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International Product and Service Management - IPM

MASTERARBEIT

MARKET ANALYSIS FOR A LONG RANGE ULTRASONIC INSPECTION PROGRAM OF THE ENTERPRISE AREVA

Supervisor 1

Prof. Dr. Michael Schugk

Supervisor 2

Munoz Ardila Luisa Fernanda

Autor

Alvar Castello Esquerdo
Av del Raval 14
46702 Gandia. Spain

Matrikelnummer

74292

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Hochschule für angewandte Wissenschaften
University of Applied Sciences

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I. List of abbreviations

FAC:	Flow-accelerated corrosion
NDT:	Non destructive Test
NDE:	Non destructive examination
UK:	United Kingdom
SwRI:	Southwest Research Institute
LRUCM:	Long Range Ultrasonic Condition Monitoring of Engineering Assets
LRUT:	Long Range Ultrasonic Testing
LRU:	Long Range Ultrasonic
GW:	Guided Waves
MT:	Magnetic testing
PT:	Penetrant testing
ET:	Electro-magnetic testing
UT:	Ultrasonic testing
RT:	Radiographic testing
SWOT:	Strengths, Weaknesses, Opportunities and Threats Analysis
SW:	Strengths, Weaknesses
OT:	Opportunities and Threats
GUL:	Guided Ultrasonics ltd.

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III. Abstract

As the nuclear power plant fleet has aged, the industry has increased its focus on the integrity of piping assets. The common strategy used in the nuclear plants is leak before break (LBB), which relies on monitoring leaks from the pipelines as indications of possible pipe break.

However significant parts of piping systems are partly or entirely inaccessible for the Non Destructive Examination (NDE) inspectors and this complicates the use of proactive strategies. Besides, some times the cost to access to such pipes for inspection take a significant part of the inspection budget, that customers may prefer to replace them right away, rather than inspecting, e.g.: excavating buried pipes.

Therefore, there is a strong desire to remotely examine the pipes. Long Range Ultrasonic Guided Wave examination is the primary inspection technology that can be used to perform pipe inspections from a remote location, requiring only small portions of the pipe to be exposed and prepared

Nevertheless, the use of Guided Wave inspection technology to inspect pipes is relatively new, and the technology, especially in this application, is complex. Many variables that are not well known affect the successful implementation of the technology. Actual capabilities and limitations are not well known by utilities. Furthermore currently they are no codes or accepted industry guidance for using guided wave technology to examine pipes in Nuclear Power Plants (NPPS).

The aim of this project is to analyze this technology and study its potential market application in the nuclear industry. AREVA has a special interest in the market analysis results, since it has been in the last years performing tests with this equipment.

1. INTRODUCTION

1.1. Thesis Background

1.1.1. Flow-accelerated corrosion background

Flow-accelerated corrosion (FAC), also known as flow-assisted corrosion, is a corrosion mechanism in which a normally protective oxide layer on a metal surface dissolves in fast flowing water. The underlying metal corrodes to re-create the oxide, and thus the metal loss continues [1]. Flow assisted corrosion is a frequent degradation phenomena in NPPs' pipe systems [2].

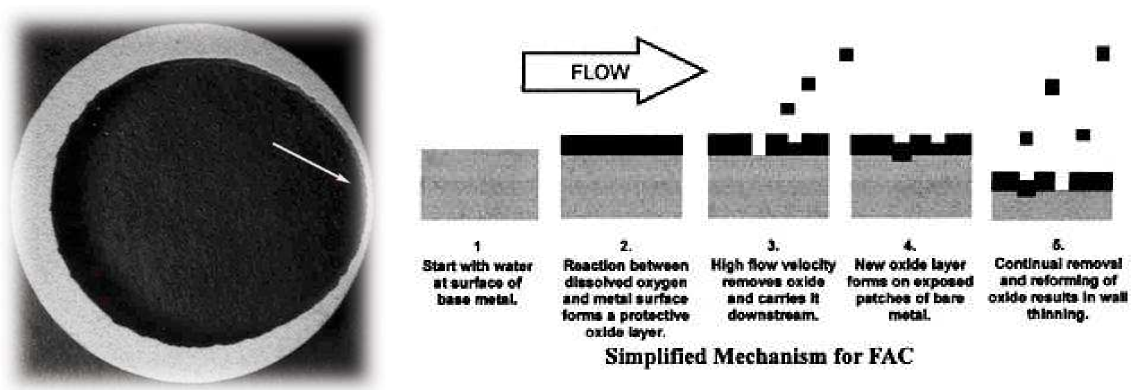

Figure 1. Flow-accelerated corrosion mechanism (source: The Analyst, 2002)

When left unchecked, FAC can cause wall thinning in steel piping and vessels and has resulted in sudden ruptures. Currently operators check wall thickness in endangered areas during outages by manual inspections methods.

Therefore AREVA has a strong interest in deliver a leading edge FAC inspection method that improves the current state of the art.

1.1.2. Project history

The AREVA´s Long Range Ultrasonic Guide Wave project started in 2008 with the analysis of the available NDT solutions for FAC. After this, on the following year (2009) the project was paused.

On the year 2010 the project started again with acquisition of the long range condition monitoring Guided Wave system, Wavemaker G3, manufactured by Guided Ultrasonics ltd (GUL ltd). With this acquired system, AREVA started a series of tests in le Creusot (France) and begun contacts with EON as project partner company. On 2011 the test continued in le Creusot and first results were collected and evaluated. As a result of this evaluation, more tests were decided to be carried. On 2012 while new tests were undergoing a market analysis case study was started.

The scheme below summarizes the AREVA´s LRU Guide Wave project history.

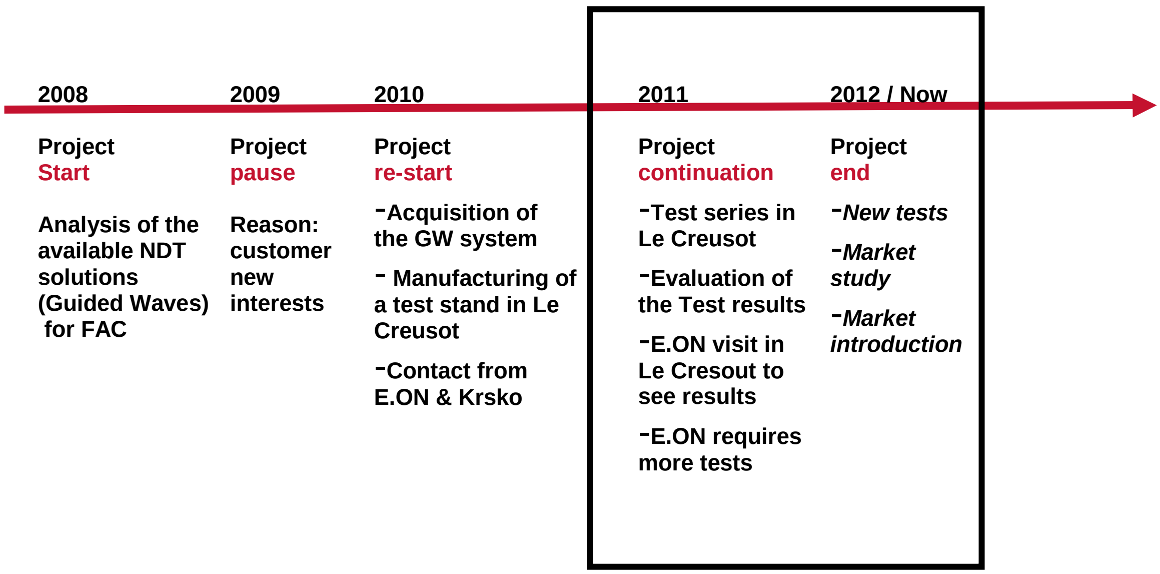

Figure 2. LRU Guided Wave project history (source: AREVA, 2012)

1.2. Thesis Objectives and Procedures

1.2.1 Thesis Objective

The objective of the thesis is the definition of a market strategy for the new diagnostic system that AREVA has acquired, for the monitoring of Flow Accelerated Corrosion (FAC) in pipelines systems, the WAVEMAKER G3, which is based on Long Range Ultrasonic Guided Waves technology.

Flow Accelerated Corrosion is a phenomenon that occurs on the inner sides of the tube and therefore, cannot be detected by visual inspection. This ultrasound waves have the advantage that they spread out along a tube structure, therefore, is possible to make diagnosis of structures with a total strait length of up to 50 m with only one measuring point. By using this system, defects can be detected before a leak occurs. Within the context of this thesis, is to identify the customer needs in this area and the potential fields of application, to develop a market penetration strategy for the acquired guided wave.

1.2.2 Thesis Procedure

Following the identification of the FAC diagnostics customer needs and the potential fields of application, a market analysis (what are dynamics for Non Destructive Examination within the Nuclear market and how could develop) and a market target analysis (market viability of the long range ultrasonic guided waves method) are done with the aim to establish a market introduction strategy for the system, primarily for the Nuclear Power Plant market and potentially for other industrial applications.

2. Theoretical foundations of the Master Thesis

2.1 Theoretical foundations of the technology

2.1.2 Long Range Ultrasonic Guided Wave System description and State of Art

Long Range Ultrasonic (LRU) Guided Wave inspection is a Non Destructive Examination (NDE) method of detecting flaw mechanisms such as corrosion. Guided wave technology can be used to examine, in some cases, relatively large volumes of buried/unburied pipes from a single probe location (see figure 3), requiring only small portions of the pipe to be exposed and prepared. The use of this technology to examine pipes is relatively new and complex.

Although the guided wave technology is a highly attractive method for examining pipe system, there are significant limitations that must be assessed, some of which are not well known [3]. For example, coatings attenuate guided wave energy, which has a substantial impact on the effective examination length. Pipe fittings such as reducers and elbows distort guided wave energy and examination effectiveness. Sensitivity is based on a defect's signal-to-noise ratio, which depends on flaw shape and size as well as mode selection, component configuration, coating, and other variables.

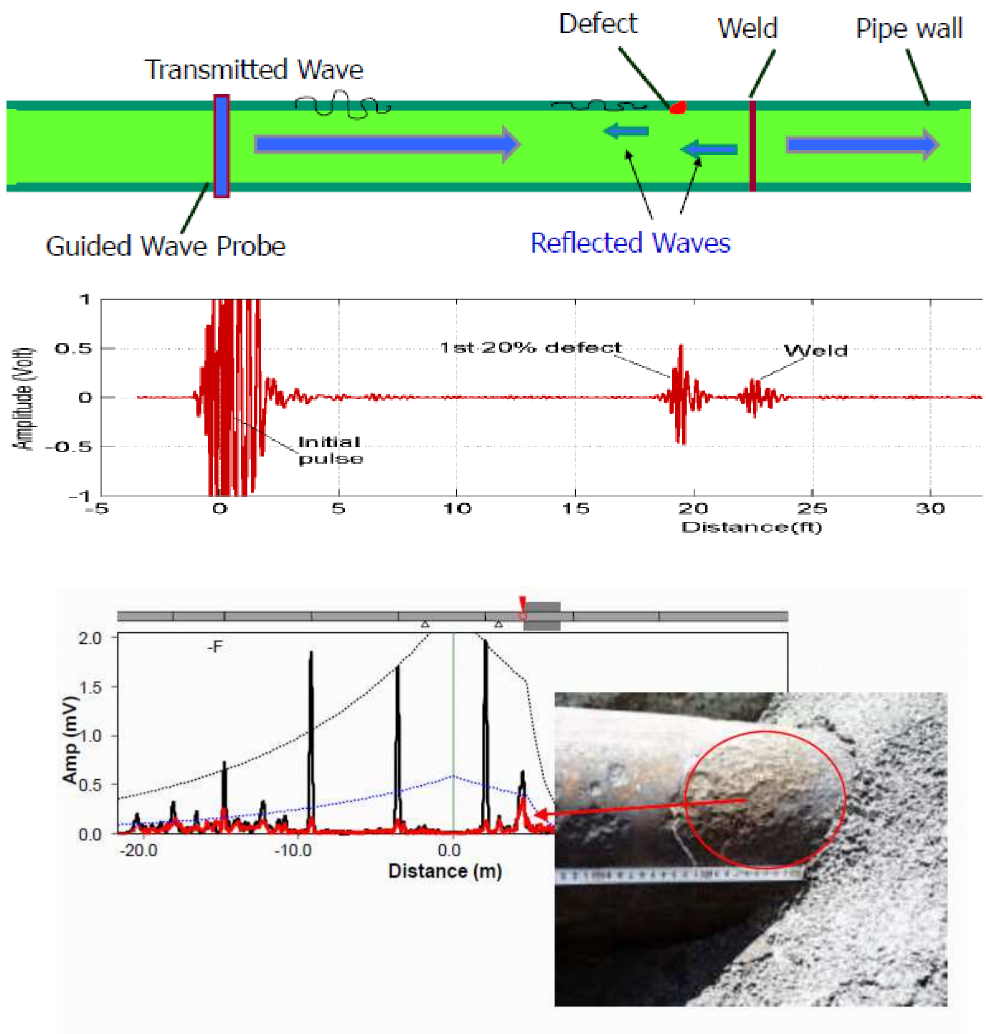

Figure 3. Guided Wave examination (source: HDR & Schiff, 2010)

Guided waves are generated by positioning either piezoelectric or magnetostrictive ring probes around the pipe diameter and pulsing it to generate a mechanical vibration in the pipe wall that travels down the length of the pipe. After the energy is generated in the material, the instrument is put into the receive mode to listen for reflected energy. Ultrasonic energy is reflected by variations in structure, such as an increase (weld crown) or decrease (thinning) in wall thickness or the presence of discontinuities caused by impedance changes. The extent of the reflection depends on the difference in acoustic impedance at the location—the higher the difference, the more energy reflected [3]. Reflected energy with sufficient energy is sensed by the probe, and the instrument generates and records signals that can be evaluated by the examiner.

Figure 4. A piezoelectric guided wave piping probe (source: Guided Ultrasonics ltd., 2009)

The technology has detection and application limitations that must be considered when planning for and assessing results. Variables such as pipe geometry, coating type, coating thickness, soil loading, backfill material, burial depth, and pipe content have a substantial effect on guided wave propagation, sensitivity, and coverage capabilities. In many cases, these variables are not known until the examination is performed. For this reason, the effectiveness of the examination in many cases is not known until the examination is performed. However, the better these variables are understood before the examination, the better the chance of success [4].

The wave propagation in a wave guide is much more complicated than in a bulk media. In a bulk media (boundaries are much farther apart than the wavelength), only longitudinal and shear wave modes exist. They each have their own displacement and speed of propagation that does not change with frequency. In contrast, guided waves require a boundary to propagate and exist within a structure [5]. A comparison of bulk wave and guided wave ultrasonic inspection is illustrated in figure 5. The coverage volume increases as a result of guided wave inspection.

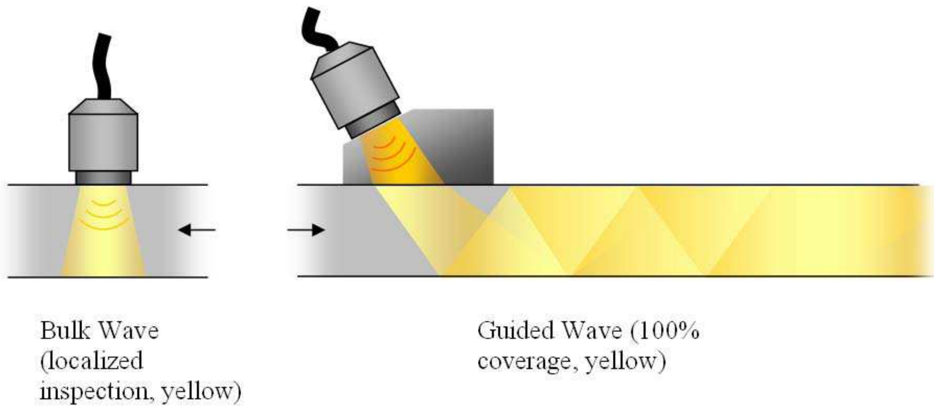

Figure 5. Comparison of bulk wave and guided wave ultrasonic inspection (source: EPRI, 2009)

Guided Wave Sensors

Piezoelectric

Guided waves can be generated with piezoelectric transducers. Guided wave energy is generated in the material, based on the piezoelectric effect, by positioning the transducer in contact with the material and pulsing it with an electrical charge to generate a mechanical vibration into the pipe. Returned energy encountered by the piezoelectric transducer is converted from mechanical energy to an electric voltage, proportional to the magnitude of the mechanical force [6], which is recorded or presented on an instrument display.

Long-range guided wave pipe probes typically contain many piezoelectric transducers assembled into a probe that is wrapped around and attached to a pipe. The collars are typically made for specific pipe diameters and allow for insertion of individual test modules into the rings.

Individual transducer modules are inserted into the probe collars to make up the probe. Each module contains several transducers that will make up the rings of transducers that go around the pipe. The number of transducer rings to be placed around the pipe is a factor of what guided wave type is desired and the method of generating the wave type. The Teletest ring shown in figure 6 has five rings and is capable of generating both torsional and longitudinal waves in a pipe.

Figure 6. Teletest probe containing well over 100 transducers (source: TWI ltd, 2009)

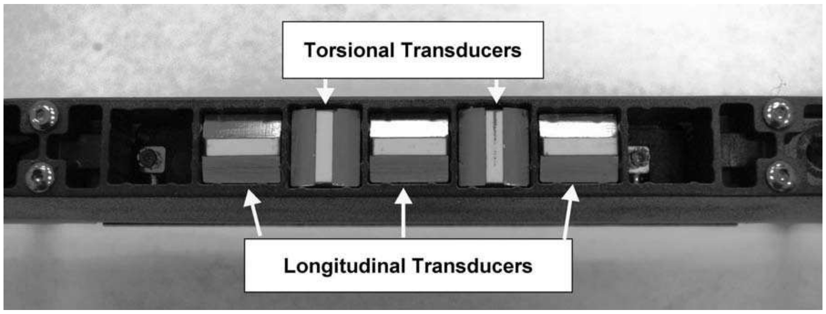

Figure 7. Teletest transducer (source: TWI ltd , 2009)

Figure 7 shows a picture of the transducer module containing five transducers. The outer and middle transducers are used to generate longitudinal waves, and the other two transducers are used to generate torsional waves. The properties of all five transducers are the same. The difference is the orientation of the transducers.

For low-frequency ultrasonic applications, such as those used for long-range guided wave pipe inspection, the transducers are placed in firm contact with the pipe material without the use of a couplant. This is accomplished by putting the probe around the pipe and mechanically locking the probe ends together. The outer portion of the probe contains an air bladder, which is inflated to press the transducers into firm contact with the pipe to the extent that couplant is not required (figure 8).

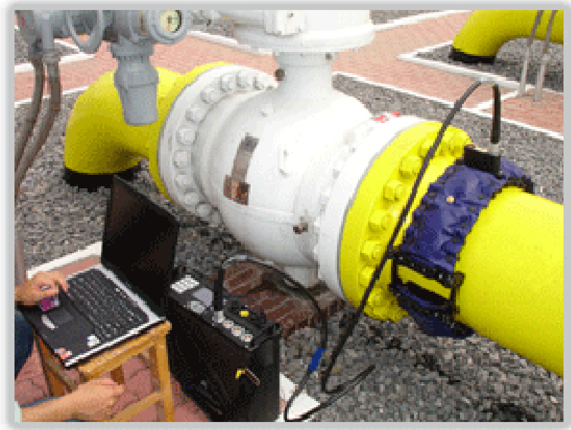

Figure 8. Guided Ultrasonics, Ltd. probe attached to a pipe (source: GUL ltd, 2011)

Magnetostrictive

A magnetostrictive sensor generates and detects guided waves based on the *magnetostrictive effect*, a phenomenon whereby variations in magnetization cause a physical dimension change in ferromagnetic materials. Mechanical waves are generated by supplying an electrical charge to a coil placed adjacent to a ferromagnetic material. This causes a change to the magnetization within the material near the coil. The material changes its length locally in a direction parallel to the applied field. This abrupt change (magnetostrictive effect) results in the generation of the guided wave in the material [7].

When a mechanical wave (such as reflected energy) is encountered by the coil, it generates a changing magnetic flux in the coil, resulting in an electric voltage proportional to the magnitude of the mechanical wave.

A magnetostrictive sensor setup typically consists of bonding or dry-coupling a thin ferromagnetic strip (such as iron-cobalt material) onto the component and placing coils over the strip. An example of a magnetostrictive sensor probe used on a pipe is shown in figure 9.

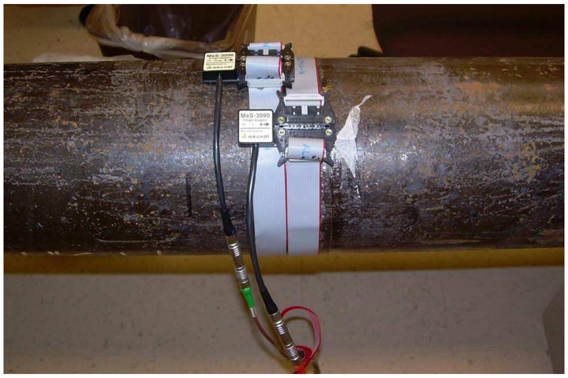

Figure 9. SwRI magnetostrictive sensor probe (source: Guide Waves Analysis, 2012)

Sensitivity and Range

Sensitivity is the ability to detect defects and at shorter distances higher sensitivity is desired. It also depends on the defect shape and geometry. Guided waves could, for example, be more sensitive to a transverse crack than to a patch of corrosion [8].

Although guided waves could travel long distances under good conditions (over 100m in uncoated, straight, gas filled pipe) the effective range on most pipes is less (say 5-50m), due to the attenuation of the guided wave propagation. The following Table 1 summarizes the features that can attenuate or disrupt wave propagation.

Table 1. Conditions/features that affect wave propagation (source Guide Waves Analysis, 2011)

EFFECTS OF PIPELINE GEOMETRIC FEATURES AND OTHER CONDITIONS ON INSPECTION CAPABILITIES

Features/Conditions	Effects
Flange/Valve	Prevents wave propagation; forms end point of inspection range
Tee	Causes a large disruption in wave propagation and limits inspection range up to that point
Elbow	Causes a large disruption in wave propagation and limits inspection range no farther than the elbow region
Bend	Has negligible effect if the bend radius is greater than 3 times the pipe OD; if the bend radius is less than the above, behaves like an elbow
Side Branch	Causes a wave reflection and thus produces a signal; no significant effects on inspection capabilities
Clamp	Causes a wave reflection and thus produces a signal; no significant effects on inspection capabilities
Weld Attachment	Causes a wave reflection and thus produces a signal; if the attachment is large (such as pipe shoes), can reduce inspection range
Paint	Has negligible effects
Insulation	Has no effects unless the insulation is bonded to the pipe surface, in which case the inspection range will be shortened due to higher wave attenuation
Coating	Has negligible effects if the coating is thin (e.g., fusion-bonded epoxy coating); thicker coating (e.g., bituminous coating, polyethylene coating) increases wave attenuation and shortens inspection range
Liquid in Pipe	No effect on T-wave; significant degradation on L-wave
General Surface Corrosion	Increases wave attenuation and shortens inspection range
Soil	If pipe is buried, the surrounding soil increases wave attenuation, and the inspection range is shortened

Dead Zone and Near Field

Two areas beneath and adjacent to the probe must be considered to have limited or no inspectability. The first area of concern is referred to as the dead zone; it is the area beneath and adjacent to the probe at which no inspection results can be obtained.

This is because when the transducers in the probe are pulsed to generate the ultrasonic energy, it is not possible for those same transducers to simultaneously listen for the reflected energy. The length of the dead zone is based on variables such as sound velocity and pulse duration, and it can be calculated [3]. Some instruments calculate and display the dead zone area on the display.

The second area of concern is the *near field,* which is immediately beyond the dead zone. This area is where the guided wave energy is setting up in the pipe wall and might not be fully established. Unlike the dead zone, energy can be received; however, the energy might not be uniform or provide accurate results. The near field can be confined within the dead zone in some cases. The near field region can be calculated.

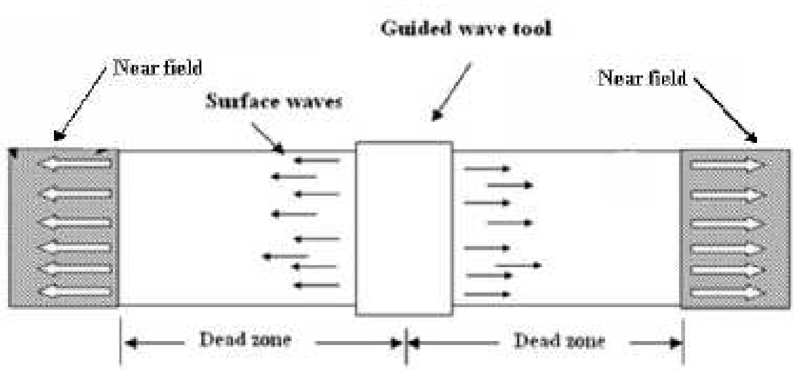

Figure 10. Dead zone and near field (source: EPRI, 2009)

Applications and performance of Long Range Ultrasonic Guided Waves NDT method

The potential applications of ultrasonic Guided Waves are [9]:

- **Pipe racks**.

Pipe racks consist of a series of group of pipes that run along a length of a process unit.They are generally easy to test; over 40m of longitudinal distance can be tested with one single test and in ideal conditions up to 100 m can be done.

- **Insulated pipes**

It generally consists on one steel pipe with insulating layer, and an outer casing. As the guided wave sensors needs to be in contact with the pipe material, one small section of insulation removed at each test point is required; over 20 m can be tested with one single test depending on insulation coatings

- **Overhead pipes**

Consist on pipes generally located above ground. Only limited access needed for inspection; over 40m can be tested with one single test.

- **Sleeved road crossings**

Consist in generally a pipeline road crossing loosely surrounded by a casing under the roadbed with its ends vented to the atmosphere. Only external access is required; up to 30m can be screened from one single location depending on coatings (Figure 11)

- **Wall penetrations**

It consists generally on pipelines crossing walls. Only external access is required for inspection; with concrete wall up to 1m thick and earth wall up to 20m thick can be screened.

- **Buried pipes**

Consist on pipes generally located under the ground. Holes dug at predefined intervals are required to be excavated to allow the needed access; up to 20m of pipe can be tested depending on pipe, coating and soil conditions (Figure 12).

- **Offshore pipe**

Consist generally on pipes locates offshore (sea) platforms. The riser splash zone inspection and sub-sea pipe inspection using special transducers and instrumentation (Figure 13)

Figure 11. Sleeved road crossing

Figure 12. Buried pipe

Figure 13. Offshore pipe

<u>Performance and main advantages</u>

Guided Wave technology offers key performances over more conventional technologies:

- **Detection threshold:** It is the minimum detectable defect and typically is set around 5% of cross sectional loss. If pipe is in good general condition defects down to 1% have been detected. By e.g. 1% defect in a 3” pipe equates to a wall size defect of 5mm (0.2”).

- **Diagnostic Range:** It is the distance that the pipe can be screened in each direction from a single test location. In ideal conditions could be up to 100m, but the typical range on above ground pipes is 40-50m in each direction. For buried pipes 20m in each direction is more typical unless the pipe is sleeved.

- **Frequency sweeping:** Correspond at the frequency of the generated waves. The higher frequency the better detection threshold but less diagnostic range. Wide frequency range transducers from 5 KHz - 120 KHz (piezoelectric) or 5 KHz - 250 KHz (magnetostrictive).

- **Unrolled Pipe “C Scan” –** It consists in an enhanced focusing capability allowing the display in an unrolled C-scan plot of the pipe inspection result. With this circumferential orientation can be determined accurately. Works best with developed 16 channel rings.

In summary the main advantages the Long Range Ultrasonic Guided Wave technology are:

- Long range of inspection (40-50m) and 100% volumetric coverage.
- Rapid screening (can examine large volumes in a short period of time).
- Service inspection with pipelines in service.
- Significantly reduced access costs as only one small area is required to be prepared for system installation.
- Access to inaccessible components or areas for other NDT technique (e.g. buried pipes, wall traverse, etc).
- Potential reduction of inspection cost due to the speed of the inspection

Conclusions

Long Range Ultrasonic Guided Wave technology enables volumetric screening of structures (which covers 100% of the cross sectional area of the structure) within the diagnostic length of test. In most cases, many tens of metres can be screened from a single test position making it a rapid and cost effective Non Destructive Examination (NDE) method, especially for pipes. Additionally, access to the structure under test is only required at the test position (remote inspection) which makes guided wave screening technology an ideal solution for inspecting structures that are difficult to access, such as cased and insulated or buried pipelines.

2.1.2 Nuclear Power Plants requirements for pipe inspections

The needs for the nuclear industry, requires Non Destructive Examination (NDE) systems that can detects flaws caused by corrosion and erosion on the main steam lines and others pipe systems with an inspection range of at least 30m. This requirement is currently offered by the commercial available systems with inspection ranges from 30-50 m and in ideal pipe condition (strait and low corroded pipes) it could reach up to 100m.

As temperatures up to 300°C can occur at the main steam lines during operation, the industry demands for systems that are able to do inspection during plant operation and at high temperatures. Currently the commercially available systems are able to work up 120°C and with specific procedures to insulate the sensors; the piezoelectric systems can work up to 180°C and the magnetostrictive up to 300 °C.

Another requirement of the nuclear industry is that the diameter of the steam lines to be inspected varies form 400mm to 600mm and pipes with wall thickness from 10mm to 150mm could be inspected. This results in a need for ultrasonic NDT systems of a frequency range from about 20 kHz to 320 kHz. The frequency range influences the range of inspection, the sensitivity and the spatial resolution. The higher frequency the better detection threshold, but reduces the inspection range. Currently the commercial available versions have a frequency range between 5 kHz to 120 kHz (250 kHz for magnetostrictive probe).

The applied inspection system has to be able to monitor pipes with bends and other pipe features (tees, elbow, Valves, etc). Although none of the commercially available systems is explicitly able to inspect pipes with bends, with an acceptable degree of accuracy due to wave reflections. [10] [11]

Also there is requirement from the Nuclear Regulator that any Non Destructive Examination method requires being qualified and certified for its use in the nuclear industry. [11]

2.2 Theoretical foundations of the Market Analysis

2.2.1 Objectives of a Market Analysis

A market analysis studies the attractiveness and the dynamics of a special market within special industry, both now and in the future. Organizations evaluate the future attractiveness of a market by gaining an understanding of evolving opportunities and threats as they relate to the organization's own strengths and weaknesses [12].

This means that customer needs should be analyzed with a view of segmenting the market on this basis. From this flows the targeting of particular segments with a segment-specific marketing mix. This positions products in the market, based on an understanding of buyer needs, attitudes and behavior [13]
Organizations use the finding to guide the investment decisions they make, to advance their success. The findings of a market analysis may motivate an organization to change various aspects of its investment strategy.

Figure 14. Dimensions of the market analysis (source: fotolia; 2012)

2.2.2 Understanding the Market

To help to understand the market and buyer behavior, marketers should answer the following questions:

What market need does the business address?
What products serve that need?
Who buys the products?
Why customers buy?
Who makes the buying decision?
Where the customers buy?

The focus of understanding markets is the understanding of customers and buyer behavior [14]

2.2.2.1 Market Segmentation

Market segmentation is the basis for a differentiated market analysis. Differentiation is important. One main reason is the saturation of consumption, which exists due to the increasing competition in offered products.

Consumers ask for more individual products and services, and are better informed about the range of products than before. As a consequence, market segmentation is indispensable [15].

Segmentation includes a lot of market research, since a lot of market knowledge is required to segment the market. Market research about market structures and processes must be done to define the “relevant market”.

The relevant market is a part of the whole market, on which the company focuses its activities. To identify and classify the relevant market, a market classification or segmentation has to be done. [16]

Figure 15. Market segmentation (source, web business 2community; 2012)

2.2.2.2 Market Targeting

A target market is a group of customers that the company has decided to aim its marketing efforts and ultimately its merchandise towards [17]. A well-defined target market is the first element to a marketing strategy. The target market and the marketing mix variables of product, place(distribution), promotion and price are the four elements of a marketing mix strategy that determine the success of a product in the marketplace.

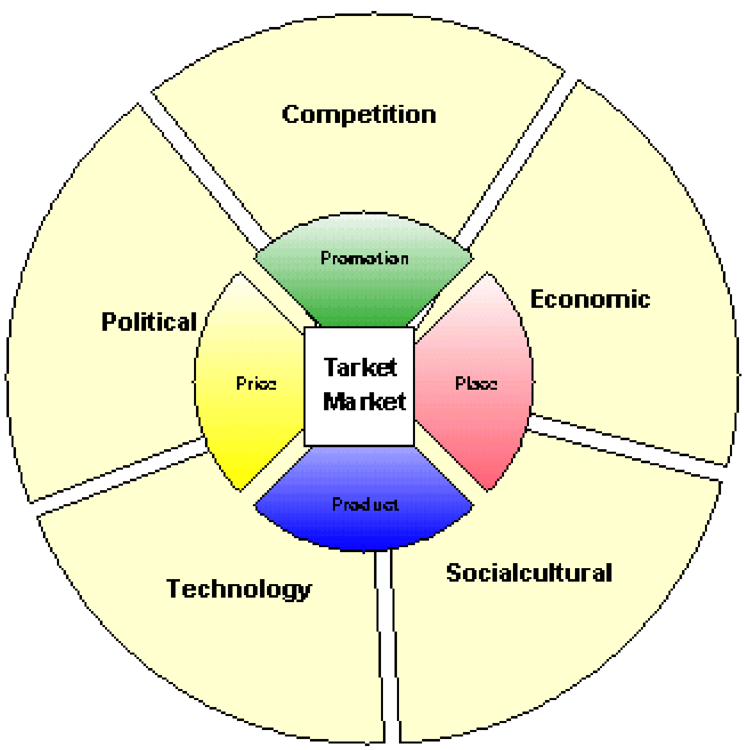

Figure 16. Target Market (source: http://www.finntrack.co.uk; 2011)

2.2.2.3 Market competition

Competitor analysis is an assessment of the strengths and weaknesses of current and potential competitors in a specific market. This analysis provides both an offensive and defensive strategic context to identify opportunities and threats.

Competitor analysis has two primary activities, first obtaining information about important competitors, and second using that information to predict competitor behavior [18].

The goal of competitor analysis is to understand:

- With which competitors to compete.
- Competitors' strategies and planned actions.
- How competitors might react to a firm's actions.
- How to influence competitor behavior to the firm's own advantage.

2.2.3. Dimensions of a Market Analysis

David A. Aaker outlined the following dimensions of a market analysis [19] [20]:

- Market size
- Market Trend
- Market growth rate
- Market profitability
- Industry cost structure
- Distribution channels
- Success factors

2.2.3.1 Market size

The market size is defined through the market volume and the market potential. The market volume exhibits the totality of all realized sales volume of a special market. The volume is therefore dependant on the quantity of consumers and their ordinary demand.

Furthermore, the market volume is either measured in quantities or qualities. The quantities can be given in technical terms, like gigawatts for power capacities, or in numbers of items.

Qualitative measuring mostly uses the sales turnover as an indicator. That means that the market price and the quantity are taken into account. Besides the market volume, the market potential is of equal importance. It defines the upper limit of the total demand and takes potential clients into consideration.

Although the market potential is rather fictitious, it offers good values of orientation. The relation of market volume to market potential provides information about the chances of market growth [20].

The following are examples of information sources for determining market size:

- Government data
- Trade association data
- Financial data from major players
- Customer surveys

2.2.3.2 Market Trends

A market trend is a putative tendency of a market to move in a particular direction over time [21]. Changes and trends in the market are important because they often are the source of new opportunities and threats. Moreover, they have the potential to dramatically affect the market size.

Examples include changes in economic, social, regulatory, legal, and political conditions and in available technology, price sensitivity, demand for variety, and level of emphasis on service and support.

Figure 17. Market trends: Past and Futures (source: www.mignongamekit.org; 2010)

2.2.3.3 Market growth rate

A simple means of forecasting the market growth rate is to extrapolate historical data into the future. While this method may provide a first-order estimate, it does not predict important turning points. A better method is to study market trends and sales growth in complementary products. Such drivers serve as leading indicators that are more accurate than simply extrapolating historical data.

Important inflection points in the market growth rate sometimes can be predicted by constructing a product technology diffusion and adoption curve. The shape of the curve can be estimated by studying the characteristics of the adoption rate of a similar product in the past. Ultimately, many markets mature and decline. Some leading indicators of a market's decline include market saturation, the emergence of substitute products, and/or the absence of growth drivers.

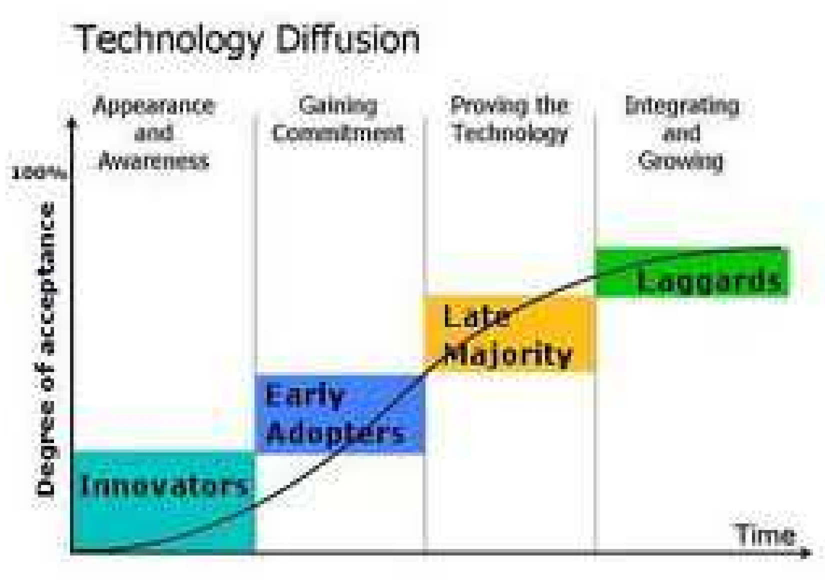

Figure 18. Technology diffusion curve (source: blog, Design at the edge, 2007)

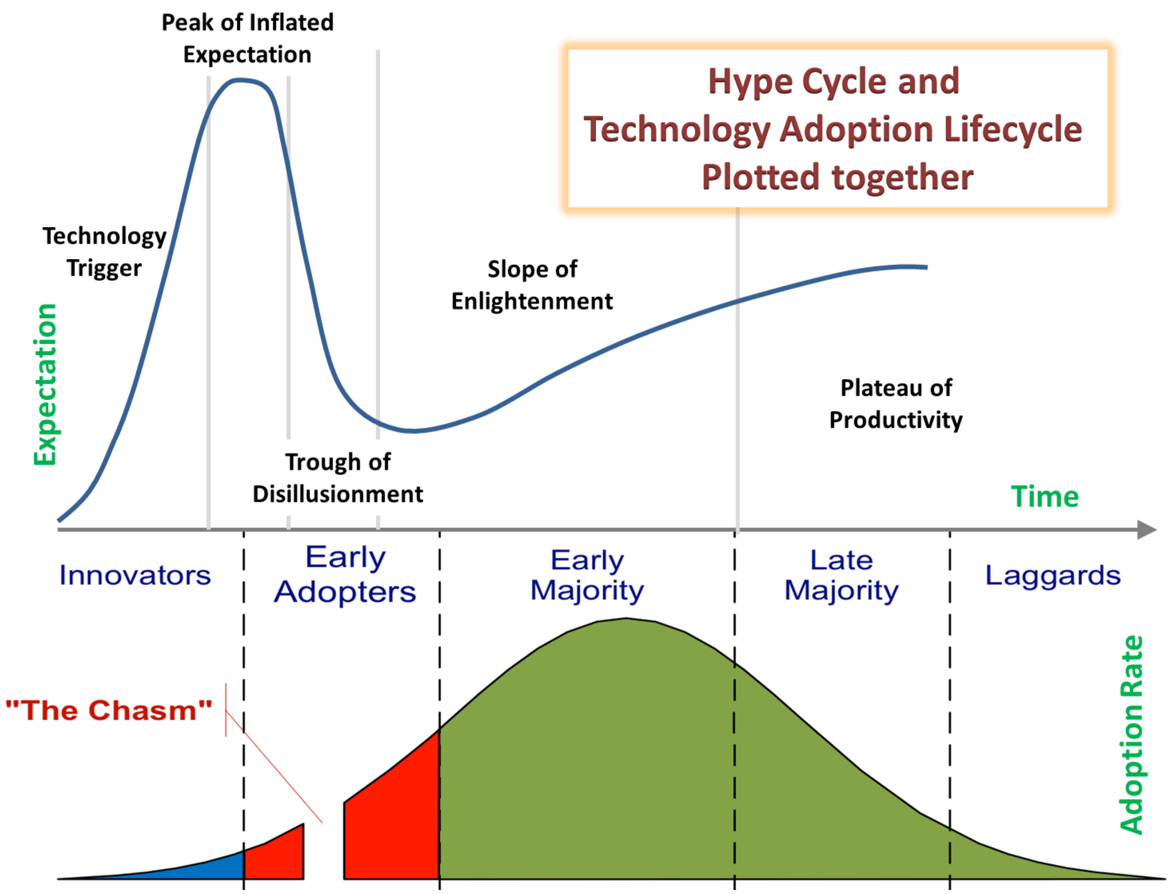

Figure 19. Hype Cycle and Technology Adoption curve, The Hype Cycle is a graph used to show the typical stages through which technology innovation gets adopted. (source: Aggregated intelligence, 2012)

2.2.3.4 <u>Market opportunity</u>

A market opportunity is potentially favorable condition in which a business can capitalize on a changing trend or an increasing demand for a product or service by the market. It is based on the fulfills of the needs of a market better than the competition and better than substitution-technologies within the given environmental frame (e.g. society, politics, legislation, etc.).

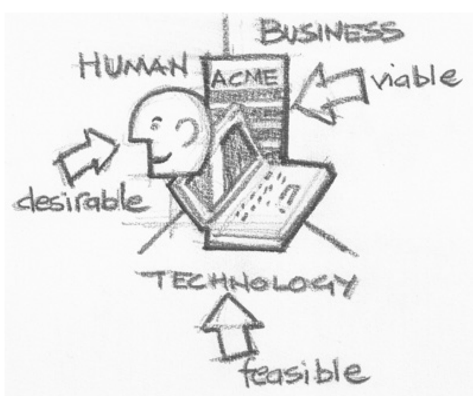

Figure 20. Market opportunity factors (source: design thinking; 2008)

2.2.3.5 Market profitability

While different organizations in a market will have different levels of profitability, they are all similar to different market conditions. Michael Porter devised a useful framework for evaluating the attractiveness of an industry or market [22]. This framework, known as Porter five forces analysis, identifies five factors that influence the market profitability:

- Buyer power
- Supplier power
- Barriers to entry
- Threat of substitute products
- Rivalry among firms in the industry

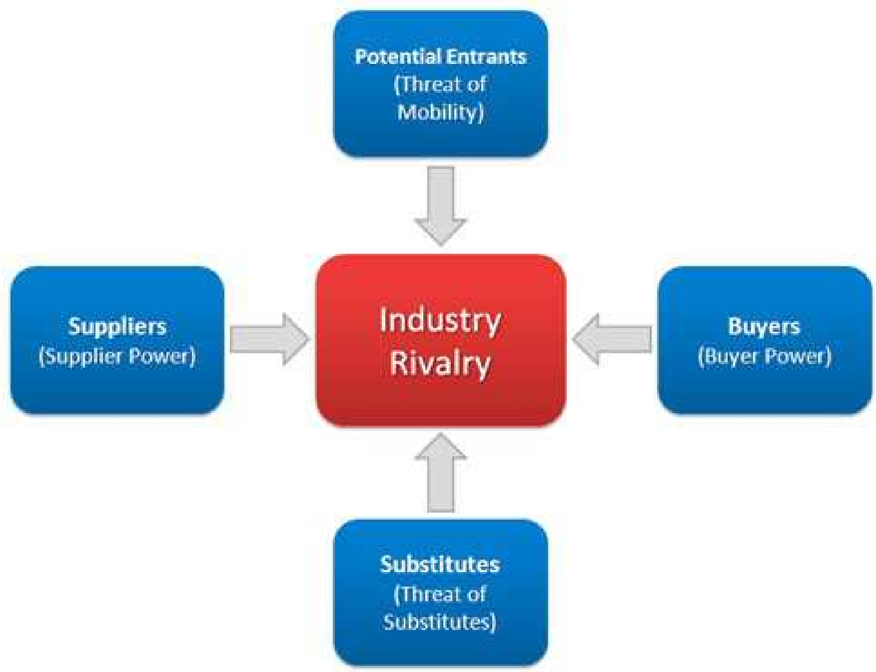

Figure 21. The five forces analysis of and industry market (source: www.notesdesk.com, 2012)

2.2.3.6 Distribution channels

Examining the following aspects of the distribution system may help with a market analysis:

- Existing distribution channels - can be described by how direct they are to the customer.
- Trends and emerging channels - new channels can offer the opportunity to develop a competitive advantage.
- Channel power structure - for example, in the case of a product having little brand equity, retailers have negotiating power over manufacturers and cannot capture more margins.

2.2.3.7 Success factors

The key success factors are those elements that are necessary in order for the firm to achieve its marketing objectives. A few examples of such factors include:

- Access to essential unique resources.
- Ability to achieve economies of scale.
- Access to distribution channels.
- Technological progress.

It is important to consider that key success factors may change over time, especially as the product progresses through its life cycle.

2.2. Theory of the SWOT Analysis

2.2.1. Objective a SWOT Analysis

The analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT) brings together the results of the analysis of the firm (internal), the environment analysis (external) and the portfolio analysis. A SWOT analysis allows looking at the strengths and weakness in the context of the opportunities and threats [23] [24].

Implicit in the SWOT analysis is the aim of achieving the optimum match of a firm's resources with the environment in order to gain sustainable competitive advantage by [25] :

- Building on a firm‘s strengths.
- Reducing weaknesses or adopting a strategy that avoids weaknesses.
- Exploiting opportunities, particularly using the firm's strengths.
- Reducing exposure to or countering threats.

Setting the company objective should be done after the SWOT analysis has been performed. This would allow setting achievable goals or objectives for the organization. A SWOT analysis used on its own is a crude, rather subjective tool therefore the SWOT analysis could be use to carry out a quick strategic review.

The process of creating a SWOT analysis is valuable because it involves discussion among managers or key people in a business. This stimulates thinking in a way that is not too structured or restrictive

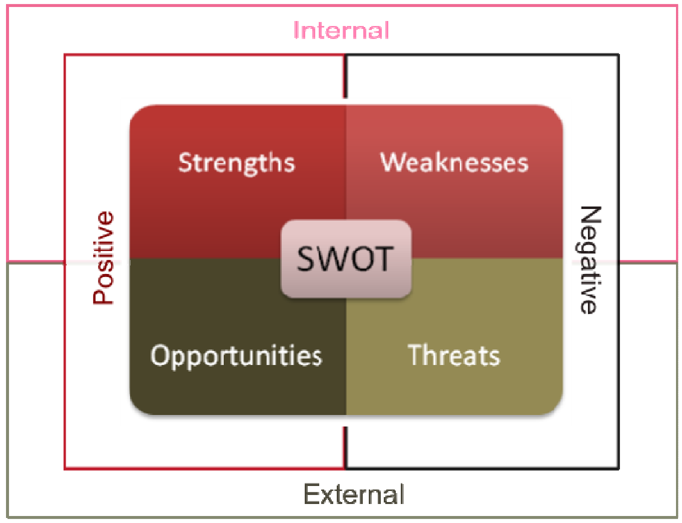

Figure 22. SWOT analysis diagram (source: Northwoods, 2008)

2.2.2. Conducting a SWOT Analysis

A SWOT analysis could be viewed as bringing together the outputs from the strategic review, in particular:

- The analysis of the firm (internal elements)
- The market analysis (internal and external elements)
- The product, portfolio and matrix analysis (internal and external elements)
- The analysis of the general environment (external elements)

The first step of the SWOT analysis is to list strengths, weaknesses, opportunities and threats. Only important factors should be included, but some factors will invariably be more important than others. Factors should be listed in order of importance or ranked, and an importance score could be assigned to each factor.

Each factor should be a short bullet point, so that the swot analysis fits on one page.

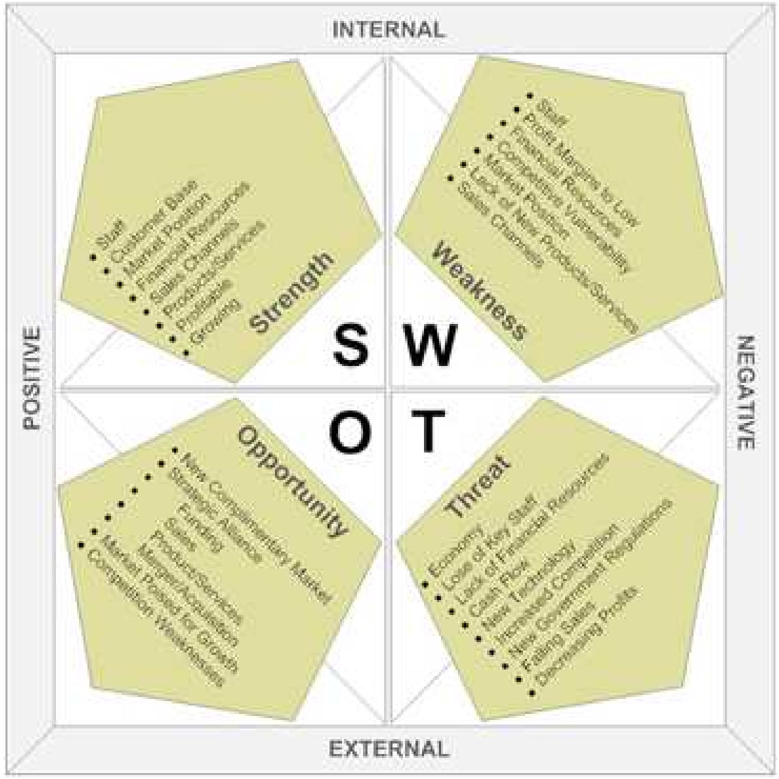

Figure 23. SWOT Analysis chart (source: www.bizstrategies.biz, 2008)

<u>Strengths and weaknesses</u>

The SW-Part comprises internal factors – the strengths and weaknesses of the organization. These are competences and resources that the organization possesses and that are under its control. Strengths and weaknesses can relate to a variety of aspects and may depend on the actual situation. For example, if new technology is becoming available and a business has a good product – development department that can take advantage of this new technology, this is an opportunity, but in contrast if the business can not take advantage, this is a weakness.

<u>Opportunities and threats</u>

The OT-Part of the SWOT identifies Opportunities and Threats that the organization faces from trends and changes in its environment. These external factors are not under the control or influence of the organization. For example, a high customer loyalty is an (internal) strength of the organization, since it has to satisfy its customers again and again in order to keep them loyal. If, however, the industry faces a new trend that customers become less loyal to any organization, this is an external threat that might undermine the companies' competitive advantage.

3. Market Analysis for Non Destructive Tests for FAC Pipe diagnostics

3.1 Procedure for the Market Analysis for NDT for FAC Pipe diagnostics

Following the analysis of the causes and consequences of the Flow Accelerated Corrosion (FAC) phenomenon, one study was conducted to identify the Non Destructive Examination customer needs and potential fields of application for FAC pipe diagnostics.

With the aim to understand the market, a competition and trend analysis (how does the market currently operate and how could develop) and a market opportunity analysis (it is techno - economically viable) was undertaken with the aim to establish a market penetration strategy for FAC diagnostics market in the Nuclear Power Plants sector, by using more advanced NDT methods (LRU Guided Waves).

3.2 The Long Range Ultrasonic Inspection Market Analysis

3.2.1. Objective of the Long Range Ultrasonic Guided Waves Market Analysis

The objective of the Long Range Ultrasonic Guided Waves market analysis is to evaluate the potential market for the AREVA´s Wawemaker G3 long range guided wave diagnostic system, for the monitoring of the Flow Assisted Corrosion phenomenon in pipelines.

3.2.2. Analysis of the LRU Guided Waves market

3.2.2.1 <u>Market Segmentation</u>

The LRU Guided Waves market is mainly segmented between:

- Inspection service providers.
- Inspection equipment manufacturers and suppliers.
- Owner - operators of engineering assets.
- Engineering contractors.
- Research and technology organizations.

Inspection service providers

Consist in generally small and medium enterprises. They provide a Non Destructive Test (NDT) inspection service to the owners or operators of engineering assets and to their equipment and component suppliers. They may also provide services to engineering contractors that manage construction projects and later maintain the assets.

Inspection equipment manufacturers and suppliers

They are mainly small and medium enterprises that manufacture and supply LRU Guided Wave equipment to inspection service providers and to some owner/operators that have retained their own inspection departments. Many inspection equipment manufacturers and suppliers offer also training as integral part of their service to customers. Research and development is also a key activity of some equipment manufacturers to develop new products and find new applications for their equipments.

Owner - operators of engineering assets

These include oil refineries, power stations, railways and bridges. As they ultimately generate the Non Destructive Test (NDT) demand for monitoring, either as equipment they use themselves, or as hired inspection services. They are the ultimate arbitrators of whether a new NDT technology is successful or not.

Engineering contractors

Their view on NDT technology is increasingly important, though more from the point-of-view of short term cost benefit than long-term investment.

Research and technology organizations

Many are developing new NDT technology. NDT is supported by research in many universities, because the underlying technology in sensor development is at the leading edge of research.

3.2.2.2 Market Trends

The NDT Long Range Ultrasonic Guided Wave technology is an expanding condition monitoring market, which will be of major benefit in the inspection and maintenance of pipelines systems and other vital parts of infrastructure. LRU Guided Wave inspection techniques are also in development for several other applications, including the detection of corrosion in large areas of plates, the detection of cracking in railway lines, the detection of cracking in rock bolts, and the detection of corrosion in heat exchanger tubing.

It is anticipated that the technique will have in future an increase on functional capabilities in terms of test range, defect detection, defect positioning and sizing [26].

3.2.2.3 Market Targeting

The main market for Long Range Ultrasonic Guided Wave is concentrated in industries and/or assets which require large piping systems like in refineries, chemical plants and power generation plants. Typically, these pipe sections had never been checked due to the difficulty and expense of exposing them, yet if they had been suspected due to the nature of their environmental conditions.

Figure 24. Guided Waves buried pipe examination (source: GUL ldt , 2011)

3.2.2.4 Companies competing on LRU Guided wave equipment

The Long Range Ultrasonic Guided Wave systems manufacturers currently active on the market are:

Guided Ultrasonics Ltd (UK). It is the world leader and their Wavemaker Pipe Screening System is composed of three primary components: the air-inflated transducer ring with piezoelectric transducers, the Wavemaker G3 battery operated instrument, and the controlling computer. This model of LRU Guided Waves system has been acquired by AREVA

Figure 25. Wavemaker G3 system (source: Guided Ultrasonics Ltd, 2012)

Plant Integrity Ltd (UK). A subsidiary of TWI Ltd, offers an instrument very similar to Wavemaker G3 which they market as Teletest Focus+. Teletest is a battery operated, computer controlled unit provided with piezoelectric transducers also in the form of air-inflated collars.

Figure 26: Teletest Focus+ system (source: Plant Integrity Ltd, 2012)

Southwest Research Institute (SwRI) in USA has developed the magnetostrictive sensor (MsSTM) technology. A commercial version of guided waves using this technology is available from Guided Wave Analysis LLC, (USA). It is composed of a laptop computer, the MsSR3030R instrument, and MsS probes. The MsSR3030, instrument generates and detects guided waves electromagnetically in ferromagnetic materials. The MsS software in the laptop computer controls parameters of the MsSR3030R, acquires data through a USB port, analyzes data, and generates inspection reports.

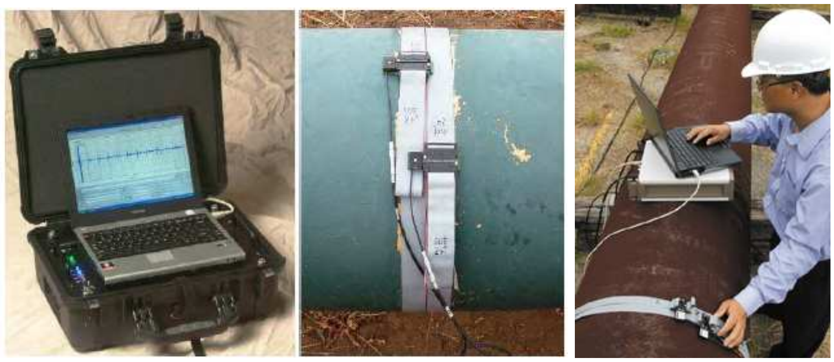

Figure 27: MsSR3030R system (source: Guided Wave Analysis LLC, 2012)

The following Table 2 evaluates the different LRU Guided Waves systems that currently are in use for pipeline inspections. The score show the relevance of the manufacture characteristics on a scale from 1 to 5, with the lower score the better: Very good: 1, Good: 2, Medium: 3, Bad: 4, Very bad: 5. The result of the comparative, indicates similar performances of the three guided systems although with an slightly better score for MsSR3030R, due to its wider range in frequency and operation temperature.

Table 2. LRU Guided Wave manufacturer comparative

Manufacturer's specifications	**Distances (straight over ground pipes)**	**Frequency Range**	**Price of the system**	**Pipe diameter**	**Temperature Range**	**Permanent monitoring option**	**Total score**
(AREVA) Guided Ultrasonics Ltd (UK). - Wavemaker3G	50m (150m in ideal conditions)	5 – 120 kHz	high	From 3" to 72".	< 125 °C (180C° with specific procedures)	Yes (with comparable performance that the standard version)	
Weighting	2	3	3	2	3	3	16
Plant Integrity Ltd (UK). - Teletest Focus+.	50m (150m in ideal conditions)	5 – 120 kHz	high	From 2" to 48"	< 125 °C	Yes (with developed low cost transducer rings)	
Weighting	2	3	3	3	3	2	16
Guided Wave Analysis LLC, (USA). The MsSR3030	50m (200m in ideal conditions	5 - 250 kHz	high	Any diameter (usually 0.25- to 80" outer diameter)	< 125C° (300° C with specific procedures)	Yes (with low cost probe ring)	
Weighting	2	2	3	2	2	2	**13**

*Values are estimations. The lower, the better.

3.2.2. Long Range Ultrasonic Guided Wave technology European industry survey.

LRU Guided Wave is a new non-destructive testing (NDT) technology, which is being supported by the European Commission in a collaborative project entitled 'Long Range Ultrasonic Condition Monitoring of Engineering Assets' (LRUCM). The European Commission sponsored the survey among Industrial Association Groups (IAGs) and Small-to-Medium Enterprises (SMEs) across Europe [26].

The introduction of any new technology requires a thorough knowledge of its market, therefore a survey of European industry has been undertaken by the IAGs across Europe, from Portugal to Russia, to assess both potential applications for this new technology and implementation routes to ensure its adoption.

They have surveyed potential users of the technology and perhaps more importantly, because of their own knowledge of the condition monitoring business, the Non-destructive Testing (NDT) service companies that provide equipment and services to owners and operators of engineering assets. The specific objectives of the survey have been:

- To survey the specific needs for LRU Guided Waves of small or medium companies.
- To survey the general needs for LRU Guided Waves within industry in countries covered by IAGs in the project.

<u>Results of the survey</u>

In the survey, respondents were asked for some background information about their companies and then to respond to rank a list of answers to questions in order high, medium, low or not relevant. The outcome of the survey is summarized as follow:

Respondent activity

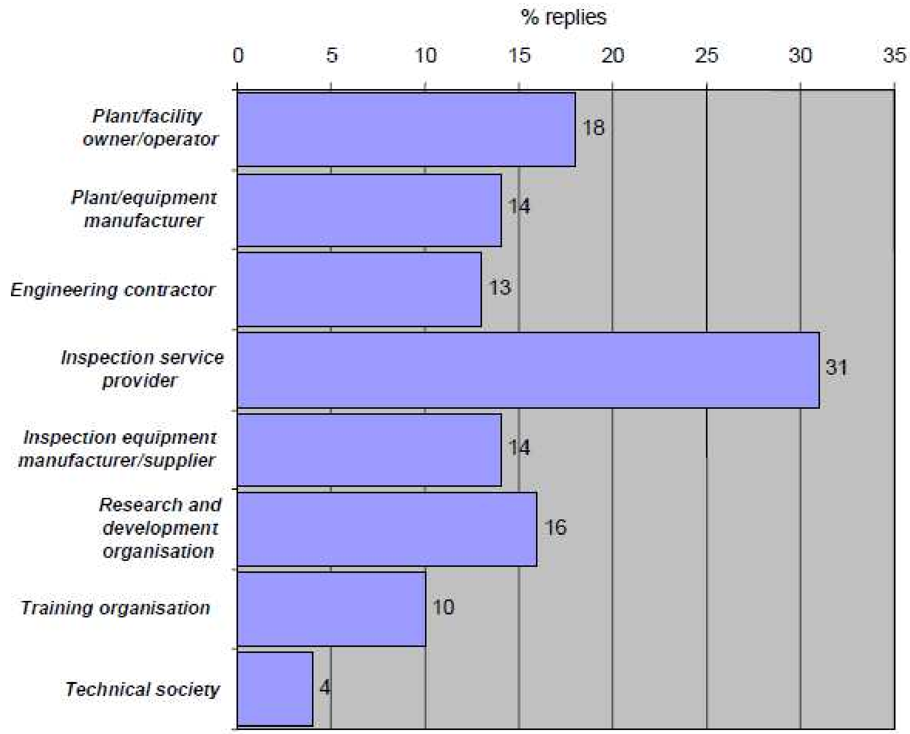

Figure 28. Respondents' Activities (source: LRUCM, 2008)

From the respondent activity (figure 28) it can be outlined that the majority of respondents (31%) were inspection service providers. They provide an inspection service to the owners or operators of engineering assets and to their equipment and component suppliers. The 18% of respondents were owner/operators of engineering assets. These include oil refineries, power stations, railways and bridges.

Around 16% of respondents were research and technology organizations, many of which are developing new NDT technology.

The 14% Inspection equipment manufacturers and suppliers to inspection service providers and some owner/operators that have own inspection departments. The 13% of respondents were engineering contractors.

Products relevant to company

The respondents were asked to score the relevance of products in a table on a scale from 3 (High importance) to 1 (Lowest importance).

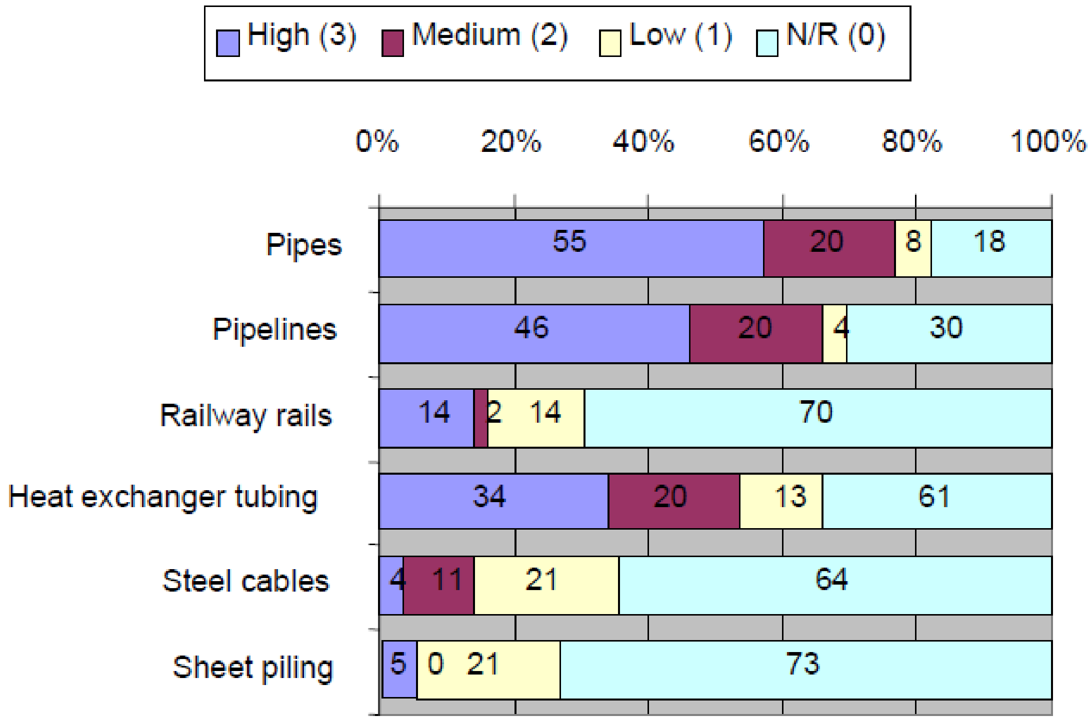

Figure 29. Products relevant to respondents (source: LRUCM, 2008)

The results shows that the respondents were mainly interested in pipes (figure 29); mainly those used in process plant (34%), in transmission lines (46%) and in plant equipment, such as heat exchangers (19%).

Like steel cables, sheet piling is another example of an application in civil engineering, where there is currently little demand for inspection services based on the lack of satisfactory technology.

In-service inspection methods used

The principal inspection methods in use by the respondents are: magnetic testing (MT), penetrant testing (PT), electro-magnetic testing (ET), ultrasonic testing (UT) and radiographic testing (RT).

These five methods are covered by national and international standards and by schemes for training and qualifying test operators.

Automated ultrasonic (UT) uses mechanical scanners to guide the sensors and computer software to gather, display and analyze the data.

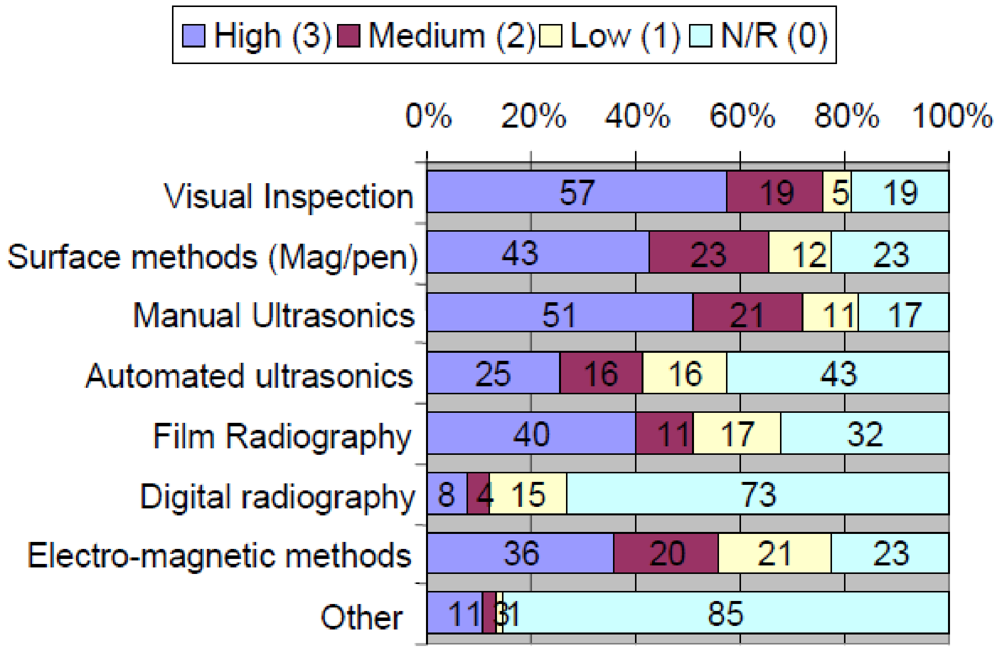

Figure 30. Current usage of NDT methods (source: LRUCM, 2008)

From the survey result (figure 30), there is still a low uptake of automated methods. Only 25% of respondents had a high level of interest in Automated Ultrasonics (which includes the LRU Guided Wave method), in contrast with the 51% who had a high level of interest in manual ultrasonic.

This low level of interest in Automated Ultrasonics remains, despite the generally accepted reduced level of costs and the recent introduction of national standards and codes of practice for automated ultrasonic for pipe-lines and pressure vessels, where it replaces radiography.

Digital radiography is a very new technology, there are no codes of practice and procedures have to undergo qualification trials before they can be implemented. Therefore only 8% of respondents had an interest in digital radiography, compared with 40% in film radiography.

Among the few other NDT methods mentioned by respondents were thermography and acoustic methods. But it is relevant that 85% of respondents had no interest at all in other new NDT methods.

<u>Confidence in inspection methods</u>

From their usage of Non Destructive Tests methods listed previously, respondents were asked to rank their level of confidence.

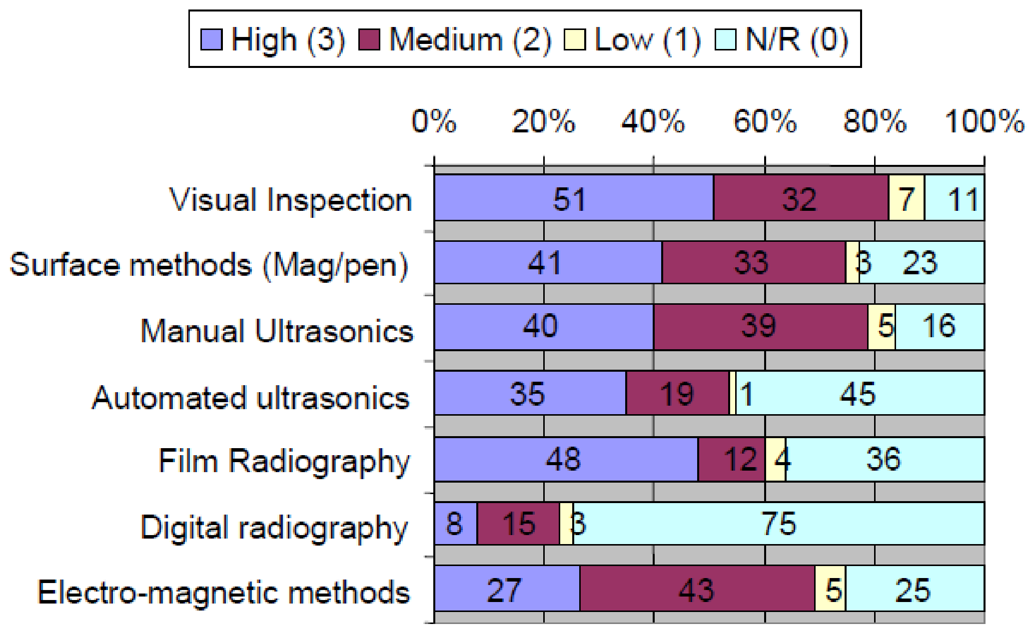

Figure 31. Level of confidence in inspection methods (source: LRUCM, 2008)

Between one third and one half of respondents had a high level of confidence in the inspection method they used, which is more than the number who had only moderate confidence (figure 31). The number with low confidence was negligible

However in the case of digital radiography and electro-magnetic methods, there were almost double the numbers with moderate confidence than with high confidence. On the other hand with film radiography, there were four times as many with high confidence than with only moderate confidence, which is a higher level of confidence than even with visual inspection.

It is significant, that the three methods that provide an image of the test results (visual inspection, magnetic and penetrant testing and film radiography) are treated with the more confidence than the methods that do not (ultrasonics and eddy current testing).

<u>Inspection issues</u>

The respondents were asked to rank the issues that affected their confidence in inspection.

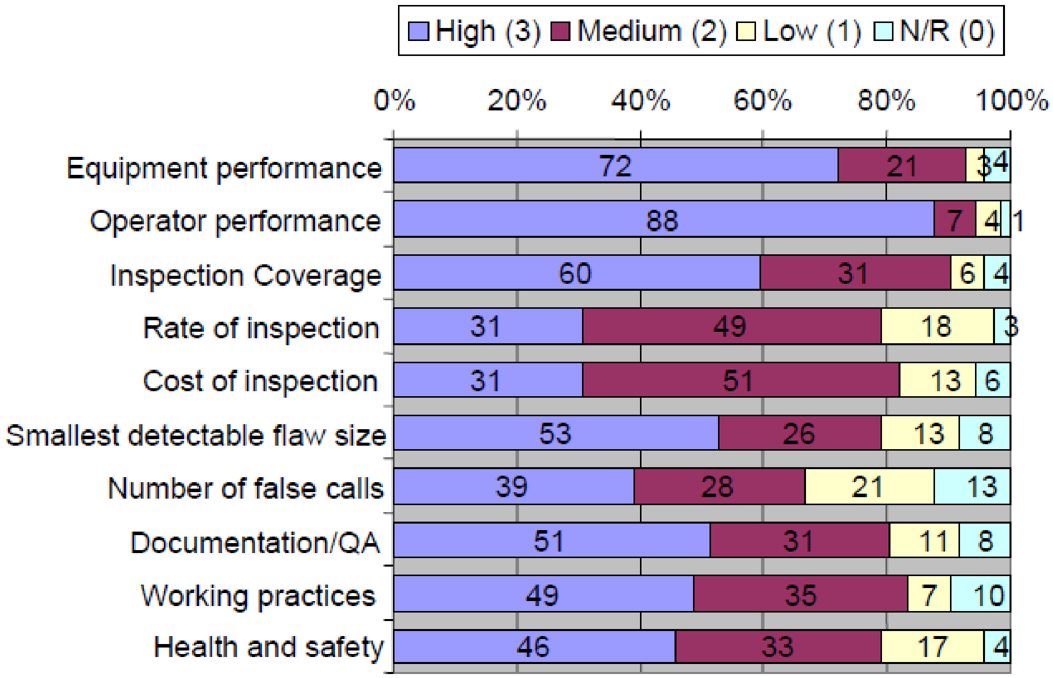

Figure 32. Inspection issues (source: LRUCM,2008)

Operator performance is the dominant inspection issue, with 88% declaring it had the highest importance and only 4% the lowest importance (figure 32). This was followed by equipment performance (72% and 3% respectively). Inspection coverage was still regarded by 60% of respondents as of high importance, despite the introduction of risk based inspection methodologies, which limit inspection coverage to areas where there was a high risk of failure. Surprisingly, the majority of respondents thought that cost of inspection was of only moderate importance (51%).A strong inter-dependency between costs and rate of inspection is evident.

The importance of finding the smallest flaws is highlighted by the 53% of respondents who thought it had high importance although this was tempered by the knowledge that as the test sensitivity is increased, so the likely number of false calls will increase. This was of high importance among 39% of respondents.

The management issues of quality assurance through proper documentation systems, good working practices and health and safety of test operators was recognized by about one third of respondents.

<u>Perceived benefits of the LRU Guided Waves technology</u>

From their knowledge of LRU Guided Wave, respondents were asked to rank a list of potential benefits in inspection of engineering assets.

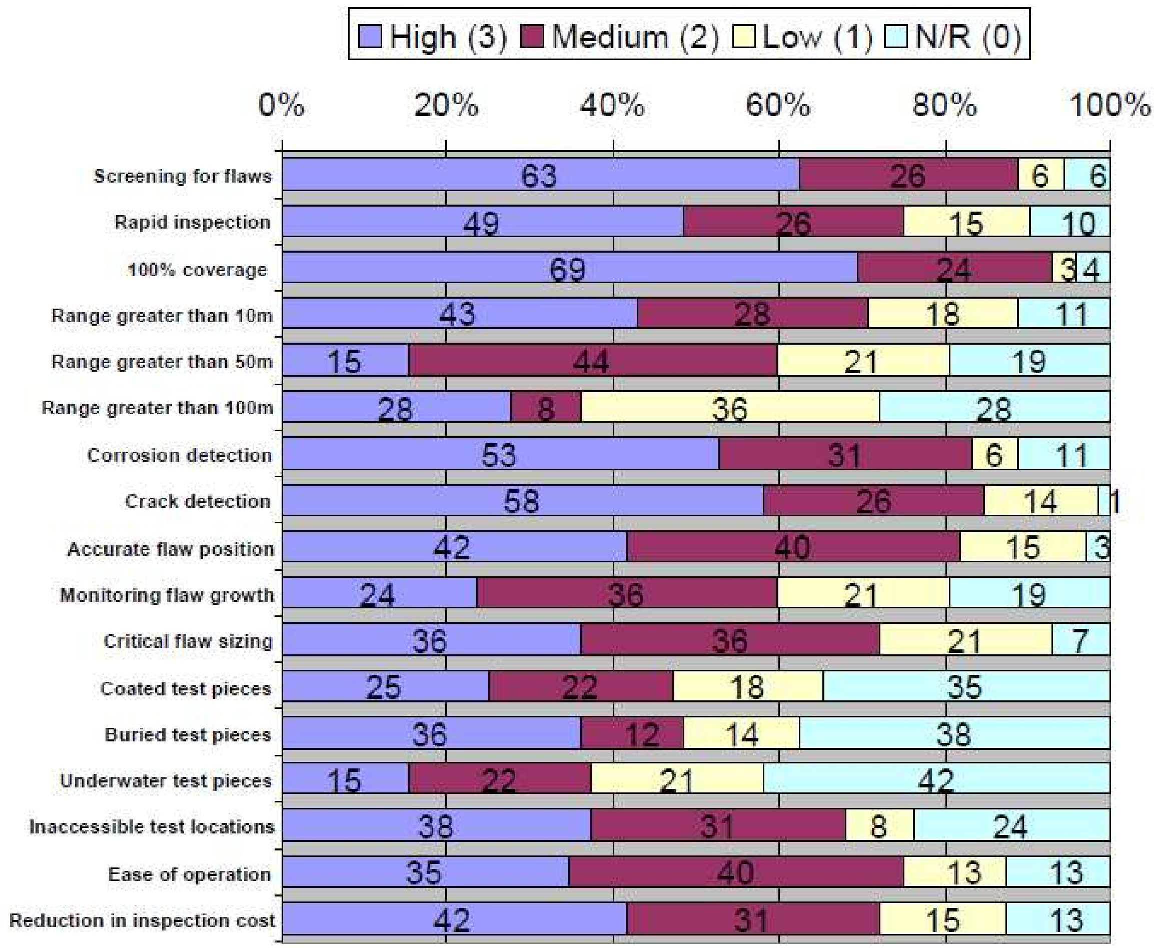

Figure 33. Perceived benefits of LRU Guided Wave (source: LRUCM, 2008)

The benefit with the highest importance (69%) perceived by the respondents was '100% coverage' (Figure 33). The benefit with the lowest importance (36%) was 'Range greater than 100m'. Screening for flaws was also regarded as of high importance by 63% of respondents. Slightly more respondents thought that crack detection (58%) was more important than corrosion detection (53%), which is the current preferred use of LRU Guided Wave on pipes.

The accurate positioning of flaws and the critical sizing of flaws were regarded equally, with slightly more high importance of flaw positioning (42%) than flaw sizing (36%). Less importance was placed on flaw monitoring, with the majority (36%) believing it was only of moderate importance.

One of the original aims in developing LRU Guided Wave was the detection of flaws in areas of pipe that were inaccessible, because they were under insulation, buried in road crossings or below the water-line. Buried test pieces are still of high importance (36%) among respondents, but there is also a need to test inaccessible areas (38%), which may be above ground and need scaffolding to reach.

In contrast to the high level of importance placed upon operator performance in the question about inspection issues, 'ease of operation' of LRU Guided Wave equipment, an important contributor to operator performance, was only regarded by 35% of respondents as of high importance.

'Reduction of inspection costs' was regarded as an important benefit in LRU Guided Wave by only 42% of respondents.

<u>Market opportunity & conclusion</u>

The dominant interest is still in pipes, which were the original application for LRU Guided Wave. These are a critical engineering asset in the oil, gas, petrochemical and power generating industries, where there is high usage of NDT and a strong interest in developing new technology. In civil engineering on the other hand (railways, cables, steel piling), there is much less awareness of NDT.

There is still a low uptake of advanced NDT techniques. Only 57% of respondents had used any automated ultrasonics at all, compared with 83% who had used manual ultrasonics. With digital radiography, the uptake was even worse, with only 27% having used the method compared with 68%, who had used film radiography.

However of those that used automated ultrasonics, there was a greater proportion with high confidence in test results (64%) than with manual ultrasonics (47%).

The linkage of higher confidence to imaging mentioned earlier is important. LRU Guided Wave bases test results on the interpretation of signals in A-scans (amplitude modulation scan). Greater confidence would be attained if these signals could be translated into images of the test piece

The industries that employ NDT techniques are therefore conservative and many barriers have to be overcome, over and above recognition that the method detects defects. The most important barrier is the inclusion of the method in national codes and standards.

The dominance of test operator performance over all other inspection issues (88% of respondents regarded it as of high importance), this highlight the importance of appropriate training for LRU Guided Wave. Generally when introducing a new technology, there is a tendency among developers to concentrate on equipment performance, without due regard to how the equipment will be used in the field. Much NDT is done under conditions that are far from ideal, where test operators work under stress-full conditions among dangerous plant and machinery.

The most important perceived benefit of LRU Guided Wave is 100% coverage and screening for flaws. This complements conventional NDT, which aims to detect and evaluate the smallest flaw in specific critical areas. These areas are often inaccessible, and can be dangerous for test operators, but could be reached by LRU Guided Wave.

3.3 The Non-Destructive Test (NDT) Inspection Market Analysis

3.3.1. Objective of the NDT Inspection Market Analysis

The objective of this market analysis is to study the attractiveness and the dynamics of the NDT Inspection market, both now and in the future.

3.3.2 Analysis of the NDT Inspection Market and Customer

The stringent government safety regulations have created a huge demand for Non-Destructive Test (NDT) inspection services and equipment. This market is relatively immune from major economic slowdowns and hence presents tremendous growth potential.

Large-scale Infrastructure Projects in Asia Pacific and Latin American Countries Hold a Huge Potential for the Non destructive Test Inspection Services Market [27].

3.3.2.1 Market Segmentation

The world NDT inspection market is highly fragmented with significantly high competition, with more than 100 competitors, each trying to consolidate their market share. As a result, this market is highly competitive with products and services offered in a number of segments from equipment manufactures to inspection vendors.

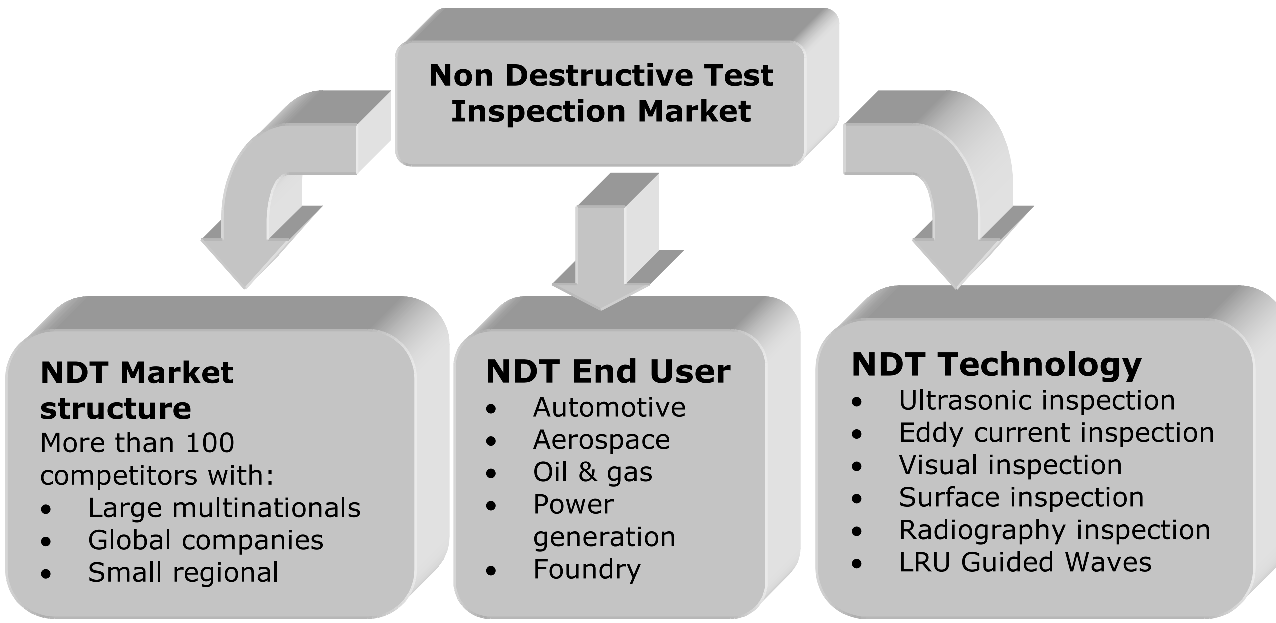

Figure 34. Schematic of the NDT Inspection market

The Non Destructive test market is mainly segmented in:

- Large NDT equipment manufacturers. They are large multinationals and global companies that have an important share of the equipment market and have high R&D capabilities in many different NDT technologies. (e.g.:GE´s NDT, Olympus's NDT division, Sonatest, etc)

- Smaller NDT equipment manufacturers and suppliers. They are mainly small & medium companies which are highly specialized and very active in R&D in a specific NDT technology. By example, LRU Guided Wave systems manufacturers that mainly is used for pipe screening (e.g.: Guided Ultrasonic, Teletest, etc).

- Low cost inspection vendors. They can be small regional companies or big global players. They core business are the inspection services using various NDT techniques; therefore they are experts in the use of NDT inspection methods. (e.g.: Silvering, Structural Integrity, Rosen, NDT ltd, etc)

3.3.2.2 Market Target

The oil and gas industry is the biggest customer segment for NDT inspection services market due to the aging oil refineries are in need of maintenance and monitoring.

Power generation industry will continue to remain a key growth opportunity segment for NDT, which is set to be driven by the increase in number of power plants under construction.

Industries such as automotive, aerospace, military, and defense are the least significant end users for NDT inspection, as they carry out most of their inspection services in-house [28]

3.3.2.3 Market Trends

Regional Trends

Asia Pacific & Latin America is expected to play an important role in the growth and demand for NDT inspection services during the next years. In terms of revenue generation, this region is expected to grow further as demand from key end user industries, such as manufacturing, oil and gas, and power generation, continues to increase.

North America continues to play an important role in terms of revenues for this market. The presence of established end users such as oil and gas, and process industries is pivotal to the demand in this region. It is expected to remain the biggest contributor to revenues in this market.

End User Trends

The oil and gas industry will remain the biggest end user for NDT inspection market. The stringent government safety regulations for this industry will maintain high demand for inspection services and equipment.

The power generation industry is expected to drive the growth in this market for the next years. The shift to clean power generation with an increased emphasis on wind energy provides the NDT inspection market with the opportunity to grow. Also with more than 60 nuclear power plants under construction worldwide and the requirements to pass very stringent safety criteria, the demand for NDT equipment and services is set to increase [29].

Technology trends

The NDT industry is undergoing rapid change. Traditional NDT technologies are evolving in important ways, providing new benefits and added value to end-users. The applications in which NDT is used are also evolving. Many industries, such as material science, electronics, solar etc, that have used NDT techniques sparingly in the past are showing increasing interest in employing newer and more advanced techniques, while some of the traditional NDT end-users such as oil & gas and power generation are skeptical about adopting newer advanced NDT technologies and prefer the traditional more proven technique. The industry in general is looking for NDE solutions that can be applied without intrusion and can be performed while the plant or system is in operation.

3.3.2.4 Market competition

Currently the inspection services providers are challenged to provide quality service at competitive prices. Therefore a major hurdle that many NDT inspection service providers face is price. “Although most established participants provide high-quality inspection, less established and relatively smaller participants occasionally compromise on safety and quality,” says the analyst [27].

This is especially witnessed in Asia Pacific, where the end-users are highly price conscious and the lack of government safety regulations has affected the effective implementation of NDT inspection services in the region.

3.3.3 Dimensions of the NDT Inspection Market Analysis

3.3.3.1 NDT inspection market size

Extending the useful life of ageing infrastructure is driving the need for inspection services. The exorbitant cost and challenges involved in building new infrastructure has resulted in significant ageing of existing infrastructure. To assess the integrity and prevent catastrophic failures, NDT inspection is of paramount importance

The NDT global inspection services market is huge and growing at a steady pace; Frost & Sullivan's initial analysis estimated it at over $2.5 billion and the global market for NDT equipment to be $1.41 billion in 2010 [28] [30]. In comparison, the NDT inspection services market is almost double that.

3.3.3.2 Market opportunity: NDT inspection market potential growth

With the economy still recovering from the effects of financial downturn and the European economy being troubled by a sovereign debt crisis, the primary regions being outlined for growth in the global market are Asia Pacific and Latin America. The rapid rate of infrastructure development in emerging economies such as India, China, and Brazil is driving the demand for NDT inspection.

In Japan, the accident at Fukushima nuclear reactor is expected to trigger widespread increase in safety regulations for nuclear power plants, besides driving short-term precautionary inspection in existing nuclear plants worldwide.

Overall, the NDT inspection market has huge potential with a steady increase demand for product and services especially in the oil & gas and power generation sectors.

4 Recommended FAC Pipe Inspection Service approach for AREVA: Market Analysis

4.1 Objective of the Market Analysis for the recommended approach

The goal of AREVA's market analysis of FAC Pipe Inspection service approach is to determine the dynamics of the FAC Pipe Inspection in nuclear market, where AREVA mainly operates and also to understand the evolving opportunities and threats as they relate to the strengths and weaknesses of the firm.

4.2 Nuclear Power Plants FAC Pipe Inspection: Market Analysis

4.2.1 Market size in EU

Review of the customer 5-year maintenance plans for Nuclear Power NPPs Plants shows that they are including items for FAC/Piping in two primary categories [31] :

- Inspection
- Piping replacement

A typical US nuclear plant will include ~$0.75 M per unit per refueling outage for piping/FAC inspections.

The total market that AREVA could capture for Piping/FAC in the European Union (EU), can be conservatively estimated by extrapolating the US nuclear plants budget for FAC inspection during the refueling operations as follows.

In the EU there are currently 133 operating reactors. By taking account of the following assumptions as the basis for the estimation of the piping/FAC inspections market in EU per year:

- 24 months between outages (conservative), this means that there are round 65 outages per year in EU
- Conversion rate 1 € = 1,5 $ (currently around 1,3$) therefore the Nuclear Power plant outage FAC inspections budget is: 750.000$ => 500.000€

In a conservatively estimation the EU market piping/FAC inspections per year could be = 33,25M €/year

4.2.2. Market trend

There is no evidence that utilities are reducing FAC scopes or budgets [31]. Instead, due to the safety implications and risk, they are resigned to include this as a standard budget line item. Furthermore, wholesale piping replacements are frequently driven by cost benefit evaluations, for example: when the cost of accessing to the pipe takes an important part of the inspection budget. Therefore there is an interest in the nuclear sector in exploring new technologies that would improve inspection times and volumes.

To better assess the market potential, it should be considered the following: There are approximately 200 components requiring FAC inspection in a Pressurized Water Reactor plant and 100 components requiring inspection in a Boiling Water Reactor plant.

Therefore is expected that the demand for FAC inspection in the EU will remain stable.

4.2.3. Market Requirements

Accurate inspections and systematic data collection system are the foundation of an effective FAC program and this could represent the biggest opportunity for AREVA to be able to impact the market. Also a balance is required by utilities between minimizing inspection time and cost and maximizing the operational life of the component [32].

The challenges facing the nuclear sector at this time, related to inspections are:

- The volume to be inspected while minimizing down the time (speed of inspections).
- Finding an accurate process that is fast (large volumes in a short time) and non-invasive (pipe examination from distances or without excavation or insulation removal).

These areas hold the biggest potential for market entry with an innovative, cost effective product-service.

4.3 Description of the recommended FAC Pipe Inspection package service

Before AREVA NP GmbH will be able to penetrate the market, their offering must (be expanded to) include break through technology and new inspection techniques (e.g.; Long Range Ultrasonic Guided Wave).

Technology currently being employed in the nuclear industry for FAC related NDT consists:

- Standard Ultrasonics
- Long Range Ultrasonic Guided Wave technology
- Radiography Test (RT) – Standard and Digital/Computed
- Eddy Current Testing
- Visual Inspection: Direct and remote (Cameras/crawlers for video inspections)

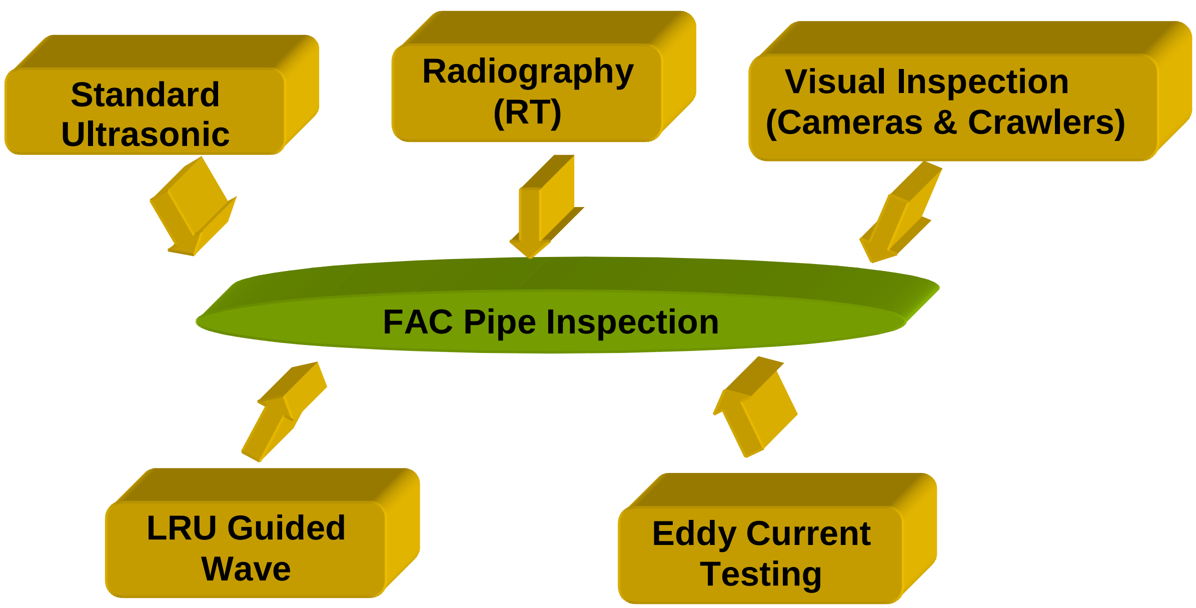

Figure 35. FAC related NDT methods.

Currently AREVA NP GmbH has the ability to perform Standard Ultrasonic Testing (UT), Radiography Testing (RT), Eddy Current Testing (ECT) and visual inspections. Digital Radiography is not in the portfolio, but is possible to subcontract. AREVA NP GmbH is currently gaining experience performing LRU Guided Wave inspections

Unfortunately, current guided waves technology is not proprietary and is being used by the smaller vendors to secure this work. Similarly, advanced RT techniques (e.g. digital, compact/low level) have already been developed and are fairly commonly used for piping inspections.

The NDT methods currently being used for the nuclear industry for FAC pipe inspection are described as follows:

Visual Inspection (VT)

VT visually checks areas to verify that they meet the applicable code or standard. Visual Inspection is done on structures, mechanical and electrical components, welds, piping and other hardware. Inspection may include magnification, remote optical viewing devices and additional measurement tools.

Figure 36. Buried pipe inspection by visual method with magnification (source: Rosen ltd , 2011)

Eddy Currents (EC)

Eddy-current testing uses electromagnetic induction to detect flaws in conductive materials. Standard eddy current testing a circular coil carrying current is placed in proximity to the test specimen (which must be electrically conductive). The alternating current in the coil generates changing magnetic field which interacts with test specimen and generates eddy current. Variations in the electrical conductivity or magnetic permeability of the test object, or the presence of any flaws, will cause a change in eddy current and a corresponding change in the phase and amplitude of the measured current.

The testing devices are portable, provide immediate feedback, and do not need to contact the item in question, allowing inspection in insulated objects.

Figure 37. Eddy current inspection method (source: GE NDT, 2011)

Standard Ultrasonic Testing (UT)

This technique uses very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are launched into materials to detect internal flaws or to characterize materials. The technique is also commonly used to determine the thickness of the test object, for example, to monitor pipe corrosion.

Ultrasonic testing is often performed on steel and other metals and alloys. It is a form of non-destructive testing used in many industries including power generation, aerospace, steel fabrication, automotive, and other transportation sectors.

In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by water or oil based coupling.

There are two methods of receiving the ultrasound waveform, reflection and attenuation:

- In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object. The diagnostic machine displays these results in the form of a signal with amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection.

- 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 traveling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence.

UT techniques provide instant results, and are sensitive to both surface and subsurface discontinuities throughout the material. UT is capable of detecting imperfections throughout the entire material thickness, and may be used with access to only one surface.

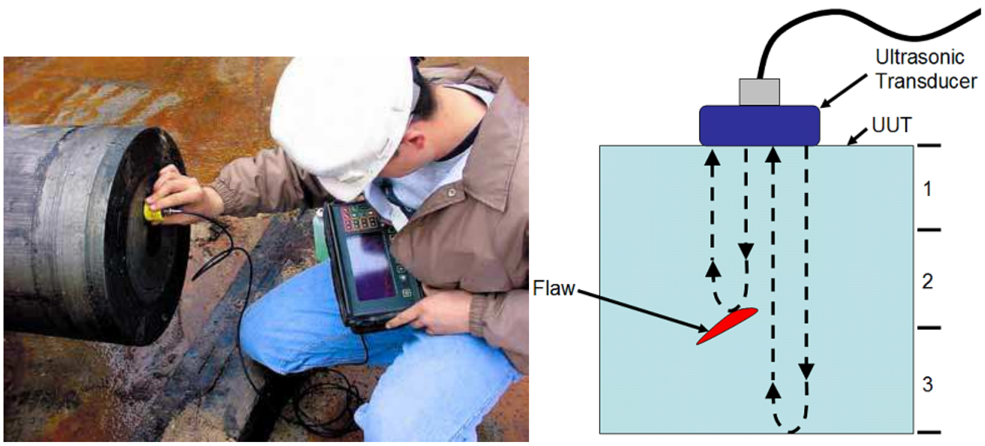

Figure 38. Standard UT inspection method (source: National Instruments, 2010)

Pipe Crawlers Inspection

Pipe robots crawlers have been especially developed for the inspection and maintenance of the interior of pipe systems. Their construction allows the robots to work in long lengths of pipes, which include many bends, and vertical sections of piping.

Pipe Crawlers can perform direct assessment of pipes with various diameters, of varying materials and liners, and in varying states of corrosion. Pipes are inspected for defects and degradation including pitting, microbiologically-induced corrosion (MIC), flow-accelerated corrosion (FAC), stress corrosion cracking (SCC), and general wall thinning.

Fabrication defects are also analyzed including for incomplete fusions on girth or long-seam welds, and misaligned pipe section or valve joints. Through the course of inspections, foreign objects and materials can be detected and cataloged.

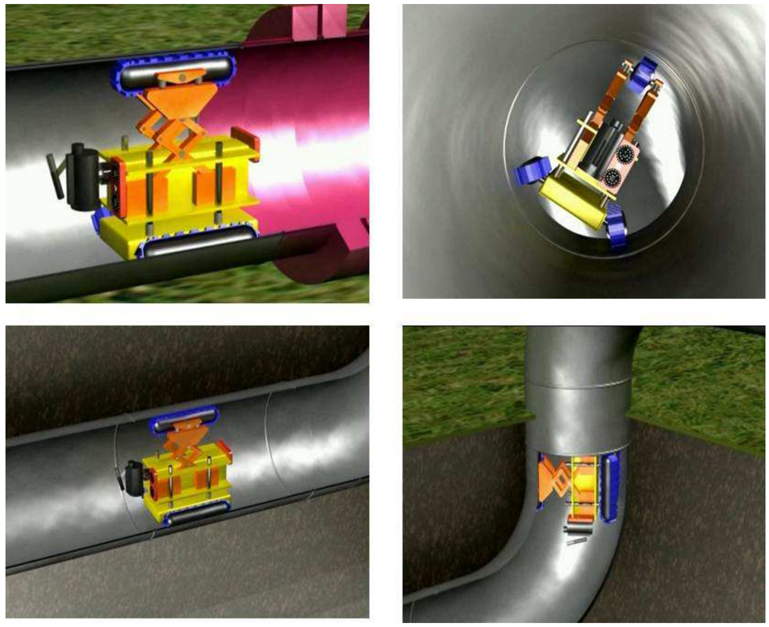

Figure 39. Diakont's innovative crawler inspection (source: Diakont's, 2012)

Computer Radiography (CR)

CRT produces digital images on reusable phosphorous plates with lower exposure requirements. The original archived image cannot be altered, thus maintaining the integrity of the raw data. Without altering the archived image, the electronic image-viewing software can be sharpened, filtered and zoomed for analysis by the technician or customer to enhance evaluation. Viewing software also allows for digital annotation and measurement using a mouse and/or keyboard instead of grease pencil or overlays.

CRT requires no film, which means there is no need to buy or dispose of chemicals.

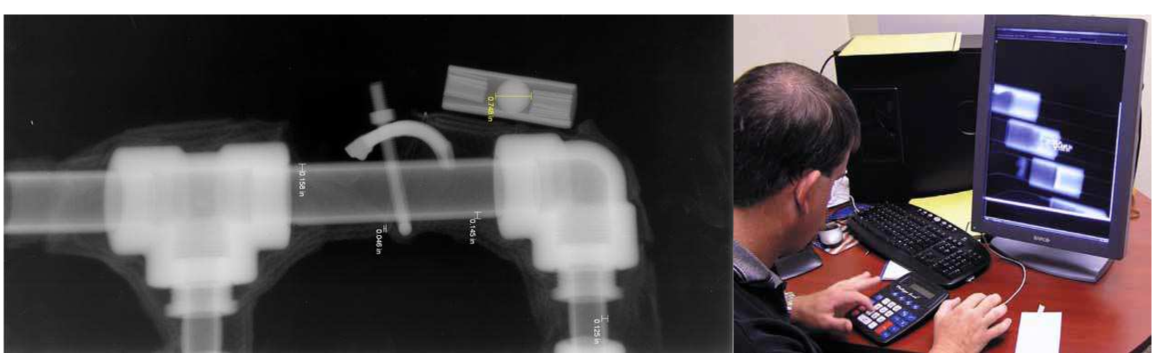

Figure 40. Computer Radiography inspection (source: IRISNDT, 2010)

Long Range Ultrasonic Guided Waves (GW)

Long Range Ultrasonic Guided Wave testing is one of latest methods in the field of non-destructive evaluation. The method employs mechanical stress waves that propagate along an elongated structure while guided by its boundaries. This allows the waves to travel a long distance with little loss in energy. Nowadays, Guided Waves is widely used to inspect and screen many engineering structures, particularly for the inspection of metallic pipelines around the world. In some cases, hundreds of meters can be inspected from a single location.

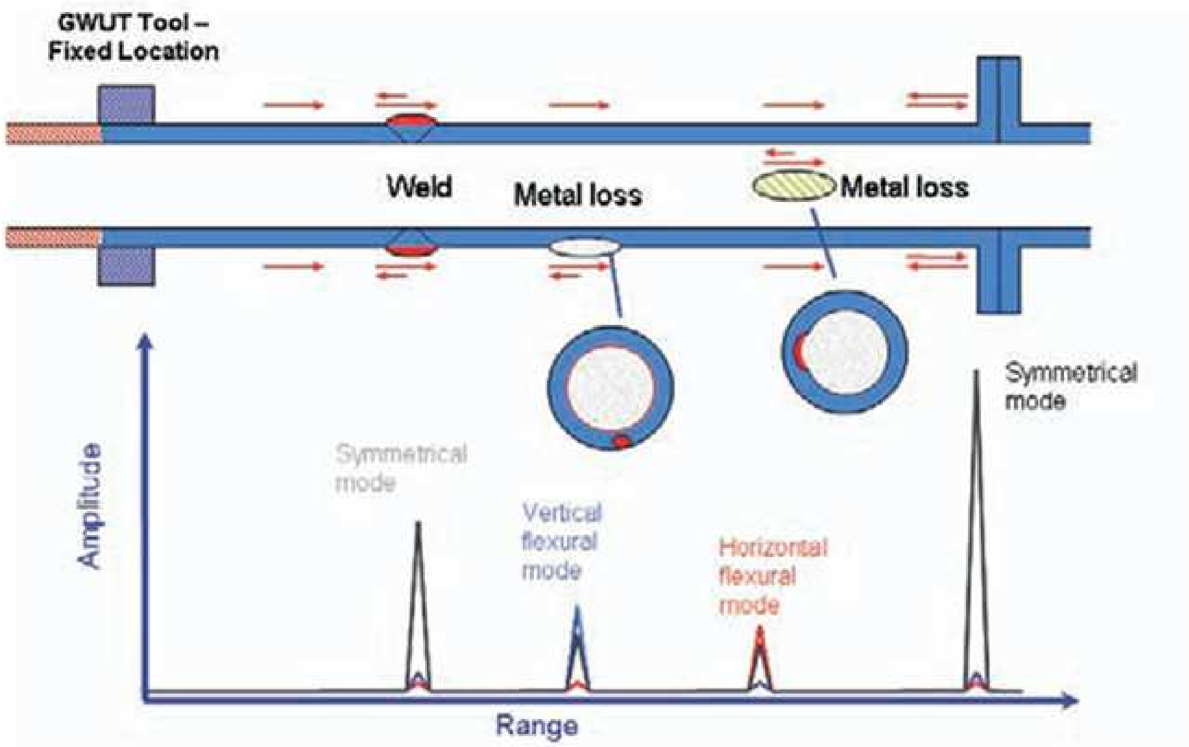

Figure 41. Guided Waves pipe inspection (source: TCR Arabia, 2010)

4.3.1 Recommended FAC Pipe Inspection package and service for AREVA

AREVA NP GmbH has the capability to offer a comprehensive pipe inspection services to help to meet Nuclear regulatory and sector requirements. Its professional staff is fully up to date on the latest standards and regulations ensuring a proactive approach to compliance.

To offer comprehensive pipeline inspection services and uncovers the most accurate results, a multidisciplinary approach implementation is recommended. AREVA NP GmbH along her sister company IntelligeNDT, can use its expertise in different Non Destructive Test methods to carefully combine and assemble them, into optimum NDT packages, and gather information into a comprehensive set of recommendations that address issues such as: corrosion, cracks, flaws and repair or replacement options.

As NO single technology solves all problems, the AREVA´s recommended NDT package inspection should combine the use of conventional Non-Destructive testing technology such as Ultrasonic, Visual inspection, Radiography, and Eddy Current along with the innovative ones ‘LRU Guided Waves and Crawlers, efficiently assembled according to its performances in each inspection to provide a safe, fast, reliable and repeatable service for its costumers.

Taking account that each of the technologies has its own particularities and performance characteristics:

- Digital Radiography offers the best result (understandable with Wall Thickness) for client but needs radiation.
- Guided Waves offers the highest inspections speed but cannot be relied on to work on every pipe always.
- Standard Ultrasonic Testing offers instant results and good sensitivity to discontinuities throughout the material but is time consuming with access to only one surface.
- Crawlers a compressive inspections form inside the pipe but only can operates in a limited pipe size range and during outages.
- A visual inspection can see details down to 0.1 mm but is slow and confidence in the results suffers when human factor is dominant.
- Eddy current gives instant results however best result in a reasonably “flat” object, with access to only one surface.

The recommendation for an inspection package with includes the use of the best NDT method to inspect the different components of a pipe line system is:

- Long lengths (30m) of pipeline: → Long Range Ultrasonic Guided Waves.
- Cased crossings: → Long Range Ultrasonic Guided Waves.
- Corrosion Under Isolation → Eddy current
- Corroded long lengths of pipeline: → Visual Inspection + Cleaning + Recoating.
- Valves, Sharp Bends, Tees: Radiography Testing → Follow up Visual inspection, Radiography and Standard Ultrasonic Tests.
- When we need to see the content: Radiography Test.

4.4 SWOT Analysis of the AREVA FAC Pipe Inspection recommendation

A SWOT analysis was completed to further evaluate the recommended FAC pipe inspection approach for AREVA

Table 3: AREVA SWOT analysis

Strengths:	Weaknesses:
• IntelligeNDT : Expertise in different NDT methods (GW, EC, UT, visual) • Established visual inspection crawlers from other AREVA product lines and regions • 3 region NDE base (wide knowledge of NDE industry worldwide) • AREVA’s outage management experience in outage reactors schedules	• No new real inspection methods offered • No existing plans for R&D in NDT inspection technology • No experience using Guided Waves in real environment - operating plant • No use Radiography (RT) • Potential high cost to enter in the FAC inspection market
Opportunities:	**Threats:**
• Coupling with repair- replace with external low cost providers • Tougher safety requirement by nationals regulators • Life time extension programs of nuclear assets in some countries. • The industry is looking for NDE solutions without removing pipe insulation and with the plant in operation.	• Shrinking market in Europe • Low cost NDE inspections suppliers in the market • New NDE potential developments may be mimicked by lower cost providers.

4.5 Strategy recommendation for AREVA NP GmbH market penetration

AREVA NP GmBH has a relevant experience in the in Nuclear Sector and has the capability to provide advice and consultation on all engineering issues related to FAC components. Moreover work has already been done with customers to assist them with material evaluations and replacement schedules.

The areas within AREVA group that are directly applicable to FAC engineering judgment are:

- Non Destructive Examination

On the basis of its more than 25 years of experience in the field of NDT testing and inspection technology, IntelligeNDT (sister company of AREVA NP) has developed an organization that has the full range of support infrastructure and can:

- Perform testing and inspection services
- Supply testing and inspection systems or components of systems for the nuclear and potential industrial market.

The NDE activities are mainly focused on the nuclear sector where IntelligeNDT testing and inspection service business maintains appropriate inspection systems for almost all the safety-related components of all common international models of boiling water and pressurized water reactors.

- Chemistry

AREVA chemists are extensively experienced in pipeline Flow Accelerated Corrosion processes. At AREVA NP laboratories in Erlangen, research activities on the field of FAC have been performed for more than 30 years. The experience gained has been compiled in analytical corrosion models, which have been integrated in a software tool. This software (COMSY) is equipped with powerful engineering tools and a sophisticated flow-induced corrosion degradation model to perform lifetime predictions for piping and vessels.

- Materials Engineering

AREVA's engineers have a solid reputation for providing materials integrity solutions and extensive field experience in assisting the nuclear sector throughout all stages of lifecycles including design, inspection, maintenance, repair, and failure analysis.

Consequently AREVA NP GmBH could provide compressive advice and consultation to its customers and should (at a minimum) be offering FAC inspection services in co-operation with IntelligeNDT, to demonstrate an awareness and concern for an issue that has such a wide range of implications in the nuclear industry

Also AREVA has the significant multidisciplinary capabilities to consider the offer of an Asset Integrity Management program as part of its market penetration strategy. The primary objective of any integrity management program is to maintain the asset in a fitness-for-purpose condition while extending the remaining life in the most reliable, safe and cost-effective manner.

Therefore AREVA is recommended to implement a FAC Integrity Management Plan consisting of:

- **Inventory:** Collection of information on the lines included in the project.
- **Prioritization:** A risk assessment is performed to classify the lines and prioritize the inspections.
- **Inspection strategy:** The expected degradation mechanisms are identified as a basis for selecting the most appropriate inspection and NDT methods when defining the initial inspection scope.
- **Execution:** Once the lines have been prioritized and a complete inspection plan is available, legal-certified survey engineers and NDT specialist will carry out the inspection work.

5. Conclusion

Flow Accelerated Corrosion (FAC) is a well-understood phenomenon that, when left unchecked, can cause wall thinning in carbon steel piping and vessels and has resulted in pipe systems failures

The safety consequences of FAC-related pipe failures are significant. There are no warnings or abnormal conditions observable before a catastrophic FAC pipe rupture occurs, raising significant risk to personnel and damage to surrounding equipment

Therefore owners-operators of power plant are supporting the implementation and maintenance of an effective FAC program that should include: the assessment of the propensity of different plant systems and components to FAC with the use of available software with water and steam chemistry corrections and periodic inspections

Currently, the plant needs to be shutdown to perform these examinations and operators check FAC corrosion during outages by manual inspections methods. As assessing piping conditions and inspecting for degradation is extremely labor intensive, accessing and preparing pipes for inspection may take an important part of the budget.

Therefore the industry would welcome improved Non Destructive Examination technology that would maximize efficiency of their FAC programs.

The long Range Ultrasonics Guided Wave technology is based in sonic beam allowing a long length of pipe to be screened from a remote location and can offers screening solutions to old pipe inspection problems never tackled using other NDT methods (buried, sleeved, insulated pipeline).

However as NO single technology solves all problems, AREVA NP GmBH is recommended to develop a multidisciplinary approach to offer comprehensive pipeline inspection services in cooperation with IntelligNDT (AREVA NP sister company). AREVA should offer NDT methods efficiently combined in optimum NDT packages, in which traditional methods along the innovative ones are combined in each inspection to maximize the inspection efficiency.

These NDT inspection service packages could offer the biggest opportunity for AREVA to target the FAC piping inspection market in the nuclear sector with the offering of leading edge technology that improves the current state of the art.

Therefore by incorporating long rang ultrasonic guided waves methods in its current NDT inspection portfolio; AREVA can position one step closer to better meet the nuclear sector requirement.

Accurate inspections and a systematic data collection system are the foundation of an effective FAC program and present the most opportunities for impacting the market. This also represents an opportunity for AREVA to explore a more complete asset management approach, e.g.: assets predictive maintenance with established customers.

Therefore AREVA NP GmBH is recommended to consider the use of a FAC Analysis Software like COMSY as supporting inspection tool as part of its FAC inspection service program.

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