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CONVERGENCE OF NUCLEAR SAFETY PRACTICES

"Convergence process of regulatory safety approaches over 25 years"

Pierre GOVAERTS (AVN - Belgium)

1. Introduction

In the late fifties, the first nuclear power plants were built in some Western European countries, at a time international organisations like IAEA and Euratom were created in the perspective of a rapid growth of nuclear applications. It was recognized that regulatory matters were a national responsibility but that transboundary effects might take place, hence the transmittal of information on new installations as requested by Article 37 of the Euratom Treaty.

Through exchange of views between Regulatory Bodies, some convergence process was de facto initiated. In this paper three different approaches will be examined:

- convergence through discussions of technical subjects in international working groups
- convergence through the development of common industrial projects
- convergence through direct comparison of safety requirements.

2. Technical Working Groups

In a European regulatory perspective, the example chosen for international working groups will be "Working Group 1" (WG1) created at the end of 1972 by the European Commission to advise it on safety matters, i.e. safety methodologies, criteria, standards, etc.

One should however not ignore also the role played by discussions between colleagues at the R and D level, and the participation to joint R and D projects. The EUROSAFE meetings and the Euratom Framework Programmes show the interest of such joint initiatives. A common understanding of the physical phenomena involved is indeed a prerequisite for a convergence process of regulatory decisions.

2.1 Composition and mandate

WG1 was composed of representatives of the Member States from "the licensing and regulatory authorities and associated safety and control organizations on one hand, and the utilities and the vendors on the other."

In the late seventies WG1 kept the same composition but meetings were also organized between only safety authorities, a working group renamed in 1992 the "Nuclear Regulators Working Group (NRWG)".

The Council Resolution of 22 July 1975 on the technological problems of nuclear safety has served as the mandate of the WG and has defined its objectives and working methodologies.

Some excerpts of that Resolution are:

- « requests the Member States […..] to continue to collaborate effectively at Community level » ;
- « agrees to the course of action in stages indicated below by the Commission in respect of the progressive harmonisation of safety requirements and criteria in order to provide an equivalent and satisfactory degree of protection of the population and of the environment against the risks of radiation resulting from nuclear activities, and at the same time to assist the development of trade on the understanding that such harmonisation should not involve any lowering of the safety level already attained […..]. The stages involve listing and comparing the requirements and criteria applied and drawing up a balance sheet of similarities and dissimilarities, formulating as soon as possible recommendations pursuant to the second indent of article 124 of the Euratom Treaty, and subsequently submitting to the Council the most suitable draft Community provisions » ;
- « requests the Member States to notify the Commission of any draft laws, regulations or provisions of similar scope concerning the safety of nuclear installations […..] » ;
- « requests the Member States to seek common positions on any problems concerning the harmonisation of requirements and criteria and the coordination of research into nuclear safety being dealt with by international organisations » ;

2.2 First achievements towards convergence

In line with the Council Resolution the work was first centered on the comparison of practices in the Member States on topics deemed important to safety. Subjects considered were accidents from internal origin, like loss of coolant, steam line break, anticipated transients without scram, fuel handling accidents… External hazards were also studied, like aircraft crash, external explosion, floods, seismic effects. For that last point, the earthquake to be considered in the design was defined, and the data of historic earthquakes in the different national catalogues were compared and made consistent for the whole of Western Europe. That catalogue was later extended to cover Central and Eastern Europe and in 1997 also the former Soviet Union. To establish consistent data is ensuring convergence at the very basic level.

Member States concluded from the experience gained in these exercises, that the comparison of practices on different topics was not enough and that it needed to be structured and put in a more general framework. In this spirit the Working Group developed the document "Safety

principles for light water reactor nuclear power plants" published in 1981 as a communication of the Commission to the Council (COM (81)519).

In its introduction the document states:

> "Although the aim is to achieve an equivalent and satisfactory degree of protection of the population and of the environment, the way to obtain this degree of protection may differ from country to country.
> The basic principles, however, must and can be common, as far as they reflect the objectives but not the way to reach them".

In its first part the document enunciates ten fundamental safety principles in order to minimize the risks from the installation, reduce the radioactive releases and the doses to the workers and to the public (ALARA principle).
The prevention of accidents is addressed in the last 5 of these fundamental principles: all reasonably practical steps shall be taken to prevent accidents, minimize their radiological consequences to the general public and to the site personnel, who should not be hampered by his exposure to take mitigating actions. The more serious the potential consequences of an accident, the smaller should be the probability of its occurrence.

The second part lists eleven general safety principles, as a way to implement the fundamental principles. It introduces inter alia the concepts of "defence in depth", of the successive barriers between the radioactive products and the environment, and stresses the importance of quality assurance, reliability and testability of the barriers and corresponding systems, the completeness of the safety analysis (which kind of events and combinations of them are taken into account), the consideration of external hazards, the man-machine interface, the training of the personnel.

The third part lists a number of specific topics, which might be possible subjects for future safety requirements. There are strong similiarities with the topics addressed later on in the safety guides of the IAEA NUSS programme.

Note that this "Safety principles" document is still relevant at the present time and also note its pioneering status, as it was the first in a series of international documents on the main nuclear safety principles, i.e. INSAG3 "Basic safety principles for nuclear power plants", the IAEA "Safety Fundamentals" listing 25 safety principles, which were reordered and better structured in the technical part of the "Nuclear Safety Convention" adopted in 1994.

2.3 Consensus documents of 1988 and 1995

The TMI accident showed the importance of the human factors in the evolution of accidents, in particular the qualification and training of operators.

The practices on this topic in the different European countries and in the USA were compared. All countries recognized the importance of operator training both for normal operation and operation under fault conditions and in particular they stressed the importance of systematic training (and retraining) programmes using simulators. The training of maintenance personnel was also seen as important, as errors made during maintenance might induce common mode failures.

Comparison of practices was also made for ALARA in design and in operation, for the integrity of the second barrier (overpressure protection system and consequences of the PISC

results on in-service inspection programmes), for the integrity of the third barrier (procedures for leak testing, hydrogen related problems), for emergency planning.

The degree of convergence reached in all these fields was described in the "Consensus document on safety of LWR" issued in 1988, which also indicated that severe accident management should be examined in the future.

From 1990 on, Western European Regulatory Bodies participated to the assistance to their counterparts in Central and Eastern Europe. In this perspective reports describing the objectives and requirements for an effective nuclear safety regulatory regime, according to Western practice, were produced. It was the occasion to reaffirm that the principal responsibility for the safety of an installation must lie with the operating organisation, and that the role of the regulator is to monitor and implement the safety objectives in accordance with the laws and regulations. The licensing procedure, as practiced in four Western countries, was also described.

The "1995 Consensus document on safety of European LWR" covered three main domains:

- safety in operation ;
- source terms and off-site consequences for design basis accidents ;
- severe accidents.

The "Safety in operation" chapter examined the in-service inspection programmes and the work pursued on the qualification of NDT at the level of the regulators and at the level of the utilities in order to establish a European methodology for inspection qualification. It also addressed ageing of components, systems and structures and stressed the need to implement data collection and record keeping systems.

Drawing on INSAG4, the concept of safety culture was discussed with all its implications for all organisations involved.

The chapter on source terms and off-site consequences for design basis accidents recognized the very large variations in the magnitude of the source terms due to widely differing degrees of conservatism at each step of the calculations. Hence there was a need to examine more realistic assumptions and better define the uncertainties affecting the different physical phenomena involved.

The chapter on severe accidents described the status of knowledge regarding in-vessel debris cooling, high pressure core melt, core concrete interactions and ex-vessel debris cooling, steam explosion in containment due to water being in the cavity, late containment failure due to overpressure, hydrogen burning or detonation, fission product retention in the containment. These evaluations were based on the work at OECD/NEA and the results of the EC research programme and other international programmes.

It was concluded there was a wide consensus on the use of improved procedures to monitor and maintain critical safety functions, like core cooling, independently of the cause of the accident. There was also a consensus on the severe accident phenomena of greatest importance for the successful containment of the severe accident consequences and the procedures for mitigating their effects. But there was still scope for reducing the uncertainties, e.g. in the assessment of debris coolability.

The report noted also initial moves between utilities and regulators of different countries to achieve a harmonized position on the requirements for future plants.

2.4 Some achievements in convergence of regulatory positions

a. In the mid-eighties the experience gained by countries which had already begun "Periodic Safety Reassessments (PSR)" was reviewed and the three main objectives of these PSR's were clearly defined:

   – to confirm that the plant is as safe as originally intended ;

   – to establish the exact plant status with respect to ageing and wear out and evaluate any factors which may limit the safe operation of the plant in the future ;

   – to justify the current levels of safety of the plant by comparison with current safety standards, and to propose eventual improvement.

   Periodic Safety Reassessments are now required in all Western European countries and there is a complete consensus about their objectives. It is a safety concept developed in the EC countries that has been introduced afterwards in the IAEA documents.

b. As mentioned above there were very large differences in the source terms used in the calculations of the radiological consequences of design basis accidents (e.g. LOCA) due to varying degrees of conservatism. Studies undertaken in the last ten years have distinguished the scenarios to be considered and have allowed to reduce the uncertainties about a number of parameters. There is now convergence on the assumptions for future plants (e.g. in EPR studies) but there is no incentive to apply these models for existing plants.

c. At the end of 1992, NRWG decided to set up a Task Force on qualification of non-destructive testing (NDT) systems for pre- and in-service inspection of light water reactors with the following objectives:

   – to agree on the philosophy and principles governing the qualification of techniques, equipment, software, procedures and personnel for NDT to be used for inspection of structural components that are important to safety in nuclear power plants ;

   – to establish a common view on essential aspects of NDT qualifications.

   It published in 1996 the common views of all participating regulatory bodies in the report : « Common position of the European regulators on qualification of NDT systems for pre- and in-service inspection of light water reactor components ».

   In parallel European utilities, grouped in the European Network for Inspection Qualification (ENIQ), finalized in 1997 its second version of its « European methodology for qualification of non-destructive tests », which is in relatively close agreement with the positions of the regulators.

   The present work of the NRWG Task Force is the evaluation of the results of ENIQ pilot studies from a regulatory viewpoint. This is underway as all the results of the ENIQ exercises are not yet available.

   In this field a common position of the regulators has been reached and they examine how the utilities implement it.

d. The report “A comparison of European practices for the qualification of electrical and I&C equipment important to safety for European LWR NPP” showed that the general principles of the qualification and the main elements of the methodologies were similar in European countries but that the test severities and the differences in test methods were two obstacles to achieving a common acceptance of the qualification between the countries.
Further detailed studies concluded that the qualification file produced in one country cannot be adopted in another country without a case-by-case appraisal of the specific qualification methods, the parameters, the equipment’s required safety function and duration against those described in the qualification file.
Hence the national requirements should first be harmonized if the aim is that a new qualification is acceptable in all countries.

e. In the mid-nineties, as applications of digital systems to perform safety functions were becoming more frequent, a Task Force was launched with the mandate of “reaching a consensus on software licensing issues having important practical aspects”.
By that time, experts had recognized that the assessment of software could not be limited to the verification and testing of the end product, i.e. the computer code. Other factors such as the quality of the processes and methods for specifying, designing and coding had proved to have an important impact on the implementation. Existing standards provided limited guidance on the assessment of these factors. An undesirable consequence of this situation was that the licensing approaches taken by nuclear safety authorities and by technical support organisations were determined independently and with only limited informal technical co-ordination and exchanges. It was also notable that several software implementations of nuclear safety systems had been marred by costly delays caused by difficulties in coordinating the development and the qualification processes.
Eighteen issue areas were selected as being the most critical ones. They were partitioned into two sets: “Generic Licensing Issues” and “Life Cycle Phase Licensing Issues”. Issues in the second set were related to specific stages of the computer based system design and development process, such as for instance the specification of the initial requirements, the coding and programming practices or the verification and validation tests. Issues of the first set have more general implications and apply to several stages or to the whole system lifecycle, such as the problems raised by independent assessment, and the validation of tools.
For each issue area, the following main aspects were systematically analysed and developed:

- A Rationale for the issue in terms of a description of the technical problems to be resolved;
- A Common Regulatory Position on these problems in terms of the minimal evidence which could be required;
- A set of recommended practices.

The Common Positions were intended to represent the common denominator of practices in the Member States taking part in the task force. The Recommended Practices were those supported by most - but not systematically implemented by all - Member States represented in the task force. Some of the recommended practices also originated from proposed common position resolutions on which unanimity could not be reached.

The results of this work have been published in the report “Common position of European nuclear regulators for the licensing of safety critical software for nuclear reactors”.
It has already been used by regulators as a guidance document and was praised by manufacturers and I&C suppliers as helping in their design work.

f. Two subjects under review now are the risk-informed in-service inspection applications and the regulatory assessment of the effects of economic deregulation of the nuclear industry.
In both cases the objectives are to sum up the experience gained in the countries already engaged in these processes, which need careful regulatory attention, to identify the difficulties and the problems and to share that experience among all countries, which will be the basis of a common approach of these subjects.

3. Common industrial projects

On the European scene, the most obvious example of a common industrial project is of course the European Pressurized reactor (EPR).

A very detailed presentation of the project and of the results achieved during the concept definition period took place in November 1995 at the joint SFEN-KTG Conference in Strasbourg.

From a regulatory perspective, it is recalled that the French and German Safety Authorities issued a common declaration in 1993 on the main safety objectives for future PWR’s, in particular the practical elimination of some severe accident sequences.

In the following years, in-depth technical discussions were devoted to the protection against external hazards, severe accident and containment design, primary system integrity, radiological consequences of design basis accidents and accidents involving core meltdown at low pressure, use of probabilistic assessments and design of safeguard systems (conceptual and basic design phases). It means there has been convergence of safety approaches up to detailed technical solutions and in many cases departure from the national rules applying to existing reactors.
It remains a Franco-German exercise but the main results have been presented to other Western Safety Authorities on several occasions.

On a more general level, work has also been performed by European Technical Safety Organisations on the key safety issues for future large evolutionary PWR’s. The study considered of course the options of the EPR project, but also other reactors recently built or at the project stage (Sizewell B, System 80+, AP600,…). A list of 30 key safety issues was prepared, and after grouping and prioritisation, 12 issues were selected for in-depth analysis and development of a common approach. A summary of that work has been recently published (EUR 20163).

On the Utilities side, a consortium of European Utilities has produced the European Utilities Requirements Document, containing the set of requirements to be met by the vendors and suppliers of nuclear systems. Compared to existing reactors, the main new requirement is the addition of a fourth safety level in the defence-in-depth concept: these are the “design extension conditions”, which encompass a number of situations formerly considered beyond the design basis, including severe accidents.
That EUR document has been submitted to the European regulators by their respective

Utilities. Some parts of the document have been reviewed in common by European regulators, but it has not been possible to review the whole document, as it was not a priority work due to restricted manpower and the difficulties for some regulators to work on projects when no application for a licence has been submitted. This situation differs from that in the USA where the USNRC has already issued a few design approvals while no construction permit application has been docketed.

4. Direct comparison of safety requirements

All Western European nuclear countries have ratified the International Nuclear Safety Convention and have consequently explained in their national reports and at the meetings of the Contracting Parties how they fulfilled the corresponding requirements.

This shows a commonality of objectives, but the ways to respect these requirements may differ, due for instance to the historical development of nuclear energy and of nuclear regulations in each country. Hence the Convention will not by itself tend to the harmonisation of detailed safety regulations.

The Western European Regulators Association (WENRA) has in its Terms of Reference the objective to proceed towards a harmonised view on reactor safety in EU countries with a nuclear programme. Accordingly it has set up a working group with the task to:

- have a common understanding on any significant differences that may exist between WENRA countries with regard to safety requirements for existing reactors of different design generations ;
- suggest appropriate steps, if necessary, to move towards a harmonised approach to reactor safety.

In this context harmonisation is defined as “no substantial differences between countries from the safety point of view in generic national safety requirements, and in the resulting implementation in the nuclear power plants”.

It means that a harmonised safety level must have a legal basis and that it is not considered sufficient to harmonise safety based on voluntary or other less formal agreements with the industry.

The working group has developed a methodology towards harmonisation: for a selected significant safety issue, the requirements existing in each country are identified with their status (legal requirements or formal recommendations); then, on the basis of the national requirements, reference requirements are defined reflecting the best national practices (“highest quartile” of existing requirements) and are compared to the latest IAEA requirements as a check; the next step is to assess in a panel the status of the requirements in each country and their degree of implementation with regard to the reference requirements and to conclude about any substantial differences to be further addressed for harmonisation.

That methodology has been applied in a pilot study to a few significant safety issues chosen in four safety areas: safety management, design, operation and safety verification.

The pilot study has just been completed and has shown the validity of the proposed methodology.

WENRA should soon decide what it intends to do on the way towards harmonisation of safety requirements for existing reactors.

5. Conclusions

Through collaboration in particular within international working groups, which are fora to exchange information and experience on selected safety topics, a convergence on safety approaches and objectives has developed between the European countries.

There is complete agreement on the basic safety principles enunciated already 20 years ago in EC documents and somewhat later in IAEA documents.

The concept of Periodic Safety Reassessments has been developed and is shared by all European countries; it is typically a European concept that has been introduced later on in the IAEA safety documents.

Common positions of European regulators have been agreed in new areas like licensing of critical software and qualification of NDT systems. In more conventional fields, like environmental qualification, the general principles and methodologies are the same but the detailed safety regulations differ.

For common industrial projects like EPR, common regulations have been developed by the French and German Safety Authorities, including detailed design considerations.

The European regulators, who made common remarks, have assessed only parts of the European Utilities Requirements.

A process of harmonisation of safety requirements for existing reactors has been started as a pilot study by WENRA, whose members should soon decide on how to pursue that preliminary work.