Working with Senses – Visual Inspection in a Nuclear Power Plant

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ABSTRACT

One of the main tasks of the nuclear power plant field operators is to perform visual inspection for detecting anomalies in the plant's equipment. According to the field operator interviews performed in this study, this task is rather solitary and requires precision and expertise and, furthermore, it is rather monotonous. Even if field operators appear to truly understand the importance of performing the inspection rounds calmly and carefully, supporting the good quality of inspection, also other means to support are needed and have been identified in the study, related to training and work practices. These development ideas will be discussed in the next phase of the study, at the managerial level of the nuclear power plant.

CCS CONCEPTS

• **Social and professional topics**; • **Professional topics**;

KEYWORDS

Field operator, Nuclear power plant, Visual inspection, Experience

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1 INTRODUCTION

Safety is essential in electricity production in the nuclear power plants and, consequently, safety is supported in the plants in various ways, such as in various roles with partly unique, partly overlapping responsibilities. One of these roles is the one of the field operators. Field operators support the safety of the plant by assisting the main control room operators in the tasks to be conducted in the nuclear facilities outside the main control room.

Briefly, field operators conduct inspection rounds and report the findings to the operators; during the rounds, they also ensure that everything is in order (close the fire doors etc.) [1]. They also do other work in the plant (conduct period testing for plant equipment etc.) [1].

In Finland, field operators are trained in the plant for about one year; after a couple of months with theoretical training, an experienced field operator is nominated as a guide to the novice field operator; they perform the rounds together till the necessary skills are acquired [1]. The maturity level of the novice field operator is tested in a demonstration of professional skills, which is supervised and evaluated by a manager [1]. After an appropriate test performance, the novice operator is qualified to take on the responsibilities of the field operator [1]. Some inspection tasks are performed rather rarely, so it may take several years before the field operator has experience in all tasks under his/her responsibility [1].

Field operators consider inspection rounds as their most important task [1]. According to the field operator interviews in Finland (ibid.), field operators primarily perform two slightly different rounds alone daily. Practices vary – in some plants, rounds are performed in some specific area and in other plants, the field operator inspects any part of the plant. Readings from the equipment are reported, depending on the plant, in paper form or a tablet. The tablet also provides a view of the reading history. Furthermore, field operators focus on anything appearing abnormal in the functioning of the equipment by utilizing their senses; for instance, an abnormal smell, unusual trembling or a heated equipment surface can be a sign of an anomaly in the equipment. The readings and observations during the round are also officially shared and discussed with their closest superior, a main control room operator or shift supervisor, and practically always discussed with their colleagues, at least during the change of shift.

This paper represents research conducted in the TONUS project as part of the SAFER2028 program [2], a Finnish nuclear safety and waste management research umbrella. The aim of this paper is to provide recommendations that support the development of visual inspection practices in Finnish nuclear power plants. Thus, the research question is as follows: What are the developmental needs for enhancing visual inspection in a nuclear power plant?

In this paper, we study the experiences and conceptions field operators have pertaining to the visual inspection rounds they perform. This experience-related information, along with the known inspection practices [1], is utilized to conclude and innovate new practices that enhance the quality of visual inspection.

2 VISUAL INSPECTION

Visual inspection is one of the non-destructive inspection testing (NDT) methods, i.e., methods that do not leave any marks or other signs on the inspected material. NDT methods can be further divided into contact methods (such as magnetic testing) and non-contact methods categories; visual inspection is one of the non-contact methods [3].

Visual inspection is one of the main quality control means in industry and it is used, e.g., in the food industry, aircraft maintenance, and medicine (for example, radiology). Visual inspection is used

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for detecting anomalies in a product [4]. The key components are the inspector's knowledge of the target of inspection, the cognitive work performed to evaluate what is detected, and the inspection performance with human senses [5]. The term 'visual inspection' is somewhat misleading as various senses are usually used; however, this term is applied here as it is widely used in scientific literature.

Visual inspection has been named "the first line of defense for safety-related failures on aircraft and provides the least expensive and quickest method of assessing the condition of an aircraft and its parts" [5]. The first level of the defense of depth in the nuclear domain includes reliable monitoring of plant status [6]. The daily inspection rounds by field operators surely serve as a cheap and quick possibility to detect or even foresee anomalies in the functioning of the nuclear equipment.

The start of the visual inspection studies is in the 1950's when the inspection process was characterized and the myths about inspection were dispelled [7]. The trends have gone through the application of signal detection theory to inspection performance in the 1970s, studies over the efficacy of computer-aided instructions in the 1990s, and the development of virtual reality techniques for training and the characterization of the utility of automated inspection tools in 2010s [7]. In the 2020's, the special theme in visual inspection publications seems to be, so far, automated or artificial intelligence-based visual inspection (e.g., [8]).

3 METHOD

3.1 Participants

We had five male field operators from the three Finnish operating nuclear power plants as study participants; all plants were represented by at least one interviewee. Their average age was 38,4 years (min 33 years, max 45 years). All had some vocational education or even various trades before entering the nuclear power plant, the most usual trades being the electrician and papermill operator. For all but one interviewee, the only work experience in the nuclear power plant was gained in the role of a field operator. The duration of their work experience as a field operator was 11 years on average (min 7 years, max 15 years).

3.2 Data collection

Data was collected by semi-structured interviews. Each interview lasted about 1,5 hours. All interviews were performed remotely, in Microsoft Teams. The main interviewer asked the interview questions and additional questions if the response was ambiguous or unclear. The supporting interviewer took notes and asked additional questions if needed.

The interview questions, 43 questions as a whole, focused on six themes: background questions (e.g., what is the background education); the main features of visual inspection (e.g., how often the inspection is performed); success and challenges of visual inspection (e.g., what is success in visual inspection); training (how training to visual inspection is conducted); procedures (e.g., do you have some procedure for visual inspection), and development ideas about visual inspection (how would you develop visual inspection); a brief look at the past (e.g., how has inspection work changed during the years), and the final question of what a good inspector is like.

3.3 Data Analysis

Interviews were transcribed. As the core of the study is the experiences the field operators have related to visual inspection, the share of the interview responses that had some experience-related content was focused on.

Thematic analysis was used so that experience related expressions were examined to identify common themes that all interviewees had discussed about. The identified themes and the related conceptions and experiences are presented in the Results section as separate sub sections.

4 RESULTS

4.1 The objective of visual inspection

The opinions on the objective of visual inspection fall into three different categories: the prevention of fault impact on the plant, the detection of faults, and the reporting of faults.

According to most (three) interviewees, the objective is related to the meaning or impact of perceiving faults; faults are to be detected before they are fully developed or have caused problems in the nuclear process or the production of electricity. One field operator just briefly stated that the detection of flaws and leaks is the objective of inspection rounds, and another commented that the reporting to the superior is the objective of work.

4.2 Qualities of well-performed visual inspection

Field operators were asked how they knew that visual inspection was performed well. Responses varied – some considered the end result as proof of a well-performed inspection process whereas others (most of the interviewees) found a distinction between the inspection process and its end result.

Most process-based responses (3 responses) emphasized the importance of care and accuracy as such in inspection work. In one process-based response, the importance of work without hurry and interruptions was noticed, with a mention of the possibility of anomaly detection. Finally, one field operator stated that the appropriate result, i.e., the detection of any kind of anomaly, makes the inspection well performed.

4.3 Information delivery regarding the observations during the inspection round

As known from an earlier study [1], readings from the alone-conduced inspection rounds are fed to a tablet or marked on a paper and all findings from the inspection round are discussed with the closest superior, i.e., some specific main control-room operator or shift supervisor. The observations during inspection rounds are discussed in the shift change meeting with other field operators (ibid.). Furthermore, those using a pen and paper said that additionally, the readings are fed from paper into a computer where the values are followed.

Those having a tablet see the readings and notes of previous inspection rounds. However, based on the interviews, the notes are scarce and typically practical, not about the more delicate sensory information-related matters.

4.4 Feedback about visual inspection

All feedback was received from the closest superior, a main control room operator or a shift supervisor.

One field operator said that feedback is provided on a daily basis. Others had much less experience with receiving feedback. One noted briefly that he gets hardly any feedback, and another implied that the only feedback he remembered was some rebuke for a work undone. Two other field operators had their experiences in between, stating that the amount of feedback depends on the control-room operator in question.

4.5 The nature of visual inspection as a work task

All field operators stated that the visual inspection is routine work.

One field operator mentioned the repeating nature of the work as the only aspect, expressing a wish to do some other tasks additionally, such as maintenance, to have some change. Other field operators mentioned some other aspects, in addition to the routine one. Two operators emphasized the importance of the work, from the perspectives of safety and energy production. Two other field operators had some personal aspect or benefit as part of the nature of the work: one pointed out that even if the work is routine, it is also important, and you always learn something new, and another said that the work is demanding even if routine, and it is rewarding if you detect something.

4.6 Challenges in visual inspection

Contrasting to other responses, all field operators found different, only partly shared challenges in their work.

One field operator found hurry at night shift and interruptions during day shift as challenging. Another found many challenges: inspection becomes boring when it is done for a long time, night shifts are demanding as such, and interruptions at work are not good for working. The list of still another field operator is as follows: the [reactor] hall is noisy so picking up sounds is challenging, it is difficult to distinguish a new leak from the old one, and there should be some change for work. The rest of the field operators mentioned only one factor; one mentioned tiredness at night shift and another that even if you constantly learn new things at work, there are no real challenges.

4.7 Development ideas

Development needs and ideas were asked directly in the interview. The ideas ranged from attitudes and fighting against boredom to training and work tool related issues.

Two field operators wanted some change in their work; one wanted to inspect in a new environment, and another would perform additional tasks to be able to look around with new intensity. Other field operators mentioned diverse matters. One emphasized the importance of people understanding the importance of the rounds. Another field operator would focus on finding a motivated field operator for the training period. One stated that the initial training period could be longer as there is so much to learn, and the software of the tablet should be updated; and one field operator wanted more technical information about the nuclear systems, and the tablet should be made reliable.

4.8 Qualities of a good visual inspector

The conceptions about the qualities of a good visual inspector were strikingly homogeneous, irrespective of the licensee in question. All field operators stated that a good inspector is calm, careful, and precise in his/her work.

In addition to that, all participants had something personal to add to that statement. One noted that when you understand the significance of the inspection, it is easier to be careful and precise. Another commented that the better you understand the equipment the better you can perform. One described that you must be wide awake; if the thoughts are somewhere else, the anomalies hardly hit the eyes, ears, or nose. One stated that you have to dare to ask anything and there are no stupid questions; and finally, one highlighted that you should be social so that informing about anomalies is easy and, furthermore, matters should be reported with a low threshold but without making a mountain out of a molehill.

5 DISCUSSION

Visual inspection seems to be rather solitary work. It is usually performed alone and the closest superior, contact to whom to report the findings, does not necessarily provide feedback which emphasizes the isolated nature of the work.

All interviewees experienced routine as an inherent part of inspection rounds. Accordingly, two field operators had development ideas with the aim to fight against boredom at work. Furthermore, many responses regarding work challenges reflect the monotonous nature of work: one mentioned boredom as one challenge, another wished for some change for the work, and yet another stated that there are no challenges at work. When this is combined with the conceptions of all but one field operator about the work objective – that the objective is to identify anomalies, the matter that cannot be realized during every round – the struggle against monotony appears rather obvious.

Countermeasures and opposing forces to the monotony seem to rely a lot on the work motivation and high work morale of the field operators themselves. The conception of all field operators was that a good inspector is not the one who identifies many anomalies but the one who is calm, careful, and precise in the inspection work. This kind of conception guarantees good performance better than the one that focuses on the more rarely obtainable result of identifying an anomaly.

Furthermore, the inspection practices could be made richer in content by supporting the exchange of inspection strategies among field operators, e.g., by having two-person (or more) inspections with discussions about inspection practices. To make the work even more meaningful and less routine, field operators could be taught more about the functioning of the equipment they inspect. Superiors could be encouraged to give more feedback; feedback not only indicates what good performance is but also enhances work well-being. It was claimed that not all guiding field operators are motivated to guide which must affect the quality of guidance. Either the choice of guiding operator should be made more carefully or some support for him/her should be provided. Finally, the contradiction between understanding the meaningfulness of sensory information and the lack of reporting that information by official

means, tablet or paper, should be mitigated. Having these observations written would not only confirm the importance of sensory information but also enable the tracking of a possibly developing malfunction of the equipment.

6 CONCLUSIONS

Field operators perform inspection rounds day after day, year after year. The most dangerous drawback in the work of the field operator seems to be the routine that easily makes the work uninteresting. Probably all experienced field operators must struggle against boredom in their work, even if they understand it is vital for the plant. It would be important to support field operators so that they can remain active and alert during the inspection.

On the other hand, the field operators appear to truly understand the importance of performing the rounds calmly and carefully. This supports the good quality of inspection, including the appropriate use of senses. The routine the work encompasses is borne and the expertise of the field operators and the rounds repeated by other field operators ensure that no important sensory information probably escapes from attention.

All in all, the field operators in the nuclear power plants are professionals who take visual inspection rounds seriously. The challenges are not overwhelming and there are various possibilities to support the demanding and delicate work of visual inspection. In the next phase of this study, the suggestions will be discussed at a managerial level in a nuclear power plant to develop visual inspection work further.

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