Developing a Safety Culture in Industrial Radiography

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Abstract. Industrial radiography brings substantial benefits to society, and as long as the standards and codes prescribe the use of radiography, it is a justified practice. However the application of the high activity sources and powerful x-ray equipment posses a risk for the radiographers and members of the public, especially in the case of site radiography. This risk or radiation dose must be kept as low as reasonably achievable (ALARA). Accidents in which radiographers or members of the public receive doses that lead to deterministic effects must be prevented by all means.

Regulations drawn up by the international and national authorities form the basis for radiation safety. The prime responsibility of radiation safety however lies with the operating company. Simply having policies and procedures in place is not sufficient in itself to ensure the required level of radiation safety. A safety culture needs to be fostered and maintained by the company to encourage a positive attitude to radiation safety and to discourage complacency.

In this paper, a general introduction on safety culture and the development thereof will be given. This will be compared with the way in which RTD Netherlands developed, and improves its safety culture.

1. Introduction

Industrial radiography brings substantial benefits to society with regard to the assessment of the integrity of industrial installations, and as long as the authorities as well as codes and standards prescribe radiography, it will remain a justified practice. Nevertheless, industrial radiography, and especially site radiography is regarded to be one of the potentially most dangerous applications of ionising radiation.

It is for this reason that in the Euratom Basic Safety Standards [1] industrial radiography is mentioned separately as one of the practices that requires prior authorisation from the relevant authorities. Further it is identified by the Radiation Protection Unit of the Directorate-General for Energy and Transport of the European Commission that in "the industrial radiography area, there is a particular need for improving radiation safety and security and for reducing radiation doses to workers and to the public during the use of radiation sources" [2].

In the Basic Safety Standards of the International Atomic Energy Agency (IAEA) [3], a distinction is made between normal exposure and potential exposure. A normal exposure is an exposure which is expected to be received under normal operating conditions of an installation or a source, including possible minor mishaps that can be kept under control. A potential exposure is an exposure that is not expected to be delivered with certainty but that may result from an accident at a source or owing to an event or sequence of events of a probabilistic nature, including equipment failures and operating errors. Next to a report on radiation protection and safety in industrial radiography [4], the IAEA has also published a report on radiation accidents that occurred in industrial radiography [5], i.e. where potential exposure became a fact. In this report it is concluded that

established safety procedures would have prevented most of the accidents. Failure to follow these procedures frequently occurs because of commercial pressures and production requirements. Further it is noted that management can quickly lose control of the level of knowledge and performance of radiographers unless systematic audits are conducted, adequacy of training is assessed, and employees are retrained. In many cases a poor safety culture resulted in degradation of safety systems and operating procedures.

The operating organisation bears the prime responsibility for the safety of industrial radiography. Management should exercise leadership in developing and maintaining a safety culture throughout the entire organisation. In the IAEA Basic Safety Standards [3] it is stated that one of the management requirements for practices[i] in general is:

2.28. A safety culture shall be fostered and maintained to encourage a questioning and *learning attitude to protection and safety and to discourage complacency, which shall ensure that:*
(a) policies and procedures be established that identify protection and safety as being of the highest priority;
(b) problems affecting protection and safety be promptly identified and corrected in a manner commensurate with their importance;
(c) the responsibilities of each individual, including those at senior management levels, for protection and safety be clearly identified and each individual be suitably trained and qualified;
(d) clear lines of authority for decisions on protection and safety be defined; and
(e) organizational arrangements and lines of communications be effected that result in an appropriate flow of information on protection and safety at and between the various levels in the organization of the registrant or licensee.

The primary responsibility for personal safety lies with the radiographer. In addition vigilance is essential if the safety of other workers and the general public is to be ensured. Amongst other responsibilities the radiographer needs to ensure that the appropriate procedures are followed without exception, to take on the responsibility for reporting unsafe conditions or practices, to refuse to perform procedures that are beyond his knowledge, or are beyond the capability of the equipment [5].

In section 2 the concept of safety culture, and related concepts are described as they are found in literature. Section 3 describes the assessment and development of safety culture. In section 4 we describe some elements of the safety culture of RTD, and in section 5 we draw some conclusions.

2. What is a Safety Culture?

Safety culture is mentioned extensively in the literature, and various definitions of this concept are proposed by the authors, see Cooper [6], Fleming et al. [7], Gadd et al [8], and Wiegmann et al. [9]. Further it appears that concepts such as safety climate and safety management which are related to safety culture, but do not (or do?) have the same meaning, are frequently used interchangeably.

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[i] A practice is defined by the IAEA BSS as any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed. The performance of Industrial Radiography is therefore a practice.

2.1 Definitions of safety culture

There is consensus on the fact that the term 'Safety Culture' was first introduced in the Summary Report of the International Nuclear Safety Advisory Group (INSAG) on the Post-Accident Review Meeting on the Chernobyl Accident, published by the IAEA as Safety Series No.75-INSAG-l in 1986 [10].

In a fourth report [11] drawn up by this group, and that was completely devoted to Safety Culture, INSAG proposed the following definition:

Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, <…> safety issues receive the attention warranted by their significance. (first proposition of INSAG)

Further INSAG states:

Safety culture has two general components. The first is the necessary framework within an organisation and is the responsibility of the management hierarchy. The second is the attitude of staff at all levels in responding to and benefiting from the framework.

Another definition of safety culture that is cited by almost all authors is given by the British Advisory Committee for Safety in Nuclear Installations [6] [7] [8]:

The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine commitment to, and the style and proficiency of, an organisation's health and safety management.

Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by the efficacy of preventive measures.

From both definitions it can be concluded that safety culture has attitudinal as well as structural components, and relates both to organisations and individuals.

Wiegmann et al. [9] derived a new definition based on the commonalties among the varies definitions of safety culture,

Safety culture is the enduring value and priority placed on worker and public safety by everyone in every group at every level of an organization. It refers to the extent to which individuals and groups will commit to personal responsibility for safety, act to preserve, enhance and communicate safety concerns, strive to actively learn, adapt and modify (both individual and organizational) behaviour based on lessons learned from mistakes, and be rewarded in a manner consistent with these values.

It is not the intention of this paper to give an opinion on what would be the best definition of safety culture, or add a new or better definition to the ones that are found in literature, but merely to give an idea of the content of this rather abstract concept, and the important role it plays in the safe performance of practices.

2.2 Safety climate, and safety management

Just like with the concept of safety culture there is no real consensus on the definition of safety climate. Safety climate can be seen as a manifestation of safety culture, and in that sense it is a more superficial concept. It is visible in the attitudes and perceptions of the members of an organisation towards safety. Safety culture concerns the underlying beliefs and convictions of these attitudes and perceptions. Safety climate is a more unstable characteristic of an organisation than safety culture, and is more influenced by environmental factors. It is also for this reason that the safety climate can differ from one part of an organisation to another part of an organisation.

Again Wiegmann et al. [9] derived a new definition based on the common themes found in the safety climate definitions:

Safety climate is the temporal state measure of safety culture, subject to commonalities among individual perceptions of the organization. It is therefore situationally based, refers to the perceived state of safety at a particular place at a particular time, is relatively unstable, and subject to change depending on the features of the current environment or prevailing conditions.

Safety management can be regarded as the documented and formalised system of controlling against risk, i.e. the written procedures. A good safety climate and safety culture are an absolute necessity for a good implementation of these procedures in the performance of a practice. This was also recognised by INSAG in their third proposition:

Safety culture requires all duties important to safety to be carried out correctly, with alertness, due thought and full knowledge, sound judgement and a proper sense of accountability.

If the safety procedures that are drawn up by the "health & safety department" are seen as a burden, or even as something that is invented only to frustrate operations, and if this perception is propagated by the operational management to the workers, it is clear that the implementation of the procedures will be very far from good. It will be even worse if the "health & safety department" propagates the same kind of perception on the national regulations. Of course the way the procedures and regulations are motivated and communicated plays an important role too.

2.3 Safety culture: a subcomponent of corporate culture

Cooper [6] states that unless safety is the dominating characteristic of corporate (or organisational) culture, which arguably it should be in high-risk industries, safety culture is a sub-component of corporate culture. The dominant corporate culture and the prevailing context such as downsizing and organisational restructuring will exert a considerable influence on the development of a safety culture and vice-versa.

Like it is the case with safety culture there are also numerous definitions of corporate culture. Most sources in the management literature define corporate culture as shared values, beliefs and assumptions that drive behavioural norms and 'the way we do things around here'. Apparently Schein is the most cited author [12]. According to him a corporate culture, or any culture, has three levels: The most visible, but most superficial, level is that of culture as a pattern of behaviour. It is 'the way things are done around here,' the norms, the stories, the symbols. These behavioural patterns reflect a second, deeper, level of culture, which are the firm's shared values. Shared values are, on their turn, driven by the third and most fundamental level of culture: shared assumptions.

Shared experience undoubtedly also plays an important role in the forming of a corporate culture. If an organisation has experienced an accident with great implications, this will certainly have an effect on the development of its safety culture.

3. How can we assess and develop a Safety Culture?

As was already recognised by INSAG [11], qualities like attitudes, beliefs, values, and style are generally intangible. Nevertheless such qualities lead to tangible manifestations; and in its second proposition INSAG states that *a principal requirement is the development of means to use the tangible manifestations to test what is underlying*. In an illustration that is reproduced in figure 1, INSAG presented the major components of safety culture. These components can form the basis for the assessment of a safety culture of an organisation.
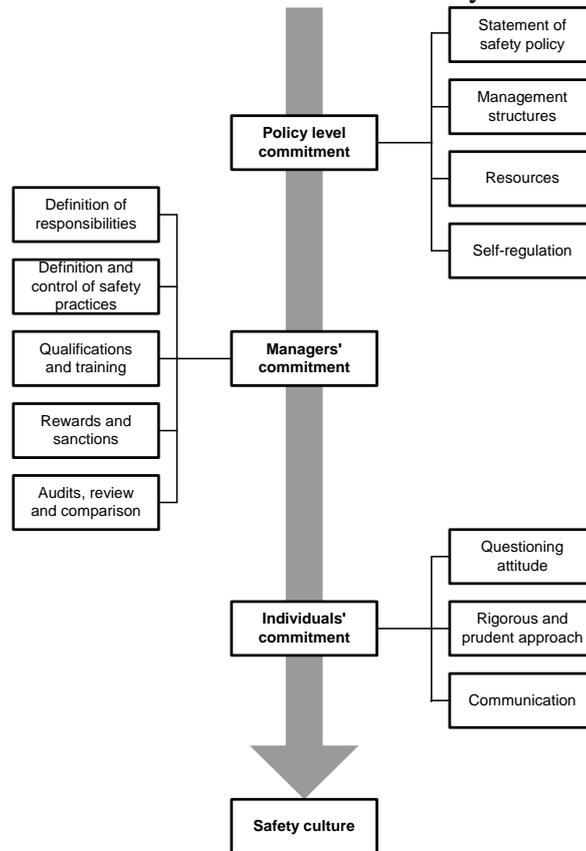

Figure 1. Illustration of the presentation of safety culture [11]

In IAEA Safety Report Series No. 11 [13], three stages through which an organisation goes in developing a safety culture are identified. These stages are summarised in table 1. In appendix IV of this report a "safety culture screening matrix" is presented by which a company can assess its score with regard to safety culture.
Fleming et al. [7] also presented a more or less comparable three stage model for the improvement of a safety culture that was developed by an offshore operating company.

The first stage is a 'dependent' culture. In this stage the emphasis is on management and supervisory control, with extensive use of discipline to enforce safety measures. There is a heavy reliance on written safety rules and procedures. Safety performance is dependent on the level of management commitment to enforcing rules and procedures. There is an upper limit for the improvement that can be reached with this type of culture, because no matter how committed management is, it is not possible to be everywhere and observe all operations.

Table 1. Three stages of safety culture according to IAEA [13]

1. Safety based solely on rules and regulations

Description	Characteristics
The organization sees safety as an external requirement and not as an aspect of conduct that will help the organization to succeed. The external requirements are those of national governments, regional authorities, or regulatory bodies. There is little awareness of behavioural and attitudinal aspects of safety performance, and no willingness to consider such issues. Safety is seen very much as a technical issue; mere compliance with rules and regulations is considered adequate	Problems are not anticipated; the organization reacts to each one as it occurs. Communication between departments and functions is poor. Departments and functions behave as semi-autonomous units and there is little collaboration and shared decision making among them. The decisions taken by departments and functions concentrate upon little more than the need to comply with rules. People who make mistakes are simply blamed for their failure to comply with the rules. Conflicts are not resolved; departments and functions compete with one another. The role of management is seen as endorsing the rules, pushing employees and expecting results. There is not much listening or learning inside or outside the organization, which adopts a defensive posture when criticized. Safety is viewed as a required nuisance. Regulators, customers, suppliers and contractors are treated cautiously or in an adversarial manner. Short term profits are seen as all-important. People are viewed as 'system components'— they are defined and valued solely in terms of what they do. There is an adversarial relationship between management and employees. There is little or no awareness of work or business processes. People are rewarded for obedience and results, regardless of long term consequences.

2. Good safety becomes an organisational goal

Description	Characteristics
The organization has a management which perceives safety performance as important even in the absence of regulatory pressure. Although there is growing awareness of behavioural issues, this aspect is largely missing from safety management methods, which comprise technical and procedural solutions. Safety performance is dealt with, along with other aspects of the business, in terms of targets or goals. The organization begins to look at the reasons why safety performance reaches a plateau and is willing to seek the advice of other organizations.	The organization concentrates primarily on day to day matters. There is little in the way of strategy. Management encourages cross-departmental and cross-functional teams and communication. Senior managers function as a team and begin to co-ordinate departmental and functional decisions. Decisions are often centred on cost and function. Management's response to mistakes is to put more controls in place via procedures and retraining. There is a little less blaming. Conflict is disturbing and is discouraged in the name of teamwork. The role of management is seen as applying management techniques, such as management by objectives. The organization is somewhat open about learning from other companies, especially techniques and best practices. Safety, cost and productivity are seen as detracting from one another. Safety is thought to imply higher cost and reduced production.• The organization's relationship with regulators, customers, suppliers and contractors is distant rather than close; there is a cautious approach where trust has to be earned. It is important to meet or exceed short term profit goals. People are rewarded for exceeding goals regardless of the long term results or consequences. The relationship between employees and management is adversarial, with little trust or respect demonstrated. There is growing awareness of the impact of cultural issues in the workplace. It is not understood why added controls do not yield the expected results in safety performance.

3. Safety performance can always be improved

Description	Characteristics
The organisation has adopted the idea of continuous improvement and applied the concept to safety performance. There is a strong emphasis on communications, training, management style, and improving efficiency and effectiveness. Everyone in the organization can contribute. Some behaviour is seen within the organization which enables improvements to be made but there is also behaviour which acts as a barrier to further improvement. Consequently, people understand the impact of behavioural issues on safety. The level of awareness of behavioural and attitudinal issues is high, and measures are being taken to improve behaviour. Progress is made one step at a time and never stops. The organization asks how it might help other companies.	The organization begins to act strategically with a focus on the longer term as well as awareness of the present. It anticipates problems and deals with their causes before they happen. People recognize and state the need for collaboration between departments and functions. They receive management support, recognition and the resources they need for collaborative work. People are aware of work or business processes in the organization and help managers to manage them. Decisions are made in the full knowledge of their safety impact on work or business processes as well as on departments and functions. There is no goal conflict between safety and production performance, so that safety is not jeopardized in pursuit of production targets. Almost all mistakes are viewed in terms of work process variability. It is more important to understand what has happened than to find someone to blame. This understanding is used to modify the work process. The existence of conflict is recognized and dealt with by trying to find mutually beneficial solutions. Management's role is seen as coaching people to improve business performance. Learning from others both inside and outside the organization is valued. Time is made available and devoted to adapting such knowledge to improve business performance. Safety and production are seen as interdependent. Collaborative relationships are developed between the organization and regulators, suppliers, customers and contractors. Short term performance is measured and analysed so that changes can be made which improve long term performance. People are respected and valued for their contribution. The relationship between management and employees is respectful and supportive. People are aware of the impact of cultural issues, and these are factors considered in key decisions. The organization rewards not only those who 'produce' but also those who support the work of others. People are also rewarded for improving processes as well as results.

In an 'independent' culture, which is the second stage, the focus is on personal commitment to and responsibility for safety. This will involve all employees in developing their own personal safety standards and demonstrating their commitment by adhering to these standards. While there will still be safety rules and procedures, employees look after their own safety and make active choices to keep themselves safe. In this stage improvement will be limited by the extent to which there is homogeneity of the safety standards of individuals and the absence of people looking out for other people's safety.

The final stage is called an 'interdependent culture'. At this stage the team commitment to safety is the dominant factor. This type of culture is manifested by workers having a sense of responsibility for safety beyond their own work and by caring for the safety of others. Employees share a common belief in the importance of safety.

The movement toward an 'interdependent' culture is difficult, as it relies on more than personal commitment; it requires shared perceptions, attitudes and beliefs. In addition, employees must be willing to help others to adopt this belief system, not by sanction but by persuasion. Further it should be noted that different parts of an organisation may be at different stages.

Fleming et al. [7] identify two approaches for the improvement of safety culture, respectively employee involvement, and developing the safety management skills of supervisors. Day-to-day control, responsibility, and decision-making are devolved to frontline employees, while supervisors become coaches. The attitudes, skills and behaviours of good supervisors are summarised as:

- valuing their subordinates;
- visiting the work-site frequently;
- facilitation of work group participation in decision making;
- effective safety communication.

4. How RTD Netherlands developed, and improves its safety culture

RTD Netherlands[ii], (est. 1937) has a long history in which it certainly developed its own corporate culture, usually referred to as the 'blue blood' that is running through the veins of its employees. This culture is manifested by the "always ready to serve the customer", and the "roll up your sleeves" behaviour of its approximately 500 employees. A behaviour of "improvisation on the spot" also belonged to the culture of the company.

In recent years there is a movement in the direction of an organisation in which responsibility and decision-making is devolved more and more to the frontline workers. RTD Netherlands is developing in the direction of a project-based organisation. For this purpose a new role is introduced, the "project manager", which can more or less be compared to the supervisors that were mentioned by Fleming et al. [7]. This project manager will be responsible for all the issues that relate to the work that is performed under his coordination and supervision, including radiation safety issues. RTD Netherlands is in the middle of the implementation of a system of competence management, and it goes without saying that the required competences with regard to attitude and behaviour, and the level thereof are different and higher than for the roles these persons had before.

In table 2 the HSE criteria are stated that have to be met by each business unit of the RTD Group, i.e. also RTD Netherlands is bound by this policy statement.

The safety culture of RTD is undoubtedly also influenced by the high safety standards that are set by it big industrial customers. However these standard mostly have to

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[ii] RTD Netherlands is a business unit of the RTD Group. This paper only deals with the safety culture of RTD Netherlands.

Table 2. HSE criteria applicable to the RTD Group [14]

- A management system for efficient control, monitoring and improvement of its activities shall be implemented. This management system shall cover organization and operational (process) management as well as aspects in the field of quality, safety and environment and shall conforming the standards EN 45004 / ISO 17025, ISO 9001, ISO-14001 and VCA/SCC-**/OHSA or appropriate standards
- Obey laws and regulations (e.g. governmental, customers). Special care where ionizing radiation emitting processes and/or hazardous chemicals are used
- Provide clarity in the organization (information)
- Record tasks, authorizations and responsibilities
- Record the business processes and implement process control by key performance indicators
- Prevent, analyze and resolve inadequacies by receiving adequate feedback (major sources being accident- and incident reports, audit results, information from medical functions and information from customers)
- Improve the performance by improving the processes
- Give customers the confidence that the quality of the service provided is adequate
- Organize the well being, motivation, health and safety of RTDís employees as well as the protection of the environment
- Assure that only equipment and accessories are used as stated in the procedures/work instructions for executing the work
- Assure that equipment complies with the calibration/ inspection and/or applicable maintenance requirements
- Understand that no conflict exists between economic objectives and the promotion of HSE (Health, Safety, Environment) performance. Organize specific measures to promote and control the HSE performance.

do with conventional safety. The customers usually put minor impact on radiation safety, let alone on radiation safety in industrial radiography.

For a long period of time RTD Netherlands had a central HSQE department that drew up the radiation safety procedures that the radiographers had to implement in their performance of industrial radiography, and performed (intentionally unexpected) field inspections to verify this. With the re-structuring of the organisation of RTD Netherlands, and following the aforementioned devolvement towards the frontline, the HSQE role has been decentralised. Each of the (now) three regions in the Netherlands now has it own local HSQE expert which advices the regional manager, and the workers in the region with regard to radiation safety issues.

Since 2004 RTD Netherlands performs industrial radiography under a new "radiation license", in which the authorities demanded a different, more structured organisation of radiation safety within the company. A radiation protection unit, which is not a separate department, was installed in which the Radiation Protection Officer of RTD, and the local experts discuss openly on radiation safety issues, and incidents. Also new developments are discussed in the monthly meetings of this unit.

The new license also requires an internal system of authorisation within the boundaries of the prescriptions stated in the license. These authorisations have to be based on prior risk assessment of the normal, and potential exposures. Justification of the practices, and optimisation of the way they are performed have to be motivated beforehand. Each region or department that performs industrial radiography, or another (new) practice or work activity has to apply for such an internal authorisation by the General Manager, and the Radiation Protection Officer of RTD.

The independently operating commercial department Radiation Protection Services which until 2005 was not much involved in the internal radiation safety matters of RTD Netherlands, now has the task to perform field inspections, and radiation safety audits in the regions. Because the core business of this department is "radiation safety" it has a different safety sub-culture or safety climate than other parts of RTD Netherlands. This potentially will have a positive effect on the safety culture of RTD Netherlands as a whole. Therefore

the emphasis of the field inspections is more on exchange of information, learning and helping, than on checking if the rules are obeyed. Nevertheless knowingly violating the rules will be sanctioned, and repeated or wilful violation will result in the dismissal of employees.

We want to create a climate in which the radiographers are encouraged to report all "near misses". In fact the report of "near misses" has always been rewarded. Safety, or toolbox meetings are organised in which radiographers are involved, and can ask questions or state their ideas on radiation safety issues. Although all our radiographers have completed a five day course on radiation protection, of which the diploma is formally recognised by the Dutch authorities, there is an initiative within RTD for tailor made refresher courses on radiation safety in industrial radiography.

Without having performed a deep analysis or a value judgement of the safety culture of RTD Netherlands, from the above description it will be clear that the components that are shown in figure 1 are implemented at RTD Netherlands.

5. Conclusion

From the literature it is clear that safety culture, although being an abstract concept, plays an important role in the safe performance of industrial radiography. Necessary elements of a positive safety culture are identified at RTD Netherlands.

The safety culture of RTD was not developed on the basis of theory but on the basis of common sense and under the influence of its corporate culture. It will be fostered, and further developed.

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