The application of Non-destructive testing (NDT) as an Aspect of Quality Control in an Industrial Plant in South Africa.

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Abstract

Non-destructive testing (NDT) is one aspect of the Quality Control (QC) function and is complementary to other long well-known QC methods**.** The purpose of the study is to alert the mass population about the need for safety measures for end users of products and those working with this plant productions through forecasting and evaluation of the use and operation of the lifespan of a part of a system at different production and operational phases. Descriptive Research Design was designed during the study. A survey research design was used to collect quantitative unprocessed information from the sample of interest. Statistical analysis was used to summarize the data. SPSS was used to run the results obtained from the survey also for validation and testing of reliability, the Cronbach alpha method was used to test the correlation of the data. From the information examination, it is seen that under half of the staff concurred that the equipment and were in a decent working condition. That is the one Variable that needs to be considered the most and changed with the end goal for development to happen.

Keywords
Non-destructive testing, Quality Control, Inspection, Forecasting, Safety.

1. Introduction

1.1 Background of the Topic

Non-destructive testing (NDT) is one aspect of the Quality Control (QC) function and is complementary to other well-known QC methods. In recent studies of Rohloff, H. pty (2018) their conclusion implies that an evaluation of materials for both internal defaults or material surface for a product or service is regarded as Non-Destructive Testing (NDT). This incorporates those test strategies used to look at a question, material or framework without debilitating its future handiness before coordinate contact is made with the end client of the item. (Rohloff, H. pty, 2018). Alternative words to use for NDT are Non-Destructive Evaluation and Non-Destructive Inspection.

NDT is in the brackets of applied science and engineering department or field which use techniques such as non-invasive techniques to identify the integrity and dependability of materials or structures measure their characteristics through a quantitative approach without rendering them unfit for a service after application (Bray and Stanley, 1996). It is important to indicate that NDT techniques have been used in the industry for more than 30 years to analyze and evaluate material, component or system properties without compromising the inspected object's integrity (Huang and Wang, 2016).

It is NDT has commonly used techniques or methods in the industry such as:

- Infrared Thermography (IRT) which is a technique that provides relatively fast results from inspection of large surface (Jama, 2017, Huang and Wang, 2016).
- Eddy-Current inspection, which has its roots in electromagnetism (Pathrotkar, 2018) is also referred to as eddy current testing (ECT), is often used to detect erosion or cracking and other changes in tubing to prevent leaks (Bond, 2012).
- Time-of-flight diffraction (TOFD) is a computerized ultrasonic system that stores, scans and evaluate indications in terms of height, length, depth and locations with accuracy (Lawson, 2009), and as indicated by Liu *et al.* (2015) as well as by Michels-Clark *et al.* (2017), TOFD is a technology of high accuracy detection using the weak diffraction signals of ultrasonic waves from defects for the NDT applications.
- Liquid/dye penetrant testing which is used to detect discontinuity in the plan production. (Lawrence, K.A. 1997).

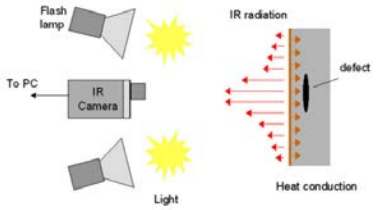

Figure 1.a IRT Application (Huang and Wang, 2016)

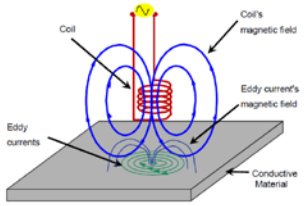

Figure 1.b ECT Application (Pathrotkar, 2018)

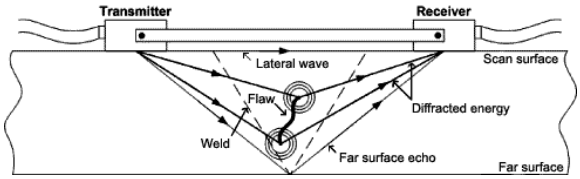

Figure 1. c TOFD Application (Michels-Clark *et al.*, 2017)

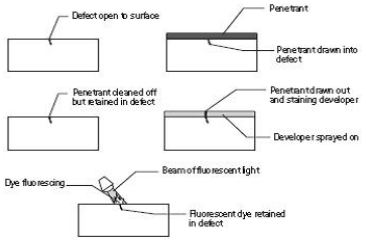

Figure 1.d Liquid Penetrant Testing Application (Mathers, 2015)

1.2 Purpose and Values of the Study

The main objective is to alert the mass population and that there is a great need for safety measures for end users of products and those working with this plant productions through forecasting and evaluation of the use and operation of the lifespan of a part of a system at different production and operational phases.

To attract students to become Non-Destructive Testers due to the gap in the industry. The application of NDT requires a certain degree of skill to be applicable at any stage of the manufacturing process to gain maximum amount of reliable information concerning the test components with major feedback or responses.

To emphasize the Safety, Health, Environmental, Risks and quality (SHERQ)'S proposition of using a method of plant production and dependability as an essential part of quality control and assurance processes due to the increasing demand in South Africa and globally (Rahim and Selva, 2007).

The harms associated with NDT is that if and when it fails to detect or be unable to forecast errors, this could present a significant or rather a severe economic loss due to costs that are being used, to make the plant production in the first place and this harm could impact large corporations negatively (Erhard, 2013). It is significant to highlight that all techniques or methods used in the NDT are however accurate in the forecasting or detecting defaults for any plant production.

1.3 Scope, Limitations, Assumptions and Significance of the Study

The scope of NDT methods are broadened as much as possible. The definition of NDT is interpreted to convey a massage that when the measurement is being performed on a certain structure and that there was no recognized degradation to the performance or serviceability of the structure. (Snyder *et al.*, 2013).

2. Literature Review

This phase of the study includes reviewing literature related to criticality and reliability of Non-Destructive Testing (NDT) in industrial plants, and factors affecting NDT.

2.1 NDT Reliability

According to Taylor & Nockermann (2015) NDT techniques are not equipped for discovering all imperfections. Determining to what extent an NDT method can detect the critical defects is generally referred as reliability. Reliability of NDT can also be explained as "the degree of an NDT system is capable of achieving its purpose regarding detection, characterization and calls". Scientific research has shown that reliability of NDT is dependent on three main elements; Application, Intrinsic Capability and the Human factor. However, a fourth factor has been added during the 4th European-American Workshop on Reliability of NDE in Berlin 2009.

2.2 Human factors in the field of NDT

According 2nd American-European Workshop of Non-destructive Inspection Reliability (1999) human factors are a psychological and physical of the individual, this incorporates singular preparing and encounter, and the conditions which an individual must work under as they affect the capacity of the NDT framework to accomplish its proposed reason. Human variables approach depends on understanding the properties of human abilities and constraints under fluctuates conditions and the utilization of learning in planning and building up a sheltered framework (Wheeler et al 1989, and Swets, 1996).

Human factors now and again, may the weakest connection in the NDT quality chain, which prompts ineffectual advancement of the NDT quality structure. A code of training on business conditions for NDT staff is required and important to set down rules in light of research s to what are a fitting business conditions and working game plans (time, weight, clamor condition) for individual required on quality basic exercises (Farley, J.M, 2008)

Human components are typically reliant on a considerable measure of components and impacts. As per Dupont (1997) the accompanying regions are vault of the likely explanations of human mistake and ought to be given uncommon consideration while considering NDT process inside the industrial plants;

- **Lack of communication**

The need for representatives to appropriately convey is exceptionally significant and ought to occur before the errand begins, while the undertaking is on-going and toward the finish of the assignment. A nitty gritty hand over report must be submitted to the capable manager/professional amid a move change (Dupont, 1997)

- **Resources**

Guaranteeing that the association has enough money to run the undertaking and pay the staff, that have the right tools to carry out the activity, have equipped labor and that there's simple stream of information and legitimate time administration is the route to an effective task. This builds the odds of accomplishing the undertaking all the more viably and effectively (Dupont, 1997).

- **Complacency**

Personnel tend to become complacent to a point where their performance decreases. This behaviour can be minimized by working in accordance to the written instructions, procedures and specifications. Job observations are another way of keeping personnel in their toes, as they are required to follow the procedure, and not work according to their memory.

- **Pressure**

Pressure can affect personnel's judgment during critical phases at work. While pressure to complete the job can be part of the stress that motivates personnel to do the job, however that can also have a negative effect on the quality of the work if there is no proper time management and communication within the organization (Dupont, 1997).

- **Lack of knowledge**

Plant equipment and piping system can be very complex and integrated that it may be impossible or difficult to execute the necessary task without considerable training and understanding of plant design drawings and process flow directions (Dupont, 1997).

- **Lack of assertiveness**

A technician or engineer with integrity is crucial to practice assertiveness. As they would not compromise their work standards and would strive to do the right things even when there is no support from colleagues and management (Dupont, 1997).

- **Stress and fatigue**

According to Dupont (1997) stress can harmfully affect personnel health physically and mentally, and it is triggered by different sources. Identifying the early signs can give personnel a chance to deal with the stress before it can affect their work performance. A few organization have now introduced the Employee wellness programs, where employees are counselled and given support in different stressful aspects of their lives.

- **Lack of teamwork**

Team work enables employees to become familiar with each other and learn how to work together. These fasters an environment of trust and good communication skills, and creates a results-oriented environment in the organization. As Dupont (1997) mentioned that lack of trust can create a hostile environment and negatively affect the work progress.

- **Distraction**

Disruption during a task can lead to an occurrence of errors, which can be minimized by double checking the work upon returning to it, if there was an interruption.

2.3 Technical capability of the NDT testing equipment

The accessibility and state of the NDT testing hardware and material are extremely basic in the NDT framework. These hardware's include diverse parts inside a modern plant in this way, it is important to direct occasional testing of equipment record their precision and distinguish their resilience (Jinhong *et al.*, 2000). Inner alignment strategies are to be recorded, and portrayed how they ought to be performed. Equipment records should obviously characterize alignment interims and the moves made if the adjustment falls outside the pre-decided cutoff points.

2.4 Operating and environment conditions affecting NDT reliability

Spanner Sr (1988) expounded that environmental factors can likewise affect human execution. These factors may incorporate the kind of work force defensive garments, warm, lighting, moistness and potential radiation presentation. The natural conditions under which the NDT examinations are executed must be good for the specialist too, meet the procedural environmental prerequisites for the kind of NDT technique to be performed.

A few authors have exhibited that shaping components and environmental variables can really affect the NDT unwavering quality; nonetheless, NDT applications parameters and other human elements should be seen better, till then this viewpoint ought to be given low need yet not be disregarded. In the event that the testing condition isn't conductive, it is in all likelihood that outcomes won't be satisfactory. Management ought to be wary of human components while arranging and executing the NDT activities and important precautionary measures ought to be taken to guarantee that the NDT staff are free from pointless weight while executing test. It is basic that NDT faculty are propelled amid the basic field testing, as it will build odds of more solid outcomes (Maes *et al.*, 2013)

2.5 Probability of detection of defects in NDT system

Probability of Non-destructive testing just means the probability, communicated as rate, that the technique will effectively distinguish and measure a deformity in a test segment. Probability of Detection (POD) is a different parameter issue that is portrayed by commitments and fluctuations in: NDT System Calibration, NDT Material Properties, NDE Acceptance Criteria/Decision Level and Flaws Interaction and Properties (Wall *et al*, 2009).

NDT techniques are an essential piece of dependability and upkeep designs in the operational plants ventures and playing out these strategies show a decent chance to lessen the likelihood of spillage or break in plants parts. Periodic use of NDT methods on the plant component prior to the end of safe life can theoretically extend the component life, as the components containing defects with sizes large enough to fail the component are rejected by the NDT process in the upcoming service period (Wall, Bruch & Lilley, 2009).

The unwavering quality of aspects of NDT strategies turn out to be greatly urgent when quantitative data is required. POD measures biggest defect that may be missed by the NDT framework. At the point when the biggest defect display in another segment is known, it permits the harm movement estimations to be utilized to foresee the sheltered existence of the segment (Stubbs, 2005).

2.6 Key NDT issues in achieving effective and reliable NDT

Checklists and auditing tools can be used by NDT managers/supervisor or Accreditation bodies to evaluate whether the NDT methods being applied are suitable in terms of overall performance and reliability (Smalley *et al.,* 2003)

- Are the selected NDT methods suitable for the detection and evaluation of the damage mechanism expected?
- Do NDT procedures adequately cover a variety of components/weld geometries to be examined?
- Are NDT personnel suitably trained and qualified to perform the tasks?
- What monitoring and control measures are in place to ensure that NDT testing equipment are functioning properly?
- Is inspection qualification required for high-risk items of the plant?
- How is the documentation and archiving system of the NDT test results?

3. RESEARCH METHODOLOGY

This section sets out the methodology for the data collection and the analyses of the collected data to assist in addressing the main research objective. The basis of methodology and data collection strategies is the information obtained from the literature reviewed in the previous section.

3.1 Research design

Descriptive Research Design was designed during the study. A survey questionnaire was used to collect quantitative unprocessed information from the sample of interest. This design involves analyzing the information and tabulating it. A Quantitative Research Method was used to transform the collected information into processed data that can be represented by graphs for usable statistics. A series of close ended questionnaire was prepared with a 1-5 scale rating answer option (1=Strongly Agree; 2=Agree; 3=Moderately Agree; 4=Disagree; 5=Strongly Disagree). In summary, vital features of the research such as the target population, sampling and data collection processes were sufficiently examined. Statistical analysis was used to summarize the data. SPSS was used to run the results obtained from the survey also for validation and testing of reliability.

3.2 Reliability:

In the reliability test, the Cronbach alpha method was used to test the correlation of the data. The results are as follows:

Table 1.a Reliability Testing Results for Items A & B

	Scale Mean If Item deleted	Scale Variance if Item deleted	Total Item Correlation	Cronbach's Alpha if Item changed
A	21.17	6.780	0.343	0.611
B	21.15	6.638	0.421	0.589

Cronbach's alpha	No. of Items
0.643	6

Table 3.b Reliability Testing Results for Items C

	Scale Mean If Item deleted	Scale Variance if Item deleted	Total Item Correlation	Cronbach's Alpha if Item changed
C	21.66	10.403	0.648	0.820

Cronbach's alpha	No. of Items
0.848	6

Table 2.c Reliability Testing Results for Items D

	Scale Mean If Item deleted	Scale Variance if Item deleted	Total Item Correlation	Cronbach's Alpha if Item changed
D	7.46	4.041	0.826	0.663

Cronbach's alpha	No. of Items
0.843	3

All variables in this combination had good contribution to the set. No variable gives higher than the Cronbach alpha if removed.

4. Results

The following questionnaires was used to obtain the results.

Table 2. Questionnaires

	Questions	Scale				
1	I understand the criticality of my job in Relation to Quality	1	2	3	4	5
2	I am well trained for the type of job that I do	1	2	3	4	5
3	This test was conducted to find out whether equipment and tools used for NDT are always in a Good Condition	1	2	3	4	5
4	Inspections are always conducted under suitable operating Conditions	1	2	3	4	5

1= Strongly Agree, 2= Agree, 3= Moderately Agree, 4= Disagree,5= Strongly Disagree

The Results of the data analysis are summarized as follows:

Table 3 and Figure 2 below depict Human factors in the fields of NDT related to Question 1: *I Understand the criticality of my job in Relation to Quality*. 100% of the Personnel Understand the criticality of theirs jobs in relation to Quality. The results of the respondents are discussed in the table and graph below

Table 3. Question 1 Survey Response

Valid	*f*	%	Valid %	Cum %
Agree	**12**	**25**	**25**	**25**
Agree Moderately	**5**	**10,4**	**10,4**	**35,4**
Strongly Agree	**31**	**64,6**	**64,6**	**100**
Total	48	100	100	

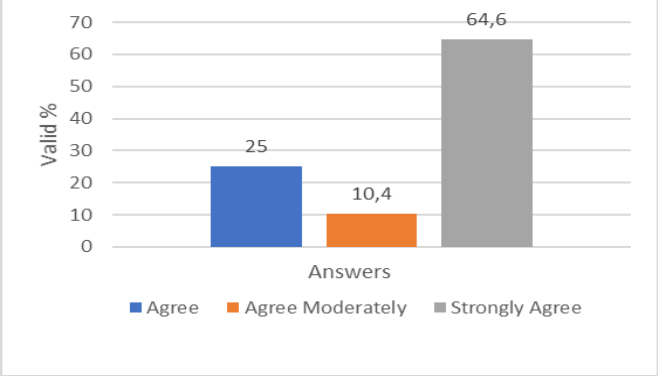

Figure 2. Question 1 Percentage Responses

Table 4 and Figure 3 below depict the percentage response related to the survey questionnaire's Question 2: *I am Well Trained for the type of job that I do*. 100% of personnel Confirmed that they are well trained in the NDT field. The results of the respondents are summarized in the table and graph below;

Table 4. Question 2 Survey Response

Valid	*f*	%	Valid %	Cum %
Agree	**13**	**27,1**	**27,1**	**27,1**
Agree Moderately	**4**	**8,3**	**8,3**	**35,4**
Strongly Agree	**31**	**64,6**	**64,6**	**100**
Total	**48**	**100**	**100**	

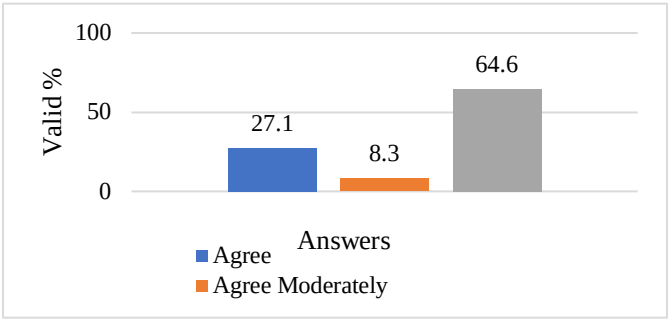

Figure 3. Question 2 Percentage Responses

Table 5 and Figure 4 below depict the percentage response related to the survey questionnaire's Question 3 about the Technical Factors of the NDT testing Equipment: This test was conducted to find out whether equipment and tools

used for NDT are always in a Good Condition. 8.3% of the Personnel would disagree that the equipment used in the tests is always in a good condition, while 91.7% Agree

Table 5. Question 3 Survey Response

Valid	*f*	%	Valid %	Cum %
Agree	**21**	**43,8**	**43,8**	**43,8**
Agree Moderately	**8**	**16,7**	**16,7**	**60,4**
Strongly Agree	**15**	**31,3**	**31,3**	**91,7**
Disagree	**4**	**8,3**	**8,3**	**100**
Total	**48**	**100**	**100**	

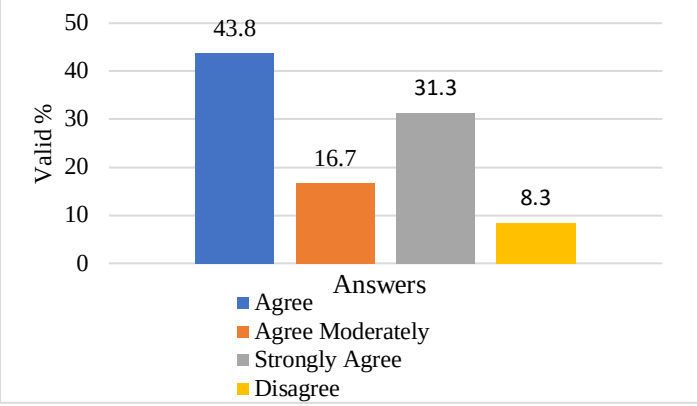

Figure 4. Question 3 Percentage Responses

Table 6 and Figure 5 below depict the percentage response related to the survey questionnaire's Question 3: *NDT Inspections are always conducted under suitable operating Conditions.* 84.5% of the personnel agree that the NDT inspections are always conducted under good environmental conditions as specified in the work procedures. 14.6% do not agree.

Table 6. Question 4 Survey Response

Valid	*f*	%	Valid %	Cum %
Agree	**16**	**33,3**	**33,3**	**33,3**
Agree Moderately	**11**	**22,9**	**22,9**	**56,3**
Strongly Agree	**14**	**29,2**	**29,2**	**85,4**
Disagree	**5**	**10,4**	**10,4**	**95,8**
Strongly Disagree	**2**	**4,2**	**4,2**	**100**
Total	**48**	**100**	**100**	

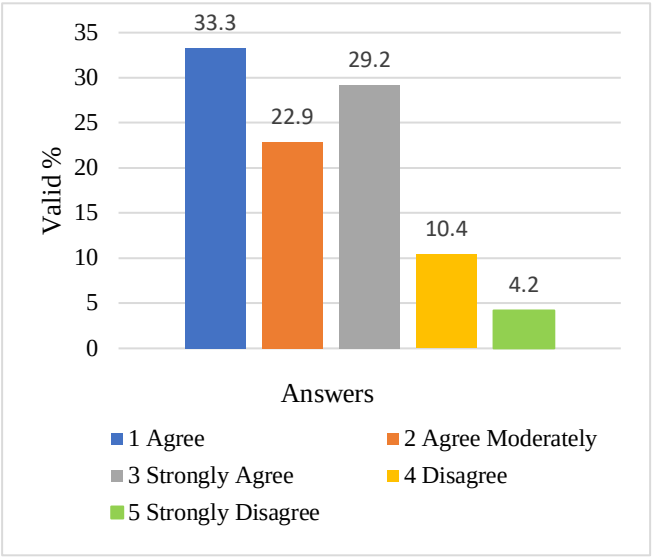

Figure 5. Question 4 Percentage Responses

5. Conclusion

The reliability of Non-Destructive Testing in Industrial Plants is dependent on all the mentioned variables i.e. Technical Capability of the testing equipment and Operation and environmental conditions. Training and employee encouragement has an influence on the reliability of NDT. From the data analysis it is seen that less than 50% of the personnel agreed that the equipment and tools were in a good working condition. That is the one Variable that should be considered the most and changed in order for improvement to take place. The rest of the elements revealed no concerns at all, which generally implies that there is a good practice within the NDT field in the industrial plants.

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Biographies

Sambil C. Mukwakungu is an award-winning academic who has been lecturing Operations Management to first year students, Food Production, and Quality Management at the University of Johannesburg since 2009. His passion for teaching and learning has allowed him to make a difference in at least one student's life every year. He is a young researcher who is still establishing himself in knowledge creation with keen interest in Service Operations Management, Lean Operations, Continuous Improvement, as well as business innovation and innovation in Higher Education. He was awarded Best Track Paper Awards at the 2016 IEOM Conference in Rabat, Morocco, in the 2018 2nd European Conference in Paris, France, and his is together with his team from the IEOM UJ Student Chapter a recipient of the 2018 IEOM Outstanding Student Chapter Gold Award for exceptional chapter activities and contributions to the field of industrial engineering and operations management.

Sihle Mankazana is a currently pursuing her Baccalaureus Technologiae in Operations Management, in the Quality and Operations Management Department at the University of Johannesburg. She was awarded her National Diploma with Cum Laude in Operations Management (2017) from the University of Johannesburg. She is also a tutor at the University of Johannesburg with great passion for teaching and learning, and an interest in research.

Ruth Mpho Maphosa is a student in the University of Johannesburg studying Sport Management under the Health Sciences Department. She is still in her second year of study and aims to advance in the business side of Sport as soon as she has completed her national diploma.

Temosho Bapela is a Management Services Graduate and currently completing his Baccalaureus Technologaie in Quality Assurance at the University of Johannesburg. In 2015 he was one of the University's First Year's Top Achiever for his Diploma in Management Services. He is employed as a tutor at the institution currently.

Queenza Obakeng Klaas is a QHSE Manager within the Energy and Industry Division of Applus+ Africa Region. Her expertise and experience greatly lie within the Non-Destructive Testing, Quality Control and Assurance fields as well as management of integrated QSHE management systems (ISO 9001:2015, ISO 14001:2015 and ISO 18001:2007) within the Engineering and Operation management divisions. Her current role involves implementation, maintenance and improvement of the ISO Integrated Management System within the Applus + Africa regional offices to ensure smooth operations as well as ensuring that customer needs and expectations are met and exceeded. She has a widespread experience working in the Power generation and Petrochemical plant environment. She is very passionate about Quality, Technology Management, working with people and adding value in people's lives. She aspires to make a great impact within the Non-Destructive Testing and Quality industry through knowledge sharing and continuous learning, and ultimately giving back.