ABSTRACT

This thesis deals with the design and fabrication of leak test rig. This thesis will discuss about leakage problems in industrial pipelines. The objective of this thesis is to design and fabricate a leak test rig. The thesis describes the approaches of designing and fabricating a leak test rig. There are numerous steps taken to design and fabricate the test rig. The structural three-dimensional solid modelling design of test rig was developed by using the Solidwork engineering drawing software. The fabrication process also undergoes many steps such as material marking, cutting, drilling, welding and grinding. In addition, it also explains the procedure of testing by the simulation of three types of common leakages which includes pinhole, pipe crack/dent and gasket leak. The testing the rig is also explained in this thesis by maintaining a pressure of 4 bars in the test rig to prove whether the test rig is functioning efficiently. Finally, the conclusion about this project is that the project objectives were achieved which was design and fabrication of a leak test rig and the recommendations for the improvement of the rig are also included together with this thesis as for instance to design and fabricate a support the leak test rig to statically hold it in place.

ABSTRAK

Tesis ini berkaitan dengan reka bentuk dan fabrikasi alat penguji kebocoran. Tesis ini akan membincangkan tentang masalah kebocoran dalam paip perindustrian. Objektif tesis ini ialah untuk merekabentuk dan menghasilkan alat penguji kebocoran. Tesis menerangkan pendekatan reka bentuk dan fabrikasi pelantar ujian kebocoran. Terdapat beberapa langkah yang diambil untuk mereka bentuk dan menghasilkan rig ujian. Struktur tiga dimensi pemodelan pepejal rig ujian telah dibangunkan dengan menggunakan perisian Solidwork lukisan kejuruteraan. Proses fabrikasi juga menjalani langkah-langkah yang banyak seperti menandakan bahan, memotong, penggerudian kimpalan, dan pengisaran. Di samping itu, ia juga menerangkan prosedur ujian oleh simulasi tiga jenis kebocoran biasa yang termasuk lubang jarum, paip retak / penyok dan kebocoran gasket. Ujian rig juga dijelaskan di dalam tesis ini dengan mengekalkan tekanan 4 bar di pelantar ujian untuk membuktikan sama ada pelantar ujian berfungsi dengan cekap. Akhirnya, kesimpulan tentang projek ini adalah bahawa objektif projek telah dicapai yang reka bentuk dan fabrikasi alat penguji kebocoran dan cadangan untuk penambahbaikan rig juga dimasukkan bersama-sama dengan tesis ini sebagai contoh untuk mereka bentuk dan menghasilkan sokongan bagi menempatkan alat penguji kebocoran secara statik.

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LIST OF SYMBOLS

σ	Hoop Stress
σmax	Maximum Allowable Stress
σyield	Yield Stress
P	Pressure
R	Radius
SF	Safety Factor
mm	Millimetre
Ø	Diameter

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
ASME	American Society of Mechanical Engineers
MIG	Metal inert gas

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Pipelines are the most economical and safest pipeline transport for mineral oil, gases and other fluid products. Since pipelines are used for long-distance transportation, high demands of safety, reliability and efficiency are needed to be fulfilled. The market parameters for oil and gas pipeline construction experienced tremendous growth due to the economy change in 2008. The industry grew from $23 billion in 2006 to $39 billion in 2008 [3]. As pipelines for the transfer of liquids or gases usually are only implemented at the beginning and the end, the intimation on a leak along the pipeline during normal operation can only be based on these available measurements. Mostly just the input and output flows are coherent. However, according to the inherent flow dynamics and the superimposed noise, leaks can be detected with this simple method which is about more than 2% for liquid and more than 10% for gas pipelines [1].

This significance now converses and proposes a leak detection method which is able to detect considerably smaller leaks. The unintentional release of fluid from pipelines is known as leak. Pipeline leak may result, for example, from bad workmanship or from any destructive cause, due to sudden changes of pressure, corrosive action, cracks, defects in pipes or lack of maintenance. In most cases, the deleterious effects associated with the occurrence of leaks may present serious problems and, therefore, leaks must be quickly detected, located and repaired [4].

1.2 PROBLEM STATEMENT

Pipelines leakage has the potential to cause significant environmental damage and economic loss. While pipelines are designed and constructed to maintain their integrity, it is difficult to avoid the occurrence of leakage in a pipeline system during its lifetime. The problem of leaks in underground water pipeline has been source of concerns for a long time due to its potential danger to public health, economic loss, environmental damage and wastage of energy. In dry parts of the world, e.g. Middle East, drinking water is a precious commodity and monitoring hydraulic network to save water is significantly important. Exit of water from an opening on the pipe wall may cause several physical changes in the pipe and surrounding soil such as pressure drop in the pipe, making acoustic noise, changing moisture of soil and etc.

Pipeline is a prime energy-efficient means for natural gas transportation from fields to customs. As the total lengths of gas pipelines have increased significantly in recent years in China, pipeline leakages occur randomly, which can cause huge economic losses and environmental pollution. So, it is important to find an efficient way to detect the leakage quickly and locate the leak position accurately [5]. Pipelines, as a means of transport, are the safest but this does not mean they are risk-free. Therefore, assuring the reliability of the gas pipeline infrastructure has become a discerning need for the energy sector. The main threat considered, when looking for means of providing the authenticity of the pipeline network, is the occurrence of leaks [6].

The deficit of an AM 350 steel bellows, which was to be used in the control rod drive mechanism (CRDM) of the fast breeder test reactor (FBTR), was watched during helium leak testing. The leak test was performed out before performance testing in a test rig. Visual examination of the leak area did not denote any obvious defect. Stereo microscopy and optical microscopy indicated the presence of pits. A few of these pits had propagated through the thickness. EDAX of the corrosion products revealed the presence of chlorides. The exposure of the bellows to a marine atmosphere during a storage period of 13 years was suspected to have caused the pitting [17]. With these types of failures, this certainly calls for the further need of leak study and thus boosts the need of leak test rig fabrication.

1.3 OBJECTIVES

Pipelines leakage has been a constant threat to both economical and environmental issues. And therefore the need to boost leak study is vital to solve this problem which in this case boosts the fabrication of leak test rig. The main objective of this thesis is to design and fabricate the mechanical part of the leak test rig.

1.4 SCOPE OF WORK

Finishing this leak test rig requires precise scope of work to be followed. A number of unique scopes of work should be determined to achieve the purpose and goal of the project. The scopes are:

I. Literature review on the knowledge of design analysis of leak test rig that simulates mainly for pinhole, gasket and crack leak. Conduct research regarding leak study about the different types of leak test rigs that simulates different types of leaks in pipelines.

II. Conceptual design of leak test rig. Design leak test rig using Solidwork software.

III. Fabricate the mechanical part of the test rig by applying different machining process.

IV. Test designed and fabricated leak test rig by simulating any of types of leak mentioned above.

CHAPTER 2

LITERATURE REVIEW

2.1 LEAK

A leak is a way (usually an opening) for fluid to escape a container or fluid-containing system, such as a tank or a ship's hull, through which the contents of the container can escape or outside matter can enter the container. Leaks are usually unintended and therefore undesired. The entry, exit, or exchange of matter through the leak is called leakage. The matter leaking in or out can be gas, liquid, a highly viscous paste, or even a solid such as powdered or granular solid or other solid particles [14].

2.2 LEAKAGE PROBLEM IN INDUSTRY

Early ascertainment of leaks in oil and product transmission pipelines is covetable in order to detect deteriorating or glitched up components and to minimize the release of hazard materials [7]. Huge number of inevitably valve leakages, which pose major problems to several industrial processes. Low cost portable instruments for detecting valve leakage rates are somehow crucial in many industries. However, there has not been such a device with sufficient sensitivity in place to detect the small leakage while the plant is operating, and hence preventive measures to avoid the problem are not usually applied on time. This normally incurs substantial cost from process interruption and in some cases may result in contamination of the product or even more severe problems. In addition, the measurement results may also be useful for further maintenance planning, [18]. It can be classified as a serious problem not only from a safety and environmental standpoint, but also from the energy loss that impacts a country's economy.

Reassuring the reliability of the gas pipeline infrastructure has become an essential need for the industrial sector. The main concern considered, when looking for means of providing the authencity of the pipeline network, is the emergence of leaks. No matter what are of their size, pipeline leaks are a major concern due to the considerable effects that they might have. These effects prolong beyond the costs involved by downtime and repair expenses, and can include human injuries as well as environmental disasters. The main causes of gas pipeline accidents are external interference, corrosion, construction defects, material failure and ground movement, [6].

2.3 TYPES OF DEFECT THAT LEADS TO LEAKAGE

Deformity usually happens over time. The types of defects that leads to leakage includes, corrosion, gouges, plain dents, kinked dents, smooth dents on welds, smooth dents containing gouges, smooth dents containing other types of defects, manufacturing defects in the pipe body, girth weld defects, seam weld defects, cracking, environmental cracking. Other than that, leaks are often the result of deterioration of materials from wear or aging, such as rusting or other corrosion or decomposition of elastomers or similar polymer materials used as gaskets or other seals.

2.3.1 Pinhole-Type Pitting Corrosion

Most pipes that depend on supports are more likely to develop localized pinhole-type pitting corrosion and/or stress corrosion crack-like deformation; both of these may severely affect the structural integrity. To evade sagging, long pipes usually rest on supports. The crevice or bottom region of pipes, at the support locations, is more prone to corrosion due to the presence of water, air, and minerals as well as additional local contact stresses. Several types of corrosion are found to happen. The more common types include the wide area corrosion that leads to wall thickness reduction, and the pitting corrosion leading to through thickness pinhole damage. Among the various type of corrosion in pipelines, pinhole-type pitting corrosion (localized in nature) is considered to be of prime importance due to the degree of difficulty of detection and the increased risk for causing leaks. The pipe surface at these support locations may look to be normal during visual inspection of the visible surface (top and side region of pipe), while the condition of the pipe in the hidden region (bottom portion), where it is in contact with the support cannot be evaluated. These pipelines carry hazardous chemicals and gasses and the presence of a small leak or rupture in lines may lead to a catastrophic situation. Hence, these lines have to be inspected periodically to assess them for any possible damage before a catastrophic failure occurs**,** [8]

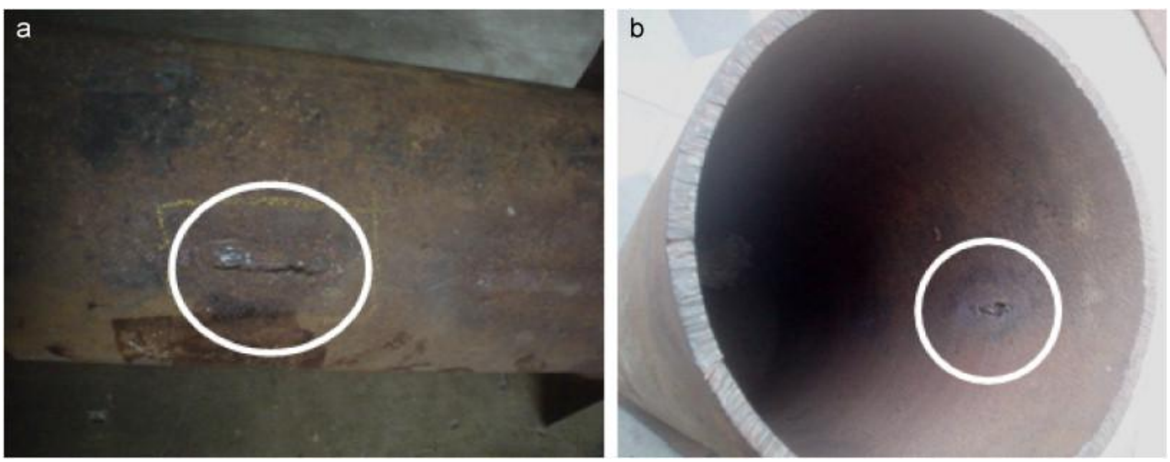

Figure 2.1: Photograph of an external and internal corrosion defect in an 8 in MS pipe specimen. (a) External corrosion. (b) Internal corrosion.

Source: L. Satyarnarayan 2008[8]

2.3.2 Gasket Failure

Gaskets play a vital role in the enclosing performance of bolted flange joints, and their nature is complex due to nonlinear material properties combined with permanent deformation. The many of contact stresses due to the rotation of the flange and the material properties of the gasket play important roles in achieving a leak proof joint. Flanged joints with gaskets are very common in pressure vessel and piping systems, and are designed mainly for internal pressure. These joints are also used in special applications such as in nuclear reactors and space vehicles.

The complication associated with the analysis of bolted flange joints with gaskets are due to the nonlinear nature of the gasket material combined with permanent deformation. The material undergoes permanent deformation under excessive stresses. The degree of elasticity (stiffness) is a function of the compressive stresses, which act on the gasket during assembly and after it is put into service. It is commonly recognized that gasket stiffness has a predominant effect on the behaviour of the joint because of its relatively low stiffness.

Gaskets are often multilayered materials, exhibiting nonlinear behaviour in loading and unloading conditions. The modulus of elasticity for the bolting-up or compression (loading) stage is different from the decompression (unloading) stage of the gasket due to the internal pressure. When the gasket is decompressed, it shows strong hysteresis which is nonlinear and leads to permanent deformation usually confined to through-thickness. The contribution to the stiffness from membrane (in plane) and transverse shear are much smaller and hence neglected [9].

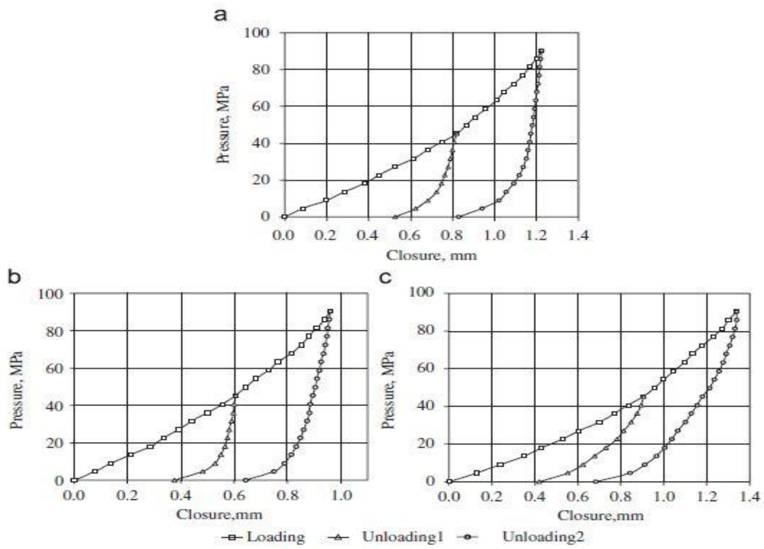

Figure 2.2: Characteristics of different types of spiral-wound gaskets obtained experimentally: (a) asbestos filled (b) graphite filled and (c) PTFE filled.

Source: M. Murali Krishna 2007[9]

2.3.3 Cracking/Dent in Pipelines

A dent in a pipeline is a permanent plastic deformation of the circular cross section of the pipe. Dent depth is defined as the maximum reduction in the diameter of the pipe compared to the original diameter (the nominal diameter less the minimum diameter). This definition of dent depth includes both the local indentation and any divergence from the nominal circular cross-section (out-of-roundness or ovality).

A dent causes a local stress and strain concentration and a local reduction in the pipe diameter. The dent depth is the most significant factor affecting the burst strength and the fatigue strength of a plain dent. The profile of the dent does not appear to be a critical parameter, so long as the dent is smooth.

Dents caused by external interference (unconstrained dents) are typically confined to the top half of a pipeline. Rock dents (constrained dents) are found at the bottom of a pipeline. The most likely failure mode of a constrained dent is by puncture, but only if the indenter (e.g. a rock) is sufficiently hard and sharp, and the bearing load is high. Dents may be associated with coating damage, and hence may be sites for the initiation of corrosion or environmental cracking [10].

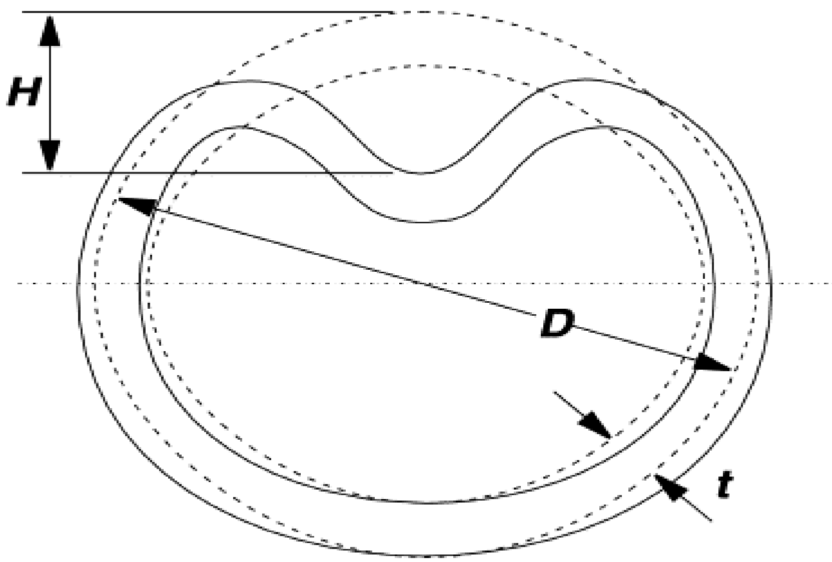

Figure 2.3: The dimensions of a dent.

Source: Phil Hopkins 2003[10]

Cracks is not reliant on material toughness, but is dependent on the stress/strain state, e.g. at the front of not removed notches at the inner component surface. These notches are usually applied during the manufacturing procedure - e.g., weld seams, grooves but can also be caused by local corrosion damage. The crack growth rate after crack initiation is dependent, besides the state of toughness ahead the crack tip, on the loading ranges particularly in interaction with the corrosion assisting environment. The corrosive influence can cause a material "'embrittlement" in a " micro" region just ahead the crack tip. Under a constant load from this region there can be originated a slow stable growth of small cracks which then get linked and form long shallow cracks. In case of ductile behaviour stable tearing at the crack tip (monotonic crack growth) can take place which normally leads to leakage, so counter measures can be seized. In case of brittle material large fracture of components initiating from cracks cannot be excluded in all cases concerning realistic parameters. This contribution presents some example for cracking of components originated by operation conditions in real plants as well as in the laboratory [11].

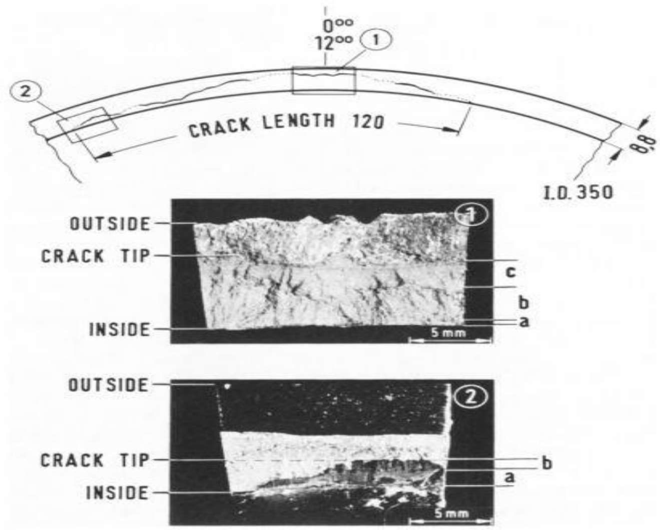

Figure 2.4: Circumferential macro-crack in connecting weld of feedwater pipe to reactor pressure vessel nozzle with sections 1 and 2 from the surface of the macro-crack (above).

Source: D.Blind 1984[11]

2.4 LEAK TEST RIGS

There are many types of leak test rigs existed to simulate different types of leakages in pipelines. The function of this leak test rigs is to detect the leakage point and to identify the cause of the leakage. In general, the cause of leakage in a pipeline is due to impact forces of construction equipment. Therefore these leak test rigs must be designed and fabricated in a precise and accurate manner. Below illustrates the details of two types of leak test rigs which includes moisture-sensitive tape and rod seal test pod.

2.4.1 Moisture-Sensitive Tape

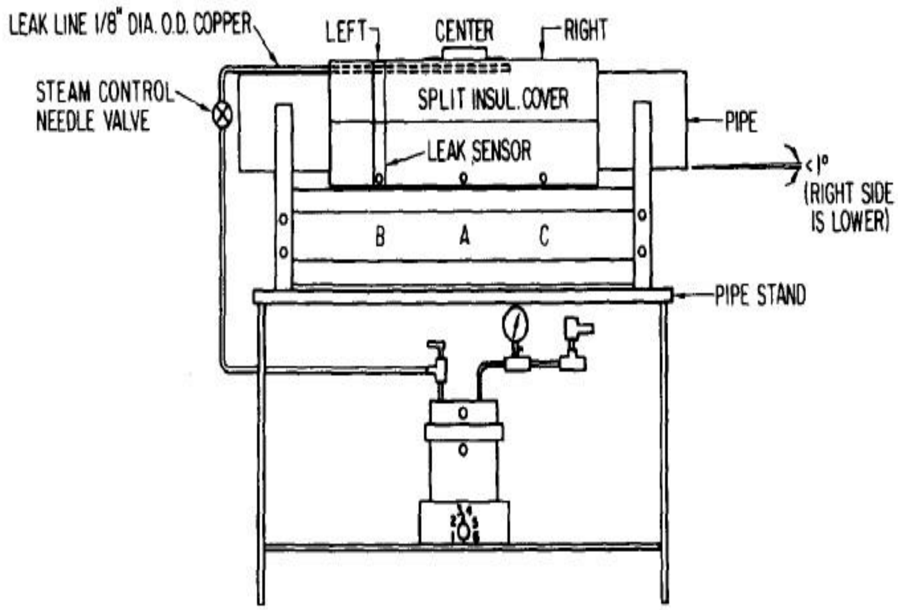

Figure 2.5: Schematic representation of facility used to evaluate moisture sensitive tape. The leak source is placed at one of the indicated positions along the top of the pipe; the leak sensor is placed at one of the three corresponding positions along the bottom. The distance between the centre position and the left or right position is about 1 m.

Source: D.S. Kupperman 1985[12]

The technology is available to improve leak detection capability at specified sites moisture-sensitive tape. Seven cracks, including three field-induced IGSCC specimens and two thermal-fatigue cracks, have been installed. Tests have been carried out to help assess the effectiveness of moisture-sensitive tape for leak detection. Tapes were supplied by Techmark. Fig. 2.7 shows a schematic representation of the facility used for these tests. Leaks are simulated by feeding water through a copper tube to the surface of a 10 in Schedule 80 pipe. The tapes are located at three positions on the bottom of the pipe, which is tilted approximately 1 ° as indicated. The pipe is wrapped with either reflective insulation or "soft" insulation (Nu-Kon). The "soft" insulation allows water vapor to penetrate to its outer surface and severely limits the useful range of the tape. The relative positions of leak and tape on a slightly tilted pipe can have a significant effect on the response time.

Some of the advantages of this type of test rig are based on the analysis of these results which suggests that moisture sensitive tape may be useful for the detection of leaks in reactors. Under the right conditions, the tapes can detect leaks at order of 0.01 gal/min. The tapes, however, will be significantly more effective in systems that employ reflective insulation. However, despite the sensitivity nature of the tapes, they do not provide any quantitative data other than the location at which the system has been triggered. A large leak a long distance from the tape could cause the same response as a small leak at a short distance. Moreover, its usefulness with "soft" insulation needs to be demonstrated. Hence, leak detection techniques need further improvement in the following areas that includes identifying leak sources through location information and leak characterization, to eliminate false calls, quantifying and monitoring leak rates as well as by minimizing the number of installed transducers in a "complete" system through increased sensitivity.

2.4.2 Rod Seal Test Pod

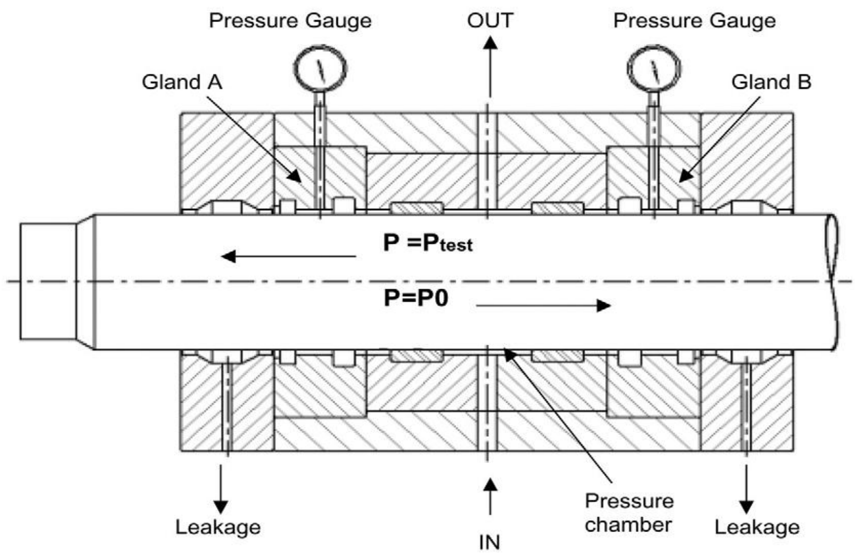

Figure 2.6: Cross-section through seal test pod.

Source: Nick Peppiatt 2003[13]

This is the result of testing a number of different rod wiper profiles with one standard rod seal type. Tests have been carried out at different rod speeds, pressures and temperatures on a reciprocating seal test rig. A major potential leakage point of a hydraulic system is where the rod emerges from the actuator. The needed performance of the rod sealing system is becoming more stringent because of the understandable demand for leak-free hydraulics, including dry cylinder rods. The gland sealing system of a hydraulic cylinder consists of a number of elements, including the seal housings, the rod seal, the rod wiper, the rod bearing, the hydraulic fluid and the rod itself. The rod wiper has the primary function of preventing external contamination reaching the rod seal and gland bearings, and for this reason is fitted to the vast majority of hydraulic cylinders. However, this component has often been omitted in the laboratory testing of reciprocating seals.

An external cylinder is used to drive the rod through a pressurized test pod at various speeds and temperatures. In all the tests reported here, the pressure was cycled in accordance with the rod direction, so that for gland B, the rod extends from the gland under slack or return pressure, as in a conventional double acting cylinder. For gland A the rod extends under test pressure, representing the gland in a displacement or single acting cylinder. Five different wiper profiles have been tested with one profile of rod seal. The results indicate that the wiper is an important factor in the control of leakage from a hydraulic cylinder gland. Despite this, it is a component relatively neglected in the seals literature. Single lip wipers can give a much greater leakage than a seal without a wiper, but this leakage is reduced with a double lip profile. It is shown that a new design, which overcomes a number of the problems associated with double lip wipers, gives very good leakage control.

An advantage of this type of test rig is that that power is used against seal friction only, whereas in cylinder tests there must be a far greater power consumption to generate the required pressures. Another advantage is this test rig overcomes the pressure trapping problems of conventional double lip wipers, and is also shown to minimize leakage from the gland and dirt ingress into it. However, as for the disadvantage of the typical double lip wiper is that it can induce a pressure trap between itself and the main rod seal, which can cause either the wiper or rod seal to be ejected from its groove.