Preventive Program for Small Bore Piping Failure At Gas Processing Plant

by

Mohd Husairil Bin Ibrahim

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

JANUARY 2009

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.

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MOHD HUSAIRIL BIN IBRAHIM

ABSTRACT

Small bore piping failures are one of the main problems occurred in the gas processing plant. These failures had caused plant interruption such as product leakage, unscheduled plant downtime and also impact on plant safety and reliability. Based on the data analysis, the most common failure is due to the internal erosion effect at elbow and tee joint pipe. This project is to investigate internal erosion effect at elbow and tee joint small bore piping. This is done by using the Computational Fluid Dynamic (CFD) analysis to validate the actual case study. By creating the models and then simulating with CFD, it is found that the failure occurred at the elbow pipe and tee joint pipe as the pressure concentration occurred there. Therefore, in order to prevent piping failure due to the internal erosion effect, proper piping design and material selection and proper inspection planning need to be done in the future. The methods to improve piping design and material are increasing pipe diameter, increasing the wall thickness and using more erosion-resistant alloys. For inspection planning, do prioritize inspection on suspected area based on Risk-Based Inspection (RBI) and perform non-destructive testing such as Ultrasonic testing and radiography testing. As a conclusion, the significance of this research would be important to solve internal erosion effect in small bore piping.

ACKNOWLEDGEMENTS

I would like to take the opportunity to express my utmost gratitude to the individuals who have taken the time and effort to assist me in completing this project. Without the cooperation of these individuals, I would undoubtedly have faced complications throughout the project.

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This special thanks and appreciation also dedicated to all staff of Universiti Teknologi PETRONAS and colleagues for their continued support, guidance and contribution towards completing this project. With the full cooperation from the various people above, I have successfully achieved the objective of Final Year Project course. Thank you very much.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Small bore piping failure is a serious issue in any processing plant. These failures can cause in product leakage, unscheduled plant downtime and also will impact the plant safety and reliability. It is usually detected as small cracks or leaks before major pressure boundary ruptures occur. There are various types of failure modes, which could affect a piping system such as internal erosion, external corrosion, improper welding, vibration induced and others. For this project, the author will focus on the highest factor which is internal erosion in steam condensate line at elbow and tee joint pipe.

The significance of this research would be important to solve internal erosion problem in small bore piping. Two important parts in this project is Risk-Based Inspection (RBI) and computational fluid dynamic (CFD) analysis. Finally, the author will come out with recommendation: Preventive program for small bore piping failure at Gas Processing Plant. The recommendations based on two major methods:

- Piping design and material by using CFD analysis
- Inspection Planning by using Risk-Based Inspection (RBI)

1.2 Problem Statement

Over the years, Gas Processing Plant, GPP at PETRONAS Gas Berhad (PGB) had experience a number of small bore failures which consist of different consequences.

Certain failures have to either one of these conditions:

i. Total plant shutdown
ii. Unit shutdown (loss of ethane production, sales gas half load, loss of butane or propane production)
iii. Lesser degree to item i & ii above.

Cost of loss for main products at GPP, PGB (Table 1.1):

Table 1.1: Estimated cost of product loss at GPP, PGB [1]

1	Sales gas	2.0 millions/day, per processing plant
2	Ethane	1.0 millions /day, per processing plant
3	Propane	0.6 millions /day, per processing plant
4	Butane	0.4 millions /day, per processing plant

From analysis on small bore piping failure database (Table 1.2), it indicated that the majority of such failures are commonly caused due to internal erosion in steam condensate line. Therefore, this project will be focus on small bore piping failures subjected to internal erosion. Investigation and researched on the internal erosion will be conducted.

Table below (Table 1.2) shows numbers of failures for small bore piping from 2007-2008 at PGB:

Table 1.2: Damage mechanisms for small bores at GPP, PGB [1]

Ranking	Type of Failure	Total
1	Internal erosion	25
2	Internal & External corrosion	21
3	Vibration induced failure	7
4	Highly stressed joint due to dead load	5
5	Improper welding of threaded connection	0
6	Improperly jointed connections	0
7	Pinhole leak due to improper welding QC	0
8	Excessive vibration of particular PSV line	0
9	Stress corrosion cracking	0

The integrity of the small bore piping is dependent on accurate assessment of internal erosion through Computational Fluid Dynamic (CFD) software and preventive program by using Risk-based Inspection (RBI) method.

1.3 Objectives and Scope of The Study

The objectives and scope of study for this project are:

i. To investigate and identify the factors that contributes to the small bore piping failures
ii. To validate internal erosion effect in small bore piping by using a Fluid Mechanics software; FLUENT
iii. To develop recommendations as preventive program for small bore piping by using Risk-based inspection (RBI) method.

CHAPTER 2

LITERATURE REVIEW

2.1 Design Code and Standard

The ASME Code for Pressure Piping B31.3-2002 Process Piping [2] states that piping is a system of pipes used to convey fluids, from one location to another location. The piping typically found in petroleum refineries, chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants, and related processing plants and terminals.

2.1.1 General Equation for Straight Pipe

The required thickness of straight sections of pipe is determined by ASME Code for Pressure Piping B31.3-2002 Process Piping [2] :

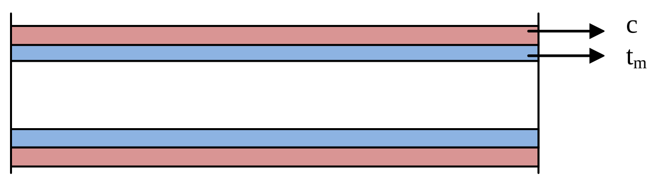

Figure 2.1: The required thickness of pipe

$$\mathbf{t = t_m + c} \quad \text{-----------------(1)}$$

The minimum thickness, t for the pipe selected, considering manufacturers minus tolerance, shall be not less than pressure design thickness, tm.

The following nomenclature is used in the equations for pressure design of straight pipe:

- t = minimum required thickness, including mechanical, corrosion, and erosion allowances
- t_m = pressure design thickness, as calculated in accordance with para. 304.1.2 for internal pressure or as determined in accordance with para. 304.1.3 for external pressure
- c = the sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances.

2.2 Factors of Small Bore Piping Failures

The API 570-Repair, Alteration, and Rerating of in-service Piping Systems (2001) [3] states that failures of small bore piping (diameter less than or equal to 2-inch) connections continue to occur frequently in power and process plants, resulting in degraded plant systems and unscheduled plant downtime. Some of the failures occurred due to internal corrosion and erosion, vibration induced, improper welding, improper jointed connection, stress corrosion cracking, poor inspection on piping and so on.

According to Inspection Department, PGB [1], the majority of such failures are caused by internal erosion in steam condensate line. Erosion can be defined as the removal of surface material by the action of numerous individual impacts of solid or liquid particles. It can be characterized by grooves, rounded holes, waves, and valleys in a directional pattern. Erosion usually occurs in areas of turbulent flow, such as at changes of direction in a piping system or downstream of control valves where vaporization may take place. Erosion damage is usually increased in streams with large quantities of solid or liquid particles flowing at high velocities [3].

A combination of corrosion and erosion (corrosion/erosion) results in significantly greater metal loss than can be expected from corrosion or erosion alone. This type of erosion occurs at high-velocity and high-turbulence areas.

Examples of places to inspect include the following as shown in API 570 [3] :

- Downstream of control valves, especially when flashing is occurring.
- Downstream of orifices.
- Downstream of pump discharges.
- At any point of flow direction change, such as the inside and outside radii of elbows.
- Downstream of piping configurations (such as welds, thermo wells and flanges) that produce turbulence, particularly in velocity sensitive systems such as ammonium hydrosulfide and sulfuric acid systems.

Areas suspected of having localized corrosion/erosion should be inspected using appropriate NDE methods that will yield thickness data over a wide area, such as ultrasonic scanning, radiographic profile, or eddy current.

Sample of internal erosion (Figure 2.2) at small bore by using radiography testing:

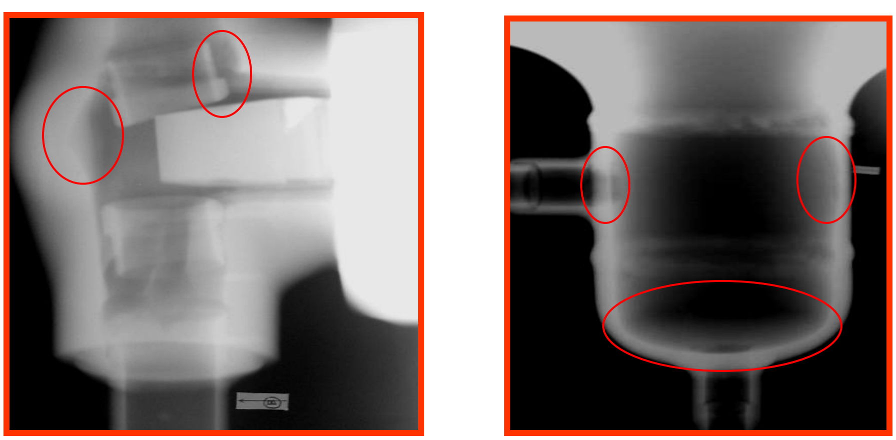

Figure 2.2 : Radiography examination for small bore

2.3 Risk Based Inspection (RBI) on Small Bore Piping

The API 580-Risk-Based Inspection [4] states that RBI, as a risk-based approach, focuses attention specifically on the equipment and associated deterioration mechanisms representing the most risk to the facility. In focusing on risks and their mitigation, RBI provides a better linkage between the mechanisms that lead to equipment failure and the inspection approaches that will effectively reduce the associated risks.

- Categorization Of Probability Of Failure

Where possible, the probability of failure on a component inspected and examined needs to be determined and categorized. For the rule of thumb, breaking up the categorization of failure probability is recommended as following (Table 2.1):

Table 2.1: Probability of failure categorization

A	High probability of failure
B	Medium probability of failure
C	Low probability of failure

- Categorization Of Consequence Of Failure

For the categorization of consequence of failure, the following breakdown is to be used throughout all the modules of the damage mechanism identified (Table 2.2):

Table 2.2: Consequence of failure classification of piping system

Class SD 1	Failure leads to total plant Shut Down (S/D)
Class SD 2	Failure cause unit S/D (loss of ethane, butane or propane, or reduce Sales Gas to Half Load
Class SD 3	None of the above

- Small Bore Prioritization Through Risk Criticality Matrix

Once the Probability of Failure and the Consequences of Failure are formulated, then prioritize the risk associated with the every piece of small bore item into a 3 by 3 risk matrix.

Table 2.3: 3 by 3 Risk matrix

SD 1	1C	1B	1A
SD 2	2C	2B	2A
SD 3	3C	3B	3A
	C	B	A

Table 2.4: Risk/criticality ranking

(red)	**High Risk**
(yellow)	**Medium Risk**
(green)	**Low Risk**

When we do inspection on small bore piping, we must follow the inspection step based on recommendation practice [3]:

Flow of inspection as stated in API 570 [3]:

1. Identify location
2. Take Photo (area photo based on ISO drawing), Tagging & Marking
3. Request scaffolding & insulation removal (if required)
4. Perform NDT at the identified location (RT, UTTM).
5. Interpret and evaluate the RT result.
6. Assessment of wall loss and Calculate remaining life as per API 570
7. Determine Consequences category
8. Determine action /rectification/repair required
9. Update record

Successful implement of RBI for internal erosion depend on the analysis of difficult assessment for internal piping. To inspect the internal flow, computational fluid dynamic (CFD) software, FLUENT will be used to simulate the effect of internal erosion in small bore piping.

2.4 Numerical Simulation of Erosion-Corrosion in Four-Phase flow

According to Marco Ricotti (2006) [7], the problem of the simulation of erosion-corrosion phenomena in four phase flows of relevance to the petrochemical industry can be simulate by using Computational Fluid Dynamic (CFD). In off-shore crude-oil extraction systems, and pipes in particular, a four-phase flow typically develops in which two immiscible liquids are present (oil and seawater) together with a gaseous phase (a hydrocarbon mixture) and a solid particulate (sand). Scope of the study is the investigation of the erosion-corrosion of pipe walls, due to the internal flow of gas-liquid multiphase mixtures carrying an inert particulate solid phase.

.

The analysis aims at the qualitative and quantitative evaluation of the corrosion effects enhanced by erosion at the walls of a pipe bend, into which a fluid mixture of two liquid phases plus a gas phase flows and transports a solid phase. A computational fluid dynamic tool has been selected for the simulation of the flow field inside the piping and for the simulation of the particle trajectories and their impact on the bend walls. CFD is currently one of the more sophisticated and promising approaches for the analysis and solution of a wide class of problems involving flow domains and in a wide set of research and industrial application fields. CFD codes solve the full set of fluid dynamic balance equations, usually in Navier-Stokes formulation for momentum balance, taking into account for the fluid turbulence via different models.

The present case study has been performed by adopting a 3-D unstructured mesh (dimension: 105 hexahedral cells) for the pipe, an implicit method for the numerical solution of mass and momentum equations and a k-e model for the turbulence. The mixture composition and phase velocities are defined at the inlet boundary. A specialised model is used for the simulation of particles transported in the continuous flow field. The Discrete Phase Model (DPM) solves the equation of motion for a discrete phase dispersed in the continuous phase, by adopting a Lagrangian frame of coordinates and leading to the calculation of the particle trajectories.

The model available in FLUENT code in order to calculate the erosion flux is a simplified model taking into account the mass flow rate of the impacting stream, the surface area of the impacted wall boundary cell) and an impact angle function. Physical parameters describing independent erosion and corrosion phenomena were derived from experiments. The synergistic effects were simulated numerically, a typical result of erosioncorrosion distribution is shown in the figure reported below.

Four fluid dynamic characteristic parameters have been selected as key points for the Case Matrix definition, namely:

1. Fluid Flow inlet velocity;
2. Inlet Volumetric Flow ratio for the Gas phase;
3. Inlet Volumetric Flow ratio for the Water (liquid) phase;
4. Mass Flow rate of inert particles injected.

Two values each have been selected to compose the 16 cases set; the values assumed by the parameters define a range sufficiently wide to cover a representative domain for the phenomena.

The figure below shows flow pattern in pipe (Figure 2.3):

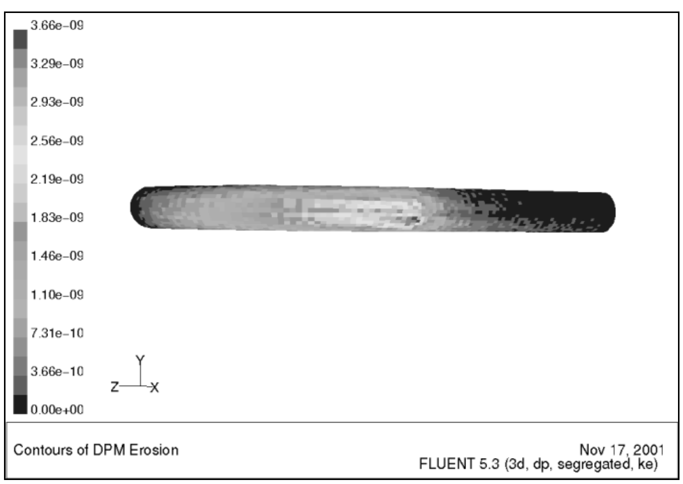

Figure 2.3: Flow Pattern in Pipe

CHAPTER 3

METHODOLOGY

3.1 Process Plan

This project is started by collecting database for small bore failure finding at PGB. The author will get database from Inspection Department, PGB. Then, the author will do analysis to choose the major failure happened and will focus on it for further investigation. Next, the simulation design using Fluid Mechanics Software; FLUENT will be executed to do computational fluid dynamic (CFD) analysis as actual case study for fluid flow to investigate internal erosion effect.

After get the result from FLUENT, the author will do research and study these following references to come out with recommendation for preventive program:

1. API 570-Repair, Alteration, and Rerating of in-service Piping Systems [3]
2. API 580 : Risk Based Inspection [4]
3. ASME Code for Pressure Piping B31.3 (2002) Process Piping [2]

The recommendation for preventive program based on two major methods:

- Piping design and material
- Inspection Planning

3.1.1 Schematic Process Flow

Figure 3.1 showed the flow chart of the procedures that had been implemented to complete this study:

Get Database for Small Bore Failure at PGB from Inspection Department.

- Analysis to choose major failure factor : internal erosion

↓

Validate the simulation design using Fluid Mechanics software; FLUENT

- Get result for internal erosion effect from FLUENT software

↓

Give recommendation: Preventive Program for small bore piping failure

- Recommendation : Piping design & material and Inspection Planning
- Based on research and study for : API 570, API 580 and B31.3

Figure 3.1: Flow Chart

3.2 Case study

The modelling and simulating of the project is based on the actual case taken during the researched period. Several models are designed (such as overall structure, elbow, tee pipe, and etc.) according to the actual case. Based on the models that have been designed, these models will be simulated and analyzed using the computational fluid dynamic software; FLUENT. And lastly, the finding is discussed.

The figures below (Figure 3.2 and Figure 3.3) show the actual case pictures of small bore piping failure occurred at Gas Processing Plant. These failures occurred several times because internal erosion effect at the same piping design; elbow pipe and tee pipe. Therefore, the pressure develop will be measured to investigate internal erosion effect.

3.2.1 Actual case study for elbow pipe (Appendix 2)

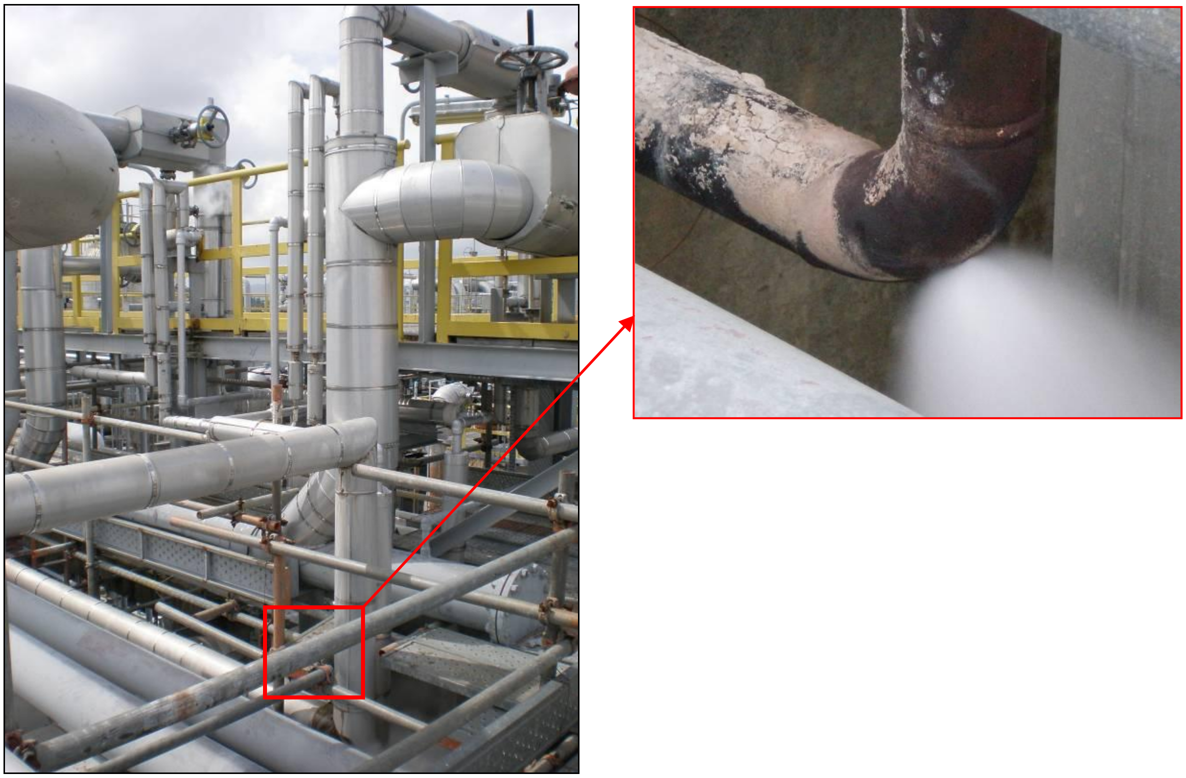

Figure 3.2: The Actual Case of Small Bore Piping Failures for elbow pipe

<u>DATA</u>

Pipe : 2” API 5L Gr.B 5.54mm XS

Elbow : A234GR.WPB BE

Design Pressure : 4500 Kpa

Operating Pressure : 3900 Kpa

Design Temperature : 395 ^{0}C

Operating Temperature : 249 ^{0}C

3.2.2 Actual case study for tee pipe (Appendix 3)

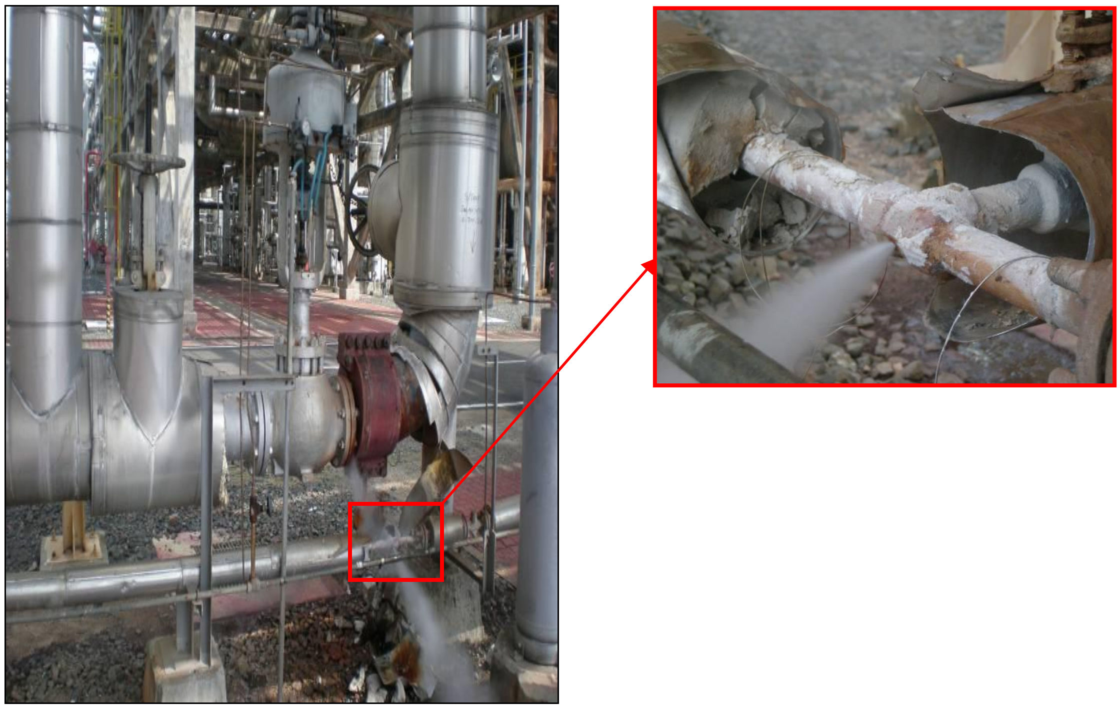

Figure 3.3: The Actual Case of Small Bore Piping Failures for tee joint pipe

DATA

Line no. : LS-12”-7523-D1101-H(N20A)

Pipe : ¾” API 5L Gr.B 3.91mm XS

Design Pressure : 800 Kpa

Operating Pressure : 650 Kpa

Design Temperature : 300 ^{0}C

Operating Temperature : 173 ^{0}C

Tee existing : ¾” A105 Class 3000

3.3 Procedure

For the next step, by referring the actual design, the author created models to simulate using the FLUENT software. The details process is stated below:

3.3.1 Elbow Pipe Simulation

For elbow pipe case study, the author design elbow specimen using AutoCAD software with nearly identical configurations (Figure 3.4) was tested. The length of straight pipes is 50mm, 90^o, 2” diameter and API 5L Gr.B 5.54mm XS.

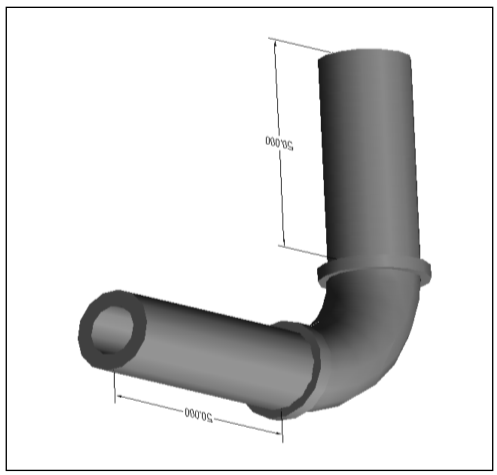

Figure 3.4: Elbow Pipe

3.3.2 Tee Pipe Simulation

For tee pipe case study, the author design tee specimen using AutoCAD software with nearly identical configurations (Figure 3.5) was tested. The length of straight pipes is 50mm and ¾” API 5L Gr.B 3.91mm XS.

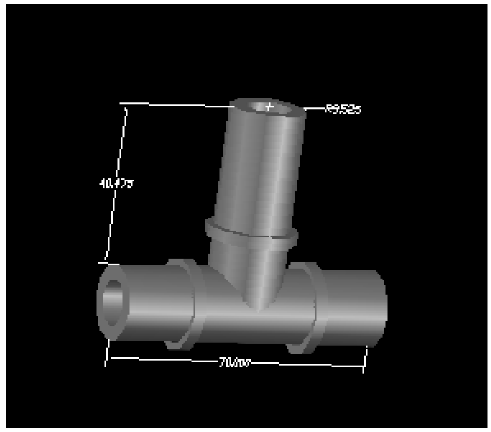

Figure 3.5: Tee Pipe

3.4 Tool Required

In completing this project, correct tools that will be used must be selected wisely. These tools include hardware, equipment, as well as software. So far, computer is the most important tool in performing this project in order to seek information through the internet, writing the reports and to analyze design calculation. Besides that, software likes AutoCAD, GAMBIT and FLUENT are also necessary in completing this project.

Figure below (Figure 3.6) showed the step taken to complete analysis by using FLUENT software:

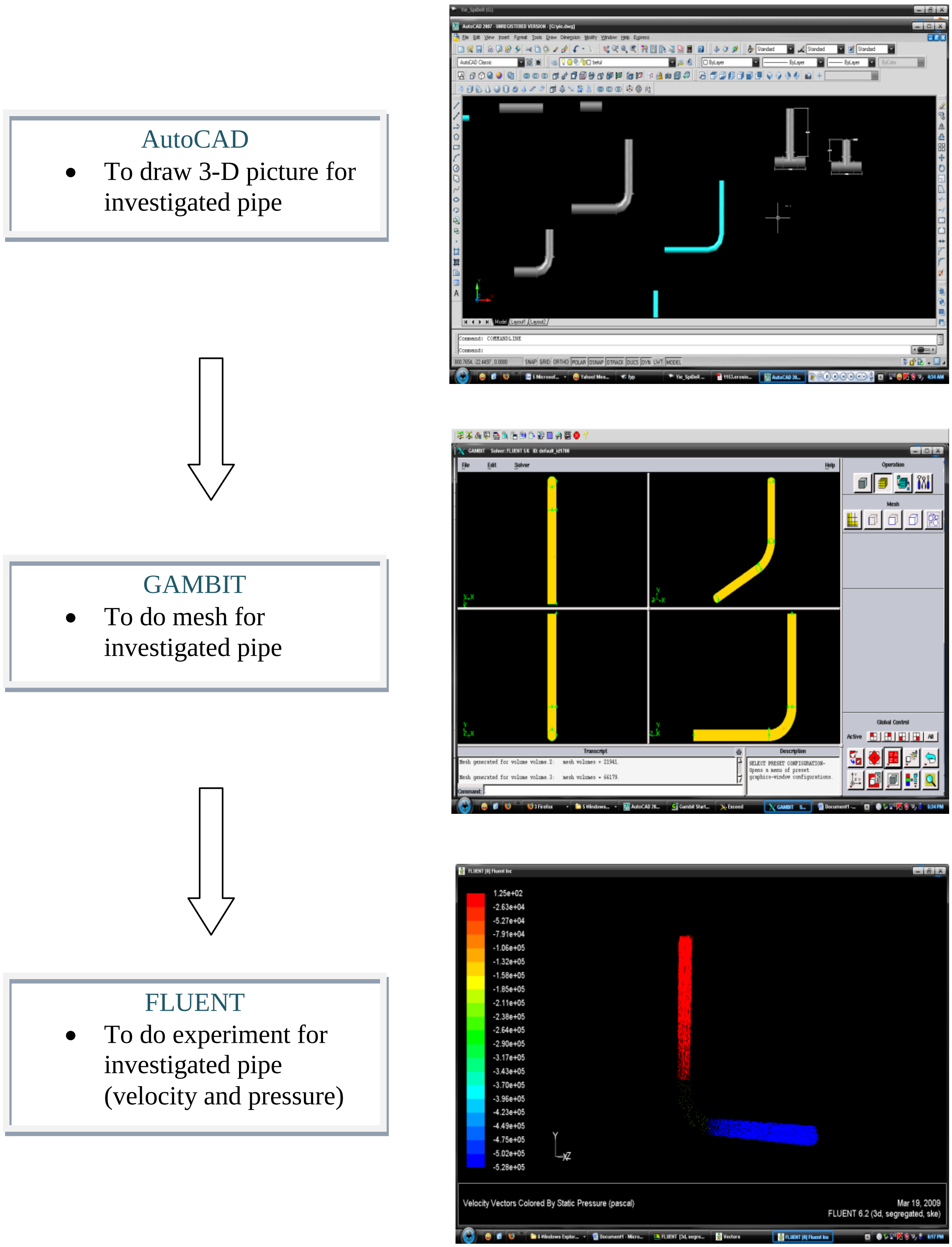

Figure 3.6: Step taken to do FLUENT

CHAPTER 4
RESULT AND DISCUSSION

4.1 Data gathering and Analysis

First of all, the author collect the data from PETRONAS Gas Berhad (PGB), Kerteh to get information about cause of small bore piping failure happened. The data was obtained from Inspection Department that responsible for any inspection task. From the data given, the author knows that internal erosion is the major cause for small bore piping failure.

Here, the graph was attached (Figure 4.1) to show clearly average failure happened/year (Y-axis) vs. cause of small bore piping failure (X-axis):

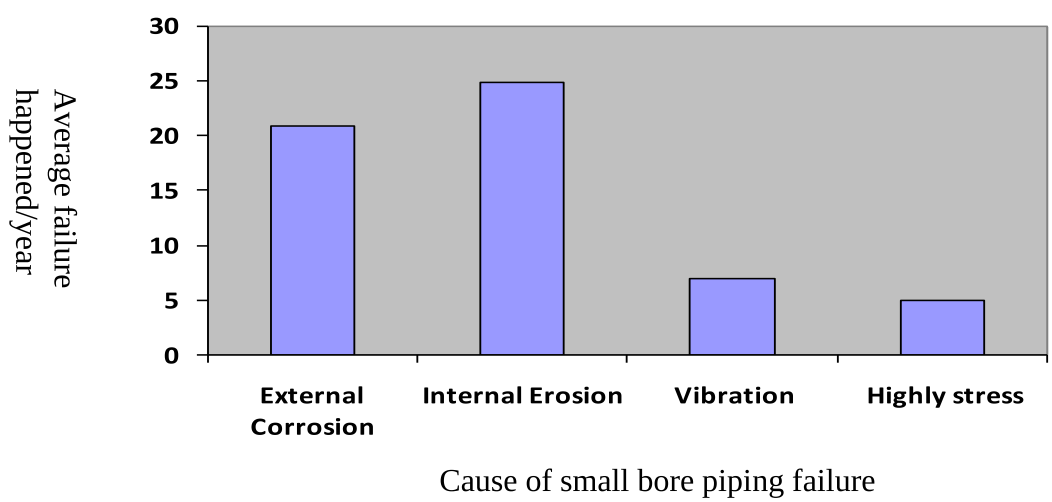

Figure 4.1: Average failure happened/year vs. cause of small bore piping failure

From the research and discussion with Inspection Engineer, the author had come out with suspected locations for internal erosion easily happened:

- Downstream of control valves, especially when flashing is occurring.
- Downstream of pump discharges
- At any point of flow direction change, such as the inside and outside radii of elbows.
- Downstream of piping configurations (such as welds, thermowells and flanges) that produce turbulence, particularly in velocity sensitive systems such as ammonium hydrosulfide and sulfuric acid systems

Figure 4.2 shows the suspected internal erosion area at PGB:

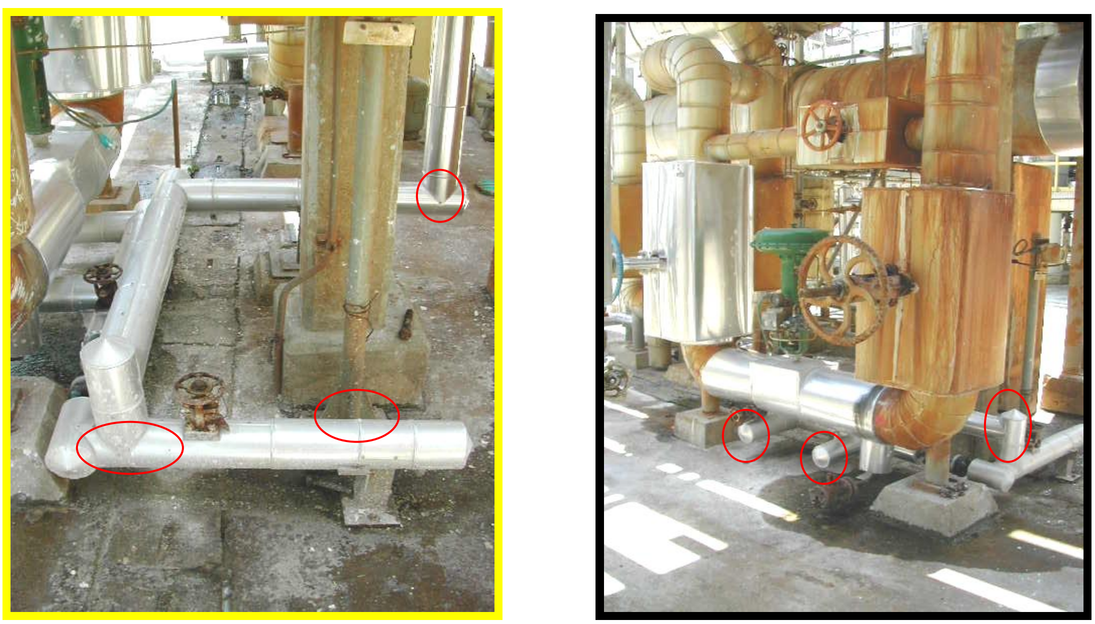

Figure 4.2: Suspected internal erosion area

4.2 Preventive Program for Small Bore

Preventive program for small bore piping failure at Gas Processing Plant have two major methods:

- Inspection Planning by using Risk-Based Inspection (RBI)
- Piping design and material by using CFD analysis

4.2.1 Modelling: Inspection Planning by using RBI

For the inspection planning method, the author use Risk-Based Inspection (RBI) method. RBI is a systematic data analysis of equipment condition, to determine the associated risk with its operation. RBI is based on Probability of Failure (PoF) and Consequence Of Failure (CoF).

<u>Probability of Failure</u>

Probability of Failure (PoF) is depending on the degree of:

- Internal corrosion
- External corrosion
- Environmental cracking & other damage mechanism

Table 4.1: Probability of failure categorization

Life A	Remaining thickness < min thickness
Life B	Remnant life < 3 years
Life C	Remnant life > 3 years

Consequence Of Failure

For the Consequence of Failure (CoF) category, it depends on the degree of :

- Flammability
- Toxicity
- Production loss

Table 4.2: Consequence of failure classification for piping system

Class SD 1	Failure leads to total plant Shut Down (S/D)
Class SD 2	Failure cause unit S/D , i.e AGRU, PRU, which s/d ethane, butane or propane, or reduce Sales Gas to Half Load
Class SD 3	None of the above

After got result for probability of failure (PoF) and Consequence of Failure (CoF), the author will come out with Risk Ranking Matrix. Risk Ranking Matrix will show the criticality of small bore piping. Based on this criticality, inspection for piping will be planned.

Risk Ranking

Table 4.3: Risk ranking Matrix

SD 1 Total	1C	1B	1A
SD 2 Unit	2C	2B	2A
SD 3	3C	3B	3A
	Life C Rem. Life > 3 yr	Life B Rem. Life < 3 yr	Life A Thick < min

Risk Prioritization and Mitigation

Table 4.4: Risk category

	Risk	Actions
(red)	High Risk	Immediate repair/replacement/rectification actions required
(yellow)	Medium Risk	i. To plan for replacement/repair in next T/A or available S/D window ii. Or to schedule a yearly monitoring
(green)	Low Risk	To monitor every 3 yearly.

Example calculation for determined RBI group based on actual case study for elbow pipe (Appendix 4):

DATA

Pipe: 2" API 5L Gr.B 5.54mm XS

Elbow: A234GR.WPB BE

Design Pressure: 4500 Kpa

Operating Pressure : 3900 Kpa

Design Temperature : 395 ^{0}C

Operating Temperature: 249 ^{0}C

Actual thickness, At / remaining thickness : 1.2612 mm

Pressure design wall thickness, dt / minimum required thickness : 1.46 mm

Corrosion rate, Cr : 0.29 mm/year

Formula to calculate Estimated Life Spent (ELS) base on minimum required thickness as stated in API 570 [3]:

ELS = (At-dt)/Cr ---(2)

ELS = (1.2612mm-1.46mm)/0.29

= -0.69 year

Based on the result (ELS=-0.69year), it shows that remaining life for this pipe is very low and the remaining thickness is lower than minimum required thickness. So, it category in LIFE A (remaining thickness < minimum required thickness) for RBI analysis.

This pipe also category in SD 1 (failure leads to total plant shut down) if the pipe leak and fail. Based on RBI analysis, this elbow pipe is in HIGH RISK category. It need immediate action to repair, replacement or rectification.

4.3 Piping design and material by using CFD analysis

4.3.1 Actual Case Study

From the actual case study for elbow pipe and tee pipe which happened at Gas Processing Plant, the author will investigate by using FLUENT software to simulate the flow in pipe. Here, the author also got Radiography film as a result for inspection purpose.

Figure 4.3 showed the actual case of small bore piping failures happened at PGB:

(a) elbow pipe

(b) tee pipe

Figure 4.3: The Actual Case of Small Bore Piping Failures

4.3.2 Result

Based on the Computational Fluid Dynamic (CFD), the results of the small bore piping analysis are shown below:

4.3.3 Elbow Pipe Simulation

First, the author got the Radiography testing result from Inspection department, PGB. From Radiography film (Figure 4.4), it shows that severe internal erosion observed at elbow's socket and severe internal erosion observed at elbow's body. This erosion effect will cause wall lose or decreasing of wall thickness.

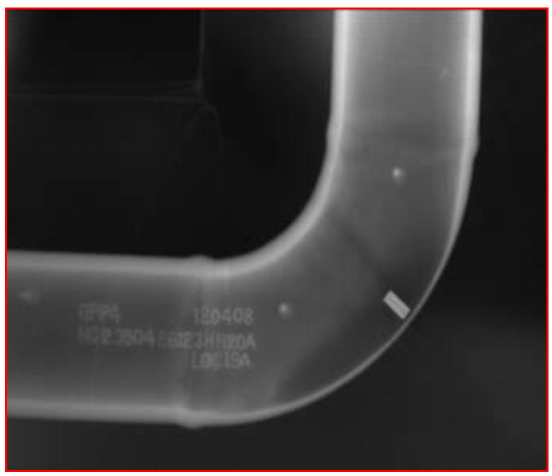

Figure 4.4: Radiography Film show wall lose

By using FLUENT software, the result for Elbow Pipe was obtained (Figure 4.5). The author investigated the velocity of steam (water vapour) in the pipe first by setting velocity is 10m/s. From Fluent result, it shows that at inlet flow, the velocity is very high because it receives high pressure.

When the steam reach elbow, the velocity decrease because the steam collide elbow wall and need to change direction of flow. The elbow wall prevents the velocity of steam from running smoothly.

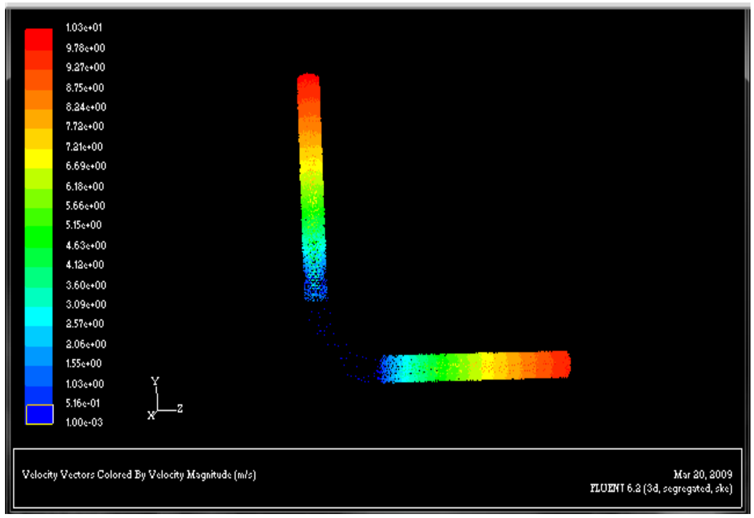

Figure 4.5: Fluent result for Velocity vector

Secondly, the author investigated pressure developed in the elbow pipe design (Figure 4.6). From the result, the pressure is higher along the pipe wall and it increase when steam reach the elbow. The pressure is very highest at elbow pipe wall because the elbow prevent the steam from running smoothly and cause change of direction.

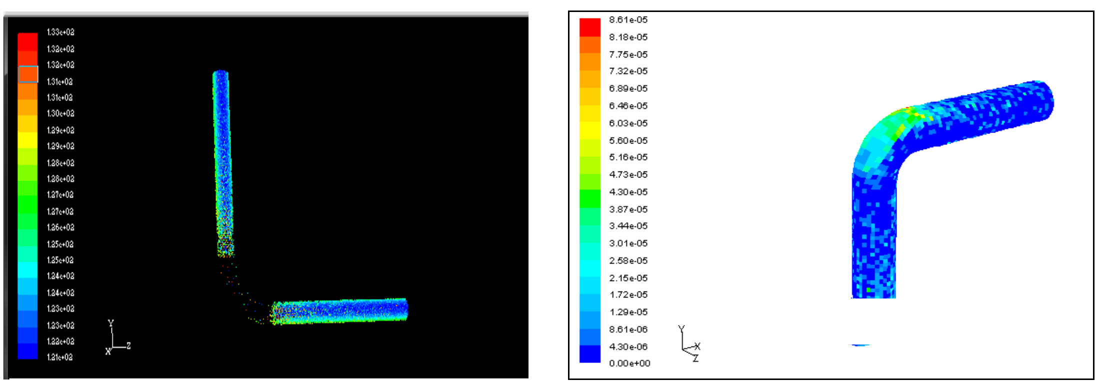

Figure 4.6: Fluent result for Pressure Developed

The author focused on elbow pipe to get clear result for contour of erosion in steam line. The result (Figure 4.7) shows that the highest erosion effect obtained at outside elbow.

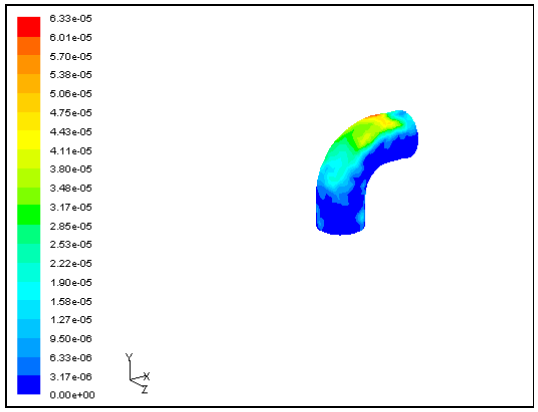

Figure 4.7: Fluent for Contour of erosion

4.3.4 Tee Pipe Simulation

The author also got the Radiography testing result from Inspection department, PGB for tee pipe sample. From Radiography film (Figure 4.8), it shows that severe internal erosion observed at tee joint and severe internal erosion observed at tee joint body. This erosion effect will cause wall lose or decreasing of wall thickness.

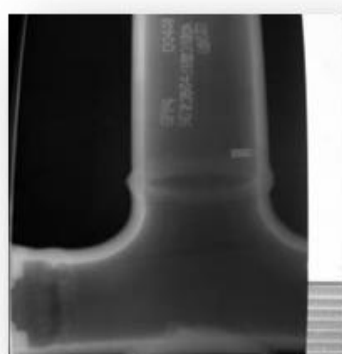

Figure 4.8: Radiography Film show wall lose

By using FLUENT software, the result for Tee Pipe was obtained. The author investigated the velocity of steam (water vapour) in the pipe first by setting velocity is 10m/s. From Fluent result (Figure 4.9), it shows that at inlet flow, the velocity is very high because it receives high pressure. When the steam reach tee joint, the velocity decrease because the steam collide tee joint wall and need to change direction of flow. The tee joint wall prevents the velocity of steam from running smoothly.

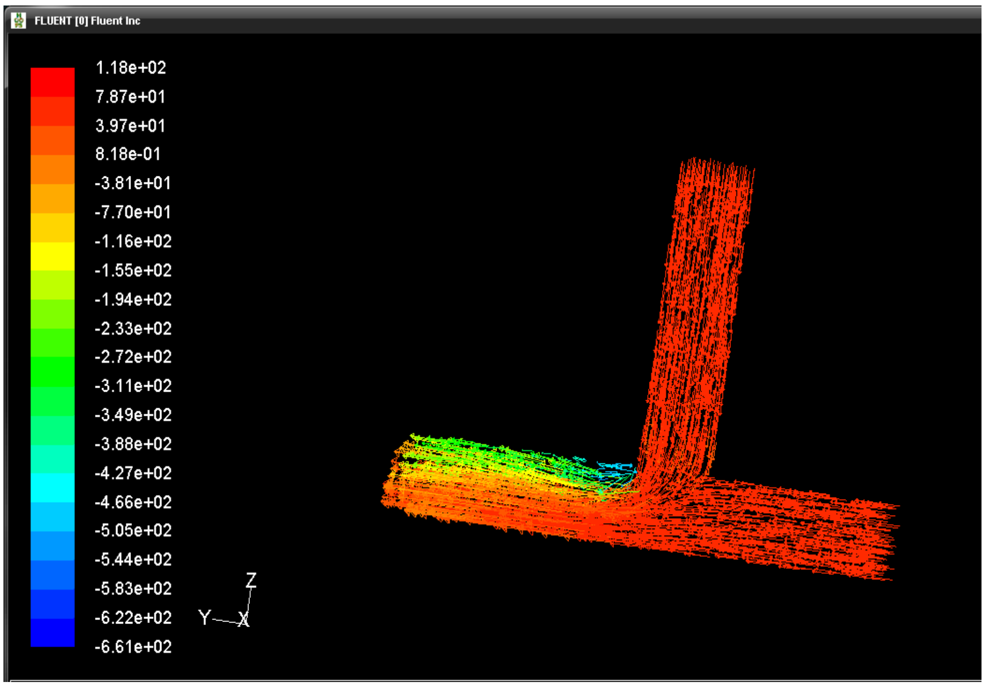

Figure 4.9: Fluent result for Velocity vector

Secondly, the author investigated pressure developed in the tee pipe design. From the FLUENT result (Figure 4.10), the pressure is higher along the pipe wall and it increase when steam reach the tee joint. The pressure is very highest at tee joint pipe wall because the tee joint prevent the steam from running smoothly and cause change of direction.

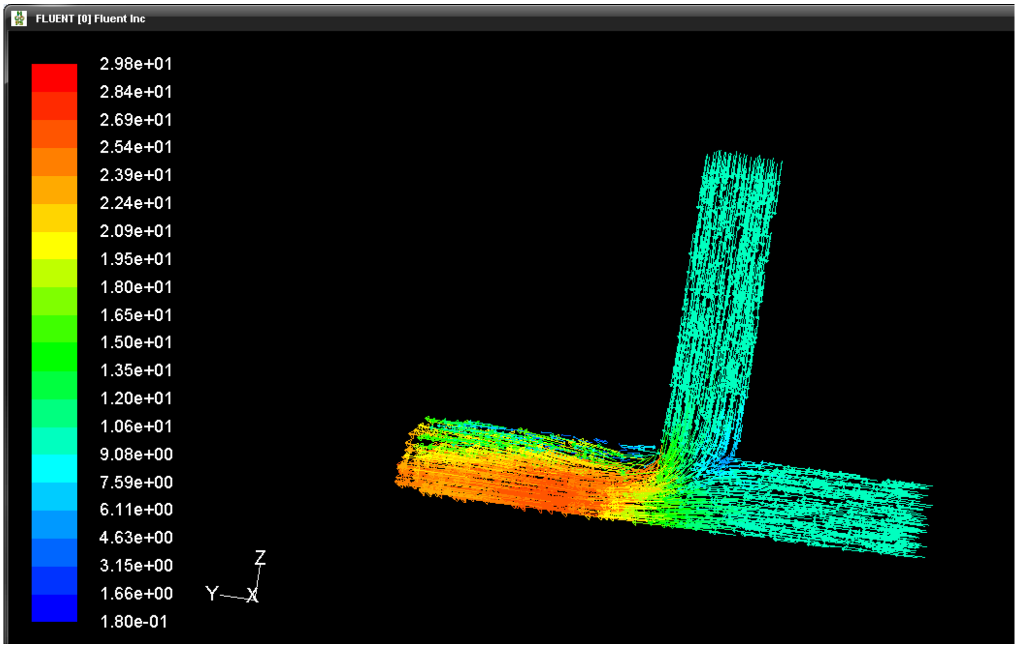

Figure 4.10: Fluent result for Pressure Developed

From the results of analysis that have been conducted by author, they have come out that erosion severely happened at:

- Elbow pipe
- Tee joint pipe

1. It is happened because at elbow pipe and tee joint pipe, there are happened flow direction changes. So, it caused the steam condensate to collide the wall and produce higher pressure.

4.4 Discussion

From the analysis, the highest factor that causes failures on the small bore piping is erosion in steam condensate line. Therefore, some preventive methods will be taken to reduce the erosion effect in pipe especially for elbow and tee joint pipe.

4.4.1 Prevention

a) Improvements in design involve changes in shape, geometry and material selection. Some examples are: increasing the pipe diameter to decrease velocity, streamlining bends to reduce impingement and increasing the wall thickness.
b) Improved resistance to erosion is usually achieved through increasing substrate hardness using harder alloys, hard facing or surface-hardening treatments.
c) Erosion-corrosion is best mitigated by using more corrosion-resistant alloys and/or altering the process environment to reduce corrosivity, for example, deaeration, condensate injection or the addition of inhibitors.

4.4.2 Inspection and Monitoring

a) Prioritize inspection planning on suspected area based on Risk-based Inspection
b) Visual examination of suspected or troublesome areas, as well as Ultrasonic Testing or Radiograhy Testing can be used to detect the extent of metal loss.
c) Focus inspection on piping that has same criteria with the previous piping failure due to the erosion effect.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 CONCLUSION

Among the biggest failure happened at Gas Processing Plant, GPP at PETRONAS Gas Berhad (PGB) is regarding small bore piping. Small bore piping is always undergo failure especially regarding internal erosion effect. From the study, internal erosion effect mostly occurred at the elbow and tee joint pipe where flow of direction change happened. Fluid Mechanics software; FLUENT will be used to execute the computational fluid dynamic (CFD) analysis as actual fluid flow to investigate internal erosion effect. The author come out with preventive program for small bore piping failure based on improving piping design and material selection and also inspection planning by using Risk-based Inspection. The significance of this research would be important to solve internal erosion problem in small bore piping. Thus, proper piping design and material selection and also inspection planning especially related to internal erosion effect must take into serious consideration to prevent failure in the future.

5.2 RECOMMENDATION

a) To further study and researched about other factors that contribute to small bore piping failures
b) Futher improvement in modelling 3D design
c) To study and work more details on piping analysis using FLUENT software

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APPENDIX 1: Gantt Chart for FYP II

APPENDIX 2: Inspection report for actual case study (ELBOW PIPE)

APPENDIX 3: Inspection report for actual case study (TEE JOINT PIPE)

APPENDIX 4: Sample ELS calculation for elbow pipe

APPENDIX 5 : Other Types of Small Bore Piping Failure.

APPENDIX 6: Small Bore Connections Screening

APPENDIX 7: Daily site Inspection Form

APPENDIX 1 : Gantt Chart for FYP II

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Literature review on small bore erosion failure	■	■	■											
	- understanding erosion behaviour														
2	Preparing Progress Report I			■	■										
3	Submission of Progress Report I				●										
4	Modelling using AutoCAD and Fluent					■	■	■							
5	Reviewing and upgrading Progress Report								■	■					
6	Submission of Progress Report II									●					
7	Simulating models using Fluent								■	■					
8	Preparing poster											■	■		
9	Poster submission												●		
10	Preparing Dissertation Draft Report												■	■	
11	Dissertation Draft Report													●	
12	Preparing slide for oral presentation													■	■
13	Oral presentation														●
14	Hardbound dissertation														●

● Milestone ■ Process

APPENDIX 2 : Inspection Report for actual case study (ELBOW PIPE)

NON-STANDARD REPAIR
DHU-GPP4

LINE NO:HC-2"-3504-E6123-H(N20A)
TAG NO: 4A-IS4-1517
PHOTO NO: 4-399

REF. NO : DHU/CL10

VIEW: FACING WEST NEAREST EQUIPMENT : T4 301 OTHER MARKS : 3RD PIPE RACK

LOCATION
Top of T4 301, 3rd pipe rack, Line from T4351A.

DATA
Pipe: 2" API 5L Gr.B 5.54mm XS
Elbow: A234GR.WPB BE

Design Press	: 4500 Kpa
Oper. Press.	: 3900 Kpa
Design Temp.	: 395 ºC
Oper. Temp.	: 249 ºC

TYPE OF CLAMPED
Elbow type clamped observed at 2" elbow

FINDING
Heavy steam splash leak observed at clamped area.

RECOMMENDATION
1. To rectify leak, i.e.: by inject sealant into elbow type clamped.
2. To be monitor the clamps quarterly and to identify the extend of internal erosion to the whole line and repair accordingly during next opportunity shutdown window.

Prepared By : Ramlan Ibrahim Date: 18.12.07 Status: LEAK Re-inspect Date: 21.2.08 Status: HEAVY SPLASH STEAM LEAK Re-inspect by: Ramlan Ibrahim

APPENDIX 3 : Inspection Report for actual case study (TEE JOINT PIPE)

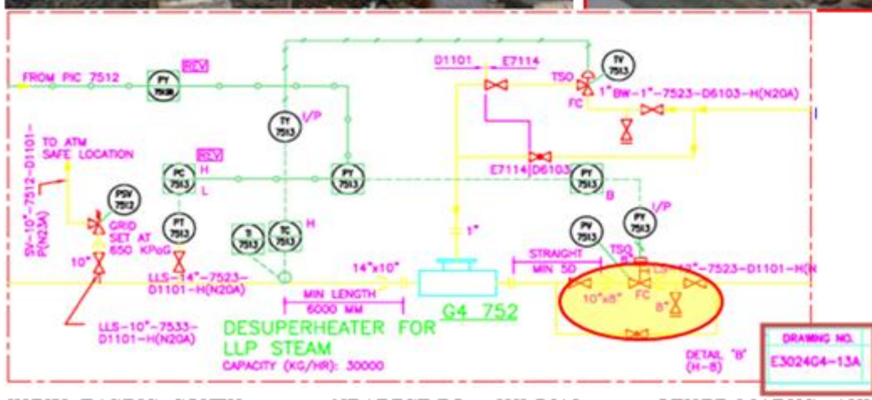
SMALL BORE INSPECTION
UTILITY 700-GPP4

GENERAL FINDING

TAG NO: 4AC-I7-2966

REF. NO : GPP4/SB/700/P/09

PHOTO : 7-349



VIEW: *FACING SOUTH* NEAREST EQ.: HV-7513 OTHER MARKS : AUXILIARY BOILER

LOCATION

Near 4PV-7513.
South side of Auxiliary boiler.

DATA

Line no.	: LS-12"-7523-D1101-H(N20A)
Pipe	: ¾" API 5L Gr.B 3.91 mm XS
Design Press.	: 800 Kpa
Oper. Press.	: 650 Kpa
Design Temp.	: 300 °C
Oper. Temp.	: 173 °C
Tee existing	: ¾" A105 Class 3000
Tee recommended	: ¾" A105 Class 9000

FINDING

1. Steam leak observed at ¾" tee fitting.
2. Previous finding also found leak at same tee fitting due to erosion attacked. Repaired done at 16.9.06 by replaced the tee with the same specification.
3. The same line also clamped at half coupling area due to leakage. (refer report no. : UTLY700/CL18)

RECOMMENDATION

To identify condition the rest of the elbows within the same line by performing profile RT – by INSA.

PERMANENT REPAIR

If the line can be isolated, replace tee fitting using schedule XXS (as per specification given above) and replace the leakage half coupling accordingly.

TEMPORARY REPAIR

If the line cannot be isolated, install with appropriate clamp and to repair on next shutdown opportunity.

Prepared by : Ramlan Ibrahim Date : 9.7.08 Status : LEAK Date Verified:

1

APPENDIX 4 : Sample ELS calculation for elbow pipe

PIPING ASSESSMENT

SHEET NO. :
REFERENCE : Loc 11
DATE : 5.5.08

Calculation Minimum Required Thickness, Corrosion Rate and Estimated Life Spent For Piping

Line Designation:	HC-2"-3504-B6123-H(N20A)		
Material:	API5L Gr. B		
Pipe Schedule:	XS	Nominal thk.:	5.54 mm
Operating Pressure:	3900 Kpa	Design Pressure:	4500 Kpa
Operating Temp.:	249 °C	Design Temp.:	395 °C

	Sym	Value	Unit	Remark
Design Pressure	P	4500	Kpa	From Line Schedule
Stress Value	S	13490	Psi	From ANSI B31.3
Outside Diameter	D	60.3	mm	From H103
Quality Factor	E	1	-	From ANSI B31.3
Corrosion Allowance	c	1.3	mm	From H103
Press. Design Wall Thickness. ANSI 31.3 (Required thickness) API 570	t_m	1.46	mm	tm = PD/2SE (ANSI B31.3)
Minimum Required Wall Thickness	t	2.76	mm	$t = t_m + c$ (ANSI B31.3)
Nominal Thickness	T	5.54	mm	From H103
Years In Service	-	15	Years	
* Pressure Design Wall Thickness		1.46		

Formula to calculate Corrosion Rate (Cr) Base on External Corrosion Rate
Cr = (Nt - At) / Years In Service (mm/year)

Required thickness (API 570) = measurement computed by the design formula before corr & manufacturer allowances are added

Formula to calculate Estimated Life Spent (ELS) Base on Minimum Required Thickness
ELS = (At - dt) / Cr

Location	Wall loss(mm)	Actual Thick. (mm) *		Cr(mm/year) *		ELS (Years)	CATEGORY	LIFE	RISK	ACTION
Loc 11	4.2788	1.2612	1.2612	0.29	0.29	-0.69	SD 1	A	HIGH	

* For calculation purpose only.

PIPING CATEGORY
SD-1 : Failure cause total plant S/D
SD-2 : Failure cause unit S/D
SD-3 : None of the above.

LIFE
Life A : Remaining thickness < min thk.
Life B : Remaining thickness < 3 years.
Life C : Remnant life > 3 years.

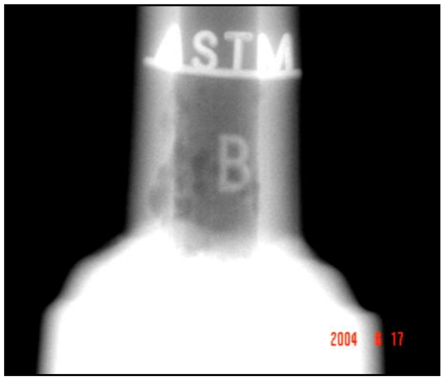
ACTION
IR : Immediate repair
IRp : Immediate replacement
IRc : Immediate rectification
IPt : Immediate repainting
SDRp : Replace in next T/A or available S/D window
SDPt : Repaint in next T/A or available S/D window
MPt : Maintain painting & monitor.

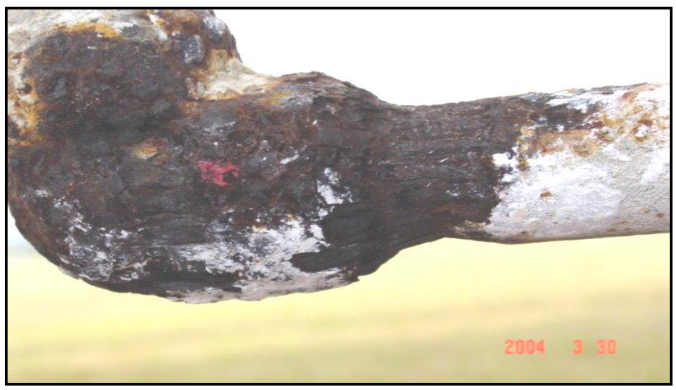
1C	1B	1A
2C	2B	2A
3C	3B	3A

(red)	High Risk	Immediate repair/replacement/rectification actions required
(yellow)	Medium Risk	(1) To perform immediate re-painting (2) To plan for replacement/repair in next T/A or available window (3) Or to schedule a yearly monitoring
(green)	Low Risk	To maintain painting & monitor every 3 yearly

* Next inspection schedule Another -0.34 years

APPENDIX 5 : Other Types of Small Bore Piping Failure.





Internal erosion and external corrosion

The Heat Affected Zone (HAZ) of a pipe weld, with the blue area being the metal most affected by the heat

Chloride Stress Corrosion Cracking - leak spots at stainless steel pipe

Small Bore Piping Failure at Air Fin Cooler (AFC)

APPENDIX 6 : Small Bore Connections Screening

1.0 Small Bore Connection Modifier

The calculation of the small bore connection modifier is categorised into two parts:

- Likelihood of failure in branch due to branch geometry
- Likelihood of failure due to main pipe geometry.

These are combined to give the small bore connection modifier. The small bore connection modifier is the minimum of the likelihood of failure in branch due to branch geometry and the likelihood of failure due to main pipe geometry.

2.0 Likelihood of Failure due to the Branch Geometry

The factors governing the likelihood of failure of the branch are:

- type of fitting;
- overall length of branch;
- number and size of valves;
- main pipe schedule;
- small bore pipe diameter.

The various factors are combined as shown in Figure A2.1 to give an overall probability of failure in the small bore branch connection.

2.1 Type of Fitting

A weldolet involves two welds and hence (in comparison to a contoured body fitting or short contoured body fitting) has doubled the number of sites at welds for potential fatigue failures. Additionally contoured body fittings and short contoured body fitting have higher natural frequencies than weldolets.

Fitting	Likelihood of Failure (LOF)
Weldolet	0.9
Contoured body fitting	0.6
Short contoured body fitting	0.4

2.2 Overall Length of Branch

The length also determines the natural frequency. Again a longer unsupported branch results in lower natural frequencies and hence greater likelihood of failure. Length is measured from the main pipe wall to the end of the branch assembly (including valve(s) if fitted).

Length	Likelihood of Failure (LOF)
over 600mm	0.9
up to 600mm	0.7
up to 400mm	0.3
up to 200mm	0.1

2.3 Number and Size of Valves

This is the element of likelihood of failure associated with the unsupported mass. Higher mass results in lower natural frequencies and hence greater likelihood of failure.

Number of Valves	Likelihood of Failure (LOF)
2 or more	0.9
1 or integral double block and bleed valve	0.5
0	0.2

2.4 Main Pipe Schedule

Thin walled main pipe is at higher likelihood of failure than the heavier schedules as its lower stiffness results in low natural frequencies and high levels of stress at the joint between the small bore branch and the main pipe.

Schedule	Likelihood of Failure (LOF)
10S	0.9
20	0.8
40	0.7
80	0.5
160	0.3
>160	0.3

2.5 Small Bore Pipe Diameter

As the diameter of the small bore fitting increases the natural frequency will also increase and hence likelihood of failure will be reduced.

Fitting Diameter (Nominal Bore)		Likelihood of Failure (LOF)
Inches	DN (mm)	
0.5	15	0.9
0.75	20	0.8
1	25	0.7
1.5	40	0.6
2	50	0.5

3.0 Likelihood of Failure due to Location on the Parent Pipe

The likelihood of failure of a connection due to the geometry of the main pipe is dependent on:

- pipe schedule;
- location of the connection on the main pipe.

3.1 Main Pipe Schedule

Thin walled main pipe has a higher likelihood of failure than the heavier schedules as its lower stiffness results in low natural frequencies and high levels of stress at the joint between the small bore branch and the main pipe.

Schedule	Likelihood of Failure (LOF)
10S	0.9
20	0.8
40	0.7
80	0.5
160	0.3
>160	0.3

3.2 Location on Main Pipe

A small bore connection located at rigid supports for the main pipe is unlikely to vibrate as the support will force a node of vibration on the main pipe and as a result no forcing for the small bore branch.

Conversely small bore branches located near bends, reducers or valves are more likely to experience high levels of excitation and therefore a higher likelihood of failure.

Location	Likelihood of Failure (LOF)
Valve	0.9
Reducer	0.9
Bend	0.9
Mid span	0.7
Partially Fixed Support *	0.4
Fixed support**	0.1

* Braced in one direction: (1 translational degree of freedom perpendicular to the axis of the small bore is fixed and the remaining degrees of freedom are free)

APPENDIX 7 : Daily Site Inspection

DAILY SITE INSPECTION DONE Date: Inspector:

	S/ Bore Tag no	Line no	Photo no	Finding- Wall loss	Need Scaff	Insul Remov	Estmtd Elev*	Type-**	Remark