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November 30, 1998

Dr. Robert E. Henry
Chairman, Data Preservation Task Force
Fauske & Associates, Inc.
16W070 West 83rd Street
Burr Ridge, IL 60521

Subject: Thermal Hydraulics Division

Dear Dr. Henry:

At the recent American Nuclear Society (ANS) board meeting held in Washington, D.C., We had a summary presentation of the data preservation activity that grew out of concern in the Thermal Hydraulics Division. As both you and Professor Reyes recall, the ANS Executive Committee heard a summary of this during the August meeting and asked for a business plan to be formulated. With the cooperation of ANS Headquarters, this plan was developed and distributed to the board members prior to the Washington meeting. During this presentation, two decisions were asked of the board:

1) an endorsement of the general process as laid out in the business plan and summarized during the board presentation (no financial commitment was asked at this time), and

2) a letter from the board to the Thermal Hydraulics Division, and the Data Preservation Task Force, stating that the board believes there is sufficient merit to this concept to request a draft ANS standard to be developed. This will provide the necessary structure for interested parties to begin documenting (preserving) important experimental information.

   If necessary, please coordinate this task development with the ANS Standards Steering Committee, Chaired by Les Ettlinger.

The board considered both of these and concluded that (a) there is a unanimous endorsement of the general concept, and (b) a draft standard should be developed.

EDWARD (TED) L. QUINN
PRESIDENT

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Dr. Henry
Page Two
11/30/98

We look forward to hearing about this continued development at the Washington Board meeting in March or the summer meeting. Several board members have questions of how this will eventually be brought to fruition, but those questions do not detract from the fact that this is an important activity for the ANS to support and develop.

Please advise if I can be of further help or answer any questions. I may be reached at (949) 365-1350.

Very Truly Yours,

Edward L. (Ted) Quinn, President
American Nuclear Society

TLQ:kjs

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AMERICAN NUCLEAR SOCIETY

Documentation of Major Experimental Results

For Direct Integration Into Computer Codes

(Data Preservation)

American National Standard

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Foreward

The United States nuclear industry places a high level of importance on the "Defense in Depth" concept for reactor fuel, reactor core, Reactor Coolant System (RCS) system and containment designs. This concept is deeply embedded in the structure for design, licensing and operation of all such systems. To facilitate an indepth understanding of the extent to which specific designs are robust with substantial margin, numerous experiments have been performed at both small and large scale to demonstrate the behaviors that would be experienced for individual components and the integral response of numerous components under transient and accident conditions. These experiments are related to a spectrum of designs for the reactor fuel, the reactor core, the Reactor Coolant System (RCS), the Emergency Core Cooling System (ECCS) and containment designs. Consequently, these experiments are a manifestation of the knowledge accumulated on the specific designs and the margins associated with respect to design limits.

Given the importance of these experiments, it is essential that the major insights derived from these are preserved and used to ensure that the lessons learned are continually ingrained into the understanding associated with individual component design, as well as the integral system behavior with numerous components. Typically, these experimental efforts have been documented as open literature and/or proprietary reports and are submitted to libraries as archival references. Furthermore, much of the experimental information has been archived on magnetic tapes, computer records such as floppy disks or compact disks, etc. All of these are helpful to the preservation of this important information. However, experience has shown that the rapidly changing computer technology has left some of these records "trapped" in a form that can no longer be read. Consequently, some of the essential information could subsequently be lost. This standard provides a means to preserve the essential aspects of the experimental information and the important insights.

Typically the experimental information has been used to benchmark various computer codes or modules of computer codes. This standard provides a structured format for defining the input for such benchmarking activities, that is independent of the code being used, while also archiving the fundamental information reported by the authors of a given experiment/experience. Once this information is compiled for the application (benchmarking) to one code, the same information can be used by other analysts using other computer codes. Furthermore, other analysts may choose to extend the archived information through this manner and the standard provides guidance on how such additional augmentation can be performed and reviewed. In this way, the basic information developed for specific experiments/industry experiences is archived within the computer software technology used in the nuclear industry and is then used as a consistent database for different computer codes addressing the same set of design conditions, plant transients, etc. Lastly, it is hoped that through the use of this standard that the important experimental information existing in the literature will be used by current and future analysts such that the important insights are retained and integrated into the decision-making processes.

Table of Contents

Documentation of Major Experimental Results For Direct Integration Into Computer Codes

1.0 Introduction and Scope

1.1 Introduction

The design and licensing of nuclear power plants has developed substantially over the decades of commercial nuclear power. This development has been the result of experiments and analyses performed on the various designs used to generate electrical power using nuclear power plants. Throughout this development small and large scale experimental studies have provided important direction towards those issues that can be considered as sufficiently understood and those where additional information is needed. These experiments and the accompanying fundamental analyses have been documented but have experienced significant difficulties in being maintained in a permanently retrievable format. To a large extent this is due to the rapid advances associated with the computer age and the rapidly changing technology for storing and retrieving information. In many cases, the advancing technology has moved so quickly that much of the fundamental information from major experimental studies becomes trapped within a technology that is no longer supported and the detailed information can no longer be retrieved.

It is important that these experimental results, which form the basis of major design decisions for the current and future nuclear power facilities are preserved in a manner which enables the information to be recalled conveniently and used continually. Furthermore, the fundamental insights associated with such substantial experiments must be retained as a base technology for the understanding of current and future designs as well as to direct the focus of future studies.

1.2 Purpose

The purpose of this standard is to provide a structured format for documenting fundamental studies in a manner that can be conveniently embedded within large software systems (computer codes) and therefore be preserved as well as used to benchmark separate effects and integral models to understand the strengths and weaknesses of the computerized models. Since large computer codes will be a continual part of nuclear technology, documenting these experiments in this manner (embedded within the codes) is a convenient way of assuring that the information is retained for continued use by the nuclear community. Furthermore, having this information available for implementation into such a large computer code strongly encourages the extensive benchmarking of computer models to further enhance the level of confidence in the computer codes.

1.3 Scope

This standard provides the structure for documenting major experimental facilities including:

- test geometries,
- the initial and boundary conditions for the experiments, and
- the important measured results from a given set of experiments.

Moreover, the structure can also be applied to document important nuclear experiences where specific plant transient information has been recorded. In the following sections, a standard structure is defined for organizing (a) the experiments objectives, (b) a summary of the results given by the authors, (c) the test specific geometric information, (d) the important initial and boundary conditions and (e) important recorded measurements (dat). Using this standard document information ensures that it can be conveniently read into existing computer codes. Furthermore, it will be cataloged and kept on file by the American Nuclear Society as permanent documentation of important experimental studies and industry experiences.

1.4 Limitations and Interfaces

This standard does not describe how the information is to be used by a computer code. Rather it focuses on preserving the information for a set of experiments/experiences exactly as given by the authors; i.e. there are no calculations or manipulation of data performed in these "information routines". Once this information is defined, it can be easily read by any computer code, which then characterizes the information in a manner that is necessary for the nodalization, input, output, etc. specific to that code.

2.0 Definitions

Computer Code - Any computerized description of mechanistic physical processes used in the design, licensing and maintenance of nuclear facilities.

Input - That information which needs to be supplied to a computerized model such that the physical processes of interest can be calculated.

Experiments - Any experiment which has provided substantial insight into an important physical process to be evaluated in nuclear power plant design, licensing and maintenance.

Output - That information that results from a calculation/experiment that shows the important results associated with specific physical processes.

3.0 Format for Documenting Experimental Information

The principle objective for data preservation is to augment current library files and data banks, such as that maintained by the Nuclear Regulatory Commission (NRC), by designing a structured process to preserve important experimental information in a manner that is, and will remain current. This process facilitates the use of important experimental information to develop, test and qualify computer codes used to support decision-making related to current and future reactor designs regarding the design itself, licensing and plant operation.

3.1 Proposed Approach

The proposed approach is to incorporate experimental information into relevant computer codes which are used for such design evaluations as dedicated input files subject to the code specific configuration control. Since major computer codes and/or their successors will advance with computer technology, the data will also be preserved in a manner compatible with state-of-the-art technology. Obviously this approach cannot be used to permanently document all of the transient measurements reported for the large numbers of experiments that have been performed since the birth of the nuclear industry. However, the important information describing the experimental facility and objectives, the test conditions, the key measurements, additional observations, as well as a summary of the results can be documented. Furthermore, the availability of this information will encourage and extend the use of the data for benchmarking relevant codes. The author of each version of the archival files should be included at the top of the file along with the reviewer(s) (an ANS division affiliation) for each version.

Since experiments have been performed at different times, in different laboratories/countries with the experimental information reported in different sets of units, the integrity of the original information needs to be preserved. Therefore, the important information should be documented as given in the cited references and in the units used by the original investigators. This also aids in subsequent reviews that need to be performed to ensure the quality of the resulting product.

3.2 Organizational Format for the Data

A common format for expressing the information simplifies the formulation, use and review of these documents. Separate sections should be developed for:

- the references used in developing the information,
- a brief description of the experiment,
- a statement of the experimental objectives,
- a summary of the results,
- units used in reporting/documenting the information,
- experimental configuration including the reference and page number where the quoted values can be found,
- pertinent initial and boundary conditions for the test including the reference and page number use, and
- important experimental results/measurements including designations of the instrument and the page number (or other designator) where the information is found.

Since the information is documented for data preservation, the primary source (reference) for each entry into this "information routine" should be given through comments. In this regard, it is essential for documenting (preserving) such key information that the source be the most appropriate, i.e. the primary source and not a source which quotes the primary source. (Use of such secondary reference is only acceptable when the primary source no longer exists.) Also personal communication references should not to be used.

3.3 System of Units

For clarity, units are to be given explicitly for each value quoted and these should be the same units as used by the authors of the base references. The archival file should include a section defining the units in terms of the abbreviation used for each. Examples of these definitions include:

SI: International System

- C: degrees Celsius
- K: degrees Kelvin
- Kg: kilogram
- m: meters
- J: Joules
- secs: seconds

British

- F: degrees Fahrenheit
- R: degrees Rankine
- Lbm: pounds mass
- ft: feet
- Btu: British thermal units
- secs: seconds

cgs

- C: degrees Celsius
- g: grams
- cm: centimeters
- J: Joules
- secs: seconds

Other systems can also be used but must be clearly defined. To clearly convey the experimental information, the units for each quoted value should be stated immediately adjacent to the value, i.e. 10^6 J or 10^6 (water energy (J)).

3.4 Documenting the Experimental Configuration

Documentation for large, integral experiments need to be structured such that users can easily find relevant information. For example, since experimental facilities typically focus on a test section, a test apparatus, etc. it is suggested that the "information routines" describing the experimental configuration be structured beginning with the central feature (the test apparatus) and working outward to describe the remainder of the experimental facility. For example, when documenting the LOFT experiments, a logical approach is to organize the experimental information from the core to the containment:

- core geometry,
- RCS configuration,
- secondary side geometry,
- containment geometry, and
- auxiliary systems.

When considering a series of experiments from the same facility, there may be changes between tests, such as the core geometry. Therefore, the documentation should include an identifier for the specific test, i.e. the test number, and those changes to the general information that are subject to this change for a given test. For example, if this information is documented as an input file, it can be organized such that the test specific information is read after the general information and is accomplished with an identifier (combination of letters and numbers) for a specific test. In this way, the test specific parameters, such as the number of fuel pins in a fuel assembly, would be overwritten with the test specific information used when the test identification letters/numbers are used. Thus, the information associated with small changes in the test configuration can be developed by extending previous "information routines" characterizing other experiments in the same facility. Of course, the major experimental results/measurements must be associated with a given test, hence the time dependent information must be associated with a test identifier of letters/numbers.

3.5 Format for Documenting the Experimental Geometry

Appendix A provides an example of documentation for the experimental geometry associated with a given test facility. Where convenient descriptions can be abstracted from the base reference(s), this should be included for easy reference by the user. An example is given for the CVTR geometry (Schmitt, Bingham and Norberg, 1970) with a concise description of the containment configuration. This section is then followed by the statement of the important information to be archived in a one-at-a-time manner with each being clearly defined along with the specific page number for the individual value. Furthermore, if the value is in a format that is difficult to implement directly as the author stated, such as feet, inches and fraction of inches, the value can be given as a decimal with the actual value stated by the authors given in a comment immediately below.

3.6 Format for Documenting the Specific Test Conditions

Since the conditions are generally specific to a given test, it is suggested that the test number be listed and the specific conditions associated with each entry given in a one-at-of-time manner. As with the description of the facility, this enables each quoted value to be clearly defined and identified with the specific page number in the base reference(s) where the specific value has been found. This format enables additional information to be added on the end of each experiment should such modifications be developed by future users of the information.

3.7 Format for Documenting the Experimental Results

Results are test specific and therefore it is recommended that the information from a specific test be documented with the initial conditions under the specific test number. Should the information for a given test become very large, separate files can be developed for individual test numbers to be read by a central file that contains the general facility description, etc. Here again it is recommended that where possible, the specific information be given in a one-at-a-time manner such that the qualification for the value quoted can be easily defined along with the page number where the value can be found. If the information is a digitized file of measured pressure vs. time, temperature vs. time, etc. then each specific file should be identified with respect to the measurement given and the location of this measurement. For clarity, it is suggested that the information be listed as individual files of variable and time which provides for the simplest interpretation by analysts.

3.8 Suggested Format for Integrating the Experimental Information Into the Computer Configuration Control

Integration of experimental information into computer codes for permanent documentation of the key information is illustrated in Figures 1 and 2. "Information routines or input files" are embedded within a computer code structure so that the information is part of the code and subject to its configuration control, including the code software and the input files. As illustrated, the "information routines" only transfer test information out and the conversion of the relevant information into a form usable by a given computer code is performed in the specific code interface routine. Consequently, these "information routines" can be used for another code (ABC) and the same fundamental information is immediately available. Moreover, if the analysts for code ABC believe that there is additional important experimental information to be added, they can consult the original references and extend the capabilities in the documented "information routines" by providing a revision to the original information. This revision is subsequently reviewed by one or more ANS divisions for correctness before being included on the ANS list of qualified archival files.

An example of an important experiment that has been used repeatedly to evaluate calculations of containment response to a postulated blowdown of the Reactor Coolant System (RCS) is the containment test using the Carolinas Virginia Tube Reactor (CVTR) containment building (Schmitt, Bingham and Norberg, 1970). In these experiments, the major observations were the pressures and temperatures at various locations in the containment building for the different experiments. Steam from an adjacent power plant was injected into the containment building for a period of time (until the pressure reached 18 psig), the steam source was terminated, and the pressure decayed. For some tests, the containment spray was actuated which accelerated the pressure decay. Since these experiments are representative of a substantial steam blowdown into a containment building, including comparative behaviors with and without containment spray, these are an important benchmark for containment codes. Figure 2 is a schematic representation of how the information could be integrated into existing of containment analysis computer codes for preservation of the essential data. Figure 3 illustrates the containment pressure transients for tests 3, 4 and 5, the data points are examples of the important information to be documented in the "information routines". As illustrated in the figure legend, test 3 was performed without containment spray, test 4 had a containment spray of 290 gpm and test 5 had a containment spray of 500 gpm. This information is included in the representations for the test conditions characteristic of the individual experiments in Appendix A.

Appendix B is an example for the documentation of a separate effects experiment for molten uranium dioxide poured into water (FARO experiments). Note that the information may be reported in different units between references, i.e. °C in one reference and K in another. As illustrated by this reference, the extent of experimental information may be simple in its concept, more numerous in the available experiments than for a large test like CVTR.

4.0 Review Function

The information archived from individual experiments need to be reviewed by the interested ANS divisions to assure that the following conditions are true.

1. That the most appropriate basis documents have been used as references for accumulating the information. If more appropriate basis documents should be used, and are available, then the reviewer can make this recommendation to the ANS such that the information is taken directly from the most appropriate references.

2. That the information given has a cited reference and page number. If the information is developed from values which are not stated, the explanation in the file would clearly specify how it is developed such that it can be potentially improved in the future.

3. Assure through random checking that the values given in the file agree with those in the cited references.

4. Assure by random checking that the experimental results listed in the reference are a reasonable characterization of the reported results when this information is taken from published curves and literature references.

5. That all comments on the listed data are resolved prior to giving ANS approval and transmitting the files to ANS headquarters.

5.0 Archival Function

After the information has been developed and undergone the review and approval process of the interested ANS divisions, the approved experimental file is transmitted to the ANS headquarters to be added to the list of archived experiments and maintained by the American Nuclear Society. Each accepted file will have a version number, such as versions 0.0, 1.0, etc. with all approved previous versions listed in the development and review section of the existing file. This provides an entire history of the individuals developing and reviewing the specific information. ANS will maintain the most current file and all previous files subject to the space limitations.

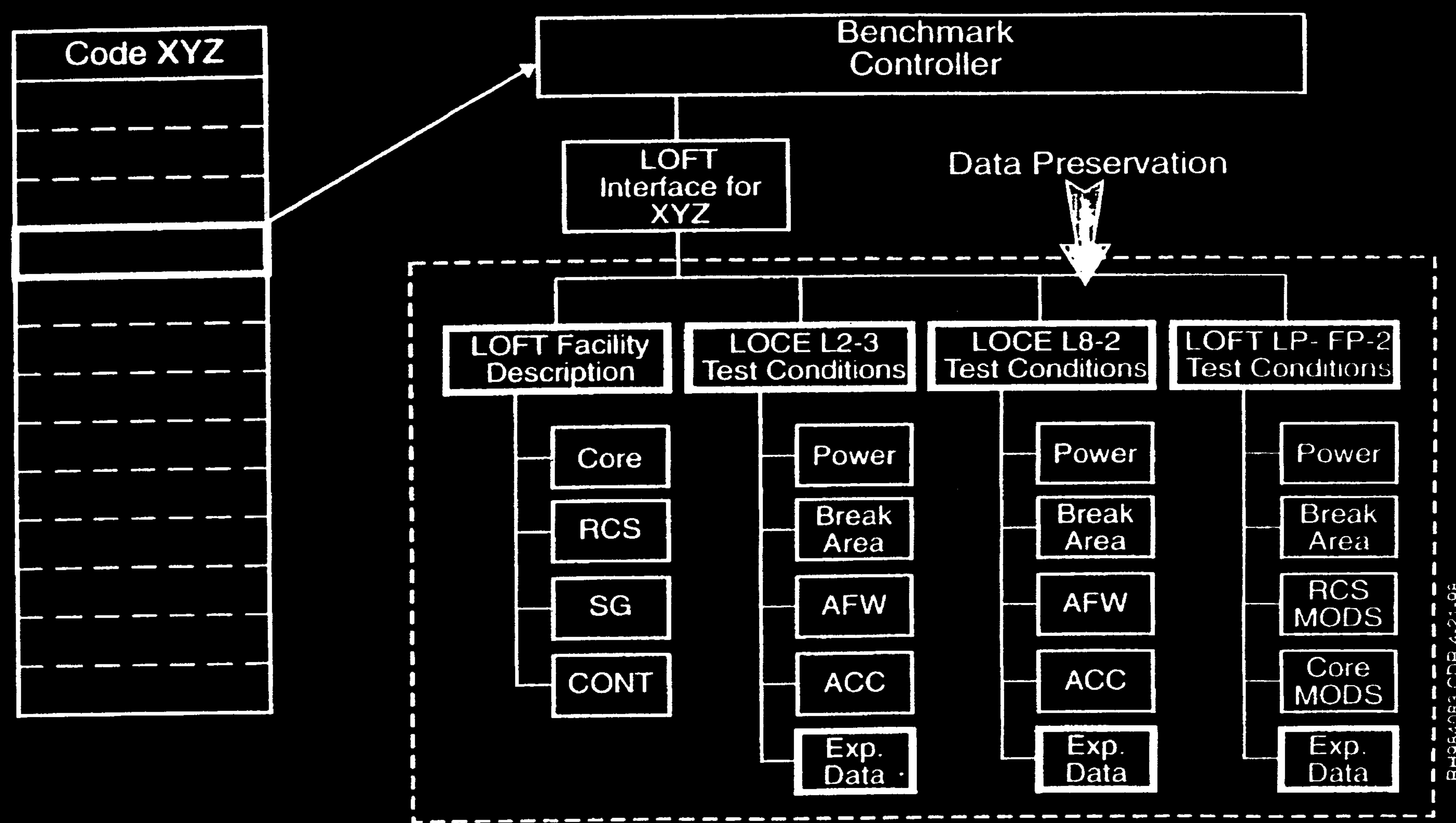
If an archival file is requested to be changed, ANS, according to their procedures, will deliver a copy of the archived file to the interested organization and note in their list of archived experiments that a specific file has been requested for change. This will not preempt the current file from being used, but will make additional users aware of the potential changes being developed by another organization. Once the additional changes have been completed and ANS is notified that such changes have been completed, the revised file should be transmitted to ANS headquarters to be sent to the interested ANS divisions for review with respect to the changes that have been made to the file in this new version. In this additional review process, only the changes to the file should be assessed since the previous version was already reviewed by the interested ANS divisions. When this new version has been reviewed and approved, it is then transmitted to the ANS and the list of archived experiments is updated to include this new version of the given experiment. Once this has been added to the archived file, this then becomes the official version of the experimental documentation that is supplied on request to the American Nuclear Society.

In this way, the American Nuclear Society is the controlling organization for the archived experimental data. Consequently, all requests for this information would be to the American Nuclear Society headquarters.

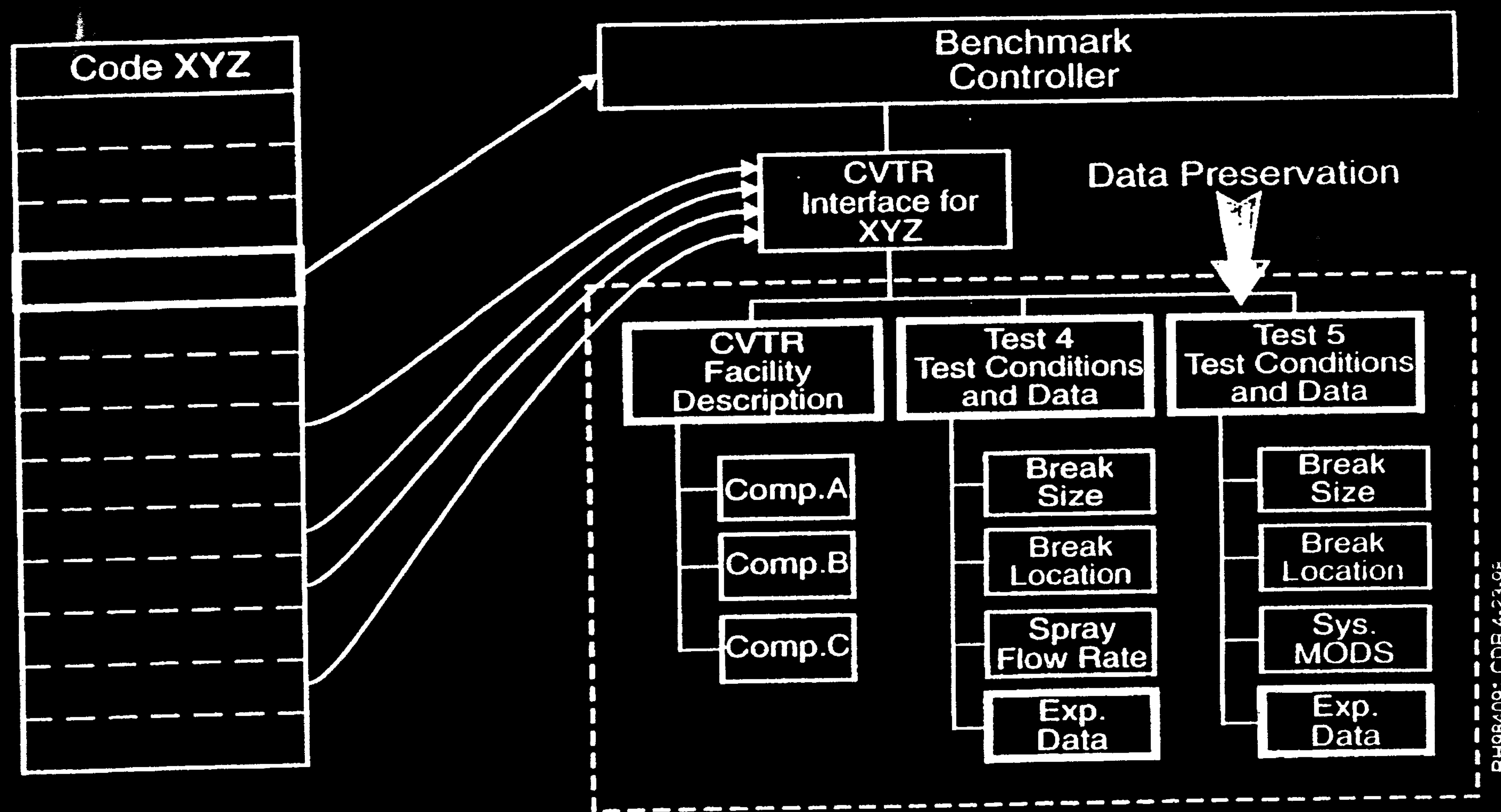
6.0 References

Schmitt, R. C., Bingham, G. E. and Norberg, J. A., 1970, "Simulated Design Basis Accident Tests of the Carolinas Virginia Tube Reactor Containment - Final Report," UC-80, IN-1403, Reactor Technology TID-4500.

Example Application
(Reactor Scale Experiment)



Example Application
(Large Integral Containment Experiment)



CVTR Containment Pressure
Example of Data Traces to be Archived