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Design Basis Reconstitution for Long Term Operation of Nuclear Power Plants

IAEA

International Atomic Energy Agency

DESIGN BASIS RECONSTITUTION FOR LONG TERM OPERATION OF NUCLEAR POWER PLANTS

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FOREWORD

A nuclear power plant design is the product of many organizations. Changes to the design will occur owing to improvements or continuous technical evolution over the plant's life cycle, which is typically between 30 and 80 years. This spans several generations of technical support staff and potentially major changes to the original design. It can also be expected that the roles of the vendors and designers needed to support the plant change substantially over time too. Therefore, the lengthy design and operation process represents a very specific challenge in maintaining the design, its intent and integrity.

The deterioration or loss of the original design basis is typically caused by inadequate configuration control processes. Once this deterioration or loss has been identified, the design basis of systems, structures, and components has to be reconstituted to maintain the safe, reliable and efficient operation of the plant, ensure plant performance, and sustain the corporate asset management of the nuclear power plant.

As observed from operating experience, the design basis reconstitution efforts can be costly and time consuming, which demonstrates the need for effective planning and a structured framework for development and implementation of reconstitution programmes and processes. A combination of design basis reconstitution and corrective actions to prevent the recurrence of these conditions would help maintain the design integrity for the rest of nuclear power plant's life cycle and achieve continued operation with a high level of safety and performance.

This publication discusses reasons, goals, key principles and elements of an appropriately scoped and structured design basis reconstitution effort, including the identification of potential issues and their possible solutions based on specific plant needs, and the lessons from previous design basis reconstitution projects.

This publication is intended to serve a wide audience of technical staff and increase their awareness of this issue. It also supports professionals in managing design basis reconstitution efforts and ensures that these efforts are adequately performed in nuclear installations. This publication may also be beneficial to senior executives responsible for the safe operation of nuclear power plants in helping them establish the necessary structure to ensure that the required design integrity of the plant is maintained throughout its operating life.

The IAEA wishes to thank all Member State experts for their contributions to this publication. The IAEA officer responsible for the preparation of this publication was H. Varjonen of the Division of Nuclear Power.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Nuclear power plants (NPPs) are required to operate in a manner that is compliant with their license and meets their design intent over a period of many decades. Maintaining the safe and efficient plant operation requires that the initial design and all subsequent changes to the initial design which occurred during its lifetime are recorded and controlled via a structured process, such that information about the design and its basis are known and available.

As result of over sixty-year long lifetime of an NPP, maintaining the integrity of design and its basis necessitates focused, structured, and continuous efforts and preservation transfer of information and knowledge by ever changing workforce and supporting vendors and designers. When one or more of these aspects become weak over this long time, this weakest link may have a snowball effect on creating deficiencies and defects in the integrity of DB and its knowledge, and plant configuration. This, in turn, will result in deviation from the original design intent for the SSCs functions and operation, or even reduction in design and safety margins.

As early as 1980s various deficiencies and defects have been discovered to complicate design and operational decisions, owing to the unknown, unclear, or missing design information that became visible during operation, most of the time latently. The implementation, effectiveness, and adequacy of maintaining and retaining facility design information got adversely affected due to this loss or omission of design information. Some of those adverse impacts perpetuated from inadequate processes that are in the control of the owner/operating organizations (e.g., their programmes, procedures, culture, and resources) while some, such as interruption of external vendor relations, did not.

Lost or not kept up–to–date DB and associated information and updated plant physical configuration and promulgation of this data among the operating organization and supporting vendors becomes visible and challenging when missing design concept, intent or information is realized. Although such deficiencies may have gone unnoticed during daily operations, they are realized when a comprehensive review and understanding of the DB is needed, particularly during design or assessment of major plant changes, such as refurbishment, power uprate, major equipment replacement, conversion of the plant to new or revised regulations, license conditions, codes, and standards and/or assessments for long term operation.

When the defects and deficiencies in having a complete, correct, and sufficient DB are recognized, the owner/operating organizations have usually undertaken a detailed and comprehensive review and assessment to compete and update the facility DB, intents, interfaces, etc. which is known as design basis reconstitution (DBR).

In parallel with this effort the owner/operating organizations have usually undertaken an evaluation of the causal effects that led to a need for the DBR, and CA to prevent a recurrence of conditions that lead to DBR. Typically, these CA’s include improvements in configuration management and design control programmes, and associated process and not addressed herein.

The restoration of DB integrity will heavily task human and financial resources of an operating organization. This programme, that is typically associated with a project, will require scope control. A cautionary tale of some of the past operation experience is that the DBR projects were abandoned, or their scope was drastically reduced, or the requirements and expectations were relaxed or dropped due to an overambitious scoping, and/or lack of understanding and planning of the project burden and strain on the human and financial resources. To put it simply, any attempts to do a ‘complete’ DBR will have a high probability of its failure.

1.2. OBJECTIVE

This document aims at describing a structured and graded approach to effectively reconstitute plant’s DB information that has been found defective, deficient, inadequate, or insufficient.

Effective DBR approaches require identification and assessment of DB information and knowledge deficiencies and scoping and planning to match the level of reconstitution effort to a desired and manageable outcome. As such, the objective of this publication is to define a structure for programmes/processes/projects, as well as the roles and responsibilities, for the efficient execution of a DBR undertaking, specifically based on the level of effort, and expected outcome.

1.3. SCOPE

This publication describes the key elements, such as the drivers, goals, methods, roles, responsibilities, and interfaces for conducting of an effective DBR effort. This publication is not intended to endorse or to invalidate a particular approach to DBR; or to provide a detailed and prescriptive implementation procedure to achieve a DBR; or to provide a ‘one-size-fits-all’ method for performing and managing DBR. Rather, it provides Member States with understanding of the importance of reconstitution of defective or missing DB information and knowledge. Also, as the need and method of DBR vary from one organization to another, this publication provides fundamentals and common elements of effective DBR and presents some examples of options that were practiced by the owner/operating organizations. It also provides a descriptive process guidance providing major technical and managerial elements, important criteria, and roles and responsibilities of parties involved in the request, preparation, and the utilization of the DBR efforts.

This publication does not discuss processes for identification and documentation of deficiencies of a DB. The identification, reporting, and resolution of DB deficiencies are controlled under corrective action program (CAP) and it needs to be treated within the station configuration management program [1].

The discussions of other plant programmes and processes that have close interface with DBR efforts (e.g., design control, document control, configuration management, corrective action, quality assurance) are not in the scope of this publication except by recognition of their interaction and interfaces with the DBR activities.

Users who are in a decision-making process on whether updating (or restoring) DB information ‘makes sense’, and if it does, whether it is feasible and viable for their utility could refer to Section 4 (Reasons for DBR).

Users who are approaching the implementation of their DBR project could refer to Sections 5 (Scope) and 6 (Implementation) to establish and maintain DBR for their decision making.

The guidance is supplemented by specific examples of effective (or ineffective) DBR, and managing organizations providing it, from operational experience as well as good practices and lessons learned; however, the IAEA does not take responsibility for the completeness and applicability of those examples for specific cases which require users' efforts to validate and verify, as well as to assess for adaptability to their own organization and situation.

1.4. STRUCTURE

The main body of this publication is divided into seven (7) sections including the introduction in Section 1 and the conclusions in Section 7.

Section 2 describes the terminology and the areas discussed in the publication providing an overall view of what DBR and associated definitions are, while Section 3 describes key elements and attributes for effective design basis reconstitution (DBR).

Section 4 provides the reasons and driving causal factors for entering DBR efforts (i.e., discussing 'why') and observed challenges in the decision for and initiation of DBR activities, while Section 5 presents the scope setting (i.e., 'what') of the project at its initiation.

Section 6 gives a view of current and past methods (i.e., 'how') utilized when performing DBR efforts and discusses advantages and disadvantages of those methods, as well as the lessons learned from their application.

Appendices to the publication supplement the discussions by providing some examples from the experience of Member States concerning DBR initiation and execution to illustrate some practices and specific discussions about practices in the Member States.

The targeted users of this publication are the Member State organizations involved or considering to be involved in a DBR for an NPP. Thus, it is expected that the primary users of this publication include the owner/operating organizations that find themselves in a situation that the DB information is insufficient, inadequate, deficient, or unknown and needs to be reconstituted for current and future design and operational decision making. Particularly those that will decide on, manage, and perform the DBR efforts may find this publication beneficial.

This publication also aims at the organizations that provide external support for DBR efforts, for understanding the 'customer' needs and the areas that they can contribute. These organizations include architect-engineers, technology owners, responsible designers, independent technical experts and groups, academia and research and development staff.

Although this document is primarily written as a guidance for NPP owner/operating organization, it may also help the regulatory bodies whose oversight ensures that the licensees maintain adequate design information and knowledge and use it for sound, safe and reliable operational and design decision making.

A list of abbreviations is also provided for the reader's aid at the end of the publication.

2. DEFINITIONS, TERMS AND RELATED DESCRIPTIONS

Literally, 'reconstitution' means the process of restoring something to its original or applicable state by building up or constructing it again for future use. Similarly, DBR is the process to recover and restore the DB information in a state needed for continued safe operation.

As such, when the needed DB information is unavailable, missing, unknown, omitted, obsolete or possibly erroneous, DBR may become necessary, involving the identification, collection, and correction of DB information. Subsequently, it could result in revised or new design documentation and/or DB information in a form that is updated and easy to access and use [2]. Therefore, before discussing DBR, the design (original and thereafter modified), its basis, and how and where they are described and documented need to be understood.

Figure 1 below illustrates flow down of requirements to various NPP elements containing information/knowledge. Understanding that change in any of these elements of NPP's knowledge may impact information in the interconnecting knowledge elements is vital to assure that impact on all elements of NPP's Knowledge Bases are considered during the DBR. The arrows represent a flow down of requirements for most of the plant documents.

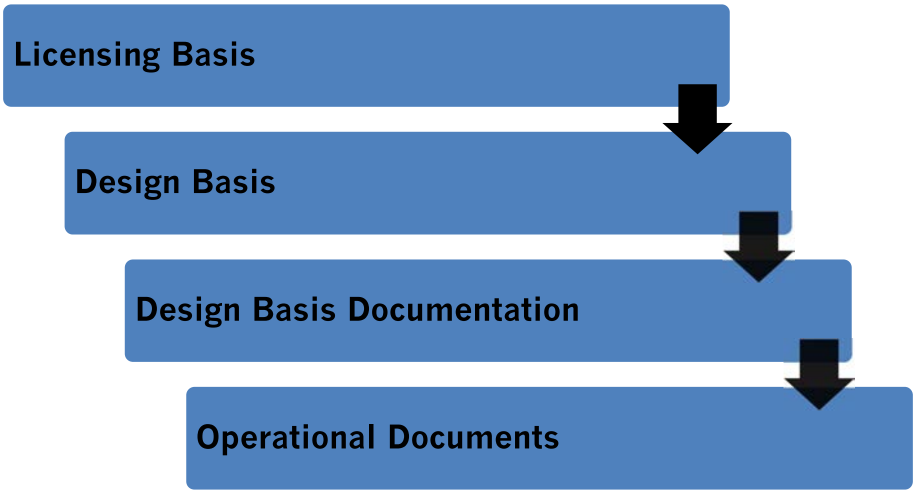

FIG. 1. Hierarchy of Knowledge Basis Elements.

2.1. LICENSING BASIS

The IAEA Safety Glossary defines the licensing basis of a nuclear facility as:

> "a set of regulatory requirements applicable to a nuclear installation. The licensing basis, in addition to a set of regulatory requirements, may also include agreements and commitments made between the regulatory body and the licensee (e.g., in the form of letters exchanged or of statements made in technical meetings)" [3].

2.2. DESIGN

The IAEA Safety Glossary defines the design of a nuclear facility as:

> "the process and the result of developing a concept, detailed plans, supporting calculations and specifications for a facility and its parts" [3].

Design of a nuclear plant is a living and continuous process from the initiation of the project until the final phase of decommissioning.

2.3. DESIGN BASIS

The IAEA Safety Glossary defines DB (for the authorization of a nuclear facility) as:

> "the range of conditions and events taken explicitly into account in the design of structures, systems and components and equipment of a facility, according to established criteria, such that the facility can withstand them without exceeding authorized limits" [3].

Noting that the facility design also includes SSCs not important to safety and equipment, such as SSCs that are designed for plant performance and efficiency, the definition provided in Ref. [3] can be applied to overall facility design. In that case, the definition includes not only safety (authorized) limits and criteria but also the performance criteria, goals, limits, and expectations.

Here, therefore, it is prudent to clarify the term 'design basis', which the DBR is to consider, and is used hereafter in this publication, within the frames of 'design for facility authorization/licensing' and 'design for facility utilization'. This clarification can be done by describing the domains 'licensed DB' and 'engineering DB'.

— Licensed DB: This is the design and its basis on which the facility is authorized, i.e., its licensing, ensuring that the design meets all the regulatory requirements applicable. The 'licensed DB' is a part of the 'licensing basis.' As a part of licensing basis, 'licensed DB' consists of the criteria, conditions and events taken into account in the design of SSCs and equipment, such that the facility is utilized without exceeding authorized limits.
— Engineering DB: This is the basis on which the overall facility is designed for accomplishing its objective, i.e., safe, and efficient electricity generation. Engineering DB is a comprehensive set of requirements and conditions that are applicable to the design of all plant SSCs and other premises regarding their form, fit and function towards the safety and performance of the plant, regardless of their safety or quality classifications. As such, the licensed DB is a part of engineering DB and include design requirements and expectations that are agreed between the responsible designer and the owner/operating organisation (and the regulatory body when/where required) and apply to design for all aspects of the facility, i.e., design for safety, constructability, maintainability, operability, etc.

Operating experience shows that DBRs have been mainly performed for the licensed DB, owing to its importance for nuclear safety and regulatory implications of unavailable, missing, unknown, omitted, erroneous DB information. However, in some cases, such as major plant equipment replacements and refurbishments, economic consequences of incomplete and/or inaccurate DB information of plant SSCs important to the plant performance can be very significant. Therefore, for the purpose of this publication, the term ‘DB’ represents the engineering DB which encompasses the engineered part of entire plant.

2.4. DESIGN BASIS INFORMATION

DB provides why and how the fit, form and functions of SSCs are conceptualized, determined, analyzed, demonstrated, and implemented (manufactured, constructed, operated, maintained, etc.) to meet the applicable design requirements and expectations which are derived during the design process based on design objectives, requirements, and constraints. These objectives, requirements and constraints typically come from applicable laws, regulations, codes and standards, performance requirements and expectations, e.g. for operability, maintainability, affordability, etc., ensuring safe, reliable and efficient use of the design [1].

In addition to the design requirements and their reasons, the DB information describes:

- Design functions to be performed by specific SSC;
- Design parameters, limits, values (or ranges of values) of SSCs;
- Design specifications for form, fit and function;
- Requirements for interfaces and operation (of SSCs and the plant); etc. to ensure safe, reliable and efficient operation and performance as designed and to be maintained during NPP lifetime [4].

DB may also include the information of the underlying science and engineering, including design concepts, philosophies, assumptions made by the designers about operation of the product, i.e. the plant, and the specifications for each SSC [5].

2.5. DESIGN BASIS DOCUMENTATION

Design, its basis and associated requirements are reflected in DB documentation (e.g., diagrams, drawings, specifications, calculations and analyses, vendor manuals, design reports, verification/validation tests, etc.) that define the form, fit, and function, capabilities, capacities, material, and physical dimensions.

Meeting design requirements, adequacy and applicability of form fit and function of SSCs is demonstrated by the facility design analyses and by establishing acceptance criteria for plants’ surveillance procedures based on design limits and instrumentation accuracy.

2.6. OPERATIONAL DOCUMENTS

Operational documents include all documents used for operation (normal, abnormal, alarm response, emergency, etc.), test/surveillance, and maintenance of NPP.

3. KEY ELEMENTS AND ATTRIBUTES FOR EFFECTIVE DESIGN BASIS RECONSTITUTION

The DBR projects are rare, unique, and first-time activities that are (or may quickly become) large and complex, with extensive, numerous and special efforts involving multiple disciplines and organisations. Furthermore, it may result in identification of existing challenges to the operating facility design, license, and operation, some of which could be significant or complex.

The DBR will demand time, resources, competencies and skills and interaction with the ongoing existing design activities. To overcome these challenges, and to minimize the impact of the DBR and the DBR identified errors on NPP's safe operation, the owner/operating organization needs to rigorously implement the following key measures:

- A sustained corporate level commitment, including a project funding including estimating and justification for costs, and a resolute policy defining philosophy, strategy, value, and allocation of resources for adequate and accurate recollection of design information and associated support for making safe, sound decisions on plant safety, reliability, and performance;
- A realization that DBR is caused by an ineffective configuration management programme (CMP) and/or deficient design change processes that if not corrected will cause a need for future DBRs. In addition to the traditional and well understood causes, the ineffective CMP may be also attributed to:
  - Incomplete, inaccurate translation of licensing basis into design documents, and/or;
  - Incomplete, inaccurate translation of licensing and DB into operating procedures;
- A realization that DBR is a special one-time use tool for identification of latent discrepancies and their documentation and is not a part of normal plant activities;
- A rigorous application of graded approach to DBR scope selection;
- An application of project management practices appropriately selected for DBR.

3.1. DESIGN BASIS RECONSTITUTION ELEMENTS

3.1.1. Commitment

In order to effectively reconstitute DB, the values, roles, priorities, and responsibilities need to be understood and agreed throughout the organization. This understanding and agreement for the process of identifying, requesting, receiving, and assessing DB basis information for a decision clarify their importance for safe, reliable, and efficient generation of electricity with quality and longevity.

Therefore, a sustained commitment for implementing DBR has to be initiated at the corporate level with the purpose of achieving safe, reliable, and efficient electricity generation. To ensure this is accomplished, a sustained funding and clearly defined expectations for all levels, including the owner/operating organization's board of directors and chief officers, are established, documented, and communicated. The commitment, including an adequate multi-year funding, emphasizes the importance of design information when needed for a safe, sound decision and of potential impacts from ineffective and incomplete DBR resulting in incorrect decisions on safety, reliability, and plant performance.

3.1.2. Policy

For DBR and its use in decision making to be effective, it is necessary to declare and promote the commitment through a corporate level policy that sets expectations regarding behaviours and values.

By this policy, the owner of the plant endorses the DBR activities and guarantees critical support for the provision of sufficient staffing and financial resources to determine, coordinate, assess and recover DB.

Also, the policy will be the foundation for building, a governing process, and procedures for correct and timely DBR and utilizing it appropriately and without delay in decisions on safety and performance.

Consequently, the established governing procedures will be written, controlled and implemented in accordance with the requirements, expectations and framework defined by the policy, such that the DBR goals, requirements, expectations and control and management measures are well defined and described [5].

3.1.3. Management system

An effective DBR implementation requires use of a systematic approach that provides a framework and organisational structure for administering, managing, and coordinating with all other programmes, processes and activities related to the DBR efforts, such as quality assurance and control, design and configuration management, condition reporting, non-conformance, and CAP.

Therefore, a structured approach for conduct of DBR is necessary and needs to address the processes involving review, identification, verification and validation, request, and use of DB information. These DBR activities follow a formalized management system (e.g., quality assurance and control) with integrated policies, programmes, procedures and/or instructions that is developed, reviewed, agreed, and implemented.

An effective DBR process also consists of administrative controls, such as written guidance and rules in the forms of procedures, request and instructions, interface requirements, etc.

3.1.4. Handling proprietary information and intellectual property

When the responsible designers prepare and perform the plant design, defined in Section 2.2, (or other vendors, that design and manufacture associated plant systems, components, and equipment), they use technologies, ideas, and concepts specific to their intellect and knowledge, which are their intellectual property (IP).

Also, in some cases, the designers want to keep the information associated with the design (i.e., DB information, that is defined Section 2.4, such as calculation and engineering methods, tools, parameters, specifications, and analyses, confidential and proprietary to their ‘customers’, i.e., the plant owner/operating organizations, as they consider those to be trade secrets of their design.

Conversely, the plant owner/operating organizations may also have IP and proprietary design information of their own (resulting from, for example, the changes they have made to the original design or to company’s financial competitiveness) that they wish not to share with third parties, or even with the responsible designers.

The DBR activities, in most cases, will need the collection and review of original design information and changes to it thereafter some of which could be IP or proprietary information. Therefore, handling IP or proprietary information is an important area of DBR as to ensuring the exchange of complete, correct, and understandable technical information. Therefore, contractual rights arrangements need to be addressed.

4. REASONS, GOALS AND CONSTRAINTS OF A DESIGN BASIS RECONSTITUTION

Long term safe operation of NPPs is a key to success of the nuclear technology, economically and from prospect of political/socially issues. Significant improvements are being continuously implemented at NPPs to ensure the safety and reliability is maintained at highest level. As a result, the process of configuration management (CM) has become a key cornerstone of a well-managed NPP. Historically, this concept has evolved during evolution of nuclear technology from simple guidelines to a mature detailed philosophy which today's nuclear industry depends on for safe operation during their long lifecycles. The CMP generally is a process used to assure that technical and regulatory requirements and their bases for all SSCs (design basis) and physical configuration of facility do not diverge.

Since there are a very few plants that are built and constructed by an owner's team only, the DB basis knowledge of plant is dispersed and much of it remains outside plant's owner entity. Gathering and collecting this scattered information from participants of NPP project and maintaining it to reflect any changes, their records, associations, and recovery throughout the life cycle of plant and maintaining has been a major challenge to all new and old nuclear NPPs.

As result of this challenging condition, failures, or weaknesses in collecting and maintaining DB information have occurred resulting in loss configuration control to various degrees. In some cases, this defect had gone unnoticed until it resulted in realization of degraded design margins, or until DB records for a major plant change were reviewed, or until the operating experience became available in other plants. This, in turn, resulted in search and recovery efforts to identify the deviation from the original design intent for the SSCs fit, form and functions and their operation and to reconstitute the DB.

4.1. NEED AND CAUSAL FACTORS FOR DESIGN BASIS RECONSTITUTION

The reason for DBR implementation is the necessity to restore certainty and confidence in DB information such that it is sufficient and accurate in its content for making informed, correct, and timely decisions related to safety, reliability, and efficiency in NPP operation. It typically comes into consideration when there is a need to inform decision makers about the current state of design for making plant operational decisions and there is not a set of adequate and/or available design information to do so. In such cases, the design information possessed by the organization may be discovered to be uncertain and/or not reliable as to its:

- Completeness;
- Correctness;
- Adequacy;
- Conformity and applicability to the current condition/configuration;
- Form of information representation;

- Information accessibility;
- Simplicity/convenience of search, information access speed.

Typically, the necessity to restore certainty and to ensure confidence in DB information arises in various situations when the owner/operator's internal or external technical support organization (as discussed in Ref. [5]) determines or reasonably supposes/assumes that, for example:

- The design information that owner/operator has at its disposal is erroneous or incomplete when requested to provide design input to decision making.
- The owner/operating organization does not possess (owns) such information (or parts of information).
- The owner/operating organization's design information management system does not provide or guarantee acceptable characteristics, such as inaccessible or contradicting design information.
- Actual and/or potential problems related to design information identified by results of analysis of own operation experience or lessons learned by other NPPs/organizations.

Such circumstances would induce the owner/operator to have a reasonable doubt that available and accessible design information answers its needs (current or future) for decision making and may necessitate a DBR effort. Examples of impairment due to loss of DB are provided in Appendix I.

Other factors driving an owner/operating organization to launch DBR are mostly related to various modification activities and are listed below:

- Modernization and/or upgrade of SSC;
- Replacement of major plant equipment, e.g., steam generators, reactor vessel head, new fuel assembly, etc.;
- Refurbishment;
- Plant objective improvement, e.g., power uprate;
- Analysis of root causes and investigation of NPP operational events;
- Safety assessment for making decision concerning long term operation (LTO) of the power unit of NPP, review of time limited ageing analysis (TLAAs), ageing management (AM) review, and review of ageing management programmes (AMPs);
- Original Equipment Supplier (OEM) is no longer in business, calculations or test reports validating components DB information are no longer available.

4.2. TYPICAL DESIGN BASIS INFORMATION

The owner/operating organizations maintain valid DB information to a sufficient level of detail required to allow it to maintain and preserve design integrity of its NPP when physical design changes are proposed or when changes to licensing safety assessments/analysis are performed. DB for each SSCs is defined by its fit, form and functions, elements of licensing rules and restrictions that are included in design concepts. Additionally, DB includes codes, standards, and manufacturing records, each of which is at a specific revision version or effective date.

4.3. OVERALL GOALS AND TASKS OF DESIGN BASIS RECONSTITUTION

The ultimate goal of DBR activities is to bring the DB information to a sufficient and accurate state that is adequately available for day-to-day decision making and for preparation and consideration of design aspects for the NPP.

The specific goals of DBR will vary for each individual situation since they are determined by the amount and need of certain design information, as well as corporate strategy. A sample set of DBR goals is illustrated in Fig. 2 based on the desired outcome and needed time and effort.

As such, the specific goals may vary from correcting and/or completing specific information identified in a specific case and leaving the rest of DB unreviewed or untouched (noted as 're-administration' in Fig. 2) to reviewing, verifying, and validating all DB information for selected or all SSCs (shown as 'restoration' in the Fig. 2). Even in some cases, such as when no or very limited access to DB is available, the specific goal is to be constructing the DB from nearly no information ('recreation' in Fig. 2).

It should be noted that the 'restoration' of all SSCs (Level 4) and 'recreation (Level 5) activities are shown for completeness only. Past experiences indicate that almost always, the costs required for a restoration of DB for all systems were found to be too excessive and plants that needed that effort of DBR were retired. A significant contributor to a decision to retire was a fact that in most cases these plants had their operating licenses withdrawn by the regulatory agencies on the account of lost DB.

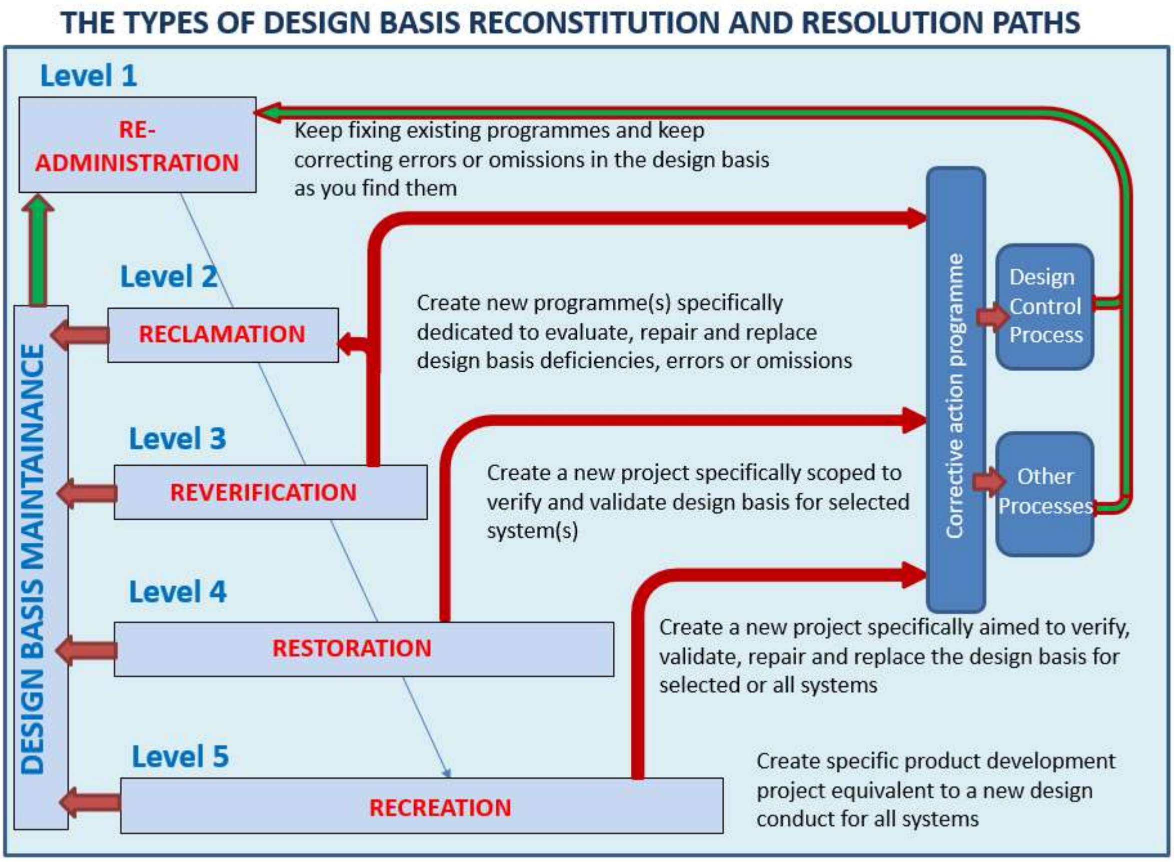

FIG. 2. Levels of Effort design basis reconstitution in accordance with its need and scope.

Regardless of specific goals, the essence of DBR activities and its main tasks for any situation is as follows:

- Collect and systematize available design information;
- Review and, if any, identify discrepancies (omissions, errors);
- Eliminate discrepancies, (fill the gaps, make up omissions, correct mistakes etc.);
- Make information accessibility, search, and retrieval easier and quicker for further utilisation and maintenance of DB information.

5. SCOPE OF DESIGN BASIS RECONSTITUTION

Weak, ineffective plant's design and configuration control processes and procedures and CA actions program will eventually result in an inaccurate, incomplete, conflicting DB, or even in a complete loss of DB. Missing and outdated DB have to be reconstituted with a scope necessary and sufficient for NPP to operate safely and efficiently for full life cycle.

The scope of DBR project, complexity and cost could significantly vary owing to the level of selected mitigation and other unique attributes, e.g., availability of DB documents. Therefore, a practical approach is to reconstruct the DB by applying a graded approach that considers both the nuclear safety and plant performance.

The DBR project scope can be selected at the plant's SSCs level, or by topical areas. For example, the scope could be set at component, system, and structure levels, or by topical areas: accident analyses, equipment qualification (EQ), seismic, flooding, internal and external events, radiation, environmental/siting, etc. In cases where a significant scope for the DBR is proposed, e.g., multiple systems and topical areas, implementation of a graded approach in conjunction with probabilistic risk assessment (PRA[1]) for selection of specific components and/or attributes of the safety-related and potentially non–safety related SSCs for inclusion in the DBR project may be beneficial. See Chapter 6, Effective Implementation of DBR for further details.

The ability to clearly formulate the scope and its limitations is critical to a successful outcome of a DBR effort. The following topics, described in detail below, should be used for formulation of the DBR scope.

5.1. DETERMINING THE SCOPE OF DESIGN BASIS RECONSTITUTION PROJECT

The level and extent of reconstitution depends on the need of the particular plant to have such DB documentation available to respond to operation or licensing concerns. As illustrated on Fig. 2, the higher levels correspond to greater DBR efforts.

5.2. PROGRAMME AND PROCESS

Since the CMPs shortfalls are one of the major causal factors they need to be addressed to assure a successful outcome of the DBR projects. With a goal of DBR being a one-time effort, its

[1] Commonly used in United States

preferable for its implementing procedures to rely on the existing CMP (after the CMP causal factors have been addressed), vs. developing any unique DBR CMP processes.

5.3. FACTORS DETERMINING DESIGN BASIS RECONSTITUTION SCOPE

As discussed previously in Section 4.1, the DBR scope determination is unique to each facility and the DBR drivers. A sample list of factors to be considering are provided in Appendix IV for the DBR scope consideration based on the industry experiences.

It is important to recognize that the DBR scope will not be static, as defined at the project's onset. During the DBR process implementation there will be discoveries that would impacts the initial scope. Fluid communication between DBR team and design authority, plant management and operation crew in control room is key to project success. Additionally, each new discovery within the existing DB may result in new deficiencies that would be documented in the CAP and assigned to the appropriate document owner organization to implement the actions.

The following are a few examples of such discoveries:

- Use of periodic safety assessment (PSA)/PRA for scoping is encouraged as a decision tool for scoping, bearing in mind the reconstituted design input information may impact the existing PSA/PRA models and if it does, the initial technical scope of DBR project, schedule and will be impacted.
- Discovery and identification of previously not identified or recognized plant specific design parameters, assumptions, licensing basis or changes to industry standards during a DBR project is probable. These type of omission for the DB would result in a site wide re–evaluation of multi SSC safety–related functions.
- Discovery and identification of differences between as–designed and as–built configurations during walkdowns and review of design output to be utilized in DB could result in additional modifications or paper changes to design output documents. Effect of such a discovery is illustrated below:
  - The lowest external temperature for design of safety systems are not specified. The effect of this reconstituted value on the ability of the SSCs to perform their safety–related function requires a plant–wide evaluation.

5.4. NEEDS DETERMINATION

The first critical step in achieving a successful DBR process implementation starts with a 'needs determination'. A following guidance is offered for implementation of this activity:

- The first step of needs determination is collection of identified/current gaps in plant configuration knowledge;
- The next step is to establish or addressing these gaps within the constraints of DBR. Typical selection criteria will include safety-related and important to SSCs, safety margins or limits, obsolescence, etc.;
- It is also important that implementation of needs determinations manages expectations: DBR cannot be a solution to all NPP problems; otherwise, the cost will become

prohibitive, and the entire project could be abandoned. Early establishment of prioritization criteria for inclusion in the scope of DBR is required for success.

5.5. RECOMMENDATION FOR PROJECT EXECUTION

PRA needs to be used as decision making tool to prioritize and categorized task as they are scheduled for timely resolution based on their risk to the plant.

Equally important to prioritization of DBR is 'Problem Children' input. Whereas the emergency core cooling systems (ECCS) would typically have the highest PRA score, they may not need to get the first DBR implementation priority. The initial prioritization of SSCs selected for DBR needs also to consider an input from CA program to prioritize safety related SSCs that challenge day-to-day operation of NPP.

Once the DBR for the most problematic safety related SSC's and functions has been completed, the NPP needs to perform an extend of condition review. The outcome of these efforts will aid in a determination if a DBR for the remaining safety-related SSCs needs to be expeditiously carryout, or DBR project may continue using a 'Pay-As-You-Go' approach, where the DBR for the remaining safety-related SSCs will be done as a part of a large modification, long term operation & life extension, and/or other large high-cost activities.

Whereas PRA, 'Problem Children', or 'Pay-As-You-Go' are used to prioritize selection of SSCs for the DBR effort, use of a vertical slice technique is highly effective in narrowing down scope of review within the selected system(s). Section 6.2.2 provides information on its description and use.

6. EFFECTIVE IMPLEMENTATION OF DESIGN BASIS RECONSTITUTION

The project management organization needs to establish and emphasise the communication of principles, organizational culture, and structure. Additionally, it will emphasise use of the existing procedures and processes to correct non–conformances identified during DBR.

If, however, DB information of the initial design (and the changes to it thereafter) cannot be obtained for any reasons/considerations, the operating organization has to undertake measures to ensure that design integrity will not be broken even in the absence of this information.

An example of a DBR project is provided in the Appendix V, Design Basis Reconstitution - Forsmark.

6.1. SCOPE CONTROL

Scope control needs to address the critical steps/items below. A failure to fully address any of these items before the onset of the DBR process will lead to a failure in the DBR implementation:

- 'Freeze' point;
- 'Discovery' resolution;
- Project controls.

6.1.1. Freeze point

Implementation of the DBR project will take a considerable amount of time. During its implementation NPP and its documentation will change. To avoid a 'moving target' review/correction that cannot ever be completed, it is critical to establish the project baseline.

The project baseline will 'freeze' the revision of documents being reviewed and the plant configuration. This is commonly referred to as 'freeze' point' and is far from simple, and as described below, requires continues attention:

- Once the initial scope based on the needs selection has been established all available associated documents needs to be identified and their revisions captured. The date of the freeze point needs to be documented;
- A number of NPPs use a configuration control practices where certain types of documents are not revised upon completion of approved changes until a maximum number permitted changes is reached. These changes are often referred to 'outstanding changes.' These outstanding changes need to be identified. These initially identified documents and their outstanding changes will constitute the 'Initial DBR Freeze Point Document Set', or, hereafter, 'Initial Document Set' (IDS);
- It is impossible to identify all documents required for DBR. As DBR review progresses additional documents not captured in the IDS will be identified for inclusion of review. Let's say review of a calculation identified that critical design inputs and/or assumptions are based on referenced documents that need to be reviewed because the revision of these documents is older than the current revision and the effect of these revisions was not captured in the calculation revision description. If these documents are not included in the IDS, they will have to be now added. In cases where the latest revision was made subsequent to the freeze point date, the revision preceding that date and not the latest one will be the subject of review and inclusion into the IDS;
- Upon the completion of the DBR project, or its parts, a change reconciliation needs to be performed. The change reconciliation process consists of review of all changes to the documents included in the IDS and the subsequent additions all changes in the latest revision of each document. An impact of the changes will be evaluated on the results of DBR.

The above-described IDS process controls are best handled by utilization of an (optional) DBR database described in Appendix VI.

6.1.2. Discovery resolution

By its very nature the DBR process will inevitably result in identification of a significant number of cases where the required DB information is unavailable, missing, unknown, omitted, erroneous, etc. These are commonly referred to as 'Discovery' Items.

Engineers, being engineers, like to solve problems, especially those they have discovered. A past implementation history shows, that unless appropriate project controls are in place, the attempts to address these discoveries by the DBR 'Discovery' team will impact both the DBR scope and its implementation schedule.

One of such suggested project controls to minimize these impacts, is to have a separate independent 'Resolution' team addressing these discoveries, including their validation, entry into the NPPs CAP and the eventual resolution. Depending on how the DBR project is set up, this resolution team maybe a part of the overall DBR project, or a part of the NPP staff. Either way, all efforts need to be made to separate identification of discovery items from their resolution.

6.1.3. Project controls

DBR is a project and as any project, its management will be controlled by the existing NPP project controls.

6.2. PROCESS

The DBR essentially is a discovery process which has a goal to identify latent design deficiencies and previously unknown or added and not captured design and/or licensing basis requirements for the SSCs in scope of DBR. This discovery process needs to be formalized to assure that the DBR goals are translated into an executable procedure.

A successful DBR implementation needs to rely on the NPPs existing design change and CA processes, once these processes have been revised to address the gaps that lead to a need for the DBR project. When a DBR review uncovers gaps in the design documentation, plant configuration, etc. these existing processes will be used to document and resolve the issues.

The discovered deficiency attributes: requirements, their source document(s), association with all affected SSCs need to be captured and make permanently available within the NPPs existing configuration processes. Use of an optional database for the DBR project implementation (see example in Appendix VI) will greatly enhance ability to associated new as well as the existing relationships between SSCs, their design and licensing basis requirements and the source documents for these requirements. This database, however, is not recommended to be made into a permanent plant record. Rather information in this database should be captured into the existing NPPs databases.

6.2.1. Approach

There are various ways to select an approach for a DBR project. Commonly used ones include ‘chapter centric,’ ‘system centric,’ or ‘safety function centric,’ or a combination of these.

Since the chapters of any given final safety analysis report/updated final safety analysis report (FSAR/UFSAR[2]) are laid out in a logical grouping/order, the scope of a DBR project could be broken down on a chapter-by-chapter basis.

Most of the past DBR projects have used both ‘system centric’ and FSAR/UFSAR ‘chapter centric’ review approaches. The outcomes of those projects have revealed that although a ‘chapter centric’ approach is a valid approach for reconstitution of *licensing DB*, it may result in gaps when it is applied to reconstitution of *engineering DB*. Hence, a chapter centric approach is better suitable for a narrow chapter specific DBR effort.

There are several reasons that support this observation, namely:

— The UFSAR[2] information about a specific system does not reside only in the system specific section of the UFSAR. This information is scattered in many other sections (and in the Technical Specifications and Basis). For example, a description of implementation

[2] UFSAR is specific in some regulatory framework

of system specific commitments with respect to loss of offsite power (LOOP), natural hazard phenomena (NHP), etc. are captured in the UFSAR[2] topical sections and not the system specific sections;

- Chapter centric approach cannot inherently allow scope limitation based on application of PRA/PSA insights, critical functions, etc. It requires a 100% verification of all UFSAR[2] 'statements of fact' (Statement of Fact [SOF] – A sentence, statement or paragraph(s) that establishes some feature or attribute of a system, structure or component or a design or operational criteria.). As repeatedly discussed in this document a 100% DBR cannot be successfully implemented;
- Using a system-by-system (system centric) approach will allow members of the DBR teams (see Section 6.4) to work in parallel until they get to the interfacing requirements between systems.

Since the chapter centric approach lacks a holistic review assuring that all of the system related requirements are captured and does not allow a limited, e.g., PRA/PSA insights informed review, a system centric review approach is typically preferred for the DBR implementation, and all the subsequent discussions are based on its implementation.

In addition to the system level reviews certain topics such as EQ, Fire Protection (FP), NPH, Station Blackout (SBO), etc. lend them self to topical reviews. No specific guidance for these topical reviews is provided, since the approach is highly topic area and local regulation specific; however, a number of elements of the system level approach may be used in these topical reviews.

Alternately, the scope could be based on safety functions of your plant design, as the safety functions often span multiple systems and disciplines the membership of your DBR team might need to be more diverse. Starting with the list of safety functions, then, they are ranked based on the purpose for the DBR project.

It should be noted that, however, regardless of the approach selected, additional reviews will likely be required to ensure that the licensing and DB requirements are appropriately translated into DB documents and operational procedures irrespective of the DBR implementation approach.

6.2.2. Vertical slice

Vertical slice is a technique that allows to narrow down scope of review of SSCs and functions within a system selected for DBR. The vertical slice is implemented as follows:

- The first step is review of licensing and DB to identify key/critical requirements.
- The next step is a critical review of design documents to verify the adequacy of translation of key/critical requirements contained in licensing and DB.
- The final step is review of operational documents to verify the adequacy of translation of key/critical requirements contained in licensing and DB.

A detailed discussion on application of this tool is provided in Section 6.4 and its subsections.

6.3. ORGANIZATIONAL STRUCTURE

This section provides a very generic discussion on this topic. A detailed description based on DBR implementation at Bruce NPP are provided in Appendix VII.

There is no ‘one size fits all’ organizational structure for implementing/performing DBR; however, the owner/operating organization needs to establish the roles and responsibilities with a dedicated technical capability and competency, as a minimum, to:

- Recognize and express the need and scope for DBR for desired output;
- Identify the competencies and qualifications needed for design aspect;
- Identify potential sources for design information;
- Discover, understand, and recover the relevant and accurate design information.

There are mainly three options for assuming/assigning the DBR personnel and their roles and responsibilities:

- Owner/operator and in–house designer, working under owner management;
- Turn key project, external vendor manages, staff and use; owner/operator personal as needed. Deliver final out put products and supporting documentations per contract; or
- Combination of owner operator and contract personnel. Under owner or vendor organizations output document content would be divided assigned to each team.

Irrespective of the implementation choice, it is highly recommended that NNP creates a new group/organization that will operate independent of daily operational teams.

6.4. DESIGN BASIS RECONSTITUTION FUNCTIONAL TEAMS

Irrespective of the DBR project staffing options, it is recommended to divide the project into two distinct functional teams:

- DBR ‘Discovery’ Team;
- DBR ‘Response’ Team.

The ‘Discovery’ team will be tasked with identification of licensing and DB and the adequacy of their translation into DB documents and operational procedures. Optimum staffing is a mix of external personnel known for their critical review skillset and plant personnel. Whereas the external personnel bring their past DBR expertise, impartiality, and not being constrained by established mind set; the plant personnel bring their knowledge of the plant design, history of operation current status and location of documents. The actual staffing composition may very somewhat dependent on a specific system being reviewed. However, the core of the team should be stable.

The ‘Response’ team should be tasked with a resolution of the discovery, e.g., effect on the operability, proposed resolution, etc. The majority of the staffing should be plant personnel. Because the set skills required for this work is system depended, the ‘Response’ team will be significantly more fluid in its makeup. This has an additional benefit of having key plant personnel exposed to the DBR process and through this interaction assuming the ownership of both the process and the product. The response team follows a plant procedure for correcting or resolving plant deficiencies.

Each team should have a designated team leader/manager. It is recommended that a senior utility design engineering manager be designated as a 'Discovery' team manager with an outside expert being the team lead. It is recommended that a senior utility system engineering manager be designated as a 'Response' team manager and the system engineer for a specific system being assessed acting as the team lead.

6.4.1. Task teams

The 'Discovery' teams should have the following three functionally separate, but closely interacting task teams:

- Licensing basis review;
- Engineering DB review;
- Operational implementation review.

6.4.1.1. Licensing basis review team

For each system licensing basis review (LBR) team has the following objectives:

- Identify the current licensing basis (CLB);
- Serve as project experts on licensing questions and research;
- Identify licensing basis elements[3] to DB and operations teams;
- Provide 'markups' of the FSAR/USFAR as appropriate.

6.4.1.2. Engineering design basis review team

For each system engineering design basis review (EDBR) team has the following objectives:

- Determine if the as–found SSC's are capable of performing their design and licensing basis safety function under design and licensing basis conditions;
- Perform plant system walkdown to identify equipment in situ, and mark up discrepancies in plant configuration on current DB drawings, manuals and equipment lists;
- Identify the key (critical) DB attributes that are in the approved design requirements and supporting documentation necessary and sufficient to establish or reconstitute the plant DB.

6.4.1.3. Operational implementation review team

For each system operational implementation review (OIR) team has the following objectives:

- • Top-down review:

- Identify key operations documents;

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[3] A Licensing Basis Element (LBE) is defined as a required attribute of the design, operating procedures, or capabilities of an SSC identified with definitive specificity that is contained within a licensing basis document.

— Review key operations documents.

- Bottom-up review:

— Perform plant walkdowns.

The intent of the OIR review is to ensure that the operational (e.g., operations, maintenance, testing and associated training) implementation of required functions is consistent with the design and licensing basis.

The process for reviewing operational implementation begins with the identification of required SSCs and related operator actions. Required SSCs include components such as pumps, motors, instrumentation, and flood barriers. Required operator actions include activities such as diesel generator starts, electrical breaker manipulation and pump flow throttling. These required SSCs and operator actions would typically be identified by the design review and provided as input to the operational implementation review. However, input from the entire project team (including the licensing review team) will also be utilized to provide reasonable assurance of completeness:

- Top-down review:

— Identify procedures and related documents that implement or contain relevant licensing basis elements (LBEs), critical system structure component attributes (CSSCAs) and critical system level attributes (CSLAs);
— Develop tools and attributes to perform verification that plant programs and documents will meet and be implementable to satisfy the LBEs, CSSCAs and CSLAs;
— Review procedures and related documents for completeness and accuracy of LBEs, CSSCAs and CSLAs implementation;
— Ensure plant programs adequately operate, maintain and test identified LBEs, CSSCAs and CSLAs.

- Bottom-up review:

— Perform plant walkdowns based on pertinent documents to ensure that the operations, maintenance, and surveillance requirements of LBEs, CSSCAs and CSLAs are implementable — Implementation will include verification that training is in place.

Provide individual reports on each document that implements and verifies meeting of LBEs, CSSCAs & CSLAs and record in the DBR database.

6.4.2. Sequence of task teams' discovery

There are two options for timing of LBR with respect to review of EDB:

— Sequential review — performing LBR prior to EDBR;
— Parallel review — performing LBR at the same time as EDBR.

The advantage of a sequential review is that licensing basis (LB) is fully documented, and all the LB requirements are known and documented before the onset of DB review.

However, there are several advantages of a parallel review that relate to a fact that if the LBR team members may not be available after completion of their task (the personnel re-assigned, unavailable, etc.). This will present the following challenges:

- Inability of addressing new LB related deficiencies identified by the EDBR team;
- Not having a common 'freeze' point (see Section 6.1.1);
- Not having an expert panel consisting of members from design, operations, and licensing teams.

Similar options and advantages/disadvantages present in relation to sequence of operational documents review with respect to DBR.

Although a parallel review is recommended, the NPP specific conditions with a key input being the composition of the whole DBR team (utility vs. contract) needs to be reviewed to arrive with an application specific decision of a sequential vs. parallel review.

6.4.3. 'Discovery' team reviews

6.4.3.1. Licensing basis reviews

There are three following phases of licensing basis review (LBR):

- Phase I: Identify documents which may contain relevant LBEs and develop screening criteria;
- Phase II: Review documents to identify LBEs;
- Phase III: Prepare summary report and UFSAR mark up.

A description of activities for each phase is provided below (using the US licensing approach and nomenclature, as an example).

a. Phase I

The following documents may contain relevant LBEs:

- Facility license, including all amendments to it;
- UFSAR and submitted updates;
- Design criteria documents (DCD)/ general design criteria (GDC) document;
- Agreements and commitments made between the regulatory body and the licensee in the form of letters exchanged or of statements made in technical meetings, licensee event reports (LERs), etc.;

Operational limits and conditions (OLCs), e.g., technical specifications, limiting conditions of operation (LCOs) and basis;

- All applicable laws, regulations, e.g., safety, security, safeguards or environmental, (for example, Code of Federal Regulation (CFR) in the USA);
- Correspondence from the regulatory body requiring responses i.e., requested licensee actions and/or information to address issues regarding issues of safety, security, safeguards, environmental significance, etc.;

- Other correspondence to/from the regulatory body (e.g., license amendment requests [LARs], safety evaluation reports [SERs], etc.);
- Other relevant plant documents, such as in-service inspection (ISI) and in-service test (IST) programmes, emergency plan;
- Exemptions, waivers, and reliefs approved/granted by regulatory bodies;
- Safety evaluations.

b. Phase II

Phase II implementation has the following actions:

- Development of initial search terms based on (See Section 6.4.6, Functional requirements for details of systems and components functional requirements:

  - List of system specific functional attributes;
  - List of attributes for selected components;

- Formation of a cross functional expert panel consisting of members from key organisations (engineering, operations, and licensing) to determine search terms to ‘filter’ population to a specific scope of reconstitution (e.g., specific systems, etc.) This filter will include both risk–based and ‘trouble children’ considerations;
- Chronological review of documents to identify LBEs;
- Determination if LBEs are consistent with FSAR/UFSAR;
- Identification of gaps and assistance with development of condition reports.

c. Phase III

Key output from Phase III is the CLB and a ‘marked up’ UFSAR which identifies any gaps or inconsistencies and capture of information into a database, such as the design basis reconstitution database (DBRDB).

6.4.4. Engineering design basis reviews

6.4.4.1. Phases of engineering design basis review

Similar to the licensing basis reviews, engineering design basis review (EDBR) also have three typical phases. A description of activities for each phase is provided below (using the US licensing approach and nomenclature, as an example).

- Phase I: Identify documents which contain relevant system and SSC fit, form and functional requirements;
- Phase II: Review documents for completeness and accuracy of implementation of these requirements; and
- Phase III: Prepare summary reports and capture results of review into DBRDB.

a. Phase I

The following documents typically contain relevant SSC functional requirements:

- FSAR/UFSAR and submitted updates;
- Technical Specifications (TS) and Basis;
- Technical Requirements Manual (TRM) (US specific);
- ISI and IST Procedures;
- Other Operating Procedures (normal, Abnormal Operating Procedures (AOP), Alarm Response Procedures (ARP), Emergency Operating Procedures (EOP), etc.);
- Calculations;
- Design Drawings;
- SSC Specifications;
- Design Basis Documents (DBDs), or similar documents;

Interface Requirements (e.g., nuclear steam supply system (NSSS) vendor and A&E interface, system interface, etc.);

- Modifications;
- Input from LBR team.

b. Phase II

Phase II implementation should have the following actions:

- Development of initial search terms based on:
  - List of system specific functional attributes;
  - List of attributes for selected components;
- Forming of an expert panel consisting of members from design, operations, and licensing teams for determination of search terms to 'filter' population to scope of reconstitution (e.g., specific systems, etc.);
- Review of Phase I documents for completeness and accuracy of implementation of system and component level functional requirements;
- Determination if actual plant configuration and operating procedures correctly reflect system and component level functional requirements; and
- Identification of gaps and assistance with development of condition reports.

c. Phase III

The *Phase III* is the presentation of the findings. Key outputs from P*hase III are:*

- Summary reports, which identify any gaps or inconsistencies;
- Capture of any other information and knowledge into DBRDB.

As aforementioned, to assure completeness of DBR, a system/function–centric 'template approach' is a preferred method to determine the engineering DB or system parameters for which calculations, analyses or evaluations were (or should have been) performed.

Without this initial template or set of expectations, it might be difficult to demonstrate that there are no critical missing documents when the DBR is completed [6]. This top-down, system/function-centric approach would consist of defining the design attributes or controlling design parameters that are necessary to:

- Establish and define the functionality requirements of SSCs;
- Demonstrate the conformance of SSCs to the DB;
- To extend possible validate that SSCs perform their intended function/s.

To facilitate implementation of a development of a system/function-centric ‘template approach’ DBR a following set of considerations is offered.

6.4.5. Elements of engineering design basis review

6.4.5.1. System boundaries

A following guidance on selection of system boundaries is offered to assure a consistent and uniform approach of selection of system boundaries.

a. Mechanical system boundaries:

Identification of components that will provide system interfaces with other plant systems provides an initial step of this effort. In addition to the physical boundaries e.g., valve, all mass and energy transfer (i.e., functional) boundaries need to be considered. Examples of functional boundaries are heat exchangers, heating, ventilation, and air conditioning (HVAC), etc. (An example of a functional boundary impact on a modification and calculations is a component modification that impacts addition/deletion energy into the area. Whereas prior to the change the area had an adequate heating/cooling, the modification’s impact on the area heating/cooling, including attributes such as heat tracing may have a negative impact).

b. Electrical system boundaries:

Identification of electrical system boundaries is dependent upon the mechanical system boundary identification and needs to include all electrical subsystems supporting the mechanical components under review.

c. Instrumentation system boundaries:

All critical instrumentation (sensing, signal conditioning/processing, control, status indication, alarms, trending/recording, and indication) shown within the mechanical system boundaries is included in the system instrumentation system boundaries.

d. Structural boundaries:

Structural aspects are rarely included in the scope of the DBR; hence, no further guidance is provided.

6.4.5.2. Unit differences

For multiple unit stations, known unit differences and shared SSCs need to be identified and described.

6.4.6. Functional requirements

The first step is a determination of what are (a) the system and (b) component level functional requirements. Identification of these requirements beforehand is recommended to assure completeness of the DBR.

6.4.6.1. Generic top-down system functional requirements

An NPP generic top–down functional assessment process uses a matrix of generic accident or event types based on the plant safety analysis presented in the FSAR/UFSAR 15/14 [7], versus generic safety functions (e.g., reactivity control, core cooling, containment integrity, radiological boundary) credited with preventing or mitigating the associated accident or event types. The matrix also includes events not addressed in Chapter 15/14, such as anticipated transient without scram (ATWS), station blackout (SBO), seismic events, tornado, flooding, etc.

This matrix is a tool used to assure completeness of the system level functional requirements. It serves as a template for providing reasonable assurance that the identification of system and component safety functions is correct, complete, and consistent with the safety analysis.

This generic matrix then is reduced to be specific for each DBR selected system. An example of application of this technique for a safety related (essential) service water (SW) system at a Pressurized Water Reactor (PWR) unit is provided in a spreadsheet SW Event–Function Matrix.xlsx. This SW system level matrix is then used to address component specific attributes. An example of this application for mechanical components is provided in a spreadsheet in Appendix VI.

Please note, that the spreadsheets are provided for illustration purpose only and not all information is filled. Additionally, the original component ID numbers were altered in order not to reveal the NPPs name.

6.4.6.2. Generic components functional requirements

All NPP components, irrespective of their system affiliation can be treated as commodities that fall under the discipline specific categories, such as:

- Mechanical;
- Electrical;
- Instrumentation and control (I&C);
- Civil/structural.

A common set of the discipline–specific requirements is compiled, and additional component unique attributes are added. Once compiled, this information serves multiple purposes. As documented above it is used to provide an added level of assurance that the system specific component level matrix is complete. It also serves to assure completeness of operational and maintenance level reviews down to a component level.

An example of a table for a SW pump is provided in a Table VI-1, located in Appendix VI.

6.4.7. Operational documents reviews

The purpose of this review is to assure that operating procedures correctly capture known design functions and look for operation modes different than proof design.

There are three phases of operational documents review:

Phase I:

- Identify operating procedures which may contain relevant LBE's and system and component level functional requirements with an input from LBR and EDBR teams;
- Develop tools and attributes to perform verification that plant programs and documents will meet and be implementable to satisfy LBEs and system and component level functional requirements;

Phase II:

- Review procedures for completeness and accuracy of LBEs and system and component level functional requirements implementation; and
- Ensure plant programs adequately operate, maintain and test identified LBEs and system and component level functional requirements;

Phase III:

- Via plant walkdowns of documents ensure that operational, surveillance and maintenance requirements of LBEs and system and component level functional requirements are implementable. Implementations include verification that training is in place;
- Provide individual reports on each document that implements and verifies meeting of LBEs and system and component level functional requirements and capture of information into DBRDB.

6.4.7.1. Phase I

The following documents need to be reviewed for fidelity of implementation of LBEs and system and component level functional requirements:

- ISI, IST, and other surveillance/test procedures[4];
- Other Operating Procedures (normal, AOP, ARP, EOP, maintenance, etc.).

6.4.7.2. Phase II

Phase II implementation will need the following actions:

- Determination if actual plant configuration and operating procedures (operations, surveillance, test, maintenance, etc.) correctly reflect requirements stated in LBEs and system and component level functional requirements; and
- Identification of gaps and assistance with development of condition reports;

[4] ISI, IST and other surveillance/test procedures require joint review by EDBR team (acceptance criteria and methodology) and operations team.

- An experts panel assess each condition record as entered. Their role is to assign a level of urgency and awareness to other organizations that may need to take action. A follow up timeline with a CAP is prepared.

6.4.7.3. Phase III

The *Phase III* is the presentation of the findings. Key outputs from *Phase III* are:

- Summary reports, which identify any gaps or inconsistencies;
- Capture of any other information and knowledge into DBRDB.

6.5. DELIVERABLES

The DBR deliverable is a comprehensive document that includes a summary of the following areas:

- Reconstituted licensing basis;
- Reconstituted engineering DB;
- Corrected operational documents;
- Findings and their resolution.

6.5.1. Licensing basis review deliverables

The outcome of the LBR need to provide the following:

- Identify the CLB;
- Identify licensing basis elements to verify that these have been correctly reflected in DB documents and operational documents;
- Provide 'mark-ups' to CLB as appropriate; and capture results of review in the DBRDB.

6.5.2. Engineering design basis deliverables

The outcome of the EDBR need to provide the following:

- Identify the specific DB accidents and events (e.g., loose of coolant accident (LOCA), SBO, fire, seismic), and the associated mitigating functions that the system is assumed to perform (e.g., reactivity control, core cooling) in the accident/event analysis;
- Identify system level functional requirements;
- Identify SC level functional requirements;
- Provide system/SSC level functional requirements to licensing basis and operation teams;
- Identify and review key design documents;
- Identify and perform a design review of key operations documents;
- Capture results of review in the DBRDB;
- Use DBR database to generate/validate DB documents.

6.5.2.1. Design basis documents

A selection of how to perform and document results of engineering DB portion of the DBR process will have a significant influence on DBR process implementation; and hence, needs be made prior to a finalization of this process. Results of the DBR process with respect to design documents are commonly referred to as DBDs. This designation will be used going forward instead of the 'results' of the DBR process.

DBDs are typically divided into:

- System level; and
- Topical: fire, flooding, EQ, etc.

Source documents that define the interrelationships between plant systems functionality under specific operating and accident or upset conditions. Some systems by definition are support systems to other primary operating systems, however, may be reliant on common supply or reliability depending on anticipated failure modes.

6.5.2.2. Quality assurance perspective

The DBD's should not be used as repository of the actual design information. i.e., used as design inputs, rather they should be a road map to design inputs. For this recommend implementation an independent design verification is not required.

6.5.3. Operational documents deliverables

The outcome of the operational document's reviews should provide the following:

- Identify and review key operations documents;
- Perform plant walkdowns;
- Capture results of review in the DBRDB.

6.5.4. Design basis review database

DB review database, although not required, is essential for the DBRs success. It needs to address the following aspects:

- Provides a mechanism which captures top-down system specific functional requirements;
- Contains links to a 'frozen' set of plant documents selected for review;
- Provides a mechanism through which plant documents are reviewed against top–down system specific functional requirements;
- Provides a mechanism through which results of review of plant documents are captured;
- Provides a mechanism through which 'knowledge' records[5] (generated during the review) can be linked into the existing plant–controlled data basis;
- Provides a mechanism for generation reports, e.g., requirements vs. results.

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[5] 'Knowledge' records – see Appendix VII for a detailed discussion.

It is important to treat DBRDB is a tool for an efficient DBR conduct and not a final deliverable to be incorporated into CM. The NPPs information technology (IT) needs to be engaged in the planning stages of DBR to assure that upon the DBR completion certain pre-designated DBRDB records can be imported into the NPPs existing data basis. This will further aid in maintaining the fidelity of CM and avoidance of future DBRs.

6.5.5. Pilot

As in any large project, it is a good practice to perform a pilot to assess the quality and breadth of the selected processes to deliver a complete and comprehensive review.

The pilot can also be used as a part of the competitive bid process, should NPP elects to perform DBR as a contract managed task.

Once the pilot has completed, review the process and its outcome, collected documentation and data to determine if it achieved a desired outcome and to determine if a sufficient/excessive level of information was assembled to begin the design requirement reviews.

7. CONCLUSIONS

DBR is a process to ensure that critical design information required to safely operate and maintain the plant can reliably be restored.

Operating experiences and lessons learned in performing the DBR is intended to be a one-time effort to reset information and knowledge and to identify and fix the programmes and processes that resulted in the situation that requires DBR.

7.1. CHALLENGES

Major challenges to reconstituting the DB include:

— Latent Plant Conditions:

  - Inadequate CMP and/or deficient design change processes. In addition to the traditional and well understood causes, the ineffective CMP may be also attributed to:

    - Incomplete, inaccurate translation of licensing basis into design documents; and/or
    - Incomplete, inaccurate translation of licensing and DB into operating procedures;

  - Inadequate design documentation, design requirement documents that were never written in a complete content format that allows evaluation against other connected systems requirements; therefore, a format for standard topical system design manuals that interconnect is necessary to be maintained;

    - Incomplete design documentation at component and sub-component levels;

- Lack of a hierarchy of system level requirements that cascade down to sub–systems and components;

— Large Project Management Challenges:

- Inadequate support of the DBR project by upper management, unreasonable schedule, etc.;
- Lack of qualified staffing with expertise;
- Lack of an organization dedicated to DBR such as a separate project with representatives from each engineering group;
- Communication challenges with vendors due to obsolescence or lost contracts and lack of economic incentive for vendor to provide vendor support.

7.2. SOLUTIONS

The following key recommendations are based on past DBR experiences:

— Performance of a root cause analysis to identify and resolve all key issues that led to a necessary to perform a DBR;
— Benchmarking past industry DBR projects to leverage experiences of successes and failures;
— Securing the upper management support for the DBR;
— Application of a realistic approach to a prioritization, scope, and schedule of DBR;
— Formation of a dedicated DBR organization;
— Use of a specially designed database to control DBR activities and capture DBR discoveries.

APPENDIX I.

EXAMPLES OF IMPAIRMENT DUE TO LOSS OF DESIGN BASIS

I.1. SEISMIC UPGRADE PROJECT

DB for motor control centres (MCC) that operate critical safety systems for emergency cooling injection at the NPP were required to be established prior to upgrading for enhanced seismic requirements due to a modification.

The design authority contracted to a design agency to develop the upgraded design specifications. OEM for the MCC based requirements on a 'Form, Fit, Function' set of criteria. This type of evaluation was acceptable for non-nuclear, 'commercial' type equipment specifications. During field testing of the installed replacement MCC to automatically transfer from normal to emergency power supply, the replacement MCC failed to pass the start-up test. This resulted in an emergency safety system impairment.

Consequently:

- Critical design attributes for new equipment were not verified; and
- Original component technical specifications and performance criteria were not duplicated.

Critical DB attributes of event related seismically qualified replacement components rapid or timed actions (relays, breakers, and similar switching components) did not properly replicate original specifications. As a result, overall system normal to emergency power supply transfer times increased from 100ms to over 140ms.

Timing analysis of the new scheme was not performed. The design agency had contacted the OEM to provide replacement components. It is understood replacement components and obsolete originals do not have identical operating parameters. Discussions with the OEM indicated satisfactory replacement components replicating original timing schemes could have been provided, though of a special order only. This would have added costs and delayed ordering time. Vendor provided components based only on form, fit, function directives were approved by the design authority.

A reactor safety test requirement for emergency transfer was not entirely satisfied following system modification and commissioning testing. Consequence of action from altered response times of various components interaction with the MCC was not appropriately reviewed during any aspect of the modification design phase. The design authority did not instruct the design agency of any requirements for system interaction such as emergency transfer start times.

It was also determined that historically transfer times problems existed with these MCCs. Such data may have indicated the need to incorporate further response time capability into modified component requirements. However, such field performance records were not used to update design requirements. There was lack of rigor in establishing critical system attributes of the DB prior to starting the component replacement project. The engineering change control (ECC) program was not followed appropriately for this safety system modification.

I.2. COMPONENT COMMERCIAL DEDICATION

Originally supplied analogue alarm meters for Boiler Feed Low Pressure Shut Down System and containment system Calandria Vault dryer were no longer available from the original equipment manufacturer (OEM).

A search for the original design specification found that there had been a substituted meter from a different supplier. Diversity of supply is required for safety systems with a reactor cool, contain, or control function. While preparing new specifications, the title ‘Indicating Alarm Meters’ had been changed from formerly just ‘Indicating Meters’. Hence the alarm functions were added before final tendering.

In searching for an equivalent replacement meter supplier, the vendor selected indicated no EMI or seismic evaluation had been done. Commercial grade dedication (CGD) process was used to prepare Inspection and Test Plans (ITP) based on Electric Power Research Institute (EPRI) guidelines.

Certain critical DB attributes for the system performance were not included in the specification. One improvement requirement was separation of the indicating and alarm functions. However, this resulted in adjustments of the indicator did not adjust the alarm setpoints. There were various quality control issues with the original meters such as ground faults, dielectric withstand and calibration. One critical issue was that meters were bought from a sole sourced company without a formal quality program. By using a CGD program, an oversight organization is brought into supplement quality control to the required level. However, the CGD program did not re-establish the original specification. Other metering performance characteristics such as hysteresis were improved based on historical performance data which resulted in a custom specification. It was not recognized that such meters cannot be fully tested at the vendor and require commissioning activities to check performance in situ.

This meant that the actual DB for the meters was not known until field testing could confirm operating parameters.

The engineering change control (ECC) process involving design, procurement, and components engineering interacting to re-establish the DB for indicating and alarming analogue meters as having evolved with operating experience would have addressed these issues.

I.3. VACUUM DUCT TEMPORARY BULKHEAD

A multi-unit NPPs has a shared containment system based on maintaining a partial vacuum relative to outside the containment boundary. Emergency rupture type panels are used to connect each reactor containment building to a common vacuum duct which is also connected to a poised containment building in the event of a loss of coolant over-pressure accident in any of the reactor containment buildings. The DB operation of this poised emergency containment system is based on calculations that model the volume and steam absorption capability of the structures. During construction phases as four additional reactors were connected to the vacuum duct, a temporary bulkhead was in place to isolate the original four in -service units from the additional four under construction.

It became necessary when commissioning the completed four reactor unit addition to the vacuum duct to leave the temporary bulkhead on its side inside the vacuum duct. This became an internal component that was not part of the DB yet required analysis to show the restriction to flow and volume available for containment inside the vacuum duct could be accommodated. The response time and overall containment capability in emergency conditions needed to be adjusted to reflect the 'as-built' current conditions of the poised safety system.

I.4. EVOLUTION OF SEISMIC MODEL CONSERVATISM

A poised containment support vacuum building connected to the operating reactor buildings has a dousing tank in the roof that activates upon emergency reactor primary loop steam leak. It functions by spraying water inside the containment vacuum building to condense the steam entering from the reactor building. The volume of the vacuum building has been sized to contain the dousing water and condensed steam from the accident reactor.

This poised safety support system has been analyzed to be capable to perform its emergency function during and after a DB seismic event.

The seismic model of the vacuum building dousing system used a computer software that simulated the mass of the water inside the roof chamber that was considered conservative at the time of initial design. Subsequently the response of the dousing tank to seismic forces imposed by movement of the water was used to design the structure of the tank.

However, as computer modelling software became more capable to simulate the effects of non-homogeneous materials as the mass of liquid water inside the tank, it was discovered that seismic loads could exceed the limits used as the original DB. It became necessary to design a modification to introduce an internal baffle plate so the water could not impact as a harmonic wave amplified seismically. This became the revised DB for the dousing system.

I.5. CONFLICTING REQUIREMENTS BETWEEN PRESSURE BOUNDARY AND FIRE PROTECTION CODES

During a modification project to add fire suppression booster pumps to the roof area of the steam turbine building it was decided that components would be selected according to the National Fire Protection Association (NFPA) code which is mandated by the building code in the plants operating license. This is a poised safety system that activates automatically to douse a fire with service water that is maintained at sufficient pressure to achieve open spray coverage of the turbines. An upgrade project was deemed necessary to add booster pumps to ensure sufficient pressure in the upper areas when operating due to inadequate service water pressure.

The NFPA code does not permit relief valves that may fail closed to be operated in line with a fire pump that needs to function in an emergency. Hence the project designers selected flow switch devices instead to regulate the booster pump flow when operating.

However, the plant also uses the service water system for cooling service and hence has to follow the pressure boundary code B31 [8]for pressure pipe. This code requires relief valves to ensure overpressure protection. Following completion of installation of the booster pumps with flow switches but not relief valves, the system experienced an over pressure event. This occurred when stagnant water within the system with the booster pump off was experiencing thermal expansion due to proximity to steam lines. A solution was found to separate the fire protection dousing system from the main plant service water system which maintains relief valve overpressure protection, which was the original DB.

APPENDIX II.

DESIGN BASIS INFORMATION CONTENT

II.1. THE FOLLOWING TYPICAL INPUTS SHOULD BE CONSIDERED AS VALID DESIGN BASIS INFORMATION CONTENT

- Information on the conceptual foundations of NPP design e.g., siting, technology section, resource, and environmental aspects;
- Information on the regulatory base for technology selected and used during conceptional design stage;
- Description of the unit's principal thermal scheme, design, and principles of operation of the main nuclear installation components;
- Description of the unit operation modes, including information concerning the design modes, violations of normal operation, DB accidents;
- Description of the concept, principles, main safety functions accepted in the design;
- Description of the principles on which the design decisions concerning classification of the systems and elements by their influence (degree of influence) on safety, by the type of their functions (for example, protective, localizing, providing, control safety systems) were based;
- Information on the methods and tools for justification and verification of the design, including information concerning calculation methods and codes, scientific and experimental studies;
- Description of the external and internal hazards which were taken into account during designing;
- Analysis of the compliance of the design with regulatory requirements, including deviations from these requirements (if any);
- Using operating experience as a justification to validate the assumptions behind DB and regularly reviewing OPEX;
- Justification (reasoning) of the accepted design decisions regarding:
- Structures design, systems composition, and layout (positioning), components design:
  - Functions of the systems, components, and structures;
  - Characteristics of the systems, components, and structures (functional, operational (lifetime, resistance to external and internal impacts, reliability analysis);
  - Description and substantiation of the choice of materials which have to be used, integrity (strength and density) of the coolant boundaries, structural strength and seismic stability of the structures, systems, and components (including calculations);
  - Local specific calculations (for example, calculation of the throughput of the safety device to protect a vessel from overpressure);
  - Acceptable limits of the systems, equipment, and elements/structures degradation (due to aging, wear, corrosion, erosion, fatigue, and other mechanisms);
  - Requirements to fulfilment of maintenance, inspection, testing, calibration, examination of main metal state and welded joints of the systems, components, and structures;

- Description and justification of the design decisions concerning nuclear fuel used, reactor core, nuclear fuel cycle, nuclear fuel management (including storage and transportation), reactivity control systems;
- Justification of technological processes (modes) of normal operation, including:

  - Thermal and hydraulic calculations;
  - Justification of nominal values of the technological parameters and their permissible deviations;
  - Justification of the setting values, technological protection, and interlocks algorithms;

- Justification of the limits and conditions of safe operation (for example, limitations in the case of unavailability/unreadiness (failure) of the safety systems as well as conditions, periodicity, and acceptable time for a withdrawal/deactivating of the safety systems for maintenance, repairs, inspections, and tests etc.);
- Analysis of the initial events of normal operation violations and DB accidents, analysis of DB accidents;
- Analysis of beyond DB accidents and severe accidents;
- Probabilistic safety assessment;
- Environmental impact assessment;
- Principles and justifications of the design decisions concerning radiation protection, radiation monitoring;
- Principles and justifications of NPP physical protection;
- Justifications of NPP siting;
- Materials concerning decommissioning.

APPENDIX III.
AVAILABILITY AND ACCESSIBILITY OF DOCUMENTS

The DB is a diverse documentation package, with elements in various forms (plain text, databases, and drawings in paper and electronic versions, or typically a mixture of both). It is a data asset that needs to be stored safely, under a document control process, allowing easy searching and controlling modification through a managed engineering change control procedure, with well developed, preferably automated version tracking.

Before we go more deeply into the topic of the availability and accessibility, let us look in historical overview at the possible forms of appearance of the sufficiently complex information package of the DB documentation. Often supporting calculations and test data may only reside with the Original Equipment Manufacturer (OEM). Therefore, a reconstitution project may be necessary to identify such unavailable DB support documentation and plan for a methodology to replace:

- The bulk of the documentation, in particular in the early years produced, used, and stored completely in printed paper form, including thick text volumes and abundant technical drawings, blueprints. The text was by the time increasingly enriched with pictures, graphs, flow charts, tables, etc.;
- With the emergence of a computer era, electronic databases and various degrees of electronic text processing appeared, and gradually widespread by the computer aided design (CAD) items;
- The next step was the collaborative work of many people on computer networks, in a greater extent of cases spreading behind the boundaries of institutes, firms and even countries;
- Internet access to storage files and cloud computing has introduced powerful sharing capability both for collaboration amongst utilities and engineering organizations. This has created the need to validate and protect source documents as well as protocols for qualifications of editing;
- In addition to the above, it was in past and is in present essential to care with the creation and storage of legally established, provided with tracking of, preparers, verifiers, and approvers, quality-assured master copies of all kinds of documents;
- The trend of recent decades is that the official practice moves from paper documents to electronic ones, initially in parallel using both forms, later exclusively in favour to electronic. More and more transactions can be handled only electronically in the relationship between the licensee and the authority too;
- The deeper penetration of scanning into computer files also means that the digitization of the most of important paper-based documents up to now has taken place.

The availability and accessibility of design documentation significantly depends on the following factors:

- Storage location:
  - Traditionally, the DB documentation was kept in centralized large rooms with filing cabinets, on kilometre long shelves. The availability was heavily dependent on the quality of the catalogues. Parallel to this, there were generally smaller, area-specific

decentralized archives with certain duplication of centralized storage. Their accessibility was better because they were physically closer to staff. Because of paper form the fire protection of the storages was a central topic;

— Searchability:

- In well implemented electronic form it increases dramatically, even to the depth of each word in documents;

— User interface:

- The revolutionary feature of the electronic era is that everybody can access the documents from working desks without moving to another buildings or institutes, cities. All the modern text management systems or CAD applications have well developed, straightforward display formats with sophisticated searching and filtering services;

— Authorization or permission to access:

- Usually, the DB documentation is under a custodian who controls access;

— Final Safety Analysis Report (FSAR):

- That document beside its other parts should be a synthesis of current, living DB description. It reflects to all safety significant changes in nuclear safety regulation, standards. It incorporates and updates all physical changes in technology, operational procedures, and analytical procedures. In practice of many countries the annual update is obligatory. Other countries are submitting periodic reports, addendums, but the FSAR text is rarely modified.

APPENDIX IV.
DESIGN BASIS RECONSTITUTION SCOPING

IV.1. FACTORS TO BE CONSIDERED FOR DBR SCOPING

- NPP Configuration Control Driven:
  - How robust were the configuration control and design control processes?
  - Are there configuration control related indicators that a DBR process is required?
  - If yes, was a root cause and extent of condition assessed?
- 'Scope':
  - Safety–related only:
    - All safety–related, or
    - Selected based on: PSA/PRA ranking, low margin, critical functions, ageing, operational challenges, etc.;
- Safety and non–safety related;
- Adequacy of translation of DB into operational and maintenance procedures;
- Other Factors:
  - Economic, e.g., power up–rate, LTO fuel economy modernization, etc.;
  - Changed/new safety standards or regulatory requirements;
  - Expected service time (operation);
- Availability and the extent of externally controlled information:
  - What DB information is controlled by NPP?
  - Can the externally (vendor) controlled information be purchased? E.g., (1) Vendor viable and willing/not willing to sell information; (2) Vendor is out of business, etc.

Addressing the IP rights will have a significant impact on scope and costs of vendor–controlled information.

APPENDIX V.

DESIGN BASIS RECONSTITUTION — FORSMARK

The need to perform a design reconstitution project was recognized as a consequence of the strainer event in Barsebäck in 1992. During the event, initiated by a spurious activation of a safety valve discharging directly in the containment's drywell, insulation material was dislodged and transported to the containment's wet–well where the strainers for the emergency core cooling system (ECCS) and the residual heat removal (RHR) are located. Clogging of the strainers caused a degradation of the RHR system.

Blowdown of insulation material was taken explicitly into account in the plant's safety analysis. It was deemed, however, that this phenomenon would not threaten the performance of the safety systems using the containment's wet–well as water source. Similar issues were found in Forsmark's safety analysis. Even though the safety significance of these issues was limited, due for example to a higher back flushing capability compared to Barsebäck's, the evaluation raised more general concerns regarding the status of the plant's safety analysis and questions on whether other hidden issues might be present.

A decision was taken by plant management to perform a design reconstitution project. The goal of this project was a systematic evaluation of the plant's safety analysis which should also take into account plant configuration in order to verify whether correct assumptions were used in the safety analysis. The work was to be performed in collaboration with the plant vendor (originally ASEA–Atom).

Explicit goals for the project were:

- To make sure that the design requirements were complete, verified, and traceable. From the description of the design requirements, it should be possible to understand how the plant was designed and why;
- To identify flaws in the plant's design and the safety analysis;
- To facilitate transmission of knowledge about plant design to a younger generation, both in the plant's and vendor's organization.

Issues found in the plant configuration, or the safety analysis were to be communicated to plant management. Resolution of the open issues found in the reconstitution project was, however, not within the scope of the project.

In order to identify eventual pitfalls or difficulties in carrying out the project and in order to gauge the quality of the project deliverables, it was decided to perform a pilot project of limited scope, narrowed to core, and fuel design requirements.

A project organization was established both on the utilities and the vendor's side, led by separate project managers and technical leads. Eight topical areas were identified within the scope of the pilot project. The work was started with a seminar with utility and vendor personnel to clarify the scope of the work within each of the eight topical areas. A preliminary version of pilot project's deliverables was prepared, and technical review of the material was performed. Results from the review, experiences, and observations from the pilot project and a first list of open issues were discussed before the final delivery.

A few general issues were observed while performing the pilot project. The pilot project's execution was often challenged by scheduling conflicts with other prioritized activities such as plant modernization and outages. This was especially true for personnel with specialist competence. In order to mitigate this problem, project milestones were combined with seminars (either internal or with vendor's participation) where the deliverables had to be presented. A further recommendation was to plan the delivery of the project's milestones outside the outage season. A further observation from the pilot project was that the 'big picture' was often lost resulting in difficulties in reviewing some of the material produced. Issues were also found in the description of the application of certain guides and standards due to the fact that the application had often evolved during time.

The main design reconstitution project was started in 1995. The project was loosely structured on the basis of plant's safety functions:

- General reactor safety requirements;
- Reactivity Control;
- RCPB integrity;
- Containment;
- Emergency Core Cooling;
- Residual Heat Removal;
- Secondary containment;
- Electrical and control systems;
- Structural verification.

A project handbook was developed to document roles and expectations for the participants in the plants and vendor's organization.

The compilation of the reports describing the DB was a task assigned to the vendor's organization. The idea was to describe, for each function, the design requirements at the plant level, at the safety function level, down to the system/component level. A description of how the design requirements were verified was also included within the scope of the vendor's delivery. This meant, in practice, that even the requirements on calculation tools used in the safety analysis were to be described. Furthermore, a complete list of topical reports, to be used as references in the safety analysis, had to be provided by the vendor. Such references were to be included in the plant's documentation system. The documentation produced by the vendor should be sufficiently complete to be used as a starting point to update the safety report, when necessary.

The plant's organization was responsible for the review of the material produced. The goal of the review process was also to guarantee that the DB documentation matched the actual plant configuration. Issues of technical nature, identified in the review process, were to be handled as open issues.

Generally, three versions of each document were produced. A first version was delivered by the vendor after an internal review. This first version was, in turn, reviewed by the technical lead in the plant's organization in order to verify that the expectations with regard to scope and depth of the produced material were met. A second version was produced after the technical lead's review. This second version underwent a broader review performed within the plant's organization. The comments formulated during the second review were discussed in meetings with participation of both plants and vendor’s personnel, in order to leverage the competencies in both organizations. A third and final version of the report was then compiled. The final version of the report also contained a list of open issues with regards to the topic of that particular report.

In some cases, for example for the description of the DB of the emergency core cooling and the residual heat removal function, all the reports related to the same safety function were delivered at the same time.

The number, topic and structure of the reports describing the DB for each area were defined beforehand. The structure was generally as follows:

- General requirements. General and specific requirements relating to the safety function were described, in relation to requirements contained in 10CFR50, Regulatory Guides, standard review plan (SRP) and NUREG-0933 [9, 10]. Appropriate requirements for electrical and control systems, RPS and operator information as related to the safety function were described as well;
- Plant conditions and acceptance criteria. Events challenging the safety function were identified and categorized according to different Plant conditions. Acceptance criteria for different Plant conditions were formulated;
- Code requirements. Both the requirements regarding the computer codes used in the safety analysis and the actual calculation codes used by the vendor were described;
- Function’s performance in the safety analysis. Minimum systems’ capacity as used in the safety analysis was described;
- Interoperability analysis. Description of the requirements on systems not strictly belonging to the safety function because of the needed interoperability with the safety function;
- Technical Specification requirements for the system needed to accomplish the safety function.

Separate reports were compiled for all systems needed to accomplish a safety function. Even in this case, the report structure was defined beforehand:

- Requirements contained in 10CFR50, Regulatory Guides, standards etc. applicable to the system;
- Requirements on the system’s capacity down to the component level;
- Requirements due to the interoperability with other systems;
- Requirements related to separation, redundancy, and diversification;
- Requirements on tests and inspections;
- Requirements on maintenance;
- Requirements on operator information and control systems;
- Requirements on power supply;
- Requirements on material and chemistry;
- Requirements on structural verification;
- Requirements of fire protection;
- Requirements on environmental qualification;
- Safety classification.

The design reconstitution project was completed in 1999. Some of the problems which were identified in the pilot project were not completely solved and also affected the main project. In the latest years, however, in the framework of activities meant to increase the quality of the safety report, the documentation generated in the design reconstitution project has begun to be used as it was originally intended.

APPENDIX VI.
DESIGN BASIS RECONSTITUTION IMPLEMENTATION ELEMENTS

VI.1. DESIGN BASIS RECONSTITUTION DATABASE DESCRIPTION

The DBR Database (DBRDB) is a highly recommended optional tool that could provide a significant savings in the DBR process and the post DBR assurance of the fidelity of configuration control. DBRDB will enable to house the collected information for all reviewed SSCs, and documents and to allow 'publication' of DBDs. A screen shot, illustrating the use of a DBRDB for collection of information using the system and component level functional requirement attributes is provided in Figure 3.

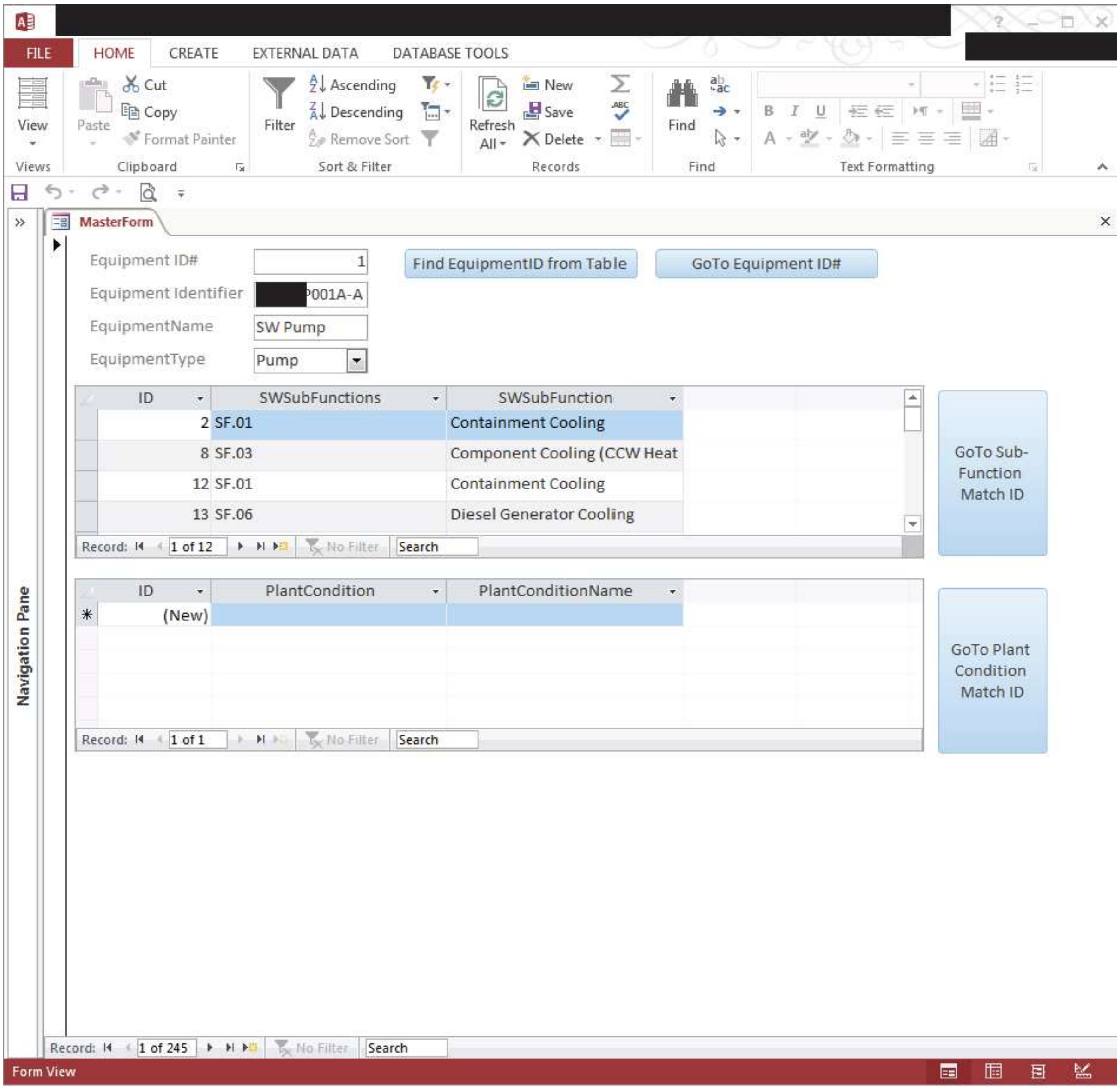

FIG. 3. Database information collection screen shot.

The DBRDB provides the 'framework' of the functional assessment process. The DBRDB serves three very important functions:

- A mechanism through which completeness of implementation of DBR is assured;
- A mechanism through which results of reviews are captured; and
- A mechanism through which will generate 'Knowledge' Records for inclusion into plant data basis. 'Knowledge' Records capture application of design and licensing basis requirements against individual plant components and design and operational documents.

VI.2. 'KNOWLEDGE' RECORDS

'Knowledge' Records are Statement of Facts (SOFs) that capture plant specific licensing and DB requirements for SSCs and design and operational documents implementing these requirements.

Importing these 'Knowledge' records, records thereafter, into the plant-controlled databases and 'linking' them to components and documents would allow the plant to assure continuing accuracy the derived DBDs at very little or no cost. The goal is not to create a new database that needs to be controlled and be updated, but to integrate the acquired knowledge into the existing plant databases. Addition of new search tools for these databases could provide additional benefits in day–today operational challenges, e.g.:

- Address non-confirming conditions and other operational challenges;
- Identify 90 to 95% of scope and functional requirements of future modifications and determine its feasibility.

VI.3. IMPLEMENTATION OF DESIGN BASIS RECONSTITUTION

The DBRDB will provide the framework for the functional assessment. The DBRDB documents the relationship between the identified system components and specific required functions and plant conditions. As discrete functions are identified that require specific plant components to accomplish these functions, they are entered into the DBRDB. The document that identifies this required/committed relationship e.g., Updated Final Safety Analysis Report (UFSAR), Technical Specifications (TS), etc.) and a specific location in this document is also recorded. By its nature, the database will allow documentation of relationships, components that fulfil multiple functions, and functions requiring multiple components.

The DBRDB also documents the relationship between the identified system components and specific plant conditions. As discrete plant conditions are identified that require specific plant components to be available and functional, these are entered the DBRDB. Similar to above, the document that requires/commits a component be available during a specific plant condition (e.g., UFSAR, TS, etc.) and a specific location in this document is also recorded. By its nature, the database will allow documentation of relationships, components being required in multiple plant conditions, and plant conditions requiring multiple components.

VI.4. CAPTURE OF DESIGN BASIS RECONSTITUTION REVIEWS

The DBRDB will record the results of the functional assessment. the DBRDB will provide reports of the implementation (or the lack of thereof) of assigned sub–functions per each identified component. It will also provide reports of the implementation (or the lack of thereof) of identified plant conditions requiring each component. For example, information tabulated in in enclosures B and C are reports generated by the DBRDB.

The DBRDB will capture the design and operational documents that document implementation of the sub–functions and plant conditions. This enables the DBRDB to be a mechanism for the verification of design and operational documentation validating the ability of the component to satisfy the sub–functions and plant conditions.

VI.5. HISTORICAL PERSPECTIVE

The US DBR efforts from late 80s through the 90s were based on use of word processing (WP), which was a contemporary state–of–the–art Information Technology (IT) tool.

Advances in the ease of use of databases makes their use for generation of DBDs an attractive alternative.

To better understand pros and cons of both options, let's review what are the documents available for DBR capture from the IT perspective:

- The overwhelming majority of the documents are 'One Dimensional' e.g., reports, calculations, drawings, specifications, procedures, etc. Some of these are searchable and some are not searchable. The 'One Dimensional' designation signifies that each document needs to be reviewed, by and large, in its entirety to identify the relevancy of the information. Since the early DBDs were/are WP documents they fall into this category;
- Tables & Spreadsheets source documents fall into a 'Two Dimensional' category;
- Lastly, Database source documents fall into a 'Multi-Dimensional' category.

One can refer to these source documents as 'Loosely Connected (Mostly Not) Islands of Information.' Hence, to paraphrase, one of the goals of the DBR process should be to interconnect these islands of information.

A comparison of the WP vs. the database developed DBDs reveals the following clear advantages of the database developed DBDs:

- Initial Information Harvesting:

    - Each type of a DBD (System or Topical) will have a different and unique template for information population irrespective of whether it is WP, or a database developed DBD. The initial process, described below, can be equally optimized for either WP, or a database developed DBD. However, the database approach has a clear advantage. The major advantage is based on the ability to harvest the information directly into the database, do the subsequent reviews in the database, and 'publish' the DBD as a database report. Additional advantage lies in the ability for automation of the information extraction directly into the database, e.g., from the existing plant databases;

- The initial manual entry of the information can be done by less experienced personnel — use of junior engineers and even engineering students for these activities was proven to be very cost effective and mutually benefitable;
- Subsequent to this, the results are reviewed/approved by senior engineers;

— DBD Maintenance:

- The biggest disadvantage of the WP vs. the database developed DBD is in the update costs. The database developed DBD can be designed to be integrated into the existing plant databases; and hence, be virtually 'automatically' updated after implementation of a modification (see DBD Process discussion), whereas updates of the WP developed DBDs require a labour–intensive effort by highly skilled engineers.

VI.6. POSSIBLE DESIGN REQUIREMENTS DOCUMENTATION SOURCES

This is not intended to be an exhaustive set of documentation and data but rather a starting point for your own collection activities. The documentation available will vary from plant type to plant type and from OEM to OEM since each entity has their own way of documenting their design. A non-inclusive list of typical documents is provided below:

— Design Documentation:

- GDC – General Design Criteria;
- SDC – System Design Criteria;
- SFD – System Functional Description;
- FAS – Functional Analysis Summary;
- Design Drawings:
    - Physical:
        - Piping;
        - Electrical;
        - Conduit;
        - Composite;
        - Areas;
        - Rooms, etc.;
    - Zones:
        - Fire;
        - Flood;
        - Radiation, etc.;
    - Schematics:
        - P&ID – Piping & Instrumentation Diagram;
        - C&ID – Control & Instrumentation Diagram;
        - CLD – Control Logic Diagram;

    – SLD – Single Line Diagram, etc.;

- Calculations;
- Specifications:
  - Purchase;
  - Construction;
- Supplier Documentation:
  - Drawings;
  - Specifications;
  - Datasheets;
  - Performance test reports;
  - Bills of materials, etc.;

— Operations Documentation:

- Operating Procedures;
- Current Surveillance Testing;

— Maintenance Procedures;

— Licensing Documentation:

- Operating License;
- License Conditions;
- License Amendments;
- FSAR – Final Safety Analysis Report (Some plants use a Living safety analysis report (SAR), Updated FSAR after the Operating License is issued);
- Technical Specifications;
- OLC/LCO – Operating Limiting Conditions/Limiting Conditions of Operation;
- Letters of Commitment;
- Regulatory Body Approvals, Confirmation, etc.

A common set of the discipline–specific requirements is compiled, and additional component unique attributes are added. An example of a table for a SW pump is provided in Table 1.

Once compiled, this information serves multiple purposes. As documented above it is used to provide an added level of assurance that the system specific component level matrix is complete. It also serves to assure completeness of operational and maintenance level reviews down to a component level.

TABLE 1. PUMP – COMPONENT FUNCTIONS MATRIX

Designation		
Code	Design-Related Attributes	Notes
SI	*Structural integrity*	
SI.1	Committed pressure code requirements – ASME Code, B31.1, B31.7[8]	
SI.2	Code edition	
SI.3	Fluid temperature range	
SI.4	Design temperature / design pressure of fluid circuit	
SI.5	Seismic qualification including II/I interactions	
PF	*Pump Fluid Characteristics*	
PF.1	Type of pump – positive displacement or centrifugal	
PF.2	Type of fluid being pumped – borated water, demin treated water, untreated water (lake, river, sea, estuary, other)	
PF.3	Pump performance curve	
PF.4	Net positive suction head (NPSH)	Minimum required, run-out flow
PF.5	Vortex	Design and operational limits
PF.6	Minimum flow requirements	How they are achieved (orifice, control valve, other)
PF.7	Single pump/parallel pump	Operational characteristics (strong pump/weak pump interaction)
PS	*Pump Support Functions*	
PS.1	Pump & driver lubrication requirements	
PS.2	Pump & driver cooling requirements	
PS.3	Pump seal design requirements	
PS.4	Pump leakage limits	
PS.5	Positive Displacement Pump suction & discharge pressure suppression aids	
OA	*Operations Aspects Attributes*	
OA.1	Maximum allowable time to start operation	

TABLE 1. PUMP – COMPONENT FUNCTIONS MATRIX

Designation		
Code	Design-Related Attributes	Notes
OA.2	Required mission time	
OA.3	Required minimum cycles of operations	
ST	*Surveillance Aspects Attributes*	
ST.1	Relationship between Acceptance Criterion and design requirements.	
ST.2	Impact of instrument error.	
MA	*Maintenance Aspects Attributes*	
MA.1	Minimum recommended component maintenance periodicity	
MA.2	Spare parts	
MA.3	Shelf life for spare parts	
MA.4	Obsolescence	

APPENDIX VII.
EXAMPLE OF DESIGN BASIS RECONSTITUTION ORGANIZATION FOR DESIGN BASIS RECONSTITUTION

As the objective of a DBR task/project/programme/process, which is driven by the reasons explained in Section 3, is to obtain clear understanding about characteristics of design information possessed by owner/operator, the NPP decision authority in need of design support for decision making (e.g. the highest level of the licensee organization [5]) has the prerogative to define the roles and responsibilities, and consequently the organization, based on the particular decision or current and desired state of DB information and in accordance with company policy and strategy.

The final report should be presented to the design authority and then the owner decision maker prior to the start of DBR project and project should be treated with project management similar to plant modification.

During and after DBR project, CM processes should be utilized for long-term maintenance of DB by the NPP organization on its own. Procedures for the DBR process should be established as early as possible in the plant life cycle to ensure safekeeping and ease of maintenance and records. The DBR portion of CM should refer to sum of all design inputs and outputs documents procedure. This should be enough for DBR archival and its use during the plant life cycle. However, owners and engineering organization may select to produce a 'new' design output document such as 'design basis manual (DBM) (paper or electronic)' to increasing the availability and ease of access to information. Such a document will be summation of extracted information and references to all documentation supporting an SSC DB with in CMP including operational procedures and licensing basis. Basically, this document is summation of all implicit/explicit data and knowledge basis available at designer level when design is reconstituted. Such a design output document needs continuous update, and it is maintained as a configuration management records.

A hierarchy of topical Design Manuals is required, with essential system design requirements that should not change when components within the system are replaced. Overall system functionality should not be adversely impacted when different design components are substituted.

There is no 'one size fits all' organizational structure for implementing/performing DBR; however, the owner/operating organization needs to establish the roles and responsibilities with a dedicated technical capability and competency, as a minimum, to:

- Recognize and express the need and scope for DBR for desired output;
- Identify the competencies and qualifications needed for design aspect;
- Identify potential sources for design information;
- Discover, understand, and recover the relevant and accurate design information.

If the company's/decision maker's strategy is to collect and preserve all design information within the NPP owner/operating organization, for example, the roles and responsibilities may be associated with the 'one house approach' (i.e., establishing, utilizing, and maintaining a fully capable and competent internal DBR roles and responsibilities). Even with this approach, it is highly likely that there will be complex or special issues or unique cases which would exceed the capabilities and capacities of the internal DBR staff for which an external resource will be necessary. As the DB primarily falls under the roles and responsibilities of the technical support organization (TSO), the roles and responsibilities for DBR has to align with the TSO form and structure, similar to that is described in [5].

Therefore, there are mainly three options for assuming/assigning the DBR personnel and their roles and responsibilities:

— Owner/operator and in–house designer, working under owner management;
— Turnkey project, external vendor manages, staff and use; owner/operator personal as needed. Deliver final out put products and supporting documentations per contract; or
— Combination of owner operator and contract personnel. Under owner or vendor organizations output document content would be divided assigned to each team.

The following sections discuss various options for fulfilling the roles and responsibilities.

VII.1. INTERNAL RESOURCES

VII.1.1. Roles and functions within the DBR programme

VII.1.2. Owner/operating organization

Owner should establish and contractually maintain long-term support relationships with the designer ('responsible designers' — the NSSS vendor and the other significant design organizations involved in the original design, such as the architect–engineer [2] (to identify and record critical DB information).

The organization assigned/selected to perform a DBR project needs to be trained and required to participate in the owner's CAP.

VII.1.3. DBR organization team members

The DBR team members should be selected based on design and operating support experience at specific NNPs. Also, specific training in document reconstitution by source investigation is required for the team. It is recommended that a new group/organization be created independent of daily NNP operational teams. However, there needs to be support from plant operations representatives to consult and review the project team's findings. The DBR team be a combination of permanent team members staffed with NNPs experts (internal or external) and a lead/supervisor that would be reporting to the NNP Design Authority. The following is a suggested composition for a DBR project:

— Permanent team members:

    - The technical lead/project manager;
    - Experienced classical discipline engineers, mechanical, electrical, Instrument and control, civil and nuclear engineers;

- Seasoned licensed nuclear operator and/or technical shift advisor6;
- Maintenance engineers;
- Experienced compliance and licensing engineers;
- Experienced safety/accident analysis and PRA engineers;
- A dedicated design oversight quality assurance/control (QA/QC) expert qualified in CAP for condition identification and reporting of non-conformances, determination of corrective actions and completion of closeouts (noting that it is also a good practice to have one expert for QA/QC and another specialist for CAP).

— Temporary team members, these individuals would be from any of owner, operator, architect and engineering (A&E), vendors originations on as-needed basis;

  - Plant support technical equipment inspectors and maintainers to conduct in-plant 'walkdowns' to validate current actual plant equipment status and location;
  - Expert engineers for relevant areas, for which the needed engineering expertise varies significantly based on DB of the SSC that is being reconstructed, that may include:

    - Specific SSC experts/engineers;
    - Equipment qualification (environmental, seismic);
    - In-service, code, and material engineers;
    - Chemistry and ageing experts;
    - Topical experts (i.e., fire protection, emergency safety system plan and testing, environmental standards, health and safety, pressure boundary, electrical protection, etc.);

— Plant operation and maintenance experts:

  - Radiation Protection/chemistry;
  - Radioactive Waste management; and
  - Outage;

— Drawing preparation and component data sheet parts validators, to interface with approved suppliers and track approved component substitution or replacement;
— Technical writers to prepare manuals and design guides following the established plant procedures;
— Expert engineers for relevant areas, for which the needed engineering expertise varies significantly based on DB of the SSC that is being reconstructed, that may include.

The project organization members may interface with these functional area's nuclear safety and abnormal operation accident response:

— Environmental qualification (exposure of components to extreme temperature, radiation, humidity);
— Probabilistic risk assessment, risk, and reliability;

[6] In some Member States, there is required role/position of a qualified engineer and technical manager with extensive knowledge of the plant design and configuration as a part of the operations and reactor operating shift crews, such as the shift technical advisor (STA) in the USA.

- Seismic qualification;
- Pressure boundary;
- Welding and metallurgy, corrosion, and materials compatibility;
- Chemistry and materials compatibility;
- Electrical supply and reliability;
- Fire protection, plant personnel life safety;
- Software design and software security;
- Components life cycle aging management;
- Design agency and components vendors qualifications;
- Procurement and supply chain surveillance; and
- Licensing, regulatory codes and standards compliance.
- Human factors (machine–human interface);
- Operations training;
- Maintenance planning;
- Radiation protection;
- Nuclear waste management;
- Plant systems chemistry;
- Plant boundaries security;
- Environment external to plant, emissions controls;
- Outage and maintenance configuration control;
- CAP oversight owners;
- Procurement and supply chain QA; and
- Component engineering and calibration/test.

VII.2. ASSIGNMENT OF ROLES AND RESPONSIBILITIES

VII.2.1. Responsible designer

Role: To ensure preservation of the initial design and maintain current design status incorporating modifications transferred to the operating organization configuration management system, as well as supporting calculations, test data and approved document revisions.

The main tasks of the responsible designers/vendors in the field of reconstitution of design requirements and DB are the following (on the base of agreement between the parties):

- Identifying or confirming undocumented missing DB and/or design requirements in owner/operator organization's records;
- Extracting and documenting the needed explicit and implicit knowledge underlying the design, (reconstructing it, if needed, such as in cases of when the implicit DB does not exist, or may be lost due to change of original design engineers 'sources and references;
- Providing the owner/operating organization with sources for DB information and design requirements information of the initial design and/or modification designs based on the commercial and proprietary knowledge rules and agreements.

VII.2.2. Owner organization

Role: make sure that design integrity in support of safe operation within design limits is maintained over NPP lifetime.

The main tasks in the field of reconstitution of design requirements and DB are following:

- Identify the critical plant system requirements that together define safe operation;
- Through a ‘gap assessment’ identify which missing or incomplete system requirements need reconstitution or replacement of supporting documentation;
- Owner has taken the necessary measures to properly use design knowledge (including DB information) when preparing design changes and safety assessments/analysis; or if a part of DB information of the initial design cannot be obtained (due to any reasons/considerations) the owner has taken measures to ensure that design integrity will be maintained even in absence of original source documents.

Owner has programmes and processes to ensure multiple modifications on NPP design integrity are properly analysed and understood incorporating DB information and maintaining configuration control).

VII.2.3. Roles and responsibilities of permanent team members of DBR project

When forming/initiating a project under the DBR programme the following need to be considered when assigning resources.

VII.2.3.1. Selecting design basis specialists

The allocation of responsibilities strongly depends on the number of NPPs belonging to a utility. In a single NPP case the responsibility and knowledge concentrate at the NPP, if multiple plants are owned, a central corporate engineering function should coordinate tasks.

External contractors that specialize in DBR and have proven experience in successful projects can provide reconstitution services for the NPPs.

Some activities may be delegated to other subcontracted technical organizations that have unique skills such as testing or modelling through simulation. Responsibility for the quality and accuracy of the DBR rests with the plant technical authority, the Chief engineering design authority responsible for maintaining the design conditions in the operating licence. Quality audits and specialty reviews may be performed for the technical authority to demonstrate compliance with quality standards.

VII.2.3.2. Permanent team role and responsibilities:

- Adhere to all procedural requirement of site including but limited to CM and CAP;
- Follow all project polices process rules;
- Report all safety issues with a complete and clear description and possible resolution through corrective action program to technical authority or equivalent management for timely resolution and initiation of communication with regulator and control room operators;

- Establish a universal format for all DBR output documents and ensure all products of each SSCs have consistent content;
- Understand and include operation needs and include a section with output documents for their use;
- Maintain project within its schedule and budget. Avoid scope expansion beyond owner accepted scope; and
- Identify procedural errors for plant corrective action through the CAP program.

Recruit and qualify staff as required to fulfil roles in the project.

The plant document control and plant records departments will maintain original DB documents at the latest approved revisions following the DBR project.

VII.3. EXAMPLE DEIGN BASIS RECONSTITUTION PROCESS CHART

Figure 4 is one example of DBR process and correlations between line, CMR project and DBD team.

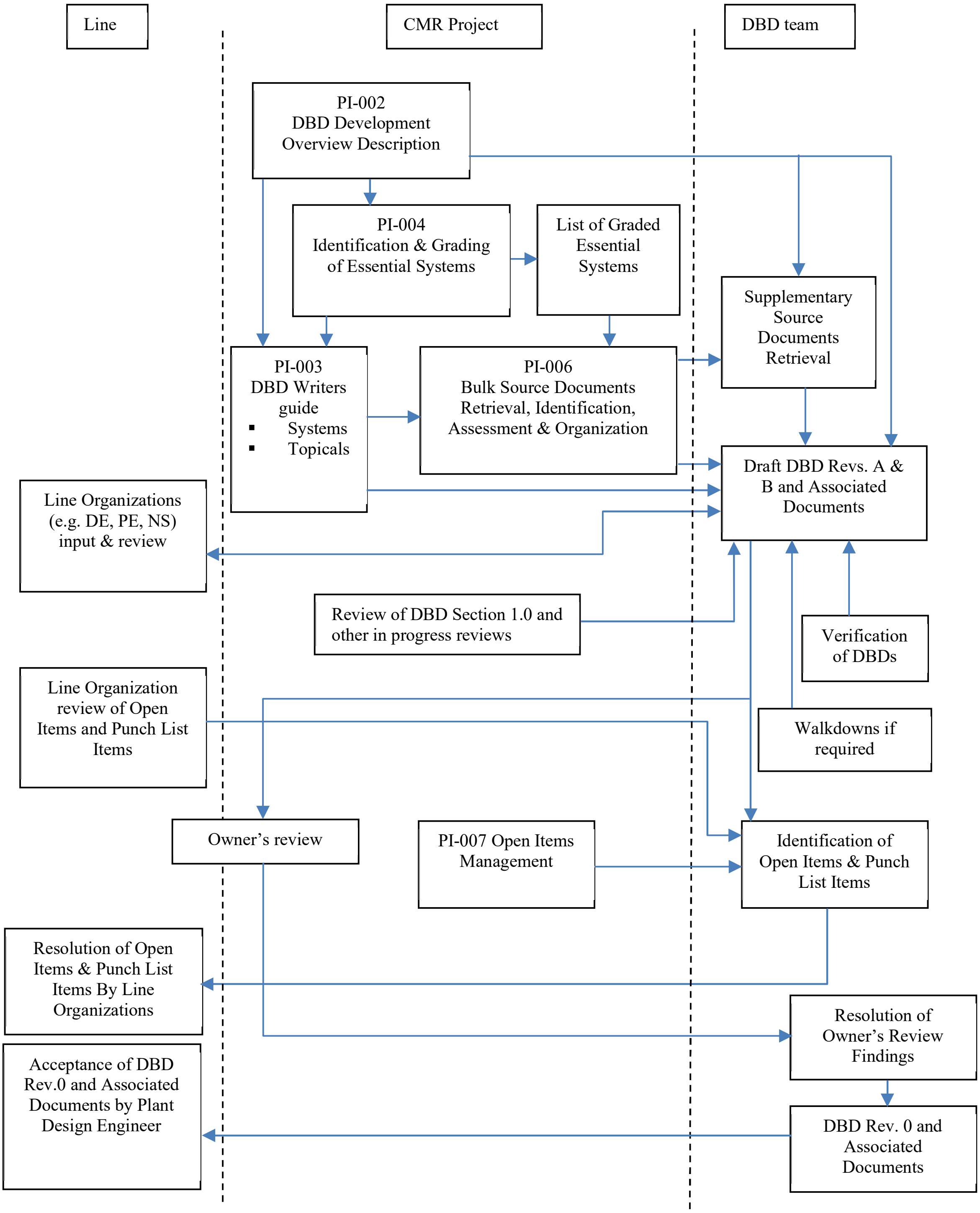

FIG. 4. A sample configuration management reconstitution process (CMRP) design basis reconstitution process.

VII.4. SUPPLY CHAIN INTERFACE WITH EXTERNAL VENDORS

Initial design and construction of a plant and its approved design is a collaboration of architect–engineer; the manufacturer of the nuclear steam supply system (NSSS), turbine manufacturer and number of other vendors providing a full range design in all engineering design disciplines.

Also, equipment suppliers that retain ownership and control of DB and/or DB information, such as calculations, DBMs, detail drawings, are critical contributors to the plant DB.

Therefore, it is a good practice for NPP owners who share a common technology to cooperate in the DBR of critical DB calculations for nuclear safety analysis, component failure rate data, and other design limits. The costs and methodology of such reconstitution can be shared and independently verified. Some examples of such cooperative reconstitution may be found within NPP regulatory bodies.

External suppliers (i.e., by the external organizations) to DBR may be asked to prepare or qualify management systems, procedures, specific to the DBR tasks assigned to them. They also agree to the criteria of interface and communication such that the project requirements are consistently define, and owner/operating organization's expectations are understood and applied by the external organizations to meet and exceed these requirements and expectations. In the bids submitted by external agencies they may be asked to present briefly about their understanding of scope of work and approach and methodology of doing.

VII.5. EXTERNAL AND INTERNAL ORGANIZATION INTERFACES AND INTERACTIONS

The requirements of DBR including items of reference need to be clearly brought out and a contract need to be entered between both the parties.

Owner needs to have the clarity of the DB requirements and accordingly to be mentioned in the contract. Similarly, after award of contract the DBR preparer may be asked to prepare list of drawings/documents which are part of the DBR and accordingly ensure that all are prepared by the DBR preparer and reviewed/accepted and possessed by the owner.

When the DBR contract is awarded to an outside organization, the owner/operator needs to provide adequate management, supervision, and oversight of the work of the external organization.

The detail scope and classification of DBR project has to be established and approved by owner/operating organization, and if an external supplier is utilized, both parties, i.e., owner and DBR preparer.

If such oversight skills are not available internally, a qualified independent third-party engineering organization should be contracted. The oversight organization evaluates the work performed by the external organization as the work progresses in accordance with the defined objective and scope of work and the contractual agreements. The NPP's supply chain organization maintains and monitors equipment and component vendors that meet design requirements through SSC's technical specifications. It audits vendors capability and quality to meet the standards required and searches for replacement vendors when current suppliers no longer meet those standards. Awareness of evolution amongst the vendors is a critical supply chain function to support the DB.

In interfacing with external contributors to the DBR project, the responsibilities of owner/operator's internal organization include, as a minimum, ensuring:

- Clear understanding of the need, objective, and provisions of performing the DBR activities and tasks, including all the requirements (technical, regulatory and owner's), by the external organization;
- Provision of all relevant and correct plant information to the external organization, including the changes to the original design (this is particularly essential when the original responsible designer is interfaced) as the identification of plant systems that are affected by such changes is key to recognizing which external support organizations are needed to reconstitute the designs to the current basis;
- Conveying specific technical and programmatic (regarding design) expectations and concerns of the NPP management and decision makers to the external organizations;
- Maintaining a quality programme for the DBR project.

Therefore, the internal staff members assigned to interface and oversee the external organizations work need to:

- Have sufficient knowledge and proficiency to understand the work performed;
- Fully understand the need for the external support and the context in which the work is being performed;
- Support access to the plant as needed;
- Know the objective, scope and requirements so that the product received meets the intended needs;
- Be aware of the time frame for delivery of the work;
- Supervise the work in accordance with the owner/operator procedures and perform technical reviews on it whenever necessary; and take ownership of actions arising from DBR findings through the CAP; and
- Ensure regular interaction and facilitate the interaction with the other parties (internal and external) related to the task, if necessary.

After the external supplier's work is completed, the owner/operator needs to review and accept the product. The owner/operator has to ensure that the work has been verified in accordance with the quality assurance procedures and satisfies any applicable regulatory requirements with respect to quality and documentation, as well as the other contractual requirements.

One important area is the exchange of correct and understandable technical information. This may necessitate proprietary ownership of technical source documents to the plant, therefore contractual rights arrangements need to be in place.

Some proprietary design features may be site specific or unique to meet initial requirements based on availability from local suppliers. However, such features may no longer represent the current DB as the site environment or evolution of supplier's technology has changed over time.

Most DB calculations that establish safety limits, and form, fit and function for critical systems, and interface parameters between plant systems and structures needs to be identified and reviewed by responsible engineers of NPP and the responsible designer and other external support organization.

Many SSCs that responsible designers have designed or procured are important to the nuclear safety and performance of the plant. When the plant is put into service, much of the detailed knowledge used in the approved design should have been transferred to the owner organization by the lead constructor through documentation such as the safety report, design manuals and other design input documents (e.g., calculations and specification), operational guides and start–up documents.

However, due to complexity and wide range of organizations evolved, the critical knowledge that is transferred generally is not complete or not transfer at all as result of contractual agreement or proprietary/intellectual property (i.e., manufacturing methodologies, analytical/numerical methods, software) nature of document.

Much of the highly specialized knowledge underlying the design will remain with the original designers' organizations. Over an operating lifetime of several decades for any given plant, it can be expected that some of the original design companies may be taken over by other companies or even disappear altogether.

Furthermore, there are situations where the OEM, or the overall NPP's internal design engineering organization, is unwilling to share DB calculations or development information with the NPP owner/operator for commercial competition reasons. There may be contractual limitations on such availability to reproduce the DB calculations without the OEM support, and restrictions on sharing such knowledge with potential commercial competition.

Therefore, loss of collective memory of designer and vendors could jeopardize design reconstitution project in older NPPs. Establishing and selecting qualified vendors needed to re-create the DB and succeed in DBR project has to start at initial project scoping and budgeting stage. A long–term relation with the original vendor is critical to achieving the successful completion of the project.

It is recommended that at early stage of the project a vendor qualification schedule and budget be prepared for each external vendor. Meeting should be held with each vendor to discuss scope and to assess their capability of providing needed information.

As project starts the vendors will be ask to provided experts and supporting documents or a certified summary of a proprietary document/intellectual property. The engineering team should visit the vendor location for 'at site review' of proprietary document/intellectual capability for each selected reconstitution DBR sub–project.

If during initial meetings, it is concluded by owner that vendor does not possess the needed information, or a vendor is not willing to provide, then alternative vendor selection should be considered. This decision needs to be document in project record and captured in initial DBR schedule and budget to avoid scope change during the project.

Nevertheless, a scope change process needs to capture how and when proprietary vendor changes are made.

Alternative to primary vendor is not a preferred option. Possible solution could be using similar constructor, component or system manufacturing vendor's that built a sister plant or similar installation or employing experts building current NNPs to aid in deciphering the original design. Also, other similar design 'fleet' plant should be contacted for information needed. This is usually in the corporate engineering function rather than at the plant level. Cooperation with other NPPs to reconstruct a design could be beneficial for short– and long–term relation in operation of all NPPs.

Other available resources are international and national research centres for component, numerical method, software, such as EPRI or operating organizations, such as WANO, INPO and IAEA although they may not have direct knowledge base, they could aid to coordinate resources amongst a wider group of engineering organizations to locate or reconstitute DB documentation.

The responsibility and rights to make revisions DB documents will depend on whether the plant owner or contract agency has contracted to do so.

APPENDIX VIII.
IMPACT OF MODIFICATION PROJECTS ON DESIGN BASIS

The modification itself is not the driver for the DBR, however it is necessary to update documents affected by the modifications. Modifications may or may not require DBR, depending which design documentation are affected.

Scope of work control of modification needs to include Reconstitution of missing or altered DB documentation.

Cost estimates using baseline information from similar or shared operating experience (OPEX) to fund DBR of critical plant documents.

Stakeholder reviews by construction, operations, maintenance, and nuclear and conventional safety at key design completion milestones during a modification project.

'As Built' and 'As Found' plant system walk–down by configuration control specialists to record 'paper plant to match physical plant'. Project designers to disposition or request changes to physical plant to match' as designed'.

VIII.1. REGULATORY AUTHORITY

Regulatory licensing authority reviews and gives approval to proceed at key design milestones prior to commitment to plant design changes:

Witness testing, verification that as-installed modification meets design intent.
Commissioning and acceptance testing to verify key design requirements prior to completion of installation of plant modifications.

Periodic post-installation testing of modified plant systems to ensure operation meets design intent.

VIII.2. ENGINEERING PROGRAMS

Engineering change control program (ECC) uses staff specialists or subject matter experts (SME) to provide review oversight of proposed plant modifications for risk or impact to SSCs. The overall project risk is then given a graded 'score' to use for the level of engineering evaluation to prove the implementation of the modification stays within the DB.

Risk-based ECC refers to a set of governing Engineering procedures to be followed by the Design Project organization executing a particular plant modification. The plant modification is given a systematic score based on a prescriptive evaluation table that assigns higher risk to nuclear or personnel safety potential impact, and lower score if only conventional or non-safety impact. Costs to implement and potential loss of plant operating revenue risk are also assigned a relative score. The level of Design effort and oversight of contractors performing Design modification engineering is prescribed by the risk Evaluation score.

Procurement Engineering Responsible Specialists periodically review ‘state–of–the–art’ engineering developments within the industry for potential impact on current plant configuration.

For example: motor controller’s technology going modular in parts replacement to expedite replacement and maintenance.

Lubrication technology evolves into sampling and recycling in situ.

Digital replacing analogue switching and Wi-fi replacing hard wired communication.

As these technological evolutions impact plant design at the component level, their operation may change overall system functions by altering instrumentation response time and limits. Consequently, as they are introduced into the operating plant there needs to be plant systems design review by the engineering programs group.

Plant design engineers maintain topical design manuals produced and maintained by centralized design functions to represent inter-related functional requirements of all plant systems. Revisions to topical design manuals are rare and only intended to capture major plant modifications.

Component and system engineers maintain a current status of each major plant system and component to be within its DB limit by keeping records of operation life cycle and degradation.

VIII.3. CONFIGURATION MANAGEMENT (BY WHOM)

DB as a permanent record of how the plant is intended to function as designed is continually challenged by minor, temporary physical changes, or alterations to operating equipment. These changes can occur during maintenance or testing evolutions on equipment that has been left with replaced components or set points or locked out equipment not in service but still part of the physical plant. Unless such components are identified clearly on DB documents that are periodically reviewed against the physical plant, the configuration gradually is at risk.

In anticipation of such changes, good design practice requires that design responsible engineers are involved to review and approve each minor change prior to and after implementation so that the critical design features of each plant system are maintained. Experienced engineers are not always available when such changes are implemented, and often are required to review a backlog especially after a large maintenance plant outage. Consequently, the risk of having unintentional permanent changes that affect the DB becomes greater.

Only by having a systematic change management program that includes engineering holds before the plant is put fully back into service post-outage can such risk be addressed.

VIII.4. DESIGN BASIS RE-CONSTITUTION (WHEN, HOW)

It may be necessary at the time of review of a plant operating license that a formal project to reconstitute or bring up to date DB documentation is required. The timing may also be driven by plant life cycle decisions around whether to continue operation or replace and upgrade. Without reliable knowledge of the current DB, it becomes difficult to prepare accurate cost estimates to support the decisions to continue operation or shutdown to replace.

When original design manufacture suppliers are no longer available to support the plant, and alternate suppliers do not have the original design documentation, then it becomes a challenge to decide how to share the costs to reconstitute critical design documentation. Understanding the plant operating life cycle becomes an important starting point.

The scope of work or extent of necessary reconstitution needs to be established first. This is often done by preparing a generic design manual outline for each plant system, then using current plant documentation available from each engineering functional group, fill in the contents of the generic design manual. Where missing documents such as drawings, operating manuals, schematic diagrams need to be generated, a configuration reconstitution project will prepare a list of such items and plan investigating the physical vs documented status and all ‘gaps’ that need to be addressed. Each gap (or discrepancy) between the physical plant and the current documented record needs to be dispositioned by qualified design engineers who has to act as design reconstitution SMEs.

Planning such physical plant layout inspections can be very intrusive. It is usually only possible during system shutdown or maintenance outage intervals. Therefore, the reconstitution project needs to be coordinated with plant outages, and station management needs to support the extra costs involved.

For example, containment structures and barriers may require inspection ports to be added to verify material conditions that are not accessible when on power.

Timing of a reconstitution project may depend on other modification projects planned for execution and therefore when the plant systems are available for intrusive inspection. There is a risk however, that the scope of the modification will impact the final disposition of the reconstituted DB documents until final close–out of the modification.

For example, a refurbishment project is replacing the reactor core components due to end of service life creep and fatigue limits. Until the replacement components are installed and tested/commissioned, the verified DB for refurbished service life and operability limits are not established. This has consequences on many auxiliaries and reactor support systems that provide refuelling, primary moderator control, reactivity measurement, and the ability to calculate and predict critical core parameters.

Source documents that were originally provided by suppliers that either no longer are available or were not kept up to date due to obsolescence may need to be reconstituted. It may be necessary to negotiate with those suppliers to release calculations or reports that support DB documents.

IP agreements that may have been in place at the time of original design documentation preparation may have expired. Source documents may need to be reconstituted based on plant history dockets or other sources that prove how the physical plant systems are interconnected.

Due to the lack of verifiable records, qualified analysts may need to be added to the project to provide quality checks at critical hold points to demonstrate accuracy and reliability of the input data to analysis reports.

Reconstitution projects need to follow good project management practices where the project scope is controlled, and cost controls along with earned value measurement is maintained for project reporting. Decisions on whether original design documentation is no longer necessary or can be consolidated with other more recent documentation needs to make early in the project by the engineering design organization ‘customers’ of the project.

VIII.5. MAINTAINING THE DESIGN BASIS

Testing: Modelling on a simulator or a mock-up facility is often used to prove the operating response of a particular component or plant system prior to actual modification. Various scenarios can be predicted before committing to the modification. Once the plant system simulator or mock-up has been constructed it becomes available to further evaluate on–going degradation of equipment through life cycle tests. This becomes a valuable tool in prediction and analysis of DB operating margin, and equipment replacement.

VIII.6. DESIGN MANUALS AND REPORTS

DB manuals and their related supporting materials such as calculation reports, system flow diagrams, probabilistic risk assessments, fault tree analyses, all require a document control program to ensure they are kept up to date to support continuing plant operation. This document control program identifies both affected and reference documents that are linked to the controlled document so that the document 'owner' responsible for the content can be aware for the need to update the controlled DB document. The timing or need for document revision can be caused by a plant modification where the plant system classification identifies all common system potentially affected design documents. Alternatively, the DB document may require annual or other periodic updates based on the need to report to an oversight or licensing review organization.

Engineering change control (ECC) programs require that when a modification to the plant is proposed, DB documents that may be affected are reviewed first to decide if the impact is acceptable then how to revise the DB document.

VIII.7. OBSOLESCENCE

Spare parts and Original Equipment Suppliers (OEM) are maintained in a data base of critical plant equipment by the components engineering, procurement and supply chain organizations. When a replacement part is either no longer available from the OEM, or the design of the part has changed according to the 'Form/Fit/Functional' engineering specification by procurement engineering, then it becomes necessary to find an alternative designed component.

However, each obsolete component replacement challenges the plant DB. A high-level system design manual may only identify system level requirements, where component response time and other operating characteristics have been incorporated into an overall system response to inputs.

It may be necessary to maintain an analytical system modelling tool to predict the system response to a changed component's design. Even if the analytical model shows acceptable replacement component performance, once the new component is installed in the plant a period of system testing may be required prior to putting the modified system in service.

Complex component assemblies are often substituted as a single item during a maintenance outage in order to reduce plant down time. These assemblies can then be sent off-site to a vendor facility for service. During such off-site service, configuration management becomes critical in order to identify potential unintended DB changes.

VIII.8. DESIGN EVOLUTION

Design changes to improve component reliability, performance, or other desired attributes may also have unintended DB results. Before continuing with such evolutions on components, predicted analytical modelling should be used to assess wider potential DB impact.

VIII.9. APPROACHES TO RECONSTITUTION OF DESIGN BASIS INFORMATION AND DESIGN REQUIREMENTS INFORMATION.

At the replacement component level when a specification is either missing or needs to be created for a new component the procurement engineering department prepares a list of requirements to be defined that cross-reference DB source documents. If those higher-level system requirements are insufficient or missing key information, it becomes necessary to reconstitute the source design document. DBR project is one of the possible ways to reconstitute design requirements information (and DB information). If it is impractical to initiate a DBR project for a few missing source documents, then a process between procurement and design engineering to fast-track calculations with necessary verification should be in place. Each such calculation then enters the overall system design manual for regular periodic updates.

For example, procurement engineering evaluations for replacement parts often use a ‘Parent-Child’ relationship between component assembly specifications and the subset of parts. Such an example could be a pump set with auxiliary cooling and control components, and the bill of materials for all the parts within each subset assembly. The Form, Fit, and Functions of each subassembly and part is defined within the higher-level pump set specification often as a design constraint rather than a requirement. Several different subassembly cooling or control equipment may be substituted. However, once a particular selection has been made these constraints become defined necessary inputs to the overall system response analysis (PRA) of the current plant configuration. Control devices response times become inputs to overall system response.

At the plant system level, the need for reconstituting depends mostly on decisions to change or extend operating conditions. A plant life extension project certainly is a reason for re-establishing the DB prior to starting such a project.

Questions from the regulator licensing authority may be outside the original plant license. As codes and standards evolve a review of how the current plant design meets such codes may necessitate some reconstitution.

Information about using external or internal ‘contractor’ depends on utilities engineering organization whether it is centralized/corporate or at the plant level only.

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ABBREVIATIONS

CA	corrective action
CAP	corrective action programme
CM	configuration management
CMP	configuration management programme
CSLA	critical system level attributes
CSSCA	critical system structure component attributes
DB	design basis
DBD	design basis drawings
DBR	design basis reconstitution
DBRDB	design basis reconstitution database
ECC	engineering change control
EDBR	engineering design basis review
FSAR	final safety analysis report
IDS	initial document set
IP	intellectual property
LB	licensing basis
LBE	licensing basis element
LBR	licensing basis review
MCC	motor control centres
NPP	nuclear power plant
OEM	original equipment manufacturer
PRA	probabilistic risk assessment
PSA	periodic safety assessment
SSC	systems, structures and components
SW	service water
TS	technical specifications
UFSAR	updated final safety analysis report

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