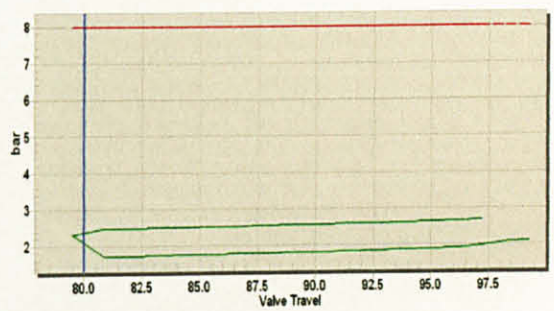
Second Stroke:



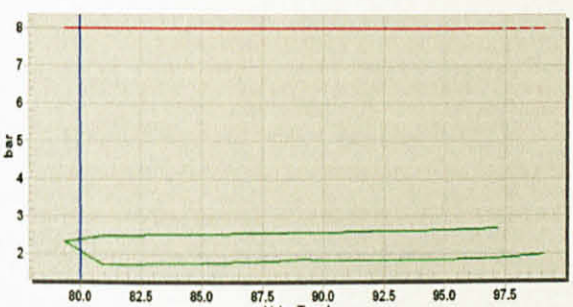
Third Stroke – PST + FST:



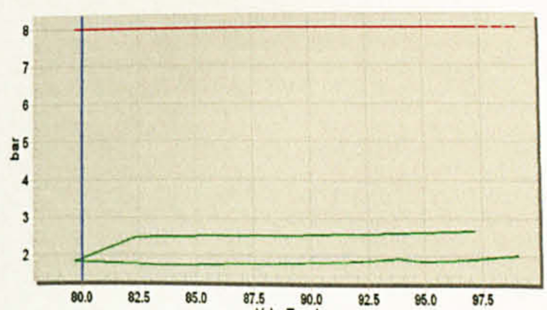
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

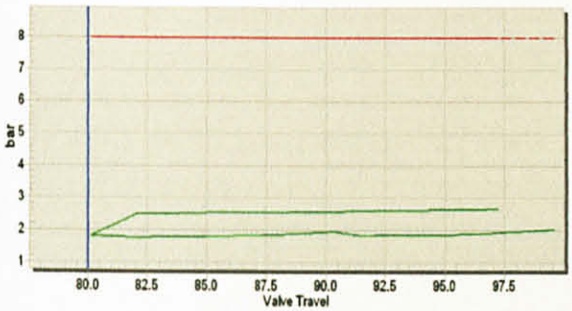


Sample 6: Day 50

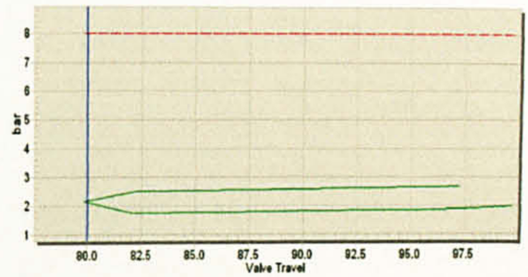
Test Date: March 16th, 2009

Time : 12:45 pm – 2:00 pm

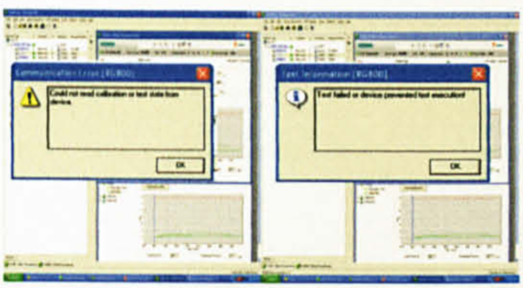
First Stroke:



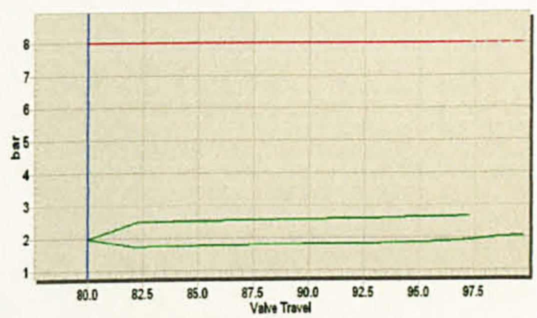
Second Stroke:



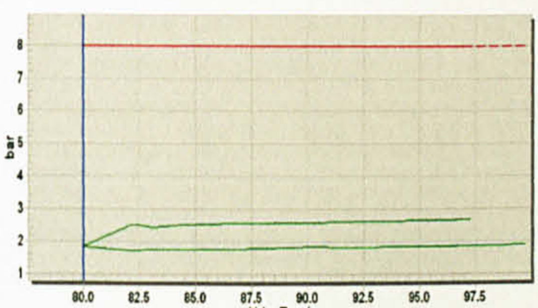
Third Stroke – PST + FST:



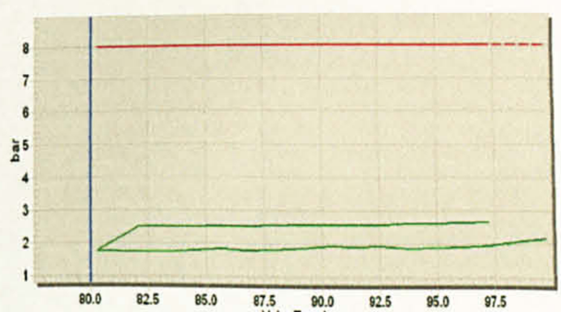
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

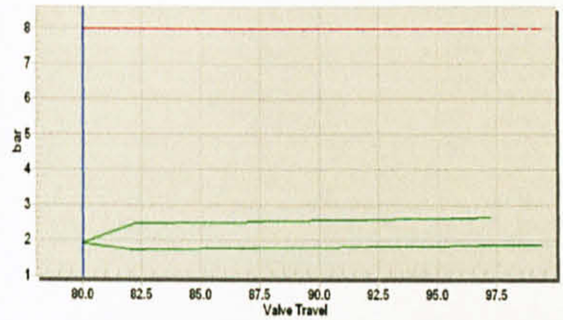


Sample 7 : Day 60

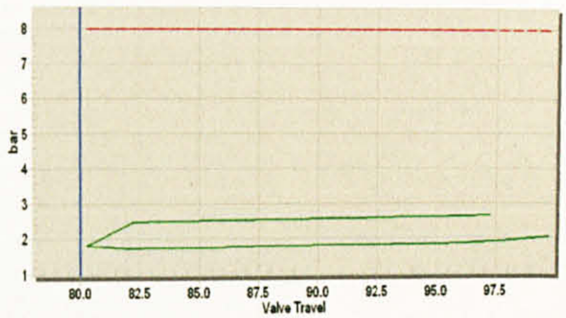
Test Date : July 26th, 2009

Time : 11.50 am – 1:15 pm

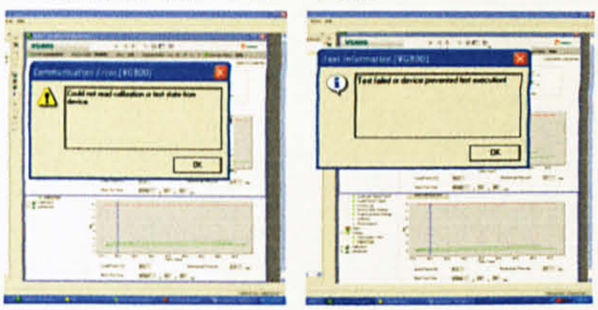
First Stroke:



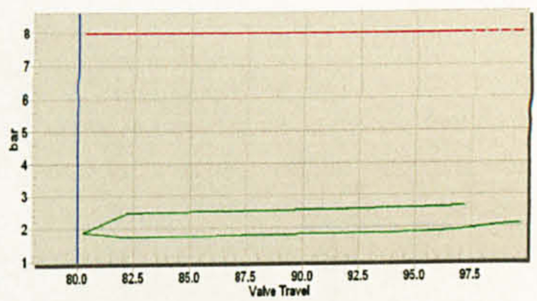
Second Stroke:



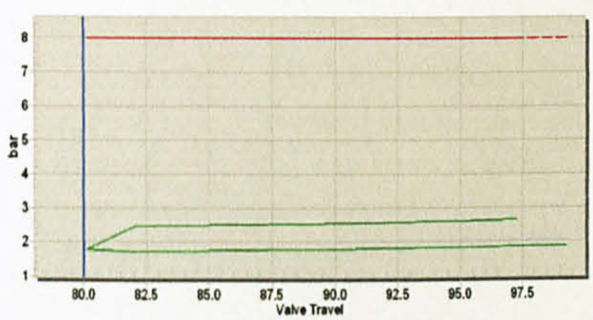
Third Stroke – PST + FST:



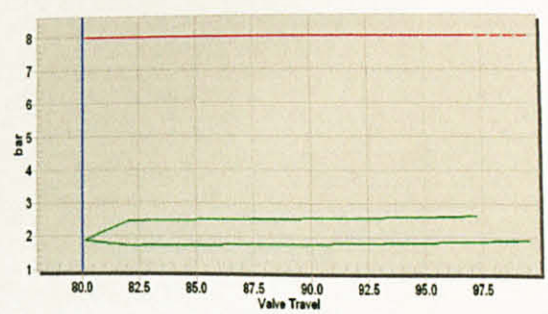
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

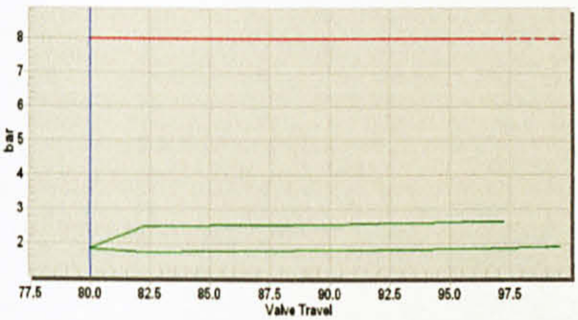


Sample 8: Day 70

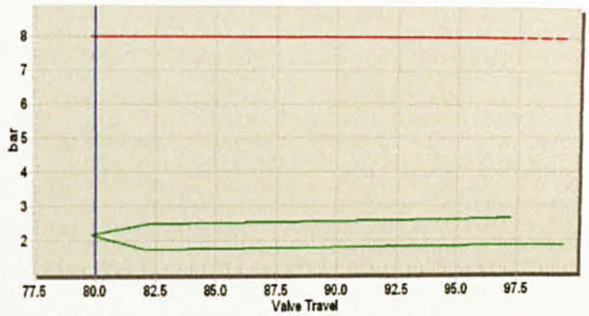
Test Date: August 21st, 2009

Time : 12:45 pm – 2:00 pm

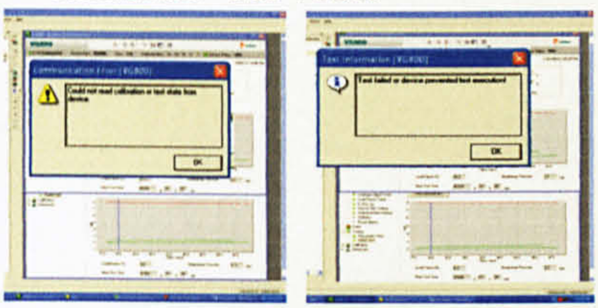
First Stroke:



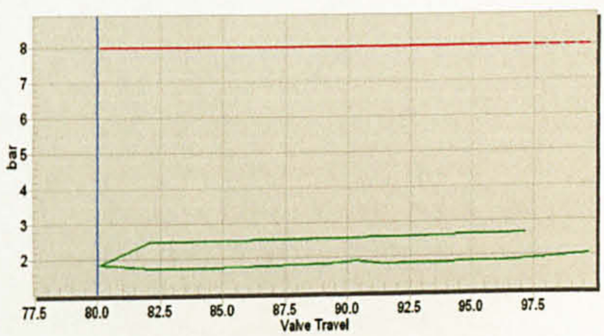
Second Stroke:



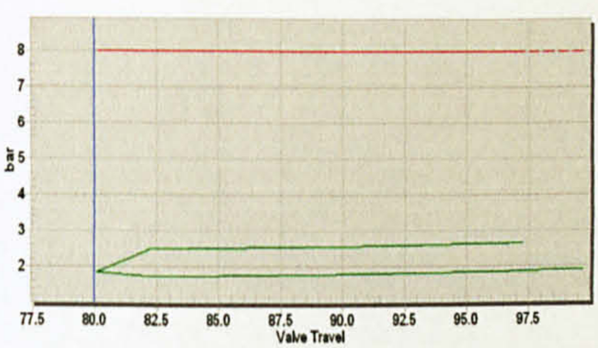
Third Stroke – PST + FST:



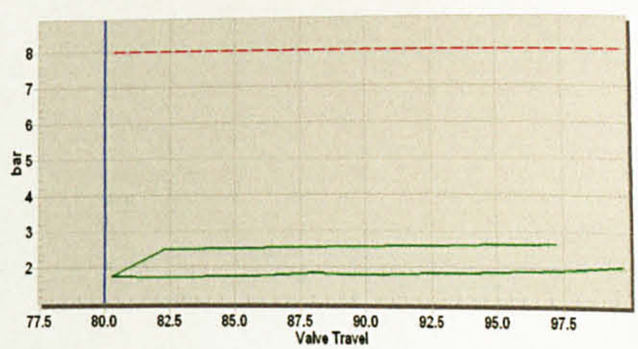
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

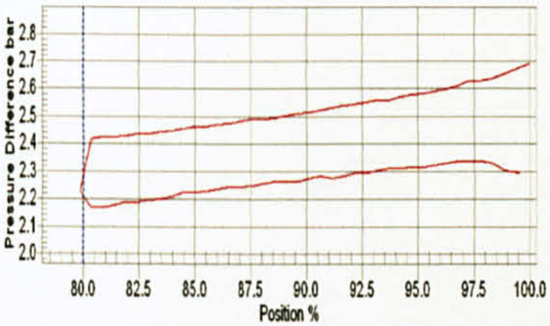


Sample 9 : Day 80

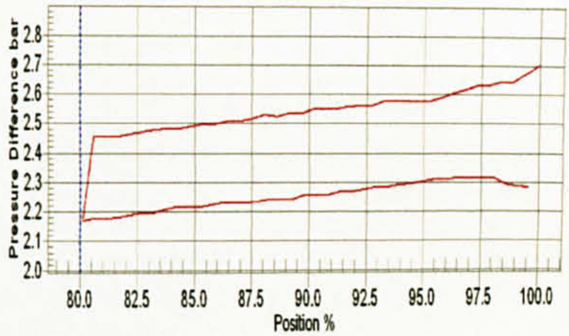
Test Date : December 3rd, 2009

Time : 9.30 am – 11:00 am

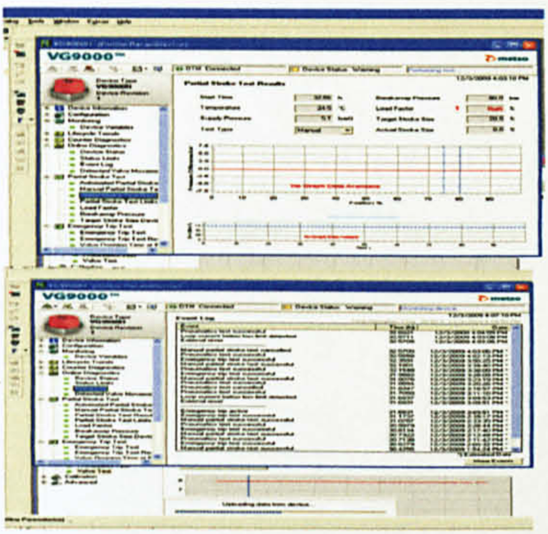
First Stroke:



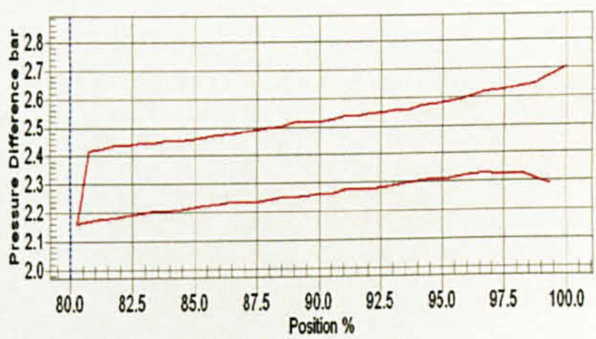
Second Stroke:



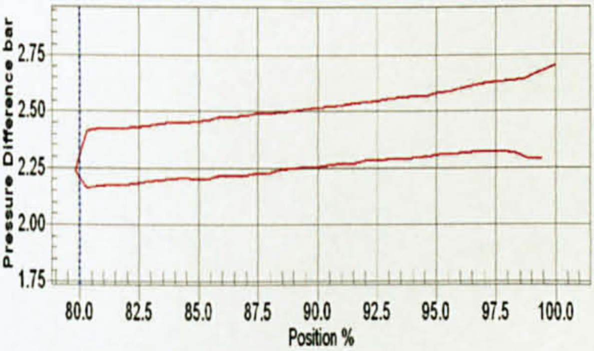
Third Stroke – PST + FST:



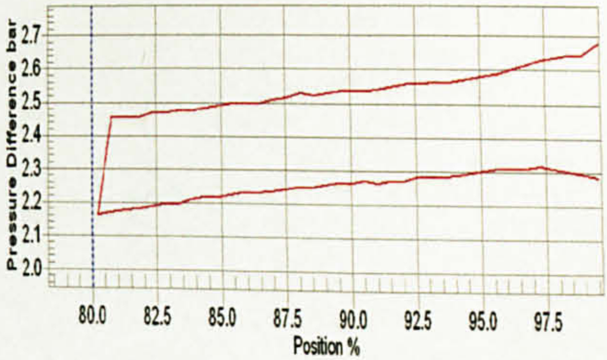
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

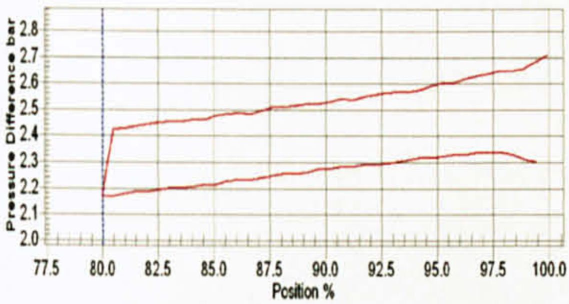


Sample 10 : Day 90

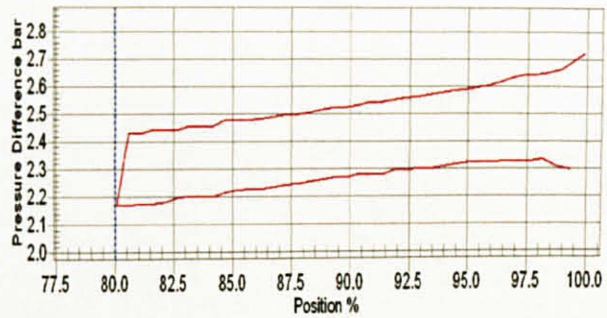
Test Date : January, 24th 2010

Time : 2.30pm – 4.00pm

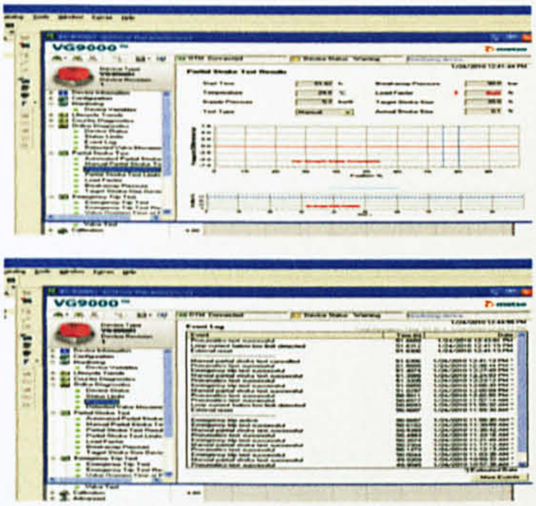
First Stroke:



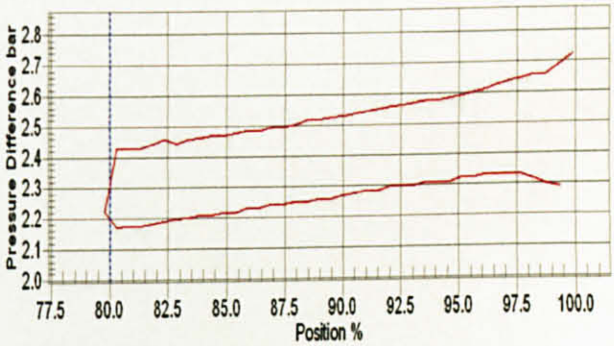
Second Stroke:



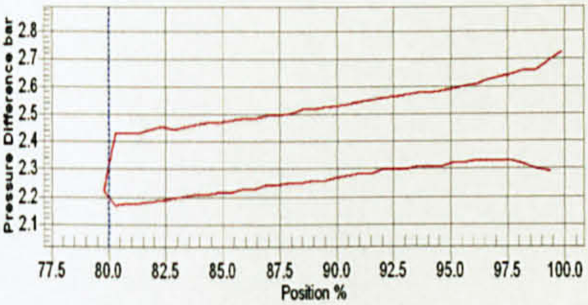
Third Stroke – PST + FST:



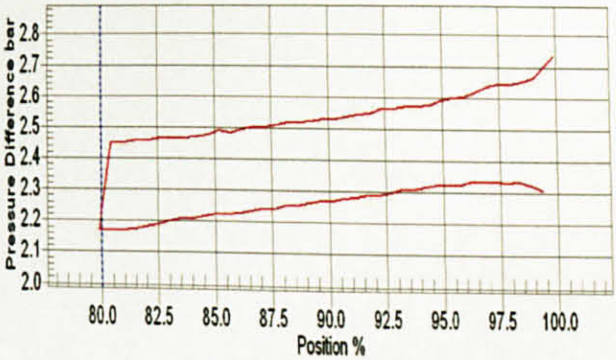
Forth Stroke:



Fifth Stroke:



Sixth Stroke:



APPENDIX F

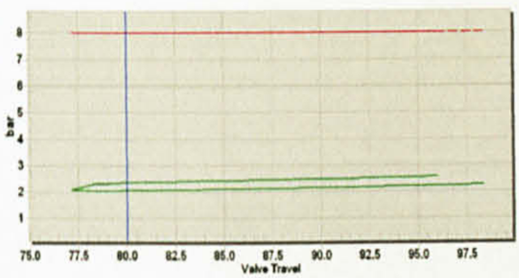
PHASE I RESULT FOR BUTTERFLY VALVE

Sample 1: Day 1

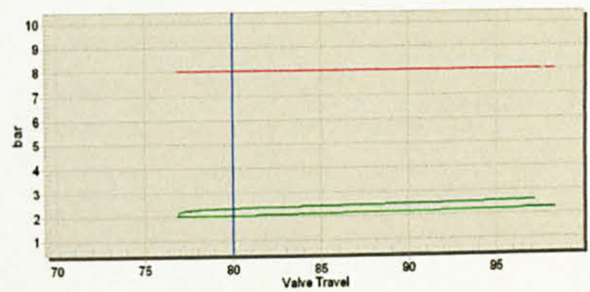
Test Date: December 22nd, 2008

Time : 10.20am – 11.35 am

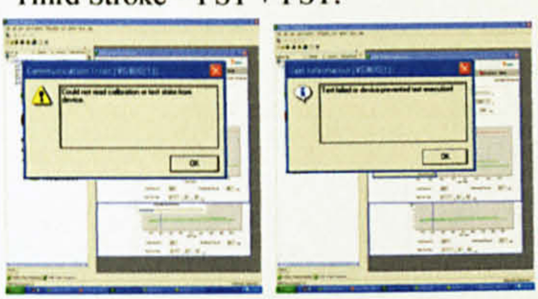
First Stroke:



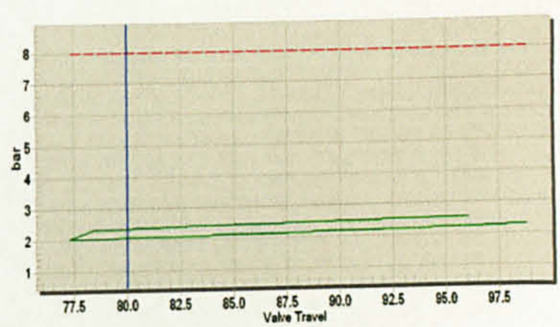
Second Stroke:



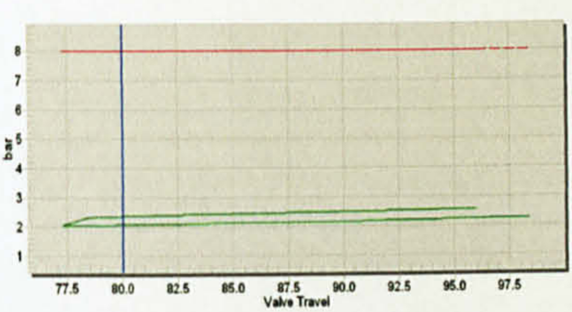
Third Stroke – PST + FST:



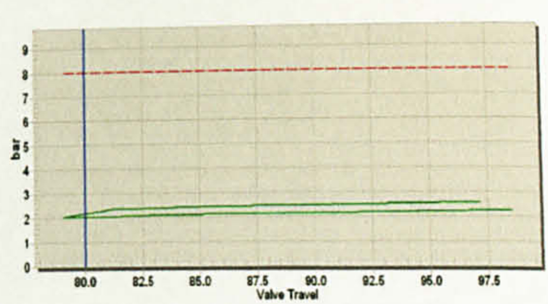
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

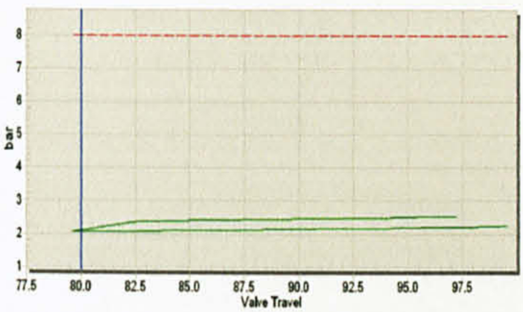


Sample 2: Day 10

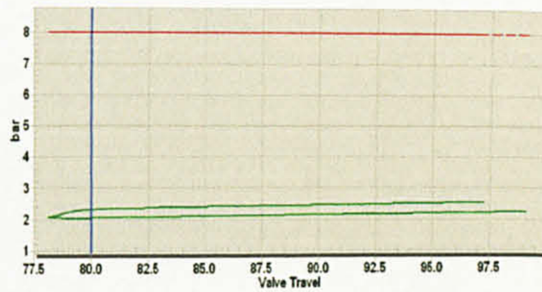
Test Date: January 14th, 2009

Time : 8:50 am – 10:05 am

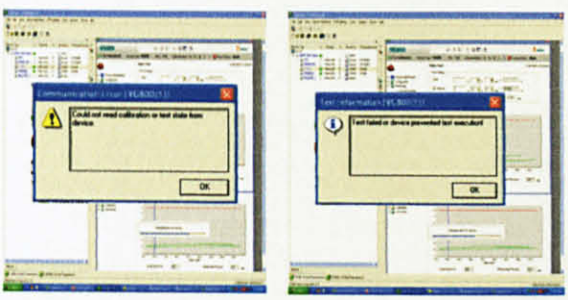
First Stroke:



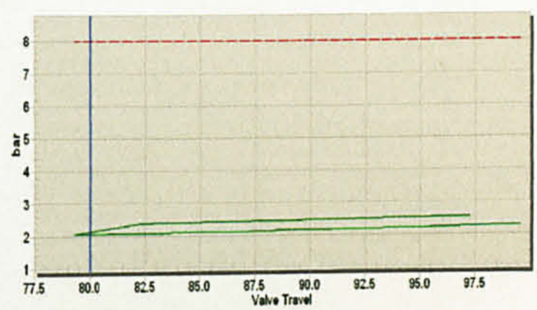
Second Stroke:



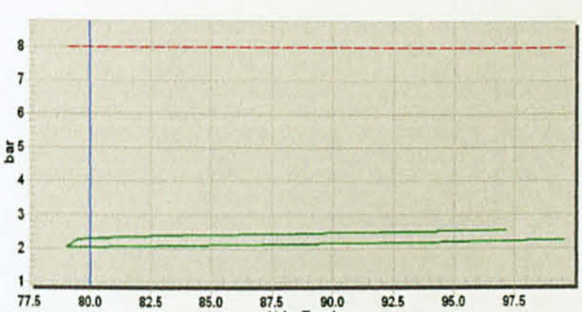
Third Stroke – PST + FST:



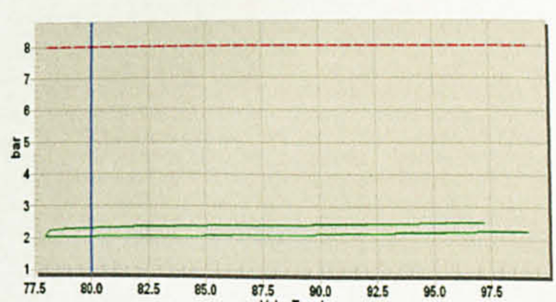
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

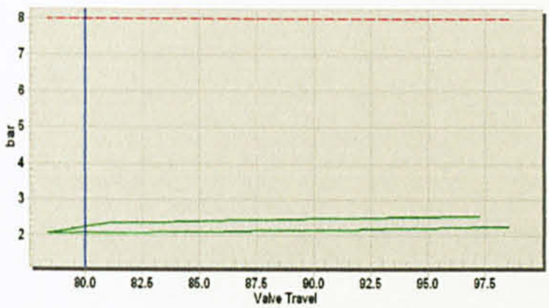


Sample 3: Day 20

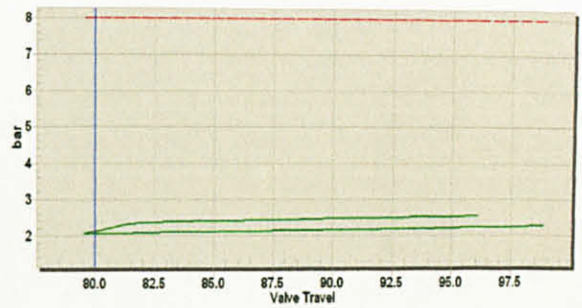
Test Date: January 24th, 2009

Time : 9:00 am – 10:15 am

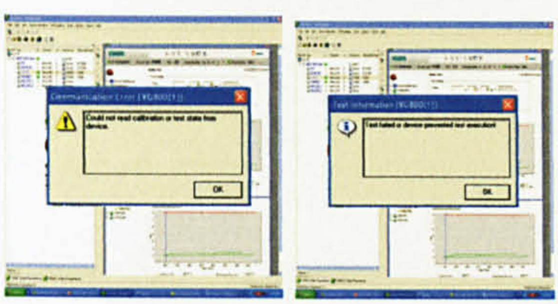
First Stroke:



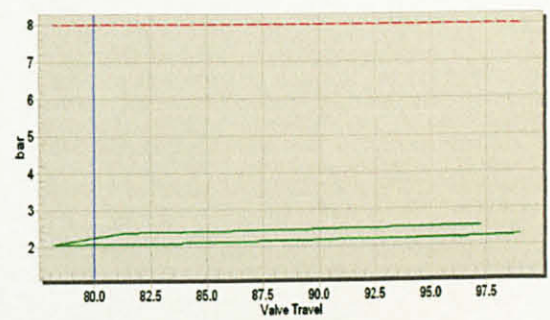
Second Stroke:



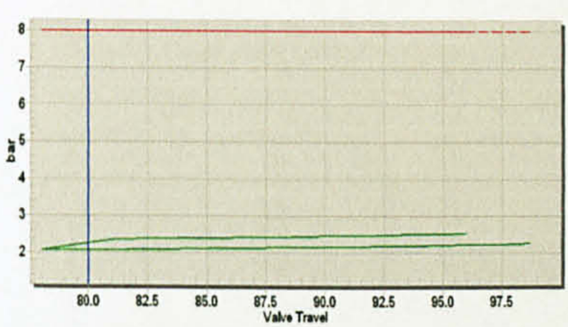
Third Stroke – PST + FST:



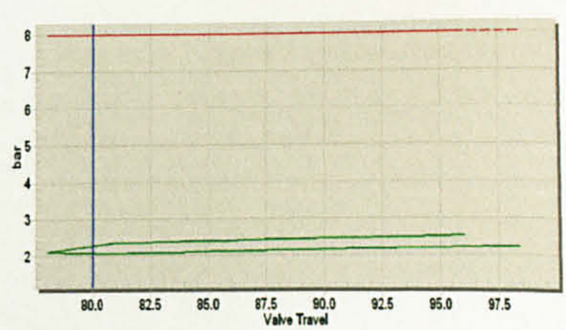
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

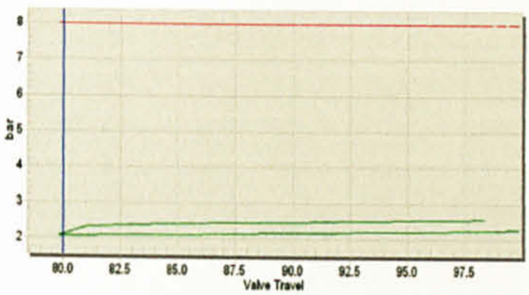


Sample 4: Day 30

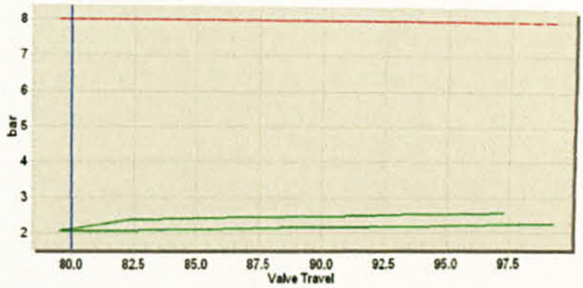
Test Date: February 12th, 2009

Time : 11:20 am – 12:35 pm

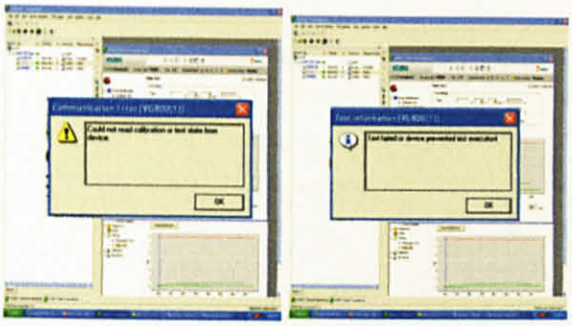
First Stroke:



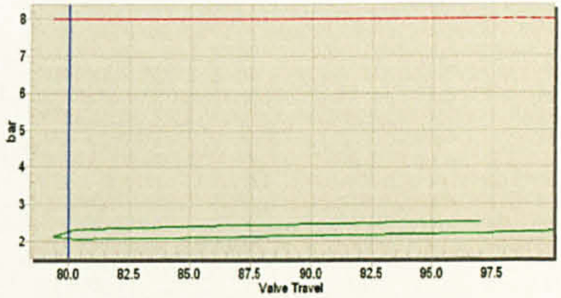
Second Stroke:



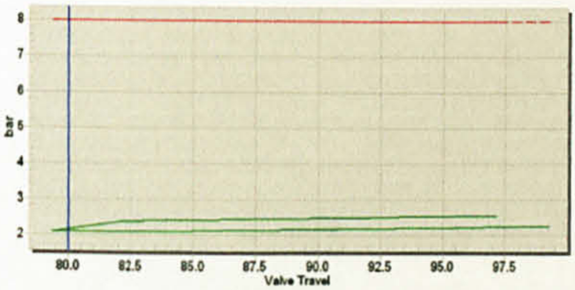
Third Stroke – PST + FST:



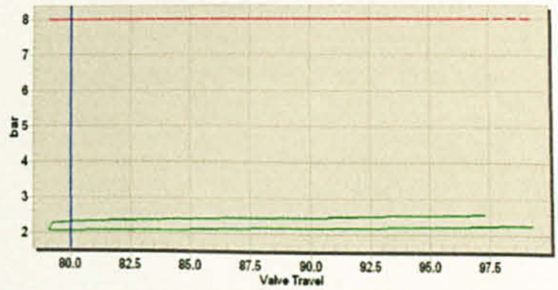
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

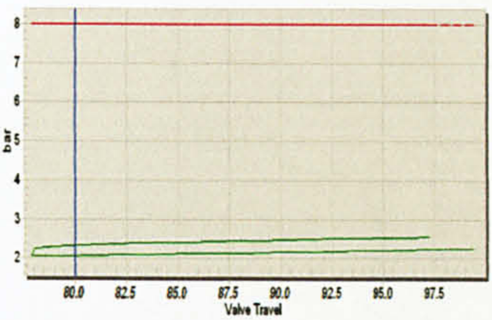


Sample 5: Day 40

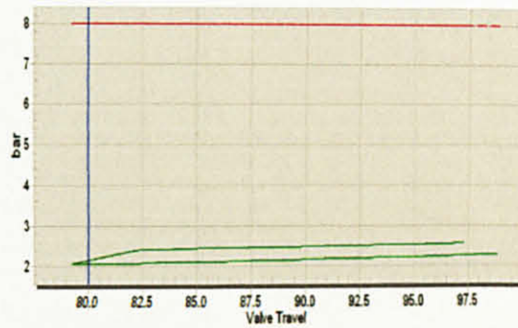
Test Date: February 28th, 2009

Time : 2:40 pm – 3:55 pm

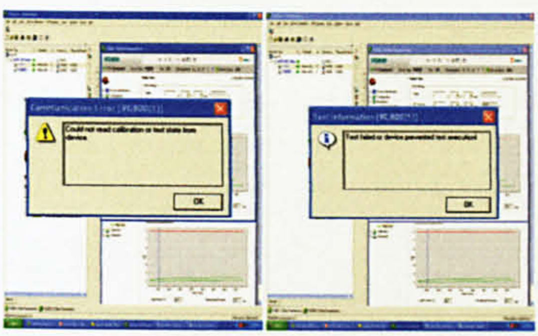
First Stroke:



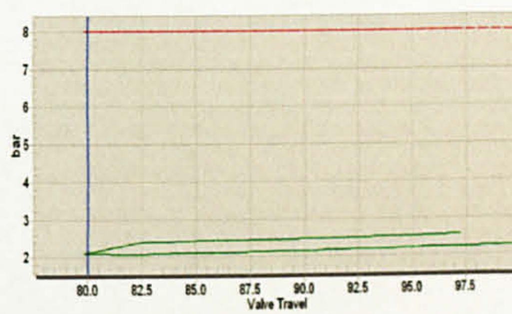
Second Stroke:



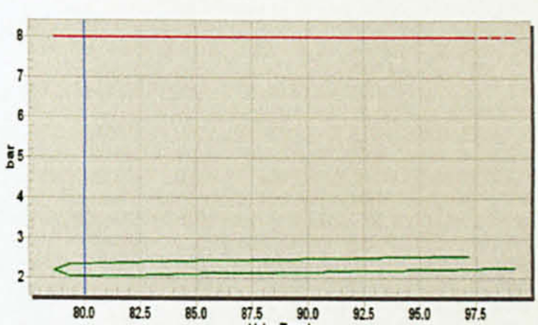
Third Stroke – PST + FST:



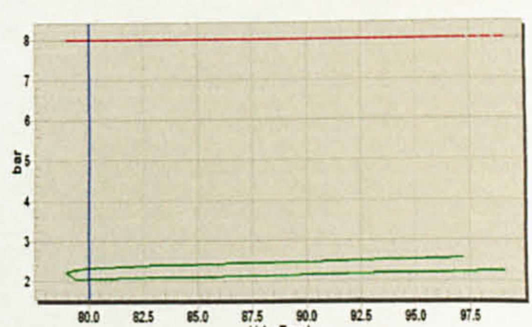
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

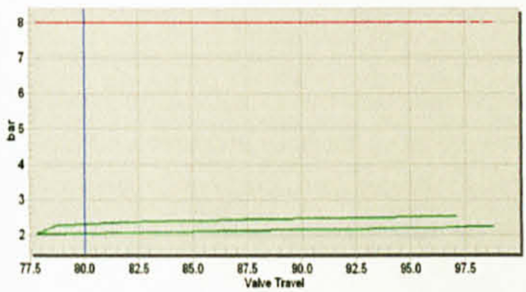


Sample 6: Day 50

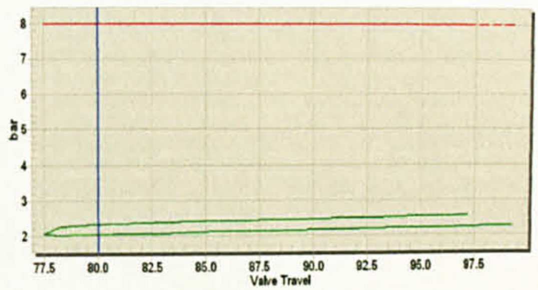
Test Date: March 16th, 2009

Time : 9:00 am – 10:15 am

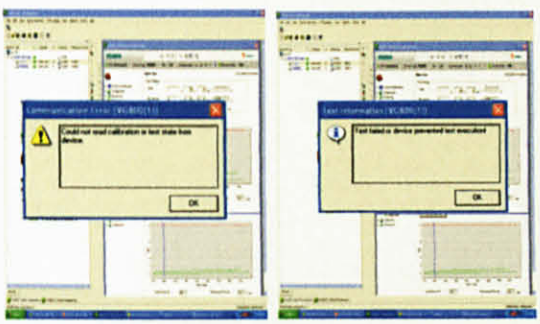
First Stroke:



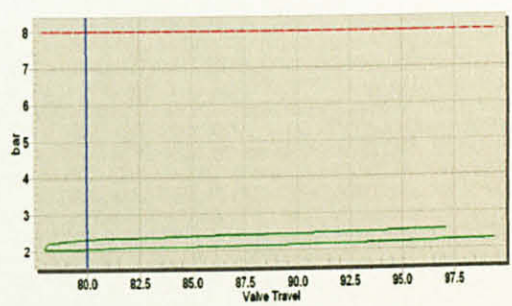
Second Stroke:



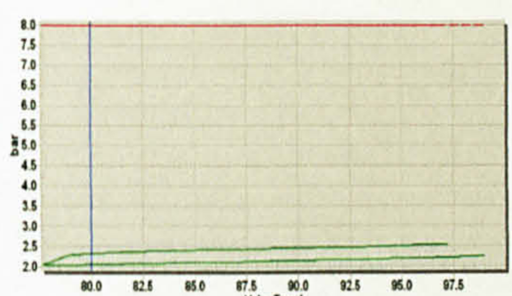
Third Stroke – PST + FST:



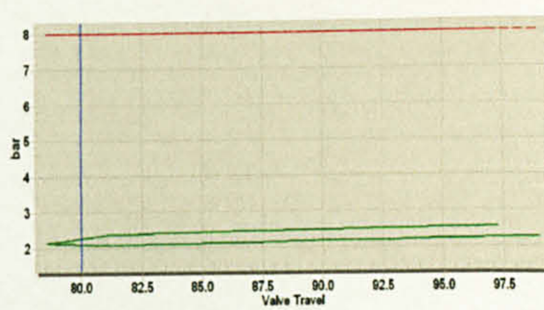
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

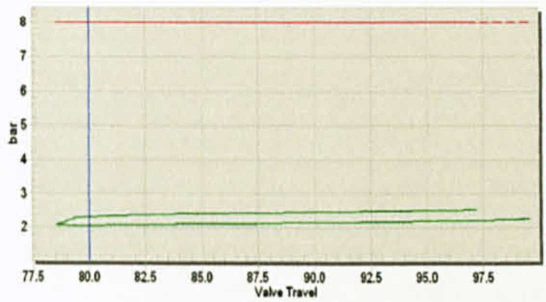


Sample 7: Day 60

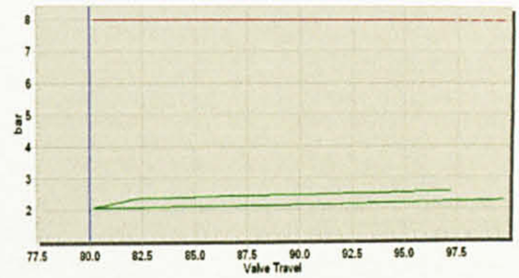
Test Date: July 26th, 2009

Time : 12:45 pm – 1:05 pm

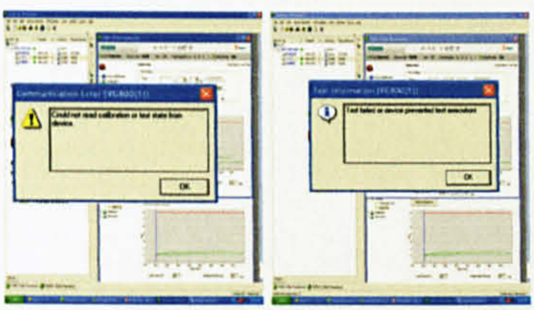
First Stroke:



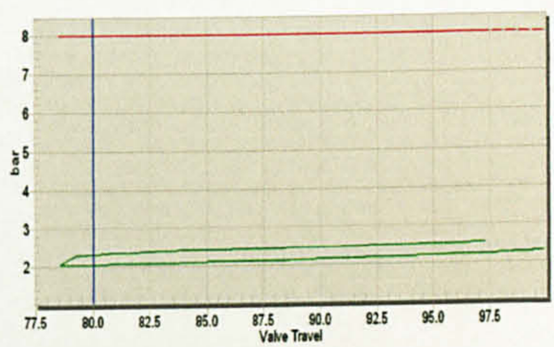
Second Stroke:



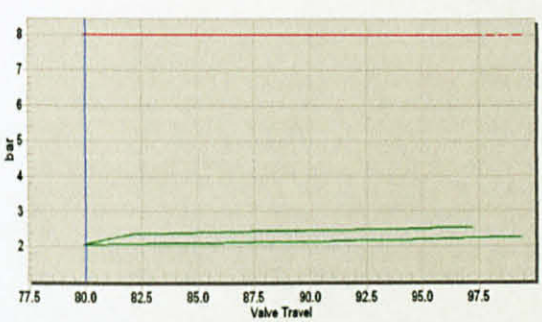
Third Stroke – PST + FST:



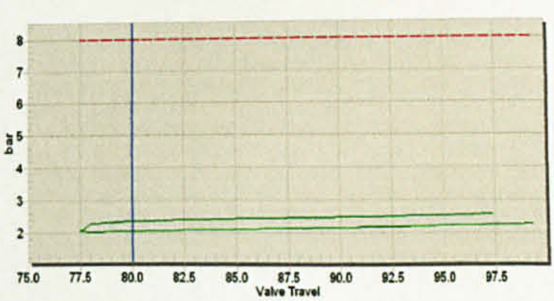
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

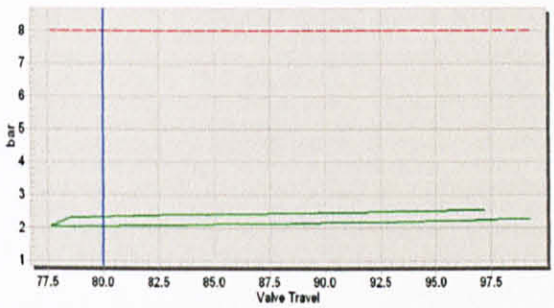


Sample 8 : Day 70

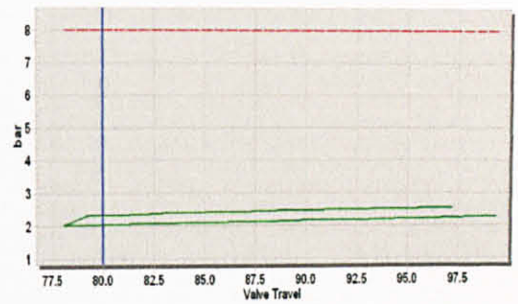
Test Date : August 21st, 2009

Time : 11.50 am – 1:15 pm

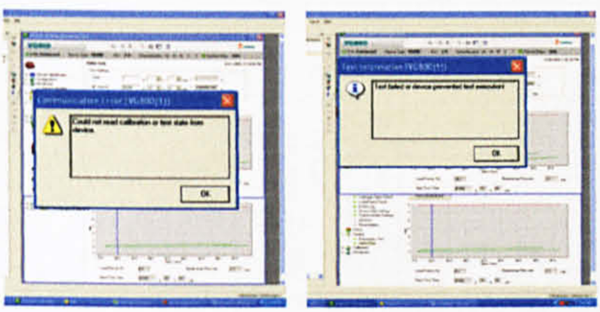
First Stroke:



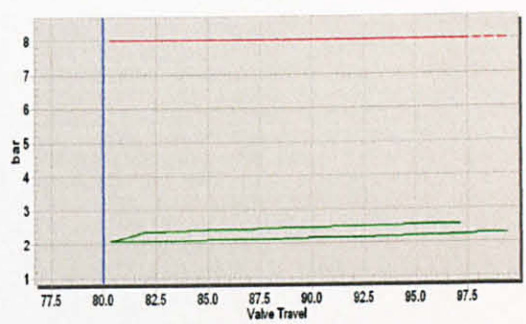
Second Stroke:



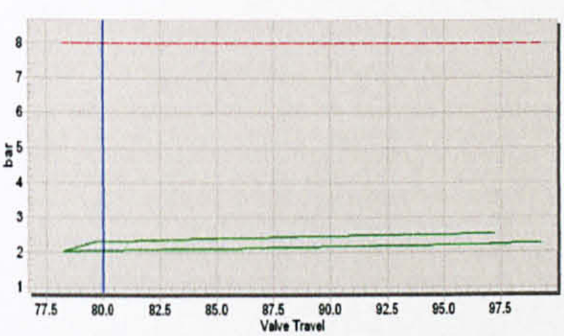
Third Stroke – PST + FST:



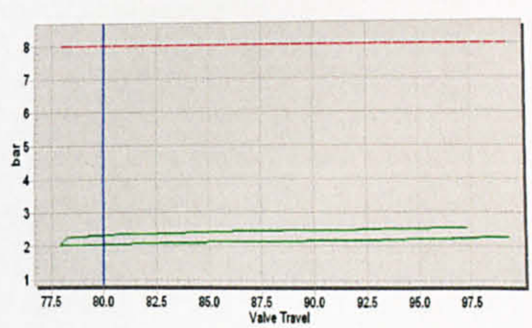
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

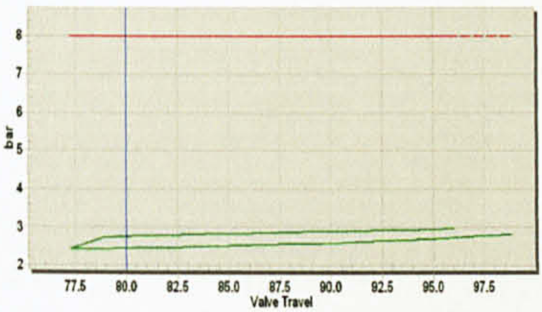


Sample 9 : Day 80

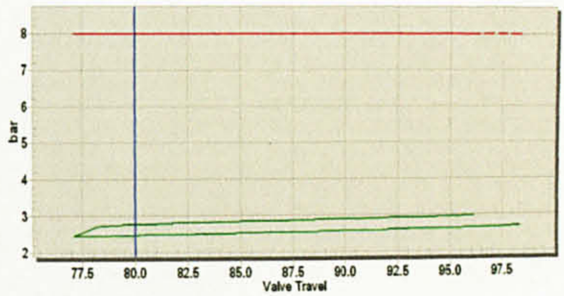
Test Date : December 3rd, 2009

Time : 9.30 am – 11:00 am

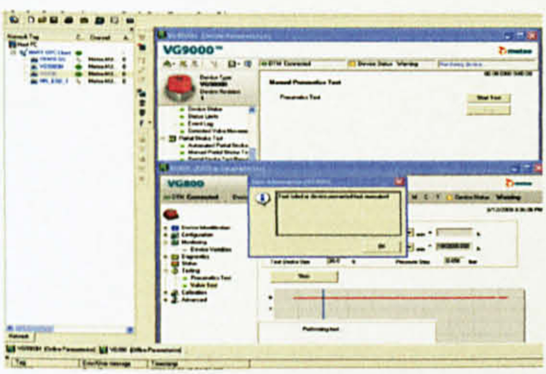
First Stroke:



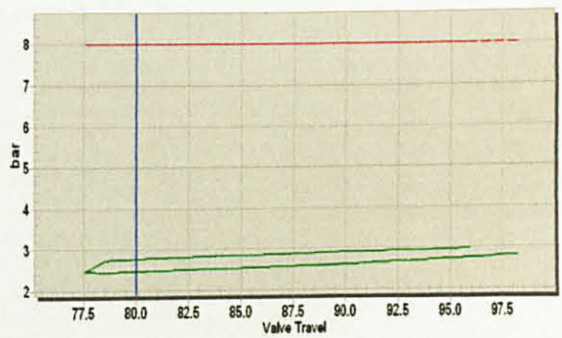
Second Stroke:



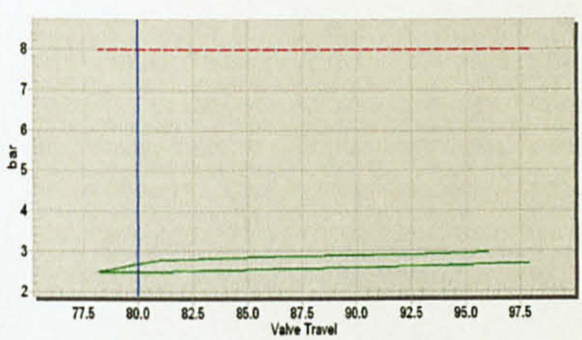
Third Stroke – PST + FST:



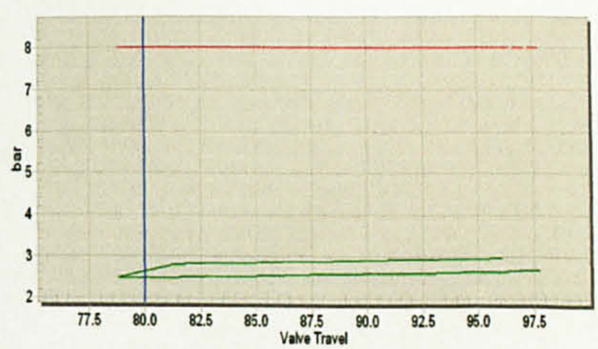
Forth Stroke:



Fifth Stroke:



Sixth Stroke:

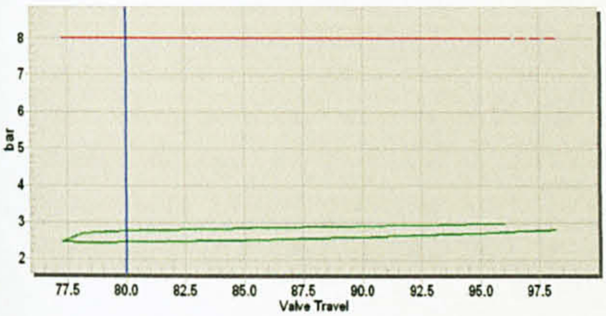


Sample 10 : Day 90

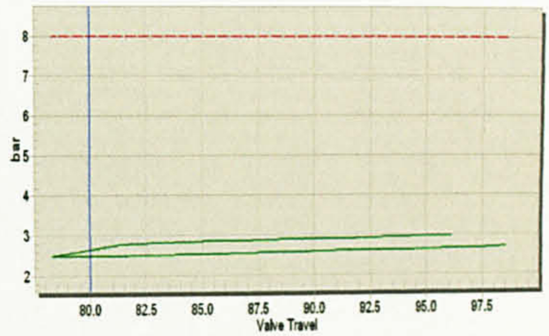
Test Date : January 24th, 2010

Time : 2.30pm – 4.00pm

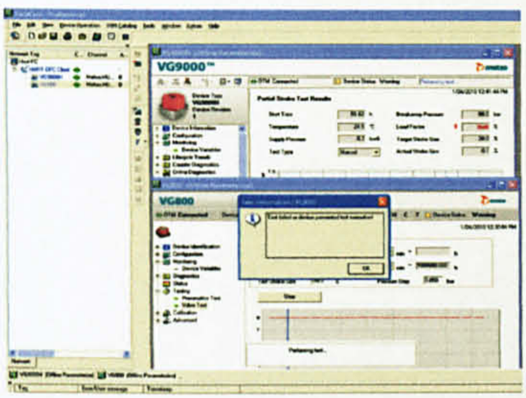
First Stroke:



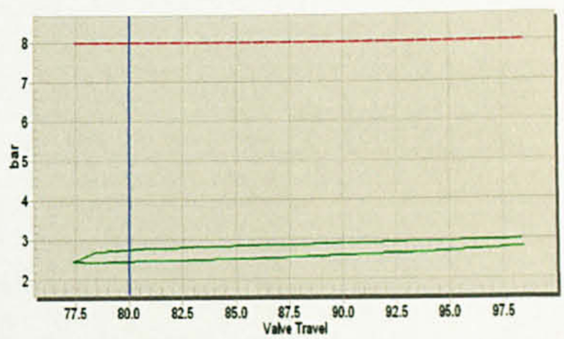
Second Stroke:



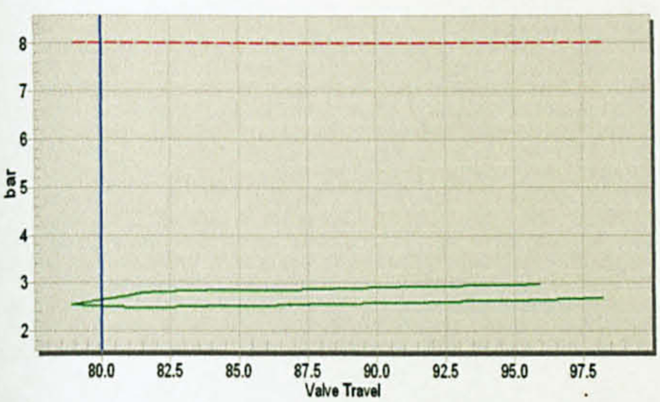
Third Stroke – PST + FST:



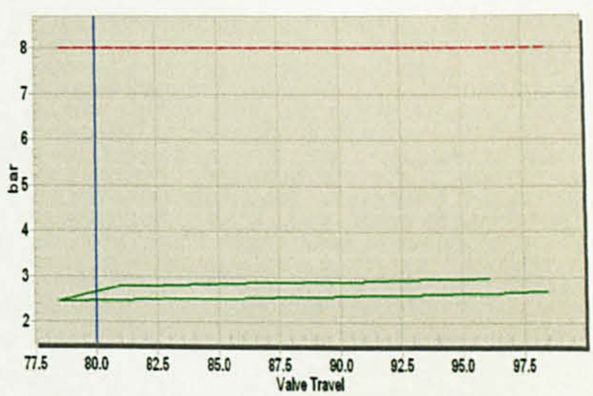
Forth Stroke:



Fifth Stroke:



Sixth Stroke:



APPENDIX G

HOOK UP DIAGRAM

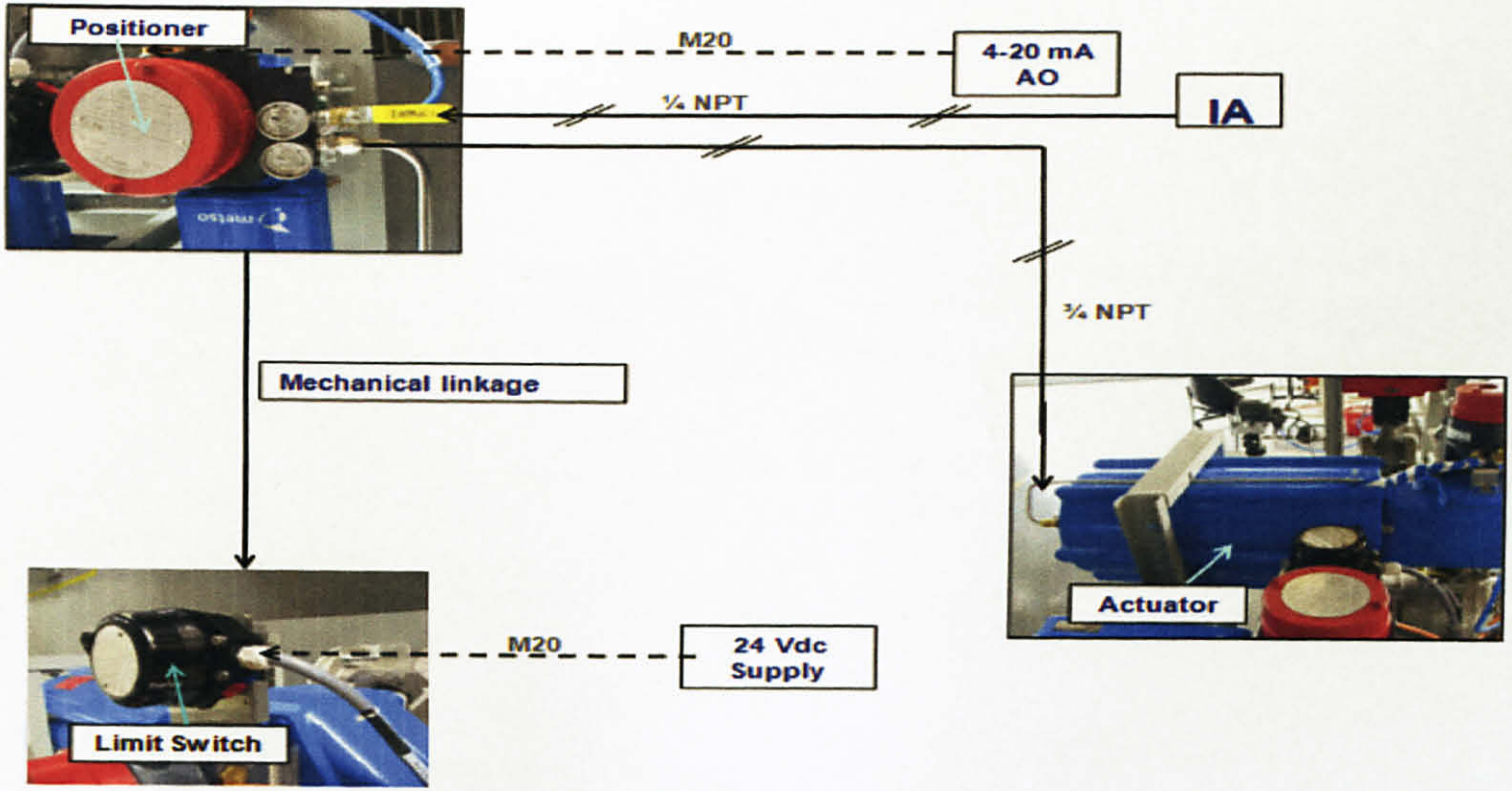


Figure 47: Hook Diagram for Ball Valve

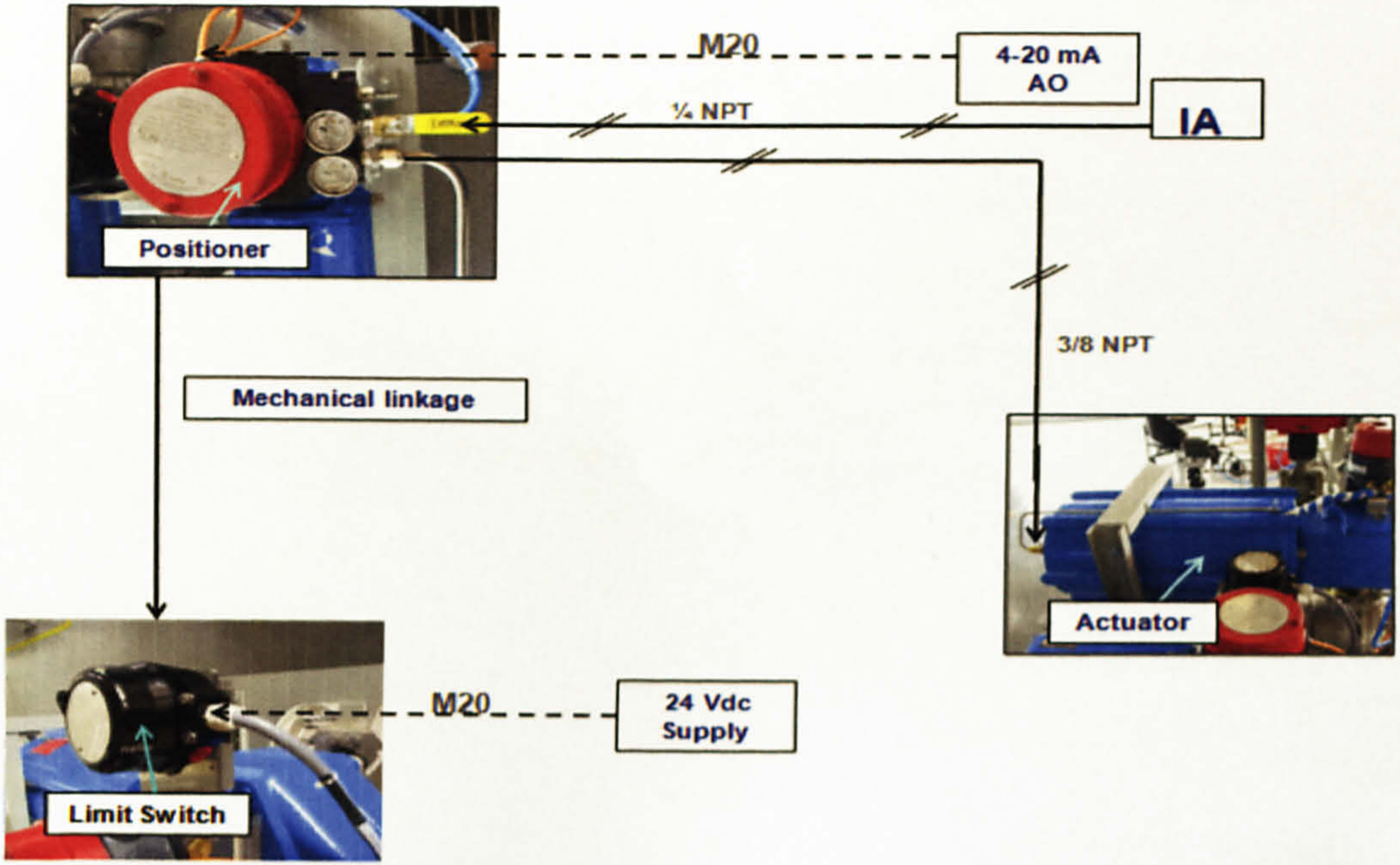


Figure 48: Hook Diagram for Butterfly Valve