# TRENDS IN NUCLEAR LICENSING

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**ABSTRACT**

The development of nuclear safety and licensing is briefly reviewed in four stages namely: The Formative Period (1946-1959), The Expansive Period (1960-1969), The Mature Period (1970-1979) and the Apprehensive Period (1980-1989). Particular safety issues in the respective periods are highlighted to indicate the changing emphasis of nuclear licensing over the past thirty years or so. Against this background, nuclear licensing in South Africa is discussed and possible future trends indicated.

## INTRODUCTION

Although the civilian nuclear power industry is still relatively young, having its origins some ten to fifteen years after World War II in the USSR (1954), UK (1956), USA (1957), France (1959) and Canada (1962) (NB. Dates denote approximate year for first criticality associated with electrical power generation outside the military environment), its growth potential during the coming decade will be severely limited unless ways are found to gain greater public acceptance. The credibility of nuclear power as a safe, cost-effective, environmentally clean method for meeting the world's energy demands has been severely impacted both by a number of major nuclear accidents (e.g. USA Browns Ferry (1975), USA TMI-2 (1979) and USSR Chernobyl (1986) ) as well as costly delays in the construction, licensing and commissioning of nuclear power plants. Public perception of nuclear power has been influenced by many factors such as its association with the tragic events during World War II (Hiroshima, Nagasaki (1945) ), the health hazards associated with nuclear fuels (short-term and long-term effects of radiation on the human body), the complexity of the technology, and the roles of participants in the nuclear industry (vendors, architect-engineers, licensees, regulators and governments).

Whereas thirty years ago the industry was driven by an optimistic vision of unlimited amounts of low cost energy sources and concerned primarily with problems of design, siting and construction of large (~ 1000 MW) reactors, today, problems of escalating costs, safe operation, accident management, waste disposal, decommissioning and public acceptance weigh heavily upon the industry. Throughout this period nuclear safety has occupied a central role, more so today than at previous times, and will continue to play a vital role in any future nuclear development.

The focus of attention of the licensing bodies responsible for overseeing that high standards of safety are maintained by the industry participants has varied over time, and from country to country, depending upon the particular circumstances of that country at that time. Factors such as the nuclear infra-structure (presence or absence of nuclear research capability, nuclear skills base), state of economic development, and governmental strategies towards the individual components of the total nuclear fuel cycle, have a strong influence on the licensing capability of a particular country.

To review the evolutionary development of licensing world-wide is not possible in a short paper. However by selecting particular aspects of licensing as they have evolved in particular countries it is possible to identify certain shifts of emphasis in the licensing process which have taken place during the past thirty years or so. Against this background it is instructive to view the licensing development in South Africa and possible directions for development during the next decade.

For the purposes of this paper it is convenient to consider the background licensing activities and nuclear power development in four phases, namely:
The Formative Period (1946-1959), The Expansive Period (1960-1969), The Mature Period (1970-1979) and The Apprehensive Period(1980-1989). This will provide a suitable framework for reviewing licensing development in South Africa.

## THE FORMATIVE PERIOD (1946-1959)

Following World-War II the five major countries involved in nuclear development (i.e. USSR, USA, UK, France and Canada), turned their attention to the peaceful uses of nuclear energy. Organisations were set up in the different countries to control nuclear development, (e.g. U S Atomic Energy Commission (1946), U.K. Atomic Energy Research Establishment (1945) / U.K. Atomic Energy Act (1946), French Atomic Energy Organisation (CEA) (1945), Canadian Atomic Energy Control board (1946) ), as plans were made to design nuclear reactors instead of nuclear bombs. Although nuclear safety considerations were implicit in all design work no formal licensing bodies existed at that time although various safety committees were brought into being as nuclear research and design work progressed (e.g. U.S. Reactor Safeguards Committee (1947) ).

By 1950 'rule-of-thumb' siting criteria had been issued in the USA (WASH-3 (1950)[1]), significant progress made by the NCRP and ICRP organisations towards defining permissible doses for radiation workers e.g. Second Tripartite (U.S., U.K., Canada) Conference on Permissible Doses (1950), and questions concerning physical security of nuclear installations addressed. The concept of containment as a measure of reducing the impact of incidental radioactive releases on the public had been significantly developed although specific criteria were not then available. Reactor designs tended to concentrate on electrical power outputs of the order 100-200 MW, rather than the 1000 MW or larger stations of today, so that cooling requirements were much less onerous. Commercial considerations of profitability were not so important during the Formative Period since most costs were being underwritten by Governments.

Serious concerns regarding the inherent safety of nuclear plants began to emerge during the late fifties when the adequacy of the design bases of reactors was beginning to be questioned more openly by critics both within and outside the nuclear industry. Predictions of the consequences of a severe nuclear accident as postulated in WASH-740 (1957),[2] notwithstanding the low probability of such an event, the Windscale Accident in the U K (1957)[3] and the demand of utilities for larger power reactors (500-600 MW) all contributed to a greater safety awareness towards nuclear power. This led to the establisment of a number of statutory bodies, such as the Advisory Committee on Reactor Safeguards (ACRS) (1957) in the USA and the formation of the U K Nuclear Installations Inspectorate (1960), specifically charged with overseeing the safety aspects of nuclear development particularly in the civilian field. It was also recognised that nuclear power and nuclear safety needed to be developed in a co-ordinated manner on a world-wide basis. This in part contributed to the formation of multi-country organisations such as the European Atomic Energy Community (EURATOM) (1957), and the International Atomic Energy Agency (IAEA) (1956).

By the end of the fifties there was limited experience with the operation of commercial nuclear power plants (USSR (6), USA (2), U K (8), France (1):- () denotes the number of operating reactors), all of low power by to-day's standards (< 280 MW), minimal public reports of significant nuclear accidents, significantly larger reactors (500-600 MWs) in design or under construction, but a growing concern with regard to design safety issues (e.g. siting criteria, maximum credible accident, single failure criterion).

**THE EXPANSIVE PERIOD (1960-1969)**

By the beginning of the sixties a basic safety philosophy had emerged which is conveniently expressed in the following four goals:

(1) There must be no release of radioactive material in dangerous quantities from a nuclear facility to the general public.
There must be no Public Safety Accidents.

(2) The likelihood of a serious accident which would result in severe damage to the nuclear facility should be kept as small as possible.
The Economic Accident should be prevented.

(3) Every reasonable effort should be made to eliminate accidents involving plant employees.
The frequency of Industrial Personnel Accident should be reduced to the lowest possible level.

(4) System malfunctions and deviations from normal behaviour should be reduced to a minimum, especially since a system with minor faults is more likely to develop major crises.
The number of Operational Problems should be kept to a minimum.

These qualitative goals are taken word for word from Thompson and Beckerley (1964),[4] some thirty years ago, and still remain valid today albeit with certain quantitative refinements in definition. Chernobyl (1986) and TMI-2 (1979) are examples of failure of the industry to achieve goals 1 and 2 respectively. There are also a significant number of recorded examples during the past thirty years (e.g. operator accidents, LER's, Occurrences, Incidents) demonstrating the failure of the industry to meet goals 3 and 4.

In order to meet the above goals, designs had to have appropriate quantitative criteria to work with. Defining Design Basis Events (Accidents) and associated loadings for containments was complicated by a lack of clear demarcation between Design Basis Events and Beyond Design Basis Events. The Single Failure Criterion was straightforward to apply but concern was raised about the possibility of multiple simultaneous failures either independent (low frequency) or dependent (high frequency).

An analysis of all nuclear related accidents up until 1963 had shown that three basic causes were primarily involved in a nuclear accident, namely:

1. An undetected design flaw
2. An instrument or equipment malfunction or omission
3. A human error of omission or commission.

One or two of the above causes could be present at the same time without causing an accident but combined simultaneously (i.e. low likelihood) with the third cause could lead to a major accident.

The licensing approach during this period was therefore much concerned with defining and interpreting appropriate safety design criteria (e.g. maximum credible accident, reactor site criteria 10 CFR Part 100 (1962) ) as well as resolving major safety issues related to reactor pressure vessel integrity (1966), the adequacy of the Emergency Control Cooling System (ECCS) (1966), recognition of the China Syndrome problem and correlation of core-melt with containment failure (1966). This led to the establishment of safety research programs such as the Heavy Section Steel Test programme for vessel integrity and the LOFT program for ECCS - LOCA analysis (1966), and the evolution of licensing requirements for improved integrity of pressure vessels, pre-operational and in-service inspection of reactor pressure vessels (1966), stringent Quality Assurance (1968), and the separation of control and instrumentation systems (1967). The licensing approach was basically deterministic and placed heavy emphasis on adherence to industry approved codes (with nuclear refinements where necessary) such as ASME and IEEE. This was also a period where more emphasis was being placed on Accident Mitigation rather than Accident Prevention.

Whilst the USA proceeded with its LWR programme, the main European countries such as the UK, France and Germany were also forging ahead with their own nuclear programmes using different nuclear technologies. In addition, ten other countries introduced commercial nuclear power throughout the sixties namely FRG (1960), CANADA (1962), BELGIUM (1962), ITALY (1962), JAPAN (1965), GDR (1966), SPAIN (1968), NETHERLANDS (1968), INDIA (1969) and SWITZERLAND (1969). Whilst the UK proceeded with its own gas-cooled technology (AGR (1965) ), as did France under de Gaulle, Germany entered into negotiations with General Electric (BWR) and Westinghouse (PWR) to import USA LWR technology into Germany under licence agreements.

The licensing of such reactors was carried out by various bodies such as the Nuclear Installation Inspectorate (UK), the centralised SCSIN in France advised by a technical department (IPSN) of the CEA, and by a two-tier licensing process in Germany involving both Federal (Commission for Reactor Safety RSK, Commission on Radiation Protection (SSK) ) and State (Land) organisations. Due to the international character of nuclear safety the types of safety issues then of concern in the USA applied also to the European countries but the acceptance criteria were not necessarily the same owing to differences in nuclear technology, the degree of acceptability of safety research results by the licensing bodies involved, as well as public and political pressures.

Although the deterministic approach to licensing was satisfactory in many respects, it still did not address the fundamental problem of Beyond Design Basis Accidents, albeit of very low frequency of occurrence. Rather, an approach which, in principle, addressed all types of accidents, and measures to mitigate against them, was called for particularly in the light of the first goal stated above. Since 1966 the ACRS had been urging the US Atomic Energy Commission and the American utilities to adopt a broader approach without much success. Similar pressures had been building up in other countries, particularly in Canada and the UK, but it was not until 1967 that a non-deterministic approach to safety was formally proposed by Farmer[5] in the UK. This gave birth to the probabilistic approach to nuclear safety which gained momentum throughout the seventies.

THE MATURE PERIOD (1970-1979)

By the beginning of the seventies the licensing process in the USA was becoming very cumbersome and time-consuming for several reasons.

a) The number and variety of reactor and plant designs and vendors with which regulatory staff had to deal increased the delay time for issuing licenses.

b) A policy of openness in nuclear decision-making and a multi-stage decision process involving the public and court hearings added to delays. The requirement for an Environmental Impact Statement (1970) provided an opportunity for environmentalists to prevent or delay the issue of licences.

c) The number of generic safety issues needing attention was growing all the time. By 1972 a list of 47 such issues had been drawn up including loss of emergency power supplies, hydrogen burn after a LOCA, protection against pipe-whip, anticipated transient without scram, vibration of reactor internals and so on.

d) A large number of pressing licensing issues still required attention such as interpretation of the Single Failure Criterion, severe natural phenomena design bases, nuclear safety classifications of systems and components, and containment design pressure calculations.

e) A range of plant operational problems was beginning to emerge and continue throughout the seventies e.g. leaking valves and seals, pipe-cracking in BWRs, steam generator tube corrosion and problems with condensers.

f) Poor communication between different regulatory departments on the status of regulatory positions added to the confusion.

A similar situation existed in Germany in that the licensing process involved several stages (site application to the Land, a public announcement of the application by the Land, a public hearing which may or may not allow proceeding to the next stage for application to construct a plant, and so on). In addition public opposition to nuclear power in Europe was probably more intense than in the USA which manifested itself in several violent site demonstrations involving several deaths. France was in a stronger position to expedite the licensing process since it was more centralised and standardised and provided less opportunity for the public to participate in the licensing process. Nevertheless it did not escape a number of violent anti-nuclear demonstrations at some of its nuclear sites.

In order to streamline the licensing process in the USA a number of steps were taken with some degree of success i.e.

(i) separation of siting issues from plant design issues

(ii) separation of generic safety issues from individual plant applications

(iii) the production of a Standard Review Plan to provide uniformity and consistency of licensing reviews by regulatory staff

(iv) the production of standardised Safety Analysis Reports to address the different vendors designs (GESSAR for General Electric, RESSAR for Westinghouse and CESSAR for Combustion Engineering)

(v) the incorporation of industry standards (e.g. ASME, IEEE) in the licensing review process where possible

(vi) the application of the same levels of quality assurance to internal regulatory reviews as was required of applicants.

To the degree that the above steps were successfully implemented significant improvements in the licensing process were obtained. However any gains achieved by streamlining of the licensing process were more than counter-balanced by the increased volume of work stemming from the avalanche of reactors coming on-line during the seventies. The USA led the field with an incredible additional 59 reactors followed by Japan (20) and the USSR (18). Other problems in the mid-seventies, such as the Browns Ferry Fire (1975) and the financial and contractual difficulties of certain vendors and utilities (e.g. of Westinghouse resulting from fixed-price fuel contracts) led to increased public opposition to nuclear power which also contributed to licensing delays. The TMI-2 accident in 1979 virtually sealed any future nuclear development in the USA for some time to come.

By the end of the seventies an additional eight countries had been added to the commercial nuclear power base namely: SWEDEN (1970), PAKISTAN (1971), ARGENTINA (1974), BULGARIA (1974), FINLAND (1977), KOREA (1977), TAIWAN (1977) and CZECHOSLAVAKIA (1978).

## Probabilistic Risk Assessment

Possibly the most significant licensing shift to occur during the seventies was a greater emphasis on the use of risk methods in regulatory decision-making. This arose out of a genuine safety concern that the distinction between 'credible' and 'incredible' accidents was purely arbitrary, and that nuclear plants designed purely on the basis of a fixed set of Design Basis Accidents may well have severe safety shortcomings due to the fact that other more important accidents may have been overlooked. Since it was also recognised that the completeness of a set of Design Basis Accidents could never be proved i.e. there would always exist a residual risk, however small, of an unidentified nuclear accident, suitable risk criteria needed also to be developed e.g. along the lines suggested by Farmer (1967). For these reasons a comprehensive risk study of a USA nuclear power plant was instigated under the guidance of Rasmussen in 1972 and published in final form in 1975.[6] Owing to differences in plant design a similar study was initiated in Germany in

1976 under Birkhoffer and published in 1979.[7]

The results of such studies generated mixed reactions from vendors, licensees and regulators. Critics of the probabilistic approach highlighted the large uncertainties inherent in the method (e.g. scarcity of statistical data, arbitrariness of subjective judgements, inadequacies of mathematical modelling, lack of clearly defined safety risk criteria) whereas proponents stressed the rationality of the methodology, its attempt to quantify subjective judgements, and its ability to uncover system design flaws. The primary cause for much misunderstanding amongst the scientists and engineers appeared to be a lack of appreciation of the dual nature of the probability concept i.e. probability as a measure of degree of belief (subjective) and probability as a measure of statistical success (objective) both of which are essential for carrying out a risk assessment.

For the above reasons probabilistic methods were not adopted generally in the licensing process throughout the seventies, although they were used as an input to primarily deterministic regulatory decision-making. However the accident at TMI-2 in 1979 prompted a complete rethink on the value of probabilistic risk assessments and heralded a major upsurge in the use of such methods during the next decade.

## THE APPREHENSIVE YEARS (1980-1989)

Nuclear power development and licensing were severely impacted by the TMI-2 (1979)[8] and Chernobyl (1986)[9] accidents. Two extremely unlikely accidents which were not expected to occur during the 40 year lifetime of nuclear power plants (even taking into account the whole population of nuclear power plants) had occurred within a space of ten years. These in the eyes of the layman reflected badly on the safety credibility of the nuclear industry, including vendors, licensees and regulators, and had a major negative effect on the public perception of nuclear power. On the positive side many valuable safety lessons were learned leading to a number of institutional reforms, equipment improvements, enhancements in operational performance, increased attention to accident and post accident management issues, a greater acceptance of beyond design basis accidents and the use of probabilistic risk analysis methods, an acceptance of the need for a 'safety culture' amongst all nuclear participants and at all management and worker levels, and greater openness and co-operation between countries on all nuclear safety matters[10,11].

Since this paper is primarily concerned with the licensing process no attempt will be made to review the wide ranging changes which have taken place in the nuclear industry during the eighties. However as indicative of some of the changes in the immediate post-TMI period it is worth mentioning the setting up of the Institute of Nuclear Power Operators (INPO) and the Nuclear Safety Analysis Centre (NSAC) in 1979, the requirement for probabilistic safety analyses for many nuclear plants in the USA, improved training for nuclear operators, the development of symptom-based procedures and a number of back-fitting safety improvements. The Chernobyl (1986) accident led to a greater recognition of the international implications of a nuclear accident, the post-accident implications of land contamination and delayed health effects on the local communities, the establishment of the World Association of Nuclear Operators (WANO) (1989), the IAEA Incident Reporting System (IRS) (1989), as well as a strong move towards greater operational safety (e.g. OSIP and OSART programmes initiated by the IAEA).

From the regulatory perspective the immediate Post-TMI period led to the development of a large number of safety requirements in the areas of operator training and staffing, procedure improvements, risk assessments, and hardware backfits. However it was soon realised that the imposition of more and more requirements could be counter-productive to increased safety, since it shifted attention from fundamental safety concerns to keeping track of, and adhering to, a voluminous body of safety rules and regulations. This tended to encourage an attitude amongst licensees of "provided one adhered to all the safety rules and regulations, safety would automatically be assured". The safety intent of the rules and regulations would thus be missed or overlooked and would encourage the notion that the ultimate responsibility for safety resides with the regulator rather than the licensee, where it lawfully belongs.

Probabilistic Risk Assessment

Acceptance of the value of probabilistic methods to supplement deterministic methods in regulatory decision-making became more widespread amongst most regulatory authorities throughout the world. However the degree of use and levels of probabilistic development required of licensees varied widely in the different countries. These variations resulted from

(i) different definitions of acceptable safety criteria or goals; and
(ii) different levels of probabilistic risk assessment required of the licensee (i.e. Levels 0, 1, 2, or 3).

Safety goals

Since Farmer's original suggestion of a limit line on a frequency-consequence (Iodine-131) plot, several alternative sets of safety criteria have been proposed using a combination of Radiation Protection principles (maximum limits, ALARA, ALARP) and probabilistic criteria for nuclear safety. This has resulted in a hierarchy of safety goals ranging from global criteria at the public health level i.e.

public health criteria:
- Societal risk
- Individual risk
- Cost-benefit effectiveness

down to a variety of sub-tier goals at the plant level i.e.

plant level criteria:
- large release of radioactive materials outside of the containment (i.e. source term)
- containment performance (reliability)
- core-melt frequencies
- dominant accident sequences
- safety systems reliability

- safety functions
- safety component reliability
- initiating event frequencies

In general there is less consensus amongst regulators in the value of developing public health criteria than in defining appropriate plant level criteria which can be used for setting quantitative safety objectives at the plant level. Nevertheless criteria involving individual risk limits, boundary or limit lines for frequencies of exposure intervals, and complementary cumulative distribution functions have all been proposed for serious consideration.

Plant level criteria have been developed either from setting criteria for the frequency of core-melt damage, which can then be propagated downwards to the safety function, system and component levels, or setting system function criteria which can then be allocated to systems and components.

The current status of safety goals and examples of the quantitative figures proposed can be found in Okrent (1987)[12] for the USA, Cannell (1987)[13] for the UK, and IAEA (1986, 1987)[14] technical reports and the Proceedings of a recent conference on Regulatory Practices (1989)[15] for several other Member countries.

Levels of PRA

Four levels of PRA are currently considered in regulatory decision-making, namely

LEVEL 0 - reliability studies of components and systems

LEVEL 1 - analysis of plant response to accident progression terminating at core damage

LEVEL 2 - analysis of plant response to accident progression through to loss of containment integrity and the release of radioactive materials to the environment (source term)

LEVEL 3 - analysis of accident progressions including environmental and population health effects outside of the plant (e.g. emergency planning, early and late fatalities)

The complexity of the risk studies increases from Level 0 through to level 4 as does the impact of uncertainties. As a rule-of-thumb the uncertainty bands increase approximately by an order of magnitude in passing from a lower to a higher level. This explains why regulatory authorities are reluctant to impose Level 3 PRAs on licensees in view of the difficulties of assessing compliance with specific public health criteria.

Experience of PRA techniques throughout this period led to many refinements of the pioneering WASH-1400 study (1975) and resulted in a complete reassessment of the status of PRA with the publication of NUREG-1150 (1989)[16].

By the end of 1988 a total of 26 countries were involved in commercial nuclear power, the last four to connect to the grid being YUGOSLAVIA (1981), BRAZIL (1982), HUNGARY (1982) and SOUTH AFRICA (1984). This constituted a total nuclear generating experience of 5040 reactor-years world-wide.

The safety philosophies of the different regulatory bodies appear to be reaching a consensus (75-INSAG-3 (1988))[17] and the differences between their respective approaches (i.e. deterministic vs probabilistic) is becoming less marked. Whilst in the early stages of licensing the primarily deterministic approaches of countries such as the USA, Germany and France contrasted significantly with the probabilistic emphasis of countries such as Canada and the UK, today most licensing approaches involve a combination of deterministic and probabilistic practices although the particular emphasis varies from one country to another.

## LICENSING IN SOUTH AFRICA

Nuclear development in South Africa began in 1959 when the Cabinet approved the S.A. Atomic Energy Board's proposal for a nuclear research and development program. This was followed by the construction and commissioning of the 20 MW SAFARI-1 research reactor in (1965) and the decision to purchase a twin unit 1000 MW lightwater reactor from overseas in the early seventies. (NB. An order was subsequently (1976) placed with Framatome to purchase two PWRs based upon the Tricastin reference plant.) However, since South Africa did not have an indigenous source of relevant nuclear power experience and skills to draw upon it relied heavily on the use of overseas consultants in the early stages of nuclear power development.

During the late sixties much attention was given to determining the safety and licensing philosophy to be followed in South Africa. As has been mentioned earlier, probabilistic methods for licensing were in their infancy during the late sixties but it was felt at that time by the emerging licensing authority in South Africa that, notwithstanding the known problem areas, a risk philosophy was the most appropriate basis for licensing.

Quantitative risk criteria, based on considerations of average and individual societal and occupational risk were established (Tattersall (1972),[18] Simpson et al (1974))[19] and incorporated in a South African licensing guide LBG/1 (1974)[20]. This effectively made the submission of a Level 2 PRA by the licensee a licensing requirement for nuclear power stations operating within South Africa. Where appropriate, derived radiological protection criteria for operational purposes were also laid down.

The basic safety principles adopted by the Council for Nuclear Safety are as follows:

1. The risk presented by a nuclear plant must not increase significantly the total risks to which the population is exposed.

2. The nuclear risk must compare favourably with those associated with other major industrial enterprises.

3. Allowance must be made for possible demands by society for greater standards of safety over the period (usually several decades) of the working life of the enterprise.

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A consideration of the available historical data pertaining to accidents led to the following public health and plant level criteria:

Public health criteria - Societal risk

- The average annual mortality risk resulting from normal and accident operation shall not exceed $10^{-7}$ deaths/person/year

- Individual risk

- The peak individual risk resulting from normal operation shall not exceed $5 \times 10^{-6}$ deaths/person/year

Thus the peak to average risk ratio shall not exceed 50 in communities or regions within which there is regular social mobility and contact.

Operator (worker) health criteria -

- Site personnel

- The average annual mortality risk resulting from normal and accident operations shall not exceed $2 \times 10^{-4}$ deaths/person/year

- Individual operator

- The peak individual risk resulting from normal operations shall not exceed $10^{-3}$ deaths/person/year

Thus the peak to average risk ratio shall not exceed 5 for radiation workers at a particular site and/or to such subdivisions of this workforce as may be deemed appropriate by the CNS.

<u>Plant level criteria</u> - <u>Radioactive releases</u>

- A Farmer-type limit line of the form frequency = constant x $(\text{consequence})^{-2}$ on a frequency- consequence diagram shall be used to assess compliance (Level 2 PRA)

The form of the limit line (i.e. slope of -2 on a log-log plot) was chosen to provide a bias against large accidents.

The determination of the limit line (plant level criterion) for a particular site involves assumptions concerning the relationship between releases and deaths (e.g. linear dose-effect relationship and the magnitude of the dose-casualty coefficient), population levels around the site and the method for allocating national risk to individual sites. With regard to the latter point the situation is more complex if the sites contain installations of different types (e.g. a power reactor, fuel reprocessing facility, waste disposal).

In common with many other countries, a staged approach to licensing is followed in South Africa e.g. application for a nuclear licence, submission of a Preliminary Safety Report, approval of submissions, start of construction, preparation of an Intermediate Safety Report, small stage approvals, application to store fuel on site, permission to approach criticality, and staged approvals for power raising. The level and detail of documentation to be submitted at each stage is comparable to that required by licensing authorities in other countries such as the USA, France and Germany.

## FUTURE DEVELOPMENTS IN SOUTH AFRICA

Nuclear safety is never static but changes with the knowledge and experience gained with nuclear power operations. It is therefore incumbent upon a licensing authority to ensure that the safety of nuclear facilities within its own country reflects the best safety practices in the light of world-wide experience consistent with its own safety philosophy. In view of this the Council for Nuclear Safety recognizes the need for on-going review of nuclear safety-related topics, fundamental safety philosophy and the formulation of any requirements that may originate from these.

Probabilistic Risk Assessment

Stemming from the Council's fundamental risk approach to safety, and in view of the above, it is necessary to develop and improve the application of probabilistic techniques to regulatory decision-making. To this end a licensing requirement has been issued for the Koeberg nuclear power plant to periodically update the risk assessment to reflect actual plant operating experience (i.e. maintain a 'living PRA'). This is to ensure that regulatory decisions are based upon the most up-to-date state of the plant rather than the plant as commissioned. A licensing guide of how this should best be accomplished (e.g. frequency of update, application of Bayesian techniques, incorporation of common cause effects) is currently being prepared.

The current Level 2 PRA refers specifically to the consequences of radioactive iodine (or Iodine equivalents) whereas it is known from actual accidents that other radioisotopes, such as caesium, ruthenium and strontium etc, are also important in terms of health effects. The implications of specifically incorporating non-iodine radioisotopes within the Level 2 framework is under review as is the requirement for a full level 3 PRA.

Recent findings of the U.S. National Research Council's BEIR V Committee has increased estimates of the cancer risk from radiation exposure. The implications of these findings are currently under review.

Safety culture and Licensee performance

The TMI-2 and Chernobyl accidents highlighted once again the importance of the human element as a major cause of nuclear accidents. Whereas much attention has focussed on the reactor operators, it is recognised that other members of a licensee organisation, such as maintenance personnel and management can also have a significant effect on either preventing or indirectly causing a nuclear accident. Thus the 'safety culture' of an organisation has been identified as a major factor in considerations of nuclear safety (e.g. 75-INSAG-3 (1988) ). Progress in quantifying 'safety culture' or licensee performance as a global indicator of safety level in an organisation is limited at present. However, the Council is exploring possible ways in which this might be improved.

Licensing of Personnel

Although the licensing of operators has received much attention since the inception of the nuclear power industry, little attention has been given in the past to the licensing of other classes of radiation workers, such as maintenance personnel (e.g. Non-destructive Examination specialists, welders) whose impact on safety can be comparable to that of nuclear operators. The Council is therefore considering whether the current vetting applied by the licensee in this regard is adequate from a nuclear safety point-of-view, or whether additional requirements should be applied. These deliberations also extend to questions of the suitability of particular staff for nuclear safety-related work in cases of a known history of alcoholism or drug abuse.

Safety of the Nuclear Fuel Cycle

In view of the fact that South Africa is involved in several components of the nuclear fuel cycle i.e. uranium mining and milling, uranium refining and conversion to hexafluoride, uranium enrichment, fuel manufacture, fuel storage and radioactive waste management, the Council has been considering for some time the manner in which such processes or facilities should best be licensed within its safety philosophy e.g. setting appropriate derived safety criteria relevant to the type of installation. Clearly the public safety implications of nuclear accidents at such installations will be different from those associated with an operating nuclear power reactor. Possibly of greater relevance in these cases are the health risks associated with occupational workers rather than with the public at large.

## Software Reliability

In view of the trend towards the greater use of computers in the man-machine interface, either as information processing systems or in process control applications, greater attention is currently being given by the Council towards available methods for ensuring and quantifying software reliability. This is also a major on-going area of concern in the computer industry e.g. operating systems reliability, as well as the defence industry e.g. mission critical systems. Such considerations from the nuclear regulatory viewpoint involve assessing the adequacy of the software quality assurance, software validation and fault-free programming methodologies adopted by the licensee.

## Individual Plant Examinations

The USA has introduced a program (Individual Plant Examination (IPE)) whereby comprehensive periodic reviews of the status of a power plant must be carried out (e.g. every ten years). Such reviews will provide valuable input to plant life extension programs (PLEX) as well as identify areas of plant deterioration. Other countries are considering implementing similar programs for their own power plants and related nuclear facilities. In line with this trend the Council is reviewing the necessity for IPEs bearing in mind that the requirement of a 'living PRA' implies a continual feedback of plant-related data.

## Containment Integrity

The importance of containment integrity as the last barrier against release of radioactive products to the environment and public has been well demonstrated with the TMI-2 and Chernobyl accidents. This aspect of nuclear safety is being considered actively in order to determine whether there is a need for improvements.

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**SUMMARY**

The primary aim of this paper is to provide a particular perspective of nuclear safety and licensing during the past thirty years or so. No attempt has been made at completeness. Some of the key licensing issues during four phases of nuclear power development (i.e. The Formative Phase (1946-1959), the Expansive Phase (1960-1969), the Mature Phase (1970-1979) and the Apprehensive Phase (1979-1989) ) have been highlighted to indicate the shifts in licensing emphasis. Against this background the development of licensing in South Africa has been discussed and possible future trends indicated.

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