In Wilpert, B. & Itoigawa, N. (eds.) (2001): Safety Culture in Nuclear Power Operations
Taylor & Francis, London, ISBN 0-415-24649-0.

CHAPTER TEN

Assessing the Influence of Organizational Factors on Nuclear Safety

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The importance of organizational factors in the causal mechanisms of human errors and in the control of recovery in nuclear safety has been recognized by many organizations around the world. Despite this recognition, there are as yet very few methods for systematically assessing and improving organizational factors. The majority of research efforts applied so far have tended to be modest and scattered. This chapter builds on various projects at VTT Automation, which is one of the nine research institutes of the Technical Research Centre of Finland (V7'T). A preliminary framework is presented which describes how various organizational aspects may influence nuclear safety. This framework is thought to provide a kind of metamodel to be used for defining methods and tools for assessing safety and organizational efficiency. Ideally, the framework should support the definition of safety indicators, the construction of organizational surveys, the implementation of self-assessment methods, and so on. Some thoughts on how to continue this research are provided in the conclusion.

It is widely recognized today that the safe and reliable operation of nuclear power plants depends not only on technical excellence but also on individuals and the organization. Unfortunately, there are far fewer models and methods for assessing the influence of human and organizational systems on safety than there are for assessing the influence of technical systems. Safety management must build on a thorough understanding of the interactions between technical and organizational performance in order to be efficient. Investigations of incidents and accidents clearly demonstrate the importance of organizational factors as initiators of events and as factors that can make the consequences of events worse.

Since the use of nuclear power for the generation of electric power, the nuclear power industry has experienced two devastating accidents. Both accidents initiated a thorough reevaluation of contributors to nuclear safety. The first accident was in 1979 in the United States at the TMI-2 plant near Harrisburg, Pennsylvania, and demonstrated the importance of the human factor to the whole nuclear commu-

nity. A contributing factor to the second accident in 1986 at Chernobyl Unit 4, near Pripyat in the Ukraine, was a deficient safety culture at the plant.

The history of nuclear power illustrates a shift of emphasis in the safety considerations from mainly technical issues to human factors and broader issues connected to organization and management. This shim can also be seen in international interest in the concept of safety culture and the assessment of safety culture through peer reviews. Of course, the risk of accidents cannot be removed from nuclear power operations, but today there is an increased recognition among nuclear power plant operators that the economic risk connected to extended outages can be equally important to address.

The concepts of organizational factors and safety culture are closely linked, and the methods proposed for their assessment have much in common (see Wilpert, in this volume). Unfortunately, neither of these concepts is directly applicable to operational safety management at nuclear power plants. Various efforts have been made to bring the concepts closer to the normal day-to-day activities at nuclear power plants, but there is still considerable confusion even in the definition of the concepts.

This chapter reviews some ideas and findings connected to organizational factors and safety culture from recent and ongoing projects at VTT Automation. In particular, the project "Organisational Factors: Their Definition and Influence on Nuclear Safety" (or "ORFA"), funded by the Nuclear Fission Safety Programme of the Commission of the European Communities, has been very influential (Baumont et al., 2000).

A CHANGED ENVIRONMENT

The nuclear power plants of today operate in an environment that has changed dramatically over the last 25 years. In the 1970s, nuclear utilities were large state or municipality-owned companies that were able to recover their costs through electricity tariffs. Today, the deregulation of the electricity supply has forced electricity producers to respond to signals from a competitive market. The increased competition has also forced nuclear utilities to become cost-efficient. Where technical excellence was the driving force for many nuclear utilities in the past, today nuclear utilities are more often governed by concepts such as rightsizing, return on investments, and shareholder values. Structural changes throughout the industry, brought on through acquisitions and mergers, also necessitate bringing together different company cultures.

The changes brought on by deregulation have triggered an increasing pace of change in nuclear power plant operations. In search of efficiency and cost reductions, nuclear power plant operators have applied concepts and methods from business management in the market-driven industries, but this strategy brings its own dangers. The process of carrying out cost reductions entails a risk that crucial competencies will disappear, bringing on devastating consequences. Sound succession planning and the maintenance of organizational memory are also problematic at

present, for the recruitment of young people has become increasingly difficult. These changes are further aggravated by aging plants and obsolete Instrumentation & Control systems, which force nuclear power plants to modernize even though the scarcity of resources and personnel make it difficult to manage such projects.

The regulatory climate of nuclear power has also changed. In the pioneering days of nuclear power, regulation was created almost in parallel with plant concepts. Today there is a well-established regulatory framework, and regulation requires continuous investments in safety improvements. Early regulation was technical in its content, but today regulators also stress the quality of work in various safety-related work processes. Requirements concerning human and organizational factors are also coming under regulation. Changes in the regulatory framework have increased the burden of proof for nuclear power plants in demonstrating continuing safety. International cooperation has brought some harmonization into national regulation and safety practices, but there are still considerable differences in regulatory approaches.

The largest problem, with which the entire nuclear community is struggling worldwide, is the waning societal support for nuclear power. During its early phases nuclear technology was seen as very advanced, but now media coverage often connects nuclear power with images of backwardness and danger. In some countries, the societal support of earlier times has now declined to such an extent that even societal disobedience is tolerated as a way of expressing opposition to nuclear power.

REQUIREMENTS FOR ASSESSING ORGANIZATIONAL PERFORMANCE

Practices for safety management have improved considerably over the years. The primary force behind this improvement has been a systematic collection and analysis of operational experience. This pool of knowledge has been efficiently shared between nuclear power plant operators all over the world through the efforts of international organizations such as the International Atomic Energy Agency (IAEA), the World Association of Nuclear Operators (WANO), and the Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA). The difficulty, however, is that in periods of rapid change, learning through experience may not be efficient enough to avoid safety-related incidents. It has actually been argued that rapid societal changes combined with increased pressure for cost-effectiveness may create situations in which organizations have a high tendency to failure (see Rasmussen, in this volume).

The organization of a nuclear power plant can be seen as analogous to a control system, which ensures that activities and work processes are carried out efficiently and satisfactorily. This control system is implemented by people and through people, which means that it is both self-structuring and adaptive. When this control system functions as intended, the nuclear power plant can be operated safely over prolonged periods. An organization, like any other control system, re-

lies on continuous feedback on performance at several levels in order to initiate corrective actions when problems are detected. An assessment that provides feedback on organizational performance in its entirety can be seen as one way of closing the loop.

An organizational assessment requires a norm so that comparisons can be made. What are the characteristics of organizational excellence, which organizational structure is optimal, and how can deficient performance be detected? Unfortunately, there are no generally accepted norms by which the performance of a nuclear power plant organization can be assessed. Various models and methods have been suggested, but they are mostly based on assumptions, limited experience, and expert opinions. Another problem is that any assessment will be subjective when both the assessors and the assessed have stakes in the outcome.

In building models and methods for organizational assessments, one has to have a good understanding of how an organization functions. This prerequisite includes an understanding of how sometimes subtle influences can, through avalanche effects, simultaneously undermine several safety precautions. The models also must include a description of the processes and activities by which safety is ensured at a nuclear power plant. The rapid changes taking place in the nuclear power industry make it increasingly important to bring in proactive organizational planning together with feedback on experience. Unfortunately, there are very few, if any, methods available for assessing the safety impacts of organizational changes.

CONCEPTS, ACTIVITIES, AND PROCESSES IN BUILDING SAFETY

Goals and requirements set the scene of all activities in an organization. Goals and requirements are in part provided from the outside and in part defined within the organization. An organization responds to goals and requirements through a process of planning and execution. In this process various tools and methods are used to achieve the required work quality. Finally, the collection and analysis of operational experience provides feedback for further refinements in control processes.

The concepts of authority and responsibility are important in considering the tasks people do within an organization. A common requirement in high reliability organizations is that a clear line of authority and responsibility should be in place by means of which everyone has a superior to whom he or she reports. The line organization is typically represented through an organizational chart. Assumptions about authority and responsibility are written into organizational handbooks, but they are also implicit in procedures and practices.

A few basic activities can be used to break up tasks into smaller parts. One set of such activities is to manage, construct, operate, maintain, verify, and analyze. These activities can influence the technical systems for resources used by the organization. In a discussion of resources the following types may be distinguished: financial, human, information, tools, methods, space, and time. Activities are con-

nected to larger entities, which together form the work processes within safety management (Rollenhagen, 1999).

Work processes are sometimes considered to be complementary to organization line organization. Work processes give a horizontal view and the line organization a vertical view of the organization. Of course, when considering work processes at a nuclear power plant, one can define and structure them in many different ways. Some work processes are directly connected to the nuclear power plant itself and others to creating and maintaining resources used by the main processes. Often, models of the work processes need to be built in order to be able to assess how they interact. Formal tools have been developed for this purpose.

Many attempts have been made to identify and define issues connected to organization and management that are important for nuclear safety. One recent report identified 12 organizational factors that should be considered in an assessment of safety management practices (OECD/NEA Committee on the Safety of Nuclear Installations, 1999). In spite of general agreement on the importance of organizational factors, there is unfortunately, no consensus on their definition or relationships. A general categorization of relevant variables connected to organizational factors important for nuclear safety is provided in Figure 10.1 (Wilpert, Miller, & Wahlström, 1999).

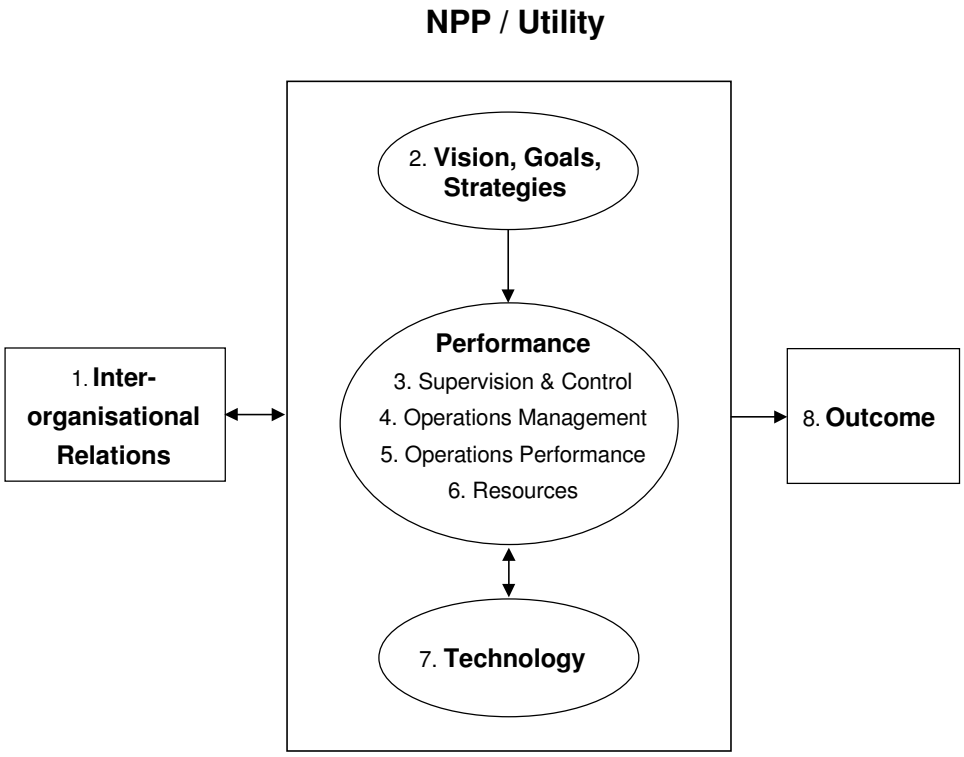

Figure 10.1 Organizational factors and nuclear safety: a categorization of relevant variables. From *Report on Needs and Methods* (Report No. AMM-ORFA(99)-R03) by B. Wilpert, R Miller, and B. Wahlström, May 1999.

DIFFICULTIES CONNECTEED TO DECISION MAKING IN NUCLEAR POWER PLANT ORGANIZATIONS

There are many similarities between organizations in general and organizations managing nuclear power plants, but there are also important differences. The most important difference is the very high safety requirement, which is due to the fact that the reactor requires continuous attention and that failures in this regard can lead to serious hazards. Experience has also shown that an incident anywhere in the world has an influence on the industry everywhere. The dilemma in this situation is that essentially no errors are allowed, yet the business risk is still connected to the worst performers in the whole industry.

A nuclear power plant is a very complex system, which for its operation demands high skills in several disciplines. The complexity of the interaction between various technical systems on the one hand and between the technical systems and the human and organizational systems on the other makes it very difficult to predict in detail how a nuclear power plant will perform in a specific situation. Management of the knowledge needed both in nuclear power plant operations and in the industry in general therefore becomes a very challenging task, especially when many young persons do not feel attracted to a career in the nuclear power industry.

Operational experience has shown that it is difficult to maintain the vigilance needed for continuous attainment of safety. There have also been examples where difficulties in managing the transition from design and construction to operation and maintenance have led to problems (Andognini, 1999). One may even advance the observation that past success can lead to complacency within the organization, which may produce a widening gap between actual and perceived safety performance. In addition, the higher levels of management must be extremely careful not to convey a mixed message on the need to cut costs, thereby shifting the focus away from safety issues.

Hands-on operational decisions are made in the main control room. These decisions depend on information presentations and procedures, which were created by design engineers. Various disturbances require a proper functioning of safety systems, which may be impaired by hidden maintenance errors. Plant management should be alert to problems both within the technical systems and in the interaction between technical systems and people. However, for various reasons management may not get proper signals of emerging problems (see Carroll & Hatakenaka, in this volume).

Probabilistic safety analysis (PSA) is one tool for modeling interdependencies in the systems. Unfortunately, this tool is not well suited to modeling the influence of human and organizational factors. The tool can, however, give indications of event sequences, which are sensitive to human errors and thus target efforts in developing information presentation, procedures, and training. One way to use the tool for assessing organizational factors is to define the assumptions (which should be present for the PSA to provide a believable estimate of the risk) as an organiza-

tional norm. When these assumptions are made explicit it is easier to check their validity in an organizational assessment.

METHODS FOR ASSESSING ORGANIZATIONS

Organizational performance can be assessed through various methods. Some rely on an external team of assessors, but most methods can also be used for self-assessments. Data for the assessment can be collected through the use of observations, inspections, interviews, and questionnaires. Checklists are available for carrying out audits and peer reviews. One problem with many methods is that they are not theoretically grounded. This situation makes it difficult to carry out intercomparisons of results obtained through two methods. All methods must be adapted to the language and the organizational culture to which they are applied, which makes it difficult to do intercomparisons between data collected at different nuclear power plants.

As a service to their members, the IAEA and WANO have developed various schemes for carrying out peer reviews. Typically, a team of 10 to 15 international experts during a two- to three-week mission carries out the reviews, which include observations, inspections of documents, and interviews. The services provided by the IAEA include Operational Safety Review Teams (OSART: organization and management), Assessment of Safety Significant Events Teams (ASSET: incident analysis), and Assessment of Safety Culture in Organizations Teams (ASCOT: safety culture).

Most nuclear power plants have well-established practices to monitor and analyze operational events and incidents at their facilities. The goals of implementing these practices are to learn from available experience and to correct observed deficiencies in the plant and its operations. A common aim in the investigation is to identify root causes of the incident. In the analysis process it is important to search for not only the technical causes but also the human and organizational causes. In assessing organizational performance one can consider events that have been analyzed and conclusions that have been reached and thereby assess the event analysis process itself.

Performance indicators axe used by some nuclear power plants to give regular feedback on performance. Such indicators can give management valuable information on the performance of the technical, human, and organizational subsystems. When work practices are compared across different nuclear power plants, performance indicators can also give valuable information on different ways of designing and conducting safety-related activities. Such benchmarking exercises can both provide a qualitative feeling for differences between two organizations and give hints for further improvements (Wahlström & Kettunen, 2000).

When making an organizational assessment it is necessary to agree on the depth of the exercise and to identify the topics to be addressed. A decision to go deeply into organizational activities may involve a great deal of effort, but a shallow study may not be able to bring the most important issues to light. Activities

with a big influence on safety are always more important to investigate, but a focus on such activities may leave problems in peripheral activities unnoticed. It is sometimes necessary to involve outsiders to ensure impartiality in making interpretations and recommendations. It also may be easier to achieve openness in interviews if persons outside the organizations carry them out.

A FRAMEWORK FOR CONSIDERING ORANIZATIONAL FACTORS

A systems approach provides a suitable basis for establishing a framework to consider organizational factors. A systems approach involves a division between the system to be investigated and its environment. It also assumes that the construction of a model of the system can aid significantly in understanding and controlling the system. The concept of a model carries the related concepts of components and their interactions. The division of a system into smaller parts also enables two views: that of the entire system and that of its details. In considering interactions between components of a system, the concept of causality is important. In the examination of human and organizational systems' components, understanding and intention are added to the usual physical causality of technical systems.

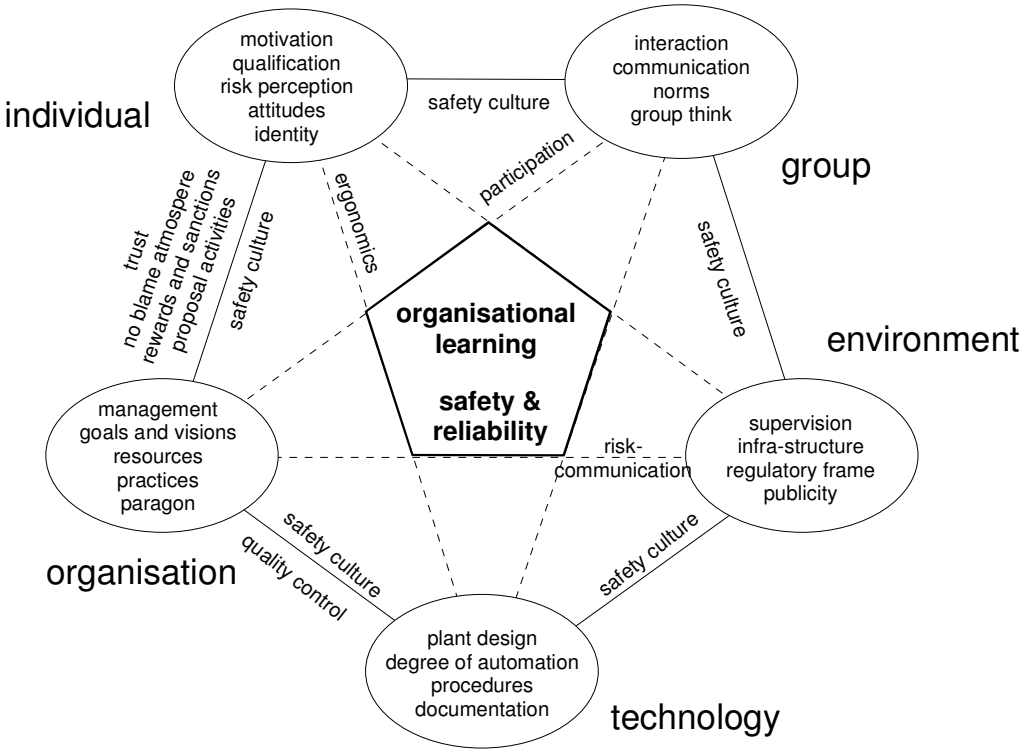

Figure 10.2 The five interacting systems of nuclear safety

The first step in dividing the nuclear power plant system into components is to consider the four subsystems of technology, organization, groups, and individu-

als together with their interactions. There are also interactions between the environment and each of these subsystems. Important parts of the nuclear power plant environment are supervision, infrastructure, the regulatory framework, and publicity. Within the technology subsystem there are important parameters to be considered, such as plant design, degree of automation, procedures, and documentation. In the organization subsystem issues such as management, goals and visions, resources, practices, and best-practice examples become important. On the group level, interaction, communication, norms, and groupthink should be considered. Finally, on the individual level issues such as motivation, qualifications, risk perception, attitudes, and identity contribute to performance. In this way safety culture can be seen as a feature that penetrates all subsystems and their interactions (see Figure 10.2).

Further examination of the organizational subsystem entails many more dimensions that can be considered relevant to an assessment. The extent to which an organization has structure is an important characteristic when one assumes that a nuclear power plant organization requires some minimal degree of structure. A second dimension relates to the integration of the activities and the assumption that efficiency requires some reasonable amount of integration. A third dimension is the degree of self-reflection that the organization is able to exercise, assuming that self-reflection is necessary for consciously proactive nuclear power plant operation.

Table 1.1 Common dilemmas of efficient management

traditions	vs.	renewal
formal	vs.	informal
self-confidence	vs.	willingness to listen
co-operation	vs.	competition
centralised	vs.	distributed
discipline	vs.	flexibility
focus on details	vs.	maintaining an overview
monitoring & reporting	vs.	confidence & accountability
short term	vs.	long term optimisation
specific/practical	vs.	generic/theoretical

Similar considerations that may be used in assessing organizational characteristics are qualities conveyed through the dimensions "open/closed" and "formal/informal. The "openness" or "closedness" of an organization gives a measure of how easy it is to become a member of the organization and the extent to which it reveals its principles of operation to outsiders. Open internal communication can be assumed to be necessary to detect and correct problems, but a nuclear power plant organization must also be somewhat closed to protect its members. Similarly, the formality of an organization expresses the extent to which it relies on established procedural tasks as opposed to flexibility and ad hoc procedures. Nuclear power plants certainly depend on formalized procedures, but these procedures should not

be allowed to stifle individual initiative. More generally, these dimensions can be thought of as a conceptualization of common dilemmas faced by efficient management (see Table 10.1).

Recommendations for Further Research

There is a long way to go before models and methods for the assessment of the influence of organizational factors on nuclear safety reach a stage where they can be applied routinely in operational safety management. To reach such a level, efficient communication between theory and practice must be established. Such communication must build on trust that the information disclosed by nuclear power plants is not used against their interest. If the polarization of opinions on the use of nuclear power is further increased, it may, unfortunately, be difficult to reach the required level of trust.

The nuclear power plant subsystems and organizational factors to- be considered were discussed earlier in this chapter. Further research might attempt to map the interfaces between subsystems and organizational factors more accurately and investigate causal couplings between factors. To some extent this step also implies the elicitation of tacit knowledge that skillful managers use to make their experience sharable within the nuclear community. The contribution of the research community in this endeavor would be to systematize and generalize the knowledge collected.

It may even be possible to move forward by only making the consideration of organizational factors more explicit than in the past. If a discussion of organizational factors can create greater self-reflection together with an awareness of various pitfalls, the participants can improve as managers. These improvements will, however, not make various models, methods, and tools unnecessary but rather give them a place among other organizational resources in meeting the challenge of ever-increasing efficiency and safety needs.

In the short term, future research might engage in building models of organizational structure and work practices, describing good practices in a rapidly changing environment, identifying obstacles to organizational learning, developing methods for considering organizational factors in incident analysis, suggesting methods for organizational self-assessments, and comparing safety management practices. In the longer term, research could engage in the development of theoretical models of how organizational factors interact with crucial components of performance, proactive methods for organizational design, methods for the integration of organizational factors into PSA models, and an understanding of the impact of cultural influences in the safety management of plants and in the relationship between plants and regulators.

CONCLUSIONS

The consideration of organizational and management issues as contributors to nuclear safety is becoming increasingly important. One difficulty is the absence of a theoretical framework within which organizational factors and their causal relationship can be dealt with. Such a theoretical framework could also support data collection and organizational development.

A consideration of organizational factors must rely on well-grounded models. A theoretical framework can be found in psychology, sociology, and the management sciences. The problem in finding suitable models is to strike a proper balance between models that are too simple and give only trivial answers and models that are too complex to be practical. The models must be understandable for those expected to use them.

When beginning research aimed at investigating connections between organizational factors and nuclear safety, there are some pragmatic guiding principles that should be attended to. First, the efforts should address real cases of organizational change in nuclear plants or companies. Second, the data should be collected in a way that supports systematic intercomparison of important issues. Third, each case study should be summarized with an account of lessons learned in the use of methods and tools. And finally, general findings should be drawn and documented in a way that makes them accessible across national and company cultures (cf. Hofstede, 1997).

Safety is a fundamental prerequisite for the use of nuclear power. The extreme safety requirements of nuclear power generation necessitate special precautions and methods, which may not be found among those precautions and methods used in the market-driven industries. The consideration of high reliability organizations as an object for research may help in this endeavor. A fruitful combination of theory and practice is a necessary precondition for success. If these efforts succeed, nuclear power can continue to be a realistic energy option in the future.

Acknowledgement

The support for this research from the Fourth Framework Programme on Nuclear Fission Safety of the Commission of the European Communities (Contract No. ERB FI4S-CT98 0051) is gratefully acknowledged.

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