Risk Based Inspection on Gas Processing Plant

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2008

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.

MOHD ZULFADLI BIN MOHD YUNUS

ABSTRACT

This report describes a study of risk based inspection conducted on Gas Processing Plant focusing only on relief valves. The main purpose of this study is to find out whether risk based inspection is actually beneficial for conducting an inspection especially in terms of cost savings and risk management. The risk based inspection is a method of delivering and identifying highly risk equipment by calculating each risk level by means of optimizing the data collection. Risk is defined as a combination of probability of failure and the consequences of failure of equipment. The major findings of this study are the determination of risk ranking of each equipment represented by risk matrix and the cost comparisons of inspection between applying RBI and not applying RBI. The result shows that RM 410000 can be saved if RBI methods were employed. These saving were achieved by systematically planning on how, where and when to inspect the relief valves.

ACKNOWLEDGEMENTS

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

In the name of Allah, The Beneficent, The Merciful.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

Risk Based Inspection (or RBI) is a risk-based approach to oil and gas industries. This type of inspection analyzes the possibility consequences of failure especially in oil and gas industries. It is also named Risk Based Integrity Management (RBIM), Risk Based Management (RBM), Risk Based Asset Management (RBAM) or simply Reliability Based Mechanical Integrity (RBMI).

Risk Based Inspection is used to prioritize equipments that needed inspection, by using non-destructive testing such as hardness testing and ultrasonic testing to determine the equipment condition, and it is also a requirement for major oil refineries and chemical installations to get Department Occupational Safety and Health (or DOSH) approval to extend turnaround intervals.

Equipments with high probability and high consequence of failure are given a higher priority for inspection than equipments with high probability of failure but have low consequences. This strategy allows for a rational investment of inspection resources. [1]

This project will be performed in collaboration with Oil & Gas Management Sdn. Bhd. Initially the RBI study was to be conducted on offshore platform but after meting with the company Oil and Gas Management Sdn.Bhd, the project will now be performed instead on a gas processing plant located in the state of Johor Darul Ta'zim. Mainly there are two areas in the gas processing plant which involved RBI study on relief devices.

1.2 PROBLEM STATEMENT

Traditional inspection methods are costly and inefficient because they rely on time based inspection governed by minimum compliance with rules, regulation and standards for inspection. Traditional inspection is also costly because there is no standard reference strategy of doing what is needed for maintaining integrity and improving reliability of the equipments. A more efficient method for inspection is needed where the probability and consequences of failure of the equipment is answered.

1.3 OBJECTIVES AND SCOPE OF STUDY

The objective of this project is to utilize RBI approach to optimize inspection process and data collection to anticipate the most critical equipments on failing, making the cost of inspections minimize and the risk of a equipments are being reduce effectively.

This project will be focused on relief valves used in a gas processing plant located in Johor Darul Ta'zim, Malaysia. The initial the work of the project involves retrieving any kind of valve data related to risk analysis process such as design and operating data of the valves. The data will then be analyzed using the RBMI version 7.5.7 software provided by OGM Sdn. Bhd. A ranking level will then be produced to determine equipments with high risk level and equipments with low risk level.

An inspection plan can then be recommended on how, where and when to inspect the relief valves. Upon finishing the project a final report will be produce to explain the details of the project.

1.4 SIGNIFICANCE OF STUDY

With this method, inspection labour can be reduced and probability of failure events occurring on the site can be diminished. The result is a safer work environment and fatal accidents can be put out of sight.

For example, in one plant there are four hundred relief valves and for a single valve to be maintain takes approximate eighty to one hundred ringgit during a turnaround. If we used traditional time based inspection method, all the relief valves are needed to be replaced because they have reach five years of service. Thus approximate thirty two thousand ringgit is needed for the turnaround, simply for relief valve replacement.

Risk based inspection method require only valves which are critically in risk to be replaced, which results in only one hundred valves requiring replacement. This saves a total of twenty four thousand ringgit for a single turnaround.

CHAPTER 2
LITERATURE REVIEW

2.1 RISK BASED INSPECTION

Risk Based Inspection is designed to meet the requirements of API (American Petroleum Institute) recommended practice 580. Risk Based Inspection is a systematic process for evaluating risk and factoring it into decisions concerning how, where, and when to inspect. "Risk" is defined as measurements of probability and consequence of failure of certain equipment. It is also dependent on time. Therefore the initial element of this report is to define the terms "consequences of failure", "probability of failure" and "risk values" as follows.

1. Consequence of failure

Consequence is the outcome of an event and in RBI terms the event is normally defined as the loss of containment. It is the outcome of a failure event and can be expressed in terms of safety personnel, economic loss or damage to the environment. Examples of consequences of a failure event are injury of a individual, damage to equipment and loss of money [2].

2. Probability of Failure

Failure is the loss of ability to perform the design function. In RBI we usually deal with failures that lead to loss of containment. The event is driven by material damage mechanisms, their rate of progression, and the tolerance of the equipment to damage, amount and type of inspection activities that have been performed in the past. Examples which contribute failures are internal corrosion, external corrosion and cracking mechanism to a equipment [2]

3. Risk Valves

Risk is the chance of something bad happening, where "chance" refers to a probability and "something" refers to a defined consequence. If values can be assigned to the consequence and probability of failure then a risk value can be obtained from this simple equation.

Risk = Probability of Failure x Consequence of Failure.

Risk can be represented in the form a matrix displaying the level of likelihood and consequence. This method of visualizing risk is used by Oil and Gas Sdn Bhd. It is not the only method used in an attempt to quantify risk, however the important detail is that "Risk" is a function of both the "Consequences" and the "Probabilities" of failure [2].

2.1.1 Why Do We Need RBI

Risk Based Inspection was introduced to the oil refining and petrochemical industries to try and reduce the amount of mechanical failures, of which the largest percentages were, attributed to piping systems failures. Due to sheer volume of piping items within a process plant the ability of RBI to identify and prioritize the highest risk pipes was perceived to be the best way of combating the large amount of piping system. In addition to tackling the volume of mechanical failures, RBI also has a smaller influence on Operational Error, Process Upset, Design Error and Natural Hazards. This is because RBI is a management system which covers a variety of data. It is also dynamic process since risks change every day. The potential benefits of a reliable RBI system are:

1. Increased plant availability due to better inspection and maintenance management, reducing failure events in plant site and also updating the any changes that occur on site by using on-line methods.
2. Reducing risk of failure by suggesting the suitable inspection techniques for specific potential failure mechanism.
3. Reducing directly inspection cost of low risk items and focusing on only critical equipment. Risk based inspection systems have been developed so that the benefits can be observed on all equipment including storage tanks, pressure vessel, column, heat exchanges and mechanical equipment [2].

2.2 RELIEF VALVE

The relief valve is a type of valve used to control or limit the pressure in a system or vessel which can build up by a process upset, instrument or equipment failure, or fire. The pressure is relieved by allowing the pressurised fluid to flow from an auxiliary passage out of the system. The relief valve is designed or set to open at a predetermined pressure to protect pressure vessels and other equipment from being subjected to pressures that exceed their design limits [5].

When the pressure setting is exceeded, the relief valve becomes the "path of least resistance" as the valve is forced open and a portion of the fluid is diverted through the auxiliary route. The diverted fluid (liquid, gas or liquid-gas mixture) is usually routed through a piping system known as a flare header or relief header to a central, elevated gas flare where it is usually burned and the resulting combustion gases are released to the atmosphere. As the fluid is diverted, the pressure inside the vessel will drop. Once it reaches the valve's re-seating pressure, the valve will re-close. This pressure, also called blow down, is usually within several percent of the set-pressure [5].

The pressure relief system may be considered in three separate parts which are the pressure relief device, connection to the equipment which it protects, and the disposal arrangement downstream of the relief device. The most commonly used relief devices are safety valves **(Figure 1)** and bursting discs **(Figure 2)**, either singly or in combination, although there are other devices that can be used in special circumstances.

Meanwhile there are many types of safety valve but majority of the relief valves studied are conventional safety valve and bellows safety valves. The different is bellows type are longer sustain in service because its design is to prevent from the spring to corrode quickly.

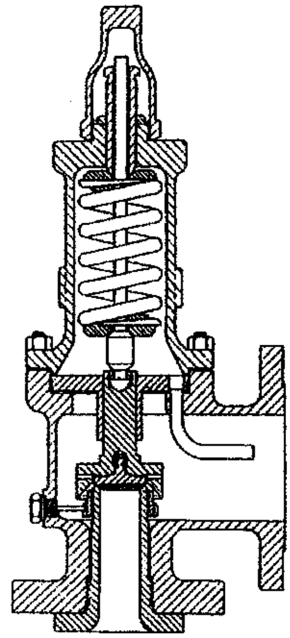
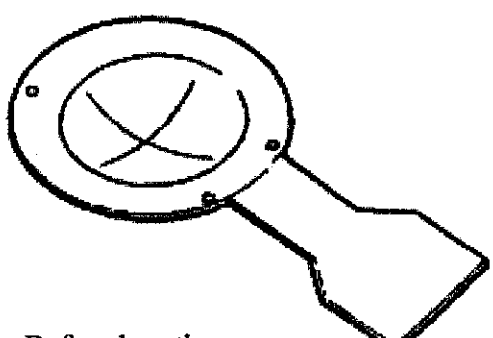
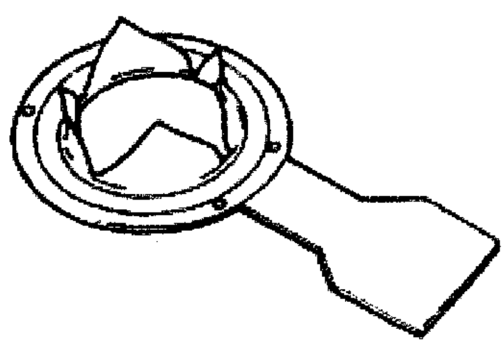


Figure 1: Conventional Safety Valve [4].

Each of the devices has it own advantages and disadvantages in term of maintenance, durability and safety. It is worth remembering that not all tanks and vessels require a dedicated pressure relief device such as tank operating at atmospheric pressure and vented to atmosphere [4].



a) Before bursting



b) After bursting

Figure 2: Bursting disc [4].

2.3 ASSESSING RISK

Assessing the risk for the relief valves requires that the Probability and Consequence of Failure to be evaluated. The Likelihood of Failure of a relief valve is has to be calculated for each of the failure scenarios of interest. Mostly there are three common failure scenarios:

1. Pressure boundary loss of containment.
   The ability to keep something harmful such as H_2S gas from equipment protected.

2. Valve leak-through.
   Valves that fail to reseat back causing a production loss in the overall operation cost.

3. Failure-to-relieve.
   Valves that fail to relieve at the intended pressure causing a greater risk of an over pressure failure to the equipment protected.

However, the failure mode of the greatest concern is failure to relieve because the relief valve installation purpose is to function as a layer of protection to prevent over-pressurization of the system and potential failure of the equipment. Thus, this failure mode will affect the risk ranking integrity of the device under RBI study.

Meanwhile to estimate the "Consequence of Failure" values, the three failure scenarios above will be used to estimate the loss of containment, safety, environmental, production loss and also potential failure event such as explosion. Most of the estimated values resemble the Consequence of Failure values of the equipment it protected.

The risk level of a relief valve is then determined by taking the highest rating of both probability and consequence of failures values. In general, the dominant risk is due to failure to relief scenario where the pressure did not achieve being reduce to set pressure because of corrosion influences and also fouling created by the substance relief in the systems [6].

2.4 RELIABILITY BASED MECHANICAL INTEGRITY SOFTWARE

Reliability Based Mechanical Integrity also known as RBMI^{TM} software is a well defined software for managing inspection program. Developed by Capstone for RBI to meet the requirements of API recommended practice 580, it manages data by prioritizing the equipment data to be collected and maintained. It collects less inspection data but provides good interpretation of data, evaluates the equipment conditions and makes appropriate data available with queries.

The software also try to understand how equipment will fail by identifying the likelihood of failure, determining the appropriate inspection methods, confirming prediction with measurements, and used business rules to create a dynamic inspection plan.

The software philosophy is firstly to incorporate business rules into inspection and maintenance planning strategies by providing consistency in optimizing maintenance plans and allowing the software to make recommendations.

The approach the software uses is by taking the best available failure data and modifies it specifically for design, operation, and deterioration of the process. The software continually compares condition-monitoring results with predictions of deterioration, and will reassess the predictions if result monitoring does not agree with the prediction.

2.4.1 DATA GATHERING AND ANALYSIS

The general methodology of RBI is actually a life cycle inspection database which never stops (**Figure 3**). The first step of RBI process is data collection and analysis of the equipment study such as data from general assessment drawings, organization, plant unit location and system description.

Information of the equipment such as functions and conditions should also be acquired. The RBI process is then continued by identifying deterioration mechanisms of the equipments such as creep, erosion and hot hydrogen attack.

Then the process continues with risk analyses where the risk ranking is determined based on probability of failure and probability of consequence. After the risk rankings are determined, the process continues by reduction of action where non priority equipments are inspected less frequently due to low risk than higher risk equipment. This step is then continued by development and execution of the inspection plan. Finally, repair and modification of the equipment is executed and the process will start over again to reassess the risk ranking of the equipment.

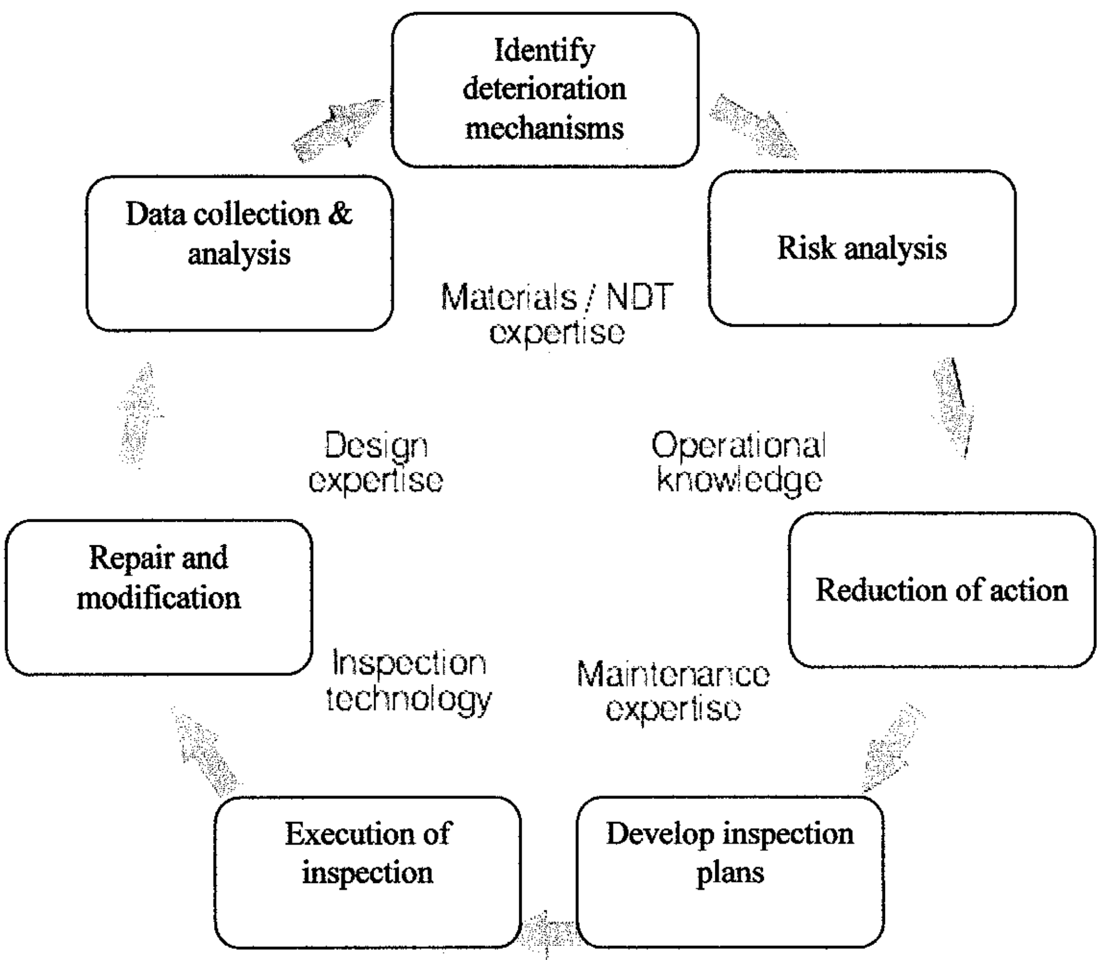


Figure 3: Inspection life cycle database [3].

CHAPTER 3
METHODOLOGY

3.1 PROJECT WORK FLOW

The project work flow started with the approval and endorsement of the project by the supervisor and also FYP coordinators. Then a concise preliminary report was produced to clarify the definition of the problem, the objectives of the project, and to define the type of tasks needed to be conducted to smoothen the process of research of the project.

After deciding and planning the direction of the project, a short meeting with the OGM Sdn Bhd was conducted to update issues related to the project. Then the project continued with the data collection, process study, data upload, critical analyses on the relief valves, generating the inspection plans and lastly producing the final report.

The following diagram (**Figure 4**) is a simplification of the project work flow. Boxes which are coloured red indicate completed tasks yellow boxes indicate on going event while green boxes indicate current tasks.

Currently the project has reached the final stage which is generation of the final report detailing the results and findings of cost analysis for site A and site B. This was then continued by determining which equipment needs to be prioritized for inspection and when the inspection should be executed.

Meanwhile **Table 1** on page 15 shows the time interval for the activities needed to be conducted during semester two of final year report. The tasks generally involved data upload, risk analyses, inspection plan generation and finally dissertation writing.

PROJECT WORK FLOW

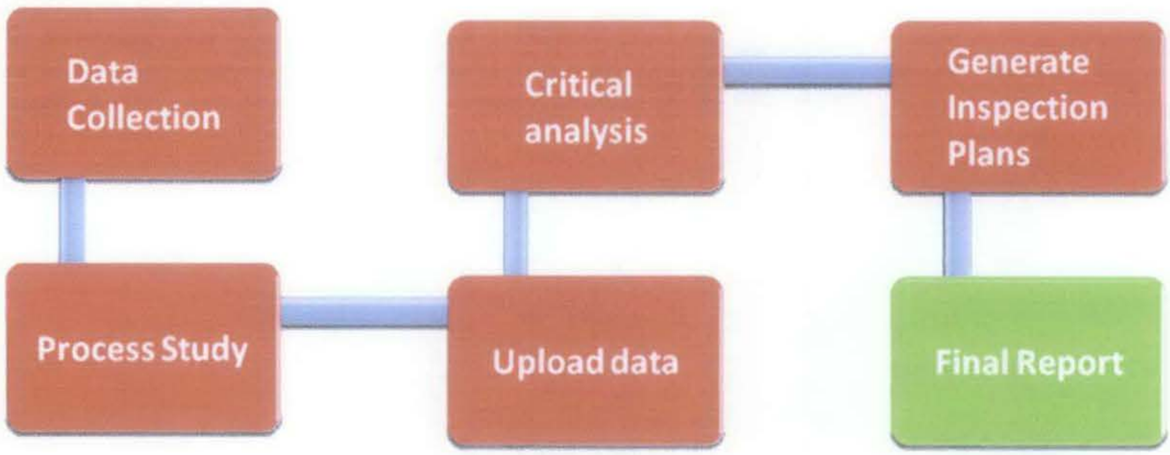


Figure 4: Project work flow diagram

3.2 RBI STEPS INVOLVED IN RELIEF VALVE

Each device in RBI analysis has its own methodology on how to analyse the equipment. The differences include what data to collect, types of inspection to be reviewed and also strategy plans on maintenance and risk analyses. The methodology to conduct RBI study for relief valves device can be simplified into seven steps listed below:

1. Data Collection,
2. Process Data / Study,
3. Upload data into RBMI software (version 7.5.7),
4. Critical analysis,
5. Generate Inspection Plans,
6. Submission Final Report.

The first procedure is collecting the data of the valves through existing documents such as general assessment drawings, inspection history reports and service reports. These documents will provide data such as location ID, relief valve ID, protected equipment types and ID, plant section, operational parameters, existence of rupture disk, piping and instrumentation devices and process flow diagram series numbers, orientation of the device, design properties data and others.

This is then followed by process study whereby the major part of the study is to determine the existence of fouling and also the corrosion rate for the internal and external surface of the valves. The purpose of the study is to predict what kind of failure mode is likely to occur on the relief valves.

The relief valve is then checked in the field to verify the existence of the device. This is because they may be cases of lack of information of the device existence in the documents and the plant. Some of the device could have been removed or changed without notice.

Basically **Figure 5** shows the component of the relief valve where the most important task is to verify the material specification of the device and the size of the orifice device which is between the spring and disc. This is done by overlooking at its design drawings provided by the plant. This two data are important to resolve the corrosion potential and fouling potential when conducting risk analysis on page 16.

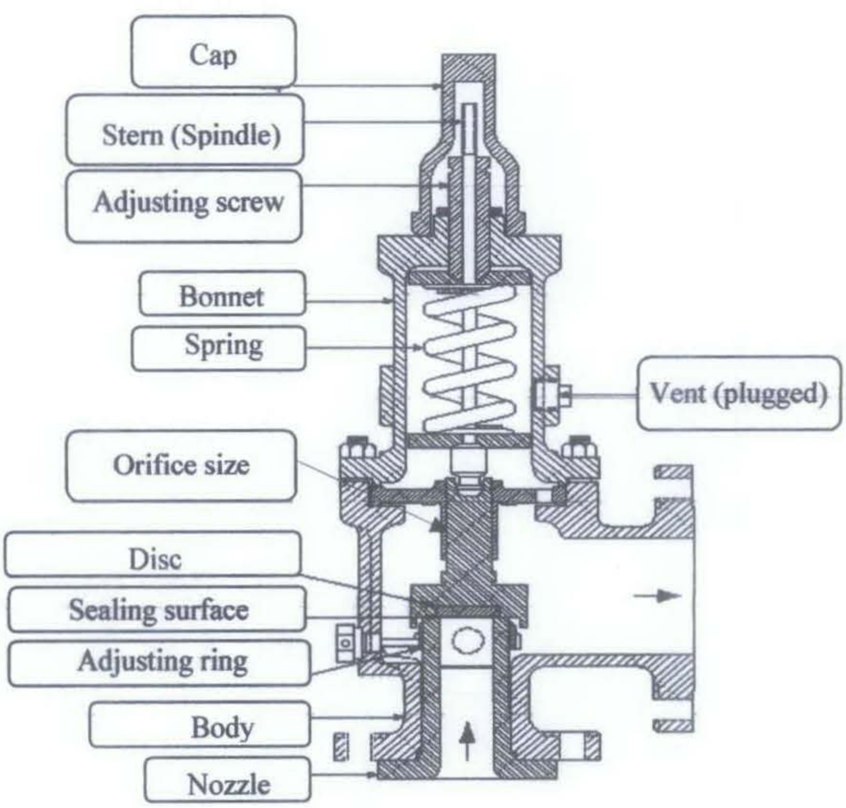


Figure 5: Component in conventional relief valve

After data collections have been completed, the data will be uploaded for recording and analyzing into the RBI software provided by the company. At this stage the risk ranking is influenced by the probability and also consequence of failure of the device. This stage is the most important part of RBI analysis because it will identify the most critical device potential to failure and will allow us to focus on the particular device.

The result of the analysis will help develop the best option to recommend of inspections for the valves. The option will then be reviewed by experts from OGM and also by the client to finalize the inspection plan.

Finally a report will be submitted to the client to present the findings of the analyses. The process will start over again to reassess the risk of the device by updating the condition of the device since risk is also continuously dependent on time. While for the final report written by the author will conclude the findings of the result which is to find out the cost analysis using and not using risk based inspection based on cash flow graph predicted in the coming ten years.

Table 1: Gantt chart for Final Year Project 2

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW
1	Literature review & Upload data		■	■	■												
2	Submission of Progress Report 1					■											
3	Upload Data & Critical Analysis					■	■	■	■								
4	Submission of Progress Report 2									■							
5	Inspection planning & Dissertation									■	■	■	■				
6	Submission of Dissertation Final Draft													●			
7	Oral Presentation														■	■	
8	Submission of Project Dissertation (Hardbound)																■

● Suggested milestone

■ Process

Project progress position

3.3 CRITICALITY CALCULATION FLOW

The **Figure 6** below is the basic concept of criticality calculation flow for relief valve to quantify the risk ranking of relief valve device. As said in the pervious page the ranking are based on probability category and also consequence category.

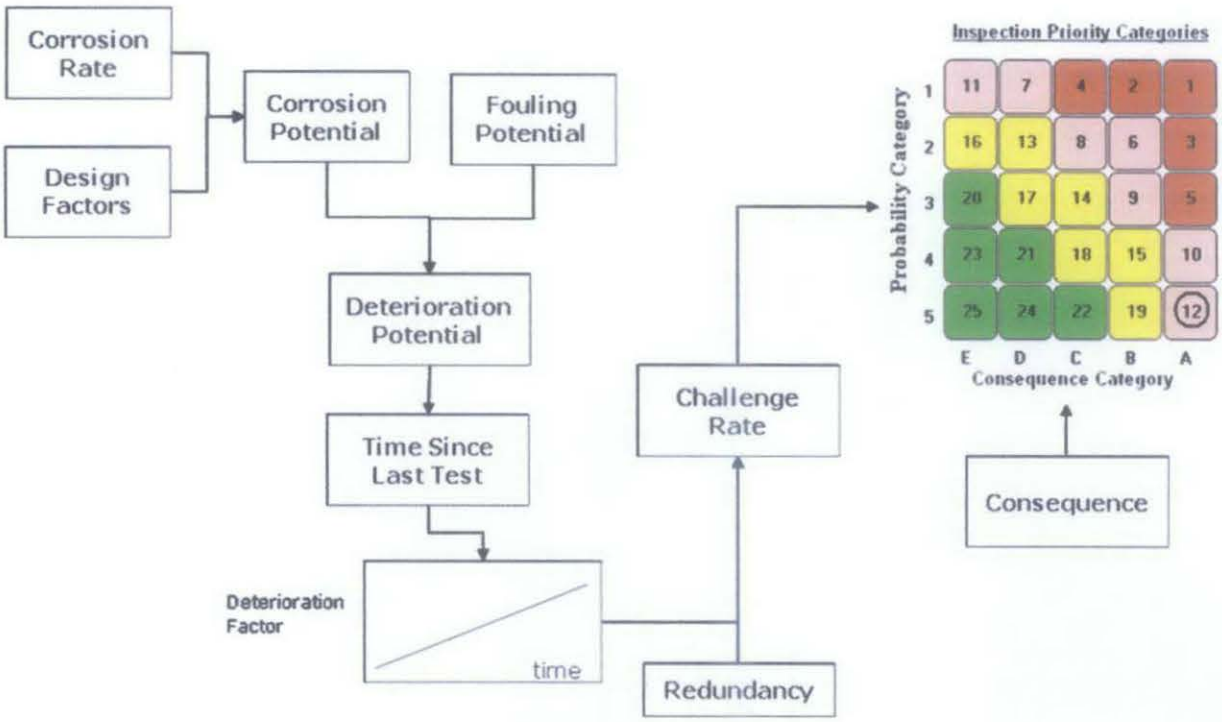


Figure 6: Criticality calculation flow [7].

Corrosion potential studies the expected corrosion rate assigned to the equipment item that the relief device is protecting. The corrosion potential will increase if the relief device relieve to atmosphere because moisture can enter the valve and accelerate the corrosion on valves internal.

While if the relief device is made of higher alloy metals, bellows design or rupture disk protected the corrosion potential will decrease in value. The corrosion potential is given by the corrosion experts based on the upper point.

Potential for fouling is often quite subjective to determine and basically is depend on expert opinion of the process and operation personnel.

They are four degree of fouling which are based on level of severity. For fouls to point of degraded capacity in less than a year is indicate as very high severity. For fouls to point of degraded capacity within 1- 2 years is indicate as high severity while fouling seen in 2 -3 years of service is indicate medium severity and for fouling almost never occurs is indicate low severity.

There is also another way to assess the potential for fouling based on quantitative methods. This is done by measuring the internal diameter of the orifice after the relief device has been in service for one year.

If there us no reduction in the diameter due to fouling, it is given a low potential fouling. If there us 0.1% to 5.0% of reduction in the diameter due to fouling, it is given a medium potential for fouling. If there is 5.1% to 10.0% reduction in diameter due to fouling, it is given a medium-high potential for fouling. Lastly if there is more than 10% reduction in diameter it is given a high potential for fouling.

Deterioration potential stage is where the corrosion potential and fouling potential are being compare to one another. Whereby the highest potential stage is being uses for representing the condition of the device. If the two are having the same stage of potential and is not in low potential stage. The deterioration potential is raise to the next level of severity.

"Years since last inspection" value is the recorded time of the previous inspection to the current inspection based on the inspection history of the device. This is needed to calculate the distribution of deterioration factor value. Based on the deterioration potential value the deterioration factor can be determined. The graph is show at the next page of this report (**Figure 7**).

Deterioration factor is then revaluate back by determine if the relief device have a redundancy valve in the equipment it protected. If there is a redundancy valve on the equipment, the deterioration factor is divided by ten. This is because the existed of redundancy valves help to elongated the time of the relive valves study.

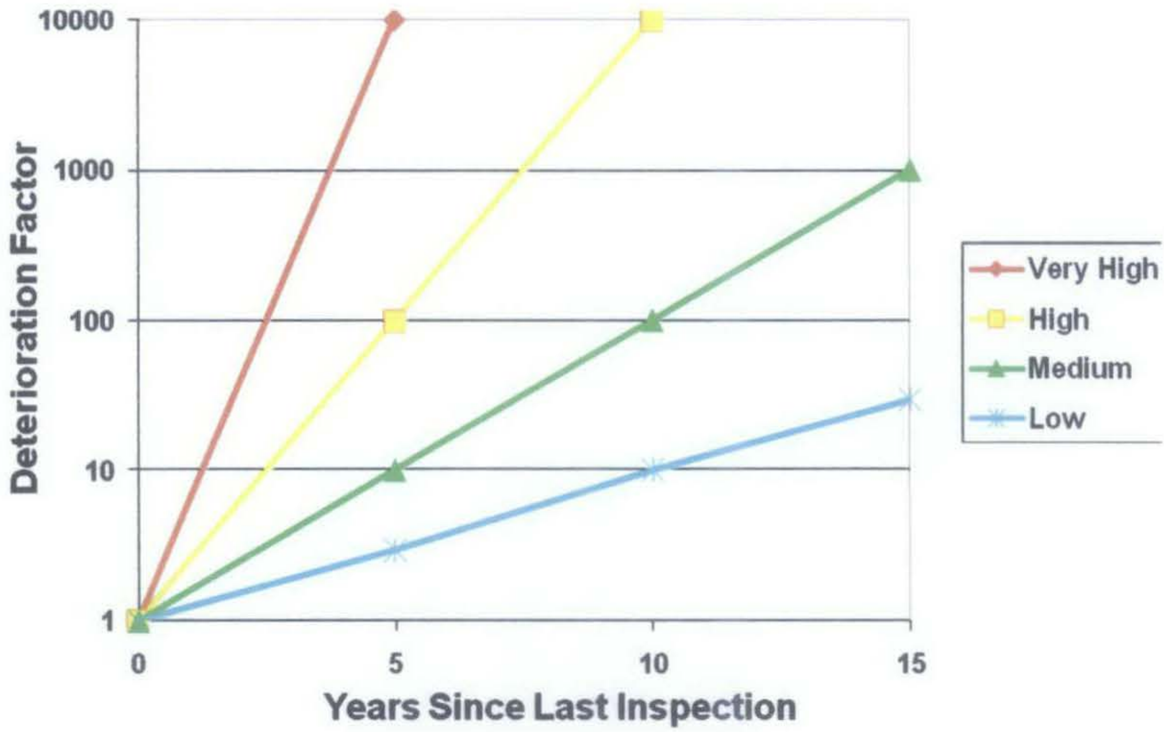


Figure 7: Deterioration factor over years since last inspection [7].

This is continued by challenge rate stage where it accounts the probability of demand on the relief device to determine the challenge factor. The value is then multiplied with the deterioration factor to get the adjustable deterioration factor.

There are two ways to asses the challenge factor firstly by calculating the ratio of operating/ design pressure or estimates from the process engineer. The guideline table for process engineer estimating the rate is given below.

Table 2: Usage of relief valve interest [7].

Frequency of Challenge	Challenge Factor
More than once every 6 months	3
Once every 6 months to 2 years	1
Once very 2 to 5 years	0.7
Once every 5 to 10 years	0.5
Less than once every 10 years	0.3

Another way to determine the challenge factor is to calculate the ration of pressure between the operating and also the design pressure as stated in the table below.

Table 3: Ratio of relief valve pressure [7].

Ratio of Operating to Design Pressures	Challenge Factor
Greater than 0.90	3
0.75 to 0.89	1
0.50 to 0.74	0.7
Less than 0.50	0.3

Where by after verify the challenge factor it is then multiplied with the deterioration factor to determine the finalize value of the deterioration factor. The value is the used to determine the probability category of the device.

The table below shows the finalize deterioration factor determines the probability category of the device.

Table 4: Probability Category based on the Finalize Deterioration Factor [7].

Finalize Deterioration Factor	Probability Category
1-9	4
10-99	3
100-999	2
1000+	1

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

Basically in this chapter the results were categorised based on the six step methodology applied to conduct the analysis. The result of each section will be explained one by one starting from data collection until cost analysis.

4.2 DATA COLLECTION RESULTS

1. Plant and Equipment Information

The site of the project is conducted on gas processing plants which utilize some of the hydrocarbon groups to process another type of product. The site can be divided into four sections but only two areas were involved in RBI analyses. Due to confidential reasons the areas are rename as site A and site B.

In general there are 350 relief valves under going the RBI study where all the valves are spring loaded valve type but can be group into conventional design type or bellows design type.

The results of data collection stage are shown in the following pages. The types of data being retrieved can be divided into two groups which are data required in the RBI study and supplementary data not required for the RBI analysis. Some confidential information are listed with alphabets.

2. Types of data collected

The results of RBI-related data collected are been listed below:

1. Location id.
2. Device id.
3. Protected equipment id.

4. Component type.
5. Plant section.
6. Operating unit.
7. Existence of rupture disk.
8. Rupture disk id.
9. Existence of redundant relief device.
10. Potential for fouling.
11. Direction of relief device.
12. Design type.

The results of supplementary data collected are been listed below:

1. Allowable over-pressure
2. Orientation of the device
3. Differential set pressure
4. Manufacturer
5. Relief set pressure and temperature
6. Construction code
7. Inlet size
8. Outlet size
9. Orifice size
10. Series number of P&ID files.

The process then continued by gathering the visual and parts inspection service report data for the relief valve and key in the data into Microsoft Excel template. The author's role is to arrange the data according to the relief device ID, notify missing data, and also update any missing data.

The author have divided the data gathering done into four sections where each section was conducted in a weeks time and involved an average of forty new data entry send by the company to the author each week. These sections started during week nine and ended week twelve based on the Gannt chart for the Final Year Project 1 last semester. The data was compiled in Microsoft Excel and was send through the email between the author and the company supervisor. The reason it was compiled in Microsoft Excel was to make it easy to upload the data into the RBMI software version 7.5.7 and to minimize the mistakes done by human error. Such partial of data are been listed in the **Table 6** on page 24.

4.3 PROCESS STUDY RESULTS

The results for process study are to determine the corrosion potential and also fouling potential of each relief valve studied.

1. Corrosion Potential

Basically the result of corrosion potential can be verified by determining the material specifications of the device studied based on the data collection. By knowing the material specifications, one can determine the average corrosion rate per year by using the material average corrosion rate table provided by the Capstone research. From the author's observation, the common types of material used on relief valves are carbon steel and stainless steel, thus the average corrosion rate of this material are be given below.

Table 5: Average corrosion rate per year [2].

Material Specification	Average corrosion rate per year (mm/year)
Carbon steel	0.05 mm/year
Stainless steel	0.02 mm/year

2. Fouling potential.

Potential for fouling is often quite subjective to determine and basically it depends on expert's opinions of the process. Essentially there are two ways on determining this potential which are by finding out the fouling history device or by quantitative measurement through measuring the orifice size reduction after one year of service. Basically the project uses the first method by acquiring the inspection and service history of the device during data collection which tells the fouling potential. The average of fouling potential for the relief valves studied are in medium fouling category.

Table 6: Partial of the completed data collection

LocationID	DeviceID	AllowOverPress	BackPress	ConstCode	DesignType	DeviceModelNo	DeviceSerNo	DevManuf
PSV-07	120752	10		API	Bellows	A	124752	A
PSV-47	120753	20		API	Bellows	A	124753	A
PSV-01	120655	20		API	Conventional	B	124655	A
PSV-04	120656	10		API	Bellows	C	124656	A
PSV-05	120657	10		API	Bellows	D	124657	A
PSV-69-0	120658 A	10		API	Bellows	E	124658 A	A
PSV-69-1	120658 B	10		API	Bellows	E	124658 B	A

DevServDate	P&ID	Protected Equipment.	MaxBackPress	Orientation	OrificeSize	OutletSize	ReliefSetPress	ReliefTemp
27-Mar-96	D-21-1225-801	V	157	Vertical	47.784	150	637	38
5-Jul-93	D-21-1225-872	V	49	Vertical	2.433	50	343	115
8-Mar-06	D-21-1225-001	ES	69	Vertical	0.882	50	2138	195
8-Mar-06	D-21-1225-002	ES	167	Vertical	119.403	250	1079	86
8-Mar-06	D-21-1225-002	ES	382	Vertical	9.621	80	1079	93.3
9-Mar-06	D-21-1225-109	ES	45	Vertical	119.403	200	343	401
9-Mar-06	D-21-1225-109	ES	45	Vertical	119.403	200	343	401

4.4 UPLOAD DATA

During the semester break, the author went to the associate company OGM Sdn. Bhd. to conduct the critical analyses for the relief valve. Thus the next stage was to upload the data into the RBMI software which took around three weeks to finish.

There were 269 valves in site A and 81 valves in site B. The following on **Table 7** are the details of the task preformed. **Figure 8**, **Figure 9** and **Figure 10** are partial screen image of the RBMI™ software. The example of how the data was uploaded are shown in **Figure 8** while **Figure 9** is where the data was been analysed and **Figure 10** is where the data is being implemented.

Table 7: List of equipments perform uploading data on software

Time conducted	Location ID	Site
Week One (9 Jun – 13 Jun)	PSV-1369-0	A
	PSV-1369-1	A
	PSV-1369-2	A
	PSV-1369-3	A
	PSV-1370-0	A
	PSV-1370-1	A
	PSV-1370-2	A
	PSV-1370-3	A
Week Two (16 Jun – 20 Jun)	PSV-7216	A
	PSV-7217	A
	PSV-7218	A
	PSV-7223	A
	PSV-7226	A
	PSV-7302	A
	PSV-7311	A
	PSV-8027	A
Week Three (23 Jun – 27 Jun)	RV-0007	B
	RV-0029	B
	RV-0047	B
	RV-1101	B
	RV-1204	B
	RV-1205	B
	PSV-0210A	B
	PSV-0210B	B

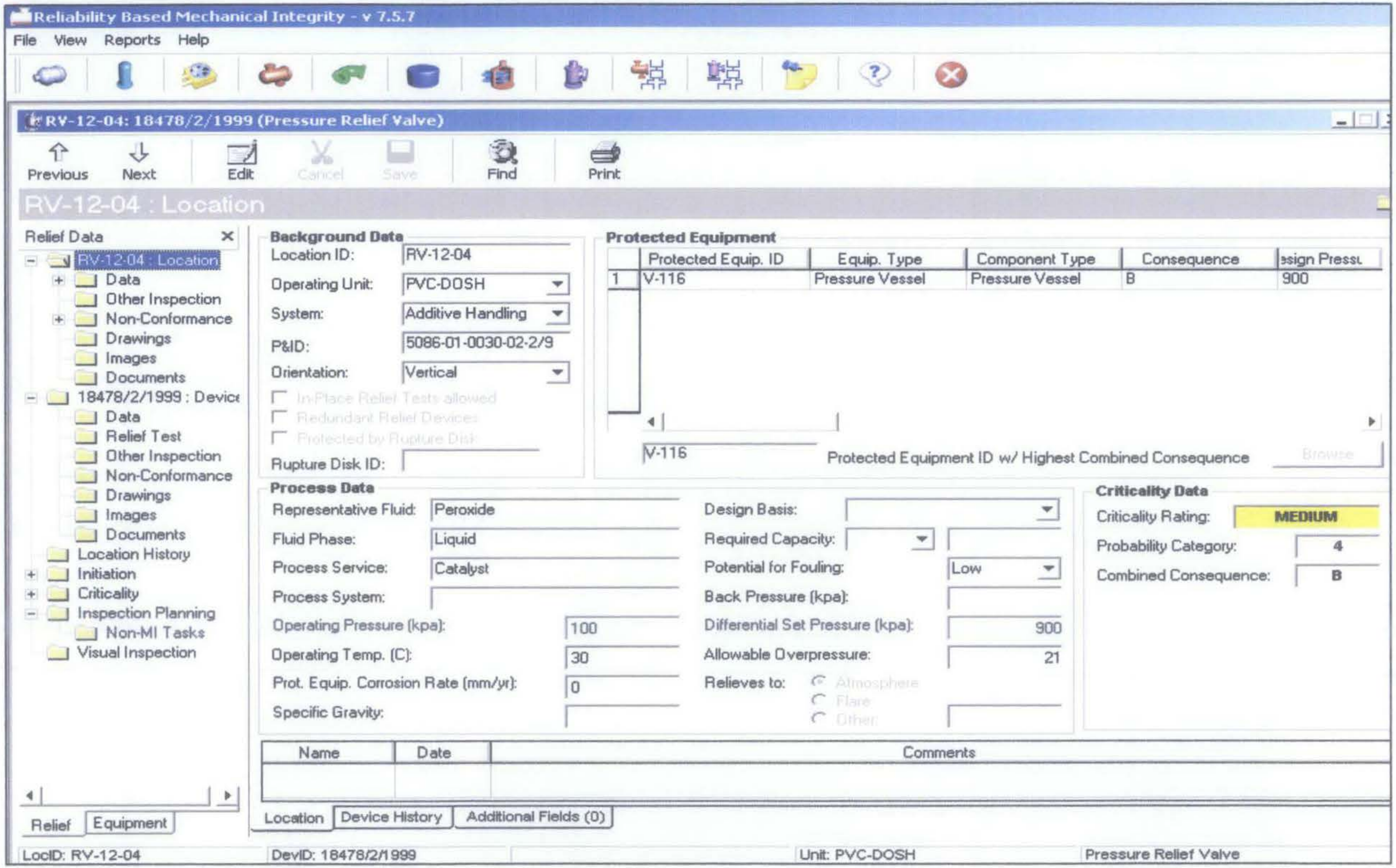


Figure 8: Software RBI for Data Location of Relief valve

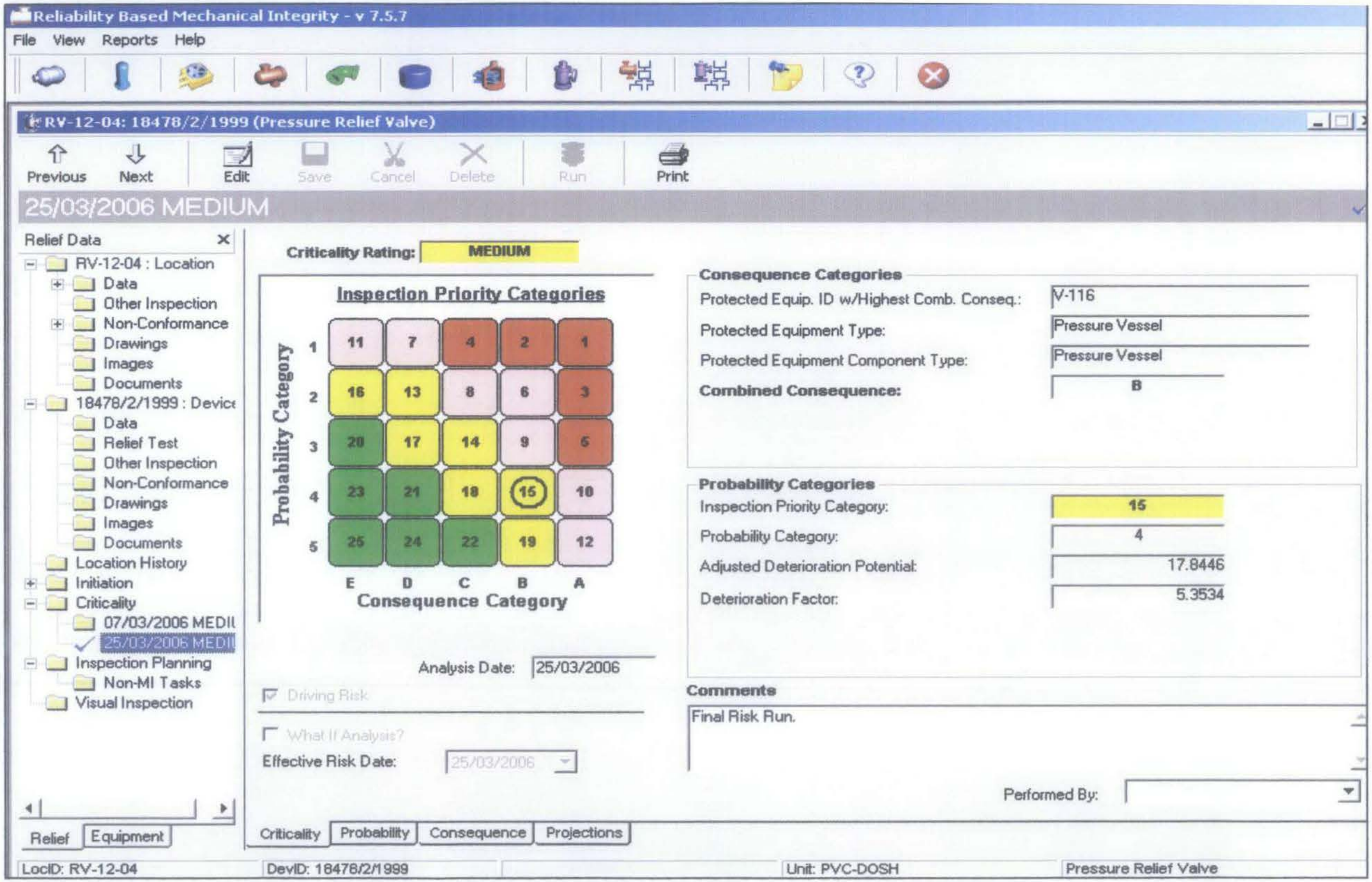


Figure 9: Software RBI for Critical Analysis of Relief valve

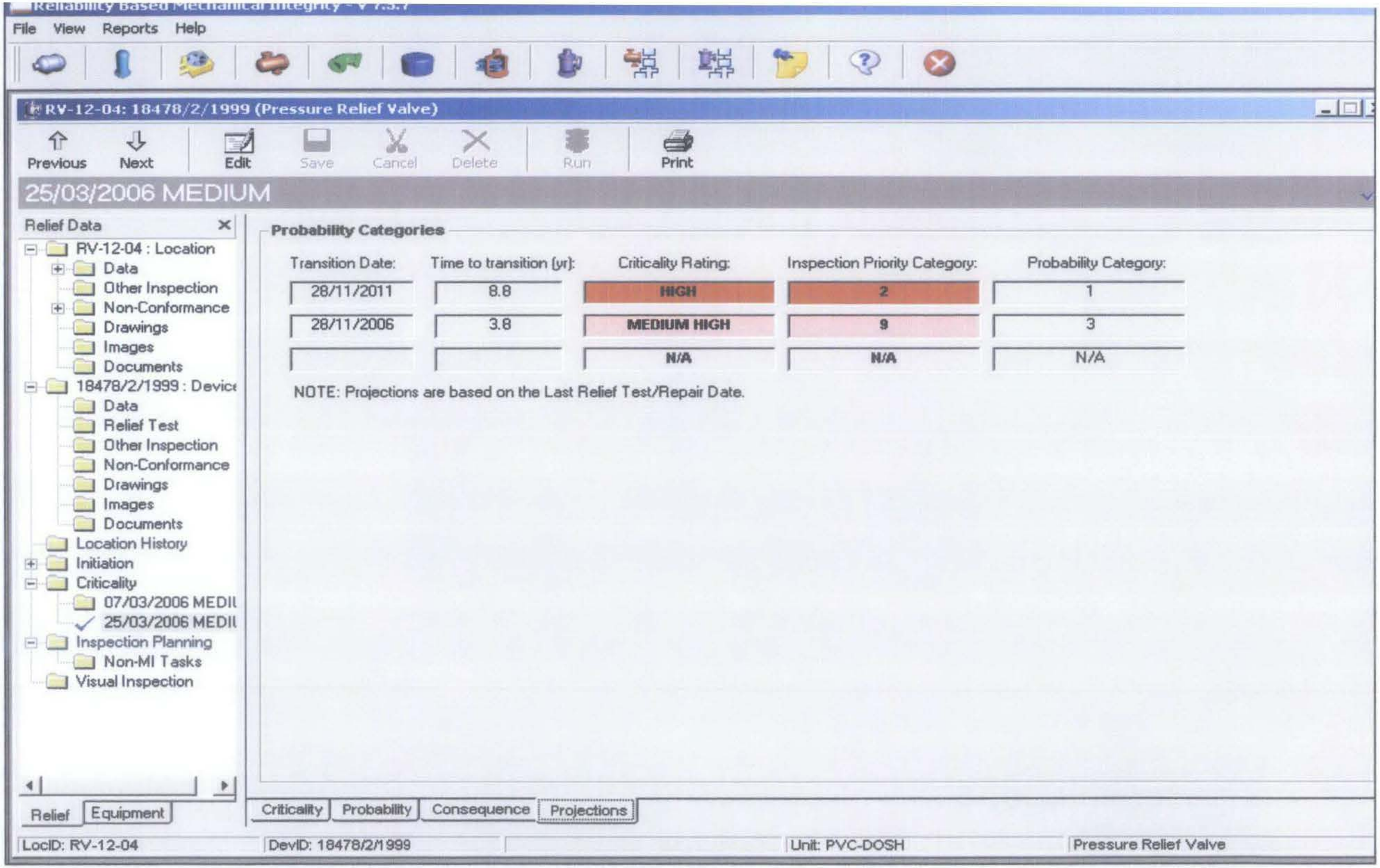


Figure 10: Software RBI for Projection of Relief valve

4.5 CRITICALITY ANALYSIS RESULT

Unit	Equipment Count	High	Medium High	Medium	Low
A	269	0	45	161	63
B	81	0	15	54	12
Total	350	0	60	215	75

Table 8: Distribution of Criticality Ratings

As shown above, none of the relief devices were in the "HIGH" criticality category. The number of relief devices in "MEDIUM HIGH" category is 60 relief devices where 45 of them is from site A and 15 were from site B.

The criticality rankings were calculated in order to provide required information for the baseline inspection planning. They were derived from the results of the process/ corrosion information, previous plant inspection history and basic data gathered. Based on the results of this study, inspection work plans have been developed for the unit to provide guidance to inspection and maintenance to ensure the current criticality ratings are maintained or lowered. Without further inspection and maintenance, the equipment criticality ratings could be expected to increase, assuming process conditions remain constant. Through the implementation of the RBMI program, the criticality rating of each relief device in the study can be kept within the acceptable limit.

Figure 11 shows the Criticality Distribution for all of the relief devices in the study. The criticality rating considers both the probability and consequence of failure categories both plants.

Risk Distribution (Site A)

Totals		E	D	C	B	A
1	1	0	1	0	0	0
16	2	13	3	0	0	0
29	3	9	1	12	5	0
223	4	42	12	37	95	39
0	5	0	0	0	0	0
269	Totals	64	17	49	100	39

Risk Distribution (Site B)

Totals		E	D	C	B	A
0	1	0	0	0	0	0
1	2	1	0	0	0	0
10	3	1	0	2	7	0
70	4	10	1	13	38	8
0	5	0	0	0	0	0
81	Totals	12	1	15	45	8

Figure 11: Criticality Distribution for all of the relief devices

4.5.1 Consequence of Failure

Risk assessment is based on the defining a failure scenario. The scenario should describe the causes and consequences of each identified failure. Typically, defining the Consequence of the Failure involves using an event tree that could lead to different end events. Each end event has a certain probability of occurring. It is important to develop credible failure scenarios for each identified failure mechanism.

Since Consequence Analysis constitutes half of the risk equation, it is reasonable to expect that an effort similar to that used to define Probability of Failure should be applied to determining Consequence of Failure. Flammable event, toxic releases, environmental risk, business interruption and asset repair and maintenance costs are such example for Consequence of Failure. For the Consequence of Failure, "A" is categorized as a Catastrophic and "E" as Minor.

The Consequence of Failure Distribution for site A and B relief devices are shown in below.

Figure 12: Consequence of Failure Distribution for site A.

Figure 13: Consequence of Failure Distribution for site B.

4.6 CONVENTIONAL INSPECTION VERSUS RISK BASED INSPECTION.

Basically conventional relief device are based on visual inspection with intrusive inspections. Based on the Rule 467 Pressure Relief Devices the inspection requirements needed to be conducted are:

1. Visually inspect each PRV on each working day.
2. Inspect each pressure relief device handling volatile organic compounds quarterly with a portable hydrocarbon detection instrument, except that after four quarterly inspections in which no leakage is detected the inspection frequency shall be annually.
3. Where both a rupture disc and relief device are used in series, the downstream device shall be inspected.
4. When a pressure relief device is know to have relieved, such device shall be subjected to an additional inspection with a portable hydrocarbon detection instrument within 15 working days of the date of the known pressure relief.
5. Inspect each pressure relief device removed from service for repair within 15 working days of the device's return to the service.

6. Pressure relief devices which are found to be leaking and which are tagged or logged for repair at the turnaround need not be inspected before the turnaround.

Meanwhile there are three basic methods to test the relief valve during inspection which are Set Pressure Test, Back Pressure Test and Seat Leakage Test [8]. Those tests are explained in the Appendix. While the comparison between the two types of inspection are explained below based on the cost analysis.

4.6.1 Cost Analysis.

Cost analysis is based on the criticality result of the equipment. It also compares the cost using conventional inspection which uses time based and cost using RBI method. Assuming the inspection cost for a relief valve is approximately RM1000.00 per devices, the total cost for the inspection method can be determined. The cost value is based on the estimate from OGM Sdn Bhd. The cost analysis are shown in **Table 8** and **Table 9** and also shown graphically in **Figure 14** and **Figure 15**.

Table 9: Distribution of equipment inspection for site A

RBI method for site A:

Time to be inspected (Years)	1	3	5	10
No. of equipment inspect	0	45	269	538

Conventional method for site A:

Time to be inspected (Years)	1	3	6	9
No. of equipment inspect	0	269	538	807

Figure 14: Cost Analysis for site A.

Basically there is a large difference using RBI method and conventional method to maintain the relief valve. From the graph, the difference basically started from third year and continued afterwards. Around RM 224000 will be saved during the third year if the RBI method is being applied while around RM 317000 will be saved on the ninth year if this method continued.

Table 10: Distribution of equipment inspection for site B

RBI method for site B:

Time to be inspected (Years)	1	3	5	10
No. of equipment inspect	0	15	81	162

Conventional method for site B:

Time to be inspected (Years)	1	3	6	9
No. of equipment inspect	0	81	162	243

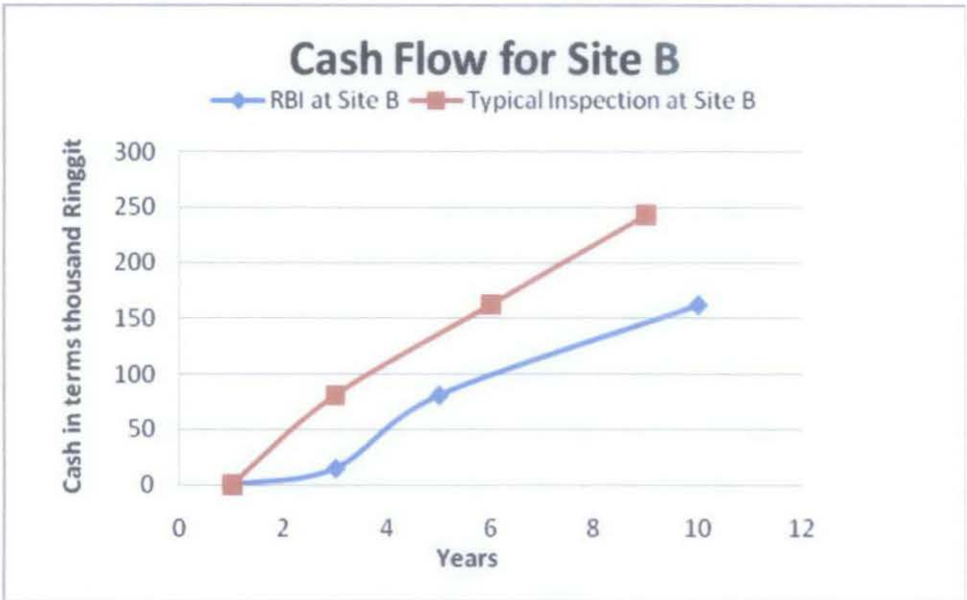


Figure 15: Cost Analysis for site B.

From the cost analysis graph for site B, there is also a big difference starting from third year and continued afterwards. Around RM 66000 will be save during the third year if the RBI method is being applied and if this continues then the cost to maintain the relief valve will be save around RM93000.

4.7 RISK SUMMARY FOR FINAL REPORT.

The risk summary listed in the Appendix shows the probability of failure categories, consequence of failure category and inspection priorities for all the relief devices included in the scope of work for site A and site B.

4.7.1 Inspection Work Plan Summary for Final Report.

Inspection plans were generated for all relief devices in the study and are based on the LR Capstone inspection planning rules. Each plan includes the relief devices Inspection Priority Ranking, the extent or inspection coverage and the inspection frequency. The Inspection Priority Matrix in **Figure 15** defines where each

Inspection Priority Ranking falls within the matrix. The Inspection Priority Ranking is a combination of the consequence of failure and probability of failure.

Inspection Priority Matrix

1	11	7	4	2	1
2	16	13	8	6	3
3	20	17	14	9	5
4	23	21	18	15	10
5	25	24	22	19	12
	E	D	C	B	A

Figure 16: Inspection Priority Matrix.

The inspection interval was set to the shorter of the following intervals:

1. The inspection interval established by the Criticality Rating on the date of the criticality runs:
   - Low: 5 years
   - Medium: 5 years
   - Medium High: 3 years
   - High: 1 year

2. Time required for the relief device to increase two levels of criticality or become "HIGH" criticality category.

CHAPTER 5
CONCLUSION

5.1 CONCLUSION

The main objective of this project is to compare the cost of inspection using risk based inspection to conventional inspection on relief valves. These findings were then plotted in a cash flow graph diagram to compare which inspection method is better. Basically the findings of the results not only reduce the cost of inspecting and maintenance of the equipment but also at the same time reduce the cumulative risk of the plant. The cumulative cash findings expected to be saved from site A and site B after nine years are to reach about RM 410000 when using risk based inspection method. The technique is done by parametering only highly risk relief valves, focusing on the equipments and put effort more into when to inspect or to maintain the equipment. All of this is done by optimizing the data collection, uploading the data via software and analyzing the risk by producing the risk matrix. The results then will indicated on how, where and when to inspect and maintain the equipment. The final objective of this project is achieved by executing the plan generated based on the scope given in the project. The report support the hypothesis where risk based inspection is a better inspection method than conventional inspection.

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Plant	LocationID	DeviceID	Protected by Rupture Disc	Rupture DiskID	Probability Category	Consequence Category	Criticality Rating	Inspection Priority	Last Insp Date
Site A	NG-101	NG-101	N		4	C	MEDIUM	18	12/09/1995
Site A	NG-102	NG-102	N		4	C	MEDIUM	18	13/12/2004
Site A	PSV-0007	124752	N		4	B	MEDIUM	15	08/03/2006
Site A	PSV-0029	322068	N		3	C	MEDIUM	14	29/07/1997
Site A	PSV-0047	124753	N		4	C	MEDIUM	18	08/03/2006
Site A	PSV-0101	124655	N		4	B	MEDIUM	15	08/03/2006
Site A	PSV-0204	124656	N		4	B	MEDIUM	15	08/03/2006
Site A	PSV-0205	124657	N		4	B	MEDIUM	15	08/03/2006
Site A	PSV-0210A	PSV-0210A	N		3	C	MEDIUM	14	01/03/1994
Site A	PSV-0210B	PSV-0210B	N		3	C	MEDIUM	14	01/03/1994
Site A	PSV-0210C	PSV-0210C	N		3	C	MEDIUM	14	01/03/1994
Site A	PSV-1	PSV-1	N		4	D	LOW	21	11/02/1999
Site A	PSV-1369-0	124658 A	N		3	C	MEDIUM	14	09/03/2006
Site A	PSV-1369-1	124658 B	N		3	C	MEDIUM	14	09/03/2006
Site A	PSV-1369-2	124658 C	N		3	C	MEDIUM	14	10/03/2006

Plant	LocationID	DeviceID	Protected by Rupture Disc	Rupture DiskID	Probability Category	Consequence Category	Criticality Rating	Inspection Priority	Last Insp Date
Site A	PSV-1369-3	124659 D	N		3	C	MEDIUM	14	10/03/2006
Site A	PSV-1370-0	124659 A	N		3	C	MEDIUM	14	09/03/2006
Site A	PSV-1370-1	124659 B	N		3	C	MEDIUM	14	10/03/2006
Site A	PSV-1370-2	124659 C	N		3	C	MEDIUM	14	09/03/2006
Site A	PSV-1370-3	124658 D	N		3	C	MEDIUM	14	10/03/2006
Site A	PSV-1401-0	124660	N		4	C	MEDIUM	18	07/03/2006
Site A	PSV-1401-1	124661	N		4	C	MEDIUM	18	26/07/2006
Site A	PSV-1401-2	124662	N		4	C	MEDIUM	18	07/03/2006
Site A	PSV-1401-3	124663	N		4	C	MEDIUM	18	07/03/2006
Site A	PSV-1402-0	124827 A	N		4	C	MEDIUM	18	07/03/2006
Site A	PSV-1402-1	124827 B	N		4	C	MEDIUM	18	26/07/2006
Site A	PSV-1402-2	124827 C	N		4	C	MEDIUM	18	07/03/2006
Site A	PSV-1402-3	124827 D	N		4	C	MEDIUM	18	19/10/2004
Site A	PSV-1403-0	124828 A	N		4	C	MEDIUM	18	07/03/2006
Site A	PSV-1403-1	61389	N		4	C	MEDIUM	18	25/07/2006

Plant	LocationID	DeviceID	Protected by Rupture Disc	Rupture DiskID	Probability Category	Consequence Category	Criticality Rating	Inspection Priority	Last Insp Date
Site A	PSV-1403-2	124828 C	N		4	C	MEDIUM	18	07/03/2006
Site A	PSV-1403-3	124628 B	N		4	C	MEDIUM	18	04/10/2007
Site A	PSV-1V11	2069201	N		3	B	MEDIUM HIGH	9	11/01/2001
Site A	PSV-2	PSV-2	N		4	D	LOW	21	11/02/1999
Site A	PSV-2305A	224832	N		4	B	MEDIUM	15	09/03/2006
Site A	PSV-2305B	224826	N		4	B	MEDIUM	15	09/03/2006
Site A	PSV-2305C	124665	N		4	B	MEDIUM	15	09/03/2006
Site A	PSV-2320A	124666 A	N		4	E	LOW	23	07/03/2006
Site A	PSV-2320S	124666 B	N		4	E	LOW	23	07/03/2006
Site A	PSV-2321A	124667 A	N		4	E	LOW	23	08/03/2006
Site A	PSV-2321S	329625	N		4	E	LOW	23	06/03/2006
Site A	PSV-2605	329628	N		2	D	MEDIUM	13	08/01/2001
Site A	PSV-2606	124669	N		4	B	MEDIUM	15	03/07/2007
Site A	PSV-2607	124668 B	N		2	D	MEDIUM	13	08/01/2001
Site A	PSV-2608	124668	N		2	D	MEDIUM	13	05/01/2001

Plant	LocationID	DeviceID	Protected by Rupture Disc	Rupture DiskID	Probability Category	Consequence Category	Criticality Rating	Inspection Priority	Last Insp Date
Site A	PSV-2V11	2069202	N		3	B	MEDIUM HIGH	9	04/01/2001
Site A	PSV-3115	124670	N		4	B	MEDIUM	15	02/02/2006
Site A	PSV-3118A	224833	N		4	B	MEDIUM	15	25/01/2006
Site A	PSV-3118B	224828	N		4	B	MEDIUM	15	26/01/2006
Site A	PSV-3118C	329610	N		4	B	MEDIUM	15	27/01/2006
Site A	PSV-3123A	224834	N		4	B	MEDIUM	15	06/02/2006
Site A	PSV-3123B	224830	N		4	B	MEDIUM	15	07/02/2006
Site A	PSV-3200A	122363	N		4	D	LOW	21	06/03/2006
Site A	PSV-3200B	122356 A	N		4	D	LOW	21	06/03/2006
Site A	PSV-3200S	122356 B	N		4	D	LOW	21	06/03/2006
Site A	PSV-3201S	LE1124	N		4	D	LOW	21	13/03/2006
Site A	PSV-3212	124673	N		3	B	MEDIUM HIGH	9	18/01/2001
Site A	PSV-3213	124674	N		4	D	LOW	21	07/03/2006
Site A	PSV-3215	124675	N		4	B	MEDIUM	15	03/02/2006
Site A	PSV-3315	124676	N		4	B	MEDIUM	15	08/03/2006

Plant	LocationID	DeviceID	Protected by Rupture Disc	Rupture DiskID	Probability Category	Consequence Category	Criticality Rating	Inspection Priority	Last Insp Date
Site B	PSV-9803	124803	N		3	B	MEDIUM HIGH	9	01/06/1994
Site B	PSV-9804	PSV-9804	N		3	B	MEDIUM HIGH	9	19/09/1995
Site B	PSV-9805	PSV-9802	N		4	C	MEDIUM	18	17/02/2005
Site B	PSV-9806	124804	N		4	B	MEDIUM	15	10/06/1998
Site B	PSV-9807	124805	N		4	C	MEDIUM	18	10/07/1998
Site B	PSV-9861	124810	N		3	C	MEDIUM	14	25/01/1995
Site B	RV-007	91FY045	N		4	B	MEDIUM	15	30/01/1999
Site B	RV-029	91FY046	N		4	B	MEDIUM	15	30/01/1999
Site B	RV-047	91FY047-1	N		4	B	MEDIUM	15	20/01/1999
Site B	RV-103B	91FY047-2	N		4	B	MEDIUM	15	30/01/1999
Site B	RV-104	91FY019	N		4	B	MEDIUM	15	07/02/1999
Site B	RV-105	91FY049	N		4	B	MEDIUM	15	07/02/1999
Site B	RV-106A	91FY050-1	N		4	B	MEDIUM	15	30/01/1999
Site B	RV-106B	91FY050-2	N		4	B	MEDIUM	15	30/01/1999
Site B	RV-106C	91FY050-3	N		4	B	MEDIUM	15	30/01/1999

Plant	LocationID	DeviceID	Protected by Rupture Disc	Rupture DiskID	Probability Category	Consequence Category	Criticality Rating	Inspection Priority	Last Insp Date
Site B	RV-201	90FX331	N		4	B	MEDIUM	15	30/01/1999
Site B	RV-202	90FX332	N		4	B	MEDIUM	15	30/01/1999
Site B	RV-203	90FX333-1	N		4	B	MEDIUM	15	29/01/2005
Site B	RV-1101	90FX334	N		4	B	MEDIUM	15	29/01/2005
Site B	RV-1204	90FX335	N		4	B	MEDIUM	15	29/01/2005
Site B	RV-1205	90FX336	N		4	B	MEDIUM	15	30/01/1999
Site B	SV-051	C88079	N		4	B	MEDIUM	15	11/10/2004
Site B	SV-052	C88080	N		4	B	MEDIUM	15	11/10/2004
Site B	SV-101A	125218A	N		4	A	MEDIUM HIGH	10	01/06/1994
Site B	SV-101B	125218B	N		4	A	MEDIUM HIGH	10	01/06/1994
Site B	SV-102	91FY051	N		4	A	MEDIUM HIGH	10	28/01/1999
Site B	SV-103	91FY052	N		4	B	MEDIUM	15	21/03/2005
Site B	SV-104	92FX135	N		4	B	MEDIUM	15	29/01/1999
Site B	SV-171A	SV-171A	N		4	C	MEDIUM	18	07/02/1999
Site B	SV-171B	SV-171B	N		4	C	MEDIUM	18	08/02/1999

Plant	LocationID	DeviceID	Protected by Rupture Disc	Rupture DiskID	Probability Category	Consequence Category	Criticality Rating	Inspection Priority	Last Insp Date
Site B	SV-172A	SV-172A	N		4	B	MEDIUM	15	07/02/2008
Site B	SV-172B	SV-172B	N		3	B	MEDIUM HIGH	9	08/02/1999
Site B	SV-181	SV-181	N		4	E	LOW	23	24/03/2005
Site B	SV-183	SV-183	N		4	E	LOW	23	22/03/2005
Site B	SV-184	SV-184	N		4	E	LOW	23	24/03/2005
Site B	SV-185A	SV-185A	N		4	E	LOW	23	07/02/1999
Site B	SV-185B	SV-185B	N		4	E	LOW	23	21/03/2005
Site B	SV-187	111209	N		4	E	LOW	23	22/03/2005
Site B	SV-188	91FY053	N		4	E	LOW	23	22/03/2005
Site B	SV-201A	025064A	N		4	A	MEDIUM HIGH	10	01/06/1994
Site B	SV-201B	025064B	N		4	A	MEDIUM HIGH	10	01/06/1994
Site B	SV-202	90FX328	N		4	B	MEDIUM	15	29/01/2005
Site B	SV-203	90FX329	N		4	A	MEDIUM HIGH	10	01/02/2005
Site B	SV-204	90FX330	N		4	B	MEDIUM	15	22/04/2005
Site B	SV-271A	SV-271A	N		4	C	MEDIUM	18	29/01/2005

Plant	LocationID	DeviceID	Protected by Rupture Disc	Rupture DiskID	Probability Category	Consequence Category	Criticality Rating	Inspection Priority	Last Insp Date
Site B	SV-271B	SV-271B	N		4	C	MEDIUM	18	02/02/1999
Site B	SV-272A	SV-272A	N		4	B	MEDIUM	15	29/01/2005
Site B	SV-272B	SV-272B	N		4	B	MEDIUM	15	02/02/2005
Site B	SV-401A	91F7564-2	N		4	E	LOW	23	29/01/2005
Site B	SV-401B	91F7564-1	N		4	E	LOW	23	02/02/2005
Site B	SV-402A	91FY054	N		2	E	MEDIUM	16	01/06/1994
Site B	SV-402B	SV-402B	N		3	E	LOW	20	01/06/1994