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Window-Based Computer Code Package CONPAS for an Integrated Level 2 PSA

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Abstract

A PC window-based computer code, CONPAS (CONtainment Performance Analysis System), has been developed to integrate the numerical, graphical, and results-operation aspects of Level 2 probabilistic safety assessments (PSA) for nuclear power plants automatically. As a main logic for accident progression analysis, it employs a concept of the small containment phenomenological event tree (CPET) helpful to trace out visually individual accident progressions and of the large supporting event tree (LSET) for its detailed quantification. Compared with other existing computer codes for Level 2 PSA, the CONPAS code provides several advanced features: computational aspects including systematic uncertainty analysis, importance analysis, and sensitivity analysis, reporting aspects including tabling and graphic, and user-friend interface.

1. INTRODUCTION

Most recently, a PC window-based computer code, CONPAS, has been developed to satisfy these needs with integrating the numerical, graphical, and results-operation aspects of Level 2 PSA automatically [1]. As a main logic for accident progression analysis, the CONPAS code employs a concept of the small CPET helpful to trace out visually individual accident progressions and of the large supporting event tree (LSET) for its detailed quantification. In the approach, three types of main trees and two types of supporting trees are utilized: Plant damage state (PDS) event tree for PDS categorization and system event tree (SET) extended to containment systems for its quantification, CPET for accident progression analysis and Decomposition event tree (DET) for its quantification, and Source term category (STC) event tree for STC grouping. All these trees are then linked by using event classification logic rules and the quantified outcomes are obtained. The approach for containment or accident progression analysis produces not only a scrutable and understandable model of containment failure mechanisms and enough details to analyze important factors for containment responses to severe accidents, but also a flexible and concise containment response model so that addition and elimination of new events for potential containment improvements are relatively easy. Table 1 shows key characteristics of CONPAS compared with other computer codes for Level 2 PSA. The major emphasis of this paper is on the key features of the CONPAS code and the utilized approaches.

2. CODE DESCRIPTION

As an integral code system for Level 2 PSA, as shown in Fig.1, the CONPAS utilizes four distinct, but closely related modules: (1) *ET Editor Module*, (2) *Computation Module*, (3) *Text Editor Module*, and (4) *Mechanistic Code Plotter Module*. Key characteristics of each module are sequentially described in this section.

2.1 Event Tree Editor Module

The module is used to prepare five distinct, but closely related tree structures: PDS event tree, SET, CPET, DET, STC. In the quantification stage, all these trees are inter-linked by using event classification logic rules [1,2]. The logical flow of information between each trees is illustrated in Fig.2. In addition, this module provides highly effective user-interfaces. Key convenience is to calculate automatically the sequence frequencies/probabilities under given branch probabilities and to check its validity. Additional is to produce each event tree diagram in a variety of ways. The detailed features of the options are described in the Reference 1.

2.2 Event Tree Computation Module

Main function of the module is to analyze quantitatively the five types of event trees constructed from ET Editor module and to plot the resultant numerical outcomes. In order to quantify the intermediate or final results, all these trees are linked in this module by using event classification logic rules. Four types of quantification can be done in this module: point estimate, uncertainty analysis, importance analysis, and sensitivity analysis. Basic approach for the analyses and related main features are described in the following section.

2.2.1 Point Estimate

Point estimate analysis is simply made up of three steps: PDS quantification by SETs, CPET quantification by the quantified PDS and DETs specified in the CPET top headings, and STC quantification by the quantified PDS and quantified CPETs for each PDS. This means that the PDS must be quantified to analyze the CPET in advance. In the same manner, the CPETs for each PDS must be quantified to analyze the STC in advance.

2.2.2 Uncertainty Quantification

In CONPAS, the principal approach for uncertainty quantification is to utilize a Latin Hypercube Sampling (LHS) or a Monte Carlo method optionally, with incorporating the correlations into a sampling scheme. All uncertainty inputs are assigned to the DET basic events and they are utilized in the form of uncertainty input deck. For uncertainty analysis, four types of uncertainty inputs can be utilized: phenomenological uncertainties (subjective probability), expert's opinion (subjective probability), operator actions (frequency distribution), and containment loading and capacity (parameter distribution). For each PDS, there exist the quantified CPETs corresponding to the required number of uncertainty samples. They are then integrated to obtain the probability distributions for CPET endpoints and/or STC. The final result is presented as quantiles of distribution and a form of plotting data.

2.2.3 Importance/Sensitivity Analysis

This parts manipulate the intermediate results obtained for each stage of accident progression analysis. The principal approach for importance analysis is to utilize matrix formula for quantitative risk analysis which provides a verified mean to identify the dominant contributors to the specified outcomes [3]. In CONPAS, twelve types of importance analyses can be performed, including initiators to STC, PDS to STC, CPET sequences to STC, etc. All the results can then be displayed graphically in the form of Pie graph or Bar chart. If needed, they can also be printed in table form.

On the other hand, the sensitivity analysis is taken by two levels. One is the intermediate level sensitivity analysis which investigates the variation of intermediate results due to the change of initiator, SET, and PDS events. This type of sensitivity is analyzed by the matrix formula like the importance analysis. Three types of sensitivity analyses can be performed in this module: initiators to PDS, initiators to STC, and PDS to STC. Then all the results can be displayed in the form of sensitivity table. The other level characterized by CONPAS is the basic event level sensitivity analysis which identifies the variation in the probability estimates on the overall results for each phenomenological event in DETs.

2.2.4 Calculation of Containment Failure Probability

The containment failure modes and related probabilities are somewhat differently affected by the pressurization rate of containment, i.e., fast pressurization and slow pressurization [4]. In CONPAS, the slow pressurization model is used to evaluate the containment failure probabilities. In the case of point estimate, these peak pressures can be utilized in the form of parameters in DETs rather than probabilities. In this case, CONPAS evaluate automatically the resultant containment failure probability for each failure mode (like a leak or a rupture) without external calculation. For the evaluation of containment failure probability, five containment capacity distributions were currently hard-wired in CONPAS: uniform, loguniform, normal, lognormal, and empirical distribution. For uncertainty analysis, however, they should be manipulated in the input deck. As the result, peak loading pressure distributions and capacity distributions are combined to generate a specified number of failure probabilities.

2.3 Text Editor Module

Many PSA applications require a diverse presentation of the results. Tools could be developed to automate PSA output and simplify the level of effort required to generate results. While CONPAS Computation Module utilizes a function for plotting the results of uncertainty and importance analysis for those purpose, Text Editor module is used to report the results and to prepare the uncertainty input deck without any help from commercialized editors.

2.4 Mechanistic Code Plotter Module

The Mechanistic Code Plotter Module utilizes the results of accident progression analysis based on the phenomenological codes. It is to extract the control variables from accident scenarios and to summarize the ranges of severe accident issues. For the purpose, the module has three options: (1) individual plot for each control variable, (2) merged plot for several control variables, and (3) merged plot for several different scenarios.

3. CONCLUDING REMARKS

Key features of the CONPAS are summarized as follows :

- CONPAS provides a highly effective user-interface including convenient edition of event trees through mouse-driven and colored graphics, systematic data operation.
- CONPAS utilizes a modularized accident progression logic which is characterized by two types of supporting trees. As the result, it possible to describe effectively the accident progressions with pertinent number of event headings on the CPET.
- CONPAS provides several computational features including systematic uncertainty, importance, and sensitivity analysis, essential in Level 2 PSA.
- CONPAS provides several functions for reporting, including colored plots, graph, and tabling of final outcomes. Also, it provides two additional features: data analyzer for

analysis of severe accident code results and text editor for refined reporting of the calculational results.

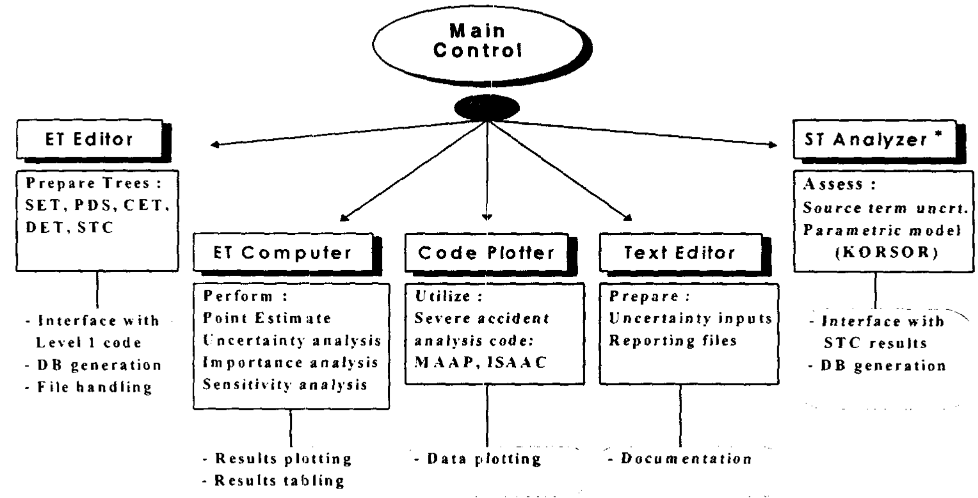
As an on-going work, ST analyzer module is being currently developed and in near future the product will be incorporated into the CONPAS. Its main purpose is to assess source terms of a more complete range of accident scenarios or for uncertainty analysis, which utilizes a data base obtained through a parametric calculation using MAAP or MELCORE code, etc. After completing this additional work, the CONPAS code will have more extended capability for Level 2 PSA.

REFERENCES

[1] K.I. Ahn et al., "CONPAS 1.0 (Containment Performance Analysis System) Code Package User's Manual, KAERI/TR -?/96, KAERI (April 1996, to be published).
[2] Fulford and R.R. Sherry, "NUCAP+ user's manual," NUS-5282 (April 1991).
[3] S.Kaplan, Matrix Theory Formalism for Event Tree Analysis: Application to Nuclear-Risk Analysis, *Risk Analysis*, **2**, pp.9-18 (1981).
[4] J.C.Helton, R.J. Breeding, and S.C. Hora, Probability of containment failure mode for fast pressure rise, *Reliability Engineering and System Safety*, **35**, pp91-106 (1992).

TABLE 1
Key Characteristics of CONPAS compared with the Existing Level 2 PSA Codes

Code Name	Source	Approach for Accident Progression	OS	Key Characteristics
EVNTRE	USNRC	APET (accident progression event tree)	DOS	. General CET (very large size) . Uncertainty quantification . Use of parameters within CET
RM-ETA	PLG	(conventional CET)	DOS. OS/2	. General CET (large size) . Links tree modules
CAFTA	EPRI	CET/PFT (containment event tree / phenomenological fault tree)	DOS	. General CPET (medium size) . Quantification by support tree (PFT)
NUCAP+	HNUS	CET/DET	DOS	. General CPET (medium size) . Importance / sensitivity analysis
CONPAS	KAERI	CET/DET	MS Windows	. General CPET (medium size) . Improvement of user-interface . Uncertainty / importance / sensitivity analysis



(*) : currently not available

Fig.1 General Structure of CONPAS Code System

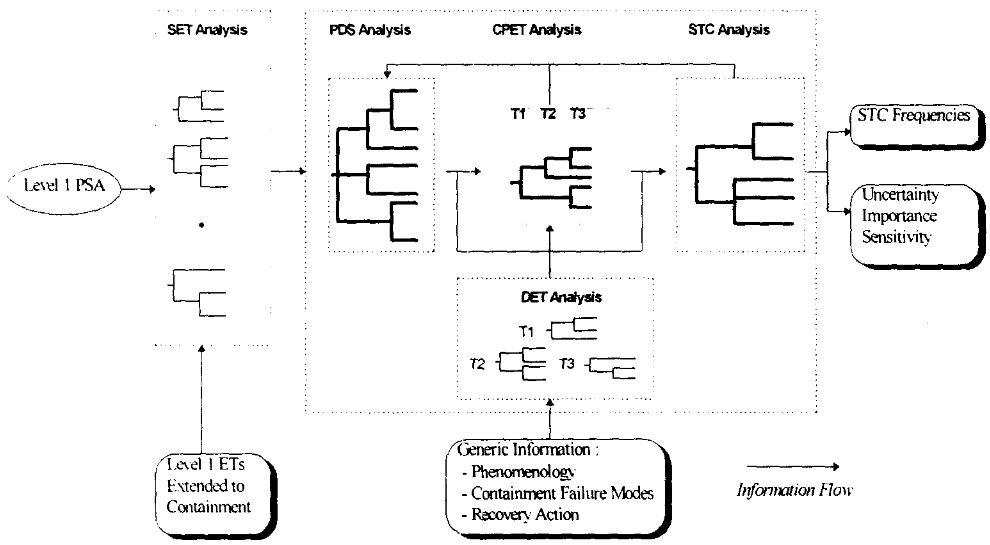


Fig.2 Information Flow between Event Trees used in **CONPAS**