NON-DESTRUCTIVE TESTING OF DAHEJ-URAN PIPELINE SECTION FROM KM12 TO KM15

By
ASHISH GUPTA
R160206004

College of Engineering
University of Petroleum & Energy Studies
Dehradun
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A thesis submitted in partial fulfillment of the requirements for the Degree of
Master of Technology
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By
Ashish Gupta

Under the guidance of

Mr.R.P.Shriwas
Senior Adjunct Prof.
Mtech(Pipeline Engg)
U.P.E.S, Dehradun

Mr. P.D Rao
Project Manager,
DUPL Project, Mumbai,
Gammon India Limited.

Approved

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Dean

College of Engineering
University of Petroleum & Energy Studies
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UNIVERSITY OF PETROLEUM & ENERGY STUDIES
(ISO 9001:2000 Certified)

CERTIFICATE

This is to certify that the work contained in this thesis titled **"Non-Destructive Testing of Dahej-Uran Pipeline from Km 12 to Km 15"** has been carried out by **Ashish Gupta** under my/our supervision during March/May 2008 and has not been submitted elsewhere for a degree.

Mr. R.P.Shriwas

Senior Adjunct Professor,

College of Engineering,

University of Petroleum and Energy Studies,

Dehradun, India.

DATE: 23 / 5 / 08

Corporate Office:
Hydrocarbons Education & Research Society
3rd Floor, PHD House,
4/2 Siri Institutional Area
August Kranti Marg, New Delhi - 110 016 India
Ph.: +91-11-41730151-53 Fax : +91-11-41730154

Main Campus:
Energy Acres,
PO Bidholi Via Prem Nagar,
Dehradun - 248 007 (Uttarakhand), India
Ph.: +91-135-2102690-91, 2694201/ 203/ 208
Fax: +91-135-2694204

Regional Centre (NCR) :
SCO, 9-12, Sector-14,
Gurgaon 122 007
(Haryana), India.
Ph: +91-124-4540 300
Fax: +91-124-4540 330

Regional Centre (Rajahmundry):
GIET, NH 5, Velugubanda,
Rajahmundry - 533 294,
East Godavari Dist., (Andhra Pradesh), India
Tel: +91-883-2484811/ 855
Fax: +91-883-2484822

Email: info@upes.ac.in URL: www.upes.ac.in

Abstract

This paper shall present different, contemporarily available non-destructive testing (NDT) methods of pipelines and their analysis from the technical and economical point of view. In the analysis together with the reasons for the weld failures, certain suggestions are also given so as to avoid such failures.

Non-destructive testing is a key component of optimized plant inspection and maintenance programs. Risk based inspection, condition based maintenance and reliability centered maintenance systems all require detection, location and sizing of defects or flaws by non-destructive methods. Internal damage of pipeline by corrosion and erosion-corrosion is an ongoing problem requiring inspection and subsequent maintenance decisions to ensure safe and reliable performance. Conventional manual ultrasonic testing to determine remaining wall thickness has major limitations, particularly when damage is of a random and localized nature. Therefore, it is necessary to explore alternative non-destructive methods that offer potential benefits in terms of accurate quantification of size, shape and location of damage, probability of detection, ability to use on-line over long ranges, and economics. Based on this, on going research will concentrate on long range guided wave and dynamic methods.

ACKNOWLEDGEMENT

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Lastly I would like to express my heartfelt thanks to all staff members of Gammon India Limited (Pipeline Divison) who gave me unending support right from the initial stage of my project.

Ashish Gupta

CONTENTS

LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CI	Corrosion Index
DI	Design Index
IOI	Incorrect Operations Index
ILI	Inline Inspection Technique
HAZID	Hazard Identification
LIF	Leak Impact Factor
LV	Leak Volume
MOP	Maximum Operating Pressure
O & M	Operation and Maintenance
PH	Product Hazard
ROW	Right of Way
ROU	Right of Use
SCADA	Supervisory Control and Data Acquisition
TPDI	Third Party Damage Index

CHAPTER 1
INTRODUCTION

INTRODUCTION

Non-Destructive Testing (NDT), also called Non-Destructive Examination (NDE) and Non-Destructive Inspection (NDI), is testing that does not destroy the test object. NDE is vital for constructing and maintaining all types of components and structures. To detect different defects such as cracking and corrosion, there are different methods of testing available, such as X-ray (where cracks show up on the film) and ultrasound (where cracks show up as an echo blip on the screen). Non-destructive testing (NDT) is the descriptive term used for the examination of materials and components in a way which does not change or destroy their usefulness. It is used at all stages of plant or equipment construction and for integrity monitoring during operation and maintenance. NDT plays a crucial role in ensuring cost effective operation, safety and reliability of plant, with resultant benefit to the community.

NDT has been proven to be an essential tool for assessing corrosion- and erosion-related damage and an integral part of cost-effective maintenance programs in the chemical and petrochemical industries. Early detection of corrosion- and erosion induced damage through routine NDT prevents unexpected failures and unscheduled maintenance. For maximum benefit NDT needs to be combined with issues of critical flaw size, fracture mechanics, probability of failure and acceptable level of risk. It is essential that any NDT program takes into consideration the prevailing damage mechanisms, uses appropriate methods to detect the specific type of damage expected and targets the elements at risk. In the case pipeline damage concern is corrosion caused by high temperature acidic and chloride-laden fluids and erosion corrosion associated with flow, particularly for two phase fluids. Detection of pitting or other random localized types of corrosion is important as this is a common occurrence in geothermal environments. The selection of NDT methods for pipeline must also take into account practical considerations such as the presence of thermal insulation and scale, accessibility, operational temperatures, geometric parameters, and internal versus external inspection. The ability to detect corrosion under scaling or coatings would also be beneficial.

CHAPTER 2
COMPANY PROFILE

ABOUT THE COMPANY

Gammon India Limited:

Gammon India is not only the largest civil engineering construction company in India, but can lay claim for the largest number of bridges built in the whole of Commonwealth. With over seventy years of tradition in the field of construction. Gammon is a name that is inextricably woven into the fabric of India.

As builders to the nation, Gammon has made concrete contributions by designing and constructing bridges, ports, harbors, thermal and nuclear power stations, dams, high-rise structures, chemical and fertilizer complexes environmental structures, cross country water, oil and gas pipelines. Gammon has accomplished this by fusing tremendous engineering knowledge with innovative skills, harnessing men and materials to build structures.

Structures that stand out as living testimonies to the victory of man over nature. Structures conceived and built by minds in constant search of new methods, ideas, applications and solutions. Because Gammon believes that today's solutions will not be adequate tomorrow.

This insatiable quest has led Gammon to pioneer Reinforced and Pre-stressed Concrete, Long span bridges, Under water concreting using the Concrete process, Thin shell structures, Non-Shrinking concrete, Aluminium trusses for launching precast, pre-stressed beams and many more.

These resounding achievements have won Gammon the status of an R&D Institution - an unequalled honour for an unmatched Performance

They had work over on various projects they are:

1. Numaligarh Siliguri Pipeline Project
2. Koyali Ratlam Pipeline Project
3. Paradip Haldia Pipeline Project
4. Mora Sajod Pipeline Project
5. Baruni Patna Pipeline Project

Mission statement:

"To Develop, Build & Service Physical Infrastructure for better living, work environment and Transportation."

Vision:

To be the leaders in innovative engineering, and timely deliver of our quality construction services, upholding our tradition of being 'Builders to the nation'.

Dahej-Uran Pipeline:

Gammon India is constructing natural gas pipeline from Dahej to Uran for transporting natural gas to MSEB (Uran), ONGC (Uran), DFPCL and Trombay areas for GAIL. Being part of GAIL natural gas network in the states of Gujarat and Maharashtra, it will also supply gas to GAIL customers.

All pipelines and systems shall be designed, constructed and tested as per the present Particular Technical Specifications and General Technical Specifications and also the latest edition of ASME B31.8 and other relevant applicable codes and standards.

The Pipeline laying contract is divided into 3 spreads as follows:

Spread 1:

Section 1: Mainline from Dahej dispatch station (CH: 0.00km) to Natural gas station SV7 (CH:132.3km)

Nominal diameter : 30"

Length : 132.3km

Section2 : Supply line from Shell Mora Station to Dispatch & Intermediate pigging Station-1 at Hazira station

Nominal diameter : 30"

Length : 7.2km

Spread 2 : Mainline from Natural gas station SV7 (CH:132.3km) to Intermediate pigging Station-3 at Bhoirpada (CH: 279.72km)

Nominal diameter : 30"

Length : 147.42km

Spread 3:

Section 1: Mainline from Intermediate pigging Station-3 at Bhoirpada (CH: 279.72km) to Intermediate pigging Station-4 at Panvel (CH:386km)

Nominal diameter : 30"

Length : 106.28km

Section 2: Intermediate pigging Station-4 at Panvel (CH: 386km) to Receiving Station at Uran –MSEB (CH: 417.1km)

Nominal diameter : 24"

Length : 31.1km

Section 3: Receiving Station at Uran –MSEB (CH: 417.1km i.e. 0.00 km) to Uran-ONGC (CH: 7.13km)

Nominal diameter : 18"

Length : 7.13km

Section 4: SV 20(R) at Hazimalangwadi (CH: 367.64km i.e. 0.00km) to Receiving Station at DFPCL (CH: 8.125km)

Nominal diameter : 18"

Length : 8.125km

Section 5: SV 20(R) at Hazimalangwadi (CH: 367.64km i.e. 0.00km) to Receiving Station at Trombay (CH: 39.5km)

Nominal diameter : 24"

Length : 39.5km

CHAPTER 3
LITERATURE

DEFINITION OF NON-DESTRUCTIVE TESTING

Nondestructive testing (NDT) has been defined as comprising those test methods used to examine an object, material or system without impairing its future usefulncss. The term is generally applied to nonmedical investigations of material integrity.

Strictly speaking, this definition of nondestructive testing does include non-invasive medical diagnostics. Ultrasound X-rays and endoscopes are used for both medical testing and industrial testing. In the 1940s, many members of the American Society for Nondestructive Testing (then the Society for Industrial Radiography) were medical X-ray professionals. Medical nondestructive testing, however, has come to be treated by a body of learning so separate from industrial nondestructive testing that today most physicians never use the word nondestructive.

Nondestructive testing is used to investigate the material integrity of the test object . A number of other technologies - for instance, radio astronomy, voltage and amperage measurement and rheometry (flow measurement) - are non-destructive but are not used to evaluate material properties specifically. Nondestructive testing is concerned in a practical way with the performance of the test piece - how long may the piece be used and when does it need to be checked again? Radar and sonar are classified as nondestructive testing when used to inspect dams, for instance, but not when they are used to chart a river bottom.

What Is Not Non-destructive Testing?

Non-destructive testing asks "Is there something wrong with this material?" Various performance and proof tests, in contrast, ask "Does this component work?" This is the reason that it is not considered non-destructive testing when an inspector checks a circuit by running electric current through it. Hydrostatic pressure testing is usually proof testing and intrinsically not non-destructive testing. Acoustic emission testing used to monitor changes in a pressure vessel's integrity during hydrostatic testing is non-destructive testing.

Another gray area that invites various interpretations in defining non-destructive testing is that of future usefulness. Some material investigations involve taking a sample of the inspected part for testing that is inherently destructive. A non-critical part of a pressure vessel may be scraped or shaved to get a sample for electron microscopy, for example. Although future usefulness of the vessel is not impaired by the loss of material, the procedure is inherently destructive and the shaving itself - in one sense the true "test object" - has been removed from service permanently.

The idea of future usefulness is relevant to the quality control practice of sampling. Sampling (that is, the use of less than 100 percent inspection to draw inferences about the un-sampled lots) is nondestructive testing if the tested sample is returned to service. If the steel is tested to verify the alloy in some bolts that can then be returned to service, then the test is non-destructive. In contrast, even if spectroscopy used in the chemical testing of many fluids is inherently non-destructive, the process is destructive if the test samples are discarded after testing.

Hardness testing by indentation provides an interesting test case for the definition of non-destructive testing. Hardness testing machines look somewhat like drill presses. The applied force is controlled as the bit is lowered to make a small dent in the surface of the test piece. Then the diameter or depth of the dent is measured. The force applied is correlated with the dent size to provide a measurement of surface hardness. The future usefulness of the test piece is not impaired, except in rare cases when a high degree of surface quality is important. However, because the piece's contour is altered, the test is rarely considered non-destructive. A non-destructive alternative to this hardness test could be the use of electromagnetic non-destructive testing.

Discontinuity Detection

Non-destructive testing is not confined to crack detection. Other discontinuities include porosity, wall thinning from corrosion and many sorts of disbonds. Non-destructive material characterization is a growing field concerned with material properties including material identification and microstructural characteristics - such as resin curing, case hardening and stress - that have a direct influence on the service life of the test object. Non-destructive testing has also been defined by listing or classifying the various methods. This approach is practical in that it typically highlights methods in use by industry.

PURPOSES OF NON-DESTRUCTIVE TESTING

Since the 1920s, non-destructive testing has developed from a laboratory curiosity to an indispensable tool of production. No longer is visual examination the principal means of determining quality. Non-destructive tests in great variety are in worldwide use to detect variations in structure, minute changes in surface finish, the presence of cracks or other physical discontinuities, to measure the thickness of materials and coatings and to determine other characteristics of industrial products.

Modern nondestructive tests are used by manufacturers

(1) To ensure product integrity, and in turn, reliability;
(2) To avoid failures, prevent accidents and save human life;
(3) To make a profit for the user;
(4) To ensure customer satisfaction and maintain the manufacturer's reputation;
(5) To aid in better product design;
(6) To control manufacturing processes;
(7) To lower manufacturing costs;
(8) To maintain uniform quality level; and
(9) To ensure operational readiness.

Ensuring the Integrity and Reliability of a Product

The user of a fabricated product buys it with every expectation that it will give trouble-free service for a reasonable period of usefulness. Few of today's products are expected to deliver decades of service but they are required to give reasonable unfailing value. Year by year the public has learned to expect better service and longer life, despite the increasing complexity of our everyday electrical and mechanical appliances.

America has always been a nation on the move. Today our railroads, automobiles, buses, aircraft and ships carry people to more places faster than ever before. And people expect to get there without delays due to mechanical failure. Meanwhile factories turn out more products, better, faster and with more automatic machinery. Management expects machinery to operate continuously because profits depend on such sustained output. The complexity of present-day products and the machinery which makes and transports them requires greater reliability from every component. If a product has one part that has a probability of failure of 1 in 1,000 before it has served a reasonable life, it may be satisfactory. This seems to be a very low chance of failure. Now suppose that a product is assembled from 100 critical parts of various kinds and that each part has a failure possibility of 1 in 1,000. What then is the possibility of failure of the assembled item? The overall reliability of any assembly is the mathematical product of the component reliability factors. Overall reliability of this example is then:

$$R = 0.999^{100} = 0.9057 \quad \text{(Eq. 1)}$$

The possibility of failure of the assembly is then:

$$1.00 - 0.9057 = 0.0943 \quad \text{(Eq. 2)}$$

Or almost 1 in 10. It is certain that the user of this product will be highly dissatisfied if 1 out of every 10 units fails prematurely. The point is that component integrity and, in turn, reliability must be immensely greater than the required reliability of the assembled product. Consider the ordinary V-8 automobile engine. It has only one crankshaft but eight connecting rods, sixteen valve springs and hundreds of other parts. Theoretically, failure of any one of these could make the motor useless. Yet how frequently does the car owner experience a part failure? This amazingly low incidence of service failure during the normal life of an automobile is a great tribute to the ability of the automotive engineers to design well, of metallurgists to develop the right materials, of production personnel to cast, roll, forge, machine and assemble correctly, and of inspectors and quality control staff to set standards and see that the product meets those standards.

Preventing Accidents and Saving Lives

Ensuring product reliability is necessary because of the general increase in performance expectancy of the public. A homeowner expects the refrigerator to remain in uninterrupted service, indefinitely protecting the food investment, or the power lawnmower to start with one pull of the rope and to keep cutting grass for years on end. The manufacturer expects the lathe, punch press or fork lift to stand up for years of continuous work even under severe loads.

But reliability merely for convenience and profit is not enough. Reliability to protect human lives is a valuable end in itself. The railroad axle must not fail at high speed. The front spindle of the intercity bus must not break on the curve. The aircraft landing gear must not collapse on touchdown. The mine hoist cable must not snap with people in the cab. Such critical failures are rare indeed. And this is most certainly not the result of mere good luck. In large part it is the direct result of the extensive use of non-destructive testing and of the high order of nondestructive testing ability now available.

Ensuring Customer Satisfaction

While it is true that the most laudable reason for the use of non-destructive tests is that of safety, it is probably also true that the most common reason is that of making a profit for the user. The sources of this profit are both tangible and intangible.

The intangible source of profit is ensured customer satisfaction. Its corollary is the preservation and improvement of the manufacturer's reputation. To this obvious advantage may be added that of maintaining the manufacturer's competitive position. It is generally true that the user sets the quality level. It is set in the market place when choosing among the products of several competing manufacturers. Certainly the manufacturer's reputation for high quality is only one factor. Others may be function, appearance, packaging, service and price. But in today's highly competitive markets, actual quality and reputation for quality stand high in the consumer's mind.

Aiding in Product Design

Non-destructive testing aids significantly in better product design. For example, the state of physical soundness as revealed by such non-destructive tests as radiography, magnetic particle or penetrant testing of a pilot run of castings often shows the designer that design changes are needed to produce a sounder casting in an important section. The design may then be improved and the pattern modified to increase the quality of the product. This example is not academic; it occurs almost daily in manufacturing plants the world over.

Somewhat outside the scope of discontinuity detection are non-destructive tests to determine the direction, amount and gradient of stresses in mechanical parts, as applied in the field of experimental stress analysis. These play a very important part in the design of lighter, stronger, less costly and more reliable parts.

Controlling Manufacturing Processes

Control is a basic concept in industry. Engineers, inspectors, operators and production personnel know the problems of keeping any manufacturing process under control. The process must be controlled, and the operator must be trained and supervised. When any element of a manufacturing operation gets out of control, quality of the affected product is compromised and waste may be produced.

Almost every non-destructive testing method is applied in one way or another to assist in process control and so ensure a direct profit for the manufacturer. As one example of thousands which could be cited, consider a heat treating operation. The metallurgist sets up a procedure based on sound material of a given analysis. One non-destructive test, applied to all parts or to a few from each batch of parts, tells whether the chemical analysis of the material is so erratic that the procedure will fail to produce the desired hardness or induce cracking. A second test may show when and where cracking has occurred. Another test may show that the desired hardness has not been developed. If so, process variables may be corrected immediately. In these ways, cost and processing time are saved for the manufacturer.

Lowering Manufacturing Costs

There are many other examples of both actual and potential cost savings possible through the use of non-destructive tests. Most manufacturers could cut manufacturing costs by deciding where to apply the following cost reduction principle: a non-destructive test can reduce manufacturing cost when it locates undesirable characteristics of a material or component at an early stage, thus eliminating costs of further processing or assembly. An example of this principle is the testing of forging blanks before the forging operation. The presence of seams, large inclusions or cracks in the blanks may result in a woefully defective product. Using such a blank would waste all the labor and forge hammer time involved in forming the material into the product.

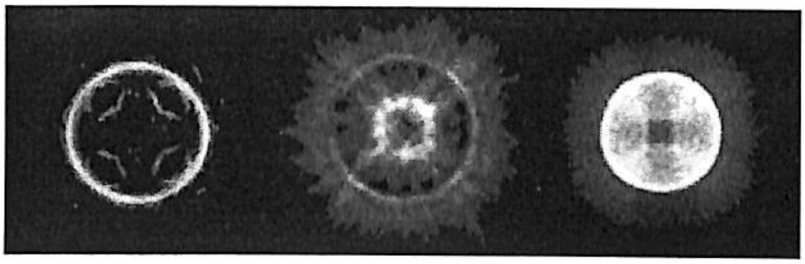
Another profit making principle is that a non-destructive test may save manufacturing cost when it produces desirable information at lower cost than some other destructive or non-destructive tests. An example of this principle is the substitution of a magnetic particle test for acid pickling to detect seams or cracks. As it has in many plants, a straightforward economic study of comparative costs of the two methods may show the cost saving advantage of the non-destructive test over the pickling examination.

Maintaining Uniform Quality Level

Improved product quality should be an aim of and a result of non-destructive testing. Yet this is not always the case, for there is such a thing as too high a quality level. The true function of testing is to control and maintain the quality level that engineers or design engineers establish for the particular product and circumstances.

Quality conscious engineers and manufacturers have long recognized that perfection is unattainable and that even the attempt to achieve perfection in production is unrealistic and costly. Sound management seeks not perfection but pursues excellence in management of workmanship from order entry to product delivery. The desired quality level is the one which is most worthwhile, all things considered. Quality below the specified requirement can ruin sales and reputation. Quality above the specified requirement can swallow up profits through excessive production and scrap losses. Management must decide what quality level it wants to produce and support. Once the quality level has been established, production and testing personnel should aim to maintain this level and not to depart from it excessively either toward lower or higher quality.

In blunt language, a non-destructive test does not improve quality. It can help to establish the quality level but only management sets the quality standard. If management wants to make a nearly perfect product or wants at the other extreme to make junk, then non-destructive tests will help make what is wanted, no more and no less. In preparing a drawing for a part, the designer sets tolerances on dimension and finish. If a drawing specifies a certain dimension as 32 mm (1.25 in.) but fails to specify the tolerance, the machine shop supervisor rejects the drawing as incomplete or assumes the standard tolerance. In non-destructive testing, a quality tolerance (the tolerance on the characteristic being tested) or criteria for acceptance or rejection must also be specified.



Reconstructions of test shapes by ultrasonic tomography.

RAPID GROWTH AND ACCEPTANCE OF NON-DESTRUCTIVE TESTING

Increased Complexity of Modern Machinery

Consider the present-day automobile. First, the manual choke became obsolete. The old rod from the dashboard to a butterfly valve in the carburetor has been replaced by more reliable and efficient metered fuel injection. The mechanically connected brake pedal and brake shoe have given way to hydraulic and antilock braking systems. The old manual windshield wipers are now powered by vacuum or electricity and complicated by washer jets and variable timers. Today's components include complex ventilation, heating, defrosting and air conditioning systems, power seats, power actuated windows and sun roofs, expanded electronics, emission controls, cruise controls, stereo equipment, digital gaging and automatic transmissions. The automobile industry, while carrying design complexity to great lengths, has also tremendously raised component reliability. Otherwise, most people would never dare to take their car from the garage for fear of serious failure.

As an even more startling example of component reliability arithmetic, consider computers. They require complex microprocessors, chips, resistors, wire connections, counters and other parts whose functioning demands operational reliability in each component. The automobile and the electronic instrument industries are examples of complexity that could never have been achieved without parallel advances in nondestructive testing.

Increased Demand on Machines

Within a lifetime, average speeds of railway passenger and freight trains have doubled. The speed of commercial air transport has quintupled. Transonic speeds for rocket powered missiles and for piloted aircraft are common. Automobile, bus and truck speeds have increased and their engines turn twice as fast. Elevators in tall buildings are fully automatic and much faster, with speeds limited only by the comfort of the passengers. The stress applied to parts in these vehicles often increases as the square or cube of the increased velocity.

In the interest of greater speed and rising costs of materials, the design engineer is always under pressure to reduce weight. This can sometimes be done by substituting aluminum or magnesium alloys for steel or iron, but such light alloy parts are not of the same size or design as those they replace. The tendency is also to reduce the size. These pressures on the designer have subjected parts of all sorts to increased stress levels. Even such commonplace objects as sewing machines, sauce pans and luggage are also lighter and more heavily loaded than ever before. The stress to be supported is seldom static. It often fluctuates and reverses at low or high frequencies. Frequency of stress reversals increases with the speeds of modern machines and thus parts tend to fatigue and fail more rapidly.

Another cause of increased stress on modern products is a reduction in the safety factor. An engineer designs with certain known loads in mind. On the supposition that materials and workmanship are never perfect, a safety factor of 2, 3, 5 or 10 is applied. Because of other considerations, a lower factor is often used, depending on the importance of lighter weight or reduced cost or risk to consumer.

New demands on machinery have also stimulated the development and use of new materials whose operating characteristics and performance are not completely known. These new materials create greater and potentially dangerous problems. As an example, there is a record of an aircraft being built from an alloy whose work hardening, notch resistance and fatigue life were not well known. After relatively short periods of service some of these aircraft suffered disastrous failures. Sufficient and proper nondestructive tests could have saved many lives.

As technology improves and as service requirements increase, machines are subjected to greater variations and to wider extremes of all kinds of stress, creating an increasing demand for stronger materials.

Engineering Demands for Sounder Materials

Another justification for the use of nondestructive tests is the designer's demand for sounder materials. As size and weight decrease and the factor of safety is lowered, more and more emphasis is placed on better raw material control and higher quality of materials, manufacturing processes and workmanship.

An interesting fact is that a producer of raw material or of a finished product frequently does not improve quality or performance until that improvement is demanded by the customer. The pressure of the customer is transferred to implementation of improved design or manufacturing. Nondestructive testing is frequently called on to deliver this new quality level.

Public Demands for Greater Safety

The demands and expectations of the public for greater safety are apparent everywhere. Review the record of the courts in granting higher and higher awards to injured persons. Consider the outcry for greater automobile safety, as evidenced by the required use of auto safety belts and the demand for air bags, blowout proof tires and antilock braking systems.

The publicly supported activities of the National Safety Council, Underwriters Laboratories, the Environmental Protection Agency and the Federal Aviation Administration in the United States, and the work of similar agencies abroad, are only a few of the ways in which this demand for safety is expressed. It has been expressed directly by the many passengers who cancel reservations immediately following a serious aircraft accident. This demand for personal safety has been another strong force in the development of nondestructive tests.

Rising Costs of Failure

Aside from awards to the injured or to estates of the deceased, consider briefly other factors in the rising costs of mechanical failure. These costs are increasing for many reasons. Some important ones :-

Greater costs of materials and labor;
Greater costs of complex parts;
Greater costs due to the complexity of assemblies;
Greater probability that failure of one part will cause failure of others, due to overloads;
Trend to lower factors of safety;
Probability that the failure of one part will damage other parts of high value; and
Failure of a part within an automatic production machine may shut down an entire high speed, integrated, production line.

Responsibilities of Production Personnel and Inspectors

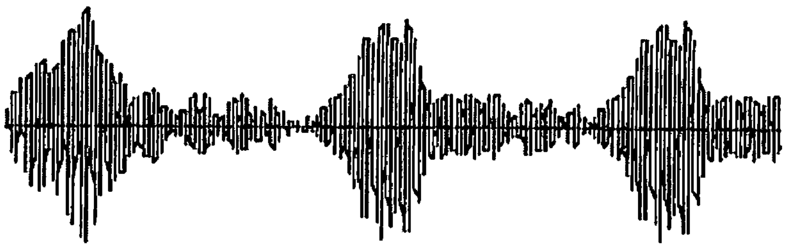
Labor today often means a machinery operator. Formerly, a laborer in a shop manually made a part and the work piece received individual attention. Today the laborer may be just as skilled but the skill is directed toward the operation of a machine. The machine requires attention rather than the work piece. Production rates are also higher. This prevents paying personal attention to individual parts.

Formerly everyone who worked on a part gave it some sort of inspection, even if cursory. Today that is seldom the case. Many production operations are covered by hoods, safety devices and other mechanical fixtures so that the operator scarcely sees the part. This has increased the number of inspectors and size and complexity of jobs. They, too, need faster, more definitive and more accurate test devices. Inspectors have become skilled specialists. They have progressed far beyond the individual who walked down the railroad track tapping car wheels with a hammer, scarcely knowing the purpose of the job. Today the railroad wheel is tested by specialists with far greater reliability and by infinitely superior means.

To meet demands of their customers, nondestructive testing specialists, physicists, metallurgists, chemists, electrical engineers and mechanical engineers continually develop better and more accurate tests. They find out more about materials and components than was ever known without destroying them. And when these scientists produce one new answer, they find that the user has posed two new problems.

One problem with increased use of nondestructive testing is that some people think of nondestructive testing as a cure-all. However, unless engineers design products that can be inspected, nondestructive testing will not be helpful. Nondestructive testing engineers must be involved early in the design process so that later they can provide service the design engineers require and also facilitate the job of the inspector.

In the 1930s, nondestructive testing, where it had been heard of at all, was generally considered an evil. Later it became a necessary evil. For a number of years now NDT has been a necessary aid in tens of thousands of shops in a multitude of industries. Most importantly, nondestructive testing has saved uncounted thousands of lives.



Ultrasonic waves recorded as they pass through a concrete coated steel plate.

CLASSIFICATION OF NDT METHODS

Non-destructive testing is a branch of the materials sciences that is concerned with all aspects of the uniformity, quality and serviceability of materials and structures.

The science of non-destructive testing incorporates all the technology for detection and measurement of significant properties, including discontinuities, in items ranging from research specimens to finished hardware and products. By definition, nondestructive techniques are the means by which materials and structures may be inspected without disruption or impairment of serviceability.

Non-destructive testing has become an increasingly vital factor in the effective conduct of research, development, design and manufacturing programs. Only with appropriate use of non-destructive testing techniques can the benefits of advanced materials science be fully realized. However, the information required for appreciating the broad scope of non-destructive testing is widely scattered in a multitude of publications and reports. Tables 1 and 2 summarize information about non-destructive testing methods arranged to show their purposes and similarities.

The term method as used here refers to the body of specialized procedures, techniques and instruments associated with each non-destructive testing approach. There are usually many techniques or procedures associated with each method. The following text describes these methods without details on application or procedure, providing a resume of each method in a single place, for quick reference.

The National Materials Advisory Board (NMAB) Ad Hoc Committee on Non-destructive Evaluation adopted a system that classified methods into six major categories: visual, penetrating radiation, magnetic-electrical, mechanical vibration, thermal and chemical-electrochemical . A version of the classification system is presented in Table 1, with additional categories included to cover new methods. The first six categories involve basic physical processes that require transfer of matter or energy to the object being tested. Two auxiliary categories describe processes that provide for transfer and accumulation of information, and evaluation of the raw signals and images common to non-destructive testing methods.

TABLE 1. **Nondestructive testing method categories**

Basic Categories	Objectives
Mechanical and optical	color, cracks, dimensions, film thickness, gaging, reflectivity, strain distribution and magnitude, surface finish, surface flaws, through-cracks
Penetrating radiation	cracks, density and chemistry variations, elemental distribution, foreign objects, inclusions, micro porosity, misalignment, missing parts, segregation, service degradation, shrinkage, thickness, voids
Electromagnetic and electronic	alloy content, anisotropy, cavities, cold work, local strain, hardness, composition, contamination, corrosion, cracks, crack depth, crystal structure, electrical and thermal conductivities, flakes, heat treatment, hot tears, inclusions, ion concentrations, laps, lattice strain, layer thickness, moisture content, polarization, seams, segregation, shrinkage, state of cure, tensile strength, thickness, disbands
Sonic and ultrasonic	crack initiation and propagation, cracks, voids, damping factor, degree of cure, degree of impregnation, degree of sintering, delaminations, density, dimensions, elastic moduli, grain size, inclusions, mechanical degradation, misalignment, porosity, radiation degradation, structure of composites, surface stress, tensile, shear and compressive strength, disbonds, wear
Thermal and infrared	bonding, composition, emissivity, heat contours, plating thickness, porosity, reflectivity, stress, thermal conductivity, thickness, voids
Chemical and analytical	alloy identification, composition, cracks, elemental analysis and distribution, grain size, inclusions, macrostructure, porosity, segregation, surface anomalies
Auxiliary Categories	**Objectives**
Image generation	dimensional variations, dynamic performance, anomaly characterization and definition, anomaly distribution, anomaly propagation, magnetic field configurations
Signal image analysis	data selection, processing and display, anomaly mapping, correlation and identification, image enhancement, separation of multiple variables, signature analysis

Classification of NDT Methods (continued)

Each method can be completely characterized in terms of five principal factors:

- Energy source or medium used to probe the test object (such as X-rays, ultrasonic waves or thermal radiation)
- Nature of the signals, image or signature resulting from interaction with the test object (attenuation of X-rays or reflection of ultrasound, for example)
- Means of detecting or sensing resulting signals (photo emulsion, piezoelectric crystal or inductance coil)
- Method of indicating or recording signals (meter deflection, oscilloscope trace or radiograph) and
- Basis for interpreting the results (direct or indirect indication, qualitative or quantitative, and pertinent dependencies).

The objective of each test method is to provide information about the following material parameters:

- Discontinuities (such as cracks, voids, inclusions, delaminations)
- Structure or malstructure (including crystalline structure, grain size, segregation, misalignment);
- Dimensions and metrology (thickness, diameter, gap size, discontinuity size);
- Physical and mechanical properties (reflectivity, conductivity, elastic modulus, sonic velocity);
- Composition and chemical analysis (alloy identification, impurities, elemental distributions);
- Stress and dynamic response (residual stress, crack growth, wear, vibration); and
- Signature analysis (image content, frequency spectrum, field configuration).

The terms used above are defined in Table 2. The limitations of a method include conditions required by that method: conditions to be met for technique application (access, physical contact, and preparation) and requirements to adapt the probe or probe medium to the test object. Other factors limit the detection or characterization of discontinuities, properties and other attributes and limit interpretation of signals or generated images.

TABLE 2. Objectives of nondestructive testing methods

Objectives	Attributes Measured or Detected
Discontinuites	
Surface anomalies	roughness, scratches, gouges, crazing, pitting, inclusions and imbedded foreign material
Surface connected anomalies	cracks, porosity, pinholes, laps, seams, folds, inclusions
Internal anomalies	cracks, separations, hot tears, cold shuts, shrinkage, voids, lack of fusion, pores, cavities, delaminations, disbonds, poor bonds, inclusions, segregations
Structure	
Microstructure	molecular structure, crystalline structure and/or strain, lattice structure, strain, dislocation, vacancy, deformation
Matrix structure	grain structure, size, orientation and phase, sinter and porosity, impregnation, filler and/or reinforcement distribution, anisotropy, heterogeneity, segregation
Small structural anomalies	leaks (lack of seal or through-holes), poor fit, poor contact, loose parts, loose particles, foreign objects
Gross structural anomalies	assembly errors, misalignment, poor spacing or ordering, deformation, malformation, missing parts
Dimensions and metrology	
Displacement, position	linear measurement, separation, gap size, discontinuity size, depth, location and orientation
Dimensional variations	unevenness, nonuniformity, eccentricity, shape and contour, size and mass variations
Thickness, density	film, coating, layer, plating, wall and sheet thickness, density or thickness variations
Physical and mechanical properties	
Electrical properties	resistivity, conductivity, dielectric constant and dissipation factor

Magnetic properties	polarization, permeability, ferromagnetism, cohesive force
Thermal properties	conductivity, thermal time constant and thermoelectric potential
Mechanical properties	compressive, shear and tensile strength (and moduli), Poisson's ratio, sonic velocity, hardness, temper and embrittlement
Surface properties	color, reflectivity, refraction index, emissivity

Chemical composition and analysis

Elemental analysis	detection, identification, distribution and/or profile
Impurity concentrations	contamination, depletion, doping and diffusants
Metallurgical content	variation, alloy identification, verification and sorting
Physiochemical state	moisture content, degree of cure, ion concentrations and corrosion, reaction products

Stress and dynamic response

Stress, strain, fatigue	heat-treatment, annealing and cold-work effects, residual stress and strain, fatigue damage and life (residual)
Mechanical damage	wear, spalling, erosion, friction effects
Chemical damage	corrosion, stress corrosion, phase transformation
Other damage	radiation damage and high frequency voltage breakdown
Dynamic performance	crack initiation and propagation, plastic deformation, creep, excessive motion, vibration, damping, timing of events, any anomalous behavior

Signature analysis

Electromagnetic field	potential, strength, field distribution and pattern
Thermal field	isotherms, heat contours, temperatures, heat flow, temperature distribution, heat leaks, hot spots
Acoustic signature	noise, vibration characteristics, frequency amplitude, harmonic spectrum and/or analysis, sonic and/or ultrasonic emissions
Radioactive signature	distribution and diffusion of isotopes and tracers
Signal or image analysis	image enhancement and quantization, pattern recognition, densitometry, signal classification, separation and correlation, discontinuity identification, definition (size and shape) and distribution analysis, discontinuity mapping and display

NDT METHODS FOR TESTING OF PIPELINES

Visual Inspection Services

Non-Destructive visual inspections can be preformed on-site or at the laboratory facility, and are based upon the requirements of the client or specification. Industries utilizing this service include Fabrication, Construction, Automotive, Power Generation and Transportation. Inspections can be performed at the laboratory facility or onsite. These inspections are performed to IS, BS, ASTM, AWS, ASME (American Society for Mechanical Engineers) and many others.

Radiography

Radiography is the most commonly used non-destructive testing method for pipeline inspection. The principle is that a source of radiation is directed toward the inspected object. A sheet of radiographic film is placed behind the object. The setup usually takes a few minutes, the exposure 1-10 minutes and film processing about 10 minutes. Advantage of this method is its reliability. Nowadays digital images can also be used and information saved and transported by computers. Disadvantage is the radiation danger.

Radiography procedure

Radiography utilizes very short wavelength electromagnetic radiation, namely X-rays or γ rays, will penetrate through solid media but will be partially absorbed by the medium. The amount of absorption which will occur will depend on the thickness and density of the material the radiation is passing through, and also the characteristics of the radiation the radiation which passes through the material can be detected and recorded on either film or sensitized paper, viewed on a fluorescent screen or detected and monitored by electronic sensing equipment.

Types of radiography

Computed Radiography (CR) uses very similar equipment to conventional radiography except that in place of a film to create the image, an imaging plate is used. Hence, instead of taking a film into a darkroom for developing in chemical trays, the imaging plate is run through a computer scanner to read and digitize the image. The image can then be viewed and enhanced using software that has functions very similar to conventional image-processing software, such as contrast, brightness, and zoom.

Differences from Direct Radiography

Computed radiography is commonly distinguished from Direct Radiography (DR). In the same way that a CR system requires a short burst of radiation, so does a DR system. The difference is that on exposure a DR system will almost instantly display the image on the screen in front of the radiographer, therefore removing any need for processing. Post production can of course be performed on DR images in the same way that CR images can.

This is not to be confused with Fluoroscopy, where there is a continuous beam of radiation, and the images appear on the screen like on a TV. This is the system most people are familiar with, as this is what is used in airport security systems.

Imaging plate

The imaging plate contains photo stimulable storage phosphors, which store the radiation level received at each point in local electron energies. When the plate is put through the scanner, a scanning laser beam causes the electrons to relax to lower energy levels, emitting light that is measured to compute the digital image. Imaging plates can be re-used thousands of times if they are handled carefully, although handling under industrial conditions may result in damage after a few hundred uses. An image can be erased by simply exposing the plate to a room-level fluorescent light, and the plate is then ready for re-use. In the software, the scanned image is encrypted so that the original data is kept secure and can not be tampered with.

Industrial applications

Common applications for computed radiography include:

- Corrosion surveys on pipes, often through insulation;
- Examination of valves for erosion;
- Information shots on industrial components; e.g. checking to see if a valve is closed properly, or checking for obstructions in valves and pipes;
- Examination of boiler water walls.

Radiographic testing using computed radiography has pros and cons:

Advantages

- No film or chemicals; instead a computer is used
- Image available faster; commonly one minute instead of seven minutes, as with conventional radiography
- By adjusting image brightness, a wide range of thicknesses can be examined in one shot, unlike conventional radiography, which requires a different exposure time for each thickness in a component. Computed radiography thus requires fewer re-shots due to under- or over-exposure.
- Images can be stored on disk or transmitted for off-site review.

Disadvantages

- Due to the high cost of the CR equipment and the training required to operate the CR systems, pricing is typically higher when compared to traditional film radiography. In medical situations though, the break even point with not having to use chemicals and have a darkroom reduce the ongoing cost considerably.

Digital radiography is a form of x-ray imaging, where digital X-ray sensors are used instead of traditional photographic film. Advantages include time efficiency through bypassing chemical processing and the ability to digitally transfer and enhance images.

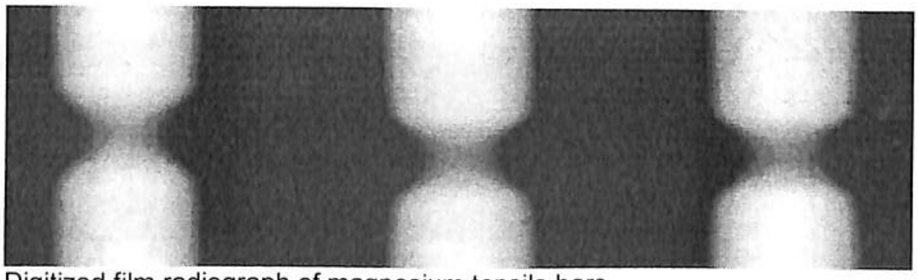
Also less radiation can be used to produce an image of similar contrast to conventional radiography.

Digital radiographic systems

One particular type of digital system uses a Memory Phosphor Plate (aka PSP - Phosphor Plate) in place of the film. After X-ray exposure the plate (sheet) is placed in a special scanner where the latent formed image is retrieved point by point and digitized, using a laser light scanning. The digitized images are stored and displayed on the computer screen. This method is half way between old film based technology and the current direct digital imaging technology. It is similar to the film process because it involves the same image support handling and differs because the chemical development process is replaced by the scanning process. This is not much faster that film processing and the resolution and sensitivity performances are contested. However it has the clear advantage to be able to fit with any pre-existing equipment without any modification because it replaces just the existing film.

Also some times the term "Digital X-rays" is used to designate the scanned film documents which further are handled by computers.

The other types of digital imaging technologies use electronic sensors. A majority of them first convert the X-rays in light (using a GdO2S or CsI layer) which is further captured using a CCD or a CMOS image sensor. Few of them use a hybrid arrangement which first convert the X-ray into electricity (using a CdTe layer) and then this electricity is captured as an image by a reading section based on CMOS technology.



Digitized film radiograph of magnesium tensile bars.

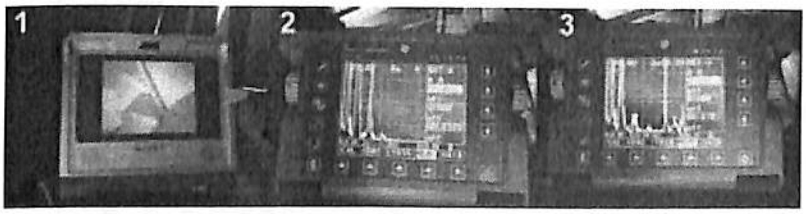
Ultrasonic Testing

Ultrasonic testing is used as an NDT-method to evaluate the integrity of automatic welded pipeline girth welds. It is widely used for the detection of internal defects in materials, but they can also be used for the detection of small surface cracks. Ultrasonic Inspection is often performed on steel and other metals and alloys, though it can be used on concrete and other materials such as composites. They are used for the quality control inspection of part processed material, such as rolled slabs, as well as for the inspection of finished components.

Procedure

The principle is to employ high frequency acoustic waves to probe the inspected sample. As the acoustic wave penetrates the sample, the wave is attenuated and/or reflected by any change in the density in the material. By observing the returned signal many of the characteristics of the material can be determined. Setup takes less than an hour and scanning time varies from a few minutes to hours depending on the size of the sample and the desired resolution. Advantages are that there are no health risks for the environment, and it is possible to define very accurately where the defect is located and how big it is. On the other hand the suitability for thin objects, like pipes, is restricted. Ultrasonic inspection also requires that the inspecting technicians must be very experienced in order to get reliable results. The waves used for the non-destructive testing of material are usually within the frequency range 0.5MHz to 20MHz.

In fluids, sound waves are of the longitudinal compression type in which the particle displacement is in the direction of propagation; but in solids, they are shear waves, with particle displacement is normal to the direction of wave travel and elastic surface waves can also occur. The latter are termed Rayleigh waves.



How it works

In ultrasonic testing, a transducer connected to a diagnostic machine is passed over the object being inspected. In reflection (or pulse-echo) mode, the transducer sends pulsed waves through a couplant (such as water or oil) on the surface of the object, and receives the "sound" reflected back to the device. Reflected ultrasound comes from an interface - such as the back wall of the object or from an imperfection. The screen on the calibrated diagnostic machine displays these results in the form of a signal with an amplitude representing the intensity of the reflection and the distance taken for the reflection to return to the transducer. In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after travelling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted thus indicating their presence.

Non-destructive testing of a swing shaft showing spline cracking

Advantages

1. Superior penetrating power, which allows the detection of flaws deep in the part.
2. High sensitivity, permitting the detection of extremely small flaws.
3. Only one surface need to be accessible.
4. Greater accuracy than other nondestructive methods in determining the depth of internal flaws and the thickness of parts with parallel surfaces.
5. Some capability of estimating the size, orientation, shape and nature of defects.
6. Nonhazardous to operations or to nearby personnel and has no effect on equipment and materials in the vicinity.

7. Capable of portable or highly automated operation.

Disadvantages

1. Manual operation requires careful attention by experienced technicians
2. Extensive technical knowledge is required for the development of inspection procedures.
3. Parts that are rough, irregular in shape, very small or thin, or not homogeneous are difficult to inspect.
4. Surface must be prepared by cleaning and removing loose scale, paint, etc. (UT can often be used successfully through paint that is properly bonded to a surface.)
5. Couplants are needed to provide effective transfer of ultrasonic wave energy between transducers and parts being inspected unless a non-contact technique is used. Non-contact techniques include Laser and Electro Magnetic Acoustic Transducers (EMAT).
6. Inspected items must be water resistant, when using water based couplants that do not contain rust inhibitors.

2.3 Eddy Current

In eddy current testing, a time varying magnetic field in induced in the sample material by using a magnetic coil with alternating current. This magnetic field causes an electric current to be generated in conducting materials. These currents, in turn, produce small magnetic fields around the conducting materials. The smaller magnetic fields generally oppose the original field, which changes the impedance of the magnetic coil. Thus, by measuring the changes in impedance of the magnetic coil as it traverses the sample, different characteristics of the sample can be identified. The testing time is usually a few hours. Eddy current method has a limited depth of penetration, 4...8 mm only. In pipe industry it is however a widely applied inspection method. It is suitable for detecting for example porosity, cross and seam cracks and checking seams and butt welds. The testing method is relatively simple and costs moderate.

Liquid Penetrate Testing or Dye Penetrant Test

Liquid penetrant testing is a technique, which can be used to detect defects in a wide range of components, provided that the defect breaks the surface of the material.This method is suitable for detection of cracking and porosity in welded joints. The principle is that the surface of the sample is coated with a penetrant in which a colorful or fluorescent dye is dissolved or suspended. The penetrant is pulled into surface defects by capillary action. After a waiting period to insure that the dye has penetrated into the cracks, the excess penetrant is cleaned from the surface of the inspected part. A developed, a white powder, is sprayed over the part. This lifts the penetrant out of the defect and the dye stains the developer. By visual inspection under white or ultraviolet light, the visible or fluorescent dye indications can be identified defining the defect. Less than one hour is usually required as an inspection time. The method is a lot cheaper compared to radiography or ultrasonics, but can only detect external defects.

Magnetic Particle Inspection

Magnetic particle inspection is a sensitive method of locating surface and some sub-surface defects in Ferro-magnetic components The basics processing parameters depend on relatively simple concepts. The principle is that the sample is magnetized by dusting magnetic particles over it. A surface defect will form a magnetic anomaly, attracting and holding magnetic particles and thus giving a visual indication of the defect. The evaluation time is typically few minutes. The sample must be ferromagnetic and therefore this technique can not be used on most stainless steels. This method also is a lot cheaper compared to radiography or ultrasonic, but like the dye penetrate, it only can detect external defects.

Hardness Testing

As Per ASTM E110, this testing is normally used for on-site applications or on very large samples. The portable hardness unit performs the hardness testing by applying a 5 kg. Vickers load indenter and electronically converts the values in the preferred scale.

CHAPTER 4
THEORETICAL DEVELOPMENT ON RADIOGRAPHY

THEORETICAL DEVELOPMENT ON RADIOGRAPHY

PURPOSE:

All the butt-welds in pressurized gas facility pipeline and other pressurized piping shall undergo non-destructive testing shall be used to satisfy the requirements for non-destructive testing of field made girth welds.

SCOPE: The scope covers all welding joint to be carried out 100% radiography

4.1) PROCEDURE:

Radiography shall be carried out using any one of the following Techniques with X-Radiation.

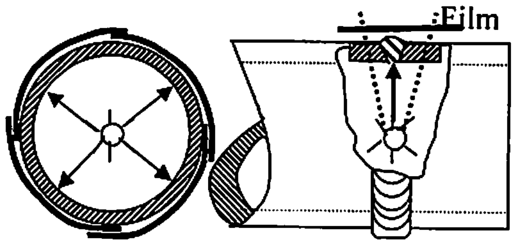
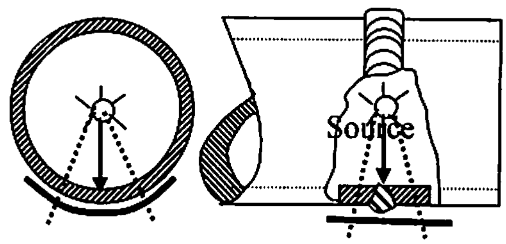
A) SINGLE WALL SINGLE IMAGE:

This Technique is ideal for plates, Pipelines or Vessels, Tanks, Structures and components. In this technique the radiation penetrates through single wall of Test Object & image of the Single wall is recorded on the Radiograph. Radiography Equipment with Panoramic X-ray fitted with a Crawler is placed at the Center of the Pipeline.

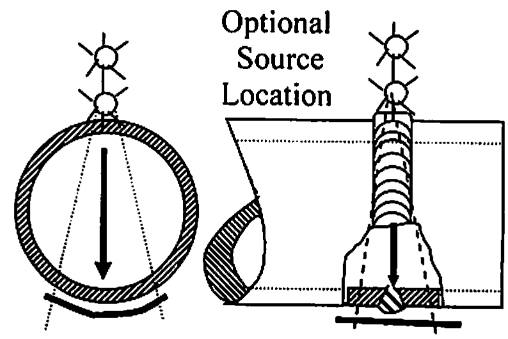
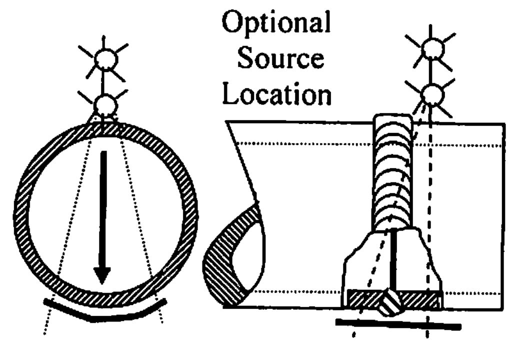
B) DOUBLE WALL SINGLE IMAGE:

This Technique is ideal for pipes of diameter 2 ½" and above & components (where the Single wall single image is not Possible). In this technique the Radiation penetrates through both the walls of test object (Pipe) and Single image of the part closest to the film is recorded on the Radiograph.

SINGLE WALL RADIOGRAPHIC TECHNIQUES

Pipe O. D.	Exposure Technique	Radiograph Viewing	Source-Weld-Film Arrangement		IQI Penetrameter		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Single-Wall : T-271.1	Single – wall	 Exposure Arrangement - A		T-276 And Table T-276	Source Side T-277.1(a) Film Side T-277.1 (b)	Either Side T-275.3 T-275.1(c)
Any	Single-Wall : T-271.1	Single – wall	 Film Exposure Arrangement - B		T-276 And Table T-276	Source Side T-277.1(a) Film Side T-277.1 (b)	Film Side T-275.1 (b) (1)

DOUBLE – WALL RADIOGRAPHIC TECHNIQUES

Pipe O. D.	Exposure Technique	Radiograph Viewing	Source-Weld-Film Arrangement		IQI Penetrameter		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Double-Wall : T-271.2 (a) At Least 3 Exposures 120° To Each Other For Complete Coverage	Single – wall	 Film Exposure Arrangement - D		T-276 And Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Either Side T-275.1 (b) (1)
Any	Double-Wall : T-271.2 (a) At Least 3 Exposures 120° To Each Other For Complete Coverage	Single-wall	 Film Exposure Arrangement - E		T-276 And Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Either Side T-275.1 (b) (1)

4.2) EQUIPMENT, CONSUMABLES & ACCESSORIES:

- X ray generator with control units (Internal & Externals) with all connecting cables
- Battery Packs and Chargers
- Pilot Command
- Survey Meter
- Dosimeter
- Warning Placards
- Cordoning Rope
- Lead Markers
- Crayon or Paint Markers
- Measuring tape
- Elastic
- Pentameters (I.Q.Is)
- Dark Room Accessories & Consumables
- Radiography Film Viewer
-

Manpower

For the radiography for one crew

1.0 NDT supervisor	- 1 no.s
2.0 Operator	2 no.s
3.0 Helper	-2 no.s
4.0 Developer	-2 no.s

4.3) SURFACE PREPARATION:

As far as possible all irregularities from the surface (to the extent of coverage of films) shall be removed for better results and interpretation.

4.4) PREVENTION OF BACK SCATTERING:

To achieve better Radiography definition, it is required to check back scattering by placing lead no. 'B' on the backside of film holder to ensure the back scattering does not harm the film quality. In such case, it is advised to place lead sheets on the backside of holder.

4.5) PLACEMENT OF MARKER AND I.Q.I.

Lead markers shall be kept to identify the test object, date of Radiography, area of interest of the object, the location of the Radiographs and any other information as specified by the client.

I.Q.I. shall be placed such a way that thinnest wire of the penetrameter shall be far most from the source. In case of panoramic exposure techniques, 4 nos. IQI's shall be placed equidistant along the circumference. The film with the cassette shall be in firm contact with the object to be Radiographed for better contrast.

4.6) SOURCE TO FILM DISTANCE:

Source to film distance shall be such that the geometrical unsharpness (Ug) shall be as per the chart below.

Material thickness (inches)	Ug Maximum (inches)
Under 2	0.020
2 to 3	0.030
Over 3 to 4	0.040
Greater than 4	0.070

The Ug is determined by

Ug = FD / d

Where Ug - geometrical un sharpness
F - Source size the maximum projected dimension facing perpendicular to film center.
D - Distance from source of radiation to the specimen being radio graphed. (S.F.D.)
d - Distance from source side of the specimen to the film. (Thickness)

4.7) EXPOSURE TIME:

Exposure time shall be calculated with actual source strength, penetrated wall thickness, S.F.D. / F.F.D. and film speed using Exposure chart or Exposure calculator.

4.8) FILM LOADING:

Film shall be loaded in the dark room under proper safe light, Filter. Films shall be cut carefully without any damages, scratches or finger marks. Sandwich the film between pair of screens & loaded into light tight PVC cassettes or holders.

4.9) NUMBER OF EXPOSURES:

The number of Exposures will be such that the area of Interest is completely covered and when multiple films are used the overlap between any 2 films will be a minimum of 20%. Minimum two exposure shall be taken in Double Wall Double Image Technique and a minimum of three Exposures for Single Wall Single Image or Double Wall Single Image technique for Pipeline joints.

4.10) FILM PROCESSING:

Film shall be processed in a dark room under safe light. The temperature of the chemical shall be 20°C ± 1°C or as specified. The film shall be unloaded in hangers / spools care fully to avoid any marks. The manual processing involves the following steps.

All the steps shall be performed on a test film initially to determine any effect of processing.

Step: 1 **Developer:** Shake the hangers or spools to avoid any uneven developing marks. Developing time shall be as recommended by film manufacturer varies from min. 3 to 8 minutes for, class II films & 3 to 8 minutes for class I Film.

Step: 2 **Stop bath:** The stop bath is water with 5 to 6 drops of Acetic Acid per gallon of water .To arrest developing action films are immersed in a stop bath. . Shake hanger for 2 to 3 minutes in the stop bath.

Step: 3 **Fixer:** To remove the excess silver grains from unexposed or less exposed part of film & to harden base of film, the hangers shall be immersed in fixer for at least 10 minutes.

Step: 4 **Running water**: Films shall be kept in running water tank where excess fixer will be washed from the surface of the film. Wash at least for 30 minutes.

Step: 5 **Drying:** Film shall be dried in open space or in dryer with circulating hot air less than 55°C

4.11) FILM VIEWING:

The Films shall be viewed under a high intensity Film Viewer, capable of reading Radiographs of Density up to 4 & with adjustable light intensity. Viewing shall be done under subdued background lighting of an intensity that will not cause troublesome reflections.

4.12) FILM DENSITY:

To measure the film density a calibrated densitometer (or) certified Step Wedge Density Strip shall be used.

4.13) FILM CONTRAST:

Contrast of the film shall be adequate to manifest on the Radiograph even the smallest thickness differential. Better the contrast better the interpretation of discontinuity.

4.14) SENSITIVITY:

The film sensitivity shall be better than 2 % & shall be confirmed by computing or in accordance with ASME Section V, Article 2, Table 276 equivalent wire size, for X-Ray Radiography.

$$\% \text{ Sensitivity} = \frac{\text{Diameter of thinnest wire Visible on the Radiograph}}{\text{Penetrated thickness at the area of interest (diagnostic area)}} \times 100$$

INTERPRETATION:

All indications that are equal to or greater than rejection level described in acceptance / rejection criteria as per API 1104 and TE specification shall be considered representing defects and may be cause of rejection or repair of the weld or base metal.

ACCEPTANCE OR REJECTION CRITERIA:

Acceptance or rejection criteria shall be in accordance with API 1104. All defect location shall be marked & / or recorded for repairing.

REPORTING:

All details of inspection and results of inspection shall be documented in report and shall be signed by NDT inspector and client's representative.

FILM STORAGE & ARCHIVE LIFE:

Films shall be stored in dry place with humidity less than 80 % in proper storage boxes with identification. Methylene blue test shall be carried out to find out its archive life.

SAFETY:

Safety in this NDT method is first priority; hence all Technicians must work as per radiation safety guide & all local rules and regulations.

RADIOGRAPHIC EXAMINATION TECHNIQUE – 1

(PIPELINE RADIOGRAPHY) – INTERNAL

1.	Object	Butt Weld of 30", 24" & 18" OD pipeline
2.	Wall thickness range	7.1 mm to 19.1 mm
3.	Extent of Examination	100%
4.	Material to be Radio graphed	API 5L x Gr.70
5.	Make of Equipment	IPSI, France.
6.	Type of Equipment	Internal X-Ray Crawler, Panoramic
7.	Kv Range	225 kV
8.	mA X-Ray	5 mA
9.	Effective focal size	5 mm × 0. 5 mm
10.	I.Q.I Type	ASTM Wire Type/DIN Wire Type
11.	Sensitivity	1.8 % or better
12.	Technique as specified in	ASME V, Art. 2 Exposure Arrangement – A
13.	Radiation angle with respect to weld and film	360°
14.	Focus to film distance	50% of the ID
15.	Object to film distance	In Full contact as max. Possible
16.	Geometrical Unsharpness	0.5 mm or less
17.	Film type	D7 or equivalent, class II, medium speed
18.	Film dimensions	70 mm ×Circumference + 2" overlapping on either side
19.	Overlap of film	40 mm
20.	Diagnostic film length	Entire length of the film
21.	Intensifying screens	Lead
22.	Screen thickness	0.125 mm Front and Back
23.	Maximum base fog level	0.3
24.	Film density	1.8 and 3.5
25.	Check on back scatter	Yes
26.	Identification on film	As per this procedure
27.	Film processing	Manual
28.	Processing chemicals	Developer, stop bath, Fixer, wetting agent
29.	Acceptance Criteria	API 1104 and TE Specification
30.	Reporting	STG-GIL/DUPL/RT/IR/06
31.	Identification of repairs	R-for repair, RW- for reweld, RT for Retake, RS for Reshoot, B for back scatter radiation

RADIOGRAPHIC EXAMINATION TECHNIQUE – 2

(PIPELINE RADIOGRAPHY) – EXTERNAL

1.	Object	Butt Weld of 30", 24" & 18" OD pipeline
2.	Wall thickness range	7.1 mm to 19.1 mm
3.	Extent of examination	100%
4.	Material to be Radiographer	API 5L x Gr.70
5.	Make of Equipment	ICM, BELGIUM
6.	Type of Equipment	X-Ray Uni directional
7.	KV Range	260 kV
8.	MA X-Ray	5 mA
9.	Effective dim. Focal spot	2.5 mm × 2.5 mm
10.	I.Q.I.Type	ASTM Wire type or Plaque type/ DIN Wire type
11.	Sensitivity	1.8 % or better
12.	Technique as specified in	ASME Sec.V Exposure Arrangement – E
13.	Radiation angle with respect to weld and film	90°
14.	Focus to film distance	Varies (depends on φ)
15.	Object to film distance	Full contact as max. possible
16.	Geometric unsharpness	0.5 mm or less
17.	Film type	D7 or equivalent, class II, medium speed
18.	Film dimensions & No of Exposures	Circumference /4 + 4" × 70 mm width & 4 Exposures.
19.	Overlap of film	40 mm
20.	Diagnostic film length	Total length
21.	Intensifying screens	Lead
22.	Screen thickness	0.125 mm Front and Back
23.	Maximum base fog level	0.3
24.	Film density	1.8 and 3.5
25.	Check on back scatter	Yes
26.	Identification on film	As per this procedure
27.	Film processing	Manual
28.	Processing chemicals	RP Photographic/MEK/Kodak/Premier etc.
29.	Acceptance Criteria	API 1104
30.	Reporting	STG-GIL/DUPL/RT/IR/06
31.	Identification of repairs	R-for repair, RW- for Reweld, RT for Retake, RS for Reshoot, B for back scatter radiation

	HOLE TYPE DESIGNATION	ESSENTIAL HOLE	WIRE DIAMETER, INCH	HOLE TYPE DESIGNATION	ESSENTIAL HOLE	WIRE DIAMETER, INCH
Up to 0.25, incl.	12	2T	0.008	10	2T	0.006
Over 0.25 through 0.375	15	2T	0.010	12	2T	0.008
Over 0.375 through 0.50	17	2T	0.013	15	2T	0.010
Over 0.50 through 0.75	20	2T	0.016	17	2T	0.013
Over 0.75 through 1.00	25	2T	0.020	20	2T	0.016
Over 1.00 through 1.50	30	2T	0.025	25	2T	0.020
Over 1.50 through 2.00	35	2T	0.032	30	2T	0.025
Over 2.00 through 2.50	40	2T	0.040	35	2T	0.032
Over 2.50 through 4.00	50	2T	0.050	40	2T	0.040
Over 4.00 through 6.00	60	2T	0.063	50	2T	0.050
Over 6.00 through 8.00	80	2T	0.100	60	2T	0.063
Over 8.00 through 10.00	100	2T	0.126	80	2T	0.100
Over 10.00 through 12.00	120	2T	0.160	100	2T	0.126
Over 12.00 through 16.00	160	2T	0.250	120	2T	0.160
Over 16.00 through 20.00	200	2T	0.320	160	2T	0.250

Thickness to be considered for Sensitivity Calculations / Penetrameter selection.

1. Single Wall Single Image Technique: Single wall Thickness.+ Weld reinforcement

Thickness

2. Double wall Single Image Technique: Single wall Thickness + Weld reinforcement Thickness.

3. Double wall Double Image Technique: Single wall Thickness + Weld reinforcement.

RESPONSIBILITIES

SITE ENGINEER

Shall report to the Project Manager and will be responsible for

- Preparation to radiography Schedule addressing specific issues and characteristics of each section/ spread.
- Responsible for overall control of site and safety managements and for the implementation of approved procedure and supervise the activity
- Generation reports during the activity

- Explain to contractor and all other persons involved in work, the detailed operation to be done during various phase of activity.

QA/QC Engineer

- Shall report to manager QC for technical matters and projects Manager at site for administrative matters.
- Shall be responsible for over control of QC activities and Sub Contracts QC activities, Supervision & develop inspection and test plans.
- Checks and verifies the activity.
- Verifies and counter sign Radiographic report.
- Shall be responsible for custody, Maintenance calibration certificates and issuance of test Equipments

CHAPTER 5
ANALYSIS ON RADIOGRAPHY

ANALYSIS ON RADIOGRAPHY

Analysis on radiography of Dahej Uran pipeline section from Km 12 to Km15

5.1) Sections details:

Section –V from KM12 to KM15 i.e Mankhund to Uran with 24" outer diameter.

- Pipe detail API 5LX70
- 14.3mm with 3000.00 m length
- Total length of the section=3000.00 m

Pipe-book of Section – V of Spread -3 is attached to next

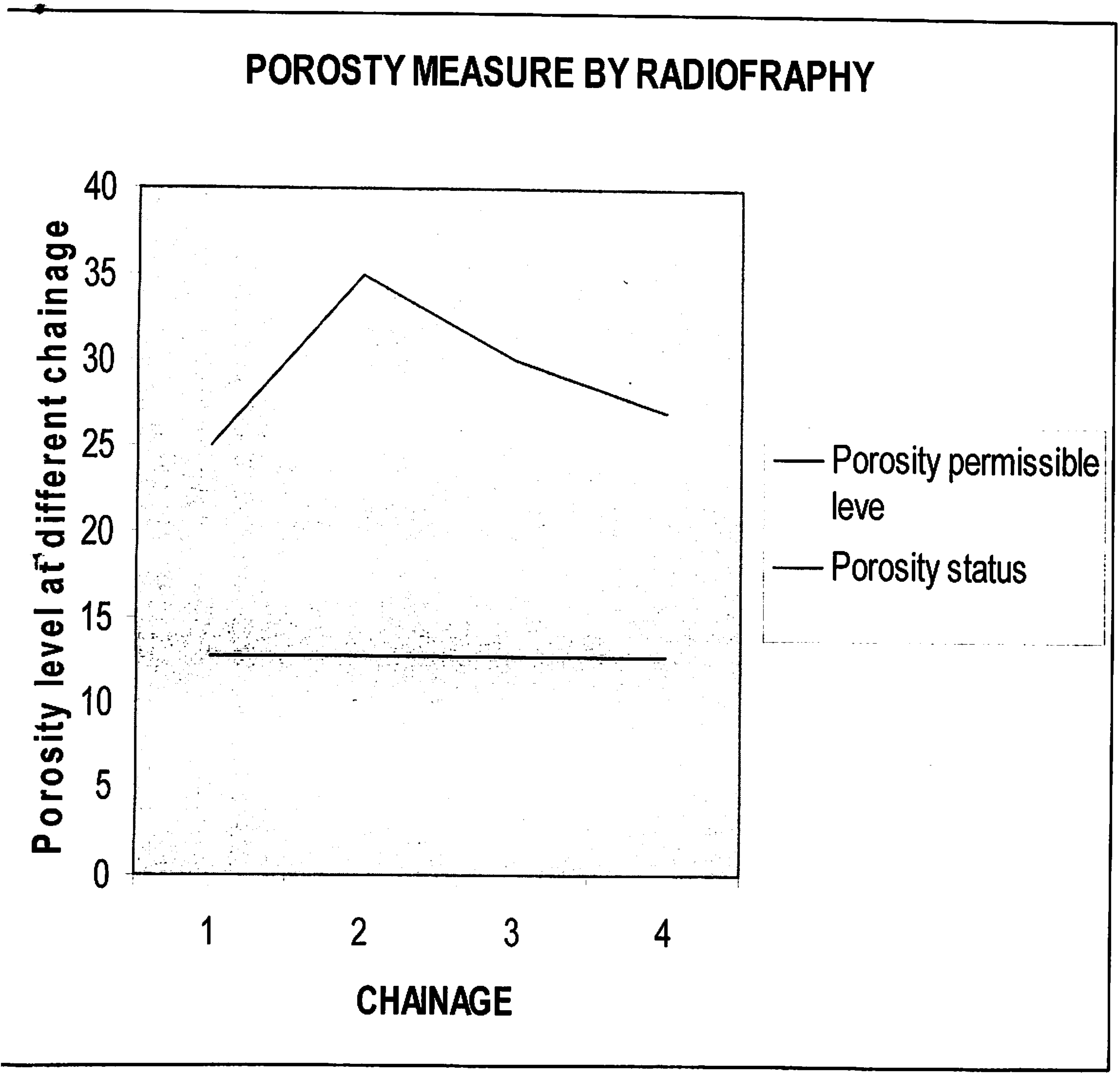


Fig. Porosity acceptance criteria

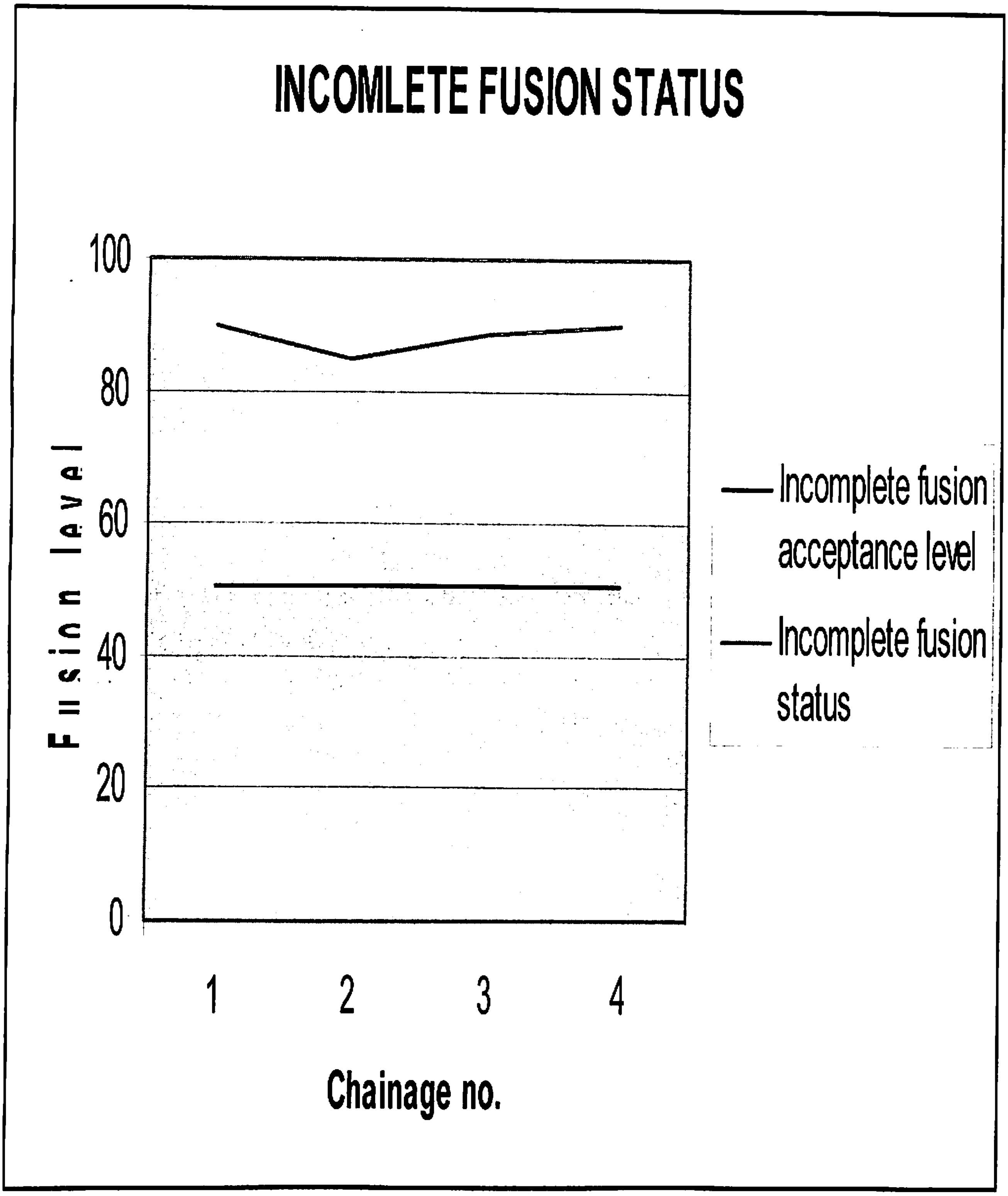


Fig. Incomplete fusion acceptance criteria

Some defects which occurs on this pipeline section and are suspect by radiography are as follows :

- Porosity
- Internal concavity
- Incomplete fusion due cold cap
- Inadequate penetration due to high low

5.2) Porosity Porosity is defined as gas trapped by solidifying weld metal before the gas has a chance to rise to the surface of the molten puddle and escape. Porosity is generally spherical
but may be elongated or irregular in shape, such as piping (wormhole) porosity. When the size of the radiographic indication produced by a pore is measured, the maximum dimension
of the indication shall apply to the criteria given in :

1 Individual or scattered porosity (P) shall be considered a defect should any of the following conditions exist:

a. The size of an individual pore exceeds 1/8 in. (3 mm).

b. The size of an individual pore exceeds 25% of the thinner of the nominal wall thicknesses joined.

c. The distribution of scattered porosity exceeds the concentration permitted by

2 Cluster porosity (CP) that occurs in any pass except the finish pass shall comply with the criteria of API -1104 that occurs in the finish pass shall be considered a defect should any of the following conditions exist:

a. The diameter of the cluster exceeds 1/2 in. (13 mm).weld exceeds 2 in. (50 mm).

b. The aggregate length of CP in any continuous 12-in. (300-mm) length of weld exceeds 1/2 in. (13 mm).

c. An individual pore within a cluster exceeds 1/16 in. (2 mm) in size.

3 Hollow-bead porosity (HB) is defined as elongated linear porosity that occurs in the root pass. HB shall be considered a defect should any of the following conditions exist:

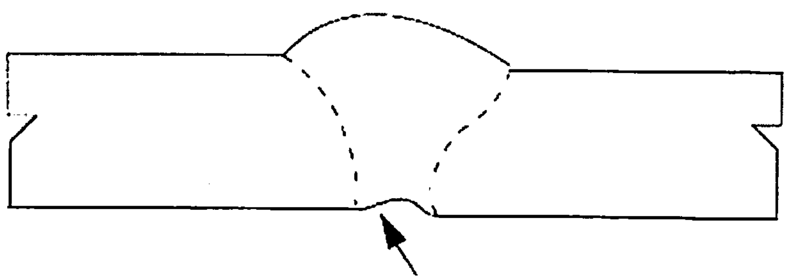
a. The length of an individual indication of HB exceeds 1/2 in. (13 mm).

b. The aggregate length of indications of HB in any continuous 12-in. (300-mm) length of weld exceeds 2 in. (50 mm).

c. Individual indications of HB, each greater than 1/4 in. (6 mm) in length, are separated by less than 2 in. (50 mm).

d. The aggregate length of all indications of HB exceeds 8% of the weld length.

5.3) Internal concavity Internal concavity (IC) is defined is shown schematically in Figure. Any length of internal concavity is acceptable, provided the density of the radiographic image of the internal concavity does not exceed that of the thinnest adjacent parent material. For areas that exceed the density of the thinnest adjacent parent material, the criteria for burn through.



Root bead is fused to both surfaces, but center of root pass is slightly below the pipe's inside surface.

1 A burn-through (BT) is defined as a portion of the root bead where excessive penetration has caused the weld puddle to be blown into the pipe.

For pipe with an outside diameter greater than or equal to 2.375 in. (60.3 mm), a BT shall be considered a defect should any of the following conditions exist:

a. The maximum dimension exceeds 1/4 in. (6 mm) and the density of the BT's image exceeds that of the thinnest adjacent parent material.

b. The maximum dimension exceeds the thinner of the nominal wall thicknesses joined, and the density of the BT's image exceeds that of the thinnest adjacent parent material.

c. The sum of the maximum dimensions of separate BTs whose image density exceeds that of the thinnest adjacent parent material exceeds 1/2 inch (13 mm) in any continuous

12-in. (300-mm) length of weld or the total weld length, whichever is less.

2 For pipe with an outside diameter less than 2.375 in. (60.3 mm), a BT shall be considered a defect when any of the following conditions exists:

a) The maximum dimension exceeds 1/4 in. (6 mm) and the density of the BT's image exceeds that of the thinnest adjacent parent material.

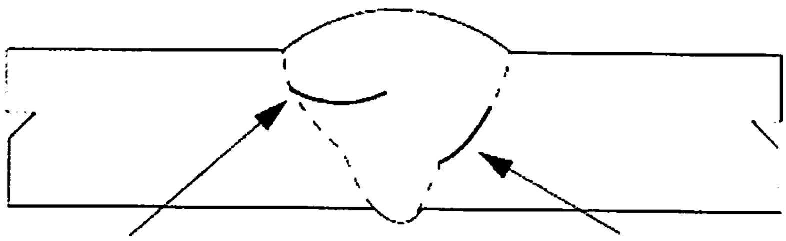
b. The maximum dimension exceeds the thinner of the nominalwall thicknesses joined, and the density of the BT's image exceeds that of the thinnest adjacent parent material.

c. More than one BT of any size is present and the density of more than one of the images exceeds that of the thinnest adjacent parent material.

5.4) Incomplete fusion due cold cap

Incomplete fusion due to cold lap (IFD) is defined as an imperfection between two adjacent weld beads or between the weld metal and the base metal that is not open to the surface. This condition is shown schematically in figure shall be considered a defect should any of the following conditions exist:

1. The length of an individual indication of IFD exceeds 2 inch(50 mm).
2. The aggregate length of indications of IFD in any continuous 12-in. (300 mm) length of weld exceeds 2 in. (50 mm).
3. The aggregate length of indications of IFD exceeds 8% of the weld length.



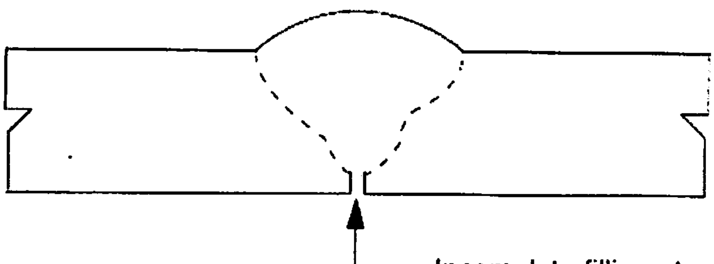
Note: The cold lap shown is not surface-connected.

5.5) Inadequate penetration due to high low

Inadequate penetration due to high-low (IPD) is defined as the condition that exists when one edge of the root is exposed (or unbonded) because adjacent pipe or fitting joints are misaligned. This condition is shown schematically in figure.

1. IPD shall be considered a defect should any of the following conditions exist:
2. The length of an individual indication of IPD exceeds 2 in.(50 mm).
3. The aggregate length of indications of IPD in any continuous 12-in. (300 mm) length of weld exceeds 3 in. (75 mm).

The figure shows Inadequate Penetration Without High-Low (IP) Incomplete filling at root



Note: One or both root faces may be inadequately filled at the inside surface.

5.6) Causes for failure :

Based on fractographic, metallurgical, mechanical and fracture mechanics analysis, the causes of failures in welded full encirclement sleeve repairs in a 24 inch gas pipeline were evaluated.

- These failures were related to poor manufacturing procedures.
- No appropriate/ skilled welder for work.
- The aim of Contractor / Sub Contractor to finish the work as soon as possible.
- The material used to build the sleeves was old and had poor transverse strength.
- High heat input cellulosic electrodes were used to weld the field joints, which lead to hydrogen embrittlement in the HAZ, also helped by relatively high circumferential stresses and defects of lack of fusion.

A series of changes were introduced, including improvements in the in-plant fabrication and the in-field installation of the repair sleeves. A low hydrogen weld procedure with controlled penetration, NDE specifications and epoxy fillers were introduced to minimize the risk of sleeve failures and plastic collapse of the pipe.

Conclusion

The NDT department in the sector of pipeline is very intense area. Lot of emphasis is given by both of the side whether it is from the contractor side or the owner side.
The authorized person from the owner side make decision from these NDT reports. And the improper result of these results leads the cost of the project to satisfy the authorized person.
So for the good NDT and better result so that the repair work will be less some consideration always taken into consideration so that it does not affect direct to the project.
These consideration are

- The working conditions should be Ideal.
- Welders previous record should be known.
- Presence of engineer at site has to be mandatory.
- Time to time check of records.
- Use of good strength material.
- Strict adherence to the approved procedure/specifications.

These are the some of these consideration that are taken in to consideration during the work and at time of NDT.

Suggestion

- Repair work should be carried out as per the procedure
- Similar analysis is carrid out for the entire pipeline

Information Resources

- PRODUCTION TECHNOLOGY by " R..K. .JAIN"
- BOOKS ON THERMAL ENGINEERING.
- www.heavens-above.com
- www.epa.gov
- www.naturalgas.com
- Office of pipeline safety.
- Gas Research Institute
- www.pipelinerisk.com
- Internet