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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

GOOD PRACTICES FOR USER EFFECT REDUCTION

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article I of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral. non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of all OECD Member countries except New Zealant and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers. It was set up in 1973 to develop and co-ordinate the activities of the Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries.

CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of its programme of work. It also reviews the state of knowledge on selected topics of nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus in different projects and International Standard Problems, and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups and organisation of conferences and specialist meeting.

The greater part of CSNI's current programme of work is concerned with safety technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, containment performance, risk assessment and severe accidents. The Committee also studies the safety of the fuel cycle, conducts periodic surveys of reactor safety research programmes and operates an international mechanism for exchanging reports on nuclear power plant incidents.

In implementing its programme, CSNI establishes co-operative mechanisms with NEA's Committee on Nuclear Regulatory Activities (CNRA), responsible for the activities of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA's Committee on Radiation Protection and Public Health and NEA's Radioactive Waste Management Committee on matters of common interest.

Good Practices for User Effect Reduction

R. Ashley, M. El-Shanawany °, F. Eltawila [*], F. D'Auria [+]

AVNuclear (AVN)
Avenue du Roi, 157
B-1190 Bruxelles
Belgium

° Health & Safety Executive
Nuclear Installations Inspectorate
St Peter's House, Balliol Road, Bootle
Merseyside L20 3LZ
United Kingdom

[*] Office of Nuclear Regulatory Research
Nuclear Regulatory Commission
MSTW10E46, 11555 Rockville Pike
Rockville, MD 20852
United States of America

[+] Dipartimento di Costruzioni Meccaniche e Nucleari
Universitá di Pisa
Via Diotisalvi, 2
56100 Pisa
Italy

Abstract

User effect has been identified in previous CSNI activities since 1991. The present report has as objectives to outline the consideration given to the user effect problem by various concerned organisations, and to present a consensus about recommended practices for user effect reduction.
A survey of relevant literature is summarised, together with the answers collected through the Task Group on Thermal Hydraulics Applications members about characteristics of overall safety analysis process including validation, safety culture, staffing levels, staff competencies and responsibilities, on the job training, required documentation, and quality assurance.

An outline is given of the adequacy demonstration process to be undertaken by a code user, when the code is being used in new situations for which assessment has not been performed by the code developers or by other user groups.

A list of fifteen recommendations is set up, dealing with organisation and responsibilities, build up of competence, checks and assessments, and uncertainties.

Acknowledgements

Agreeing upon a consensus report is always a hard task when several organisations from different countries are involved. This report could only be established thanks to the open discussions the authors had with the members of the Task Group on Thermal Hydraulics Applications.

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1. Introduction

Best-estimate thermal-hydraulic system codes are used by designers and vendors of nuclear plants, by utilities, by licensing authorities, by research organisms, including universities, by nuclear fuel companies and by other organisations supporting in various manners one of the above. The purposes for the use of a code may be quite different, ranging from safety or design calculations to just the understanding of the transient behaviour of a simple system.

The capabilities of these codes to predict plant behaviour under a wide variety of transient and accident conditions have substantially improved in the last few years, have reached a noticeable level of maturity, and can now be considered satisfactory for the current needs, which include performing analyses for existing plants and advanced reactor designs for both design basis accident (DBA) conditions and beyond-DBA conditions before the loss of coolable core geometry.

Among the uses of the best-estimate thermal-hydraulic system codes (e.g., RELAP5, CATHARE, ATHLET, TRAC) are optimising a plant’s emergency operating procedures and performing safety evaluation of reactors to support major plant modifications (i.e., steam generator replacement), reactor power level increases, plant operator training, and other activities such as technical specification changes and support for probabilistic safety assessments.

A wide range of activities has recently been completed in the system thermal-hydraulic area as a follow-up to huge research investments (refs. [1.1] to [1.6]). Problems have been addressed whose solution has been at least partly agreed on an international basis. These include the need for best-estimate system codes (refs. [1.1] and [1.2]), the general code qualification process (integral test facilities and separate effects test facilities validation matrices have been made available, refs. [1.3] and [1.4]), the proposal for nodalization qualification, and the attempts at the qualitative and quantitative accuracy evaluations (ref. [1.7]). In this regard, following the pioneering study at NRC (ref. [1.8]), complex uncertainty methods have been proposed to account for, among other factors, user effects on code results. More recently, an international study aiming at the comparison of code uncertainty methodologies' assumptions and results has been completed (ref. [1.9]).

These codes are very complex and the level of current scientific knowledge varies regarding the various thermal-hydraulic processes occurring in nuclear power plants under accident conditions. Some physical processes are well understood, while others are only partially understood (ref. [1.10]). A computer code cannot be expected to precisely model phenomena that are not yet fully understood by the scientific community. A question arises: If the physics of important phenomena and associated physical processes are not understood fully, can computer codes attempting to model these processes be used with any degree of confidence? The answer is a qualified “yes”. Models have been proposed for important thermal-hydraulic phenomena for which complete understanding is lacking. These models are based on data that usually are limited in some manner (e.g., geometry, range of thermodynamic state variable, or orientation). Because of these limitations, the data’s applicability is compromised by users when these models are used outside the range of applicability unless it can be demonstrated that the data scale up to plant geometries and conditions.

In addition, while the governing field equations for single- and two-phase flows are well known, dimensional reduction, transfer terms, etc. give rises to mathematical representations for certain parameters in the field equations that are not generally well known from first principles. Empirical closure models are developed to represent these parameters and the development includes correlation with experimental data. The adequacy of a closure model is assessed by determining if the model reproduces applicable fundamental, integral and separate effects test data..

Extensive programs of testing have been performed in scaled integral facilities (e.g., LOFT, MIST, BETHSY, ROSA, LOBI, PKL, 2D/3D). Although the data base supporting some individual code closure or constitutive models may be limited, the integrated capabilities of the code are assessed using data from the scaled integral facilities. Therefore, assessment of the code against data from integral facilities assumes an important role in demonstrating code adequacy (ref. [1.11]).

However, the results of code predictions, specifically when compared with experimental data gathered from properly scaled test facilities, have revealed inadequacies that raised concerns about the reliability of the codes and their practical usefulness. Discrepancies between measured and calculated values were attributed to model deficiencies, approximation in the numeric solution, computer and compiler effects (see ref. [1.12]), nodalization inadequacies, imperfect knowledge of boundary and initial conditions, unrevealed mistakes in the input deck, and to “user effect.” This report focuses on the user effect; the other causes of code deficiencies have been extensively discussed in a variety of publications, and will not be repeated here.

In several ISPs sponsored by CSNI, several users modelled the same experiment using the same code, and the code-calculated results varied widely, regardless of the code used. Some of the discrepancies can be attributed to the code user approach as well as to a general lack of understanding of both the facility and the test.

The above discussion illustrates why code users have a significant influence on the calculation results and why user effects have been identified in numerous publications as the origin of many of the calculations' failures either in the physical simulation or in the numbers. For example, the problems connected with the user effect on code results clearly appeared in the many Standard Problems proposed by CSNI; specific discussions have been held during meetings of the “Thermalhydraulics Task Group” of the PWG-2 since 1991. In this framework, considering the results already achieved and documented in [2.1], the objective of the present report is twofold:

- to outline the consideration given to the user effect problem by various relevant organisations;
- to achieve a consensus about recommended practices for user effect reduction.

The definition of user effect may be subjective; however, for the purpose of this report, the user effect will be defined as follows:

User effects are any differences in calculations that use the same code version and the same specifications (e.g., initial and boundary conditions) for a given plant or facility.

The following are some of the reasons for the user effects which will be further discussed in the main text of this report.

- Code use guidelines are not fully detailed or comprehensive;
- Based on the current state of the art, the actual 3-dimensional plant geometries are usually modelled using several 1-dimensional zones, these complex 3-dimensional geometries are suitable for different modelling alternatives. As a consequence an assigned reactor vessel part is modelled differently by different users of the same code.
- Experienced users may overcome known code limitations by adding engineering knowledge to the input deck.
- Problems inherent to a given code or a particular facility have been dealt with over the years by the consideration and modelling of local pressure drop coefficients, critical flow rate

multipliers, or other dials to obtain improved solutions. This has been traditionally done to compensate for code limitation (e.g., application of steady state qualified models to transient conditions, and lack of validity of the fully developed flow concept in typical nuclear reactor conditions).

- An increasing number of users have access to system codes and are able to perform calculations; however, they may not correctly interpret results due to lack of understanding of the code capabilities and limitations.

- A non-negligible effect on code results comes from the compiler and the computer used to run an assigned code; this has been found to be true also for very recent code versions.

- Interpretations of the facility set-up and the experimental data used as the bases of the comparison are, in the large majority of cases, left up to the user.

- Error bands and the values of initial and boundary conditions which are needed as code inputs are not well defined.

- Analysts lack complete information about facilities before developing input decks and hence filling the gaps with unqualified data.

Due to the lack of common agreement about code capabilities, code developers may also exacerbate the user effect problem through feedback from the code's validation and verification process. They may change nodalization of those systems, components, processes, and phenomena that have the most influence on the predicted course of an accident without assessing the implication on a wider application of the code. This problem can be minimised by requiring that code models necessary for accurately simulating the most important systems, components, phenomena, and processes fully satisfy appropriate adequacy standards and guidance be given to the users about the nodalization schemes to be used for plant calculations.

With the current capabilities, a system code (e.g., RELAP5, CATHARE, TRAC, and ATHLET) that constitutes the reference tool for this study, can be put into operation in a few days. In the same time, results can be achieved, provided the availability of a nodalization. Although it is possible to set up an unqualified input deck related to a complex system (e.g., the nuclear power plant) in a few weeks using the available code manuals, this practice should be discouraged. Experienced code user groups exist.

Thereafter, this study mainly concerns the most critical use of the code, dealing with the consequences of the results obtained for the design of the nuclear plant, for the normal and off-normal operating procedures, and for safety.

2. Background and Common Practices to Reduce User Effects

2.1 Literature Survey

This section examines and discusses the views of earlier work relevant to the “user effect” on thermal-hydraulic transient analysis results. User effects led to unexpected differences when the same code and the same specifications are used. Although the discussion concentrates on thermal-hydraulic system codes, the findings are applicable to any system code (e.g., severe accident, ref. [2.6]). Although, user effect was expected to be drastically reduced with the new generation of the advanced computer codes, many ISPs showed that this goal was not reached (see also ref. [1.5]).

2.1.1 Identification of User’s Effects

Ref. [2.1] examined the reasons for discrepancies between code predictions and measured experimental data, when the same code and the same specifications had been used by different users. Considering experience with code assessment case studies and ISPs, it was concluded that code users have a dominant effect on the predicted system behaviour. Other factors that also affect the results include specific characteristics of experimental facilities, limitations of the thermal-hydraulic codes used, and misinterpretation of experimental data by the code users. While there have been attempts to establish methodologies to evaluate the accuracy of the code predictions, none of them address the influence of the code user on the calculated results.

The main sources of code user effects on the predicted code results are as follows:

(1) System nodalization

The user has to construct a predominantly one-dimensional thermal-hydraulic network to map the whole system. It is the user’s responsibility to develop an adequate nodalization. Two problem areas are spatial convergence and mapping of multi-dimensional effects.

(2) Code options and physical model parameters

Although the number of user options is thought to be reduced in the advanced codes, for some codes there are several models and correlations for the user to chose. The user is also required to specify some uncertain parameters such as pressure loss coefficients, manometric characteristics, efficiencies, and correlation factors.

(3) Input parameters for system characteristics

Specific effects such as small by-pass flows or distribution of heat losses might exacerbate the user effect.

(4) Input parameters for system components

Beside the major 1-dimensional code modules, a number of empirical models for system components, such as pumps, valves, or separators, are specified by the users, sometimes based on extrapolation from scaled devices, thereby introducing additional inaccuracies.

(5) Specification of initial and boundary conditions

Users fail to obtain a stable steady state prior to the initiation of the transient.

(6) Specification of state and transport properties

Indirect entries to property tables are sometimes to be specified by the user, such as those related to fuel rod gaps. These entries might have an important effect on the evolution of the transient.

(7) Time steps

Most codes have algorithms to adjust the time step control (e.g., current limit) to maximum efficiency and minimise run time. However, users are allowed to change the time step to overcome code difficulties and impose smaller time steps for a given period of the transient. If the particular code uses an explicit numerical scheme, the result will vary significantly with the time step size.

(8) Code input errors

Quality assurance guidelines should be followed to check the correctness of the values introduced in the input decks despite the automatic consistency checks provided by the code.

Typical examples of user and other related effects on code calculations of selected experiments are presented in several CSNI reports (e.g., ISP-25, ACHILLES reflooding test; LOBI natural circulation test; ISP-22 on SPES loss-of-feedwater test; ISP-26 on LSTF 5% cold-leg-break LOCA; ISP-27 on BETHSY 2” cold-leg LOCA without HPSI).

2.1.2 Good Practices

Code user effects on the predicted system behaviour cannot be completely avoided. However, the following are some suggestions for reducing user effects. These summaries distil information presented in studies by CSNI, CNRA (Committee on Nuclear Regulatory Activities) and European Nuclear Regulators.

2.1.2.1 CSNI

(1) User training

To perform analyses using a computer code, the user is required to construct and/or understand input decks in terms of geometry and operating conditions of the facility or plant. Therefore the user needs to have received adequate training to be fully aware of the physical modelling and the limitations of the code. Some scattering in the results, as encountered in ISPs, might be attributable to inexperienced users. Studies with significant consequences, such as safety analyses, should be run by experienced users, with adequate review.

(2) Improved user guidelines

Detailed user guidelines are recommended to reduce mistakes; however, they cannot be a substitute for training and experience.

(3) User discipline

Sensitivity studies are a good way to understand code capabilities and deficiencies. However, tuning of the results through unrealistic values for physical parameters only adds to the confusion and leads to getting the right answer for the wrong reasons, the errors compensating each other.

(4) Quality assurance

Input decks should only be produced according to a quality assurance strategy that includes review, checking and feedback. When input decks are shared and used to produce a new version, the process should follow the same quality assurance standard.

(5) Code improvement

In the long term, the best way to reduce the user effect is through improvement of the code physical modelling and numerical techniques as by using of numerical methods for automatic mesh refinement and multi-dimensional capabilities for important subsystems. It would be an advantage if the code developer has experience in carrying plant analysis and hence appreciates the difficulties that the user might have in performing real plant calculations.

(6) Graphical user interfaces

Graphical user interfaces (GUIs) would reduce user effect by allowing the code users more time to check the input deck, interpret the data, and run time control. One of the main advantages of such tools is they develop input decks by eliminating inconsistent choices. A GUI would also isolate the code users from the computational engine, automatically preventing the user from selecting an option.

2.1.2.2 CNRA

User effect has also been addressed in Ref. [2.2], which was prepared by the Committee on Nuclear Regulatory Activities (CNRA) Working Group on Inspection Practices (WGIP) and which scrutinised the calculations of a large number of codes dealing with various phenomena, ranging from in-vessel to out-vessel phenomena. It is interesting to look at the section concerning the code users. It can be summarised as follows:

- The codes should be designed so that an analyst who is quite familiar with the phenomena can use the codes reliably.
- The analyst must have a good knowledge of:
  - the reactor systems
  - the phenomena addressed, the applicability of the models limitations
  - the meaning and significance of the input and output variables
- Because of complexity of the issues, the codes should not be treated as “black boxes.”
- The choice of the time step should be checked through sensitivity studies focussed on convergence. If numeric instabilities cannot be avoided, the code is not appropriate to the application.

In addition to the above, the report pointed out that quality assurance requirements for the analyses are being set up through regulatory guides in several countries (Finland, The Netherlands, Hungary, and the USA).

2.1.2.3 European Nuclear Regulators

The European Community member states task force, (ref. [2.3]), identified “common position” requirements from the member states represented in the task force and “recommended practices” that, although are not currently supported or systematically implemented by all the members, are recommended by most of them. The task force pointed out the following important issues:

(1) Organisational Requirements

Well-structured and effective organisations are regarded as necessary to reduce the faults introduced into a system. Proper documentation of input decisions is needed to minimise the risk of incorrect safety system behaviour. This applies to any code.

(2) Safety culture

Safety culture is a key issue, emphasising safety within the organisation and promoting practices to keep organisations aware of the risk linked to potential consequences of incorrect operations. The staff must be aware of the risks posed by the plant. Safety culture should reduce - unfortunately it cannot eliminate - inattention to details and slipshod procedures that could adversely affect the outcomes of an analysis.

(3) Delineation of responsibility

Clear delineation of responsibility should eliminate unsafe decisions due to a lack of attention.

(4) Staffing levels

Inadequate staffing levels may result in safety issues not being explored properly, leading to inadequate concepts.

(5) Staff competencies

If the staff does not have the appropriate level of training and experience, errors will be introduced and not be detected.

(6) Project pressure

Both financial and temporal project pressures might lead to inadequate safety provisions.
In summary, common positions have been identified as follows:

- Only reputable companies, with a demonstrably good track record in the appropriate field should be involved in safety analyses.

- The licensee, its suppliers, and its subcontractors shall each provide evidence of the following.
    - A written safety policy shall be available demonstrating a commitment to a safety culture.
    - The responsibilities of, and relationships between, all staff and organisations involved shall be documented.

  - It shall be demonstrated that the levels of staffing are adequate. There shall be an appropriate balance between the numbers of hired staff and full-time employees.
  - Suitable evidence of staff’s appropriate level of training and experience shall be available for inspection.
- The licensee should submit written proposals to the regulatory authority on the methods to be employed to ensure that the safety level will be adequately maintained.

The recommended practices are listed below:

- Adequate procedures should be in place for controlling the documentation and the specifications.
- Evidence should be provided that the safety aspects are adequately monitored.
- An independent licensee’s safety department should be in charge of ensuring that project or operational pressures will not jeopardise safety.
- Regular progress reports should be available for inspection.

2.2 Summary of the Response to Questionnaire to TG on THA members

2.2.1 Objectives

A number of factors affect the modelling process and the computer codes' analysis. The user is one of these factors and needs to be assessed as part of the overall process.

A questionnaire was sent to the TG members to discover their common views on and practices in reducing the causes of discrepancies in the results of the analysis of a given task. The questions covered the characteristics of the overall safety analysis process, which including validation, the safety culture, staffing levels, staff competencies and responsibilities, on-the-job training, required documentation, and quality assurance.

Responses to the questions (ref. [2.4]) have been received from Belgium (TRACTEBEL), France (CEA-Grenoble, EDF, FRAMATOME), Germany (GRS, Siemens/KWU), Italy (University of Pisa), Korea (KAERI), Spain (CSN), UK (HSE), and USA (USNRC).

After the views of the TG members on the above points were received, an ad hoc meeting of the Writing Group was held in January 1998 to discuss and examine the responses to the questions.

2.2.2 Approach to Safety Analysis

2.2.2.1 Validation

Computer code analysis of plant design and operation forms an important part of a modern safety case. The validation procedures, therefore, are an essential part of the overall process. A computer code validation package is expected to cover validation against separate-effect tests, integral test facilities, the limitations of application of the code, physical and numerical methods, claimed accuracy, comparison with plant data if possible, and the applied quality assurance and procedures. The validation process should identify the strengths and weaknesses of the code as well as the associated code uncertainties. It is important that the user understands the code and is well aware of its limitations.

Each study has to be verified in order to guarantee the quality of the results. The overall validation process is regarded as a guarantee of the quality of the code results as far as it covers the parameter range for any particular application.

The final goal is the safe operation of the plants, the regulator must be satisfied by the way the code is used, therefore he must trust the organisation that runs it. As stated in ref. [2.2], “Only reputable companies shall be used in all stages of the safety system development life-cycle. Each shall have a demonstrably good track record.”.

2.2.2.2 Responsibilities for safety analysis

Any organisation that performs computer safety analyses must ensure that its analysis has been systematic and the details are adequately recorded. This process is usually done by having in place organisation procedures and a well-established quality assurance system. The procedures usually identify the role of the analyst, the reviewer, and the approving manager. Any calculation seeking approval must clearly indicate the codes, the authors, and how it has been validated before being proposed to the licensing authorities.

Experience shows that one should not rely on the assumption that any calculation provider company has a QA system. Failures of control are assessed through reactive monitoring and auditing. All organisations involved in computer code analysis should have a satisfactory QA system, including internal reviews and subject to independent audits.

2.2.2.3 Safety culture

Organisations that are successful in achieving high standards of health and safety have strict safety policies and meet their responsibilities to people and the environment. As the validation procedures make clear, experienced and knowledgeable staff is an essential element in maintaining safety culture.

Even if not formally requested in certain countries, the organisations involved in safety activities generally have a written safety policy. The quality assurance system and documentation of the company are a reflection of the safety culture of the organisation.

2.2.2.4 Staffing levels

Staffing levels are usually determined by a combination of the work load, the disciplines covered, and the quality and competence of the staff. How to judge whether the levels of staffing are adequate is mainly a matter of experience. However, there is a critical mass for a team of analysts. Knowledge must be shared and questions exchanged between the members of the team. Good results can only be obtained through a multi-disciplinary team effort.

To maintain such multi-disciplinary team effort, organisations involved in safety related activities have full-time employees as well as contractors. The team responsibility includes overall development, physical modelling, and assessment.

The ownership of a plant safety case requires a minimum permanent staff who could answer any question in relation to the safe operation of the plant at any time (even years later). Continuity must be ensured, as it is by NSSS and fuel vendors who perhaps have more long-term staff dedicated to safety analysis plant operating organisations.

It is recognised that skilled people in the organisations do not do analyses all the time; therefore experience records must exist to keep trace of the activities and to help avoiding mistakes when tackling new scenarios.

2.2.2.5 Staff competencies

The competence of the staff can be assessed as follows.

- New staff members are generally accepted on the basis of their education level (a university degree in science or engineering) and training records. Adequate knowledge of nuclear engineering is demonstrated by postgraduate courses, on-the-job training, or attendance of specific training courses. Technical and scientific production (reports, papers, ISP, etc.) is also considered. Experience with the code used and participation in code validation process are assets.

- Later the staff members are judged on their experience in different projects or in specific areas and on their personnel skills. Also of interest is the number of projects performed with or without supervision in a specific area.

The responsibility of assessing the staff always belongs to the hierarchy (team leader, section manager, project manager, department head or staff’s supervisor). Assessments may also be the subject of an audit or peer review.

2.2.2.6 Documentation

Detailed documentation is essential. Documentation involves:

- information coming into the organisation such as computer codes manuals,
- information circulating within the organisation, such as experience and lessons learned from carrying out analysis, and
- information flowing out from the organisation such as reports and submissions to other organisations.

The documentation needed to ensure appropriate modelisation usually covers three domains: the code, the model, and the application.

The code documentation should comprise at least the developmental assessment, the user guidelines and manual. More extensive documentation is nevertheless recommended dealing with the description of the physical models and correlations, the numerical methods, the code structure and a user implementation guide. Verification and validation reports for code model development and physical qualification against SET and IET are also of great interest, as is the quantification of the uncertainties. This documentation should be updated at each version delivery.

Internal documentation should contain the calculation sheets for the input as well as their references to all as-built plant drawings and materials used for geometric and boundary and initial conditions. The documentation has to be detailed enough so that one can trace the origin of each figure used in the model and the justification of selection if different references are inconsistent.

All assumptions and calculations used in modelling plant components must be included in the calculation notebook or work report, which consists of calculation pages that should be checked by an independent engineer. The transformation of these calculations into the input deck syntax required by the code is documented and checked, as is the justification for the selection of any code options, including the model numerics. Any deviation from the guidelines should be justified. At an appropriate time in the modelling process (i.e.: the way the input deck is being obtained and validated), a “design review” of the approach and the major assumptions for plant components and for the global model should be conducted by the responsible persons. The documentation has to reflect the real status of the model and of the input decks and be updated each time a model modification is made.

The application documentation must contain at least the specification of the problem, the application procedures followed, the modelisation of the case, and an evaluation of the results. Each sensitivity study run must be recorded.

2.2.2.7 Streamlining the user’s contribution

An analyst should be aware of how the calculation fits into the overall estimate of the safety detriment for the plant and should therefore have an understanding of the confidence level that is required of any calculated results.

The following are useful elements in reducing the “user effect” on the analysis:

(1) On-the-job training

This training is usually ensured through internal training and mainly through co-working with experienced users. When necessary, experienced code users and developers will be asked to perform a special training. Validation exercises should be carried out: e.g. separate effects’ validation, integral tests’ validation. Also, an analyst should perform a number of uncertainty analyses and sensitivity studies before finally carrying out plant analyses.

(2) Procedures

There is generally a need for internal procedures to minimise errors and explain the code guidelines. The documentation should aim at passing information about the corporate knowledge base. The verification process is usually done by an independent analyst or a senior expert, and approved by the group leader.

(3) Pre-processor

There is an agreement to recommend the use of a pre-processor the development of which should follow the same quality assurance process as the code itself. It is even generally requested although it was stated that one cannot depend on it.

The benefits of using such a pre-processor are:

- reducing the user errors through controls of the input deck (noding and meshing rules, main guidelines, elevations, wall area and mass, etc.) and of various balances and integrated quantities

- increasing the efficiency of handling the large amount of data required to build up a model

- improving the visualisation of the models (checking the geometry, friction coefficients, etc.)

- improving the understanding of all the logical signals
- allowing the use of a high level language that reduces the need for the code syntax knowledge

(4) Output checking

In some countries a special training is devoted to this activity. It is felt important to correctly interpret the calculation results and necessary to train people in using specific software tools to extract and filter the output data. The training is extended to the application of assessment guidelines, especially when they relate to experimental uncertainty. In other countries, this training is part of the overall training, usually coming after some years of experience.

Checks of calculation results (output) should be made both at a qualitative level and a quantitative level. Having available reference data (i.e. from relevant experiments), the qualitative accuracy can be evaluated by considering physical phenomena part of the reference data base, checking that the same phenomena appear in the calculated data base. The quantitative accuracy evaluation implies the definition of a suitable algorithm to process experimental and calculated data: the use of the Fast Fourrier Transform (FFT) proved to be a valuable tool in this context (ref. [2.5]).

Comparison to experimental results or plant measured data are usually the bases for assessment. Typical parameters are: mass-flow rates, pressure and temperature distributions, pump speed, mass and energy balance, output of control systems, output of logical signals, etc. It is desirable to check at the node, component and system level. Expert judgement may be needed, when raw data are not available. Codes usually have their own internal checks to verify against an acceptable criterion, usually the time variation of relevant variables.

It is felt that pure graphical post-processors alone do not allow a complete analysis but they are needed to allow the engineer to focus on the physical issues rather than on text-processing issues. The experience of code users as well as guidelines from the code developers should be assembled. This experience should be available in a readily accessible, searchable, hyperlinked manner (e.g. a code's web page should be accessible from the graphical user interface and should form the rationale for default nodalizations and code options, as well as for input and output validation).

Post-processors are generally welcomed and sometimes recommended, but the output check should not be limited to post-processing because that might narrow the set of data too much. An intelligent post-processor (that is, an inference tool capable of warning and advising the user) would be a powerful instrument for evaluating steady states well beyond the mere graphical. In the transient cases, that kind of post-processing is necessary as the trajectory of the transient is uncertain and so the original validation of the numerical algorithms may not apply to the current scenario. Finally, although they have not yet been proven in practical use, schemes that employ neural network techniques to "learn" from successive code results and analyses may be useful.

(5) Quality assurance

Quality assurance is essential at each step of the study. The procedures should cover the following:

(5a) Quality assurance for code calculation

Quality assurance for code calculation requires that an identified and frozen version be used after appropriate installation and implementation tests; this ensures that no unjustified modifications of the constitutive models will alter the study results. The code must be able to correctly simulate all the transient dominant phenomena. Quality assurance must demonstrate code assessment and qualification; justifying documents must be provided (see next section).

(5b) Quality assurance for the methodology

The methodology - frozen and described within specific documents - reduces the user's effect because it imposes a common and precise formalism to all users. This formalism requires the user to:

- Describe the type of accident studied:
  - initiators
  - study rules
  - criteria to respect
- Describe the accident transient, using the physical knowledge acquired during physical analysis, (R&D). For this step, comparison with studies performed previously with an equivalent calculation code (and the experience of other users) can be useful.
- Justify the code capability to simulate all the physical phenomena of the transient. For this task, the user relies on:
  - code descriptive documentation
  - code qualification documentation
  - and (eventually) complementary validation tests.
- Describe and justify the chosen nodalisation.
- Describe the chosen methodology:
  - chosen scenario
  - main assumptions (according to plant operation, for example)
  - uncertainties in the initial conditions
  - uncertainties in the calculation code and in the dominant phenomena
  - treatment of uncertainties, introduced conservatism

2.3 Adequacy Demonstration Process

Thermal-hydraulic system analysis code assessment and adequacy demonstration are the responsibility of the code developer. However, to develop an appreciation for and an understanding of a code's capabilities and limitations, the code user must perform several independent assessments. There are three essential elements of code assessment: (1) a complete and accurate understanding of the facility and the test, (2) accurate facility boundary and initial conditions, and (3) understanding of the code architecture, the numerics, and the governing equations and physical models. When a particular code is used in new situations for which assessment has not been performed by the code developers or by other user groups (e.g. new plant designs), a complete adequacy demonstration must be performed by the user. The process described below, will help the user identify code capabilities and limitations and reduce potential adverse user effects.

The adequacy demonstration process must be undertaken by a code user, when a code is used outside its assessment range, when changes are made to the code, and when a code is used for new applications where different phenomena are expected. The impact of these changes must be analysed and the analyses must be thoroughly reviewed to ensure that the code models are still adequate to represent the phenomena that are being observed.

The process to demonstrate code adequacy for a specific application involves the following key activities as shown in the figure enclosed in this section:

- The relative importances of systems, components, processes, and phenomena are identified, with particular emphasis on those that are most important.

A phenomena identification table lists the phenomena occurring in a specific plant during a specific accident scenario. The process considers the thermal-hydraulic phenomena, processes, and conditions that affect the plant response. Phenomena with a controlling influence on that behaviour are ranked high (refs. [1.1] to [1.4]).

The above process, itself, is not used to decide whether a particular code feature is adequate. Rather, it is used to guide user’s evaluation of whether the code contains the essential capabilities for modelling phenomena important for the plant and the scenario being analysed. Additionally, the information is central in the decision as to whether specific models that are deemed to be inadequate must be corrected before the code can be considered adequate and applied with confidence for plant analysis.

- Standards should be established against which code models and performance can be measured (see also section 2.2.2.7).

- Code assessments are performed by comparing both the closure and constitutive relationships and the performance of the integrated code against the measurement standards in the context of relative importance of the various systems, components, processes, and phenomena.

Code assessments have two parts. One part is the “bottom-up” evaluation of the code closure relations and the other part is the “top-down” evaluation of the code governing equations, numerics and integrated performance.

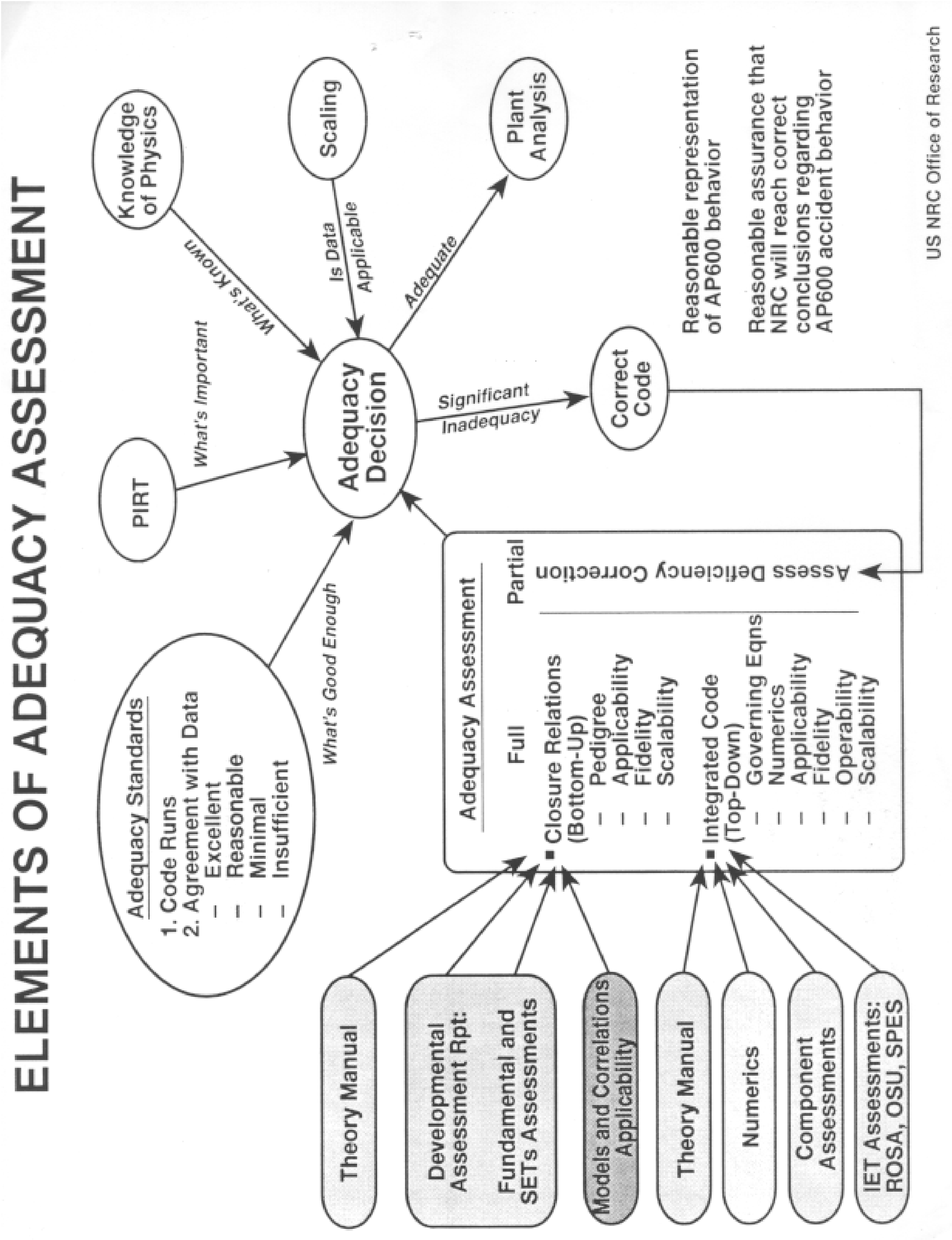
The bottom-up assessment focuses on the fundamental building blocks of the code, for example, the closure relationship for interphase drag in rod bundle regions. The user must be familiar with the physical basis of a closure model, the assumptions and limitations, and whether the use of a particular model, as implemented in the code, has been justified over a broader range of conditions.

The top-down assessment focuses on capabilities and performance of the integrated code. The user must be familiar with the integral assessment to ensure that the integrated code is capable of modeling the plant systems and components.

- Establishing code scale-up capability involves:
  - (A) assessing the scaling base for facility design and data
  - (B) establishing code applicability at facility scale
  - (C) verifying code scale-up capability to plant

The *code adequacy decision* is the culmination of the adequacy demonstration process described above and in the figure.

ELEMENTS OF ADEQUACY ASSESSMENT



Reasonable representation of AP600 behavior

Reasonable assurance that NRC will reach correct conclusions regarding AP600 accident behavior

3. Recommended Good Practices

This section provides recommendations aiming at reducing the user effect. These recommendations are generally based on common practices adopted by organisations involved in safety analysis.

Organisation and responsibilities

1. It is important to develop appropriate organisational structures and an organisational culture to ensure quality control and secure the full participation of all members of the organisation.

2. Adequate resource should be in place to plan policy implementation adequately.

3. Responsibilities for policy formulation and development (planning, implantation and reviewing) should be clearly allocated.

4. Allocate the responsibility of reviewing and approving analysis to people with the necessary authority and competence and give them time and resources to carry out their duties effectively.

5. Ensure that individuals are held accountable for their responsibilities.

6. Effective communications should be secured by means of written material and face-to-face discussion. Ensure adequate documentation of important issues (the details of documentation should reflect the degree of importance of the issue).

Build up of competence

7. Ensure competence through training, selection, placement, and the provision of adequate specialist advice.

8. User manual and guidelines must be provided to the user as well as complete documentation on the code (models, numerics, assessment).

9. Scrutinise and review performance so as to learn from experience.

10. An analyst should perform a number of uncertainty analyses and sensitivity studies when carrying out plant analyses.

11. Code users should be familiar with the code adequacy demonstration process when applying the code in situations that have not been thoroughly assessed by the code developers or other organisations.

Checks and assessments

12. The analysis team should have an active self-monitoring system to measure the achievement of objective and specified standards. It should also have a reactive monitoring system to collect and analyse information which suggests failure to achieve the required level of quality. Information from active and reactive monitoring should be evaluated by people competent to ascertain the analysis approach which fails to achieve the required standard.

13. Analyse all collected data to identify common features or trends and initiate improvements.

14. The code output should provide global mass and energy balance for checking.

15. Auditing ensures that appropriate remedial actions are taken to deal with the specific identified issues.

4. CONCLUSIONS

This report provides a review and discussion of earlier work relevant to the user effect on the results of system codes transient analyses; responses to a questionnaire proposed by the OECD/CSNI Task Group on Thermal-Hydraulic Applications are considered, together with results of activities started in 1991 in the same CSNI context.

Some recommendations aim at reducing the user effect. These recommendations are generally based on good common practices adopted by organisations involved in safety analyses.

Some of the reasons for the user effect are mentioned in the report. Code deficiencies may be to blame in a number of cases; however, here the attention is focussed on the application of the code and not on improving of the code models.

A critical aspect is the internal organisation of institutions performing system code applications; the engagement of permanent and hired staff has a role in the quality and reliability of produced results. Independent check of user results by an expert supervisor or team leader is strongly recommended in this context.

Practices more or less established and diffused in various institutions to promote at user training and the use of pre-processors or post-processors have been found effective in decreasing user effect. However, there is no substitution for user discipline.

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