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PROJECT REPORT

CONSTRUCTION OF A CRACK GROWTH TESTING APPARATUS ASSOCIATED WITH STRESS CORROSION CRACKING (SCC) STUDY

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DEDICATE TO MY LOVING FAMILY, SISTER AND BROTHER AND ALL MY FRIENDS WHO HAS SUPPORTED AND ENCOURAGED ME THROUGH GOOD TIME AND HARD TIME

THANK YOU AGAIN FOR YOUR SUPPORT AND ENCOURAGEMENT.

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ABSTRACT

A case study of Stress Corrosion Cracking or SCC is a part of this project title. Ammonia tank always related with the SCC problem especially at -33^{0}C. Stress corrosion cracking (SCC) can be divided into three important keywords to differentiate the mechanism which is tending to cause the fracture mechanism over the metallic material. SCC is caused by three conditions such types of environment, types of materials and types of stress. Continuous research was encouraged to solve this problem from time to time in order to recognize main problem in obtaining the best solution. Hence, various design of the prototype had been carrying out to study the material with concerning the major problem, condition, material used in the study and etc. The methodologies used for development of the proposed project were selection of the crack growth apparatus, determining apparatus or equipment and resulting from the testing to the fabrication of the prototype. The testing is a must to carry out in order to detect a failure or defect on the prototype. From the result obtained, the data will be analyzed and the discussion is carrying out to discus the defect of the prototype.

ABSTRAK

Kajian kes tentang "Stress Corrosion Cracking" atau juga dikenali sebagai SCC adalah sebahagian daripada tajuk ini. Tangki ammonia sering dikaitkan dengan permasalahan yang dikaitkan dengan SCC terutama pada suhu -33^{0}C. SCC terbahagi kepada tiga kekunci yang penting bagi membezakan mekanisma yang menyebabkan kegagalan pada bahan logam. SCC disebabkan oleh tiga keadaan seperti keadaan persekitaran, jenis-jenis bahan dan jenis tekanan. Kajian yang berterusan amat digalakkan bagi menangani masalah ini dari semasa ke semasa dan juga bagi mengenal pasti masalah utama yang membawa kepada penyelesaian yang amat diperlukan. Oleh sebab itu, pelbagai jenis rekabentuk atau model telah direka dan diguna pakai bagi menjalankan kajian bahan berpandukan permasalahan utama, keadaan, bahan yang ingin dikaji dan sebagainya. Metodologi yang digunakan semasa perkembangan projek ini adalah pemilihan rekabentuk model yang sesuai untuk "Crack Growth Apparatus", penentuan alat dan software, diikuti lukisan berskala and pembinaan rekabentuk model tersebut Pengujian terhadap rekabentuk model ini adalah dikehendaki bagi mengetahui kecacatan yang dijangka akan berlaku. Daripada keputusan pengujian yang diperolehi, data tersebut akan dianalisa bagi membincangkan permasalahan terhadap rekabentuk model tersebut. Sejurus itu, rekomen akan diberi bagi memperbaiki model tersebut.

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94300 Kota Samarahan

LIST OF CONTENT

CHAPTER 1 INTRODUCTION

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 BACKGROUND STUDY

CHAPTER 4 RESEARCH METHODOLOGY

CHAPTER 5 RESULT AND DISCUSSION

CHAPTER 6 CONSLUSION AND RECOMMENDATION FOR FUTURE WORK

LIST OF TABLES

LIST OF FIGURES

Nomenclature

ε	Strain
dF_s	Electrical resistance
F	Strain gauge factor
R_s	tensile strain pulse increase
R_b	Ballistic resistor
V_s	Potential difference of strain gauge
E	Voltage supply
n	Constant
k	Strain constant

CHAPTER 1

INTRODUCTION

1.0 General Introduction

Oil and gas industry is becoming one of the main incomes for the oil-producing country beside the other sectors of manufacturing industrial. The development of this industry between the oil-producing countries had been helping much and beneficial for their economic supports. Thus, large petroleum and petrochemical manufactures is spending large amount of money to build process plant to process the products from the offshore raw materials such as oil and gas.

Most chemical plant needs storage facilities for feedstock and products which are able to store large quantities of the products produce. Therefore, various risks are involved in storing and handling large quantities of flammable liquids and liquefied gases. Hence the developer has to develop highly sophisticated safety concepts to counteract such risks especially for tank terminals with long operating periods. Beside the purpose of storage, the tank is most useful to keep the liquid product temporarily before its loading to shipping and exported out.

Due to this situation, the tank is to be inspected at certain period which is recommended by authorities and recommendations by special codes and internal recommendations (companies). According to D. Schirmer, besides the regulation and recommendations technical aspect are the reasons for the tank inspection. This will lead to the shut down activities for the overall of plant operation once there are found that all the equipments, instruments, valves, piping materials, electrical materials and so on are in worst and in improper condition. Generally, from the inspection through technical aspect, the related causes to the inspection implementation are because of following factors:

1. Corrosion caused by medium
2. Corrosion caused by atmosphere, water, ground water
3. Cracks caused by high strength of deformation by unequal foundation settlement
4. Crack caused by high strength of un normal operating condition
5. Crack cause by stress concentration (SCC)
6. Safety reasons
7. Damages from outside
8. Lack of maintenance

To overcome these problems, the management of the petroleum or petrochemical industrial specially has to spend a large sum of costs annually on mitigating the effects of chemical and environment that was induced the failure of materials used over the storage tank and other equipments in process plant. Their have to spend a cost in anti corrosion mechanism, materials selection and modern fracture mechanics before construct the tank.

1.1 Tank Inspection Procedure

To inspect the tank, it must following certain procedure and regulation which is outline to guide the process of inspection. The main objective is to keep the shutdown time of the storage as short as possible and preplanning is required to determine the date and duration will be taken to implementing the inspection and overhaul works. Time frame is presented which are including the whole activities during the shutdown.

Site survey is the continuous task to be implemented before the shutdown operation is proceeding. The tank and others facilities are to be inspected when they are still in service. The conditions of all the components or equipments are stated and reported, any malfunction or damages methods of equipments are evaluated for the next actions. Daily report will help much in cope up the problem of malfunction and damage components through the process.

From the survey and the inspection report it is the basis for the scope of inspection of all components. The report from the investigation will brought to the meeting room of knowing further action should be overhaul or renewal or replacement. All required jobs are to determine and the time demand is to be evaluated by preparing the time frame and planning for scheduling. All the requirements such as manpower, mobilisation and demobilisation, materials are summarized in the planning and scheduling. The decommissioning procedure must be prepared together. For the proper planning step, it is shown in *Appendix IV.*

1.2 General Description Of Ammonia Storage Tank

Through the case study, the author found that almost all of the ammonia storage tanks are atmospheric refrigerated type. The capacity of ammonia storage tank is designed according to the manufacturer request. Based on D. Schirmer (June, 1987), ammonia is design for 41.6m diameter x 12.9 straight shell height with flat bottom and rafter supported domed roof of spherical radius 30m. It is contained within a full height pre-stressed concrete bund. The design pressure is 800mmWG/-50mmWG. The refrigeration unit is 2x275000Kcal/h. The flare capacity is $750Nm^3/h$ gas. The tank is design to contain 10,000 tones of liquid ammonia tank at -33.4^0C and a maximum filling height of ammonia (NH_3) to 12.3 as shown in *Figure 1.1 a* and *Figure 1.1 b.*

The second example of ammonia tank design is a "double integrity tank (cup-in-tank), 40m diameter, 36.225m high; the outer tank is 42.3m, externally insulated with a spherical roof, and stands on a piled, insulated, concrete foundation about 600mm clear of the ground. The installation is refrigerated and operates at the normal boiling point of ammonia of -33^0C and has a design pressure of 14kPa. The tank materials is specified low temperature impact properties and has a thickness of 32mm at the lowest strake and a minimum thickness of 10mm in the upper one third of the tank. (http:// www.ncedaust.org/peter3.htm)

1.2.1 Design of Ammonia Storage Tank

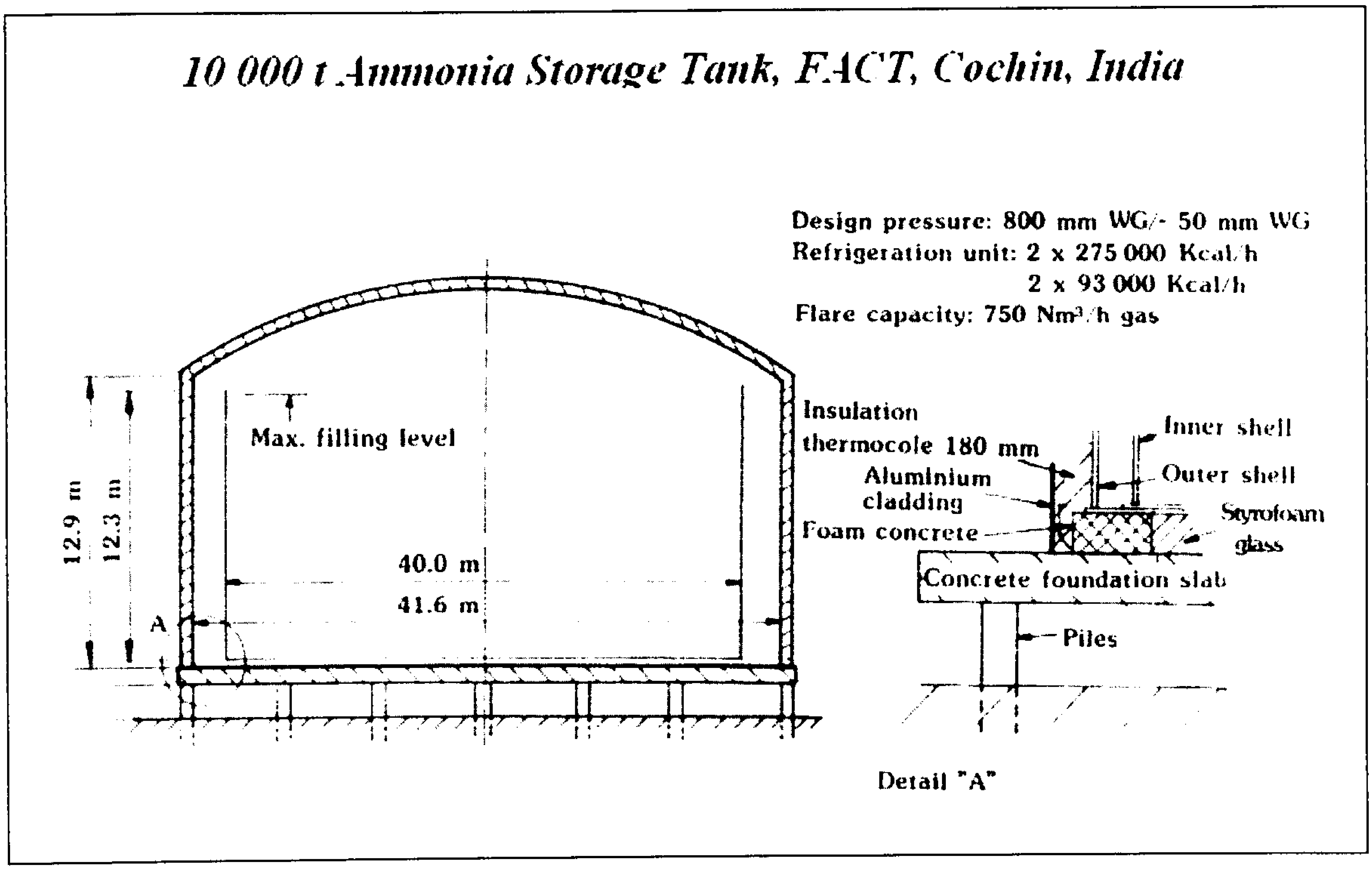

Figure 1.1 a Design of 10,000 tones of ammonia storage tank.

(Source: D. Schirmer 1987)

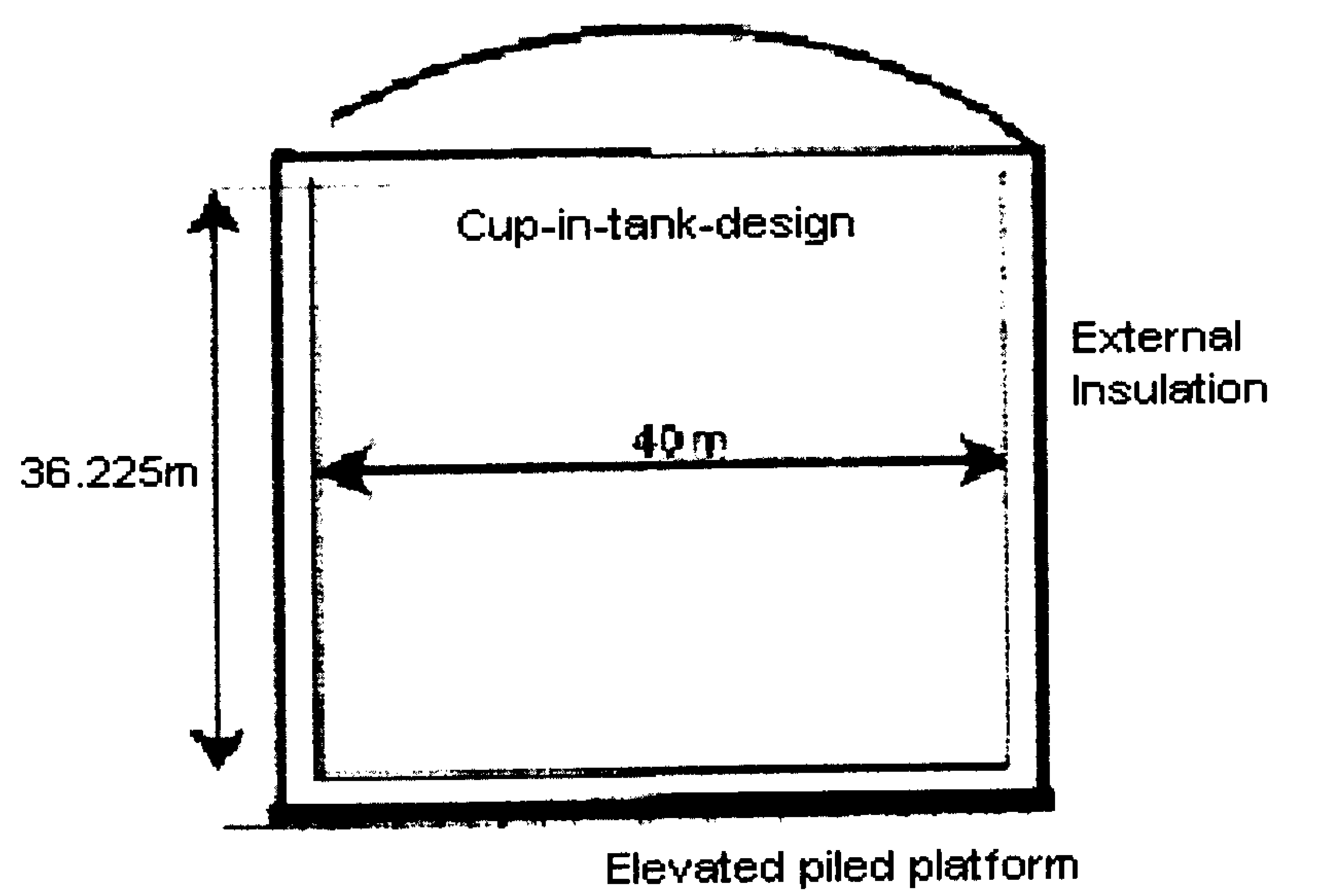

Figure 1(b): Design of 30,000 tones of ammonia storage tank

Figure 1.1 b Design of 30,000 tones of ammonia storage tank.

Source: (http:// www.ncedaust.org/peter3.htm)

Aluminum and zinc metal spray both prevented cracking. Aluminum spray has a low potential margin and high consumption rate. Zinc spray has a large potential margin and low consumption rate in range 0.02 mm/year, which it allowing about 10 years lifetime.

1.4 Objective of Project

In this final year project, the author reviewed the case study of the fracture mechanism which always occurred in metallic material in petrochemical process plants. Stress corrosion cracking of ammonia storage tank is the study that will involve in this topic where author have to study how does it occurred in the beginning and how does the environment influence the mechanism. The main project objectives are as follows.

1. To study and review SCC and other potential hazards associated with commissioning of ammonia tank.
2. To design and fabricate a prototype which is used to study the crack growth.
3. The commission and do conduct initial test on the prototype constructed to investigate the prototype's performance.

In order to obtain those objectives mentioned above, the testing was carried out using Compact Tension (CT) specimen. The testing procedure is mentioned in chapter four in details. Lastly the author will do some recommendation and suggestion on the prototype built.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Stress corrosion cracking (SCC) is the most serious corrosion problem for metallic materials encountered in service. Recently experimental study had been carried out and it is found that SCC can be defined as the failure mechanism in metallic structure initiate cause of the weakness of the bonding structure affected by the environment and the others factors and wherever finally turn to cracking.

Lunde and Nyborg (1989) carried out their study in stress corrosion cracking (SCC) by using two types of methods which are by using of Compact Tension (CT) specimens and the other one is by electrochemical study. The purpose of their study is to study the crack growth and means to prevent cracking in carbon steels in ammonia solution. The study is considered the characteristic of the SCC mechanism which from the theoretical study SCC can be understand as a mechanism that is occurring under active passive electrochemical condition. The absence of corrosion cause by the protective film will performs a corrosion rather than cracking. Cracking is occurred while the stress or stress intensity is applied.

Thus combination of these three mechanisms hence it will equivalent to a stress corrosion cracking. If one of stress and corrosion does not absence it will not perform as SCC.

2.1 Various Models of SCC Test Apparatus

2.1.1 Model for Crack Growth Apparatus

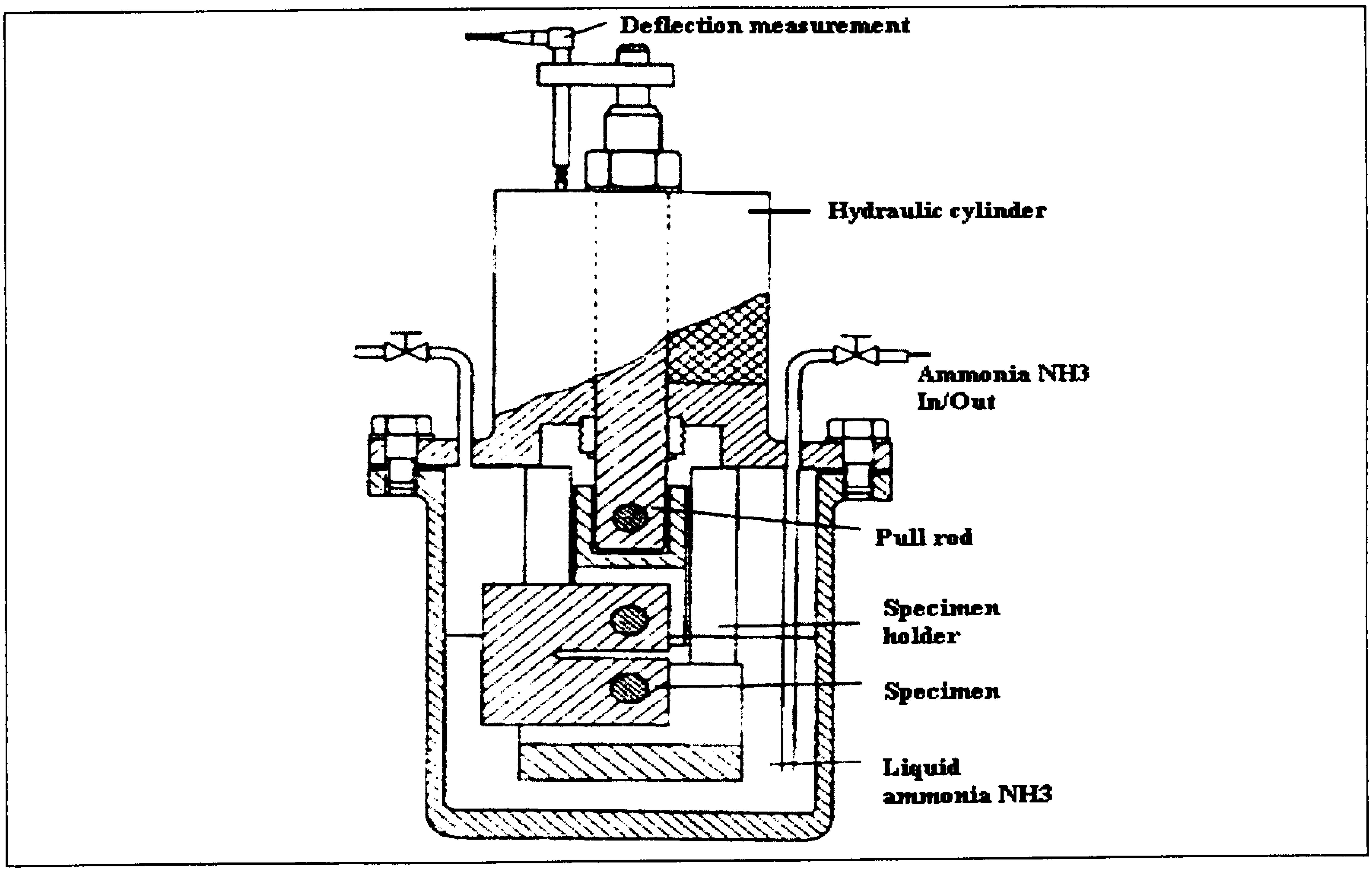

Figure 2.1: A typical equipment for crack growth studies.

(Source: Lunde L., Nyborg R. SCC of Carbon Steels in Ammonia–Crack Growth Studies and Means to Prevent Cracking.1989)

The studied of stress corrosion cracking (SCC) growth of carbon steel in ammonia had been done by Lunde and Nyborg (1989) by using the method as show in *Figure 2.1*. The objective of their study is to study the crack growth upon the pre-crack specimens and means to prevent cracking. The construction of the SCC crack growth equipment is based on their experience before proceed the experiment by using the Compact Tension (CT) specimens.

The compact tension specimens were fabricated with standard dimension and 1.5mm deep side grooves with thickness 25mm. Firstly the specimens were fabricated with Chevron Notch and a fatigue pre-crack. Later specimens made with straight notch without fatigue pre-crack. In addition, the experiment also carry out the specimens with the heat affected zone where welding plates was performed both with X-formed weld and K-formed weld. CT specimens were made with through-thickness notch located either in the weld metal or in the line heat affected zone. *Table 2.1* shows the different types of materials used by comparing the chemical composition and mechanical properties. Liquid ammonia is used for chemical reaction; the ammonia will flow in and out of the tank.

Table 2.1: Materials with chemical composition and mechanical properties

Material	Chemical Composition %					Mechanical Properties			
	C	Mn	Si	P	S	Yield Point MPa Nominal	Measured	UTS MPa	Elongation %
St. 52.3 plate DIN 17100 ASTM A537 Grade 1	0.17	1.57	0.45	0.031	0.015	415	380	550	29
St. 52.4 tube	0.18	1.43	0.31	0.014	0.021	390	-	540	35
RAEX 266 P ARC/350	0.08	1.03	0.17	0.025	0.04	290	-	410	36
BS 150: 224 490 B-LT50	0.18	1.14	0.39	0.013	0.003	360	-	530	30
Weld metal Norweld electrode Baso 120	0.06	0.9	0.4	0.03	0.03	460	-	550	26

(Source: Lunde L., Nyborg R. SCC of Carbon Steels in Ammonia–Crack Growth Studies and Means to Prevent Cracking. 1989)

Based on the data analysis and result, Lunde and Nyborg (1989) summarize that stress corrosion cracking does not occur in steel specimens with a fatigue crack because of the existent of crevice corrosion attack occurred in the outer part of the fatigue crack specimens. Their just find that stress corrosion cracking (SCC) just occurred easily in specimens with machined notch only.

Based on the experiments with increasing of stress intensity factor or crack opening/displacement it was found that maximum stress corrosion crack growth rate increased with the increasing of stress intensity factor. Their obtained the rates of crack growth in the experiments were 2mm/year at stress intensity factor of $40MPa\sqrt{m}$ and 6mm/year at $60MPa\sqrt{m}$. Just a very small amount of SCC was found at

30MPa√ m. The experiments with increasing of stress intensity factor had shown the higher crack growth rates than with the constant load.

The experiments with welded specimens showed that residual stresses in welds are important for SCC of carbon steel in ammonia, while microstructure variations in the weld and the heat-affected zone (HAZ) seem to have a little effect.

2.1.2 Model for Electrochemical Test Apparatus

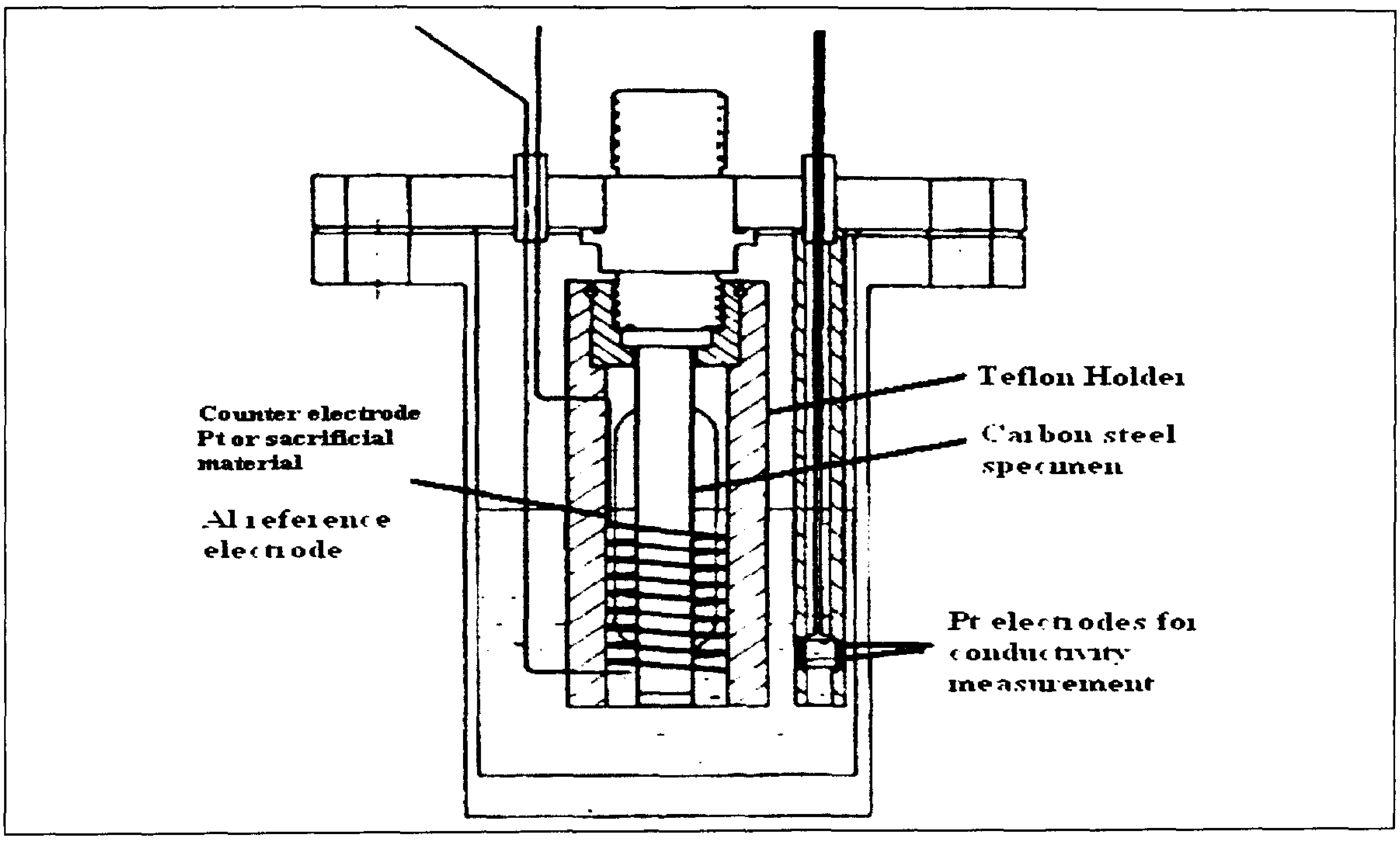

Figure 2.2: A typical equipment for electrochemical studies.

(Source: Lunde L., Nyborg R. SCC of Carbon Steels in Ammonia–Crack Growth Studies and Means to Prevent Cracking.1989)

Electrochemical studies also had been carried out by Lunde and Nyborg (1989) with the Model as show in *Figure 2.2.* This method is built up to study either stress corrosion cracking (SCC) is occurred under electrochemical potential or not. Lunde and Nyborg (1989) found that SCC of carbon steel in ammonia was prevented b cathodic polarization. The condition is when anodic polarization is high, it tend to affects SCC occurred in ammonia with 2000 ppm water and with ammonia without an Oxygen (O_2). The materials used to implement the experiment are shown in *Table 2.2.*

Table 2.2: Nominal composition of electrodes

Electrode	Al	Mg	Mn	Si	Fe	Zn	Cu	Zr-Ti
Al-wire	99.8	-	-	<0.15	<0.15	-	0.2	-
Al-plate	99.5	-	-	-	-	-	-	-
AlMn	-	0.3	0.9-1.5	0.5	0.7	0.2	0.1	0.1
$AlMg_3$	-	2.6-3.6	0.5	0.4	0.4	0.2	0.1	0.1
AlMg 4.5 Mn	-	4-5	0.4-1	0.4	0.4	0.3	0.1	0.2
Mg	-	100	-	-	-	-	-	-
Zn	-	-	-	-	-	100	-	-

(Source: Lunde L., Nyborg R. SCC of Carbon Steels in Ammonia – Crack Growth Studies and Means to Prevent Cracking.1989)

Lunde and Nyborg (1989) conclude that SCC of carbon steel in ammonia is strongly dependent on the electrochemical potential. The SCC was prevented by cathodic polarization at about +300mV vs. Al and below, while SCC was easily obtained by anodic polarization at +500mV vs.