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Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR)

User's Guide

Part 3: NUCLARR System Description

Prepared by W. E. Gilmore, C. D. Gentillon, D. I. Gertman,
G. H. Beers, W. J. Galyean, B. G. Gilbert, W. J. Reece

Idaho National Engineering Laboratory
EG&G Idaho, Inc.

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Idaho National Engineering Laboratory
Managed by the U.S. Department of Energy

EG&G Idaho, Inc.
Idaho Falls, ID 83415

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ABSTRACT

The Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR) is an automated data base management system for processing and storing human error probability and hardware component failure data. The NUCLARR system software resides on an IBM (or compatible) personal microcomputer. NUCLARR can be used by the end user to furnish data inputs for both human and hardware reliability analysis in support of a variety of risk assessment activities.

The NUCLARR system is documented in a five-volume series of reports. Volume IV of this series is the User's Guide for operating the NUCLARR software and is presented in three parts. Part 1: Overview of NUCLARR Data Retrieval provides an introductory overview to the system's capabilities and procedures for data retrieval. The methods and criteria for selection of data sources and entering them into the NUCLARR system are also described in this document. Part 2: Guide to Operations contains the instructions and basic procedures for using the NUCLARR software. Part 2 provides guidance and information for getting started, performing the desired functions, and making the most efficient use of the system's features. This document, Part 3: NUCLARR System Description, provides an in-depth discussion of the design characteristics and special features of the NUCLARR software. Part 3 also presents the organization of the data base structures and techniques used to manipulate the data.

It is recommended that the new user first become acquainted with Part 1 in order to get an overview of the NUCLARR system. Then, familiarity with Part 2 for operating the software is recommended. Access to Part 3 should be obtained if the user is interested in learning more about the internal aspects of the NUCLARR software functions and capabilities.

FIN No. A6850--Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR)

SUMMARY

The Nuclear Computerized Library for assessing Reactor Reliability (NUCLARR) is documented in a series of five volumes. Volume I: Summary Description is a general overview of the NUCLARR system. Volume I provides the background of the NUCLARR program, including a description of methods for data collection, system specification, data structures, and taxonomies. Volume II: Programmer's Guide provides information for maintaining the software for the NUCLARR system. Volume III: Guide to Data Processing and Revision contains the procedures for processing human error probability and hardware component failure data and entering the data values into the NUCLARR system. Volume IV: User's Guide instructs the end user in operating the NUCLARR software. Volume V: Data Manual is a hard-copy report of the data residing in the NUCLARR system.

Volume IV is presented in three parts for the convenience of the user. Part 1: Overview of NUCLARR Data Retrieval describes the scope of the NUCLARR system, support organizations, methodologies for screening data sources for entry, and guidance for using Parts 2 and 3. Part 2: Guide to Operations tells the end user how to get started and walks through the mechanics for performing data base operations (e.g., file management, data aggregations, and search and retrieval of data). This document, Part 3: NUCLARR System Description, describes in detail the organization and special features of the NUCLARR software, including an explanation of the methods for data aggregations and calculations.

Information for obtaining the NUCLARR software and/or documentation should be directed to:

Thomas G. Ryan
U.S. Nuclear Regulatory Commission - RES
Reliability and Human Factors Branch
5650 Nicholson Lane, NL/N-316
Rockville, MD 20852 USA
(Phone) 301-492-3550

or

David I. Gertman
NUCLARR Data Clearinghouse
Idaho National Engineering Laboratory
P.O. Box 1625, Mail Stop 2405
Idaho Falls, ID 83415 USA
(Phone) 208-526-0652

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ACRONYMS

ABT	aut) bus transfer
B&W	Babcock and Wilcox
CC	common cause failure data
CE	Combustion Engineering, Inc.
CRO	control room operator
EB	empirical Bayes
EO	equipment operator
FID	facility idnetifier codes
GE	General Electric Company
HEP	human error probability
HCFD	hardware component failure data
HHRAG	Human and Hardware Reliability Analysis Group
HPI	high pressure injection
HRA	human reliability assessment
IEEE	Institue of Electrical and Electronics Engineers
INEL	Idaho National Engineering Laboratory
IRADAP	Integrated Risk Assessment Data Acquisition Program
IRRAS	Integrated Reliability and Risk Analysis System
LCB	lower confidence bound
LOCA	loss-of-coolant accident
MAR-D	Models and Results Database
MT	maintenance technician
NRC	U.S Nuclear Regulatory Commission
NSSS	nuclear steam supply system

NUCLARR	Nuclear Computerized Library for Assessing Reactor Reliability
OJT	on-the-job training
PC	personal computer
PRA	probabilistic risk assessment
PSF	performance shaping factor
RC	recovery considered
RHR	residual heat removal
RNC	recovery not considered
SARA	Systems Analysis and Risk Assessment System
SLIM-MAUD	Success Likelihood Index Methodology via Multi-Attribute Utility Decomposition
UCB	upper confidence bound
WEC	Westinghouse Electric Corp.

NUCLARR	Nuclear Computerized Library for Assessing Reactor Reliability
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NUCLEAR COMPUTERIZED LIBRARY FOR ASSESSING REACTOR RELIABILITY (NUCLARR)

VOLUME IV: USER'S GUIDE

PART 3: NUCLARR SYSTEM DESCRIPTION

1. INTRODUCTION

The Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR) is an automated data base management system used to process, store, and retrieve human and hardware reliability data in a ready-to-use format. The NUCLARR system was developed by the U.S. Nuclear Regulatory Commission (NRC) to provide the risk analysis community a repository of data that can be used to support a variety of risk assessment activities. The system maintains a broad range of data base management functions for storing, processing, and retrieving human error and component failure rate data. Computational algorithms for aggregating the source data and routines for report generation are also provided. The system software, designed for operation on an IBM[a] personal computer (PC) (or PC compatible) microcomputer, is readily transportable to a wide range of users.

The equipment taxonomies and data structures for NUCLARR were designed specifically to support probabilistic risk assessment (PRA) techniques currently used by the nuclear power industry. The NUCLARR system aids the risk analysis process by providing the analyst with accurate and relevant data from an on-line data base. This computerized capability gives the analyst a powerful device to search and retrieve data in a timely fashion. The former drudgery of reviewing multiple hard-copy documents to obtain useful data has now been eliminated with the availability of NUCLARR.

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a. Mention of specific products and/or manufacturers in this document implies neither endorsement or preference nor disapproval by the U.S. Government, any of its agencies, or EG&G Idaho, Inc., of the use of a specific product for any purpose.

However, the capabilities of NUCLARR as a compact, transportable, and functional PRA workstation should also be contrasted with what it is not. For example, NUCLARR is not an artificial intelligence/expert system. It is assumed that the analyst must bring some prior skills and knowledge to bear in order to make effective utilization of this tool. In this regard, NUCLARR can best be classified as a library and not a chief librarian. The concept of furnishing analysts with a highly mechanistic or "cook book" approach for data usage was ruled out in exchange for a system that would be both flexible and comprehensive for adapting to a wide diversity of applications. It was also determined, at the onset, that NUCLARR would not provide the capability to construct fault trees or core melt frequencies. Other tools already exist that provide these functions, and it was felt that NUCLARR could better support the risk analyst by supplying the data inputs to these other products. The Integrated Reliability and Risk Analysis System (IRRAS), Systems Analysis and Risk Assessment System (SARA), and Models and Results Database (MRD-D) are three such products, developed under NRC sponsorship, that provide the capabilities for higher-order model development and analysis.[1-3] Recent development efforts at the Idaho National Engineering Laboratory (INEL) have focused on devising more effective ways to interface NUCLARR with IRRAS. Details of this capability are provided in sections of this document.

In summary, the present version of NUCLARR, as described in this manual, provides the experienced data requester (e.g., PRA analyst) with an important computer-based support capability for conducting risk analysis with a simple means of accessing human error probability (HEP) and hardware component failure data (HCFD).

The purpose of this three-part document is to provide the end user with a detailed description of the NUCLARR data management system, including instructions for accessing and retrieving specific data. To that end, an overview of the NUCLARR system is given in Part 1. Parts 2 and 3 of this document provide, respectively, a guide to operations (including examples) and a detailed system description that defines all attributes of the data being stored, describes the way in which these data are stored, and describes computations performed by the NUCLARR system.

2. HARDWARE/SOFTWARE OVERVIEW

Routine processing and data base management functions are performed by the system software and hardware. The minimum hardware needed for the NUCLARR system work station and the preferred configuration are shown in Table 1. IBM-PC or IBM-PC compatible equipment was selected because of its portability, industry-wide acceptance, and conformity to NRC standards. Data requesters will receive updates to their copies of the software and data files from the NUCLARR Data Clearinghouse. Later, if a need exists, direct on-line access from a central computer facility can be made available.

The software is written in the Modula-2 programming language with the aid of SAGE programming tools. SAGE is a reusable set of prepackaged subroutines and program modules developed in house at the INEL. The NUCLARR system configuration is shown in Figure 1. The software is menu-driven and supplemented with an ad hoc command structure. Color-keyed highlighted help forms are integrated into the menu hierarchy for easy reference as needed. Data retrieval and output functions are performed by the data requester (e.g., PRA analyst).

TABLE 1. MINIMUM AND PREFERRED COMPUTER SYSTEM

Minimum	Preferred
IBM PC:	IBM PC-AT:
640 kB of memory	Maximum allowable memory
Graphics card	Enhanced graphics card
Math 8087 co-processor card	Math 8087 co-processor card
Monochrome, 80 column monitor	Color monitor
20 MB[a] fixed disk	30 to 60 MB[a] of fixed disk
Floppy disk drive	Floppy disk drive
80-column line printer	Printer with IBM graphics font
DOS operating system (3.0, 3.1, 3.2, or 3.3)	DOS 3.2 operating system

a. Dependent on amount of data in the NUCLARR system.

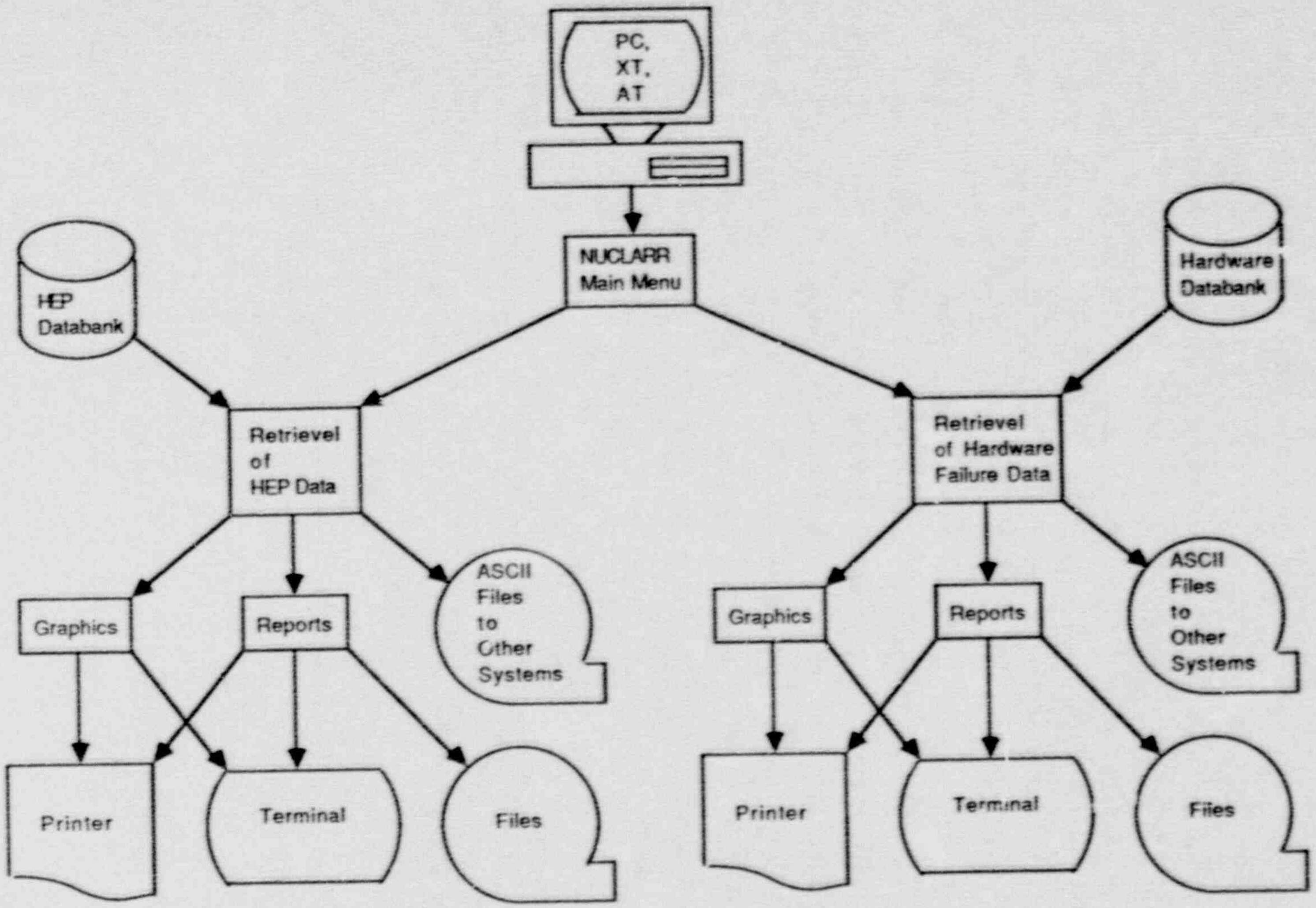

Figure 1. System configuration of the NUCLARR program.

3. SYSTEM DESCRIPTION FOR HUMAN ERROR PROBABILITY DATA

3.1 HEP Data Taxonomy and Data Structures

The HEP data are stored under a taxonomy that is structured in a series of 16 individual two-dimensional matrices. Each matrix consists of HEPs for human actions characterized by the affected hardware equipment, listed in the rows, and human action verbs, listed in the columns. The 16 matrices are categorized into a hierarchy according to the types of equipment that characterize the rows. The highest level is characterized by plant systems and contains 12 matrices identified by the different combinations of nuclear steam supply system (NSSS) vendor (four kinds) and personnel duty areas (three kinds). Level 2, which is defined by individual hardware components, contains three matrices characterized by duty area only, because at this level the NSSS distinction is not considered important. The single third-level matrix identifies specific displays, instrumentation, and controls. This distinction is viewed as being independent of both NSSS vendor and duty area.

The taxonomy and data structure are further described in the following sections.

3.1.1 Three-Level Hierarchy

As just stated, the HEP data collected for the NUCLARR system are organized and classified, for ease of access, in a three-level hierarchy, as follows:

- Level 1: The task associated with the HEP involves one or more sets of related actions that change or determine the state of a plant system or subsystem. The actions are classified by duty areas that summarize the objective of the human interaction with the system. Examples of Level 1 tasks are:

- Control room operator (CRO) at a General Electric Company (GE) plant operates the Residual Heat Removal System
- Maintenance technician (MT) at a Westinghouse Electric Corporation (WEC) plant tests the Reactor Protection System.

o <u>Level 2</u>: The task involves one or more actions that change or determine the state of a plant component. The task describes the effects of the human actions on the component. Examples of Level 2 tasks are:

- MT repairs a circuit breaker
- Equipment operator (EO) opens a manual valve.

o <u>Level 3</u>: The task is a single action directed at a specific control, instrument, or display device used to operate or maintain equipment in the plant or to communicate with other plant personnel. The task elements describe the human action when interacting with the control or display device. Examples of Level 3 tasks are:

- Subject reads a meter
- Subject positions a J-handle switch.

The objectives for developing the classification scheme were to

o Classify data useful for HRA

o Simplify filing, storage, and retrieval of the data

o Enable data from different sources to be combined

o Keep track of the data collected.

Table 2 is a representation of the taxonomy developed for HEP data in the NUCLARR system. The taxonomy permits a hierarchical approach to the

TABLE 2. TAXONOMY SCHEME FOR ORGANIZING DATA IN THE NUCLARR SYSTEM

Level	Equipment Classification	Human Actions Performed By
1 (12 matrices)	NSSS vendor plant systems GE systems WEC systems CE systems B&W systems	Duty area CRO EO (AO) MT
2 (3 matrices)	Individual components (independent of vendor)	Duty area CRO EO (AO) MT
3 (1 matrix)	Displays/instruments/ controls (independent of vendor)	Subject (independent of duty area)

data so that the human reliability analyst, like the equipment reliability analyst, can choose the appropriate level of detail for the analysis. More specifically, the analyst can choose whether or not the analysis of errors associated with the standby diesel generator system should end at the subsystem level (such as lube oil), should extend to the individual component level (bearings, fuel injection pump) of the diesel generator, or should focus on the control, instrument, or display devices. The NUCLARR classification scheme or taxonomy presents choices to the human reliability analyst by combining equipment characteristics and human actions on three separate levels.

Under characteristics of the equipment that are associated with the HEPs, the system category (Level 1) has been divided according to the following four NSSS vendors:

- o GE
- o WEC
- o Combustion Engineering, Inc. (CE)
- o Babcock & Wilcox Company (B&W).

This differentiation was incorporated into the taxonomy because of the differences in system configuration and operation among NSSS vendors. These differences are substantial enough to preclude the broad-scale combining of human error data across similar systems for different NSSS vendors. Therefore, the data are separate in the NUCLARR system, allowing the analyst the flexibility of combining data appropriate to the specific application. Classification by NSSS vendor was not done at the component level (Level 2) or the displays/instruments/controls level (Level 3) because at these levels the differences among NSSS vendors do not significantly affect the interface between the equipment and the human action.

As shown in Table 2, Level 1 (under human actions) has been divided into

- CRO duty area
- EO duty area
- MT duty area.

This division was incorporated into the taxonomy structure because of the differences in responsibilities and functions of the three positions, as well as the differences in the primary workstations of each (for example, control room versus general plant areas). These differences are also significant at the component level (Level 2). However, at the displays/instruments/controls element level (Level 3), the human actions associated with the equipment characteristics are similar for the three duty areas, so no differentiation is made.

3.1.2 Matrix Form

The previous section described the hierarchical nature of the taxonomy and the individual categories within each level. The structure of the HEP portion of the NUCLARR system is a series of two-dimensional matrices combining the levels of the equipment characteristics category with the specific levels of the human actions category. Complete descriptions of equipment characteristics and human actions are located in Appendix A.

A total of 16 separate and distinct matrices are used. A complete listing of these matrices, categorized for each level, is shown in Tables 3 and 4. Equipment characteristics are listed by rows and human actions are listed by columns for each matrix. This row by column relationship is illustrated for the sample matrix shown in Figure 2.

3.1.3 Cell Organization and Layout

The intersection of an equipment characteristic and a human action on a matrix is a cell. An example of a cell, selected from Level 3, is shown in Figure 3. Data pertaining to a specific type of equipment [push-button (other)] and a specific human action (select) are stored in the NUCLARR system computer that corresponds to the cell page number at the intersection of the equipment characteristic and human action [i.e., push-button (other)/select].

In sections below, the cell types, page numbering, and validity indicators are described.

3.1.3.1 Cell Type. Within each of the three levels, there are three different types of cells: basic equipment cells, general equipment classification cells, and functional group summary cells. This distinction depends on the equipment associated with each cell. In Figure 2, push-button (illuminated legend)/select is a basic equipment cell, two-position switches/select is a general equipment classification cell, and summary of two-position switches/select is a functional group summary cell. The differentiation among the types of cells is:

- o Data pertaining to a specific type of equipment are stored in a basic equipment cell. For example, data on errors from actions related to single push-buttons with illuminated legends are stored in the basic equipment cells corresponding to push-button (illuminated legend). This type of cell also applies for cases where the specific type of equipment is known but not listed; here, the row description for a basic equipment cell includes other (as in Figure 3).

TABLE 3. LIST OF MATRICES BY LEVEL

Level 1 Matrices

Matrix 1 - General Electric Systems/Control Room Operator Duty

Matrix 2 - General Electric Systems/Equipment Operator Duty

Matrix 3 - General Electric Systems/Maintenance Technician Duty

Matrix 4 - Westinghouse Systems/Control Room Operator Duty

Matrix 5 - Westinghouse Systems/Equipment Operator Duty

Matrix 6 - Westinghouse Systems/Maintenance Technician Duty

Matrix 7 - Combustion Engineering Systems/Control Room Operator Duty

Matrix 8 - Combustion Engineering Systems/Equipment Operator Duty

Matrix 9 - Combustion Engineering Systems/Maintenance Technician Duty

Matrix 10 - Babcock & Wilcox Systems/Control Room Operator Duty

Matrix 11 - Babcock & Wilcox Systems/Equipment Operator Duty

Matrix 12 - Babcock & Wilcox Systems/Maintenance Technician Duty

Level 2 Matrices

Matrix 13 - Components/Control Room Operator Tasks

Matrix 14 - Components/Equipment Operator Tasks

Matrix 15 - Components/Maintenance Technician Tasks

Level 3 Matrix

Matrix 16 - Displays/Instruments/Controls/Task Elements

TABLE 4. NUCLARR HUMAN ERROR PROBABILITY MATRICES

		Matrix Column (Action Verbs)			
		Tasks, by Duty Area			
Taxonomy Level	Matrix Row (Equipment)	Control Room Operator	Equipment Operator	Maintenance Technician	General Task Elements
1	GE systems	Matrix 1	Matrix 2	Matrix 3	--
	WEC systems	Matrix 4	Matrix 5	Matrix 6	--
	CE systems	Matrix 7	Matrix 8	Matrix 9	--
	BW systems	Matrix 10	Matrix 11	Matrix 12	--
2	Components	Matrix 13	Matrix 14	Matrix 15	--
3	Display/ instrument/ controls	--	--	--	Matrix 16

Matrix Summary Report

Matrix : 16

Taxonomy Level : 3

Displays/Instr/Controls

Subject

KEY
■ = Invalid, Illogical Cell
▒ = Invalid, Logical Cell
v = Valid Cell (may contain data)

ID	Equipment Description	POSITIONS 60	PUSHES 61	ADJUSTS 62	SELECTS 63	IDENTIFIES 64	VERIFIES 65	READS 66	MONITORS 67	REMEMBERS 68	DIAGNOSES 69	CALCULATES 70	RECEIVES 71	WRITES 72	MAINTAINS 73	CALIBRATES 74
030	SUMMARY OF TWO-POSITION SWITCHES	v	▒	▒	v	v	v	v	▒	v	v	■	■	■	v	■
031	Two-Position Switches	v	▒	▒	v	v	v	v	▒	v	v	■	■	■	v	■
032	Push-Button (Illuminated Legend)	v	▒	▒	v	v	v	v	▒	v	v	■	■	■	v	■
033	Push-Button (Other)	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
034	Toggle Switch/Two-Position	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
035	Knob	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
036	Rocker	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
037	Keylock	v	▒	▒	v	v	v	■	▒	v	v	■	■	■	v	■
038	Multifunction Push-Button Matrix	v	▒	▒	v	v	v	v	▒	v	v	■	■	■	v	■
050	SUMMARY OF MULTIPOSITION SELECTORS	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
051	Miltiposition Selectors	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
052	J-Handle Switch	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
053	Rotary Switch	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
054	Toggle Switch	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■
055	Stepping Push-Button	v	▒	▒	v	v	v	▒	▒	v	v	■	■	■	v	■

Figure 2. Sample matrix showing equipment characteristic and human action cell selected at intersection of push button (other) and selects.

```
Taxonomy Level: 3
Matrix: 16                 ┌──────────────────────────────┐
                           │  B u f f e r   V i e w i n g │   Page Number: 1603363
                           └──── from Descriptive Search ─┘
Job Title: Personnel
Human Action Verb: SELECTS
Equipment Class: Push-Button (Other)
NSSS Vendor/Equipment Level: Displays/Instr/Controls
─────────────────────────────────────────────────────────────────────────────
 1. Personnel              SELECTS
    the Push-Button (Other)
    operator improperly uses (selects) pushbuttons
    given:
    size<1/2", single row or col; 1-5 pushbuttons; detent; single,clear,
    concise positioning; no info on event location,or sequence; pt=1.44sec
       COMMISSION DATA  RECOVERY NOT CONSIDERED
*   1) Document:   1-82  Pg. A-17            Reference :   1-62  Page:
     + Mean: .0013932    Median HEP  : .0005230 Stress      :U      Feedback:U
     + E   :       .1    Error Factor: 10       Experience  :U      Staffing:U
     + N   :    191.2    Plant Code  :ALLP      Supervision:U       Tagging :U
     + UCB : .0052300    Perform Time:00:00:02  Procedure   :U      Training:U
     + LCB : .0000523    Time Avail. :--:--:--  Origin:Laboratory

* = Used in HEP Calculations, + = NUCLARR calculated    <Tab> & <Esc> field Help
 [ ] COMMAND:  Exit Next Previous  Show aggregated HEPs   Unselect  ? hotline #
```

Figure 3. Contents of a typical HEP data cell.

- The general equipment classification cell contains data that are reported on general equipment types. For example, data may be reported on two-position switches in general, without specifying whether it is a push-button switch or a rocker switch. Only data describing the equipment characteristics in general terms are stored in general equipment classification cells.

- The functional group summary cell contains data that have been combined from the basic equipment cells and from the general equipment classification cells. The functional group summary cell contains data that are recommended as the best overall data to use for a specific functional group.

3.1.3.2 Cell Page Numbering System. HEP data, confidence bounds, and supporting information [e.g., task statements, performance shaping factors (PSFs), and source data] are displayed in each individual cell. Cells are organized in the data structure by taxonomy level, equipment characteristic, and human action. Each cell is identified by a unique cell page number. The number is composed of seven digits grouped into three categories (i.e., XXYYYZZ) where:

XX = matrix number (e.g., 01 through 16)

YYY = equipment characteristic identification number (e.g., 000 through 999). (The last digit of the three-digit number being zero signifies that the page contains information on the functional group summary cell.)

ZZ = human action identification number (e.g., 00 through 99)

- 00 through 09 designates Level 1 CRO duties
- 10 through 19 designates Level 1 EO duties
- 20 through 29 designates Level 1 MT duties
- 30 through 39 designates Level 2 CRO tasks
- 40 through 49 designates Level 2 EO tasks

- 50 through 59 designates Level 2 MT tasks
- 60 through 99 designates Level 3 task elements.

For example, cell page number 1603363 signifies

16	=	matrix 16
033	=	push-button (other) (equipment associated with HEP)
63	=	select (human action that was omitted or executed incorrectly).

Note that this number is displayed for the user's information only; the user does not have to enter it to retrieve data.

3.1.3.3 Cell Validity. Cells selected by the data requester are automatically checked for validity by the NUCLARR system. The following possibilities exist:

- o Invalid/Illogical Cell--The equipment characteristic/human action combination is illogical or the action cannot be performed with the equipment by the person in the job position listed (e.g., indicator light/adjust). For cells of this type, the requester is asked to make a different selection. This category is indicated by a darkened cell, as shown in Figure 2 and in Volume V: Data Manual.[4]

- o Invalid/Logical Cell--The equipment characteristic/human action combination is logical, but other human actions have been chosen to categorize behavior in tasks involving this equipment (e.g., test gauge/position). For an invalid/logical cell, the cell page number in the NUCLARR system where additional guidance on verb selection may be found is presented to the user. This category is indicated by a shaded cell, as shown in Figure 2 and in Volume V: Data Manual.[4]

- Valid/Logical Cell--The equipment characteristic/human action combination is valid/logical. These cells contain HEP data for the specific combinations selected (e.g., meter/read). The NUCLARR system automatically accepts cells from this category as suitable combinations (see Figure 2). In Volume V: Data Manual,[4] this category is indicated by a star if it contains data and a hyphen if it contains no data.

3.2 Cell Data Contents

3.2.1 HEP Cell Header

The header information, located at the top of the user's CRT screen, informs the user of his relative location within the taxonomy and matrix structure. The upper portion of the cell is dedicated to location and identifier information. In this space, the matrix number, page number, equipment classification, and human action verb are presented. The specific HEP taxonomy level, NSSS plant type identification (i.e., NSSS vendor, if applicable), and job classification (if applicable) are also shown. From the example cell shown in Figure 4, the user can determine that the cell displayed is from Matrix 10, page number 1009201, at the equipment and human action intersection for high pressure safety injection and operates. In addition, it can also be noted that the data are from HEP taxonomy Level 1 for a B&W plant and that the job classification is for a CRO.

3.2.2 Data Classification Scheme

3.2.2.1 Valid/Logical Cells. HEP data values are stored and displayed in each matrix cell by HEP failure mode and data type. The failure modes in the HEP side of the NUCLARR system refer to errors of omission or errors of commission. An omission error is defined either as a failure to perform the task or a step within a task or a failure to perform a task within a stated time period. A commission error occurs when a task is attempted but is not successfully accomplished for any reason.

```
Taxonomy Level: 1
Matrix: 10                   Buffer Viewing              Page Number: 1009201
                         ---- from Descriptive Search ----
Job Title: Control Room Operator
Human Action Verb: OPERATES
Equipment Class: High Pressure Safety Injection System
NSSS Vendor/Equipment Level: Babcock & Wilcox
--------------------------------------------------------------------------------
  1. Control Room Operator  OPERATES
     the High Pressure Safety Injection System
     operator fails to maintain HPI cooling (feed and bleed)
     given: maintain core cooling
     after loss of FW

        OMISSION DATA    RECOVERY CONSIDERED
 *   1) Document:   3-84  pg. 6-33 item 3        Reference :   1-83  Page:
      + Mean: .0266383    Median HEP  : .0100000 Stress      :4        Feedback:U
      + E   :       .1    Error Factor: 10       Experience :U         Staffing:U
      + N   :     10.0    Plant Code  :NEE3      Supervision:U         Tagging :U
      + UCB : .1000000    Perform Time:--:--:--  Procedure  :U         Training:U
      + LCB : .0010000    Time Avail. :--:--:--  Origin:Subjective

* = Used in HEP Calculations, + = NUCLARR calculated    <Tab> & <Esc> field Help
 [ ] COMMAND:  Exit Next Previous  Show aggregated HEPs   Unselect  ? hotline #
```

Figure 4. Example of HEP data cell illustrating location and identifier information.

In addition, for each failure mode, omission and commission, HEPs are further defined to the extent that recovery was considered or that recovery was not considered. These distinctions are called data types. Within the context of the NUCLARR system, recovery considered (RC) errors account for actions taken by personnel in the performance of the task to mitigate the error. That is, the HEP reflects the probability of the error occurring in spite of such actions. RC errors are often observed in situations where some type of corrective action was taken. This data type also includes cases where, even though recovery actions were attempted, it was never feasible to do so after the error was committed. Recovery not considered (RNC) errors are HEP estimates that have no documented or foreseen evidence that actions were taken to mitigate the consequences of the error. That is, the error simply happened with no attempt at recovery for operator or crew. In all cases, the consideration of recovery either does not change the HEP (as in the case where recovery is not feasible) or lowers it.

In summary, HEP data can be classified in one of four categories based on failure mode and data type:

- Commission data: RC HEP
- Commission data: RNC HEP
- Omission data: RC HEP
- Omission data: RNC HEP.

Data are also classified in the matrix cells by task statements. The task statement is a sentence describing the activity for which HEP data are provided. The format of the task statement varies slightly among the three levels of the taxonomy. The standard portion of the statement describes the nature of the error or undesired performance. Examples of typical task statements for each taxonomy level are shown below:

- Level 1 Task Statement: CRO operates the high-pressure safety injection system. Standard: failure to operate to maintain high pressure injection (HPI) cooling (feed and bleed). Conditions: after loss of feedwater. (This task is shown in Figure 4.)

- Level 2 Task Statement: CRO diagnoses the steam generator tube rupture. Standard: affected steam generator not identified. Conditions: initiated by radiation monitor alarm, Shift Technical Advisor and three operators in control room.

- Level 3 Task Statement: Subject monitors the legend lights. Standard: deviant light not detected. Conditions: hourly scan, only one deviant light, legend lights are white tiles with black lettering.

In order to ensure consistency and allow for systematic data categorization and retrieval, the task statement consists of a series of standardized terms or phrases using a standardized structure and format. The specific structure and format of the task statement for each taxonomy level are described in Appendix B.

3.2.2.2 Other Cells. Only those cells classified by the NUCLARR system as valid/logical (hyphen or star; having a valid/logical cell validity) may contain HEP data from data sources. Each invalid/logical (shaded) cell contains a listing of the valid human action associated with the equipment (i.e., matrix row) that was selected by the data requester. In addition, functional group summary cells, though valid/logical, contain only combined data from the basic equipment cells and the general equipment classification cells rather than data records specifically entered in the summary cells. When data are absent from an equipment cell, the data requesters, at their option, can refer to the functional group summary cell.

3.2.3 Source Data Level

Within each of the four categories in a valid/logical cell (i.e., HEP failure mode and data type combination), HEP data may be present. As explained above, the data are further classified by task statement, which is a specific verbal description of the action being attempted. For each defined task statement, one or more records of source data may be present.

Because of the difficulty in establishing equivalence, most task statements in the NUCLARR system currently have only one source statement. The source data are the lowest, most detailed area of NUCLARR's HEP data. At this level, four general groups of information are provided for each data point: the HEP itself and associated numerical data, data origin information, PSFs, and time factors. Each of these is discussed in the following subsections.

3.2.3.1 HEP Data Points. The numerical HEP data information provided for each source data record is defined below.

- Mean HEP--the average probability estimate.

- Median HEP--The 50th percentile value of the HEP data distribution.

- UCB (Upper Confidence Bound)--The statistically determined upper limit of a 90% confidence interval for an HEP.

- LCB (Lower Confidence Bound)--The statistically determined lower limit of a 90% confidence interval for an HEP.

- Err Factor (Error Factor)--A value used to assess the characteristics of the data distribution, defined as the UCB divided by the median HEP.

- E (Error Count)--The number of errors made in performing a task as reported in the data source or computed by multiplying the HEP by an assumed number of opportunities.

- N (Error Opportunities)--The number of occurrences of the task in which there is an opportunity for an error.

- TI (Tolerance Interval)--Parameter to be considered in a future version of the NUCLARR system. Note that this parameter differs from a confidence interval. Confidence intervals are calculated from the data that have approximately at least a 90% probability of containing the true mean HEP. Tolerance limits are predictive limits within which one can be highly confident a certain percentage of the individuals of a statistical population will lie. When more data are available, tolerance intervals will be achievable.

3.2.3.2 Data Origin Information. Fields describing the source for each HEP data point and how it was collected are described below.

- Document Identification Number--This number consists of three digits followed by the last two digits of the calendar year in which the data were collected or published (XXX-YR). Each source of data is assigned a number when it enters the system.

- Origin of Source Data--Source documents, from which the HEPs were obtained, are stored and maintained in the NUCLARR system document file. This feature gives the data requester immediate access to the title, authors, publisher, and other identifying information for the document from which the HEP values were derived. The document identification number from the cell pages is cross referenced with the citations from the document file. For each HEP from each source, the data origin is classified as one of the following:

  - Field data
  - Training simulator data
  - Laboratory data
  - Consensus expert judgment
  - Subjective data
  - Simulation modeling data
  - Analytic data.

- Data Item--This is the page, table, and line number of the data source containing the information that was used to obtain the HEP.

- Reference Citation--This field is used for HEPs identified in the data source as being referenced from another document. This field describes the original source of the HEP as indicated in the source being reviewed. For example, the document with identification number 1-82 is a review of human reliability data banks and references data published in 1962. Document identification number 1-62 describes this secondary source of information. For data from Reference 1-82 that were attributed to Reference 1-62, 001-62 will be in the reference citation field.

- Plant Code--A four-character alphanumeric code that identifies the facility from which the source data were derived.

3.2.3.3 Performance Shaping Factors. PSFs are factors which affect human performance. They may be either aspects of the person, such as experience, training, general resistance to fatigue, or stress, or of the immediate work environment, such as conditions of heat, humidity, or lighting, or the type and quality of procedures available to aid the person in the proper execution of his task. Although there are many PSFs available for analysis, only a limited number have been selected for inclusion in the NUCLARR system. Any other PSFs identified in the original source of data are included as conditions in the task statement. The PSFs relating to the quality of human factors engineering design are included in this manner.

For each data source within a cell, eight PSFs have been ranked on ordinal scales. This ranking scheme allows NUCLARR system users to evaluate cell data relative to any unique characteristics of their own analysis problems. The eight PSFs that are scaled in the NUCLARR system were selected because they are applicable across a broad range of tasks and because they were identified and cited as desirable during an in-depth user survey conducted in 1986.

Definitions of the eight PSFs and the scales used to rank them are discussed below. Note that, in each case, the stated PSF must apply to all the error opportunities as well as the error events.

Stress. The extent to which stress either hindered or helped performance. Personnel may be stressed as a function of fatigue, workload demand, or just by virtue of responding to an emergency. The valid stress levels include:

U - Insufficient information available to evaluate this PSF.

1 - Optimum stress: The normal or facilitative level of stress. An optimum level of stress is associated with an optimum task load and is characterized by an active interaction between the person and the environment at a pace that can be managed comfortably.

2 - Very low stress: Insufficient arousal to maintain alertness. A very low stress level is associated with a very low task load and is characterized by routine, passive activities in which a lack of sufficient stimulation can cause boredom or inattention.

3 - Moderately high stress: A moderately high stress level is associated with a heavy task load and is characterized by a requirement to perform at a faster pace than a person is capable of, or by a large number of stimuli competing for attention. This stress level is assumed for situations in which special protective clothing must be worn, for single transients involving shutdown of the turbine or reactor, or for critical tasks performed under time constraints.

4 - Extremely high stress: An extremely high level of stress is characterized by the perception of an immediate threat to one's physical well-being, self-esteem, or professional status. This level of stress is infrequently encountered, and this rating should be used only in connection with catastrophic events such as a large break loss-of-coolant accident (LOCA), multiple transients, or situations where significant hazard to the individuals involved is clearly present and known to them (e.g., fires or very high radiation levels).

Experience. The total time an individual has performed in his current job classification in a commercial nuclear power plant. Related experience in other types of plants (e.g., Navy, fossil) or in other job classifications is generally not included. The valid experience levels include:

U - Insufficient information available to evaluate this PSF

N - No commercial nuclear power plant experience

1 - Ten or more years job experience

2 - More than five years job experience

3 - More than six months job experience

4 - Less than six months job experience.

Supervision. The degree of direction and managerial responsibility taken by senior personnel during performance of a task. The amount of supervision to oversee and monitor task activities can influence task performance. The range of supervision can range from formal approval and verification to ensure the successful completion of a task within a given standard to no supervision at all. The scaled values for this PSF are:

U - Insufficient information available to evaluate this PSF.

1 - Senior supervisor provides approval to initiate the task and verifies whether or not it has been successfully accomplished within a given standard of performance.

2 - Other operator (not a supervisory position) formally monitors and verifies satisfactory completion of task (e.g., worker sign off, checklist). Verification is explicitly stated in a procedure and/or standards and practices documents.

3 - Other operator (not a supervisory position) informally monitors and verifies satisfactory completion of task (e.g., verbal notification, ad hoc protocol). Verification not specified in a procedure or standards and practices document.

4 - No supervision provided; operator performs task independent of any direct verification from other personnel.

Procedure. In the performance of a task, the type and availability of procedures used will often influence its final outcome. In assessing operator error, it is often desirable to know if a procedure was used at all and, if so, what type. Secondly, if a procedure was used, it is of interest to understand how it was applied toward accomplishing the task. For example, was a procedure used or were parts of the procedure handed out to crew members. Categories for procedure use are a primary factor when measuring task performance. The valid categories include:

U - Insufficient information available to evaluate this PSF.

1 - A written procedure with step checkoffs was used; checkoff was performed by a second person observing the work.

2 - A written procedure with step checkoffs was used; checkoff was performed by the person performing the work.

3 - A written procedure was used.

4 - Oral instructions directed actions.

5 - A written procedure was available but not used. Contents were recalled from memory.

6 - No procedures or instructions were available.

Training. The amount of relevant training provided can significantly affect the outcome of task performance. Training adequacy can be satisfied through one or more of the following modes: on-the-job training (OJT); simulation/mockup; drill; and/or classroom. The measure of training is typically selected from the lowest level of training adequacy represented for which the HEP occurred. The valid training adequacy levels include:

U - Insufficient information available to evaluate this PSF.

1 - Training very adequate--formal training provided as well as maintaining a high level of state of current practice or skill for successful performance of the task.

2 - Training adequate but could be improved--additional instruction and/or practice (e.g., classroom, OJT, drill, etc.) would be beneficial.

3 - Training somewhat adequate but sorely lacking in specific areas--significant improvement to upgrade the adequacy of training is needed.

4 - Training NOT adequate--training is either not provided at all or is totally inappropriate (or irrelevant) for performing the task.

Feedback. The knowledge of results that a person receives about the status or adequacy of his inputs. In general, feedback refers to how the operator knows the appropriate control action has been taken, or how he is informed regarding the nature of general plant conditions. Feedback provides a person with objective information on what should be done, whether it has been performed correctly, and with detailed information on when and how a failure occurred. The level of systems feedback a person would experience in the performance of a task can range from superior to inadequate, as described below.

U - Insufficient information available to evaluate this PSF.

1 - Feedback superior: Extremely satisfactory, well above average--significantly helped performance.

2 - Feedback more than satisfactory: Better than average--helped performance.

3 - Feedback satisfactory: About average--did not help or hinder performance.

4 - Feedback somewhat satisfactory: Below average--hindered performance.

5 - Feedback NOT adequate: Well below average--significantly hindered performance.

Staffing. The number of qualified personnel who were directly involved in the performance of the task. Involvement implies actual assistance the primary crew member receives from other individuals in the operating area. If the staffing needs (or manning parameters) are inadequate, the potential for error is increased because of higher stress and workload demands placed on the primary operator. Staffing levels are generally explicitly measured as the total number of crew members participating in the task. Valid categories include:

U - Insufficient information available to evaluate this PSF.

1 - One person participated in the performance of the task.

2 - Two persons participated in the performance of the task.

3 - Three persons participated in the performance of the task.

4 - Four persons participated in the performance of the task.

5 - Five persons participated in the performance of the task.

6 - Six (or more) persons participated in the performance of the task.

Tagging. This term encompasses the total tagging system and includes all administrative controls that ensure (a) awareness of any valves or other items of equipment that are in a normal state or a protected normal state and (b) prompt restoration of this equipment to the normal or unprotected state after completion of review or maintenance operations. Thus, a tagging system includes the use of (a) tags; (b) chains, locks, and keys; and (c) logs, suspense forms, and other techniques that provide a record of the above. The adequacy of the tagging system can vary significantly in its overall sophistication and completeness--from a formal system, consisting of a high degree of administrative controls, to no tagging system at all, as described below.

N - Tagging system is not applicable to this task.

U - Tagging system is available, but information is insufficient to determine the level of tagging.

1 - A specific number of tags are used for each job. Each tag is uniquely numbered or otherwise identified. A record is kept of each tag.

2 - Tags are not accounted for individually. The operator may take an unspecified number and use accordingly. The recordkeeping does not provide a thorough checking for errors of omission or selection.

3 - Tags are used, but recordkeeping is inadequate to provide the shift supervisor with adequate knowledge of every item or equipment that should be restored. Also in this category, keys are available to users without logging requirements.

4 - No tags. A tagging system is applicable to the task, but no tags are used.

3.2.3.4 Time Factors. Time values may also be entered for each data point. The two values are:

Time Available--Refers to the total time available for successful completion of the task. This time is often dictated by plant conditions and system response to phenomenological factors. For example, the majority of operator actions can only be successfully executed when the initiating and terminating event can be completed within the time interval defined by the procedural and system requirements. An action taken beyond this time interval may be inappropriate.

Performance Time--This term refers to the average time spent by the operator or crew in performing the task.

These time factors may apply to tasks in which errors occur, but they are of primary importance in describing human performance data. That is, the probability of the omission, failure to complete a task in a specified time period, depends heavily on the time period specified. This is captured by the time available field. The average performance time field provides background information; the HEP would be expected to be high whenever it approaches or exceeds the value entered for time available.

3.3 Data Treatment

Section 3.3.1 describes the calculations that are made for each HEP source data point. In addition, aggregations of HEP data within the NUCLARR system are possible. Particular data combinations are discussed in Section 3.3.2, and Section 3.3.3 presents an overview of the algorithms used for aggregating the data and estimating bounds.

3.3.1 HEP Source Data Calculations

In some instances, the HEP data point information received for inclusion into the NUCLARR system will consist of a report of the number of errors (E) and number of opportunities for error (N). In these cases, confidence bounds are calculated by the NUCLARR system. In other instances, an estimate of the HEP and confidence bounds will be provided by the data source and an estimated number of errors and opportunities for error that would give rise to these values must be computed. In addition, the NUCLARR system will calculate a mean HEP from a median HEP and confidence bounds if the mean HEP is not provided. The NUCLARR system will typically perform calculations of this type to provide for data values missing from the original data source. A symbolic coding scheme is employed to indicate the difference between those data values that were calculated by the NUCLARR system and those entered from the original raw data source. An overview of the equations used by the NUCLARR system for performing these calculations is shown in Figure 5. A more complete description of the algorithms used to accomplish the calculations is presented in Appendix C.

3.3.2 Data Combinations

A primary function of the Human and Hardware Reliability Analysis Group (HHRAG) is to take sources of data received from the data suppliers, extract source HEPs and the associated confidence bounds (when available), and enter these values into the NUCLARR system. These raw data values are classified and stored in a form suitable for retrieval by potential data requesters. However, there may be situations during the course of a PRA where the data requester may have a need to access HEP data that have been combined from the original source HEPs. For example, a PRA practitioner may want to obtain a single aggregated HEP for <u>all</u> source HEPs that are available for a single equipment characteristic/ human action combination (e.g., a cell HEP). The NUCLARR system automatically combines HEPs and presents this information to the data requester.

Calculational Summary: Single HEP Data Point

a) Given a number of errors E and opportunities N,

$HEP = E/N = median$ (1)

$UCB = (E+1) F_U / [N-E + (E+1) F_U]$ (2a)

$LCB = E F_L / (N-E+1 + E F_L)$ for small N, or (3a)

$UCB = x^2(2E+2, 0.95) / (2N)$ and (2b)

$LCB = x^2(2E, 0.05) / (2N)$ (for large N). (3b)

EF = error factor = UCB/HEP (4)

$Mean = HEP * exp([ln (EF/1.645]^2 / 2])$ (5)

b) Given HEP and UCB, use (4) for EF; then solve the following for E:

$EF = x^2(2E+2, 0.95) / (2E)$.

Find N from HEP and E [Equation (1)].

In these equations,

$F_U = F(2E+2, 2N-2E, 0.95)$

$F_L = F(2E, 2N-2E+2, 0.05)$,

and F(df1,df2,p) and x^2(df,p) are percentiles of, respectively, F and chi-square distributions.

Figure 5. Summary of calculations for a single HEP data point.

Recall that at the highest level of HEP data cells are the functional group summary HEPs; these are based on related task statement HEPs. For example, a functional group summary HEP would be provided for open/close valves based on task statement HEPs involving opening or closing numerous types of valves in numerous situations. A cell HEP would provide a probability for errors in the open/close gate valve action across numerous situations. A task statement HEP would provide a probability for errors in opening or closing a gate valve in basically similar situations. Finally, source statement HEPs would provide the probabilities presented in the original data source that were used to develop the task statement HEP.

In summary, the types of data combinations performed by the NUCLARR system for HEPs are:

- Task Statement HEP--an estimate of the HEP with RC or with RNC for commission or omission errors in performing a task described by a task statement.

- Cell HEP--an estimate of the HEP with RC or with RNC for commission or omission errors in performing all tasks identified in a cell.

- Functional Group Summary HEP--an estimate of the HEP with RC or with RNC for commission or omission errors in performing all tasks with a common human action verb on any equipment in a functional group.

- Ad Hoc HEP--an estimate of the average HEP for all source data records identified by the user in an ad hoc search.

Note that, for the ad hoc aggregations, the user may specify values for virtually any coded field defined for the HEP data. Although this does not include information coded specifically at the task statement level of the data base, it includes all the HEP data origin information as well as the PSFs and time factors. However, in forming ad hoc aggregations, the user should be aware of the fact that, because of the sparsity of HEP data, specific HEP data points are entered wherever they would be applicable within the NUCLARR data taxonomy. That is, they are entered in as many matrices as they might be applicable to and in as many rows of each matrix as apply. This makes data access easier, because a user who wants data for errors in operating a particular WEC system, for example, does not have to access the corresponding cells in the matrices for other NSSS vendors to see if any HEPs there might be applicable. The user should avoid forming ad hoc aggregations that are likely to reflect such multiple entries of the same data points.

A conceptual overview of the data combinations other than ad hoc aggregation is illustrated in Figure 6. All calculations are automatically performed by the NUCLARR system. In the figure, source statement HEPs judged to be statistically consistent are shown being combined for a task statement HEP. Task statement HEPs are also combined for a basic equipment cell in the NUCLARR system and for a functional group summary cell. Examples of data aggregations for task, cell, and functional group summary HEPs are shown in Figure 7. In the functional group summary field, median values rather than means are shown. In all cases, data on commission errors are not combined with data on omission errors (failure mode), and data for errors with RC are not combined with data with RNC (data type).

3.3.3 Aggregation Methods

Two sets of aggregation methods are used for the NUCLARR system's HEP aggregations. The first set of methods works directly with individual HEP data records and seeks homogeneous data. It outputs an average HEP and confidence limits based on pooling such data and treating them as though they came from one large experiment or observation rather than a series of individual observations of errors and opportunities for error. This method is applied both to compute task statement HEPs and HEPs from ad hoc aggregations.

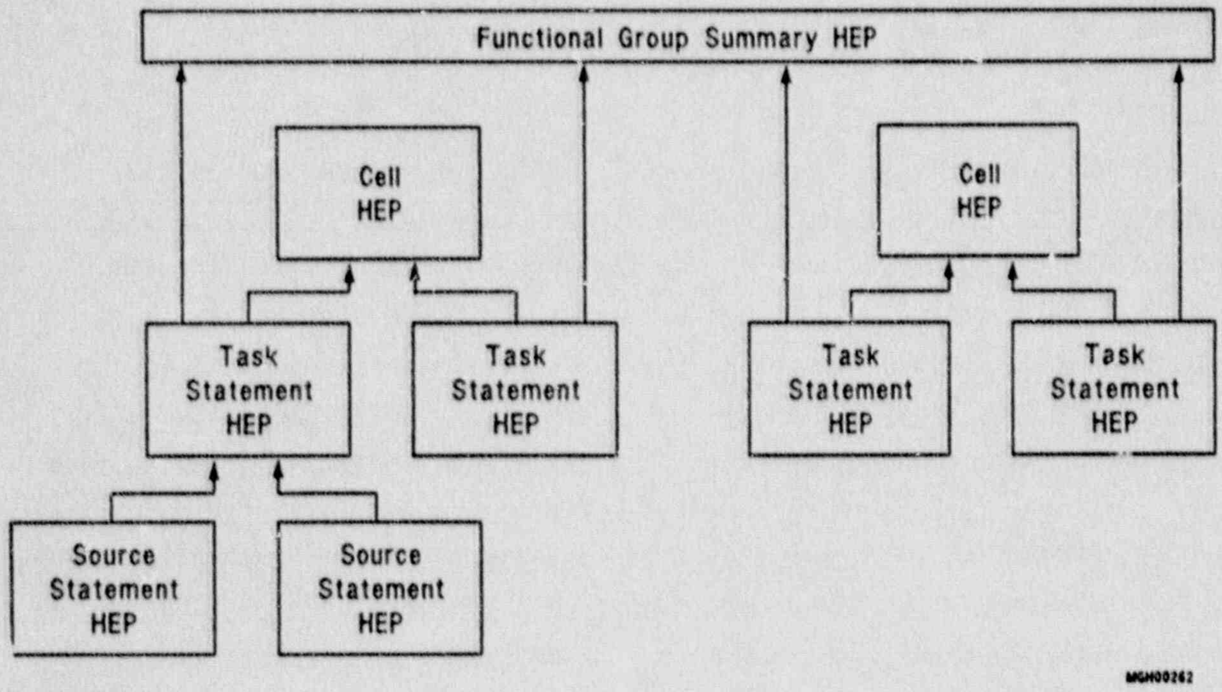

Figure 6. Overview of data combinations.

```
Taxonomy Level: 3
Matrix: 16                 Buffer Viewing             Page Number: 1600569
                       from Descriptive Search
Job Title: Personnel
Human Action Verb: DIAGNOSES
Equipment Class: Annunciator
NSSS Vendor/Equipment Level: Displays/Instr/Controls
       Aggregated HEPs                 Functional
 1.          Task          Cell          Group
     Mean  :  .5464231     .5464231      .5464231
     Median:  .5000000     .5000000      .5000000   ng time allot
     UCB   : 1.0000000     .8162635      .8162635   g time allot
     LCB   :  .2500000     .3062737      .3062737
     EF    :         2            2             2
     OMISSION DATA    RECOVERY CONSIDERED
   1) Document:   1-83   pg. 20-17, item 1     Reference : ------  Page:
    + Mean:1.0000000     Median HEP  :1.0000000 Stress      :3      Feedback:U
    + E    :    20.0     Error Factor:  1       Experience :U       Staffing:3
    + N    :    20.0     Plant Code  :ALLP      Supervision:U       Tagging :U
    + UCB  :1.0000000    Perform Time:--:--:--  Procedure  :U       Training:U
    + LCB  :1.0000000    Time Avail. :00:01:00  Origin:Simulation Modeling

* = Used in HEP Calculations, + = NUCLARR calculated    <Tab> & <Esc> field Help
[ ] COMMAND:  Exit Next Previous  Clear aggregated HEPs  Unselect  ? hotline #
```

Figure 7. Task statement, cell, and functional group summary HEPs (highlighted by box).

The second aggregation method is used to compute cell and functional group summary HEPs. It works with the aggregated results from the first method, i.e., the task statement aggregations. It produces an average HEP and limits that reflect the distribution of the average of the logarithms of the task statement HEPs being combined.

A brief summary of each HEP data combination process is presented below. A more complete description of the various algorithms for accomplishing the data aggregations for task and ad hoc combinations and for cell and functional group summary HEPs is presented in Appendices D and E.

3.3.3.1 Ad Hoc Task Statement Aggregations. The HEPs from each source are first compared for statistical consistency using a variance test for homogeneity based on the binomial distribution. The null hypothesis for this test is that the error rate reported for each source is distributed as a binomial process with a proportion equal to the average of the HEPs. The test uses the chi-square statistic to compare the variance of the reported HEPs to the variance that the HEPs would have if they were calculated from independent samples from the same binomial distribution. If the null hypothesis cannot be rejected at a 0.1 significance level, the data are pooled and the HEP is computed as the total number of errors divided by the total number of opportunities for all the source data. If the null hypothesis is rejected, the data source having the largest difference from the average HEP when multiplied by the corresponding number of opportunities is deleted from the test, and the test is repeated to compare the remaining source data. If the null hypothesis cannot be rejected in the second test, the data are combined and the HEP is computed using the remaining data. Otherwise, this process is repeated until a set of HEPs for which the null hypothesis is not rejected is found. If there are only two remaining source data points, a correction for continuity is included in the statistical test. If the null hypothesis of homogeneity is still rejected, the two data points are not combined by the NUCLARR system. The HHRAG then provides expert judgment to choose a point and its associated bounds to describe the task HEP. (For ad hoc aggregations, the user is given the opportunity to make this selection.)

If the data have been found to be statistically consistent and their HEPs have been combined, the UCBs and LCBs for the resulting HEP are calculated using a 90% confidence interval based on the pooled data and the binomial distribution. The HEP and corresponding confidence bounds for the combined data are then automatically displayed in the appropriate fields. The individual source HEPs are also listed to give the data requester the option of using either the original source data or the combined ad hoc or task statement data.

An overview of the equations used by the NUCLARR system for performing these calculations is shown in Figure 8.

3.3.3.2 Cell/Functional Group Summary Cell Aggregations. At the cell level, only the equipment category and basic human action associated with the human error are defined; thus, task statement data within a cell are expected to reflect a variety of conditions. Therefore, no tests are made for homogeneity of data for these aggregations. Instead, the HEP and associated UCB for each task statement in a cell or series of functionally related cells are used to characterize a lognormal distribution. Based on these distributions, the distribution of the geometric average of the HEPs is derived. The NUCLARR system then computes the mean, median, upper 95th percentile, and error factor of this distribution.

A summary overview of the equations used by the NUCLARR system for aggregating the cell and functional group summary HEPs is shown in Figure 9.

3.3.3.3 NUCLARR/IRRAS Interface (HEP). Two types of data may be transferred to an ASCII file formatted for use by MAR-D: (1) Data records located and aggregated, referenced in the NUCLARR search buffer (if only a single record is referenced in the search buffer, it is not necessary to use the aggregation processing before transferring that record's data); and (2) any data input specifically for such a transfer (with special provision made for input of SLIM-MAUD results).

Combining Source Data Points (Task Statement and Ad Hoc)

Let $E_T = \Sigma E_i$, $N_T = \Sigma N_i$, $p_i = E_i/N_i$, $p_T = E_T/N_T$, and $q_T = 1 - p_T$.

Homogeneity Test:

$$x^2 = \Sigma x_i^2 = \Sigma (N_i p_i - N_i p_T)^2 / (N_i p_T q_T)$$

Compared with $x^2(k-1)$ distribution. If not homogeneous, discard entry with largest x_i^2 and repeat. With just two entries, use a correction for continuity.

Combine Homogeneous Data:

Use Equations (1) - (5) in Figure 5 with $E = E_T$, $N = N_T$.

Figure 8. Summary of calculations for combining HEP source data points.

Combining Task Statements (Cell)

Let p_i = HEP_i, U_i = UCB_i, L_i = LCB_i. Suppose a total of n tasks are being combined.

$$HEP = \exp(\Sigma \ln p_i/N)$$

$$EF = \exp\{[\Sigma(\ln (U_i/L_i))^2/N]^{1/2}/2\} \text{ or}$$

$$= \exp[\Sigma(\ln (EF_i))^2/N]^{1/2}$$

$$UCB = HEP*EF$$

$$LCB = HEP/EF$$

$$Mean = HEP * \exp\{[\ln(EF/1.645)]^2/2]\}$$

These terms describe the distribution of the geometric average of the task statement HEPs.

Combining Cells (Functional Group Summary Cells)

Use the same method as for combining task statements for cells.

Figure 9. Summary of calculations for combining data for HEP cell probabilities.

Following data search and aggregation, two types of values may be entered for transfer to MAR-D: uncertainty correlation class and specification of transfer to an initiating event. If the user designates Success Likelihood Index Methodology via Multi-Attribute Utility Decomposition (SLIM-MAUD) processing, the system requires input of a median and either an error factor or upper and lower bounds. The option to input data from any other generation method necessitates input of a mean, error factor, and generation methodology description. The following equations are used in the transfer process:

t95 = 1.645, 95th percentile of standard normal distribution
Error Factor = upper bound / median
sigma = [ln (error factor)] / t95
Mean = median (Exp [(sigma) (sigma) / 2.0])

Aggregation of located records generates a median and upper and lower bounds. From these, the error factor and mean are computed for transfer to the IRRAS compatible ASCII file in MAR-D format. If a single record is located and not aggregated, its median and upper bound are used for the needed calculations.

If the SLIM-MAUD input method is used, the input median is used for these calculations. If an error factor is input, it is used; if bounds are input, the upper bound is used to compute an error factor.

4. SYSTEM DESCRIPTION FOR HARDWARE COMPONENT FAILURE DATA

4.1 HCFD Taxonomy and Data Structures

4.1.1 HCFD Hierarchy

HCFD are hierarchically configured within the NUCLARR system. However, this hierarchy differs from the HEP hierarchy because it reflects the amount of detail supplied in a data source for the component failure events rather than the types of events themselves. All the events concern component failures; the data base does not describe train or system-level failure events because each system differs from plant to plant and such differences are explicitly modeled in risk assessment studies. Similarly, there is no HCFD analogue to the HEP hierarchy distinction between errors related to components and those related to controls, instruments, and displays. All the components are treated equally. The HCFD structure selected for use in this implementation merely serves to organize the data and facilitate its access.

The taxonomy is hierarchically configured as shown below:

- o Level 1: Category of component (i.e., mechanical vs. electrical)
- o Level 2: Type of component
- o Level 3: Design of component
- o Level 4: Failure mode
- o Level 5: Normal state
- o Level 6: Applications.

Figure 10 provides an overview of these levels; each is discussed in the sections below. Note that in order to define a component failure event, Levels 2 and 4 information is the minimum required.

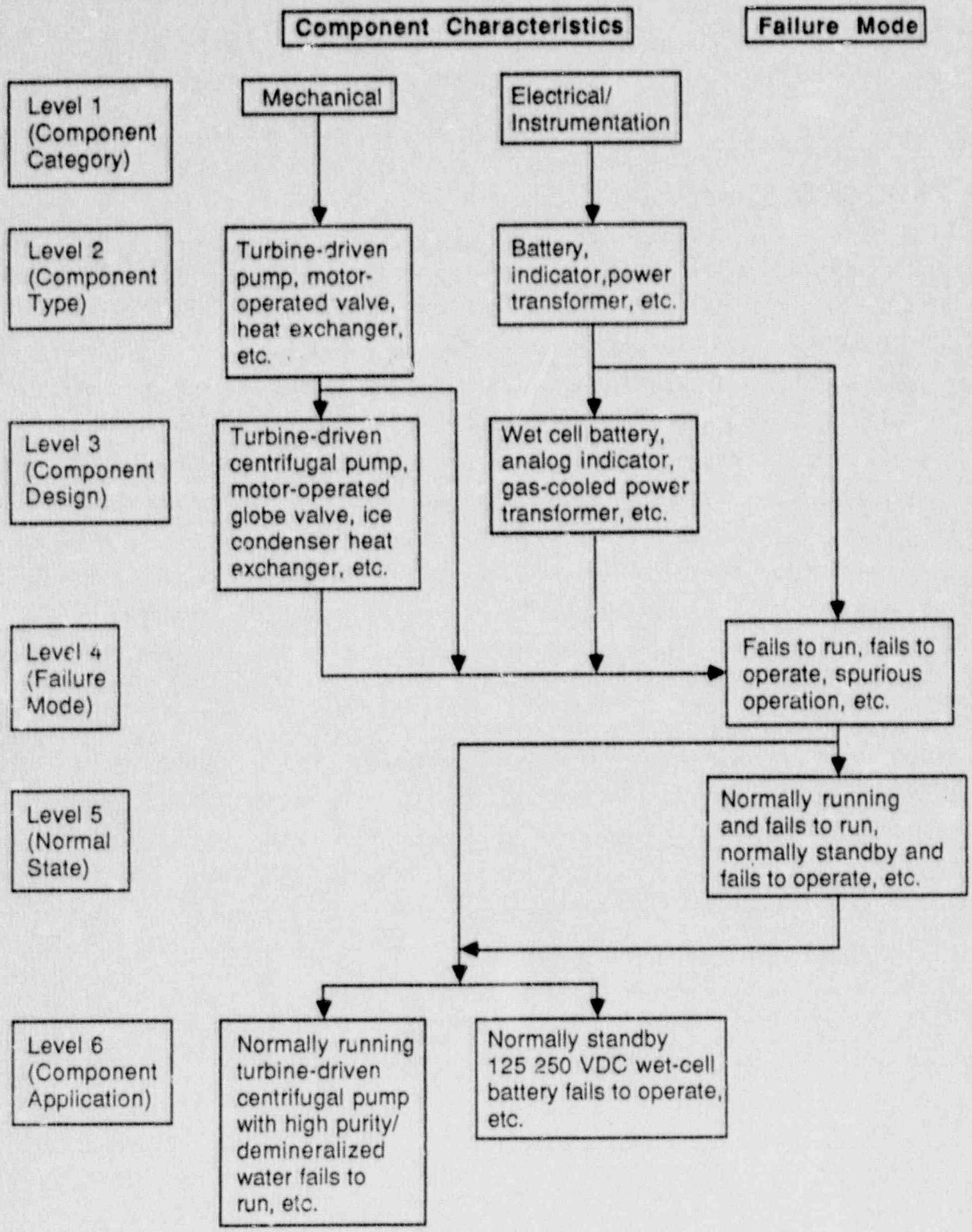

Figure 10. Taxonomy scheme for organizing component failure data in the NUCLARR system. (Note that data from Levels 1, 2, and 4 must be presented for each data point.)

In combining HCFD from various sources (discussed later under the topic of aggregation), several of the level attributes are used in defining basic events. In particular, component (Level 2) and failure mode (Level 4) are important. Design and normal state also may enter into event characterizations. The use of Level 2 implies Level 1, as explained further below.

Each component failure data record in the NUCLARR system also contains additional fields that describe the data origin, a data record log, and the failure data itself. These are discussed in Section 4.2.

4.1.2 Component-Related Levels

Levels 1 through 3 and 6 characterize the set of historical physical components whose failures are described by a record. For convenience, the component list has been divided into two categories, mechanical and electrical (Level 1). Forty-two general types of mechanical components and 33 types of electrical components have been identified (Level 2). A complete listing of these component types and the associated coding scheme is shown in Appendix F. All component types are arranged within the appendix by component category.

For data from PRAs, turbine-driven and diesel-driven pumps are nearly always separated out; these pumps are expected to have higher failure rates than motor-driven pumps because their supporting systems are more complicated. Therefore, in encoding PRA data, pumps whose drivers were not specified were assumed to be motor-driven unless the pumps were in the following systems that are known to often have other types of drivers for pumps: auxiliary/emergency feedwater, high pressure coolant injection, reactor core isolation, fire protection, and main feedwater.

Within the component types, the data may be further characterized by component design (Level 3). For example, designs for the component pumps, motor-driven include axial, centrifugal, diaphragm, and gear. A complete listing of the component designs is also in Appendix F under each component type.

Application (Level 6) is a search item that provides additional information about the application and/or design of the component. It is at the lowest level of the basic HCFD hierarchy because it generally provides the most detailed information among these levels. The general application categories are: component (the component in which a piece part is installed); driver (the component driven by a driver-type component); enclosure type; external environment; external location; facility (NSSS vendor for fuel assemblies); instrumentation (the parameter being monitored); instrument type (analog or digital); internal environment; relay function; voltage level; and valve (the valve design for valve-valve operator components). The application categories appropriate for each type of component are defined in Appendix F. For each defined category of application, exactly one specific application is listed. Appendix G provides codes for the specific applications, including the case where the specific application is not given in the data source.

4.1.3 Failure Mode

Failure mode (Level 4) defines how the failed component state or condition differs from the desired state, particularly in relation to the failed component's inability to perform its function. A listing of the component failure modes is presented in Table 5.

The fails to operate mode applies to nearly all components. This includes cases where data sources say operational failure, improper operation, no output, or, just fails. In all of these cases, the mode applies to failures per hour. However, per demand probabilities can also be associated with this mode, as in fails to operate on demand. Specific

TABLE 5. FAILURE MODES FOR HCFD

Code	Failure Mode
FTO	1.0 Fails to operate
FTS	1.1 Fails to start
FTR	1.2 Fails to run
FTP	1.3 Fails to open
FTC	1.4 Fails to close
FTE	1.5 Fails to energize
FTD	1.6 Fails to deenergize
FTT	1.7 Fails to transfer electrically (e.g., an ABT)
SO	2.0 Spurious operation
SS	2.1 Spurious start
SP	2.2 Spurious open (transfer open)
SC	2.3 Spurious close (transfer closed)
SE	2.4 Spurious energize
SD	2.5 Spurious deenergize
ST	2.6 Spurious transfer electrically
LK	3.0 Leakage
LE	3.1 External leakage/rupture
LI	3.2 Internal leakage
BL	4.0 Blockage
BP	4.1 Plugged

examples of components whose catastrophic failure mode will, for consistency, always be denoted fails to operate are

- static inverters
- batteries
- electrical busses
- battery chargers
- transformers.

Fails to start, fails to run, and the other modes listed above under fails to operate are more specific descriptions of the failure events. For standby components, these modes may have both per hour and per demand rates, depending on whether the mechanisms associated with the failures are associated with the component's use or are aging mechanisms that occur even when the component is not being used. Standby components may have both per hour and per demand failure modes. These modes also typically apply to particular component groups; for example, fails to start and fails to run apply to pumps and generators, while fails to open and fails to close apply to valves and breakers, and fails to energize and fails to deenergize apply to relays and other electrical components. The fails to transfer electrically mode applies to auto bus transfer (ABT) devices. For relief valves, the per demand rate, fails to close, describes failure to reseat.

For components such as fans and compressors, failure to run and failure to operate may both be used to describe failure events in the fail to operate (per hour) group. For consistency, the fail to run mode will be used whenever the component also has a fail to start failure mode; otherwise, the fail to operate mode will be used.

The spurious operation failure mode group is similar in that it, too, contains modes that typically apply to particular components. The spurious category includes failures that are described in the data sources as premature open, function without signal, normally open fails closed, and fails high. Unlike the fails to operate category, all spurious operation failures give rise to per hour rates only.

Failure modes associated with leakage apply to components that form a pressure boundary, primarily valves. External leakage is typically leakage through valve packing; internal leakage is leakage across the valve seat. Hourly rates for failure to seat or reseat are described by the leakage failure mode. The internal leakage mode for check valves is back leakage. All leakage rates are per hour.

Blockage, like leakage, applies to certain hourly rates for components that form a pressure boundary. The plugged failure mode applies when the blockage is known to be complete.

A feature of the failure mode scheme described above is that it is hierarchical. That is, more detailed modes are listed under general modes so that different types of data can be accommodated. Thus, for example, sources that provide data for the fails to open/fails to close failure mode can be used as well as those that provide separate characterizations for a component's failure to open and failure to close.

4.1.4 Normal State

Normal state refers to the status of the component during plant operation, as shown in Table 6. The mode of operation of a component is an important characteristic of a component that is related to its failure mode. The normal state of a component can have a major influence on its failure rates. For example, normally operating pumps generally have a lower probability for failure to start than normally standby pumps have. Where possible, the normal state for components is noted in entering data for the NUCLARR system. In cases where the normal state is not stated, it is often implied by the failure mode. For example, the spurious open mode is typically associated with a normally closed valve, particularly for a set of valves that have no spurious close failure data. The XX code is used for cases where the normal state is not specified and cannot be inferred.

TABLE 6. NORMAL STATE CODES FOR HCFD

Code	Normal State
NO	Normally open
NC	Normally close
NE	Normally energized
ND	Normally deenergized
NR	Normally running (operating, wet flowing for pipes)
NS	Normally in standby (wet stagnant, not flowing for pipes)
NA	Normally alternating (between running and standing by)
NL	Normally locked-out (dry for pipes, heat exchangers, etc.)
XX	Not specified

4.2 Data Contents

In addition to the basic parameters that define HCFD events within the data taxonomy, several event attributes as well as the failure probabilities and/or rates are stored in the NUCLARR system. Failure rate data, data origin information, and a data record log form the basic information stored for each component failure data record. A discussion of the header information that appears on the NUCLARR HCFD screens and each of these groups of attributes is presented in subsections below. The field numbers that appear in the failure data and data origin information sections refer to the fields as they are labeled on Figure 11. This figure is the NUCLARR screen that displays individual raw data records. Part 2 of this guide discusses how to access this screen and retrieve records.

4.2.1 HCFD Record Header

The header information at the top of each NUCLARR display of component failure data informs the user as to where he is within the first five levels of the component failure data taxonomy that was previously discussed. That is, the header information defines the search strategy initiated by the user for the following parameters: (1) component category, (2) component type, (3) component design, (4) normal state, and (5) failure mode. The sixth level of the hierarchy, component application, is not part of the header information; it is listed as part of the summary information for a record. As shown in Figure 11, a record number is the final piece of information appearing in the header.

4.2.2 HFCD Points

Numerical attributes are listed in the top part of Figure 11, as follows.

1. Failures--The number of failures; the numerator of the failure rate.

2. Components--The number of similar components whose failure experience is being combined to provide a rate (this field is optional).

```
┌─────────────────────────────────────────Electrical──────────────────────────────┐
│  Component: Circuit Breakers, Power                                             │
│     Design: Unknown                                                             │
│Normal State: Normally Closed                                                    │
│Failure Mode: Fails to Open                                  Record number   2   │
└──────────────────────────────────── -Raw-Data-Record────────────────────────────┘
┌Source-Provided-Raw-Data┬──────────Source-Provided-Failure-Rates─────────────────┐
│Failures     :     1    │ Rate     : 5.310E-004  Confidence Lower:------E----   │
│Components   :------    │ Type     :MEAN            -- %    Upper:------E----   │
│Demand per   :--------  │ Units    :F/D         Tolerance  Lower:------E----    │
│Total Demand :    3120  │ Variance: 9.730E-008     -- %    Upper:------E----    │
│Hours per    :----------│ St. Dev.:------E----  Error Factor    :------E----    │
│Total Hours  :----------│ Dist.    :DISCRETE        -- %    Sided:              │
└────────────────────────┴────────────────────────────────────────────────────────┘
Nuclear?      :Y     Bayesian Update?:Y             Plants :ZIS1 ZIS2
Domestic?     :      Primary Failure?:U             Systems:EA EC
IRADAP?       :Y     Include Circuit?:U                  Inclusion:I
Safety Grade?:N      Failure Degree  :    Severity:C
                     Aggregation Type:1
Failure Origin :PLNT  Rec.Type:LERS CRLE PMLG PMTR DEVR
Exposure Origin:PLNT  Rec.Type:TSTR
Document Number:21381 Detail Reference:1.5-75              Data Period: 73-79

  COMMAND  <Enter> return to data record Summary    <Tab> then <Esc>  field Help
```

Figure 11. Example of HCFD raw data record illustrating location and identifier information.

3. Demand Per--The average number of individual component demands over the period in which data were collected. Note that this field is applicable only for per demand rates; thus, it is only applicable for fails to operate-type failure modes. It is optional even for raw data supplying per demand rates if the total number of component demands for all components is provided.

4. Total Component Demands--The total number of demands on components counted in the component field during the data collection period. Note that this field is applicable only for per demand rates. Additionally, it is not needed if the number of components and the demands per field are supplied.

5. Hours Per--The average individual component exposure time in hours, used for per hour rates (this field is optional).

6. Total Hours--The cumulative component exposure time in hours (operating hours during which the failure data was collected) for all components counted in the components field. It is not needed for raw data if the number of components is supplied. It is applicable only for per hour rates.

7. Rate--The failure probability or failure rate in scientific notation (e.g., 3.57E-05). This field and the following failure rate information fields are optional if raw data (i.e., the number of failures and either the exposure time or the number of demands) are provided.

8. Type--A description of how the failure probability above was derived. Typically, one of the following codes is used: MEAN or MEDIAN. If some other type is appropriate, the six characters available for this field are generally enough to make the entry self-explanatory. Any new codes, or the code OTHER, are explained in the comments field.

9. Units--The units for the failure probability: failures per demand (F/D), failures per hour (F/H), or other units. In the case of other units, the actual units are present in the three characters available for this field if the resulting entry is self-explanatory. Otherwise, OTH is used and the new code is explained in the comments field. This field is required for use of the failure probability or failure rate.

10. Variance--The variance of the failure rate in scientific notation.

11. Standard Deviation--The standard deviation of the failure probability or failure rate in scientific notation (e.g., 2.93 E-01). Note that there is no need to provide both a standard deviation and variance; whichever is most convenient is reported.

12. Distribution--A code from Table 7 for the distribution type for cases where a distribution assumption was specified.

TABLE 7. DISTRIBUTION CODES FOR HCFD

Code	Distribution
ABSN	Absolute normal (folded normal)
BETA	Beta
BINOM	Binomial
CHISQ	Chi-square
DISCRETE	Discrete
EXP	Exponential
F	F (Fisher-Snedecor)
GAMMA	Gamma
GEOM	Geometric
GUMBEL-I	Gumbel - type I (extreme value)
HYPGEOM	Hypergeometric
LOGN	Log-normal
LOGU	Log-uniform
MULTINOM	Multinomial
NEGBINOM	Negative binomial (Pascal)
NORMAL	Normal
POISSON	Poisson
T	Student's T
UNIF	Uniform
WEIBULL	Weibull (extreme value)
OTHER	Other (describe in comments)

13. Lower Confidence Bound--The LCB of the failure probability or failure rate in scientific notation (e.g., 6.91E-05).

14. Upper Confidence Bound--The UCB of the failure probability or failure rate in scientific notation (e.g., 2.54E-05).

15. Confidence Percentage--The confidence as an integer percentage. (For example, if the lower and upper bounds correspond to 10- and 90-% bounds, then the confidence is 80. Note that this means that 80% of such intervals derived from the data that could have been observed will contain the failure probability. In this case, the confidence bounds probability field would contain 80.) The confidence probability describes a two-sided interval if a lower confidence bound has been supplied; otherwise, it describes a one-sided interval. In the latter case, the confidence bound probability is the confidence associated directly with the upper bound.

16. Lower Tolerance Bound--The lower tolerance bound of the failure probability or failure rate, in scientific notation (e.g., 2.48E-06).

17. Upper Tolerance Bound--The upper tolerance bound of the failure probability or failure rate, in scientific notation (e.g., 4.56E-04).

18. Coverage Percentage--The coverage probability as an integer percentage. (For example, if the lower and upper bounds correspond to the 5th and 95th percentiles of the distribution describing the variability in the failure probability or failure rate over the component population, then 90% of the distribution lies within the interval and the interval covers 90% of the rates. In this case, the tolerance bounds probability field would contain 90.) As with the confidence bound probability, if the lower bound is not supplied the interval is taken to be one-sided and the probability describes the upper limit coverage only.

19. Error Factor--The error factor in scientific notation (e.g., 3.00E+01). Note that the error factor is an upper tolerance bound divided by the point estimate. For a log-normal distribution, the error factor is also the square root of the ratio of the upper and lower percentiles.

20. Error Factor Coverage Percentage--The coverage probability of the corresponding tolerance bounds as an integer percentage.

21. Sided (Error Factor Type)--An indicator for whether the error factor corresponds to a one-sided or two-sided tolerance interval. The field contains a 1 for one-sided intervals based solely on point estimates and the upper bound; otherwise, a two-sided interval is assumed. The error factor probability field must correspond accordingly. Both of these fields must be present in order for the error factor information to be used.

4.2.3 Data Origin Information

The lower section of Figure 11 shows most of the component failure data fields that further describe the origin of the data and the conditions under which the failure events (if any) occurred. The attributes appearing in these fields are discussed below, ending with three fields that do not appear on the figure.

22. Nuclear ?--An indicator for whether the source data originates from nuclear plant data. If all of the data is from a nuclear power plant, this field contains a Y (yes); otherwise, it is blank or contains an N (no).

23. Domestic ?--If the data were obtained from a U.S. facility, a Y is entered. For data from foreign facilities, this field has an N. Generally, this information is inferred from a knowledge of the source that provided the data point.

24. IRADAP ?--An indicator for whether the data record is applicable for inclusion in aggregations to be supplied for the NRC's Integrated Risk Assessment Data Acquisition Program (IRADAP). The codes Y, N, blank, and U are used, as with most of the other indicator fields. This field is important in flagging data records that have possible quality problems and in some cases should not be aggregated with other data. Considerations that may cause this indicator to be set to flag a record as not applicable include the following: the record supplies only generic data and the NUCLARR system has many plant-specific data sources that supply data for its component and failure mode of interest; a desire to avoid duplication of data; the presence of known concerns with particular data points from a source, such as the belief that the station records do not contain enough accessible information to assess the number of demands for a particular component and failure mode with sufficient accuracy; the data point is believed to be not applicable for most U.S. nuclear power plant facilities because of a known atypical design or atypical application; or, finally, the corresponding data value (failure rate or demand probability) is significantly different from other sources as shown by plots of the data. (In such cases, one suspects either an atypical application or a data quality concern; until further investigation shows otherwise, such data points are flagged.)

25. Safety Grade ?--An indicator for whether the component is safety grade. This field is included in the data base because the design, inspection procedures, and test and maintenance environment of a component can be influenced by whether it is safety grade. Most components that are covered by technical specifications are safety grade. Thus, separate evaluations of components in safety-grade systems and non-safety grade systems may be useful. If the component is judged to be safety grade, then this field contains a Y (yes); if it is not safety grade, then this field contains an N (no); otherwise, this field is blank or contains a U (unknown). Few data sources distinguish whether a component is safety grade. Therefore, the NUCLARR team has assigned safety grade codes for selected records

based on their system. Components in the class 1E power systems, the emergency onsite power supply system, systems that provide engineered safety features, and systems that actuate safety functions are flagged as safety grade; components in balance of plant systems are flagged as not being safety grade. For remaining records, the safety grade remains unspecified unless it is provided in the source.

26. Bayesian Update ?--An indicator for whether the source-provided rate came from a Bayesian update calculation. If the data came from a Bayesian update calculation, then this field contains a Y (yes); if the data are known not to have come from a Bayesian update, then this field contains an N (no); otherwise, this field is blank or a U (unknown) is in this field.

27. Primary Failure ?--An indicator for those cases where the failure rates are based on primary failures only. As with the safety grade field, this field contains a Y, N, blank, or U. When this indicator is no, both primary and secondary failures are included in the numerator of the failure rate.

28. Circuit Included ?--An indicator for those cases where the control circuitry is included in the component's boundary and consequently in the failure rate. As with the safety grade field, this field contains a Y, N, blank, or U.

29. Failure Degree--The degree of a degraded or incipient failure, as indicated in Table 8.

30. Severity--The severity of the failure as defined by one of the following three levels:

   o Catastrophic--a failure that is sudden and complete.

   o Degraded--a failure that is gradual and partial with the component providing an unacceptable level of performance that may deteriorate over time into total failure.

TABLE 8. DEGREE FIELD CODES FOR HCFD

Code	Degree
OH	Output, high
OL	Output, low
SH	Setpoint range, high
SL	Setpoint range, low
LL	Leakage, large
LS	Leakage, small
TP	Timing, premature
TL	Timing, late

o Incipient--a state or condition that if not corrected may lead to one of the above states if ignored.

A C (catastrophic), D (degraded), I (incipient), or X (not specified) is used in this field. For data for reliability analyses, the emphasis is on catastrophic failure modes that prevent the component from performing its function.

31. Aggregation Type--A code showing the amount of raw data and/or bounding data present in the data record and whether the record represents homogeneous data or data that have been previously aggregated from other data sources. Specific aggregation algorithms are applied based on the value of this attribute. The particular codes are:

1 - Homogeneous with raw data (i.e., the numbers of failures and exposures) present.

2 - Homogeneous with no raw data and no tolerance interval.

3 - Homogeneous with no raw data or variation data.

4 - Homogeneous with a tolerance interval but no raw data.

5 - Nonhomogeneous (preaggregated over a variety of conditions), with a tolerance interval.

6 - Nonhomogeneous (preaggregated) with no tolerance interval.

The term, homogeneous, applies to a population of components whose failure rate per unit time or failure probability per demand for a particular failure mode can reasonably be assumed to be constant. This implies that, for per hour rates, there is no reason to expect the number of failures not to be Poisson. For per demand probabilities, this term applies whenever there is no evidence to show that the number of failures in a fixed number of demands is not described by the binomial distribution. Section 4.3 describes how the assessments for aggregation type are made.

32. Plant--Codes describing the plant(s) (i.e., facility identifier codes, FID) at which the data originated. As many as four codes from Appendix H may be listed. A single code suffices for data from a single station (e.g., ZIS for ZIS1/ZIS2). Appendix H describes additional coding conventions, including codes that describe groups of plants. Codes for NSSS vendors and architectural engineers are examples of these codes. As new plants or plant groupings are added, the table will be updated.

33. System--The system(s) represented by the set of components whose experience is described by a single record. Up to five included or excluded systems may be listed for a record. The system codes are contained in Appendix I; most of them are taken from Institute of Electrical and Electronics Engineers (IEEE) Standard 805-1984. This standard provides system drawings and guidance for determining a component's system. For example, heat exchangers are listed in the

system in which they perform a heating or cooling function; instruments are in the systems in which they sense; actuators and circuit breakers are in the systems containing the controlled equipment; valves are assigned to the system in which they control fluid; and transformers are assigned to the lower voltage system. Special codes are provided for Class 1E electrical systems; for data from sources that are not specific, the associated more general system codes may also include data for Class 1E components.

The code AL is provided for all systems; however, this code is used only when the data source emphasizes that the data combined to provide a failure rate represent all systems. The code ZZ (not specified) is selected in preference to AL if the source does not make a system distinction. For system code XX (other), the actual system is explained in the comments field.

Nuclear power plant systems are important; knowing the system often provides information on other attributes of the data. Table 9 describes some of the most common nuclear power plant systems and their typical internal environment and safety grade. In entering component failure data, values from this table have been used in certain cases where the system is specified, even when a data source did not specifically provide safety grade and internal environment.

34. Inclusion--A flag indicating whether the system field (described above) contains the systems that the components are in (Code I) or lists the systems the corresponding components are not in (Code E, for excluded systems).

35. Failure Origin--The general origin of either the number of failures for failure rate calculations or the failure rate itself, as follows:

TABLE 9. INFORMATION FOR COMMON NUCLEAR POWER PLANT SYSTEMS

Code	System	Plant Type	Int. Env.	Safety Grade
BA	Aux. Feedwater	PWR	CW	U
AB	Primary Coolant	PWR	BW	Y
BQ	High Pressure Safety Injection	PWR	BW	Y
CI	Residual Heat Removal	PWR	BW	U
BP	Low Pressure Safety Injection	PWR	BW	Y
CB	Chemical Volume Control System	PWR	BW	U
TA	Main Steam	PWR	ST	N
SJ	Main Feedwater	PWR	CW	N
SD	Condensate	Both	CW	N
CC	Component Cooling Water	PWR	CW	U
BI	Essential Raw Cooling/ Service Water	PWR	XX	U
KG	Nonessential Service Water	PWR	XX	U
BE	Containment Spray	PWR	XX	U
AA	Control Rod Drive	PWR	CW	U
DC	Diesel Fuel Oil	PWR		
SL	Feedwater Pump Turbine Lube Oil	PWR		
KE	Circulating Water	PWR	XX	N
KO	Seal Water	PWR		
AD	Recirculation	BWR	CW	Y
BJ	High Pressure Coolant Injection	BWR	CW	Y
BO	Low Pressure Coolant Injection	BWR	CW	Y
BN	Reactor Core Isolation Cooling	BWR	CW	U
BG,BM	Core Spray	BWR	CW	Y
CH	Residual Heat Removal	BWR	BW	U
BR	Standby Liquid Control	BWR	BW	U
SB	Main Steam	BWR	ST	U
SJ	Feedwater	BWR	CW	N
CC	Reactor Building Component Cooling Water	BWR	XX	U
KI	Raw Cooling Water	BWR	XX	N
KI	Essential Service water	BWR	XX	
KG	Nonessential Service Water	BWR	XX	
KP	Fire Protection	Both	XX	U

EXPJ (expert judgment); LTST (laboratory test data); PLNT (commercial nuclear power plant experience data); or OTHR (other--see comment in comment section). For IRADAP-suitable data (see Item 21), the PLNT designation means that maintenance work orders or other in-depth plant records were examined to determine the failure rates.

36. Failure Record Type--The specific type of data records used to provide either the number of failures for failure rate calculations or the failure rate itself. As many as ten types may be present; the type contributing most to the data is listed first. The codes are in Table 10; more codes may be added as new sources appear. EXTD and OTHR are further defined in the comment field. This field is often blank if the failure data origin is not PLNT.

37. Exposure Origin--The general origin of the data used to provide the population size, operating hours, or number of demands for failure rate calculations are as follows: EXPJ (expert judgment); PLNT (commercial nuclear power plant experience data); TCAL (total calendar hours); TCRT (total critical hours); or OTHR (other--see comment in comment section).

38. Exposure Record Type--The specific type of records used to provide the population size, operating hours, or number of demands for failure rate calculations. If applicable, it provides information on the origin of the information used for the denominator of the failure rate. As in the failure data record type field, ten codes may be present, beginning with the most important contributor. Codes are listed in Table 10; EXTD and OTHR are further defined in the comment field. For the exposure data, the codes that refer to testing, such as TSTR and SURV, refer also to test procedures that show the components exercised by the tests and the testing frequencies.

TABLE 10. ORIGIN RECORD TYPE CODES FOR HCFD

		Primarily Applicable to		
Code	Record Type or Data Origin	Failure Data	Exposure Data	Rates
ADLG	Administrative logs	X	X	
CRLB	Control room log books	X	X	
DCCN	Dedicated cycle counters		X	
DEVR	Deviation reports	X		
EXTD	External document (provide comment)	X	X	X
INCD	Incident reports	X		
JOBO	Job orders	X	X	
LCOR	Limiting condition for operation records	X		
LERS	Licensee event reports	X		
MFTG	Manufacturer's testing	X		
MOPR	Monthly operating status reports	X	X	
OTHR	Other (provide comment)	X	X	X
PMLG	Plant maintenance logs	X		
PMTR	Plant maintenance test records	X	X	
PMWR	Plant maintenance work requests	X	X	
RHLG	Run hour logs		X	
TCAL	Total calendar hours		X	
TCRT	Total critical hours		X	
TSTR	Test reports	X	X	
SOCR	Significant occurrence reports	X		
SSLB	Shift supervisor log books	X	X	
SURV	Surveillance tests	X	X	
UTDB	Utility data base	X		X

39. Document Number--This number consists of three digits followed by the last two digits of the calendar year in which the data were published (XXX-YR). Each source of data is assigned a number when it enters the system.

40. Detail Reference--This field contains the source page, paragraph, and line number where data reference is located.

41. Data Period--The earliest and latest year over which the failure data was collected. The comment field contains a more exact date if applicable.

The two other pieces of data source information that may be stored in NUCLARR data records but not shown in Figure 11 are

Subsystem/Train--Free-form text containing the components' subsystem and/or train designation. RHR A and RHR/SDC A2 are typical entries. This field is blank for data aggregated over multiple trains of a system or multiple systems. It is also blank if no train designation is provided in the data source.

Supplemental Reference Document Identification--a description of the root sources of the data, if any. This field is used for secondary references. It is similar to the reference citation field for HEP data (see Section 3.2.3.2).

4.2.4 Data Record Log

Three additional pieces of information are recorded for each HCFD data point. The first is a 254-character comments field. This contains additional information not contained in the coded fields or explanations of information entered in the coded fields. The second and third items are the record logs used primarily for data traceability; they are the initials of the person inputting the data and the data input date.

4.3 Data Treatment

The subsections below discuss the calculations that are made by the NUCLARR system for each component failure data record and the algorithms used to combine and aggregate component failure data records.

4.3.1 HCFD Source Data Calculations

For each HCFD record having sufficient information, the NUCLARR system displays in a summary screen the following parameters: median, mean, error factor, and upper tolerance bound. In most cases, these parameters are calculated from the data supplied from the data source. In instances where values are calculated by the NUCLARR system, an asterisk (*) appears next to the value to alert the user to this fact.

Defining the parameters being estimated is appropriate. Both medians and means are point estimates of failure rates or per demand probabilities. Technically, the median is the rate that is exceeded half of the time, and the mean is the expected value (i.e., weighted average) of the failure rate. Both of these concepts, however, have meaning in the context of the failure rate itself having a probability distribution. Many data sources provide best estimates of a failure rate, maximum likelihood estimates, or other estimates that are based on regarding the failure rate as an unknown constant rather than a random variable. For the purpose of uniform calculations and data interpretations within the NUCLARR system, individual failure rates are treated as random variables with lognormal distributions. This is similar to NUCLARR's HEP use of lognormal distributions for cell-level aggregations, although there they apply to a geometric average of HEPs rather than to the individual HEPs. Further reasons for this choice are presented in Section 4.3.3. The error factor concept is particularly related to lognormal distributions; <u>error factor</u> is loosely defined as the ratio between an upper bound and a point estimate, but for the lognormal distribution it is precisely defined as the upper bound divided by the median. Also, for the lognormal distribution, the error factor can be obtained by dividing the median by a lower bound. The bounds, themselves, are typically percentiles of the failure rate distribution. As such, the failure rate can generally be expected to lie within the upper and lower tolerance bounds with a probability corresponding to the selected percentiles. The NUCLARR system always displays, in the summary screen for a record, its assessment of the upper 95th percentile; this is the <u>upper tolerance bound</u>.

The NUCLARR system begins by making three assessments for each data point being entered

- Is a data record expected to present homogeneous data or data that have been previously aggregated from a variety of sources?

- o Does the record provide raw data, i.e., failure counts and denominator information?

- o Is tolerance information present?

If raw data are presented in a record, it is the most important information the source has provided in nearly every case. Often a source will provide means, medians, or variances that are derived from a Bayesian analysis that is influenced by other sources of data. These other data, in most cases, are already in the NUCLARR system; thus, using updated means and medians in NUCLARR aggregations will over-represent that data. The only exception to this philosophy is the case of previously aggregated data that has tolerance bounds. For previously aggregated data, pooled raw data alone do not convey information about the variation that is represented by combining data from a variety of situations. If tolerance information is provided in this case, it is the primary data (along with the point estimate of the failure rate) that NUCLARR analyzes. These concepts are discussed in more detail in Section 4.3.3.

There are three basic sets of source data calculations for the component failure data. These are described in subsections below. With the one exception just stated, raw-data-based calculations are used if at all possible. For that exception, and all other cases where tolerance information is present and raw data are not present, tolerance-information-based calculations are used. Finally, the processing of source records that lack both raw data and tolerance information is described.

4.3.1.1 Calculations Using Raw Data. If raw data are used, the mean calculated by the NUCLARR system is the number of failures divided by the number of demands or operating hours, regardless of any other rates cited by the data source for the probability of failure on demand or the failure rate. Similarly, the NUCLARR system calculates a median that may differ from the one given in the source. Reference 5 explains that, using a noninformative prior distribution, homogeneous raw per demand-based data can be characterized by a gamma distribution and homogeneous per-hour data can be described by a beta distribution. The gamma distribution is directly related to the chi-square distribution, and the beta distribution is directly related to the F. Thus, equations for the median turn out to be as follows:

- For per hour data, $x^2(df1;0.50)/(2t)$;

- For per demand data,
  $df1 \cdot F(df1,df2;0.50)/[df2 + df1 \cdot F(df1,df2;0.50)]$.

In these equations, f is the number of failures, t is the number of hours, df1 is (2f+1), df2 is (2n-2f+1) where n is the number of demands, and $x^2(df1;0.50)$ and $F(df1,df2;0.50)$ are 50th percentiles of chi-square and F distributions, respectively.

Note that these equations are applied even if the data point is not assessed as being homogeneous but instead represents preaggregated data. Such a data point lacks tolerance information in order for the raw data to be considered at all. Using the equations above for such a data point is expected to produce an upper tolerance bound that underestimates the true upper tolerance bound, and the NUCLARR system user is warned that this is the case. No more valid upper tolerance bound is available for such points.

To obtain an upper tolerance bound, the upper percentiles of the above-mentioned distributions are used, unless the source provides an upper 95% confidence bound. The confidence bound from the source is used as a tolerance bound in this case because the presence of a confidence bound implies that the data point is regarded by the source as representing homogeneous data and, in this case, the distinction between tolerance and confidence bounds is negligible. This distinction is discussed in more detail in the introduction to the aggregation methods description for the NUCLARR system's HCFD (see Section 4.3.3).

If the source has not provided an upper 95% confidence bound, the upper tolerance bound is calculated using the same equations as those for the median except that the probability levels are changed from 0.50 to 0.95.

In all cases, the error factor is taken to be the upper tolerance bound divided by the median. Note, however, that the mean of the lognormal distribution with this median and error factor is not equal to the calculated rate (f/t or f/n) that the NUCLARR system displays. In fact, this displayed rate is less than the calculated median, and the mean of a lognormal distribution is always greater than its median. However, in keeping with the importance of the raw data, the rate calculated directly from the raw data is displayed as the mean.

Note also that, although the calculated rate from the raw data will always be zero whenever the number of failures is zero, the equations cited above for the median and upper bound are appropriate for the zero failures case and will produce medians and bounds that are nonzero. For lognormal distributions, the rates must be greater than zero. In principle, all rates are greater than zero because the postulated failure events could happen eventually.

A final comment about these calculations is that on rare occasions they are applied even though no raw data have been provided in a data record. These are cases in which the record has been judged as providing homogeneous data and confidence intervals have been given. A raw data conversion procedure similar to the NUCLARR system's HEP source data calculations that compute a number of errors and a number of opportunities from an HEP and upper confidence bound [see part (b) of Figure 5] is employed. This generally results in pseudo failure counts and numbers of demands or hours that would generate the confidence bounds given in the data source. In this case, these data are treated as raw data and the above calculations are performed.

4.3.1.2 Calculations Using Tolerance Information. Data source records that contain tolerance information have some measure of the spread of the failure rate distribution. To identify a lognormal distribution that reflects this spread, two parameters must be estimated: the median and the error factor.

In fitting a lognormal distribution, the median is fitted in preference to the mean stated in the data source if both are supplied. In some cases, the point estimate of the mean failure rate is zero; the lognormal model requires that a nonzero estimate of the median be obtained. If raw data are available, the equations listed in Section 4.3.1.1 are used; otherwise, the data are treated as lacking the tolerance information.

Listed below are equations for use if the median or mean fit a lognormal distribution. Equations to derive the variance S_i^2, and the mean, M_i, of an underlying normal distribution are included. The normal distribution describes the logarithm of the corresponding failure rate or probability. These quantities are computed and stored for use in data aggregations. In the equations, z_α is an upper bound from the standard normal distribution (e.g., the 95th percentile, 1.645, when α is 0.95).

Use of the Median. Equations using the median (r_i) are as follows:

- With the upper bound (U_i):

  $M_i = \ln r_i$ (this holds in all cases)

  $$S_i^2 = [(\ln U_i - \ln r_i)/z_\alpha]^2$$

- With the error factor (EF_i):

  $$S_i^2 = [\ln EF_i/z_\alpha]^2$$

- With the variance (V_i):

$$S_i^2 = \ln [(r_i + \sqrt{r_i^2 + 4 V_i})/(2r_i)]$$

Use of the Mean. Equations using the mean (X_i*) are as follows:

- With the upper bound:

$$S_i^2 = [z_\alpha - \sqrt{z_\alpha^2 - 2 \ln (U_i/X_i^*)}]^2$$

(If this is not possible, X_i* is taken to be the median.)

- With the error factor:[a]

$$S_i^2 = [z_\alpha - \sqrt{z_\alpha^2 - 2 \ln EF_i}]^2$$

- With the variance:

$$S_i^2 = \ln [V_i/(X_i^*)^2 + 1].$$

Final Calculations. In the last three cases, where the median is not provided and the lognormal distribution mean is used, the median for the failure rate or per demand probability is calculated as

$$r_i = X_i^*/\exp(S_i^2/2).$$

Given the underlying normal distribution mean ($M_i = \ln r_i$) and variance, the corresponding lognormal distribution for the rates has median, exp M; mean, exp M * exp ($S^2/2$); and error factor, exp (1.645 S). The 95% upper bound is found by multiplying the median times the error factor.

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a. Here, the EF is treated as the upper bound divided by the mean. If it were U/r, the median r should be reported in the data source.

4.3.1.3 Calculations for Other Records. With no raw data and no tolerance information, only the mean and/or median given in the data source can be displayed. Without more information, it is not possible to calculate numbers for the missing parameters.

4.3.2 Data Combinations

One set of procedures applies to the aggregations, resulting in average failure rates or demand probabilities for various sets of component failure data. There are, however, two applications of these algorithms. The first is applied after data are entered into the NUCLARR data system and results in stored aggregates for the following sets of data:

- o Every combination of component type and failure mode group that has at least one data point in the data base.
- o Every combination of component design and failure mode group that has at least one data point in the data base.
- o Every combination of component design, specific failure mode, and normal state that has at least one data point in the data base.

(Note that component design as stated here implies that a component type has been specified also). These stored aggregations are accessed by identifying a record set (by component type, design, failure mode, and normal state) and then asking the NUCLARR system to display the aggregations without asking it first to calculate them. In such a case, it displays the stored aggregations that are most closely related to the record set that the user has specified. The set of conditions defining the data set for each aggregate is termed an event. Future versions of the NUCLARR system will allow access in a similar manner to aggregations like the first two listed above but with specific failure modes instead of the failure mode groups.

The second application is for ad hoc aggregations for sets of records defined by the NUCLARR system user. The system may require a few seconds, depending on the number of records in the data set, to obtain these aggregations.

In considering possible aggregations for the HCFD, a final observation is that the aggregations based solely on component type without considering component design will include preaggregated data if they are present. These aggregations are analogous to NUCLARR's HEP functional group summary cell aggregations. Aggregations for which each data point is from a source that supplies preaggregated data for a component type, where several component designs are reflected in each data point, are similar to the HEP general equipment cell aggregations. Specifying a known design as well as a component type and failure mode produces an aggregation similar to the HEP basic equipment cells.

4.3.3 Aggregation Methods

This section provides a brief description of the methods implemented in the NUCLARR program for treating the uncertainty in the failure data and for aggregating data from different sources. Two main quantities result from the aggregation methods: a point estimate and an upper tolerance bound. The point estimate is a weighted average of the HCFD contained in the set being aggregated. The upper bound is a percentile of a distribution that is intended to describe the population of failure rates or demand probabilities that are being combined. It is not intended to be a confidence interval describing how well the mean or median of that distribution is known. Rather, the tolerance bound is a number that the failure rates or probabilities are expected to remain less than with a probability specified by the user. In this sense, the interval from zero to the bound is intended to cover that specified amount of the distribution of the failure rates for an event. The specified probability is thus a coverage probability rather than a confidence. It is useful for predicting where future failure rates or probabilities sampled from the population variability distribution might lie.

A further remark about the tolerance interval is warranted. A classical statistical tolerance bound has two probabilities associated with it: a coverage probability and a confidence indicating how likely it is that the interval actually does cover a distribution as desired. These bounds consider the sample size and the fact that parameters influencing the tolerance bound are not really known but are estimated from the data. Atwood[6] describes a method for correcting tolerance bounds to account for the uncertainties in parameters estimated from the data and thus for increasing the confidence. However, in applications with diesel generator data, he found that the correction had little effect. Based on additional experience with the method, he concludes in Reference 6 that, when the sample size is at least moderately large, the uncertainty because of lack of data is small compared with the inherent variability in each failure rate population. That is, generally, the variation between records dominates over the variation within records, and thus, these corrections are not needed.

The following sections provide an overview of the aggregation methods, including the major formulas. For a more detailed presentation, see Reference 7.

4.3.3.1 General Approach. The component failure data aggregation algorithms are based primarily on the treatment of generic data described by Martz and Bryson in Reference 8. This article discusses the combining of various types of generic data to form prior distributions describing population variability. Although the article does not discuss the per demand type of rate, the methods for combining data therein are easily extended to this case.

In nearly all cases, the variability distributions are taken to be lognormal. This distribution is discussed in Reference 5. Apostolakis et al.[9] make use of lognormal prior distributions, as did the Reactor Safety Study.[10] It is appropriate for quantities that vary by orders of magnitude. Although it is not bounded, it is appropriate for probabilities as well as rates if the probabilities are small. The aggregation methods include adjustments for the lognormal distributions that model failure on demand probabilities that approach one; the output lognormal distribution is checked to ensure that at least 95% of its values are less than one and a truncated distribution is used if this test fails.

The data treatment discussed in Reference 8 focuses on the type of data supplied by the various data sources. For generic data, there are two main possibilities. The data may be raw data; i.e., historical observed frequency data on similar events in similar applications. Alternatively, the data may be reduced, in the form of point or interval estimates for frequencies of similar events. In the latter case, there are several possible ways to specify bounds for the rates. Tolerance bounds (for one- or two-sided intervals) may be specified, or error factors may be given. These methods have been extended to allow standard deviations or variances to be used to describe the variability.

For all of these cases, the underlying hypotheses are that the information from each separate source (i.e., individual data record) has a within-source variation and that the goal of the aggregation is to provide a point estimate and a tolerance bound that describes the between-source variation. This motivates an empirical Bayes (EB) treatment of the data in which the within-source variation is modelled by a conditional distribution, conditioned on the particular (but unknown) value of the occurrence rate for a particular source. The (unconditional) distribution that this value comes from is the desired population variability distribution. Tolerance intervals for aggregated rates are thus based on this distribution.

Further remarks on the nature of the assumed within-source variation are appropriate. For raw data, Martz and Bryson[8] assume that a constant failure rate applies for each source and that the within-source variability is thus the variability that is characteristic of a Poisson distribution. For reduced data, likewise, the bounds or other measures of variation for each source are assumed to describe the variation of data for that source. However, in this case the data may have already been aggregated by the data supplier and may already reflect population variability. This is particularly the case for generic component failure data; some individual data records may describe aggregated data. The aggregation procedures consider this distinction and do not attempt to remove within-source variation in such cases.

In all cases, the point estimates recommended by Martz and Bryson[8] are the geometric means of the values from the individual sources. In some cases, the means are weighted inversely according to the variances of the individual sources.

After combining or aggregating various sources based on the form of data provided, several aggregates may result. Each of these is characterized by a lognormal distribution with an associated point estimate (its median) and upper tolerance bound (related in a simple manner to the variance of its underlying normal distribution). To form a single overall aggregate, a mixture distribution is formed. This, in turn, is fitted to a lognormal distribution by matching moments. The individual distributions are weighted by the number of individual records contributing to each aggregate.

4.3.3.2 Aggregation Types. Following the basic approach of Reference 8, the set of data records to be aggregated is first split into sets based on the type of information supplied (whether it is homogeneous and whether it is raw or reduced data). An aggregate is formed for each set that is present among the data being considered, then the resulting aggregates are combined into a mixture distribution.

A single data point may represent homogeneous data or it may represent data that have been previously aggregated from several sources. Source data from different plants and studies are not expected to be homogeneous. The Bayes procedures described by Martz[8] are not applicable unless individual records are homogeneous. A single record is treated as homogeneous if (a) it has at least component design detail and (b) it is from a single plant and/or was used as plant-specific data for a Bayesian update. Reference 7 contains a discussion of the rationale for these rules.

The remainder of this section is a discussion of how the form of data for a record is classified based on the minimal information that is present. If an entry is present for the number of failures and for either the total number of operating hours or demands or for both the average number of operating hours or demands per component and the number of components whose experience is being combined, raw data are being provided.

The aggregation methods recognize just two types of rate variation information beyond the raw data: confidence intervals and tolerance intervals. Error factors and standard deviations or variances are assumed to be supplying tolerance interval information. Specifying any type of rate variation information except for standard deviations and variances requires a specification of the coverage probability or confidence as well as an upper bound. Lower bounds are optional; if they are not specified, the bounds are assumed to be one-sided. For error factors, the <u>error factor type</u> that indicates whether the corresponding tolerance interval is one- or two-sided is required. If one of these sets of data is present, variation information is provided.

There are several possible ways to describe tolerance intervals. The aggregation methods check first the upper tolerance bound and associated coverage probability; if this is complete, tolerance interval data are provided and any remaining tolerance interval information will be ignored. Otherwise, the error factor information will be used; the variance or standard deviation information will be used only if no other tolerance interval information is provided in the data record.

These considerations lead to six possible <u>aggregation types</u> or categories of data for aggregation. These are described in Table 11.

4.3.3.3 <u>Aggregation Algorithms</u>. The fourth column of Table 11 identifies the aggregation methods to be used. For most of the data sets, the methods are further subdivided based on the amount of data present. Two other data sets are subdivided because the presence of raw data can affect the weighting of the data.

TABLE 11. DATA SETS FOR AGGREGATION METHODS

Aggregation Type	Nature of Source Record	Form of Data Present[a]	Aggregation Method
1	Homogeneous	Raw data	
		$k = 1$ or all $f_i < 2$	Noninformative prior
		$k > 1$ and at least one $f_i > 1$	EB procedure #1
2	Homogeneous	No raw data; confidence interval only	Raw data conversion
3	Homogeneous	No raw data and no variation information	
		$k = 1$	No bound possible;
		$k > 1$	fit rates to lognormal distribution
4	Homogeneous	No raw data; tolerance interval	
		$k = 1$	Use single point
		$k > 1$	EB procedure #2
5	Previously Aggregated	Tolerance interval	
		Raw data (k_r)	
		$k_r = 1$	Use single point
		$k_r > 1$	mixture (weighted)
		No raw data (k_n)	
		$k_n = 1$	Use single point
		$k_n > 1$	mixture (unweighted)
6	Previously Aggregated	No tolerance interval	
		Raw data (k_r)	
		$k_r = 1$	Noninformative prior
		$k_r > 1$	Fit rates to lognormal dist. (weighted)
		No raw data (k_n)	
		$k_n = 1$	No bound possible
		$k_n > 1$	Fit rates to lognormal dist. (unweighted)

a. "k" is the number of points in the set; (f_i for $i = 1$ to k) is the set of failure counts.

4.3.3.4 NUCLARR/IRRAS Interface (HCFD). Located data that have been aggregated and are referenced in the NUCLARR search buffer may be transferred to an ASCII file formatted for use by MAR-D. (If only a single record is referenced in the search buffer, it is not necessary to use the aggregation processing before transferring that record's data.)

Following data search and aggregation, the user identifies the MAR-D file and family with which the data will be associated. The search buffer aggregation process segregates the referenced data into demand and hourly data and each of these into failure groups; there may be multiple sets of aggregated data available for transfer. The plant-specific update for designated data sets will be based on a Bayesian single stage method, or another user-described method.

The Bayesian method requires input of number of failures per demand or per hour. An update using any other generation method necessitates input of a mean, error factor, and generation methodology description, as well as the number of failures per hour/per demand. The following equations are used in the transfer process:

t95 = 1.645, 95th percentile of standard normal distribution
Error Factor = upper bound / median
sigma = [ln (error factor)] / t95
Mean = median (Exp [(sigma) (sigma) / 2.0])

Aggregation of located records generates a median and upper and lower bounds. From these, the needed error factor and mean are computed for transfer to the IRRAS compatible ASCII file in MAR-D format. If a single record is located and not aggregated, its median and upper bound are used for the needed calculations.

If the Bayesian update method is used, the Bayesian single stage update equations (detailed in Help screens within the NUCLARR program) are used to generate the mean and error factor transferred. If error factor and mean are input, these input values are transferred to the ASCII file.

Table 12 provides an overview of the actual aggregation algorithms. It describes five basic sets of instructions, corresponding to the NUCLARR system's aggregation types, as follows:

Records supplying homogeneous, raw data ....Type 1
Records supplying homogeneous data with tolerance interval ......Type 4
Records supplying homogeneous data but no tolerance interval ....Type 3
Records supplying preaggregated data with tolerance interval ....Type 5
Records supplying preaggregated data with no tolerance interval..Type 6

Aggregation Type 2 does not appear in this list and will never appear for a data record because the raw data conversion procedure applied to these records generally results in pseudo failure count and numbers of demands or hours that would generate the confidence bounds given in the data source; in this case, the record is reclassified as Type 1. If for any reason these counts cannot be computed, the record is classified as Aggregation Type 3.

In Table 12, dealing with zero rates requires that a nonzero estimate of the median be obtained. This is part of the calculations that are performed for each record as it enters the NUCLARR system (see Section 4.3.1). It requires that raw data be available; if this is not the case, the data are not amenable to a lognormal model and are omitted from the aggregation. Finding standard deviations for the normal distributions that describe the logarithms of the rates or per demand probabilities is also part of the initial processing that a record undergoes when it enters the NUCLARR system. The remaining notation used in the table is defined in its footnotes.

The weighting of the data is a subject for further research; currently, in a group of records with raw data, weights are based on the exposure (time or number of demands) associated with each record. When groups are combined, the weights depend on the number of records in the group.

TABLE 12. HCFD AGGREGATION ALGORITHMS

For Homogeneous Data Records:	Other Data Form	
Preferred Data Form: Raw Data	Tolerance Interval	Neither
Empirical Bayes (EB) Proc. #1:	EB Proc. #2:	Fit rates to lognormal distribution (see below.)
o Compute[a]	o Deal with 0 rates[b]	
$R = (\Sigma f_i)/(\Sigma T_i)$	o Find normal dist. stdv., S_1^b	
$R_2 = [\Sigma f_i(f_i-1)/T_i]/(\Sigma T_i)$		
o Match moments. Output underlying normal distribution:	o Compute[c]	
	$X^* = \Sigma S \ln r_i /k$	
$M = 2 \ln R - 0.5 \ln R_2$	$S^2_{SAM} = \Sigma (\ln r_i - X^*)^2 /k$	
$S^2 = \ln R_2 - 2 \ln R$	$S^2_{AVG} = \Sigma S_i^2 /k$	
	$W_i = (1/S_i^2) / \Sigma (1/S_j^2)$	
o If $S^2 < 0$, compute separate rates and fit them to a lognormal distribution.	o Output normal distrib[illegible]n:	
	$S^2 = S^2_{SAM} - S^2_{AVG}$	
	$M = \Sigma W_i \ln r_i$	
o Similar treatment for per demand data.	o If $S^2 < 0$, use $S^2 = S^2_{SAM}$.	

For Previously Aggregated Records:	
Preferred Form: Tolerance Interval	No Tolerance Interval
Mixture:	Fit rates to lognormal distribution:
o Deal with 0 rates.[b]	o Deal with 0 rates.[b]
o Find normal dist. stdv. (S_i)	o Define weights (W_i).[b]
o Define weights (W_i).[b]	o Output normal distribution:
o Output normal distribution:	$M = \Sigma W_i \ln r_i$
$M = \Sigma W_i \ln r_i$	$S^2 = \Sigma W_i (\ln r_i)^2 - M^2$
$S^2 = \Sigma W_i [(\ln r_i)^2 + S_i^2] - M^2$	

a. Here, f_i is the number of failures in time T_i.

b. See text for a description of the method.

c. Here, r_i is the median of the rate distribution and k is the number of records being combined.

In most of the cases in Table 12, special provisions apply if there is only a minimal number of records in a group. For example, a noninformative prior is used to provide R and R_2 in EB Procedure #1 if there are insufficient data. See Reference 6 for these details and for further insights on how the formulas are derived.

After the NUCLARR system has processed the records for each aggregation type represented among the records in a set being aggregated as indicated in Table 11, the resulting lognormal distributions are combined. The calculational method for this step is the same as the method for individual records having Aggregation Type 5. This is described in the lower left section of Table 12. The final result is a lognormal distribution describing the aggregated rates.

An example of a NUCLARR system screen displaying the aggregated values for a set of data is shown in Figure 12.

4.3.4 Example of Aggregation Method

For the "fails to operate" failure mode of battery chargers, the data shown in Table 13 are available. All entries except the IEEE-500 entry provide plant-specific data that are regarded as homogeneous. The IEEE-500 entry represents an aggregate that is intended to reflect performance across the industry. The point estimate of the failure rate (number of failures divided by the operating hours for the plant data) and the upper tolerance bound computed by NUCLARR for each point are also listed. Figure 12 shows the bounds and medians that NUCLARR uses for these points.

For the aggregation algorithms, the plant-specific data points fall into Table 11's Set 1, while the IEEE-500 point is in Set 5. Thus, two aggregates are formed and then combined. For Set 1, using EB Procedure #1 as outlined in Table 12, one finds that R is 9.7E-6 and R2 is 1.6E-10; thus, M_1 is -11.8 and S_1^2 is 0.52. Note that the upper bounds given in Table 13 are not used in this calculation.

```
-------------------------------Electrical---------------------------------
   Component: Circuit Breakers, Power
      Design: Unknown
Normal State: Normally Closed
Failure Mode: Fails to Operate Group                    3 Records Selected *
```

```
Ad Hoc Event Aggregations
```

Demand	Hourly
Median: 7.783E-004	Median: ------E----
Upper Bound: 5.072E-003	Upper Bound: ------E----

* 3 Qualified records aggregated

```
COMMAND [ ]  Exit  Next/Previous Event  View Event data records  ? Hotline #
         * Displaying AdHoc aggregated event for located sources *
```

Figure 12. Aggregated value for HCFD records.

TABLE 13. EXAMPLE DATA FOR BATTERY CHARGERS

Study ID[a] Document No.)	Failures	Operating Hours	Estimated Rate (failures/hr)	Upper Bound
NEE3 PRA (21281)	1	96426	1.04E-5	3.27E-5
ZIS-PRA (21381)	0	202000	0	7.96E-6
IPS2 PRA (20982)	0	95800	0	1.96E-5
MNS1 PRA (21185)	5	229488	2.18E-5	4.29E-4
HNP1 PRA (20586)	6	175200	3.43E-5	6.38E-5
IEEE 500 (5383)	--	--	6.2 E-7	2.84E-5
IPRDS (3685)	3	223375	1.34E-6	3.50E-5
IPRDS (3685)	0	56950	0	5.30E-5
IPRDS (3685)	1	733320	1.36E-6	6.50E-6
IPRDS (3685)	3	162930	1.84E-6	4.80E-5
IPRDS (3685)	5	1007400	4.96E-6	1.00E-5
X-PRA (21687)	8	304128	2.69E-5	4.53E-5

a. The Study ID is a brief study name associated with each data source. Because it describes studies, it does not have to be unique for each data source. It is an attribute of the Document file.

For the second aggregate, the single IEEE-500 point is used directly. To use a point, the mean and variance of the underlying normal distribution must be computed. The normal distribution mean is simply the logarithm of the point estimate of the rate (M_2 = -14.3). From medians and upper upperbounds, the underlying normal distribution variance (S_2^2) for the IEEE-500 battery charger fail to operate distribution is found to be 5.41. (Note that lower bounds are not needed for this calculation). If several generic data points were being combined, the mixture method at the bottom of Table 12 would have been applied. Weights would be taken to be inversely proportional to the individual variances and the resulting data would be substituted in the mixture equation at the bottom of Table 12 in order to obtain M_2 and S_2^2.

The last step is to use the same mixture equation at the bottom of Table 12 to combine the two overall aggregates, with weights W_1 = 11/12 and W_2 = 1/12. The result of the calculation is M = -12.02 and S^2 = 1.45. This is the mean and variance of a normal distribution; the corresponding lognormal distribution for the rates has median, exp M; mean, exp M * exp ($S^2/2$); and error factor, exp (1.645 S). The 95% upper bound is found by multiplying the median times the error factor.

For the battery chargers, the resulting distribution for the rate of failure to operate, per hour, has the following attributes:

Number of records:	12
Mean:	1.2E-5
Median:	6.1E-6
Upper bound:	4.3E-5
Error Factor:	7.0

4.3.5 Interpretation of Upper Bounds

As stated above, two types of calculations are performed by the NUCLARR system for the component failure data. The first is processing of individual records as they are entered into the system, while the second concerns the combining or aggregating of failure rates from several sources for a particular type of failure. A brief discussion of the impact of these calculations, particularly on the upper bounds reported for the failure rates, will help the NUCLARR user better appreciate their significance.

4.3.5.1 Bounds for Single Data Points. On data entry, the NUCLARR system computes a median, upper bound, and lower bound for each data point (if sufficient information is available). The error factor is defined as the upper bound divided by the median, and the lower bound is the median divided by the error factor. If a record supplies raw data (numbers of failures and corresponding operating hours or demand counts) and meets the criteria established in the NUCLARR system for homogeneity, upper tolerance bounds are computed using the raw data. The results of these computations are approximately as follows:

Number of Failures	Assessed Upper Bound Divided by Median (Error Factor)
0	8.4
1	3.3
2	2.6
3	2.2
4	2.0
7	1.7
15	1.5
20	1.4
50	1.3

(This table contains ratios of 95th-to-50th percentiles for chi-square distributions with two times the number of failures plus one as the degrees of freedom). Because approximately 90% of the data fall into this category, bounds from most of the single-record failure rates reflect these conditions. Individual bounds show in the plots produced by NUCLARR; most of the cases for which the median to upper bound span is one cycle on the logarithmic scale (and thus the error factor is approximately 10) are cases where no failures were observed.

In cases where no raw data are provided, bounds for individual points are computed from bounds in the data sources if these are available. The bounds are adjusted so that the upper bounds are approximately 95% bounds. In risk assessment, knowledge of upper bounds on failure rates is important in analyses the seek to limit the risk. One is seldom concerned about how small a failure rate might be. Therefore, lower bounds are simply plotted as medians divided by error factors.

The NUCLARR system retains point estimates of failure rates, such as estimates directly cited in a data source or numbers of failures divided by numbers of demands. However, the means and medians reported in the Data Summary screens are generated by NUCLARR's input data processing routines. This means that they fit a lognormal distribution.

4.3.5.2 Bounds for Aggregations of Several Data Points. The upper bounds computed by NUCLARR are percentile bounds. These bounds are upper percentiles of the lognormal distributions selected to best fit the data being combined. As such, 95% of each fitted failure rate distribution lies below the corresponding upper bound. However, points being aggregated commonly lie outside, and particularly above, the resulting aggregated bounds. Three other apparent anomalies can occur: the aggregate median may be less than the medians of each of the points being aggregated, an upper bound may decrease when a low-valued rate is deselected (omitted) from the set being combined, and the computed bounds may in some cases be very narrow. These situations can particularly be seen when one requests plots of the data. Each of these situations is discussed below.

Three aspects of the methodology account for aggregated bounds being lower than medians of some of the points being combined:

- o Points showing high failure rates are often cases where little experience is available (that is, often such points are high because the denominators are low).

- o In aggregations using raw data, often the data are pooled. The aggregate is based on the combined experience of the various sources. In cases where many of the sources show no failures, the resulting average (sum of numerators divided by sum of denominators) is lower than any of the values contributing to it.

- o The sources are weighted in proportion to the amount of experience that they represent. That is, individual rates (numbers of failures divided by numbers of demands or operating hours) having large denominators are most influential in the results. These rates are often, though not always, among the lower values shown in the plots.

The situation of an aggregated median being lower than the medians of all the points being combined occurs when the error factor is very large. The aggregation method is based on matching means and variances. Thus, the mean value and spread of a distribution are preserved. However, for a lognormal distribution, the only way to have a large error factor (showing large variation) is to have a relatively large ratio for the mean divided by the median. Thus, with the mean value fixed and a large error factor, any fitted lognormal median will be low. This constraint could be removed by matching medians instead of means or by selecting a different distribution type than lognormal. When this situation occurs, the user is advised to select the aggregated mean for analysis rather than the median.

When a record with a very low failure rate is deselected from the search buffer, one might expect the resulting aggregated median and upper bound to be larger than they were with the low rate included. As expected, medians increase when a low rate is omitted. However, upper bounds may decrease. Like the issue just discussed, this phenomenon is caused by the nature of lognormal distributions. On a log scale, these distributions are symmetric normal distributions. Omitting a low-valued data point reduces the uncertainty in the data; therefore, it automatically lowers upper bounds as well as increasing lower bounds.

Finally, low error factors are caused by two situations in the aggregation algorithms. The first is the presence of a data point showing several failures and millions of operating hours or demands. A large number of failures drives down the uncertainty in the failure rate, as shown in Section 4.3.5.1. When these failures are associated with a data point showing a large amount of experience, other data sources showing a variety of rates have little influence because of the weighting of the data. This problem is compounded by the fact that data points that reflect a great deal of experience often have been pooled across several components; the possibility exists that these components as a group do not have a constant failure rate.

In addition, lower error factors may be the result of an anomaly in the upper bound calculation for the aggregation algorithm itself. The algorithm attempts to characterize the distribution of failure rates by considering different estimates of a rate rather than the uncertainty estimated for each individual rate. The Bayesian procedures estimate a variance between separate estimates of failure rates, subtracting out the variation associated with the individual estimates. Unusually low error factors result if, for example, two points are close together even though their individual uncertainty bounds are large. Some variety is expected for generic rates that will apply across the nuclear power plant industry; therefore, the heavy influence of just one point, or of two points that are close together, may not be desirable. A possible future modification to NUCLARR is to adjust such low error factors. For example, all error factors less than 1.5 could be set equal to 1.5 and the upper bounds and mean values (based on a fitted lognormal distribution) recomputed.

5. COMMON CAUSE FAILURE DATA

Surveys of NRC and industry experts have revealed the need for a PC-format common cause data base. The inclusion of a common cause data category in NUCLARR is currently under development, with completion anticipated in early 1990.

A review of formats and methods for the calculation and presentation of common cause data revealed no conflict with the existing NUCLARR system. Many of the hardware and plant codes will be used to support the development of common cause software. In addition, the same programming environment and existing menu system of NUCLARR are particularly well suited to the addition of a common cause data module.

Within the NUCLARR system, both types of common cause failure data (historical event data and model parameter estimates) may be easily accessed by the risk analyst. Common cause data retrieval will be possible from the main menu in NUCLARR. Further specifications for accessing and aggregating historical events (primarily LER-based) and model parameter estimates (taken mainly from PRAs) will be available from a Common Cause data menu.

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*Available for inspection and copying for a fee in the NRC Public Document Room, 2120 L Street (Lower Level), NW., Washington, D.C.

APPENDIX A

DEFINITIONS OF EQUIPMENT CHARACTERISTICS AND HUMAN ACTIONS FOR CLASSIFYING HUMAN ERROR PROBABILITY (HEP) DATA

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APPENDIX A

DEFINITIONS OF EQUIPMENT CHARACTERISTICS AND HUMAN ACTIONS FOR CLASSIFYING HUMAN ERROR PROBABILITY (HEP) DATA

DEFINITIONS OF EQUIPMENT CHARACTERISTICS

Equipment characteristics on all three levels of the HEP data taxonomy are defined in this appendix. The definitions are organized as follows:

- o Level 1 (systems)
  - General Electric systems
  - Westinghouse systems
  - Combustion Engineering systems
  - Babcock & Wilcox systems
- o Level 2 (components)
- o Level 3 (displays/instruments/controls)

Within each of the above categories, the definitions are listed in the order that the equipment characteristics appear on the matrices. In addition, human actions used in NUCLARR for each level are defined.

Level 1--General Electric Systems[a]

Air Systems

Air systems provide the proper type and pressure of air to operate necessary instrumentation and equipment in the plant. The air systems include service air and instrument air systems.

Instrument Air System--The instrument air system provides a continuous supply of clean, dry, oil-free compressed air for use by plant instrumentation, various air-operated valves, and control devices.

Service Air System--The service air system provides a continuous supply of compressed air, without drying or filtration, for such functions as backwashing, mixing, and agitation as well as general plant use. Some plants utilize service air as a backup to instrument air.

Annunciator Systems

Annunciator systems are hardwired systems that provide the operator with the audio and visual alarm information required for unit operation,

---

a. An asterisk indicates that this definition of a General Electric system is based on the Nuclear Plant Reliability Data System (NPRDS).

startup, and shutdown. These systems are independent of the plant computer system and include the controls necessary to acknowledge, silence, and reset alarms.

Communication Systems

Communications systems provide reliable and convenient communciations among onsite personnel and between on-site and off-site locations. These systems include an intraplant public address system, a private telephone system to permit plant-to-off-site communication on a continuous basis, and a two-way radio communication system.

Compressed Gas Systems

Compressed gas systems store and distribute as required the necessary gases used to operate and maintain the plant. Typical gases are hydrogen, oxygen, CO_2, argon, and acetylene.

Condensate Systems*

Condensate systems deliver condensate from the main condenser hotwell to the suction of the reactor feed pumps (feedwater system) that supply the water to the reactor vessel for conversion into steam. The hotwell pumps, arrange in parallel, take condensate from the condenser hotwell and pump it through an offgas condenser, a gland steam condenser, and two steam jet air ejector intercondensers in which the condensate can gain additional energy prior to entering the feedwater system. The condensate booster pumps drive the condensate through parallel component arrangements, each consisting of a feedwater heater drain cooler and feedwater heaters. After exiting the feedwater heaters, the condensate enters the feedwater system by way of the reactor feed pumps.

The boundary of the systems is at the outlet of the condenser; however, the condensate storage tank is considered part of these systems because of its safety funcitons.

Condensate Cleanup System--The condensate cleanup system removes dissolved and suspended impurities from the condensate. The system consists of parallel operating demineralizers. External resin regeneration facilities are considered part of this system.

Condenser Air Removal System--The condenser air removal system maintains a vacuum in the main condenser sections during normal plant operation by removing noncondensible gases with steam jet air ejectors. This system, utilizing mechanical vacuum pumps, will also establish the initial vacuum when steam pressure is inadequate to operate the steam jet air ejector units. The condenser air removal system exhausts to the offgas system.

Containment Systems

Containment systems serve as a pressure boundary and shielding for the reactor if there is release of radioactivity from the reactor. The containment systems include the containment atmosphere cooling, containment combustible gas control, containment penetration/isolation, containment spray, standby gas treatment, and suppression pool support systems.

Containment Atmosphere Cooling System*--The containment atmosphere cooling system removes heat energy from the drywell atmosphere in order to maintain the containment atmospheric pressure below design pressure. The containment atmosphere cooling system consists of one or more cooling fans and cooling coils. Heat is usually via the reactor building closed cooling water system, but other cooling methods may be used.

Containment Combustible Gas Control System*--The containment combustible gas control system is one of two types: the dilution type or the recombiner type. The dilution subsystem provides the means by which the containment atmosphere is diluted with clean air and vented to the atmosphere. The hydrogen recombiner system maintains the hydrogen concentration below 4% by volume in the containment following a design-basis LOCA without reliance on purging. The system basically consists of a skid-mounted thermal recombiner unit with associated valves, piping, instrumentation, and controls.

Containment Penetration/Isolation System*--The containment penetration/isolation system comprises all primary containment penetrations and all accesses regardless of size. Equipment and personnel access hatches and fuel transfer tubes are considered components. All associated instruments, monitors, etc., are considered piece parts of the access or penetration. This system includes maintenance hatches and all electrical, mechanical, piping, and instrumentation penetrations.

Containment Spray System*--The containment spray system, a subsystem of the residual heat removal (RHR) system, aids in reducing drywell pressure following a LOCA. With the RHR system in the containment spray mode of operation, the RHR pumps transfer water from the suppression pool through the residual heat exchangers, where heat is removed by the RHR service water. The cooled water is diverted to two redundant spray headers embedded in and protected by the primary shield wall located in the drywell. Some of this water may be diverted to a header suspended above the suppression pool, as well as to a line that directs flow to the lower portion of the suppression chamber.

Standby Gas Treatment System*--The standby gas treatment system maintains a small negative pressure in the reactor building under isolation conditions and prevents ground level escape of airborne radioactivity. Filters are provided in the system to remove radioactive particulates, and charcoal absorbers are provided to remove radioactive halogens that may be present in concentrations significant with respect to environmental dose.

The system is sized to provide one air change per day in the reactor building. Two separate filter absorber/fan units are provided, and both fan units automatically start on a standby gas treatment system initiate signal. Both units receive power from emergency electrical supply.

Suppression Pool Support System*--The suppression pool support system consists of three subsystems: the makeup subsystem, the temperature-monitoring subsystem, and the cleanup subsystem. The cleanup subsystem removes sludge, corrosion products, and iodine remaining in the pool after blowdown from the reactor vessel. The temperature-monitoring subsystem consists of a number of temperature detectors located around the suppression pool that monitor the water temperature and initiate alarms if the technical specification limit is approached or exceeded. The makeup subsystem provides additional water to the suppression pool to maintain the minimum top vent coverage while the emergency core coolant pumps are operating during the initial phase of a LOCA.

Control Rod Drive Systems

Control rod drive systems comprise the hydraulic supply subsystem, the hydraulic control units, the scram discharge volume, the control rod drive housing, and the control rods. These systems provide shaping of the neutron flux across the fuel and scram the reactor. The redundant supply pumps develop pressure over the nitrogen accumulators located in the individual rod drive hydraulic control untis. A reactor scram signal releases pressurized water in the lines charged by these accumulators to drive the control rods into the reactor. The water that is displaced by this action is exhausted into the scram discharge volume.

Although hydraulic control units are not control rod drive mechanisms, they are considered to be in the same category.

Electrical Distribution Systems

Electrical distribution systems provide a means of receiving off-site power and a means of transmitting site-generated power. These systems supply power to those auxiliaries needed for power generation by the plant. The electrical distribution systems include the ac instrument power, dc power, and plant ac distribution systems.

ac Instrument Power System*--The ac instrument power system provides an uninterruptible source of power for instruments and control circuits under all plant conditions. Any load circuit breakers that may supply several loads are considered part of the ac instrument power system. Breakers that supply a single system are considered part of the system suppplied. All ac power that feeds instruments or supports a safety function is considered part of this system.

dc Power System*--The dc power system supplies electric power to both safety-related and non-safety-related dc loads under any plant conditions.

The dc power can be supplied by either a battery or battery charger. Any dc circuit breakers that may supply several loads (to different systems), such as several solenoid valve controls or control power for an ac switchgear, are considered part of the dc power system. The three dc distribution systems used in GE plants are all considered part of this system.

Plant ac Distribution System*--The plant distribution system provides electric power to both safety-related and non-safety-related loads during normal plant operation. Electric power is supplied at various voltage levels that are connected in a hierarchical fashion.

Emergency Core Cooling Systems

Emergency core cooling systems are designed to mitigate the consequences of postulated emergency situations that could otherwise lead to core damage and release of fission products to the environment. The emergency core cooling systems include the high-pressure coolant injection, high-pressure core spray, low-pressure core spray, and residual heat removal/pressure coolant injection systems.

High-Pressure Coolant Injection System*--The high-pressure coolant injection system is used in Marks 1-5 to ensure that the reactor is adequately cooled, limiting the fuel cladding temperature. It is initiated in the event of a small break in the nuclear steam system and loss of coolant that does not result in rapid depressurization of the reactor vessel. The high-pressure coolant injection system permits the plant to be shut down while maintaining sufficient reactor vessel water inventory until the reactor vessel is depressurized. The high-pressure coolant injection system continues to operate until the reactor vessel pressure is below the pressure at which low-pressure coolant injection operation or core spray system operation can maintain core cooling.

High-Pressure Core Spray System*--The high-pressure core spray system is typical of Mark 6 design. It operates in the event of a LOCA by spraying makeup water on the reactor core, thus depressurizing the reactor vessel and preventing fuel damage. In the event of a low water level in the reactor vessel, makeup water is pumped to the reactor vessel and discharged through spray nozzles onto the reactor core. The primary source of makeup water to the system is the condensate storage tank, with the suppression pool serving as a secondary source.

The high-pressure core spray actuation controls are considered a part of the system. Some plants may use a keep-fill system.

Low-Pressure Core Spray System*--The low-pressure core spray system helps prevent nuclear fuel damage in the event a LOCA occurs that might uncover the reactor core. Water is sprayed on the core to maintain the temperature at a safe level. The system goes into operation after the reactor vessel pressure has been reduced and only if other safety systems prove inadequate in maintaining the necessary water level in the reactor vessel.

The low-pressure core spray actuation controls are considered a part of the system. The number of pumps and loops will vary with design. Some plants may use a keep-fill system instead of a head tank.

Residual Heat Removal/Low Pressure Coolant Injection System*--The residual heat removal system is a closed-loop system of piping, water pumps, and heat exchangers for decay heat removal under both operational and accident conditions. This removal is accomplished by several related but independent modes of operation:

Low-Pressure Coolant Injection--The low-pressure coolant injection mode of the residual heat removal system operates to restore and maintain, if necessary, the water level in the reactor vessel after a LOCA. Low-pressure coolant injection also provides protection for small breaks in which the control rod drive water pumps, reactor core isolation cooling, and high-pressure coolant injection are unable to maintain water level and the automatic depressurization system has operated to lower reactor pressure. The low-pressure coolant injection actuation controls are also a part of the residual heat removal system.

Suppression Pool Cooling--This mode of residual heat removal is initiated manually as soon as possible after isolation of the primary system from the condenser. Its function is to cool the suppression pool so that pool temperatures do not exceed 170 F after a blowdown.

Shutdown Cooling: The shutdown cooling mode of the residual heat removal system provides for the removal of decay heat and sensible heat from the primary system during shutdowns for refueling or servicing.

Fire Protection Systems

Fire protection systems furnish water or fire extinguishing chemicals to areas throughout the station to minimize the adverse effects of fire on station structures, equipment, and personnel.

Generator Systems

Generator systems convert the rotating mechanical energy of the turbines into electrical energy. Generator systems include the generator excitation system, generator H_2 cooling/CO_2 purge system, generator seal oil system, and generator stator water cooling system.

Generator Excitation System--The generator excitation system provides a regulated, controllable source of magnetizing power to the rotating generator field winding, which controls generator output voltage. The generator excitation system consists of the alternator exciter, exciter field breaker and rectifier, voltage regulators, and all associated controls and instrumentation.

Generator H_2 Cooling/CO_2 Purge System--The generator H_2 cooling/CO_2 purge system keeps the generator adequately cooled by maintaining proper generator hydrogen pressure, temperature, and purity. The system consists of hydrogen coolers, storage cylinders, regulatory valves, a hydrogen control panel, and associated piping and instruments. The carbon dioxide supply used to purge the generator comes from a CO_2 storage tank. The generator gas monitoring subsystem is included in this system.

Generator Seal Oil System--The generator seal oil system contains the hydrogen within the generator casing, preventing leakage of hydrogen out of the generator and leakage of air into the generator. This system supplies seal oil under pressure to the generator hydrogen shaft seals. This system consists of various seal oil pumps, vacuum tank, oil filters, pressure regulators, and associated instruments. Seal oil is supplied by the turbine lube oil system.

Generator Stator Water Cooling System--The generator stator water cooling system cools generator stator bars, the generator terminal box in the lower frame extension, and the exciter rectifiers. This is a closed system that consists of cooling pumps, water coolers, deionizer and filter regulatory valves, and assorted piping and instruments.

Heating, Ventilation, and Air Conditioning (HVAC) Systems

Heating, ventilation, and air conditioning systems provide an environment with controlled temperatures, humidities, and air flow patterns to maintain an atmosphere that ensures the comfort and safety of personnel and the operability of equipment located in the containment, drywell, and other small areas.

High-Pressure Core Spray (HPCS) Diesel Generator Systems*

High pressure core spray diesel generator systems supply electric power to the HPCS during abnormal plant conditions such as a plant blackout or LOCA. Diesel start and generator breaker closing control circuits are considered a part of HPCS diesel generator systems. The ground fault breakers and exciter are considered piece parts of the diesel. The sequencer and load-shedding relays and the starting circuit breaker are considered part of the systems.

High-Pressure Core Spray (HPCS) Cooling Water Systems--The HPCS cooling water system provides adequate water flow to remove heat from the diesel engine during operation. A jacket heating loop also is provided to prevent thermal shock when the diesel is started.

High-Pressure Core Spray (HPCS) Fuel Oil Storage and Transfer System*--The HPCS fuel oil storage and transfer system supplies fuel to run the diesel engine in the HPCS diesel generator system and stores enough fuel for several days' continuous operation. Fuel supplied from the day tank may be pumped into the diesel, or a gravity feed may be used.

High-Pressure Core Spray (HPCS) Lube Oil System*--The HPCS lube oil system provides oil to lubricate the moving parts of the diesel engine in the HPCS diesel generator system, thus protecting it from excessive wear and overheating. Adequate lube oil pressure is usually a permissive signal in the diesel generator starting circuit. During diesel operation, the lube oil is normally circulated by engine-driven oil pumps that are considered piece parts of the diesel engine. Prior to the diesel start, a motor-driven oil pump supplies oil pressure.

High-Pressure Core Spray (HPCS) Starting Air System*--The HPCS starting air system is designed to provide compressed air to assist in the rapid starting of the diesel engine in the HPCS diesel generator system.

Instrumentation and Control Systems

Instrumentation and control systems provide timely operation of equipment needed for proper plant operation and the necessary indication of plant parameters and equipment conditions.

Area Radiation Monitoring System--The area radiation monitoring system indicates alarms and records abnormal radiation levels in areas where radioactive material may be present, stored, handled, or inadvertently introduced. The system consists of a number of radiation monitors and the associated instrumentation.

Automatic Depressurization System--The automatic depressurization system, in the event of a small break in the reactor coolant pressure boundary concurrent with a failure of the high-pressure emergency core cooling system to adequately cool the reactor core, depressurizes the reactor vessel and thus allows the low pressure emergency core cooling systems to flood the core and prevent fuel cladding damage.

The automatic depressurization system consists of redundant signal logics arranged in two separate channels that control separate valves on each safety relief valve that has been assigned the automatic depressurization system function.

Containment Atmosphere Monitoring System--The containment atmosphere monitoring system provides a means of measuring the drywell and containment hydrogen gas concentrations and radiation levels following a LOCA.

Electrohydraulic Control (Turbine Control) System--The electrohydraulic control (turbine control) system controls the speed and acceleration of the main turbine, operates the steam bypass system to keep reactor pressure within limits and avoid pressure/power transients, and controls main turbine inlet pressure. The electrohydraulic control (turbine control) system also matches nuclear steam supply to turbine steam requirements during automatic load following operation.

Feedwater Control System--The feedwater control system maintains the water level in the reactor vessel within a programmed range during all modes of plant operation by regulating the flow of feedwater as a function of vessel water level and steam flow from the vessel.

Leak Detection System--The leak detection system detects and annunciates the escape of potentially radioactive material from the reactor coolant pressure boundary. In addition, the leak detection system is capable of determining the rate of leakage and initiating action to isolate systems that are leaking at a substantial rate in order to protect the nuclear fuel from damage that may be caused by the loss of coolant.

Main Steam Isolation Valve (MSIV) Leakage Control System--The MSIV leakage control system controls and minimizes the release of fission products that could leak through the closed MSIVs following a LOCA by directing the leakage through bleed lines into an area served by the standby gas treatment system for processing prior to release to the atmosphere.

Neutron Monitoring system--The neutron monitoring systems provide neutron flux level monitoring of the reactor by utilizing three instrument ranges: source, intermediate, and power. These instruments perform continuous monitoring and provide automatic safety protection and interlock features.

Nuclear Steam Supply Shutoff System*--The nuclear steam supply shutoff system establishes the requirements that are necessary to maintain the leaktightness of the reactor containment. It provides the means by which the various fluid systems.that penetrate the reactor containment can be isolated reliably. Isolation is generally accomplished by utilization of the penetrating systems' isolation valves. Components in this system are considered to be any isolation valves that are part of another system (e.g., waste gas or liquid waste isolation valves) and the nuclear steam supply shutoff system actuation logic.

Process Radiation Monitoring System*--The process radiation monitoring system monitors radiation levels of certain liquid and gaseous processes throughout the nuclear power plant. The process radiation monitoring system assists in controlling the release of radioactive byproducts within legally prescribed limits and provides for personnel safety by warning of abnormal radiation levels.

The process radiation monitoring system also includes main steam line radiation monitoring, which detects significant increases in the gross gamma radiation level and initiates control action. Such increases in radiation level are caused by fission products in the main steam lines.

Reactor Protection System*--The reactor protection system detects conditions that threaten the fuel or reactor coolant pressure boundary and initiates an automatic reactor shutdown (scram) when monitored system parameters exceed predetermined limits. This action prevents fuel damage and damage to the reactor coolant pressure boundary and limits uncontrolled releases of radioactive material.

Remote-mounted instrumentation and interfaces with selected systems feed information to the reactor protection system logic circuitry. When threshold values are exceeded, actuator logic generates a signal that deenergizes the scram pilot valves, which in turn open the inlet and outlet air-operated scram valves, allowing the primary control rod drive hydraulic pressure or accumulator pressure to scram the control rods. Once the system is actuated, the scram goes to completion unless a deliberate action is taken by the plant operator. In addition to automatic operation, a manual mode is provided.

Any instrumentation is considered part of the reactor protection system if it provides input into the reactor protection system.

Remote Shutdown System--The remote shutdown system provides a reactor plant shutdown capability located outside the control room for situations when the control room may have to be evacuated. The remote shutdown system provides all the controls and indication necessary to shut down the reactor as well as to provide subsequent reactor plant stabilization and cooldown.

Rod Control and Information System--The rod control and information system (RCIS) provides a means of making changes in the reactor core reactivity so that reactor power level and power (neutron flux) distribution can be controlled. This function is performed by providing the controls necessary to permit operator execution of control rod movements in the reactor core. The RCIS also functions to limit the worth of any control rod to reduce the effects from a rod drop accident or a rod withdrawal error by enforcing adherence to predetermined control rod patterns through the use of control rod blocks. The RCIS consists of the electronic circuitry, switches, indicators, and alarm devices necessary for the manipulation of control rods. Some GE plants refer to this system as the reactor manual control system or rod sequence control system.

Traversing In-core Probe System--The traversing in-core probe system serves as a calibration device for the local power range monitoring (LPRM) system. The traversing in-core probe system is capable of sensing neutron flux in the immediate vicinity of the permanently installed LPRM fission chambers. The flux signal is used to perform LPRM channel calibrations, compensate for changes in detector sensitivity, and provide line plots of the actual flux distribution.

Process Sampling Systems

Process sampling systems monitor the operation of plant equipment and provide information needed to make operational decisions. These systems provide remote sampling facilities and the capability for sampling fluids of various process systems during normal plant power operation and shutdown conditions.

Radwaste Systems

Radwaste systems collect, process, monitor, store, and dispose of all radioactive wastes. The radwaste systems include the liquid radwaste, offgas, and solid radwaste systems.

Liquid Radwaste System--The liquid radwaste system collects, processes, stores, and monitors, for reuse or disposal, all potentially radioactive liquid wastes. The liquid radwaste system consists of one or more subsystems designed to handle specific types of liquid wastes, such as water, chemical solutions from the demineralizer resin regeneration process, and evaporator distillate.

Offgas System--The offgas system receives air and noncondensible gases from the condenser air removal system and processes the effluent for decay and/or removal of gaseous and particulate radioactive isotopes before release to the environment.

Solid Radwaste System--The solid radwaste system collects, processes, packages, and temporarily stores, prior to off-site shipping, such wastes as spent resins, evaporator concentrates, and chemical drain tank effluents. Liquid-bearing wastes are dewatered and solidified. Contaminated solids such as filters, rags, paper, clothing, and tools are compacted.

Reactor Coolant System and Connected Systems

The reactor coolant system includes the reactor pressure vessel, the reactor recirculation system, and the main feedwater system extending to and including the outermost containment isolation valves.

Systems are connected to the reactor coolant system to perform the following functions: (a) provide makeup water to the reactor, (b) remove solids and dissolved impurities from the reactor coolant, and (c) provide emergency reactivity control. Functions such as residual heat removal and emergency core cooling are not considered part of these systems.

Feedwater System*--The feedwater system provides feedwater to the reactor to maintain a constant reactor water level. It takes suction from the condensate system and delivers water to the reactor vessel at an elevated pressure and temperature.

Isolation Condenser System*--The isolation condenser system provides a heat sink for the reactor if the reactor is isolated from its main condenser or if all feedwater is lost. The isolation condenser system operates by natural circulation without the need to place the system in operation. The condenser consists of two tube bundles immersed in a large water storage tank. When the isolation condenser is in operation, steam flows from the reactor through the tubes of the heat exchanger; after condensing, it returns by gravity to the reactor. The isolation condenser is located high in the reactor building to facilitate natural circulation.

Reactor Core Isolation Cooling (RCIC) System*--The RCIC system provides makeup water to the reactor vessel during shutdown and isolation of the reactor vessel from the main condenser. The RCIC system consists of a steam-driven turbine pump unit and associated valves and piping capable of delivering makeup water to the reactor vessel.

The steam supply to the RCIC pump turbine comes from the main steam system. The steam exhausted from the turbine dumps to the suppression pool. The pump can take suction from the demineralized water in either the condensate storage tank or from the suppression pool. The pump discharges either to the feedwater line or to a full-flow return test line running to the condensate storage tanks via the high-pressure coolant injection test line. A minimum flow bypass line to the suppression pool via the residual heat removal test line provides pump protection. The makeup water is delivered into the reactor vessel through a connection to the feedwater line, where it is distributed within the reactor vessel through the feedwater sparger.

Reactor Recirculation System*--The reactor recirculation system consists of two loops external to the reactor vessel, each loop containing a recirculation pump and motor, suction and discharge valves, a discharge bypass valve, and connecting piping to the reactor vessel.

Flow Path (BWR 3 through 6)--The jet pump recirculation system provides forced circulation flow through the BWR core. The recirculation pumps take suction from the downward flow in the annulus between the core and the vessel wall, and the pressure is increased to provide the driving force for the jet pump. This driving flow is discharged in the jet pump nozzle, inducing the remainder of the downcomer flow. In the jet pumps, these flows mix, diffuse, and discharge into the lower core plenum.

Flow Control (BWR 3 and 4)--A variable-speed pump motor is supplied from a variable-frequency motor-generator set. The motor-generator set is located outside the drywell.

Flow Control (BWR 5 and 6)--The flow control valve is a ball type with electrohydraulic activator. The bypass valve is used for plant startup (low-flow) conditions.

Reactor Water Cleanup System--The reactor water cleanup (RWCU) system maintains reactor water quality by removing fission products, corrosion products, and other soluble and insoluble impurities.

The flow path of the RWCU system includes high-pressure flow through RWCU pumps, regenerative and nonregenerative heat exchangers with lines provided for system water sampling and the required instrumentation for effluent operation.

Flow can be routed through the RWCU demineralizer subsystem, which consists of filter/demineralizers and support equipment such as pumps and tanks.

Standby Liquid Control System*--The standby liquid control system is a redundant, independent control system for use in the unlikely event that the control rod system becomes inoperable. The system will shut down and hold the reactor subcritical as the reactor cools and xenon decays.

Refueling Systems

Refueling systems provide a safe and effective means for transporting and handling fuel from the time it reaches the plant until it leaves the plant. The refueling systems include the fuel handling and fuel pool cooling and cleanup systems.

Fuel Handling System--The fuel handling system consists of the mechanical and electrical components required to manipulate nuclear fuel through the various movements and operations undergone while in the reactor building. Reactor vessel servicing equipment is provided to support fuel handling as well as the nonroutine removal of reactor vessel equipment.

Fuel Pool Cooling and Cleanup System--The fuel pool cooling and cleanup system removes decay heat from the fuel and maintains acceptable pool water level, water quality, and radiation levels. The fuel pool cooling and cleanup demineralizer subsystem removes dissolved and suspended solids from the water.

Standby Diesel Generator Systems*

Standby diesel generator systems supply electric power to vital safety-related loads during abnormal plant conditions, such as a plant blackout or LOCA. These systems typically have two to four diesel generator units. The diesel start, load-shedding, generator breaker closing, and sequencing control circuits are considered part of the standby diesel generator systems.

Sequencer and load-shedding relays and the starting circuit breaker are considered part of these systems. Some units may use gas or hydraulic turbines to supply emergency power. These components are considered part of these systems.

The high-pressure core spray diesel generator system is considered a separate system.

Standby Diesel Generator Cooling Water System*--The standby diesel generator cooling water system provides adequate water flow to remove heat from the diesel engine during operation. A jacket heating loop is also provided to prevent thermal shock when the diesel is started.

Standby Diesel Generator Fuel Oil Storage and Transfer System*--The standby diesel generator fuel oil storage and transfer system supplies fuel to run the diesel engine and stores enough fuel for several days' continuous operation. Fuel supplied from the day tank may be pumped to the diesel.

Standby Diesel Generator Lube Oil System*--The standby diesel generator lube oil system provides oil to lubricate the moving parts of the diesel engines, thus protecting them from excessive wear and overheating. Adequate lube oil pressure is usually a permissive signal in the diesel generator starting circuit. During diesel operation, the lube oil is normally circulated by engine-driven oil pumps that are considered piece parts of the diesel engine. Prior to the diesel start, a motor-driven oil pump supplies oil pressure.

Standby Diesel Generator Starting Air System*--The standby diesel generator starting air system is designed to provide compressed air to assist in the rapid starting of the diesel engines in the standby diesel generator system.

Steam Systems

The steam systems are used to generate and/or transfer steam to the main turbine and other auxiliaries during various modes of plant operation.

Auxiliary Steam System--The auxiliary steam system provides a reliable source of clean steam to various plant components when the main steam system is not available.

Main Steam System*--The main steam system transports steam from the reactor vessel to the turbine-generator. The scope of the main steam system includes the four main steam lines and their components from the interface with the reactor pressure vessel to the main turbine stop valves. Also included is the automatic depressurization system comprised of safety relief valves, lines, and quencher/diffusers located in the suppression pool and the turbine steam bypass equipment.

Turbine Systems

Turbine systems convert the thermodynamic energy of steam to drive the main generator for the production of electricity. Turbine systems are composed of turbines, the extraction steam system. turbine lube oil system, and turbine seal steam system.

Extraction Steam System--The extraction steam system provides heating steam to such components as feedwater heaters for condensate and feedwater heating, seal steam evaporators, and radwaste steam generators. The extraction steam system takes steam from the high-pressure turbine and low-pressure turbine extraction points and from the moisture separators.

Turbine Lube Oil System--The turbine lube oil system continuously supplies cool, clean lubricating oil to the turbine-generator and exciter bearings. The turbine lube oil system comprises lube oil reservoirs, lube oil pumps and coolers, and associated strainers, piping, and instrumentation.

Turbine Seal Steam System--The turbine seal steam system prevents the entrance of air and noncondensible gases into the main condenser and the leakage of radioactive steam to the atmosphere. Clean sealing steam is supplied to the turbine shaft glands and valve stems. Condensed sealing steam is returned to the main condenser.

Water Systems

Water systems provide the needed cooling and makeup water throughout the plant for safe and efficient operation of water-cooled components. The water systems include the circulating water, emergency (RHR) service water, essential service water, reactor building closed cooling water, turbine building closed cooling water, and station service water systems.

Circulating Water System--The circulating water system is a closed-loop system that removes the excess heat from the turbine exhaust steam and turbine bypass steam by continuously supplying cooling water from the cooling tower basin to the main condenser and returning the heated water to the cooling tower for cooling.

Emergency (RHR) Service Water System--The emergency (RHR) service water system removes heat from safety-related coolers and heat exchangers that are required for a safe reactor shutdown or for mitigation of the consequences of postulated accidents. It also serves those nonsafety-related cooling coils and heat exchangers that, because of plant reliability considerations, are serviced when the normally operating station service water is unavailable. This system may provide the capability to flood the reactor vessel, drywell, and containment during the post-LOCA period and to provide makeup water to the spent fuel pool under emergency conditions.

Essential Service Water System*--The essential service water system provides the final heat sink for waste heat loads. Water from the ultimate heat sink (river, ocean, bay, lake, etc.) is pumped through various heat exchangers and provides cooling both directly to heat loads, such as the residual heat removal system, and to intermediate, closed water systems, such as the reactor building closed cooling water system. Only piping and valves associated with essential loads (e.g., reactor building closed cooling water heat exchangers, emergency service water system heat exchangers, motor-generator oil coolers) are considered part of the system. Nonessential loads are not considered part of the system, except for the valves that isolate these loads. If dedicated cooling pumps for systems such as diesel cooling are used, they are considered part of the essential service water system.

Reactor Building Closed Cooling Water System*--The reactor building closed cooling water system removes waste heat from components of various systems that may contain potentially radioactive material. Heat is absorbed by the system's circulating water at various coolers and heat exchangers of reactor-associated systems and then rejected to the essential service water system at the closed cooling water heat exchangers. The system thus provides a closed cooling water loop between the possibly contaminated (radioactive) systems and the essential service water system.

The system consists primarily of circulating pumps, heat exchangers, circuit breakers, expansion tank, air separator, piping, valves, instrumentation, and controls.

Turbine Building Closed Cooling Water (TBCCW) System--The TBCCW system is a closed-loop system that provides cooling water to nonessential systems that are potentially radioactive. The system consists of pumps, heat exchangers, tanks, piping, valves, controls, and instrumentation. The TBCCW pumps are used to evaluate the cooling water through the TBCCW heat exchangers and the components cooled by the TBCCW system. Heat is rejected from the TBCCW heat exchangers to the final heat sink for waste heat loads.

Station Service Water System--The station service water system provides a continuous supply of cooling water to the auxiliary mechanical equipment associated with the power conversion systems and other auxiliary systems. This system also supplies cooling water to numerous emergency service water heat loads during normal plant operation.

Level 1--Westinghouse Systems[a]

Air Systems

Air systems provide the proper type and pressure of air to operate necessary instrumentation and equipment in the plant. The air systems include the instrument air and service air systems.

Instrument Air System--The instrument air system provides a continuous supply of clean, dry, oil-free compressed air for use by plant instrumentation, various air-operated valves, and control devices.

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a. An asterisk indicates that this definition of a Westinghouse system is based on the NPRDS.

Service Air System--The service air system provides a continuous supply of compressed air, without drying or filtration, for such functions as backwashing, mixing, and agitation as well as general plant use. Some plants utilize service air as a backup to instrument air.

Annunciator Systems

Annunciator systems are hardwired systems that provide the operator with the audio and visual alarm information required for unit operation, startup, and shutdown. These systems are independent of the plant computer system and include the controls necessary to acknowledge, silence, and reset alarms.

Communication Systems

Communication systems provide reliable and convenient communications among on-site personnel and between on-site and off-site locations. These systems include an intraplant public address system, a private telephone system to permit plant-to-off-site communication on a continuous basis, and a two-way radio communication system.

Compressed Gas Systems

Compressed gas systems store and distribute as required the necessary gases used to operate and maintain the plant. Typical gases are hydrogen, oxygen, CO_2, argon, and acetylene.

Condensate Systems*

Condensate systems provide continuous condensate flow from the condenser hotwells to the main feedwater pumps, which in turn provide feedwater to the steam generators at the required pressures and temperatures under all anticipated steady-state and transient conditions. Condensate systems consist of two or more parallel, interconnected trains. These take condensate from the condenser hotwells and discharge it into the low-pressure feedwater heaters, which in turn supply the feedwater pumps.

Condensate Cleanup System--The condensate demineralizer system maintains the required purity of the condensate and feedwater by using precoat filters and demineralizers.

Containment Systems

Containment systems serve as a pressure boundary and shielding for the reactor in the event there is release of radioactivity from the reactor. Containment systems include the annulus ventilation, combustible gas control, containment/reactor building penetration, containment fan cooling, containment isolation, containment spray, containment ventilation, and ice condenser systems.

Annulus Ventilation System*--The annulus ventilation system is designed to: (a) produce and maintain a negative pressure in the containment annulus following a LOCA; (b) minimize the release of radioactivity following a LOCA by recirculating a large volume of air compared to the amount discharged for pressure control; and (c) provide long-term fission product removal by filtration.

Combustible Gas Control System*--The combustible gas control system is one of three types: the dilution type, the igniter type, and the recombiner type. Any of the types may be used to control the concentration of hydrogen in the containment atmosphere. Hydrogen must be kept below 4.1% by volume, which is the lower explosive limit of hydrogen in air. The dilution system bleeds containment air out through a filtering system, replacing it with outside air. The igniter system burns the hydrogen to water, and the recombiner system uses a skid-mounted thermal recombiner unit, usually a catalytic type.

Containment/Reactor Building Penetration System*--The containment/reactor building penetration system comprises all primary containment accesses and penetrations regardless of size. Penetrations should not be considered part of any other system. Equipment and personnel access hatches and fuel transfer tubes are components of this system. All associated components are considered piece parts of the penetration.

Containment Fan Cooling System*--The functions of the containment fan cooling system are to: (a) reduce the pressure in containment following a LOCA or a steam line break inside containment; (b) remove fission products from the containment atmosphere should they be released during a LOCA; and (c) provide containment cooling during both normal plant operation and accident conditions.

The containment fan cooling units are used to cool the containment building atmosphere following a LOCA. Heat removed by the units is rejected to the ultimate heat sink via the service water system through an air-water heat exchanger. There are several variations to the design of the system.

Containment Isolation System*--The containment isolation system establishes the requirements that are necessary to maintain the leaktightness of the reactor containment. The containment isolation system provides the means by which the various fluid systems that penetrate the reactor containment can be isolated reliably. Isolation generally is accomplished by utilization of the penetrating systems' isolation valves. Any isolation valves not considered part of another system are to be included in this system.

Containment Spray System*--The containment spray system also includes systems, such as quench spray, that perform essentially the same function as containment spray. The containment spray system depressurizes and cools the containment to subatmospheric pressure and removes iodine from the containment atmosphere following a LOCA by spraying cool, treated water into the containment. Initially, water is taken from the refueling water storage tank. When this water source is depleted to a certain predetermined level, cooling is continued by recirculation from the reactor building sump. Spray additives such as NaOH may be used to scavenge the iodine.

Containment Ventilation System--The containment ventilation system consists of several subsystems, each of which has separate design objectives. The systems are designed around objectives relating to normal operation, personnel access, containment protection and accident conditions.

The containment air cooling subsystem is designed to maintain an acceptable temperature within the containment upper and lower compartments, reactor well, control rod drive mechanism shroud, and instrument room for the protection of equipment and controls during normal reactor operation and normal shutdown.

The containment purge subsystem is designed to maintain the environment in the primary and secondary containment within acceptable limits for equipment operation and personnel access and to limit the release of radioactivity to the environment.

The vacuum relief subsystem protects the containment vessel from an excessive external force.

The air return fan subsystem enhances the ice condenser and containment spray heat removal operation by circulating air from the upper compartment to the lower compartment, through the ice condenser, and back to the upper compartment. This subsystem limits the hydrogen concentration in potentially stagnant regions by ensuring a flow of air from these regions.

Ice Condenser System--The ice condenser system is a static system that rapidly absorbs the energy release resulting from a pipe rupture. The ice condenser is a completely enclosed, refrigerated, annular compartment formed between the crane wall and the containment shell. The refrigeration system that prevents melting and sublimation and the instrumentation that monitors and controls the refrigeration system are considered part of the ice condenser system.

Control Rod Drive Systems*

Control rod drive systems position the shutdown and control rod cluster control assemblies upon commands from the operator or the automatic rod control system, thus controlling reactor temperature and power distribution within the core. Power to control rod drive mechanisms is supplied by two motor-generator sets operating from two separate 480-V, three-phase buses. The generators, driven by motors, are paralleled through circuit breakers.

The power is distributed to the power cabinets through the two series-connected reactor trip breakers. Bypass breakers can be connected in parallel with the reactor trip breakers to facilitate on-line testing of the protective system. The power cabinets contain the solid-state electronics necessary to control power to the control rod drive mechanisms. The control rod drive mechanism is a magnetic, jacking-type device that moves the rod control cluster assemblies within the core.

Electrical Distribution Systems

Electrical distribution systems provide a means of receiving off-site power and a means of transmitting site-generated power. These systems supply power to those auxiliaries needed for power generation by the plant. The electrical distribution systems include the ac instrument power, dc power, and plant ac power systems.

ac Instrument Power System*--The AC instrument power system provides an uninterruptible source of power for instruments and control circuits under all plant conditions. Any load circuit breakers that supply several components are considered part of the ac instrument power system. Circuit breakers that supply a single system or component are considered part of the system supplied. The unique breaker and controls supplying the load to a component are considered part of the system that contains the component. Not all plants have inverters. Other components that provide this function are considered part of the ac instrument power system.

dc Power System*--The dc power system supplies electric power to both safety- and nonsafety-related dc loads under any plant condition. The dc power can be supplied by either a battery or battery charger. Any dc circuit breakers that may supply several loads, such as several solenoid valve controls or control power for an ac switchgear, are considered part of the dc power system. Those that supply a single component are considered part of the system that contains the component.

Plant ac Power System*--The plant ac power system provides electric power to both safety- and nonsafety-related loads during normal plant operation. Electric power is supplied at various voltage levels in a hierarchical fashion.

Emergency Core Cooling Systems

Emergency core cooling systems are designed to mitigate the consequences of postulated emergency situations that could otherwise lead to core damage and release of fission products to the environment. The emergency core cooling systems include the high-pressure safety injection, residual heat removal/low-pressure safety injection, and upper head injection systems.

High-Pressure Safety Injection System*--The high-pressure safety injection system ensures that the reactor is cooled adequately to limit fuel cladding temperature in the event of a small break in the nuclear system and loss of coolant that does not result in rapid depressurization of the reactor vessel. The high-pressure safety injection system permits the plant to be shut down while maintaining reactor vessel coolant level until the reactor vessel is depressurized. High-pressure safety injection operates until reactor vessel pressure is below the pressure at which low-pressure safety injection operation maintains core cooling.

The boron injection subsystem is a subsystem of high-pressure safety injection used under emergency conditions. Under such circumstances, the chemical and volume control system charging pumps are used to pump concentrated boric acid into the reactor coolant system. The boric acid solution compensates for control rods not fully inserted into the reactor core when negative reactivity is needed to bring and keep the reactor subcritical.

Residual Heat Removal/Low-Pressure Safety Injection System*--The residual heat removal (RHR) mode provides for the removal of decay heat and sensible heat from the primary system during shutdowns for refueling or servicing.

The low-pressure safety injection mode of the residual heat removal system uses the RHR pumps and heat exchangers to restore and maintain water level in the reactor vessel after a LOCA. This system also provides suction to the high-pressure safety injection system and the charging pumps during the recirculation phase and provides cooling to the recirculation sump water.

The safety injection accumulator tanks are included in this system.

Upper Head Injection System*--The upper head injection system is a passive injection system designed to provide additional coolant to the reactor core during the blowdown phase of a large cold leg LOCA. The upper head injection system actuates at a relatively high reactor coolant pressure. Water from the upper head injection accumulator is driven by nitrogen pressure and is injected directly into the upper portion of the reactor vessel.

Emergency Power Systems*

Emergency power systems supply electric power to vital safety-related loads during abnormal plant conditions such as plant blackouts or LOCAs. Emergency power systems are typically a diesel generator-powered system with two to four diesel generator units. The diesel start, load-shedding, generator breaker closing, and sequencing control circuits are considered a part of emergency power systems. Some units may use other emergency power sources, such as gas or hydroelectric turbines, to supply emergency power. These components are considered part of the emergency power systems.

Diesel Generator Cooling Water System*--The diesel generator cooling water system provides adequate water flow to remove heat from the diesel engine during operation. A jacket heating loop is also provided to prevent thermal shock when the diesel is started.

Diesel Generator Fuel Oil Storage and Transfer System*--The diesel generator fuel oil storage and transfer system supplies fuel to run the diesel engine and stores enough fuel for several days' continuous operation. Fuel supplied from the day tank may be either pumped or gravity fed to the diesel.

Diesel Generator Lube Oil System*--The diesel generator lube oil system provides oil to lubricate the moving parts of the diesel engines, thus protecting them from excessive wear and overheating. Adequate lube oil pressure is usually a permissive signal in the diesel generator starting circuit. During diesel operation, the lube oil is normally circulated by engine-driven oil pumps that are considered piece parts of the diesel engine. Prior to the diesel start, a motor-driven oil pump supplies oil pressure.

Diesel Generator Starting Air System*--The diesel generator starting air system provides compressed air to assist in the rapid starting of the diesel engine.

Feedwater Systems

Feedwater systems provide a continuous supply of preheated water to the steam generators through all power operation modes of the plant.

Auxiliary Feedwater System*--The auxiliary feedwater system supplies feedwater to the steam generators following transient or accident conditions when the main feedwater system is not available. The system is also used during normal plant startup, shutdown, and hot standby conditions. The most common arrangement is the three-pump arrangement. Other arrangements contain similar components. When the auxiliary feedwater actuation logic is uniquely identifiable, it is considered part of the auxiliary feedwater system. Emergency feedwater pump(s) may be driven by a diesel engine, which is considered part of the auxiliary feedwater system.

Main Feedwater System*--The main feedwater system provides feedwater to the steam generators at the required pressures and temperatures under all anticipated steady-state and transient conditions.

Fire Protection Systems

Fire protection systems furnish water or fire extinguishing chemicals to areas throughout the station to minimize the adverse effects of fire on station structures, equipment, and personnel.

Generator Systems

Generator systems convert the rotating mechanical energy of the turbines into electrical energy. Generator systems include the generator, generator excitation system, generator H_2 cooling/CO_2 purge system, generator seal oil system, and generator stator water cooling system.

Generator Excitation System--The generator excitation system provides a regulated, controllable source of magnetizing power to the rotating generator field winding. This winding controls generator output voltage. The generator excitation system consists of the alternator exciter, exciter field breaker and rectifier, voltage regulators, and all associated controls and instrumentation.

Generator H_2 Cooling/CO_2 Purge System--The generator H_2 cooling/CO_2 purge system keeps the generator adequately cool by maintaining proper generator hydrogen pressure, temperature, and purity. The system consists of hydrogen coolers, storage cylinders, regulating valves, a hydrogen control panel, and associated piping and instruments. The carbon dioxide supply used to purge the generator comes from a CO_2 storage tank. The generator gas monitoring subsystem is included in this system.

Generator Seal Oil System--The generator seal oil system contains the hydrogen within the generator casing, preventing leakage of hydrogen out of the generator and leakage of air into the generator. This system supplies seal oil under pressure to the generator hydrogen shaft seals. This system consists of various seal oil pumps, a vacuum tank, oil filters, pressure regulators, and associated instruments. Seal oil is supplied by the turbine lube oil system.

Generator Stator Water Cooling System--The generator stator water cooling system cools the generator stator bars, the generator terminal box in the lower frame extension, and the exciter rectifiers. This is a closed system that consists of cooling pumps, water coolers, deionizer and filter regulating valves, and assorted piping and instruments.

Heating, Ventilation, and Air Conditioning Systems

Heating, ventilation, and air conditioning systems provide an environment with controlled temperatures, humidities, and air flow patterns to maintain an atmosphere that ensures the comfort and safety of personnel and the operability of equipment located in the containment, drywell, and other small areas.

Penetration Room Ventilation System*--The penetration room ventilation system collects and filters any gases that may leak through containment penetrations during accident conditions. For this reason, the system is used to keep the penetration room at slightly negative pressure. The penetration room ventilation system is designed to be used only under accident conditions. This system concept has a number of variations and nomenclature. At some stations, the penetration room ventilation system function is performed by the auxiliary building standby gas treatment system or the auxiliary building emergency exhaust system. Such systems would also be included in this system.

Instrumentation and Control Systems

Instrumentation and control systems provide timely operation of equipment needed for proper plant operation and the necessary indication of plant parameters and equipment conditions.

Electrohydraulic Control (Turbine Control) System--The electrohydraulic control (turbine control) system controls the speed and acceleration of the main turbine and turbine load by controlling steam flow to the turbine.

Engineered Safeguards Actuation and Logic System*--The engineered safeguards actuation and logic system senses plant parameters to determine the need for engineered safety features actuation and operation. This system may comprise either relays or solid-state logic. The system includes the elements in the signal path from sensors or from the output of the reactor protection system isolation amplifiers through the engineered safeguards actuation and logic system signal processors, logic circuits, relay circuits, and output controller circuits that are directly involved in the that system's functions. Outputs from the engineered safeguards actuation and logic system that are used to trip the reactor are part of the reactor protection system.

Ex-core Nuclear Instrumentation System--The ex-core nuclear instrumentation system protects the reactor by monitoring the neutron flux and generating appropriate trips and alarm signals for various phases of reactor operating and shutdown conditions. The ex-core nuclear instrumentation system consists of eight independent channels: two source range, two intermediate range, and four power range. In addition, there are four auxiliary channels: the audiovisual count rate channel, the comparator channel, the startup rate channel, and the flux deviation channel.

In-core Instrumentation System--The in-core instrumentation system provides information on the neutron flux distribution and fuel assembly outlet temperatures at selected core locations. The system consists of thermocouples, in-core flux thimbles to permit insertion of movable fission detectors, detector drive units and associated components, gas purge and leak detection components, and control and readout equipment.

Leak Detection System--The leak detection system detects and annunciates the escape of potentially radioactive material from the reactor coolant pressure boundary. In addition, the leak detection system is capable of determining the rate of leakage and initiating action to isolate systems that are leaking at a substantial rate in order to protect the nuclear fuel from damage that may be caused by the loss of coolant.

Pressurizer Level Control System--The pressurizer level control system maintains pressurizer level during expansion and contraction of the reactor coolant volume due to temperature changes. Reactor coolant average temperature is used to develop a programmed level setpoint. Water inventory is maintained by controlling the balance between water leaving the system, via the letdown flow to the chemical and volume control system, and water entering the system from the charging pumps.

Pressurizer Pressure Control System--The pressurizer pressure control system controls the pressure of the reactor coolant system at or near a fixed setpoint during both steady-state and design transient conditions. The system consists of a combination of heater banks, spray valves, and relief valves actuated at the proper times by a pressure controller with proportional, rate, and reset adjustments. The system components operate at various fixed pressure deviation points from the controller setpoint.

Radiation Monitoring System--The radiation monitoring system indicates, alarms and records abnormal radiation levels in areas where radioactive material may be present, stored, handled, or inadvertently introduced.

Reactor Protection System--The reactor protection system prevents damage to the fuel and to the reactor coolant pressure boundary. The system monitors the plant for abnormal conditions that might be indicative of an approaching unsafe operating state. When such deviations in operating conditions are detected, the reactor protection system's redundant actuator logic generates signals that deenergize a dc undervoltage coil on each reactor trip breaker. The circuit breakers open, power is interrupted to the control rod drive power supply, and the control rods fall into the core under gravity, causing reactor shutdown. The signal that deenergizes the dc undervoltage coils also initiates a primary coolant trip. In addition to automatic operation, manual initiation is also provided. The elements in the signal path from the sensor through signal processor circuits, relay circuits, and output controller circuits that are part of the reactor protection functions are considered part of the reactor protection system. Any outputs from an isolation amplifier or isolation circuit that feeds the engineered safeguards actuation and logic system are part of that system. The reactor trip breakers are considered part of the control rod drive system.

Remote Shutdown System--The remote shutdown system provides a reactor plant shutdown capability located outside the control room for situations when the control room may have to be evacuated. The remote shutdown system provides all the controls and indication necessary to shut down the reactor as well as to provide subsequent reactor plant stabilization and cooldown.

Rod Control System--The rod control system maintains a programmed average temperature in the reactor coolant system by regulating the reactivity in the core and shapes the axial flux profile of the core. The rod control system consists of the electronic circuitry, switches, indicators, and alarm devices necessary for the manipulation of the control rods.

Rod Position Indication System--The rod position indication system, composed of two subsystems, continuously senses and displays rod position information for each control rod. The individual rod position indication subsystem measures the actual rod position and displays it on the main control board. The demand position subsystem counts the number of steps demanded by the rod control system to move the rods up or down. This information is displayed by step counters located on the main control board.

The system consists of field-mounted detectors, rack-mounted electronic equipment, and control-board-mounted equipment.

Steam Dump Control System--The steam dump control system reduces the magnitude of nuclear system transients following a large turbine load reduction or reactor trip by dumping throttle steam directly to the main condenser, thereby creating an artificial load on the reactor and preventing the lifting of steam generator safety valves. The system comprises several banks of valves located downstream of the main steam stop valves and all associated circuitry and controls.

Steam Generator Water Level Control System--The steam generator water level control system provides each steam generator with a three-element feedwater controller (feedwater flow, steam flow, and water level) that maintains a programmed water level on the secondary side of the steam generator during normal plant operation. This controller, continuously compares measured feedwater flow with steam flow, and a compensated steam generator downcomer water level signal with a water level setpoint to regulate the main feedwater valve position.

Main Steam Systems*

Main steam systems contain and transport the saturated steam to the turbines, where it is utilized in the production of electricity. Main steam systems also provide the means of removing heat when the turbines are not available through the use of steam dumps and atmospheric relief valves.

Process Sampling Systems

Process sampling systems monitor the operation of plant equipment and provide information needed to make operational decisions. These systems provide remote sampling facilities and the capability for sampling fluids of various process systems during normal plant operation and shutdown conditions.

Radwaste Systems

Radwaste systems collect, process, monitor, store, and dispose of all radioactive wastes. Radwaste systems include the gaseous radwaste, the liquid radwaste, and solid radwaste systems.

Gaseous Radwaste System--The gaseous radwaste system processes and controls the release of gaseous radioactive wastes to the site environs. The gaseous radwaste system typically consists of waste gas compressor packages, gas decay tanks, and associated piping, valves, and instrumentation.

Liquid Radwaste System--The liquid radwaste system collects, processes, stores, and monitors, for reuse or disposal, all potentially radioactive liquid wastes. The liquid radwaste system consists of one or more subsystems designed to handle specific types of liquid wastes such as water, chemical solutions from the demineralizer resin regeneration process, and evaporator distillate.

Solid Radwaste System--The solid radwaste system collects, processes, packages, and temporarily stores, prior to off-site shipping, such wastes as spent resins, evaporator concentrates, and chemical drain tank effluents. Liquid-bearing wastes are dewatered and solidified. Contaminated solids such as filters, rags, paper, clothing, and tools are compacted.

Reactor Coolant Systems*

Reactor coolant systems transfer heat from the reactor core to the steam generators. They are closed piping systems consisting of two, three, or four parallel loops. Any instruments that provide a signal to the reactor protection system are considered part of the reactor protection systems.

Boron Thermal Regeneration System--The boron thermal regeneration system is designed to allow treatment of all or part of the reactor coolant system letdown flow when boron concentration changes are desired for load following. Storage and release of boron during load-following operation is determined by the temperature of the fluid entering the thermal regeneration demineralizers. A chiller unit and a group of heat exchangers are employed to provide the desired fluid temperatures at the demineralizer inlets.

Chemical and Volume Control System*--The functions of the chemical and volume control system are to:

- o Adjust the concentration of chemical neutron absorber (boric acid) in the reactor coolant for chemical reactivity control.
- o Maintain the proper water inventory in the reactor coolant system.

- o Provide seal water flow for the reactor coolant pump shaft seals.

- o Maintain the proper concentration of corrosion-inhibiting chemicals in the reactor coolant.

- o Reduce the quantity of fission and corrosion products and maintain the reactor coolant chemistry to within design limits.

- o Provide cooling to limit fuel cladding temperature in the event of a small break and during LOCAs that do not result in rapid depressurization of the reactor vessel.

Refueling Systems

Refueling systems provide a safe and effective means for transporting and handling fuel from the time it reaches the plant until it leaves the plant. The refueling systems include the fuel handling and spent fuel pit cooling systems.

Fuel Handling System--The fuel handling system consists of the mechanical and electrical components required to manipulate nuclear fuel through the various movements and operations undergone while in the reactor building. Reactor vessel servicing equipment is provided to support fuel handling as well as the nonroutine removal of reactor vessel equipment.

Spent Fuel Pit Cooling System--The spent fuel pit cooling system consists of two cooling trains, a purification loop, and a skimmer loop. It removes decay heat from the spent fuel pit water, provides adequate purification to permit unrestricted access to the spent fuel storage area, and maintains optical clarity of the spent fuel pit water.

Turbine Systems

Turbine systems convert the thermodynamic energy of the steam to drive the main generator for the production of electricity. Turbine systems include the turbines, extraction steam system, turbine lube oil system, and turbine seal steam system.

Extraction Steam System--The extraction steam system provides heating steam to such components as feedwater heaters for condensate and feedwater heating, seal steam evaporators, and radwaste steam generators. The extraction steam system takes steam from the high-pressure turbine and low-pressure turbine extraction points and from the moisture separators.

Turbine Lube Oil System--The turbine lube oil system continuously supplies cool, clean lubricating oil to the turbine-generator and exciter bearings. The turbine lube oil system comprises lube oil reservoirs, lube oil pumps and coolers, and associated strainers, piping, and instrumentation.

Turbine Seal Steam System--The turbine seal steam system prevents the entrance of air and noncondensible gases into the main condenser and prevents the leakage of radioactive steam to the atmosphere. Clean sealing steam is supplied to the turbine shaft glands and valve stems. Condensed sealing steam is returned to the main condenser.

Water Systems

Water systems provide the needed cooling and makeup throughout the plant for safe and efficient operation of water-cooled components. The water systems include the circulating water, component cooling water, essential raw cooling water, and nuclear service water systems.

Circulating Water System--The circulating water system is a closed-loop system that removes the excess heat from the turbine exhaust steam and turbine bypass steam by continuously supplying cooling water from the cooling tower basin to the main condenser and returning the heat water to the cooling tower for cooling.

Component Cooling Water System*--The component cooling water system is a closed system that supplies cooling water to various plant components during normal operations, removes residual heat from the reactor coolant system during the second phase of plant cooldown, and supplies coolant to safeguard equipment loads during and after an accident.

Essential Raw Cooling Water--The essential raw cooling water system is designed to supply cooling water directly from the main river channel (lake) to various primary and secondary systems and components necessary for plant safety during normal and accident conditions.

Nuclear Service Water System*--The nuclear service water system acts as the final heat sink for waste heat loads. Typically, it uses the same water and sink as the turbine condenser (river, lake, etc.). It supplies cooling water to equipment essential to the safe shutdown of the reactor under both normal and emergency conditions.

Level 1--Combustion Engineering Systems[a]

Air Systems

Air systems provide the proper type and pressure of air to operate necessary instrumentation and equipment in the plant. The air systems include the instrument air and service air systems.

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a. An asterisk indicates that this definition of a Combustion Engineering system is based on the NPRDS (Ref. 23).

Instrument Air System--The instrument air system provides a continuous supply of clean, dry, oil-free compressed air for use by plant instrumentation, various air-operated valves, and control devices.

Service Air System--The service air system provides a continuous supply of compressed air, without drying or filtration, for such functions as backwashing, mixing, and agitation, as well as general plant use. Some plants utilize service air as a backup to instrument air.

Annunciator Systems

Annunciator systems are hardwired systems that provide the operator with the audio and visual alarm information required for unit operation, startup, and shutdown. These systems are independent of the plant computer system and include the controls necessary to acknowledge, silence, and reset alarms.

Communication Systems

Communication systems provide reliable and convenient communications among on-site personnel and between on-site and off-site locations. These systems include an intraplant public address system, a private telephone system to permit plant-to-off-site communication on a continuous basis, and a two-way radio communication system.

Compressed Gas Systems

Compressed gas systems store and distribute as required the necessary gases used to operate and maintain the plant. Typical gases are hydrogen, oxygen, CO_2, argon, and acetylene.

Condensate Systems.

Condensate systems provide continuous condensate flow from the condenser hotwells to the main feedwater pumps, which in turn provide feedwater to the steam generators at the required pressures and temperatures under all anticipated steady-state and transient conditions. Condensate systems consist of parallel, interconnected trains. These take condensate from the condenser hotwells and discharge it into the low-pressure feedwater heaters, which in turn supply the feedwater pumps.

The demineralizers and their inlet, outlet, relief valves, and valve operators are considered part of the demineralizer beds. The remainder of the items associated with dimineralizer beds (pumps, blowers, etc.) are considered piece parts of the demineralizers.

Condensate Storage System--The condensate storage system provides the primary supply of water for the maintenance of condenser water level in the condenser hotwell, the control rod drive system, and the reactor core isolation cooling system. It also supplies makeup for other plant systems as required.

Containment Systems

Containment systems serve as a pressure boundary and shielding for the reactor in the event there is release of radioactivity from the reactor. The containment systems include the containment/reactor building penetration system, containment cooling system, combustible gas control system, containment isolation system, containment spray system, and containment ventilation system.

Containment/Reactor Building Penetration System*--The containment/reactor building penetration system comprises all primary containment penetrations and all accesses. All penetrations are considered part of this system. Equipment and personnel access hatches and fuel transfer tubes are components of the system. All associated instruments, monitors, etc., are considered piece parts of the access penetration. The system includes maintenance hatches and all electrical, mechanical, piping, and instrumentation penetrations.

Containment Cooling System*--The containment cooling system removes sufficient heat energy from the containment atmosphere following a LOCA or a main steam line break in order to maintain the containment atmospheric pressure below design pressure. The containment cooling system typically consists of cooling units with a vane axial type fan and two sets of cooling coils. There are several variations to the design of this system.

Combustible Gas Control System--The combustible gas control system is one of two types: the dilution type or the hydrogen recombiner type. The dilution system maintains the hydrogen concentration in the containment at an acceptable level by introduction of atmospheric air. The hydrogen recombiner system maintains the hydrogen concentration below 4% by volume in the containment following a design-basis LOCA without reliance on purging and without release of radioactive material to the environment. The system basically consists of a skid-mounted thermal recombiner unit with associated valves, piping, instrumentation, and controls. Designs will vary.

Containment Isolation System*--The containment isolation system provides a double barrier to the escape of radioactive material at each fluid penetration through the containment liner plate. This system consists of any isolation valves (both inside and outside containment) not already included in other systems. Examples of valves in this system are isolation valves in the waste systems and check isolation valves in the nitrogen system.

Containment Spray System*--The containment spray system reduces the pressure and temperature within the containment building following a LOCA and maintains them at acceptable levels. The containment spray system has two independent loops, each consisting of a containment spray pump and a heat exchanger. During the injection phase, the pumps take suction from the refueling water tank. During the recirculation phase, the pumps take suction from the containment recirculation sump. If the heat exchangers are shared with the shutdown cooling system, they are considered part of the shutdown cooling system.

Containment Ventilation System--The containment ventilation system comprises several subsystems, each of which has separate design objectives. The systems are designed around objectives relating to normal operation, personnel access, containment protection, and accident conditions.

The containment air cooling subsystem is designed to maintain an acceptable temperature within the containment upper and lower compartments, reactor well, control rod drive mechanism shroud, and instrument room for the protection of equipment and controls during normal reactor operation and normal shutdown.

The containment purge subsystem is designed to maintain the environment in the primary and secondary containment within acceptable limits for equipment operation and for personnel access, and to limit release of radioactivity to the environment.

The vacuum relief subsystem protects the containment vessel from an excessive external force.

The air return fan subsystem enhances the ice condenser and containment spray heat removal operation by circulating air from the upper compartment to the lower compartment, through the ice condenser, and back to the upper compartment. This subsystem limits the hydrogen concentration in potentially stagnant regions by ensuring a flow of air from these regions.

Control Element Assembly Systems*

Control element assembly systems control the reactivity of the reactor core and consist of the redundant reactor regulating system, the control element drive system, the control element assemblies, and their control element drive mechanisms. There are typically 12 groups of control element assemblies, divided as follows:

Shutdown - two groups
* Regulating - eight groups
Part-length - two groups

The control rod drive mechanisms are magnetic-operation drives. Each control element drive mechanism is capable of withdrawing, inserting, holding, or tripping the control element assembly; however, components in these systems used only for reactor regulation are not considered part of the system. The control signal is provided by the control element drive system. Electrical power to the control element drive mechanism is provided by two motor-generator sets through the reactor protection system trip breakers.

Electrical Distribution Systems

Electrical distribution systems provide a means of receiving off-site power and a means of transmitting site generated power. These systems supply power to those auxiliaries needed for power generation by the plant. The electrical distribution systems include the ac instrument power, dc power, and plant ac power systems.

ac Instrument Power System*--The ac instrument power system provides an uninterruptible source of power for instruments and control circuits under all plant conditions. Any load circuit breakers that may supply several loads are considered part of the AC instrument power system.

dc Power Systems--The DC power system supplies electric power to both safety- and non-safety-related dc loads under any plant condition. The dc power can be supplied by either a battery or battery charger. Any dc circuit breakers that may supply several loads, such as several solenoid valve controls or control power for ac switchgear, are considered part of the dc power system.

Plant ac Power System*--The plant ac power system provides electric power to both safety- and nonsafety-related loads during normal plant operations. Electric power is supplied at various voltage levels that are connected in a hierarchical fashion.

Emergency Core Cooling Systems

Emergency core cooling systems are designed to mitigate the consequences of postulated emergency situations that could otherwise lead to core damage and release of fission products to the environment. The emergency core cooling systems include the high-pressure safety injection and the low-pressure safety injection/shutdown cooling systems.

High-Pressure Safety Injection System*--The high-pressure safety injection system must function to supply core cooling during a LOCA. The safety injection system is treated as an integrated system consisting of three complementary systems: high-pressure safety injection, low-pressure safety injection, and safety injection tanks.

The high-pressure system is capable of delivering emergency coolant at discharge pressures of up to 1205 psig. Two high-pressure injection pumps take suction from two independent suction headers. These headers are initially supplied with borated water from the refueling water tank and after exhaustion are supplied from the recirculation sump of the containment. If the high-pressure safety injection pumps are shared with the chemical and volume control system, these pumps and associated valves and piping are considered part of the high-pressure safety injection system.

Low-Pressure Safety Injection/Shutdown Cooling System*--The low-pressure safety injection/shutdown cooling system is actually two systems that share common piping. The shutdown cooling portion is used to provide core cooling during cold shutdown. Piping connections draw from the reactor coolant system piping and return to four inlet nozzles on the reactor coolant system cold legs. The low-pressure injection portion operates during accident conditions. It has two modes of operation. The first mode is the injection mode. During this mode, borated water is drawn from the refueling water tank (RWT) and injected into the reactor coolant system piping through the inlet nozzles. When the water level on the RWT falls to a predetermined level, low-pressure injection suction is transferred to the emergency sump inside the reactor building. This mode of operation is called the recirculation mode.

Emergency Power Systems*

Emergency power systems supply electric power to vital safety-related loads during abnormal plant conditions such as plant blackouts or LOCAs. Emergency power systems are typically a diesel generator-powered system with two to four diesel generator units. The diesel start, load-shedding, generator breaker closing, and sequencing control circuits are considered a part of the emergency power system. Some units may use gas or hydroelectric turbines to supply emergency power.

Diesel Generator Cooling Water System*--The diesel generator cooling water system provides adequate water flow to remove heat from the diesel engine during operation. A jacket heating loop is also provided to prevent thermal shock when the diesel is started.

Diesel Generator Fuel Oil Storage and Transfer System*--The diesel generator fuel oil storage and transfer system supplies fuel to run the diesel engine and stores enough fuel for several days' continuous operation. Fuel supplied from the day tank may be either pumped or gravity fed to the diesel.

Diesel Generator Lube Oil System*--The diesel generator lube oil system provides oil to lubricate the moving part of the diesel engines. Adequate lube oil pressure is usually a permissive signal in the diesel generator starting circuit. During diesel operation, the lube oil is normally circulated by engine-driven oil pumps that are considered piece parts of the diesel engine. Prior to the diesel start, a motor-driven oil pump supplies oil pressure.

Diesel Generator Starting Air System*--The diesel generator starting air system provides compressed air to assist in the rapid starting of the diesel engines.

Feedwater Systems

Feedwater systems provide a continuous supply of preheated water to the steam generators through all power operation modes of the plant.

Auxiliary/Emergency Feedwater System*--The auxiliary/emergency feedwater system is designed to provide steam generator makeup for the removal of decay heat from the reactor coolant system during both normal and emergency cooldowns. The auxiliary emergency feedwater system consists primarily of the following: emergency feedwater pumps, valves, and instrumentation.

Main Feedwater System*--The main feedwater system provides feedwater to the steam generators at the required pressures and temperatures under all anticipated steady-state and transient conditions.

Fire Protection Systems

Fire protection systems furnish water or fire extinguishing chemicals to areas throughout the station to minimize the adverse effects of fire on station structures, equipment, and personnel.

Generator Systems

Generator systems convert the rotating mechanical energy of the turbines into electrical energy. Generator systems include the generator, generator excitation system, generator H_2 cooling/CO_2 purge system, generator seal oil system, and generator stator water cooling system.

Generator Excitation System--The generator excitation system provides a regulated, controllable source of magnetizing power to the rotating generator field winding. This winding controls generator output voltage. The generator excitation system consists of the alternator exciter, exciter field breaker and rectifier, voltage regulators, and all associated controls and instrumentation.

Generator H_2 Cooling/CO_2 Purge System--The generator H_2 cooling/CO_2 purge system keeps the generator adequately cool by maintaining proper generator hydrogen pressure, temperature, and purity. The system consists of hydrogen coolers storage cylinders, regulating valves, a hydrogen control panel, and associated piping and instruments. The carbon dioxide supply used to purge the generator comes from a CO_2 storage tank. The generator gas monitoring subsystem is included in this system.

Generator Seal Oil System--The generator seal oil system contains the hydrogen within the generator casing, preventing leakage of hydrogen out of the generator and leakage of air into the generator. This system supplies seal oil under pressure to the generator hydrogen shaft seals. This system consists of various seal oil pumps, a vacuum tank, oil filters, pressure regulators, and associated instruments. Seal oil is supplied by the turbine lube oil system.

Generator Stator Water Cooling System--The generator stator water cooling system cools the generator stator bars, the generator terminal box in the lower frame extension, and the exciter rectifiers. This is a closed system that consists of cooling pumps, water coolers, deionizer and filter regulating valves, and assorted piping and instruments.

Heating, Ventilation, and Air Conditioning (HVAC) Systems

HVAC systems provide an environment with controlled temperatures, humidities, and air flow patterns to maintain an atmosphere that ensures the comfort and safety of personnel and the operability of equipment located in the containment, drywell, and other small areas.

Penetration Room Ventilation Systems--The penetration room ventilation system consists of fans, filter trains, and duct work. The system minimizes environmental activity levels by collecting and processing post-LOCA containment leakage.

Instrumentation and Control Systems

Instrumentation and control systems provide timely operation of equipment needed for proper plant operation and the necessary indication of plant parameters and equipment conditions.

Control Element Assembly Position Monitoring System--Control element assembly position monitoring is provided by two diverse and independent indication systems. One system consists of reed switch assemblies attached to the control element drive mechanisms. The reed switches are operated by a magnet providing a signal proportional to position for display. The second system uses the plant computer to count raise-lower pulses to the control element drive mechanism power programmers. Position is displayed for group or individual control element assemblies.

Electrohydraulic Control (Turbine Control) System--The electrohydraulic control system controls the speed and acceleration of the main turbine and turbine load by controlling steam flow to the turbine.

Engineered Safety Features Actuation System*--The engineered safety features actuation system (ESFAS) consists of the sensors, logic, and actuation circuits that monitor selected plant parameters. It also provides an actuation signal to each actuated component in the engineered safety features (ESF) system if the selected plant parameters reach predetermined setpoints. There is one actuation system for each of the ESF systems.

The ESFAS includes the sensors that monitor selected plant variables. When the monitored variables reach levels indicative of conditions that require protective action, the ESFAS generates the following signals: containment isolation actuation; containment spray actuation; main steam isolation; safety injection actuation; recirculation actuation; and emergency feedwater actuation. This system includes the elements in the signal path from sensors or from the output of the reactor protection system isolation amplifiers through the ESFAS signal processors, logic circuits, relay circuits, and output controller circuits that are directly involved in ESFAS functions. Outputs from the ESFAS that are used to trip the reactor are part of the reactor protection system. The control circuitry for the components provides the sequencing necessary to provide proper ESF system operation.

Ex-core Nuclear Instrumentation System--The ex-core nuclear instrumentation system protects the reactor by monitoring the neutron flux and generating appropriate trips and alarm signals for various phases of reactor operating and shutdown conditions. The ex-core nuclear instrumentation system consists of eight independent channels: two startup channels, two control channels, and four safety channels. This system also provides readout and audio count information and rate of change of power information.

In-core Instrumentation System--The in-core instrumentation system provides information on the neutron flux distribution and fuel assembly outlet temperatures at selected core locations. The system consists of thermocouples, in-core flux thimbles to permit insertion of movable fission detectors, detector drive units and associated components, gas purge and leak detection components, and control and readout equipment.

Leak Detection System--The leak detection system detects and annunciates the escape of potentially radioactive material from the reactor coolant pressure boundary. In addition, the leak detection system is capable of determining the rate of leakage and initiating action to isolate systems that are leaking at a substantial rate in order to protect the nuclear fuel from damage that may be caused by the loss of coolant.

Pressurizer Level Control System--The pressurizer level control system maintains pressurizer level during expansion and contraction of the reactor coolant volume due to temperature changes. Reactor coolant average temperature is used to develop a programmed level setpoint, generated in the reactor regulating system. Water inventory is maintained by controlling the balance between water leaving the system, via the letdown flow to the chemical and volume control system, and water entering the system from the charging pumps.

Pressurizer Pressure Control System--The pressurizer pressure control system controls the pressure of the reactor coolant system at or near a fixed setpoint during both steady-state and design transient conditions. The system consists of a combination of heater banks, spray valves, and relief valves actuated at the proper times by a pressure controller with proportional, rate, and reset adjustments. The system components operate at various fixed pressure deviation points from the controller setpoint.

Process Monitoring System--The process monitoring system monitors the radiation levels in selected liquid and gaseous process streams in order to provide the required readouts and records of these levels. When radiation levels exceed predetermined setpoints, alarms and isolation signals are activated to control the release of radioactivity to the environment.

Radiation Monitoring System--The radiation monitoring system indicates, alarms, and records abnormal radiation levels in areas where radioactive material may be present, stored, handled, or inadvertently introduced.

Reactor Protection System*--The reactor protection system consists of sensors, calculators, logic, and other equipment necessary to monitor selected nuclear steam supply system conditions and to effect rapid reactor shutdown (reactor trip) if any one or a combination of the monitored conditions approaches specified safety system settings. Four measurement channels with electrical and physical separation are provided for each parameter used in the direct generation of trip signals, with the exception of control element assembly position. A coincidence of two like trip signals is required to generate a reactor trip signal. The fourth channel is provided as a spare and allows bypassing of one channel while maintaining a two-out-of-three system. The reactor trip signal deenergizes the control element drive mechanism coils, allowing all control element assemblies to drop into the core.

The elements in the signal path from the sensor through signal processor circuits, logic circuits, relay circuits, and output controller circuits that are part of the reactor protection functions are included in the reactor protection system. Any output from an isolation amplifier or isolation circuit that feeds the engineered safety features actuation system is part of that system.

Reactor Regulator System--The reactor regulator system automatically controls reactor temperature, and thus secondary pressure, by positioning regulating control element assemblies. This system keeps average coolant temperature within a programmed band to maintain design steam conditions. This system also operates in conjunction with the steam bypass control system and the pressurizer level control system. The reactor regulator system consists of the electronic circuitry, switches, indicators, and alarm devices necessary for the manipulation of control element assemblies.

Remote Shutdown System--The remote shutdown system provides a reactor plant shutdown capability located outside the control room for situations when the control room may have to be evacuated. The remote shutdown system provides all the controls and indication necessary to shut down the reactor as well as to provide subsequent reactor plant stabilization and cooldown.

Steam Bypass Control System--The steam bypass control system reduces the magnitude of nuclear system transients following a large turbine load reduction or reactor trip by dumping throttle steam directly to the main condenser, thereby creating an artificial load on the reactor and preventing the lifting of steam generator safety valves. The system comprises several banks of valves, located downstream of the main steam stop valves, and all associated circuitry and controls.

Steam Generator Water Level Control System--The steam generator water level control system provides each steam generator with a three-element feedwater controller (feedwater flow, steam flow, and water level) that maintains a programmed water level on the secondary side of the steam generator during normal plant operation. This controller continuously compares measured feedwater flow with steam flow and a compensated steam generator downcomer water level signal with a water level setpoint to regulate the main feedwater valve position.

Main Steam Systems*

Main steam systems consist of: main steam isolation valves, main steam safety valves, power-operated atmospheric dump valves, condenser dump valves, and associated piping. Main steam systems deliver steam from the steam generators to the turbine-generator, dissipate heat from the nuclear steam supply system when the turbine-generator is not available, and provide steam for various auxiliary systems.

Process Sampling Systems

The process sampling systems monitor the operation of plant equipment and provide information needed to make operational decisions. These systems provide remote sampling facilities and the capability for sampling fluids of various process systems during normal plant power operation and shutdown conditions.

Radwaste Systems

Radwaste systems collect, process, monitor, store, and dispose of all radioactive wastes. The radwaste systems include the gaseous radwaste, liquid radwaste, and solid radwaste systems.

Gaseous Radwaste System--The gaseous radwaste system processes and controls the release of gaseous radioactive wastes to the site environs. The gaseous radwaste system typically consists of waste gas compressor packages, gas decay tanks, and associated piping, valves, and instrumentation.

Liquid Radwaste System--The liquid radwaste system collects, processes, stores, and monitors, for reuse or disposal, all potentially radioactive liquid wastes. The liquid radwaste system consists of one or more subsystems desired to handle specific types of liquid wastes, such as water, chemical solutions from the demineralizer resin regeneration process, and evaporator distillate.

Solid Radwaste System--The solid radwaste system collects, processes, packages, and temporarily stores, prior to off-site shipping, such wastes as spent resins, evaporator concentrates, and chemical drain tank effluents. Liquid-bearing wastes are dewatered and solidified. Contaminated solids such as filters, rags, paper, clothing, and tools are compacted.

Reactor Coolant Systems*

Reactor coolant systems remove heat from the reactor core and internals and transfer it to the secondary (steam) system. These systems consist of two loops connected to the reactor vessel. Each loop contains one steam generator, two reactor coolant pumps, and connecting piping. Coolant system pressure is maintained by a pressurizer connected to one of the loops. All temperature, pressure, and flow transducers that provide signals to the reactor protection system are considered part of the reactor protection systems.

Chemical and Volume Control System*--The functions of the chemical and volume control system are to:

- o Maintain the chemistry and purity of the reactor coolant;
- o Maintain the required volume of water in the reactor;
- o Provide a controlled path for water discharge;
- o Control boron concentration;
- o Provide auxiliary spray;
- o Inject boric acid into the reactor coolant system upon a safety injection actuation signal; and
- o Control reactor coolant pump seal injection flow.

The system consists of charging pumps, heat exchangers, purification subsystem, boric acid makeup capability, volume control tank, chemical addition subsystem, and a process radiation system. If the high-pressure safety injection pumps are shared with the chemical and volume control system, these pumps and directly associated valves and piping are considered part of the high-pressure safety injection system.

Refueling Systems

Refueling systems provide a safe and effective means for transporting and handling fuel from the time it reaches the plant until it leaves the plant. The refueling systems include the fuel handling and spent fuel pool cooling and purification systems.

Fuel Handling System--The fuel handling system consists of the mechanical and electrical components required to manipulate nuclear fuel through the various movements and operations undergone while in the reactor building. Reactor vessel servicing equipment is provided to support fuel handling as well as the nonroutine removal of reactor vessel equipment.

Spent Fuel Pool Cooling and Purification System--The spent fuel pool cooling and purification system removes the decay heat from spent fuel stored in the spent fuel pool. It also maintains the clarity and purity of the water in the spent fuel pool, fuel transfer canal, refueling water pool, and refueling water tank.

Turbine Systems

Turbine systems convert the thermodynamic energy of the steam to drive the main generator for the production of electricity. Turbine systems include the turbines, extraction steam system, turbine lube oil system, and turbine seal steam system.

Extraction Steam System--The extraction steam system provides heating steam to such components as feedwater heaters for condensate and feedwater heating, seal steam evaporators, and radwaste steam generators. The extraction steam system takes steam from the high-pressure turbine and low-pressure turbine extraction points and from the moisture separators.

Turbine Lube Oil System--The turbine lube oil system continuously supplies cool, clean, lubricating oil to the turbine-generator and exciter bearings. The turbine lube oil system comprises lube oil reservoirs, lube oil pumps and coolers, and associated strainers, piping, and instrumentation.

Turbine Seal Steam System--The turbine seal steam system prevents the entrance of air and noncondensible gases into the main condenser and the leakage of radioactive steam to the atmosphere. Clean sealing steam is supplied to the turbine shaft glands and valve stems. Condensed sealing steam is returned to the main condenser.

Water Systems

Water systems provide the needed cooling and makeup throughout the plant for safe and efficient operation of water-cooled components. The water systems include the circulating water, component cooling water, and nuclear service water systems.

Circulating Water System--The circulating water system is a closed-loop system that removes the excess heat from the turbine exhaust steam and turbine bypass steam by continuously supplying cooling water from the cooling tower basin to the main condenser and returning the heated water to the cooling tower for cooling.

Component Cooling Water System--The component cooling water system is a closed system that removes waste heat from essential and nonessential equipment during normal plant operation. The component cooling water system provides a barrier between equipment containing potentially radioactive fluid and the nuclear service water system.

Nuclear Service Water System*--The nuclear service water system acts as the final heat sink for waste heat loads. The heat loads are usually transferred from the point of heat generation to the nuclear service water system by a closed loop (via heat exchangers and air handling units). The nuclear service water system typically uses the same water and heat sink as the turbine condenser (river, lake, ocean, etc.).

Level 1 Definitions--Babcock & Wilcox Systems[a]

Air Systems

Air systems provide the proper type and pressure of air to operate necessary instrumentation and equipment in the plant. The air systems include the instrument air and service air systems.

Instrument Air System--The instrument air system provides a continuous supply of clean, dry, oil-free compressed air for use by plant instrumentation, various air-operated valves, and control devices.

Service Air System--The service air system provides a continuous supply of compressed air, without drying or filtration, for such functions as backwashing, mixing, and agitation as well as general plant use. Some plants utilize service air as a backup to instrument air.

Annunciator Systems

Annunciator systems are hardwired systems that provide the operator with the audio and visual alarm information required for unit operation, startup, and shutdown. These systems are independent of the plant computer system and include the controls necessary to acknowledge, silence, and reset alarms.

Communication Systems

Communication systems provide reliable and convenient communications among on-site personnel and between on-site and off-site locations. These systems include an intraplant public address system, a private telephone system to permit plant-to-off-site communication on a continuous basis, and a two-way radio communication system.

Compressed Gas Systems

Compressed gas systems store and distribute as required the necessary gases used to operate and maintain the plant. Typical gases are hydrogen, oxygen, CO_2, argon, and acetylene.

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a. An asterisk indicates that this definition of a Babcock & Wilcox system is based on the NPRDS.

Condensate Systems*

Condensate systems collect water from the hotwell in the condenser, use it to cool other loads, purify it, and then raise its pressure before discharging it to the feedwater system. There are many configurations of condensate systems. The number and type of cooling loads may vary greatly. The particular configurations and numbers of demineralizers, pumps, and heaters also may vary considerably.

Condensate Demineralizer System--The condensate demineralizer system maintains the required purity of the condensate and feedwater by using precoat filters and demineralizers.

Containment Systems

Containment systems serve as a pressure boundary and shielding for the reactor in the event there is release of radioactivity from the reactor. The containment systems include the combustible gas control, containment/reactor building penetration, containment isolation, containment ventilation, reactor building cooling, and reactor building spray systems.

Combustible Gas Control System*--The combustible gas control system is of two types: the dilution type and the hydrogen recombiner type. The dilution system maintains the hydrogen concentration in containment at an acceptable level by introduction of atmospheric air. The hydrogen recombiner system maintains the hydrogen concentration below 4% by volume in the containment (during a LOCA) without reliance on purging. The system basically consists of a skid-mounted thermal recombiner unit with associated valves, piping, instrumentation, and controls.

Containment/Reactor Building Penetration System*--The containment/reactor building penetration system is made up of all the penetrations of the reactor building pressure boundary. All penetrations are considered part of this system, regardless of size. One penetration can have several pipes passing through it.

Equipment and personnel access hatches and fuel transfer tubes are components of the system. All associated instruments, monitors, etc., are considered piece parts of the access or penetration. The system includes maintenance hatches and all electrical, mechanical, piping, and instrumentation penetrations.

Containment Isolation System*--The containment isolation system consists of those valves that have not been included in one of the other systems and are used to isolate the reactor building in the event of an accident. The valves may be active (motor-operated) or passive (check valves or manually closed valves). The operation of the motor-operated valves is initiated by the safety features actuation system. Isolation valves in the liquid and gaseous waste systems are examples of valves considered part of this system.

Containment Ventilation System--The containment ventilation system comprises several subsystems, each of which has separate design objectives. The systems are designed around objectives relating to normal operation, personnel access, containment protection, and accident conditions.

The containment air cooling subsystem is designed to maintain an acceptable temperature within the containment upper and lower compartments, reactor well, control rod drive mechanism shroud, and instrument room for the protection of equipment and controls during normal reactor operation and normal shutdown.

The containment purge subsystem is designed to maintain the environment in the primary and secondary containment within acceptable limits for equipment operation and for personnel access, and to limit the release of radioactivity to the environment.

The vacuum relief subsystem protects the containment vessel from an excessive external force.

The air return fan subsystem enhances the ice condenser and containment spray heat removal operation by circulating air from the upper compartment to the lower compartment, through the ice condenser, and back to the upper compartment. This subsystem limits the hydrogen concentration in potentially stagnant regions by ensuring a flow of air from these regions.

Reactor Building Cooling System*--The reactor building cooling system reduces pressure inside the reactor building by cooling and condensing the steam created by an accident. During normal operation, the system can be used to cool the reactor building atmosphere, thus making the working environment more comfortable. The emergency operation of the reactor building cooling system is actuated by the safety features actuation system.

Reactor Building Spray System*--The reactor building spray system reduces pressure inside the reactor building by spraying water to condense steam that might be released in an accident. Chemicals are added to the spray to help reduce the iodine concentration of the containment air. This system is used only during an accident situation.

Control Rod Drive Systems*

Control rod drive systems control the reactivity of the reactor core. There are eight groupings of control rods. Groups 1-4 are safety rods and are used to scram the reactor, if necessary. Groups 5-8 are used for reactor regulation and power shaping. There are 69 control rods in control rod drive systems. Group 8 has eight control rods. The number of rods in all other groups will vary with core configuration. The average number is eight rods for groups 1-4 and eight to twelve rods for groups 5-7. Reactor trip breakers are considered part of control rod drive systems.

Electrical Distribution Systems

Electrical distribution systems provide a means of receiving off-site power and a means of transmitting site-generated power. These systems supply power to those auxiliaries needed for power generation by the plant. The electrical distribution systems include the ac instrument power, dc power, and plant ac power systems.

ac Instrument Power System*--The ac instrument power system provides an uninterruptible source of power for instruments and control circuits under all plant conditions. Any load circuit breakers that may supply several loads are considered part of the ac instrument power system. Circuit breakers that supply a single system are considered part of the system supplied.

dc Power System--The dc power system supplies electric power to both safety- and non-safety-related dc loads under any plant condition. The dc power can be supplied by either a battery or battery charger. Any dc circuit breakers that may supply several loads, such as several solenoid valve controls or control power for ac switchgear, are considered part of the dc power system. Those that supply a single component are considered part of the system that contains the component.

Plant ac Power System*--The plant ac power system provides electric power to both safety- and non-safety-related loads during normal plant operation. Electric power is supplied at various voltage levels in a hierarchical fashion.

Emergency Core Cooling Systems

Emergency core cooling systems are designed to mitigate the consequences of postulated emergency situations that would otherwise lead to core damage and release of fission products to the environment. The emergency core cooling systems include the decay heat removal/core flooding system, decay heat removal/low-pressure safety injection system, and high-pressure safety injection systems.

Decay Heat Removal/Core Flooding System*--The decay heat removal/core flooding system is a passive deluge system that maintains a sufficient water inventory to keep the reactor core covered during the period between high-pressure injection system actuation and low-pressure injection system actuation following a LOCA. The system injects borated water into the reactor vessel through the low-pressure injection inlet nozzles.

Decay Heat Removal/Low-Pressure Safety Injection System*--The decay heat removal/low-pressure injection system is actually two systems that share common piping. The decay heat removal portion is used to provide core cooling during cold shutdown. Piping connections draw from the reactor coolant system piping and return to two inlet nozzles on the reactor vessel. The low-pressure injection portion operates during accident conditions and has two modes of operation. The first mode is the injection mode. During this mode, borated water is drawn from the borated water storage tank and injected into the vessel through the inlet nozzles. When the water level on the borated water storage tank falls to a predetermined level, low-pressure injection suction is transferred to the emergency sump inside the reactor building. This mode of operation is called the recirculation mode.

High-Pressure Safety Injection System*--The high-pressure safety injection system injects high-pressure, borated, reactor-quality water into the reactor coolant system during small LOCAs to flood and cool the reactor core. This system consists of at least two redundant, full-capacity injection trains and associated valves, piping, and instrumentation. For those cases in which the high-pressure safety injection pump function is performed by the letdown, purification, and makeup charging pumps, the components common to both systems are considered part of the high-pressure injection system.

Emergency Power Systems*

Emergency power systems supply electric power to vital safety-related loads during abnormal plant conditions such as loss of off-site power or LOCAs. Emergency power systems are typically diesel generator-powered systems with two to four diesel generator units. The diesel start, load-shedding, generator breaker closing, and sequencing control circuits are considered part of emergency power systems.

Diesel Generator Cooling Water System*--The diesel generator cooling water system provides adequate water flow to remove heat from the diesel engine during operation. A jacket heating loop is also provided to prevent thermal shock when the diesel is started.

Diesel Generator Fuel Oil Storage and Transfer System*--The diesel generator fuel oil storage and transfer system supplies fuel to run the diesel engine and stores enough fuel for several days' continuous operation. Fuel supplied from the day tank may be either pumped or gravity fed to the diesel.

Diesel Generator Lube Oil System*--The diesel generator lube oil system provides oil to lubricate the moving parts of diesel engines, thus protecting them from excessive wear and overheating. Adequate lube oil pressure is usually a permissive signal in the diesel generator starting circuit. During diesel operation, the lube oil is normally circulated by engine-driven oil pumps that are considered piece parts of the diesel engine. Prior to the diesel start, a motor-driven oil pump supplies oil pressure.

Diesel Generator Starting Air System*--The diesel generator starting air system provides compressed air to assist in the rapid starting of the diesel engines.

Feedwater Systems

Feedwater systems provide a continuous supply of preheated water to the steam generators through all power operation modes of the plant.

Emergency Feedwater System*--The emergency feedwater system supplies cooling water to the steam generators in the event of any of several transient conditions in which main feedwater is lost. The emergency feedwater system usually draws from two to four water sources and uses both motor-driven and steam turbine-driven pumps. Steam lines leading to the pump turbines are considered part of the emergency feedwater system.

Main Feedwater System*--The main feedwater system supplies high-quality water to the shell side of the steam generators. Feedwater suction is taken from the condensate system. Feedwater pumps are typically turbine driven, although electric motors occasionally are used as drivers. The startup regulating valve is used until the unit reaches about 15% power.

Fire Protection Systems

Fire protection systems furnish water or fire-extinguishing chemicals to areas throughout the station to minimize the adverse effects of fire on station structures, equipment, and personnel.

Generator Systems

Generator systems convert the rotating mechanical energy of the turbines into electrical energy. Generator systems include the generator, generator excitation system, generator H_2 cooling/CO_2 purge system, generator seal oil system, and generator stator water cooling system.

Generator Excitation System--The generator excitation system provides a regulated, controllable source of magnetizing power to the rotating generator field winding, which controls generator output voltage. The generator excitation system consists of the alternator exciter, exciter field breaker and rectifier, voltage regulators, and all associated controls and instrumentation.

Generator H_2 Cooling/CO_2 Purge System--The generator H_2 cooling/CO_2 purge system keeps the generator adequately cool by maintaining proper generator hydrogen pressure, temperature, and purity. The system consists of hydrogen coolers, storage cylinders, regulatory valves, a hydrogen control panel, and associate piping and instruments. The carbon dioxide supply used to purge the generator comes from a CO_2 storage tank. The generator gas monitoring subsystem is included in this system.

Generator Seal Oil System--The generator seal oil system contains the hydrogen within the generator casing, preventing leakage of hydrogen out of the generator and leakage of air into the generator. This system supplies seal oil under pressure to the generator hydrogen shaft seals. This system consists of various seal oil pumps, a vacuum tank, oil filters, pressure regulators, and associated instruments. Seal oil is supplied by the turbine lube oil system.

Generator Stator Water Cooling System--The generator stator water cooling system cools the generator stator bars, the generator terminal box in the lower frame extension, and the exciter rectifier. This is a closed system that consists of cooling pumps, water coolers, deionizer and filter regulating valves, and assorted piping and instruments.

Heating, Ventilation, and Air Conditioning Systems

Heating, ventilation, and air conditioning systems provide an environment with controlled temperatures, humidities, and air flow patterns to maintain an atmosphere that ensures the comfort and safety of personnel and the operability of equipment located in the containment, drywell, and other small areas.

Penetration Room Ventilation System*--The penetration room ventilation system collects and filters any gases that may leak through containment penetrations during accident conditions. For this reason, the system is used to keep the penetration room at slightly negative pressure. The penetration room ventilation system is designed to be used only under accident conditions. This system also includes pressurization and penetration cooling components.

Instrumentation and Control Systems

Instrumentation and control systems provide timely operation of equipment needed for proper plant operation and the necessary indication of plant parameters and equipment conditions.

Electrohydraulic Control (Turbine Control) System --The electrohydraulic control (turbine control) system controls the speed and acceleration of the main turbine and turbine load by controlling steam flow to the turbine.

Ex-core Nuclear Instrumentation System--The ex-core nuclear instrumentation system protects the reactor by monitoring the neutron flux and generating appropriate trips and alarm signals for various phases of reactor operating and shutdown conditions. The ex-core nuclear instrumentation system consists of eight independent channels: two source range, two intermediate range, and four power range. In addition, there are four auxiliary channels: the audiovisual count rate channel, the comparator channel, the startup rate channel, and the flux deviation channel.

In-core Instrumentation System--The in-core instrumentation system provides information on the neutron flux distribution and fuel assembly outlet temperatures at selected core locations. The system consists of thermocouples, in-core flux thimbles to permit insertion of movable fission detectors, detector drive units and associated components, gas purge and leak detection components, and control and readout equipment.

Integrated Control System*--The integrated control system monitors various plant parameters and actuates equipment to keep unit demand, feedwater flow, and reactor power in the proper relationship. The integrated control system is made up of four subsystems: the unit load demand subsystem, the integrated master control subsystem, the feedwater control subsystem, and the reactor control subsystem. Under turbine trip conditions, the integrated control system controls steam generator water level to help establish conditions conducive to natural circulation.

Leak Detection System--The leak detection system detects and annunciates the escape of potentially radioactive material from the reactor coolant pressure boundary. In addition, the leak detection system is capable of determining the rate of leakage and initiating action to isolate systems that are leaking at a substantial rate in order to protect the nuclear fuel from damage that may be caused by the loss of coolant.

Main Steam System Steam Line Break Control System--The main steam system steam line break control system minimizes the release of steam to the containment following a breach of the main steam piping or the steam generator. This system performs its function by monitoring main steam line pressure and/or steam generator pressure. When these parameters reach predetermined setpoints, the logic circuitry automatically closes the main steam stop valves and isolates the feedwater supply to the steam generator. Some plants also monitor steam generator water level and feedwater system status to effect this function.

Pressurizer Level Control System--The pressurizer level control system maintains pressurizer level during expansion and contraction of the reactor coolant volume due to temperature changes. Reactor coolant average temperature is used to develop a programmed level setpoint, generated in the reactor regulating system. Water inventory is maintained by controlling the balance between water leaving the system, via the letdown flow to the chemical and volume control system, and water entering the system from the charging pumps.

Pressurizer Pressure Control System--The pressurizer pressure control system controls the pressure of the reactor coolant system at or near a fixed setpoint during both steady-state and design transient conditions. The system consists of a combination of heater banks, spray valves, and relief valves actuated at the proper times by a pressure controller with proportional, rate, and reset adjustments. The system components operate at various fixed pressure deviation points from the controller setpoint.

Process Monitoring System--The process monitoring system monitors the radiation levels in selected liquid and gaseous process steams in order to provide the required readouts and records of these levels. When radiation levels exceed predetermined setpoints, alarms and isolation signals are activated to control the release of radioactivity to the environment.

Radiation Monitoring System--The radiation monitoring system indicates, alarms, and records abnormal radiation levels in areas where radioactive material may be present, stored, handled, or inadvertently introduced.

Reactor Protection System*--The reactor protection system (RPS) monitors several plant parameters (core flux; reactor coolant flow, pressure, and temperature; reactor coolant pump operation; and reactor building pressure) and initiates a reactor shutdown if any of the parameters are out of limits. The RPS is made up of four electrically independent redundant channels. Two-out-of-four (2/4) coincident logic is required to initiate a reactor shutdown. A manual shutdown (trip) switch is also provided.

Any instrumentation that performs a safety or control function related to reactor coolant pump operation is considered part of the RPS. Reactor trip breakers are considered part of the rod drive system. Transmitters used in the engineered safeguards actuation and logic system or in control circuits are considered part of the RPS if they perform an RPS function.

Remote Shutdown System--The remote shutdown system provides a reactor plant shutdown capability located outside the control room for situations in which the control room may have to be evacuated. The remote shutdown system provides all the controls and indication necessary to shut down the reactor as well as to provide subsequent reactor plant stabilization and cooldown.

Rod Control System--The rod control system maintains a programmed average temperature in the reactor coolant system by regulating the reactivity in the core and shapes the axial flux profile of the core. The rod control system consists of the electronic circuitry, switches, indicators, and alarm devices necessary for the manipulation of the control rods.

Rod Position Indication System--The rod position indication system continuously senses and displays rod position information for each control rod. This system consists of two subsystems: the absolute position indication subsystem and the relative position indication subsystem. The absolute position indication subsystem consists of reed switch assemblies. The reed switches are operated by a magnet mechanically connected to the rod. The relative position indication subsystem utilizes a stopping motor to control the output of a potentiometer, which provides a voltage analogous to the control rod position.

Safety Features Actuation System*--The safety features actuation system senses plant parameters (e.g., reactor coolant pressure, both steam generator pressures, and reactor building pressure) to determine the need for engineered safety systems operation. Three analog subsystems monitor the parameters and feed into a 2/3 digital logic subsystem. When 2/3 of the analog subsystems indicate a parameter is above or below its threshold, the appropriate 2/3 digital subsystems are activated, which in turn activate one or more of the following:

- o High-pressure injection
- o Low-pressure injection
- o Building spray
- o Reactor building cooling and isolation
- o Emergency power
- o Main steam isolation valves
- o Auxiliary feedwater

All components from the sensors through the logic to the operated device are considered part of the safety features actuation system. Steam generator level and auxiliary feedwater controls should be considered part of this system if they are not in the integrated control system. Any switches or instrumentation in auxiliary shutdown panels, from sensors to indicators, are considered control circuits in this system.

Steam Dump Control System--The steam dump control system reduces the magnitude of nuclear system transients following a large turbine load reduction or reactor trip by dumping throttle steam directly to the main condenser, thereby creating an artificial load on the reactor and preventing the lifting of steam generator safety valves. The system comprises several banks of valves located downstream of the main steam stop valves, and all associated circuitry and controls.

Process Sampling Systems

Process sampling systems monitor the operation of plant equipment and provide information needed to make operational decisions. These systems provide remote sampling facilities and the capability for sampling fluids of various process systems during normal plant power operation and shutdown conditions.

Radwaste Systems

Radwaste systems collect, process, monitor, store, and dispose of all radioactive wastes. The radwaste systems include the gaseous radwaste, liquid radwaste, and solid radwaste systems.

Gaseous Radwaste System--The gaseous radwaste system processes and controls the release of gaseous radioactive wastes to the site environs. The gaseous radwaste system typically consists of waste gas compressor packages, gas decay tanks, and the associated piping, valves, and instrumentation.

Liquid Radwaste System--The liquid radwaste system collects, processes, stores, and monitors, for reuse or disposal, all potentially radioactive liquid wastes. The liquid radwaste system consists of one or more subsystems designed to handle specific types of liquid wastes, such as water, chemical solutions from the demineralizer resin regeneration process, and evaporator distillate.

Solid Radwaste System--The solid radwaste system collects, processes, packages, and temporarily stores, prior to off-site shipping, such wastes as spent resins, evaporator concentrates, and chemical drain tank effluents. Liquid-bearing wastes are dewatered and solidified. Contaminated solids, such as filters, rags, paper, clothing, and tools, are compacted.

Reactor Coolant Systems*

Reactor coolant systems transport heat from the reactor core to the steam generators, where it produces the steam that drives the turbine generators. Reactor coolant systems also define the primary pressure boundary.

Boron Thermal Regeneration System--The boron thermal regeneration system is designed to allow treatment of all or part of the reactor coolant system letdown flow when boron concentration changes are desired for load following. Storage and release of boron during load-following operation is determined by the temperature of the fluid entering the thermal regeneration demineralizers. A chiller unit and a group of heat exchangers are employed to provide the desired fluid temperature at the demineralizer inlets.

Chemical and Volume Control System--The chemical and volume control system regulates reactor coolant chemistry for reactivity and corrosion control and maintains the water level in the pressurizer of the reactor coolant system.

Letdown, Purification, and Makeup System*--The letdown, purification, and makeup system performs the following major functions:

- o Maintains the required water inventory in the reactor coolant system during normal operations through a feed-and-bleed process.
- o Controls reactor coolant system water chemistry conditions through chemical addition, removal, and coolant purification.

- o Provides for seal water injection flow and discharge from the reactor coolant pump seals.
- o Interfaces with and, in some cases, provides common component support for the high-pressure safety injection system functions.
- o Provides water for the pressurizer spray line.

If the charging pumps also supply the high-pressure injection system (no separate safety injection pumps), then the charging pumps and directly associated valves and piping are considered part of the high-pressure injection system.

Refueling Systems

Refueling systems provide a safe and effective means for transporting and handling fuel from the time it reaches the plant until it leaves the plant. The refueling systems are composed of the fuel handling and fuel pool cooling and cleanup systems.

Fuel Handling System--The fuel handling system consists of the mechanical and electrical components required to manipulate nuclear fuel through the various movements and operations undergone while in the reactor building. Reactor vessel servicing equipment is provided to support fuel handling as well as the nonroutine removal of reactor vessel equipment.

Spent Fuel Pool Cooling System--The spent fuel pool cooling system circulates spent fuel pool water to remove the decay heat from spent fuel stored in the pools. This system also purifies the spent fuel pool water, the fuel transfer canal water, and the borated water storage tank water. It maintains clarity for fuel handling operations and fills and drains the fuel transfer canal and cast loading pit.

Steam Systems

The steam systems are used to generate and/or transfer steam to the main turbine and other auxiliaries during various modes of plant operation.

Auxiliary Boiler/Steam System--The auxiliary boiler/steam system provides steam to various components within the plant. These components cannot use main steam because either non-radioactive steam is required by the component or the component operation is required when main steam is not available.

Main Steam System*--The main steam system transports the steam created in the steam generators to the main turbine. The boundary is up to, but not including, the turbine stop valve.

Turbine Systems

Turbine systems convert the thermodynamic energy of the steam to drive the main generator for the production of electricity. Turbine systems include the turbines, extraction steam system, turbine lube oil system, and turbine seal steam system.

Extraction Steam System--The extraction steam system provides heating steam to such components as feedwater heaters for condensate and feedwater heating, seal steam evaporators, and radwaste steam generators. The extraction steam system takes steam from the high-pressure turbine and low-pressure turbine extraction points and from the moisture separators.

Turbine Lube Oil System--The turbine lube oil system continuously supplies cool, clean lubricating oil to the turbine-generator and exciter bearings. The turbine lube oil system comprises lube oil reservoirs, lube oil pumps and coolers, and associated strainers, piping, and instrumentation.

Turbine Seal Steam System--The turbine seal steam system prevents the entrance of air and noncondensible gases into the main condenser and the leakage of radioactive steam to the atmosphere. Clean sealing steam is supplied to the turbine shaft glands and valve stems. Condensed sealing steam is returned to the main condenser.

Water Systems

Water systems provide the needed cooling and makeup throughout the plant for safe and efficient operation of water-cooled components. The water systems include the circulating water, component cooling water, and low-pressure service water systems.

Circulating Water System--The circulating water system is a closed-loop system that removes the excess heat from the turbine exhaust steam and turbine bypass steam by continuously supplying cooling water from the cooling tower basin to the main condenser and returning the heated water to the tower for cooling.

Component Cooling Water System*--The component cooling water system is an intermediate, closed-loop system that provides cooling for various loads inside the reactor building. Designs will vary.

Low-Pressure Service Water System*--The low-pressure service water system supplies raw cooling water to a number of loads in both the reactor and auxiliary buildings. Pump suction is normally taken from a service water pond or the condenser circulating water system and then returned to the same source after providing cooling to the loads. The number of loads and their piping configurations will vary with design.

Level 2 Definitions--Components[a]

Accumulators--devices in which pressurized fluid is stored and used later to drive an actuator, converting fluid pressure energy into mechanical energy.

Gas Accumulator--a device that stores potential energy by accumulating a quantity of pressurized gas in a suitable enclosed vessel. Pressurized liquid or gas acting against an actuator converts gas pressure energy into mechanical energy.

Liquid Accumulator--a device that stores potential energy by accumulating a quantity of pressurized liquid in a suitable enclosed vessel. Pressurized liquid or gas acting against an actuator converts liquid pressure energy into mechanical energy.

Air/Gas Dryers--devices that remove water or moisture from an air or gas system to ensure proper operation of supplied components.

Batteries--devices for producing an electromotive force (emf) by chemical means. When such a source of emf is connected to a closed electric circuit, chemical energy is transformed into electrical energy.

Battery Chargers--devices with sufficient capacity to restore a battery from its design minimum charge to its fully charged state while supplying normal and postaccident loads.

Circuit Closures/Interrupters--switching devices capable of making, carrying, and/or breaking current.

Circuit Breaker--a switching device designed to open a current-carrying circuit under abnormal conditions without injury to itself. It is adjusted to interrupt the current upon the occurrence of an overload of specified magnitude and must be capable of interrupting short-circuit currents.

Contactor--a device for repeatedly establishing and interrupting an electric power circuit.*

Disconnect--a manually operated device that provides positive isolation of associated circuit breakers.

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a. Level 2 definitions marked with an asterisk (*) are taken from the IEEE Standard Dictionary of Electrical and Electronics Terms. Level 2 definitions marked with a double asterisk (**) are taken from the McGraw-Hill Dictionary of Scientific and Technical Terms.

Motor/Load Controller--a device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the motor or groups of motors to which it is connected.*

Switch--a device for making, breaking, or changing connections in an electric circuit under conditions of load for which it is rated. It is not designed for interruption of a circuit under short-circuit conditions.

Switchgear--a type of design in which all the equipment required to control an individual circuit, including bus, circuit breaker, disconnecting devices, current and voltage transformers, controls, instruments, and relays, is assembled in a single, compartmented structure with the circuit breaker provided with means for ready removal.

Computers--programmable electronic devices used to store, retrieve, process, and display data.

Control Instruments--components that monitor, display information about, and automatically control a process.

Flow Control Instrument--an instrument that controls flow rate.

Flux Control Instrument--an instrument used to control the neutron population or reactions in a nuclear reactor.

Level Control Instrument--an instrument that controls liquid levels.

Position Control Instrument - an instrument used to determine and control position (e.g., of valves or control rods).

Pressure Control Instrument--an instrument that controls the difference between atmospheric pressure and the pressure in a pipe or vessel.

RPM Control Instrument--instrument used to control the revolutions per minute of a rotating piece of machinery, such as a turbine.

Temperature Control Instrument--an instrument used to control temperature and temperature differences.

Voltage Control Instrument--an instrument used to control the voltage from a generator, both ac and dc.

Control Rods--rods used to control the reactivity of a nuclear reactor; may be a fuel rod or part of the moderator; in a thermal reactor, commonly a neutron absorber.**

Control Rod Drive Mechanisms--mechanisms normally located above or below the reactor vessel that serve to position a control rod assembly within the core.

Demineralizers--vessels containing anion and cation resin beads that are used to clarify impure water.

Eductors--ejectorlike devices for mixing two fluids.**

Jet Pump--a pump in which an accelerating jet entrains a second fluid to deliver it at elevated pressure.**

Steam Jet Air Ejector--a device like a jet pump that removes air and noncondensible gases from a condenser or low-pressure area.

Electrical Conductors--materials, usually in the form of wire, cable, or bus bar, suitable for carrying an electric current.*

Insulated Cable--a cable enclosed in a sheath or suitable jacket to prevent the infiltration of moisture and the loss of oil, gas, or impregnate, and to provide protection against corrosion and electrolysis.

Shielded Cable--a cable in which the insulated conductor or conductors are enclosed in a conducting envelope(s), so constructed that substantially every point on the surface of the insulation is at ground potential or at some predetermined potential with respect to ground.

Electrical Equipment--any component that amplifies, modulates, converts, changes the voltage of, or regulates electric current.

Amplifier--a component used to change the amplitude of an electric signal.

Converter--a machine or device for changing alternating-current power to direct-current power or vice versa, or from one frequency to another.*

Inverter--a machine, device, or system that provides an uninterruptible source of ac power by converting plant dc voltage into an ac source of power.*

Rectifier--a device for converting alternating current to direct current.*

Transformer--an apparatus for converting electric power in an ac system at one voltage and current into electric power at some other voltage and current without the use of rotating parts.

Voltage Regulator--a device used to adjust the voltage output from the generator for varying load conditions.

Electric Generators--machines that transform mechanical power into electric power.*

Alternator--a mechanical, electrical, or electromechanical device that supplies alternating current.**

Amplidyne--a rotating magnetic amplifier having special windings and brush connections so that small changes in power input to the field coils produce large changes in power output.**

Generator--turbine-driven device used to transform rotating mechanical energy into electric energy.

Electric Heaters--components that convert electric energy into sensible heat to maintain or increase the temperature of a system.

Equipment-Nonspecific--a component in use in commercial nuclear power plants that cannot be classified in any other category.

Fans/Ventilators--devices for producing and regulating currents to circulate, exhaust, or deliver large volumes of air or gas.**

Filters/Strainers--porous or screen mediums used to filter out harmful solid objects and particles from a fluid stream.**

Heat Exchangers--devices that transfer heat from one fluid to another or to the environment.**

Boiler--a water heater for generating steam.**

Condenser--a device used for one or more of the following functions: (a) to produce a vacuum of desired backpressure in a system by condensation of a vapor; (b) to condense a vapor for reuse in a closed cycle.

Cooler--a device within which a substance or process stream is cooled when its heat is transferred, via a temperature drop, to solid, liquid, or gaseous media that are naturally or artificially colder, their lower temperature stemming from radiative, sensible, or latent heat physical effects or endothermic chemical or thermoelectric effects.

Motors--machines that transform input power into mechanical power.**

Electric AC Motor--a machine that transforms alternating-current power into mechanical power.

Electric DC Motor--a machine that transforms direct-current power into mechanical power.

Hydraulic Motor--a motor activated by water or other liquid under pressure.**

Pneumatic Motor--a motor activated by air under pressure.

Pipes--tubes made of metal, plastic, or concrete used to conduct a fluid, gas, or finely divided solid.**

Elbow--a fitting that connects two pipes at an angle, often 90 .**

Nozzle--a tubelike device, usually streamlined, for accelerating and directing a fluid, the pressure of which decreases as it leaves the nozzle.**

Reducer/Orifice--device placed in a pipe arrangement to reduce flow or pressure.

Rupture Diaphragm--a device that relieves pressure in condensers or turbine casings by rupturing at preset pressures.

Tee--a fitting that connects pipes at right angles, forming a T.*.

Pumps--a machine that draws a fluid into itself through an entrance port and forces the fluid through an exhaust port.**

Centrifugal Pump--positive displacement machine in which the liquid is forced, by atmospheric or other pressure, into a set of rotating vanes that constitute an impeller discharging the liquid at a higher pressure and a higher velocity at its periphery. Velocity energy is converted to pressure energy by means of a volute or by a set of stationary diffuser vanes surrounding the impeller periphery.

Reciprocating Pump--positive displacement machine that, at constant speed, delivers essentially the same capacity at any pressure within the capability of the driver and the strength of the pump. This pump provides pulsating flow.

Rotary Pump--positive displacement machine consisting of a fixed casing containing gears, vanes, pistons, cams, screws, etc., operating with minimum clearance. Instead of "throwing" the liquid as in a centrifugal pump, a rotary pump traps it, pushing it around the closed casing much like the piston of a reciprocating pump but discharging a smooth flow.

Vacuum Pump--any pump operated to reduce the pressure of gas in a chamber. Vacuum pumps typically entrain air and noncondensible gas, compress the gas, and discharge it.

Recombiners--devices that reduce the hydrogen concentration in the containment atmosphere by combining free hydrogen and oxygen to form water.

Catalytic Recombiner--a device that reduces the hydrogen concentration in the containment atmosphere by combining free hydrogen and oxygen to form water and that uses a noble metal catalyst bed to promote recombination at relatively low temperatures.

Flame Recombiner--a device that reduces the hydrogen concentration in the containment atmosphere by combining free hydrogen and oxygen to form water and that depends on a self-maintaining, exothermic combustion process to initiate the recombination reaction.

Thermal Recombiner--a device that reduces the hydrogen concentration in the containment atmosphere by combining free hydrogen and oxygen to form water and that uses radiant heat to bring about recombination.

Sensors--devices that respond to a stimulus and transmit a signal for measurement, recording, or operating a control, etc.

Conductivity Sensor--a device used to measure the resistance of a fluid in microohm/cm.

Current Sensor--a device used to measure the current output from a generator or input into a motor.

Flow Sensor--a device that measures the flow rate of a fluid through a system or component.

Frequency Sensor--a device used to measure the frequency output from a generator or input into a component or system.

Flux Sensor--a device used to measure the flux or neutron population in a reactor.

Humidity Sensor--a device used to measure the humidity of a room or area in a power plant.

Level Sensor--a device used to measure the liquid level of a container, tank, or system.

Position Sensor--a device used to measure the position of a piece of equipment, e.g., valve or control rod.

Pressure Sensor--a device used to measure the pressure of a system or component.

Radiation Sensor--a device used to measure radiation levels within systems and areas in a power plant.

<u>RPM Sensor</u>--a device used to measure the revolutions per minute of a rotating piece of equipment.

<u>Temperature Sensor</u>--a device used to measure the temperature of a piece of equipment or area in the plant.

<u>Velocity Sensor</u>--a device used to measure the velocity of a component or fluid within a system.

<u>Vibration Sensor</u>--a device used to measure the vibration of a piece of rotating equipment, e.g., turbine, pump, or motor.

<u>Voltage Sensor</u>--a device used to measure the voltage out of a generator or into an electrical motor.

<u>Steam Generators</u>--components that take the energy from primary coolant water at high temperature and pressure and convert that energy to secondary coolant to generate nonradioactive steam.

<u>Turbines</u>--fluid acceleration machines for generating rotary mechanical power from energy in a stream of fluid.**

<u>Valves</u>--devices used to regulate the flow of fluids in piping systems and machinery.**

<u>Angle Valve</u>--a manually operated valve with its outlet opening oriented at right angles to its inlet opening.**

<u>Ball Valve</u>--A valve in which the fluid flow is regulated by a ball moving relative to a spherical socket as a result of fluid pressure and the weight of the ball.**

<u>Check Valve</u>--automatic valve that opens with forward flow and closes with reverse flow.

<u>Diaphragm Valve</u>--a valve in which body flexibility is provided by a diaphragm.

<u>Four-Way Valve</u>--a multiport plug valve.

<u>Gate Valve</u>--a valve in which a gatelike closure member is moved across the flow passage.

<u>Globe Valve</u>--a closing-down valve in which the closure member is moved squarely on and off the seat.

<u>Needle Valve</u>--a slender, pointed rod fitting in a hole or circular or conical seat.**

Plug Valve--a rotary valve in which a plug-shaped closure member is rotated through increments of 90 to engage or disengage a port hole or holes in the plug with the parts in the valve body.

Relief Valve--pressure-relieving device that automatically relieves a pressure system of excess pressure when abnormal operating conditions cause the pressure to exceed a set limit and recloses when the abnormal pressure recedes below the set limit.

Three-Way Valve--a multiport plug valve.

Valve Operators--devices that are used to position a valve either open or closed in a controlled manner.

Electric Motor - AC Valve Operator--an ac-driven valve operator.

Electric Motor - DC Valve Operator--a dc-driven valve operator.

Explosive Squib Valve Operator--a valve operator that has an explosive charge that causes the valve to reposition. This valve operator is used in the standby liquid control system.

Hydraulic Valve Operator--a valve operator that is operated by water or some other liquid under pressure.

Pneumatic Valve Operator--a valve operator that is operated by air pressure.

Solenoid - DC Valve Operator--a valve operator that has an electric dc solenoid valve that allows air pressure to reposition the valve.

Vessels/Tanks--containers or structural envelopes in which materials are processed, treated, or stored.**

Pressure Vessel--metal container, generally cylindrical or spheroid, capable of withstanding bursting pressure.**

Tank--a large container used for holding, storing, or transporting a fluid.**

Level 3--Displays/Instruments/Controls

Qualitative Displays--devices used to present information without the use of numbers.

Annunciator--a signaling apparatus that operates electromagnetically and serves to indicate visually, or visually and audibly, the existence or termination of an abnormal condition.

Computer Alarm Printer--device used to display computer output in a paper format (versus a CRT format); programmed to produce an audible sound under specific conditions.

CRT Text--written words displayed on a fluorescent screen, usually a computer monitor.

Indicator Light--a light the on-off condition of which is used to convey information.

Legend Light--a lighted tile or panel containing printed words or symbols and the on-off condition of which is used to convey information.

Quantitative Displays--arrangements of devices that produce information of an exact or specified amount or measure.

Chart Recorder--a recorder in which a dependent variable is plotted against an independent variable by an ink-filled pen moving on plain paper, a heated stylus on heat-sensitive paper, a light beam or electron beam on photosensitive paper, or an electrode on electrosensitive paper. The plot may be linear or curvilinear on a strip chart recorder, or polar on a circular chart recorder.

Computer Printer--a computer output mechanism that prints characters one at a time or one line at a time.*

Counter - Digital Readout--a device capable of changing from one to the next of a sequence of distinguishable states upon receipt of an input signal. It produces one output pulse each time it receives some predetermined number of input pulses.**

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a. Level 3 definitions marked with an asterisk (*) are taken from the McGraw-Hill Dictionary of Scientific and Technical Terms. Level 3 definitions marked with a double asterisk (**) are taken from the IEEE Standard Dictionary of Electrical and Electronics Terms.

CRT Alphanumeric Display--an electron tube in which a beam of electrons can be focused to a small area and varied in position and intensity on a surface. The display uses all characters used by a computer, including letters, numerals, punctuation marks, etc.*

CRT Graphic Display--an electron tube in which a beam of electrons can be focused to a small area and varied in position and intensity on a surface. The display has the form of charts, drawings, or appropriate pictorial representation.*

Meter--a device for measuring the value of a quantity under observation; the term is usually applied to an indicating instrument alone.*

Printing Recorder--an electromechanical recording device that accepts electric signal impulses from transmitting circuits and converts them to a printed record of the signal received.**

Two-Position Switches--switches having two discrete positions, usually "ON" and "OFF."

Keylock--a switch that can be operated only by inserting and turning a key such as that used in ordinary locks.*

Knob--a component that is placed on a control shaft to facilitate manual rotation of the shaft; it sometimes has a pointer or markings to indicate shaft position.* A knob has only two possible positions.

Multifunction Push-button Matrix--a unit assembly of one or more externally operable push-button switches in which the function of the switches may be changed.

Push-button (Illuminated Legend)--a switch that is operated by finger pressure at the end of an operating button.* The switch title or explanation is printed on the button and is illuminated by an internal lamp when the switch is activated.

Push-button (Other)--a switch that is operated by finger pressure at the end of an operating button.* The associated title or explanation is not lighted.

Rocker--a rocking or oscillating arm or lever rotating with a moving shaft or pivoted on a stationary shaft.

Toggle Switch/Two-Position--a small switch that is operated by manipulation of a projecting lever that is combined with a spring to provide a snap action for opening or closing a circuit quickly. The circuit holds either of two states until changed.*

Multiposition Selectors--devices for making connections to any one of a number of circuits.

J-Handle Switch--a multiposition switch having a pistol-grip handle.

Rotary Switch--a multiposition switch that is operated by rotating the shaft with a knob.

Stepping Push-button--a push-button that produces incremental changes to the function being controlled with each activation.

Toggle Switch--a small switch that is operated by manipulation of a projecting lever, which is combined with a spring to provide snap action for opening or closing a circuit quickly.* The switch usually has three positions.

Continuously Variable Controls--controls that can be operated to achieve any setting within a prescribed range.

Knob--a control operated by a knob that is placed on a shaft to facilitate manual rotation of the shaft; sometimes the knob has a pointer or markings to indicate shaft position.

Lever--a control operated by a lever for making continuous adjustments.

Thumb Wheel--a control operated by the application of tangential force to the edge of a small wheel.

Keyboards--sets of keys or control levers having a systematic arrangement and used to operate a machine or other piece of equipment.*

Calculator--a device that performs logic and arithmetic digital operations based on numerical data that are entered by pressing numerical and control keys.*

Computer Terminal--a keyboard used to input data or instructions to a computer.

Teletype--a special electric typewriter that produces coded electric signals corresponding to manually typed characters and automatically types messages when fed with similarly coded signals produced by another machine.*

Typewriter--a machine that produces printed copy, character by character, as the typewriter is operated; essential parts are an input keyboard, a set of raised characters, inking means, a platen, and a mechanism for advancing the position at which successive characters are imprinted.*

Tools--devices or instruments for the performance of a manual operation.

Clippers--mechanical or electrical tools that are used for clipping or cutting; commonly referred to as shears.

Fuse Puller--tongs provided with an insulating handle and jaws; used to insert a fuse unit into a fuse support or to remove it from the support.**

Impact Wrench--a compressed air or electrically operated wrench that gives a rapid succession of sudden torques.*

Pliers--a small instrument with two handles and two grasping jaws, usually long and roughened, working on a pivot; used for holding small objects and cutting, bending, and shaping wire..

Ratchet and Pocket--a wrench with a socket to fit the head of a bolt or a nut that consists of a wheel, usually toothed, operating with a catch or a pawl so as to rotate in only a single direction.*

Screwdriver--a tool for turning and driving screws in place; a thin wedge-shaped or fluted end enters the slot or recess in the head of the screw.*

Shorting Probe--a probe with an insulated handle and cable used to remove electric potential from a circuit.

Torch--a gas burner used for brazing, cutting, or welding.*

Torque Wrench--a hand or power tool used to turn a nut on a bolt that can be adjusted to deliver a predetermined amount of force to the bolt when tightening the nut.

Welding Rod--filler metal in the form of a rod or heavy wire.*

Wrench--a manual or power tool with fixed or adjustable jaws or sockets, either at the end or between the ends of a lever, for holding or turning a bolt, pipe, or other object.*

Lifting/Moving Devices--devices used to raise something upward or to some other position at the same level.

Crane--a hoisting machine with a power-operated inclined or horizontal boom and lifting tackle for moving loads vertically and horizontally.*

Come-along--a lever-operated chain or wire-rope hoist for lifting or pulling at any angle which has a reversible ratchet mechanism in the lever, permitting short-stroke operation for both tensioning and relaxing, and which holds the loads with a Weston-type friction brake or a releasable ratchet.*

Hoist--a power unit for a hoisting machine, designed to lift from a position directly above the load and therefore mounted to facilitate mobile service.*

Jack--a portable device for lifting heavy loads through a short distance, operated by a lever, screw, or hydraulic press.*

Sling--a length of rope, wire rope, or chain used for attaching a load to a crane hook.*

Wire Rope--a rope formed of twisted strands of wire.*

Electrical Test Equipment--equipment used to assess or evaluate the performance, capabilities, or present status of any system involving electricity.

Amprobe--a device for measuring the flow of current through a conductor by means of inductance, e.g., a clamp-on ammeter.

Decade Box--an assembly of precision resistors, coils, or capacitors, the individual values of which vary in submultiples and multiples of 10; the decade box can be set to any desired value within its range by appropriately setting a 10-position selector switch for each section.

Digital Meter--a device for measuring the value of electrical quantities; the result is indicated in directly readable numerals.

Frequency Counter--an electronic counter used to measure frequency by counting the number of cycles in an electric signal during a preselected time interval.*

Multimeter--a test instrument having a number of different ranges for measuring voltage, current, and resistance.*

Oscilloscope--a test instrument that uses a cathode-ray tube to make visible on a fluorescent screen the instantaneous values and wave forms of electrical quantities that are rapidly varying as a function of time or another quantity.*

Resistance/Impedance Bridge--a resistance bridge (also known as Wheatstone bridge) is a four-arm bridge circuit, all arms of which are predominantly resistive; used to measure the electrical resistance of an unknown resistor by comparing it with a known standard resistance. An impedance bridge is a device similar to a Wheatstone bridge that is used to compare impedances that may contain inductance, capacitance, and resistance.

Signal Generator--an electronic test instrument that delivers a sinusoidal output at an accurately calibrated frequency that may be anywhere from the audio to the microwave range: the frequency and amplitude are adjustable over a wide range, and the output is usually amplitude-modulated or frequency-modulated.*

Voltage Test Lamp--a set of probes with leads attached to an incandescent lamp; used to determine whether a voltage difference exists between two points.

Measurement Test Equipment--equipment used to ascertain the extent, dimensions, or quantity of some parameter of an object or system.

Gas Detector--a device that indicates the existence of combustible or noxious gas.*

Hydrometer--a direct-reading instrument for indicating the density, specific gravity, or some other characteristic of liquids.*

Micrometer--a caliper for making precise measurements; a spindle is moved by a screw thread so that it touches the object to be measured; the dimension can then be read on a scale.*

Pyrometer and Thermometer--any of a broad class of temperature-measuring devices; pyrometers were originally designed to measure high temperatures, but some are now used in any temperature range; includes radiation pyrometers, thermocouples, resistance pyrometers, and thermistors.*

Scale--a balance or other device used for weighing.*

Stroboscope--an instrument for making bodies visible intermittently, either by illuminating the object with brilliant flashes of light or by imposing an intermittent shutter between the viewer and the object; a high-speed vibration can be made visible by adjusting the strobe frequency close to the vibration frequency.*

Test Gauge--a pressure-measuring instrument used for hydrostatic tightness tests or other tests of systems or components.

Vibration Detector--an apparatus or system used to detect the presence of vibration.*

Printed Communications--a method of imparting knowledge or providing information expressed in a written form.

Administrative Procedure--a document describing a plant policy or other instructions for managing the conduct of operations in the plant.

Graph--a presentation of data in a diagram that represents the variation of a variable in comparison with one or more other variables.

Label--a small sign affixed on or in the vicinity of a piece of equipment for identification or description.

Log Book--a bound volume in which operating data are recorded.

Maintenance Procedure--a written procedure to assist personnel in performing corrective or preventive maintenance on plant equipment.

Operating Procedure--a written procedure to assist operating personnel in controlling plant systems or responding to abnormal events.

Table--a presentation of data in a systematic arrangement of rows and columns for ready reference.

Tag--a temporary label, marker, or sign used to indicate that a component is in an abnormal or protected condition.

Test or Calibration Procedure--a written procedure used by operations or maintenance personnel in testing equipment or calibrating instruments.

Verbal Communications--a method of imparting knowledge or providing information expressed in spoken words.

Face-to-Face Communication--verbal communications between people over relatively short distances without the aid of voice amplification or transmission devices.

Page-Party System (PA) Communication--verbal communications using an electronic system for amplification and broadcasting to several remote locations.

Sound-Powered Phone Communication--verbal communication using a telephone operating entirely on current generated by speaker's voice, with no external power supply; sound waves cause a diaphragm to move a coil back and forth between the poles of a powerful but small magnet, generating the required audio-frequency voltage in the coil.*

Telephone Communication--verbal communication using an electric device for transmitting signals to a distant point via conducting wire.

Two-Way Radio Communication--a compact, combination radio transmitter-receiver that can be carried or strapped on the belt; popularly known as a walkie-talkie.*

Equipment - Nonspecific--a display, control, communications device, tool, or piece of test equipment that cannot be classified in any other category.

DEFINITIONS OF HUMAN ACTIONS

The human action verbs used in the data bank taxonomy are defined in this appendix. They are organized as follows:

- Level 1

  Control Room Operator duties
  Equipment Operator duties
  Maintenance Technician duties

- Level 2

  Control Room Operator tasks
  Equipment Operator tasks
  Maintenance Technician tasks

- Level 3 (task elements)

The definitions are listed in the order in which the human actions appear on the matrices.

Level 1

Control Room Operator

Diagnose--to use information derived from plant systems to determine the nature or cause of a condition.

Operate--to cause to function or to sustain and regulate the ongoing functioning of a system.

Monitor--to observe the status of a system and its components over extended periods.

Test--to execute a procedure or routine that will provide evidence as to the functioning of a system or component.

Equipment Operator

Diagnose--to use information derived from plant systems to determine the nature or cause of a condition.

Inspect--to examine for the purpose of detecting an abnormal condition.

Maintain--to keep a system or component in an operational state or potentially operational.

Operate--to cause to function or to sustain and regulate the ongoing functioning of a system.

Test--to execute a procedure or routine that will provide evidence as to the functioning of a system or component.

Maintenance Technician

Check--to examine for the purpose of verifying the satisfactory condition, safety, or performance of a system.

Diagnose--to use information derived from plant systems or components to determine the nature or cause of a malfunction.

Maintain--to work on a system or component to repair it or to protect it against failure or decline.

Test--to execute a procedure or routine that will provide evidence as to the functioning of a system or component.

Level 2

Control Room Operator

Diagnose--to use information derived from plant components to determine the nature or cause of a condition.

Fill/Drain--to raise or deplete the level of a substance (operated from control room).

Monitor--to observe the status of plant components over extended periods.

Open/Close--to position a mechanical component to allow or to block the passage of fluid or electricity (operated from control room).

Operate--to sustain and regulate the ongoing functioning of plant components from the control room.

Start/Stop--to initiate or terminate the action of a component (operated from control room).

Equipment Operator

Diagnose--to use information derived from plant components to determine the nature or cause of a condition.

Fill/Drain--to raise or deplete the level of a substance.

Monitor--to observe the status of components from plant areas outside the control room.

Open/Close--to position a mechanical component to allow or to block the passage of fluid or energy.

Operate--to sustain and regulate the ongoing functioning of plant components not operated from the control room.

Start/Stop--to initiate or terminate the action of a component.

Maintenance Technician

Calibrate--to determine, check, or correct the graduation of any component providing quantitative measurements.

Diagnose--to use information derived from plant components to determine the nature or cause of a malfunction.

Maintain--to perform work on a component to protect it against failure or decline.

Repair--to restore a component to a functional state by the replacement or mending of worn or damaged parts.

Test--to execute a procedure or routine that will provide evidence as to the functioning of a component.

Level 3

Adjust--to operate a continuous control.

Calculate--to determine by mathematical processes.

Calibrate--to determine, check, or correct the graduation of any instrument providing quantitative measurements.

Diagnose--to use information derived from plant instruments to determine the nature or cause of a condition.

Identify--to detect and classify objects or indications according to implicit or predetermined characteristics.

Maintain--to keep an instrument or control in an operational state or a potentially operational state.

Monitor--to observe characteristics of instruments and/or displays over extended periods.

Position--to operate a control that has discrete states.

Read--to visually examine symbolic information.

Receive--to be given written or verbal information.

Remember--to retain information or retrieve information from memory.

Select--to choose equipment, tools, or job performance aids after consideration of alternatives.

Use--to employ equipment, tools, or job performance aids (other than discrete or continuous controls).

Verify--to confirm information concerning the condition or state of equipment. Includes check reading.

Write--to reproduce symbolic information manually.

APPENDIX B

TASK STATEMENT STRUCTURE

APPENDIX B
TASK STATEMENT STRUCTURE

INTRODUCTION

The task statement is a sentence describing the activity for which human error probability (HEP) data are provided. To ensure consistency and allow for systematic data categorization and retrieval, the task statement consists of a series of standardized terms or phrases. The structure and format of the task statement for each taxonomy level are described below. Note that words rather than codes are used in the task statements.

TASK STATEMENT STRUCTURE LEVEL 1

Level 1 Task Statement: [1]Job classification [2]verb the [3]system [4]state given: [5]standard, [6]condition, [6]condition...

Job Classification

Job classification refers to the individual performing the task. The classifications of Control Room Operator (CRO), Equipment Operator (EO), or Maintenance Technician (MT) may be specified.

Verb

This is the verb that best describes the duty area involved in performing the task. The verbs applicable to each job classification are defined in Appendix A.

System

Refers to the system involved (see Appendix A).

State

Refers to the operating mode or condition of a system during or resulting from the human action. The state entry is optional and is used to specify a system configuration that makes the steps necessary to accomplish the task different than those for other similar tasks involving the same system. In the case where a system has several modes of operation that are not procedurally defined, the purpose of the system operation may be entered as its state (e.g., operate the chemical and volume control system to control coolant inventory).

Standard

The standard is the criterion for successful task performance that was not achieved. The standard entry is used to identify different types or degrees of task errors. Based on the information provided in the data source document, a short phrase that describes the criterion used to identify errors is entered (e.g., level not maintained within limits, test not performed).

Conditions

Conditions include the initiating cue, plant conditions, and abnormal environmental or system constraints that may affect the difficulty of the human action or the probability of error. The condition entries are in the form of phrases that specify performance shaping factors (PSFs) affecting the human action that differ from the eight PSFs tracked separately for each source data item. If available, information is provided on whether the action was local or remote, what nuclear power plant probabilistic risk assessment (PRA) sequence (e.g., TP, loss of offsite power) relates to the event, and what human reliability analysis (HRA) method (e.g., SLIM) was used to derive the HEP. There is no limit to the number of condition entries that may be used. However, each condition entry must apply to all the error opportunities as well as the error events.

TASK STATEMENT STRUCTURE LEVEL 2

Level 2 Task Statement: [1]Job classification [2]verb the [3]component [4]state given: [5]standard, [6]condition, [6]condition, [6]condition ...

Job Classification

Refers to the individual performing the task. The classifications of Control Room Operator (CRO), Equipment Operator (EO), or Maintenance Technician (MT) may be specified.

Verb

This is the verb that best describes the effects of the human action on the component. Definitions of verbs used in Level 2 tasks for each job classification are provided in Appendix A.

Component

Refers to the piece of equipment involved in the task (see Appendix A).

State

Refers to the condition of the component at the completion of the task. The state entry is optional and is used to specify the component status if it affects the type of human action required to accomplish the task (e.g., EO operates the valve <u>throttled</u> ...).

Standard

The standard is the criterion for successful task performance that was not achieved. The standard entry is used to identify different types or degrees of task errors. Based on the information provided in the data source document, a short phrase describing the criterion used to identify errors is entered (e.g., not completely closed, wrong component, deviant condition not detected).

Conditions

Conditions include the initiating cue, plant conditions, and abnormal environmental or system constraints that may affect the difficulty of the human action or the probability of error. The condition entries are in the form of phrases that specify performance shaping factors (PSFs) affecting the human action that differ from the eight PSFs tracked separately for each source data item. There is no limit to the number of condition entries that may be used. However, each condition entry must apply to all the error opportunities as well as the error events.

In addition to the listing of PSFs, a number of key factors related to plant conditions and the use of procedures have been coded into the NUCLARR system. By convention, the following plant transients have been designated:

Anticipated transient without scram	ATWS
Transient initiated sequence with a loss of feedwater and emergency coolant injection (BWR)	TQUV/TQUX
Transient initiated sequence with a loss of feedwater and emergency coolant injection (PWR)	TML-D
Loss of offsite power	LOSP or TP
Small LOCAs	S2 or S3
Large LOCA	A
Long-term failure of containment heat removal	TW

Operator actions are also defined in terms of their proximity to the control room and are designated as either local or remote. Events are classified as either initiating, preinitiating, or post-initiating. Operators actions are classified as planned (poa), e.g., those actions specified by procedure, or as recovery (rop) actions taken outside of procedures.

TASK STATEMENT STRUCTURE LEVEL 3

Level 3 Task Statement: The personnel [1]verb the [2]means given:

[3]standard, [4]condition, [4]condition, [4]condition ...

Verb

This is the verb that best describes the human action of the personnel. Definitions of verbs used in Level 3 tasks are listed in Appendix A.

Means

Refers to the display, instrument, or control device with which the subject interfaces (see Appendix A).

Standard

This is the criterion for successful task performance that was not achieved. The standard entry is used to identify different types or degrees of task errors. Based on the information provided in the data source document, a short phrase describing the criterion used to identify errors is entered (e.g., operated in wrong direction, wrong control, incorrect reading, deviant condition not detected).

Conditions

Conditions include the initiating cue, plant conditions, and abnormal environmental or system constraints that may affect the difficulty of the human action or the probability of error. The condition entries are in the form of phrases that specify performance shaping factors (PSFs) affecting the human action that differ from the eight PSFs tracked separately for each source data item. There is no limit to the number of condition entries that may be used. However, each condition entry must apply to all the error opportunities as well as the error events.

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Loss of offsite power	LOSP or TP
Small LOCAs	S2 or S3
Large LOCA	A
Long-term failure of containment heat removal	TW

Operator actions are also defined in terms of their proximity to the control room and are designated as either local or remote. Events are classified as either initiating, preinitiating, or post-initiating. Operators actions are classified as planned (poa), e.g., those actions specified by procedure, or as recovery (rop) actions taken outside of procedures.

APPENDIX C
DESCRIPTION OF SOURCE STATEMENT CALCULATIONS

APPENDIX C

DESCRIPTION OF SOURCE STATEMENT CALCULATIONS

This Appendix provides the algorithm that NUCLARR follows in calculations of the human error probabilities (HEP) data to be included in the NUCLARR system. The data entered in the NUCLARR system can include a HEP data point (median), a mean HEP, the confidence bounds for the HEP, the number of errors, and the number of opportunities for error.

In some instances, the information received for inclusion in the NUCLARR system will consist only of a report of the number of errors and the number of opportunities for error. In such a case, the HEP and confidence bounds may have to be computed by NUCLARR. In other instances, an estimate of the HEP and confidence bounds will be provided; and the number of errors and number of opportunities for error must be estimated.

Execution of the following calculations are described in Procedure A-8 in Vol. III.

Detailed Steps

NUCLARR breaks the calculations into three distinct cases based on the types of data that have been supplied. A different subprocedure will be followed for each case:

- If the source of the data provides both the number of errors and the number of opportunities, Case 1 is selected. Proceed to Case 1.

- If the data are psychological scaling, subjective, or analytic data for which a HEP and confidence bounds are provided and the number of errors and opportunities for error are not provided, Case 2 is selected. Proceed to Case 2.

Case 1: Data Containing the Number of Errors and Number of Opportunities

When only E and N are given, or E, N, and HEP are given, NUCLARR calculates the upper confidence bound (UCB) and lower confidence bound (LCB) based on a 90% confidence interval. NUCLARR executes the following logic:

Step 1: If the HEP is not given in the data, then the HEP is calculated by dividing E by N and rounding to two significant digits. This HEP is treated as a median.

Step 2: Using a binomial distribution, the UCB and LCB are calculated as indicated in Figure 5 of the main text.

Step 3: The error factor (UCB/HEP) and mean are calculated as indicated in Figure 5 of the main text.

Step 4: The values of HEP, UCB, LCB, mean, error factor, and N and E are stored and displayed on the source statement entry screen.

Case 2: Analytic Data with Only Confidence Bounds and HEP Value

When only the HEP, UCB, and LCB are given, NUCLARR calculates estimates for E, the number of errors, and N, the number of opportunities for error. NUCLARR executes the following steps:

Step 1: NUCLARR determines the error factor, UCB/HEP, by dividing the UCB by the HEP.

Step 2: Using Table C-1, NUCLARR finds the value of E corresponding to the ratio UCB/HEP. The values in this table in the UCB/HEP column are the ratios that would result from observing E failures in a large sample of opportunities. More specifically, each value is the upper 95th percentile of a chi-square distribution with 2E+2 degrees of

TABLE C-1. NUMBER OF ERRORS BASED ON UCB/HEP RATIO

UCB/HEP	E	UCB/HEP	E
11.82	.1	2.10	5.0
7.81	.5	2.00	6.0
4.75	1.0	1.90	7.0
3.70	1.5	1.80	8.0
3.15	2.0	1.75	9.0
2.81	2.5	1.70	10.0
2.58	3.0	1.50	15.0
2.29	4.0	1.1	20.0

freedom, divided by 2E. For cases with E<1, appropriate gamma distribution percentiles are used. In using this table, the tabled ratio that is closest to that obtained in Step 1 is used to identify E.

Step 3: NUCLARR determines the number of opportunities (N) by dividing the number of errors (E) from the table by the HEP.

Step 4: A mean (corresponding to a lognormal distribution with the HEP as median and UCB as the upper 95th percentile is calculated, as shown in Figure 5 of the main text of this report.

Step 5: E and N and the other parameters are stored and displayed on the source statement entry screen.

APPENDIX D

DESCRIPTION OF COMPUTING TASK STATEMENT HEPs

APPENDIX D

DESCRIPTION OF COMPUTING TASK STATEMENT HEPs

This appendix provides the algorithm that NUCLARR follows to compute the unrecovered and basic Human Error Probabilities (HEPs) from the HEP data points included within a failure mode for a task statement.

NOTE:

HEP DATA POINTS FOR WHICH CONFIDENCE BOUNDS ARE UNSPECIFIED ARE NOT USED IN CALCULATING THE TASK STATEMENT HEP.

Detailed Steps

This procedure can be broken into four distinct cases, and a different subprocedure will be followed for each case:

- If there are more than two HEP data points with confidence bounds specified under the task failure mode/data type, proceed to Case 1.

- If there are two HEP data points with confidence bounds specified included under the task failure mode/data type, proceed to Case 2.

- If there is more than one HEP data point included under the task failure mode/data type but no more than one of the data points has confidence bounds specified, proceed to Case 3.

- If there is only one HEP data point included under the task failure mode/data type being considered, proceed to Case 4.

Case 1: More Than Two HEP Data Points with Confidence Bounds

The steps performed by NUCLARR for Case 1 are:

Step 1: Retrieval of the data from the cell.

Step 2: Summation of Es, the number of errors, to obtain E_{total}.

Step 3: Summation of Ns, the number of opportunities for error, to obtain N_{total}.

Step 4: Calculation of HEP_{AVG}, where HEP_{AVG} equals the following:

$$HEP_{AVG} = E_{total}/N_{total}$$

Step 5: Calculation of x^2 contribution from each HEP using the following equation:

$$x^2 \text{contribution from } HEP_i = \frac{N_i\,(HEP_i - HEP_{AVG})^2}{HEP_{AVG} \times (1 - HEP_{AVG})}$$

Step 6: Summation of all contributions for x^2_{total}.

Step 7: Count of the number of HEPs listed used in calculations, minus 1.

Step 8: Selection of critical x^2 value from Table D-1 associated with the value obtained in Step 7.

Step 9: If the value of x^2_{total} is less than or equal to the critical x^2 value, use HEP_{AVG} as the task statement HEP for the failure mode/data type. The 5% and 95% confidence limits are calculated based on binomial distribution with E_{total} as the observed number of failures, HEP_{AVG} as the probability of failure, and N_{total} as the number of opportunities. The mean and error factor are also computed in this case. Refer to Figure 8 in the main text.

TABLE D-1. CRITICAL x^2 VALUES, a = .10

Number of HEPs - 1	Critical x^2 Value
1	4.61
2	6.25
3	7.78
4	9.24
5	10.64
6	12.02
7	13.36
8	14.68
9	15.99
10	17.28
11	18.55
12	19.81
13	21.06
14	22.31
15	23.54
16	24.77
17	25.99
18	27.20
19	28.41

Step 10: If the value of x^2_{total} is greater than the critical x^2 value, then the HEP data point with the largest x^2 contribution is eliminated from the calculations of the task statement HEP.

Step 11: If there are three or more HEPs remaining after deleting the data for the highest x^2 value, NUCLARR returns to Step 2 and repeats the above calculations.

Step 12: If there are two HEPs remaining, then NUCLARR performs Case 2 calculations.

Case 2: Two HEP Data Points with Confidence Bounds

The steps followed by NUCLARR for Case 2 are as follows:

Step 1: Retrieval of the data from the cell.

Step 2: Summation of Es, the number of errors, to obtain E_{total}.

Step 3: Summation of Ns, the number of opportunities for error, to obtain N_{total}.

Step 4: Calculation of A, where A equals the following:

$$A = (N_1 - E_1) \times N_2 - (N_2 - E_2) \times N_1$$

Step 5: Calculation of B using the following equation:

$$B = E_{total} \times [N_{total} - E_{total}] \times N_1 \times N_2$$

Step 6: Calculation where

$$x^2 = \frac{N_{total} \times [A - 0.05 \times N_{total}]^2}{B}$$

Step 7: If the value of x^2 is greater than 2.71, the data points cannot be combined. Case 3 is executed by NUCLARR.

Step 8: If the value of x^2 is less than or equal to 2.71, then the task statement HEP is calculated as:

$$\text{Task statement HEP} = E_{total}/N_{total}$$

Step 9: NUCLARR calculates the upper and lower confidence bounds assuming E_{total} is from a binomial distribution with parameters (n,p) equal to (N_{total}, task statement HEP). It also computes a mean and error factor. For all these calculations, refer to Figure 8 in the main text.

Case 3: More than One HEP Data Point, Confidence Bounds Not Specified, or HEP Data Points Cannot be Combined

If there is more than one HEP data point but uncertainty bounds are not specified, or if the x^2 total value is greater than the x^2

critical value, the HHRAG Manager must decide which HEP data point will be selected as the task statement HEP for the failure mode/data type. The upper and lower confidence bounds and mean and median associated with that point are also used for the task statement HEP.

Factors that should be considered in selecting which HEP to use are: the value of N for each data source (a large N is preferable), the HEP value (the higher value is more conservative), the PSFs applicable to each source (PSFs representing normal conditions are preferable), and the reliability of the source (some sources of data are considered more reliable than others). For ad hoc aggregations, the user is given the opportunity to make this selection.

Case 4: Only One HEP Data Point

Since there is only one HEP data point within the failure mode/data type, that HEP data point becomes the task statement HEP for the failure mode/data type. If it has UCB and LCB, they will be used as the task statement HEP bounds. Its mean and error factor will also be applied to the task statement or ad hoc aggregation if they are available.

APPENDIX E
DESCRIPTION OF COMPUTING CELL OR FUNCTIONAL GROUP SUMMARY HEPs

APPENDIX E

DESCRIPTION OF COMPUTING CELL OR FUNCTIONAL GROUP SUMMARY HEPS

This appendix provides the algorithm that NUCLARR follows to compute the cell or functional group summary cell human error probabilities (HEPs). Note that calculations for functional group summary cells as well as for individual cells are based on HEPs and bounds that are aggregated at the task statement level.

Detailed Steps

NUCLARR chooses one of the following two distinct cases for calculation of the cell HEP or functional group summary cell HEP.

- o If only one task statement having the task failure mode/data type is being considered, Case 1 is selected. Proceed to Case 1.

- o If two or more task statements having the failure mode/data type are being considered, Case 2 is selected. Proceed to Case 2.

Case 1: One Task Statement Having the Failure Mode/Data Type Being Considered

Since there is only one task statement HEP data point within the failure mode/data type, the HEP, UCB, LCB, mean, and median of that data point become the cell or functional group summary HEP, UCB, LCB, mean, and median for the failure mode/data type.

Case 2: Two or More Task Statements Having the Failure Mode/Data Type Being Considered

The steps followed by NUCLARR for Case 2 are as follows:

Step 1: Calculation of the natural logarithm for each task statement HEP listed to obtain the ln HEPs.

Step 2: Summation of the ln HEPs to obtain the sum of the ln HEPs.

Step 3: Division of the sum of the ln HEPs by the total number of HEPs used in the total to obtain the average ln HEP.

Step 4: Determination of the antilogarithm of the average ln HEP. This value is the cell HEP or the functional group summary HEP.

Step 5: Calculation of the ratio of the UCB to the LCB by dividing UCB by LCB for each of the task statements to obtain the ratio UCB/LCB.

Step 6: Calculation of the natural logarithm of the ratio UCB/LCB to obtain the ln ratio.

Step 7: Summation of the squares of the ln ratio to obtain the sum of square of the ln ratio.

Step 8: Division of the sum of the ln ratio by the total number of ratios to obtain the average squared ratio.

Step 9: Square root of the average squared ratio to obtain the average ratio.

Step 10: Division of the average ratio by 2 to obtain the LNEF.

Step 11: Calculation of the antilogarithm of the LNEF to obtain the error factor.

Step 12: Calculation of the cell or functional group summary UCB by multiplying the cell HEP or functional group summary HEP by the error factor.

Step 13: Calculation of the cell or functional group summary LCB by dividing the cell HEP or functional group summary HEP by the error factor.

Step 14: Calculation of the cell or functional group summary mean by the equation provided in Figure 9 of the main text.

APPENDIX F

COMPONENT TYPES AND DESIGN CHARACTERISTICS FOR HARDWARE COMPONENT FAILURE DATA

APPENDIX F

COMPONENT TYPES AND DESIGN CHARACTERISTICS FOR HARDWARE COMPONENT FAILURE DATA

Introduction

Hardware component failure data (HCFD) are hierarchically configured within the NUCLARR system. This hierarchy reflects the amount of detail supplied in a data source for the component failure events and serves to organize the data and facilitate its access.

The taxonomy is hierarchically configured as shown below:

- o Level 1: Category of component (i.e., mechanical vs. electrical)
- o Level 2: Type of component
- o Level 3: Design of component
- o Level 4: Failure mode
- o Level 5: Normal state
- o Level 6: Applications

Levels 1 through 3 and 6 characterize the set of historical physical components whose failures are described by a record. For convenience, the component list has been divided into two categories, mechanical and electrical (Level 1). Forty-two general types of mechanical components and 33 types of electrical components have been identified (Level 2). A complete listing of these component types and the associated coding scheme follows. All component types are arranged by component category.

Within the component types, the data may be further characterized by component design (Level 3). For example, designs for the component pumps, motor-driven include axial, centrifugal, diaphragm, and gear. A complete listing of the component designs is provided under each component type.

Finally, for each component type, valid applications are listed. Application (Level 6) is a search item that provides additional information about the application and/or design of the component. It is at the lowest level of the basic HCFD hierarchy because it generally provides the most detailed information among these levels. The general application categories are: component (the component in which a piece part is installed), driver (the component driven by a driver-type component), enclosure type, external environment, external location, facility (NSSS vendor for fuel assemblies), instrumentation (the parameter being monitored), instrument type (analog or digital), internal environment, relay function, voltage level, and valve (the valve design for valve-valve operator components).

Mechanical Component Design Codes

Code	Description
ACC	Accumulators (closed, pressurized)
ACCUM	Accumulators (closed, pressurized)
	Internal environment application
ACU	Air Conditioning Units/Chillers
ACUCS	Chillers
ACUCU	Air Conditioning Units
	External environment application
ADY	Air Dryers
ADYAB	Absorption
ADYAD	ADYsorption
ADYHL	Heatless
ADYHR	Heat Reactivated
ADYRF	Refrigerated
ADYXX	Unknown
ADYZZ	Other
	Internal environment application

BLC Blowers/Compressors
BLCBL Blowers
BLCGC Gas Circulator
BLCMP Compressors
BLCSC Superchargers
BLCTC Turbochargers
BLCXX Unknown
BLCZZ Other
Internal environment application

CON Control Rods
CONRD Control Rods
Facility application

CRD Control Rod Drives
CRDRV Control Rod Drives
Facility application

CTM Controllers, Mechanical
CTMHY Hydraulic
CTMMC Mechanical
CTMPN Pneumatic
CTMXX Unknown
CTMZZ Other
Driver application

DEM Demineralizers
DEMAN Anion
DEMCA Cation
DEMMB Mixed Bed
DEMPR Powdered Resin
DEMXX Unknown
DEMZZ Other
Internal environment application

DPA Dampers, Pneumatic operator
DPH Dampers, Hydraulic Operator
DPM Dampers, Motor Operator
DPO Dampers, Manual Operator
DPX Dampers, Unknown Operator
DPZ Dampers, Other Operator
___OB Opposed Blade
___PB Parallel Blade
___PL Proportioning Louver
___SB Single Blade
___XX Unknown
___ZZ Other
External environment application

DPN Dampers, Exclusive of Operators
DPNOB Opposed Blade
DPNPB Parallel Blade
DPNPL Proportioning Louver
DPNSB Single Blade
DPNXX Unknown
DPNZZ Other
External environment application

EDJ Eductors/Ejectors
EDJEC Ejectors
EDJUC Eductors
Internal environment application

ENG Engines
ENGDG Diesel
ENGGE Gasoline
ENGXX Unknown
ENGZZ Other
Driver application

FCU Fan Cooler Units
FCUFC Fan Cooler Units
External environment application

FIT Fittings
FITAG Angle
FITCP Coupling
FITEL Elbow
FITFG Flange
FITNP Nipple
FITPG Plug
FITRD Reducer
FITTB Tubing
FITTE Tee (T)
FITUN Union
FITWL Well, Process Monitor
FITYE Wye (Y)
FITZZ Other
Internal environment application

FLT Filters
FLTCC Charcoal
FLTHE HEPA
FLTXX Unknown
FLTZZ Other
Internal environment application

FUE Fuel Assemblies (fuel elements)
FUELA Fuel Assemblies (fuel elements)
Facility application

FVN Fans, Ventilators
FVNFN Fans
FVNVT Ventilators
External environment application

HTX Heat Exchangers
HTXBL Boiler
HTXCD Condenser
HTXCO Cooler
HTXEV Evaporator
HTXHT Heater
HTXIC Ice Condenser
HTXSG Steam Generator
HTXSH Superheater
HTXXX Unknown
HTXZZ Other
Internal environment application

MFI Mechanical Function Items
MFIBR Brake
MFICL Clutch
MFICP Coupling
MFIGV Governor
MFITI Timer
MFIZZ Other
Component application

MPI Miscellaneous Piping Items
MPIDF Diaphragm
MPINZ Nozzle
MPIOR Orifice
MPIRD Rupture Disc
MPISL Sensing Line
Internal environment application

MPP Mechanical Piece Parts
MPPBR Bearing/Bushing
MPPBT Belt
MPPFS Fastener
MPPGR Gear
MPPHO Hose
MPPZZ Other
Component application

MTM Motors, Mechanical
MTMHY Hydraulic
MTMPN Pneumatic
Driver application

PEN	Penetrations
PENAC	Access
PENEL	Electrical
PENEQ	Equipment
PENFU	Fuel
PENHD	Handling
PENIN	Instrument
PENPP	Piping
PENPR	Personnel
PENXX	Unknown
PENZZ	Other
	No application designated
PIP	Pipe
PIPLG	Pipe, >= 3 Inches, ID
PIPSM	Pipe, < 3 Inches, ID
PIPXX	Pipe, unknown size
	Internal environment application

PPD	Pumps, Diesel Driven
PPM	Pumps, Motor Driven
PPT	Pumps, Steam Turbine Driven
PPX	Pumps, Unknown Driver
PPZ	Pumps, Other Driver
___AX	Axial
___CF	Centrifugal
___DP	Diaphragm
___GR	Gear
___RD	Radial
___RP	Reciprocating
___RT	Rotary
___VN	Vane
___XX	Unknown
___ZZ	Other
	Internal environment application

PPN	Pumps, Exclusive of Drivers
PPNAX	Axial
PPNCF	Centrifugal
PPNDP	Diaphragm
PPNGR	Gear
PPNRD	Radial
PPNRP	Reciprocating
PPNRT	Rotary
PPNVN	Vane
PPNXX	Unknown
PPNZZ	Other
	Internal environment application

PPE Pumps, Electromagnetic
PPEMP Pumps, Electromagnetic
Internal environment application

PPJ Pumps, Jet
PPJMP Pumps, Jet
Internal environment application

PPV Pumps, Vacuum
PPVCP Cryopump
PPVDP Diffusion
PPVIP Ion
PPVMP Mechanical
PPVSP Sorption
PPVTM Turbomolecular
PPVXX Unknown
PPVZZ Other
Internal environment application

REC Recombiners
RECCT Catalytic
RECFL Flame
RECTM Thermal
RECXX Unknown
RECZZ Other
Internal environment application

RES Reservoirs (open, not pressurized)
RESVR Reservoirs (open, not pressurized)
Internal environment application

SFI Structural Function Items
SFIAK Anchors
SFIEJ Expansion Joints
SFIHG Hangers
SFISB Snubbers
SFISU Supports
SFIXX Unknown
SFIZZ Other
Component application

STR Strainers
STRDU Duplex
STRSC Self-cleaning
STRSP Simplex
STRSS Screens, Stationary
STRST Screens, Traveling
STRXX Unknown
STRZZ Other
Internal environment application

TAN Tanks (closed, not pressurized)
TANKS Tanks (closed, not pressurized)
Internal environment application

TRA Train (Series of Mechanical/Electrical Components)
TRAIN Train (Series of Mechanical/Electrical Components)
Internal environment application

TRB Turbines
TRBCB Combustion
TRBHY Hydro
TRBST Steam
TRBXX Unknown
TRBZZ Other
Driver application

VLC Valves, Check
VLCHY Hydraulic Operator
VLCMN Manual Operator (mechanical handweel)
VLCMO Motor Operator
VLCNO No Operator
VLCNT No Operator (tilting disk check valve)
VLCPN Pneumatic Operator
VLCXX Unknown Operator
VLCZZ Other Operator
Internal environment application

VLD Valves, Mechanical (dp/spring) Operator
VLE Valves, Explosive Operator (squib)
VLF Valves, Float Operator
VLH Valves, Hydraulic Operator
VLM Valves, Motor Operator
VLO Valves, Manual Operator (mechanical handwheel)
VLP Valves, Pneumatic Operator
VLS Valves, Solenoid Operator
VLX Valves, Unknown Operator
VLZ Valves, Other Operator
___AN Angle
___BF Butterfly
___BL Ball
___DP Diaphragm
___GL Globe
___GT Gate
___ND Needle
___PL Plug
___XX Unknown
___ZZ Other
Internal environment application

VLN	Valves, Exclusive of Operators	
VLNAN	Angle	
VLNBF	Butterfly	
VLNBL	Ball	
VLNDP	Diaphragm	
VLNGL	Globe	
VLNGT	Gate	
VLNND	Needle	
VLNPL	Plug	
VLNXX	Unknown	
VLNZZ	Other	
		Internal environment application
VLR	Valves, Relief	
VLRDA	Direct Acting	
VLRPI	Indirect Acting, Pilot Operated	
VLRPW	Indirect Acting, Power Operated	
VLRPX	Indirect Acting, Unknown Operator	
VLRPZ	Indirect Acting, Other Operator	
VLRXX	Unknown	
VLRZZ	Other	
		Internal environment application
VLV	Valves, Vacuum Breakers	
VLVBK	Valves, Vacuum Breakers	
		Internal environment application
VOP	Valve Operators	
VOPDO	Mechanical (dp/spring) Operator	
VOPEO	Explosive Operator (Squib)	
VOPFO	Float Operator	
VOPHO	Hydraulic Operator	
VOPMO	Motor Operator	
VOPNO	Manual Operator (mechanical handwheel)	
VOPPO	Pneumatic Operator	
VOPSO	Solenoid Operator	
VOPXO	Unknown Operator	
VOPZO	Other Operator	
		Valve application
VSL	Vessels (closed, pressurized)	
VSLCD	Containment/Drywell	
VSLPZ	Pressurizer	
VSLRV	Reactor Vessel	
VSLSP	Suppression Pool/Wetwell	
VSLTO	Torus	
VSLXX	Unknown	
VSLZZ	Other	
		Internal environment application

Electrical Component Design Codes

Code	Description
ABT	Automatic Transfer Switches
ABTSS	Solid-state
ABTXX	Unknown
ABTZZ	Other
	Voltage level application
AMP	Amplifiers
AMPCA	Current
AMPIA	Isolation
AMPPA	Power
AMPVA	Voltage
AMPXX	Unknown
AMPZZ	Other
	Instrumentation application
ANN	Annunciators
ANNAD	Audio
ANNAV	Audiovisual
ANNVS	Visual
ANNXX	Unknown
ANNZZ	Other
	Instrumentation application
BAT	Batteries
BATDC	Dry Cell (e.g., Nickel-cadmium)
BATWC	Wet Cell (e.g., lead-acid)
BATXX	Unknown
BATZZ	Other
	Voltage level application
BCH	Chargers, Battery
BCHGR	Chargers, Battery
	Voltage level application
CBM	Circuit Breakers, Molded Case
CBMSS	Solid-state Trip
CBMTM	Thermal-magnetic Trip
CBMXX	Unknown
CBMZZ	Other
	Voltage level application

CBP	Circuit Breakers, Power	
CBPAM		Air-magnetic
CBPOL		Oil
CBPSS		Solid-state
CBPVC		Vacuum
CBPXX		Unknown
CBPZZ		Other
		Voltage level application
CHA	Channels (Series of Instrumentation Components)	
CHANL		Channels (Series of Instrumentation Components)
		Instrumentation application
CND	Conductors	
CNDBS		Bus
CNDCC		Cable, Control
CNDPC		Cable, Power
CNDWI		Wire
CNDXX		Unknown
CNDZZ		Other
		Enclosure type application
		Voltage level application
COM	Computation Modules	
COMAU		Auctioneer
COMAV		Averagers
COMCA		Calculators
COMCN		Converters
COMCR		Comparators
COMDI		Differentiators
COMFG		Function Generators
COMIN		Integrators/Totalizers
COMMD		Modifiers
COMSM		Summers
COMXX		Unknown
COMZZ		Other
		Instrumentation application
CPU	Computers	
CPUAN		Analog
CPUDL		Digital, Mainframe
CPUHB		Hybrid
CPUPC		Digital, Micro/PC
CPUXX		Unknown
CPUZZ		Other
CRC	Circuits, Control	
CRCNT		Circuits, Control
		Driver application

CTE	Controllers/Regulators, Non-mechanical	
CTEEA		Electronic, Analog
CTEED		Electronic, Digital
CTEEL		Electrical
CTEEM		Electromagnetic
CTEHD		Electrohydraulic
CTEMC		Electromechanical
CTEPD		Electronic, Programmable Digital
CTEPN		Electropneumatic
CTEXX		Unknown
CTEZZ		Other Instrumentation application
DSP	Displays	
DSPCR		Cathode-ray Tube
DSPEL		Electroluminescent
DSPLC		Liquid-crystal
DSPLD		Light-emitting Diode
DSPXX		Unknown
DSPZZ		Other
EFI	Electrical Function Items	
EFICA		Card
EFICB		Circuit Board
EFICC		Circuit Card Carrier
EFICD		Conduit
EFICN		Connector
EFICR		Contactor
EFICT		Cable Tray
EFIDC		Disconnect
EFIFN		Fan, Cooling
EFILS		Sequencer, Load
EFIMS		Switch, micro
EFIPN		Panel
EFITM		Timer
EFIZZ		Other Voltage level application
EPP	Electrical Piece Parts	
EPPCL		Coil
EPPCP		Capacitor
EPPCT		Contacts
EPPDI		Diode/Rectifier
EPPIC		Integrated Circuit (IC)
EPPID		Inductor
EPPRE		Resistor
EPPTI		Transformer, Internal Power
EPPTR		Transistor

EPPTS   Transformer, Signal
EPPTY   Thyristor (SCR, TRIAC, GTO device)
EPPZZ   Other
    Voltage level application

FUS   Fuses
FUSCN   Fuses, Control
FUSPW   Fuses, Power
    Voltage level application

GND   Generators, with Diesel Engine Driver
GNG   Generators, with Gasoline Engine Driver
GNH   Generators, with Hydro Turbine Driver
GNM   Generators, with Motor Driver
GNS   Generators, with Gas Turbine Driver
GNT   Generators, with Steam Turbine Driver
GNX   Generators, with Unknown Driver
GNZ   Generators, with Other Driver
___AL   Alternator
___AP   Amplidyne
___CN   Converter
___DY   Dynamotor
___GN   Generator
___XX   Unknown
___ZZ   Other
    Voltage level application

GNN   Generators, Exclusive of Drivers
GNNAL   Alternator
GNNAP   Amplidyne
GNNCN   Convertor
GNNDY   Dynamotor
GNNGN   Generator
GNNXX   Unknown
GNNZZ   Other
    Voltage level application

HTR   Heaters
HTRHT   Heat Tracing
HTRIM   Immersion
HTRXX   Unknown
HTRZZ   Other
    Voltage level application

IND   Indicators
INDAN   Analog
INDDG   Digital
INDXX   Unknown
INDZZ   Other
    Instrumentation application

LOG Logic Modules
LOGIC Logic Modules
Instrumentation application

MOT Motors, Electrical
MOTCM Commutator, DC
MOTIS Induction, Squirrel-cage, AC
MOTIW Induction, Wound-rotor, AC
MOTPM Permanent Magnet, DC
MOTSB Synchronous, Brushless, AC
MOTSR Synchronous, Reluctance, AC
MOTSS Synchronous, Slip-ring, AC
MOTXX Unknown
MOTZZ Other
Driver application
External environment application
Voltage level application

MTC Motor Controls
MTCCE Controller, AC Wound-rotor, Electromechanical
MTCCF Controller, AC Adjustable-frequency
MTCCS Controller, AC Wound-rotor, Solid-state
MTCCV Controller, DC Adjustable-voltage
MTCCX Controller, Unknown
MTCCZ Controller, Other
MTCSM Combination Starter, Electromechanical
MTCSS Combination Starter, Solid-state
MTCSX Combination Starter, Unknown
MTCSZ Combination Starter, Other
Driver application
Voltage level application

PWS Power Electronics (Solid-state)
PWSEX Exciter
PWSFC Frequency Converter
PWSIN Inverter (except motor controllers)
PWSRC Rectifier,Ctrld w/SCRs;except exciters & mtr ctlrs
PWSRU Rectifier, Uncontrolled
PWSUP Uninterruptible Power Supply
PWSXX Unknown
PWSZZ Other
Instrumentation application
Voltage level application

RCD Recorders
RCDEE Electrical/Electronic
RCDPN Pneumatic
RCDXX Unknown
RCDZZ Other
Instrumentation application

RLC	Relays, Control	
RLP	Relays, Protective	
___EM	Electromechanical	
___EP	Electropneumatic	
___MW	Mercury Wetted	
___PN	Pneumatic	
___RD	Reed	
___SM	Solid-state/Mechanical	
___SS	Solid-state	
___XX	Unknown	
___ZZ	Other	
		Relay function application
		Voltage level application

SEN	Transducers (Detectors/Elements/Sensors)	
SENDT	Detectors	
SENEL	Elements	
SENSN	Sensors	
		Instrumentation application

SWC	Switches, Control	
SWCKY	Key	
SWCPB	Push-button	
SWCRT	Rotary	
SWCSL	Selector	
SWCTW	Thumb-wheel	
SWCXX	Unknown	
SWCZZ	Other	
		Enclosure application
		External environment application
		Instrumentation application

SWI	Switches, Instrumentation
SWIAC	Acceleration
SWIAN	Analysis
SWICD	Conductivity
SWICU	Current
SWIDP	Differential Pressure
SWIFL	Flow
SWIFN	Flux/Neutron Level
SWIFQ	Frequency
SWIFS	Fire/Smoke
SWIGD	Ground
SWIIN	Intrusion
SWILM	Limit
SWILV	Level
SWIMG	Magnetism
SWIMH	Moisture/Humidity
SWIMV	Multi-Variable
SWIPD	Speed

(Continued)

(Switches, Continued)

SWIPR	Pressure
SWIPS	Position
SWIPW	Power
SWIPX	Proximity
SWIRD	Radiation
SWIRS	Resistance
SWITF	Torque/Force
SWITG	Toxic Gas
SWITI	Time
SWITP	Temperature
SWIVB	Vibration
SWIVT	Voltage
SWIXX	Unknown
SWIZZ	Other
	Enclosure application
	External environment application

SWS	Switches, Solid-state
SWSBI	Bistable
SWSXX	Unknown
SWSZZ	Other
	Instrumentation application

SWP	Switches, Power
SWPSP	Single-phase
SWPTD	Three-phase Duplex
SWPTG	Three-phase Ganged
SWPXX	Unknown
SWPZZ	Other
	Enclosure application
	External environment application

XMT	Transmitters
XMTRS	Transmitters
	External environment application
	Instrumentation application

XTC	Transformers, Controls & Instrumentation
XTCCP	Control Power
XTCCR	Current
XTCDR	Differential/Regulating
XTCIS	Isolation
XTCTC	Transducer/Coupling
XTCVP	Voltage (potential)
XTCVR	Voltage-regulating
XTCVV	Variable Voltage

XTCXX	Unknown
XTCZZ	Other Voltage level application Instrumentation application
XTP	Transformers, Power
XTPGC	Gas-cooled
XTPLC	Liquid-cooled
XTPXX	Unknown
XTPZZ	Other Voltage application

APPENDIX G

COMPONENT APPLICATION LISTINGS

APPENDIX G

COMPONENT APPLICATION LISTINGS

Hardware component failure data (HCFD) are hierarchically configured within the NUCLARR system. This hierarchy reflects the amount of detail supplied in a data source for the component failure events and serves to organize the data and facilitate its access.

The taxonomy is hierarchically configured as shown below:

- <u>Level 1</u>: Category of component (i.e., mechanical vs. electrical)
- <u>Level 2</u>: Type of component
- <u>Level 3</u>: Design of component
- <u>Level 4</u>: Failure mode
- <u>Level 5</u>: Normal state
- <u>Level 6</u>: Applications

Application (Level 6) is a search item that provides additional information about the application and/or design of the component. It is at the lowest level of the basic HCFD hierarchy because it generally provides the most detailed information among these levels. The general application categories are: component (the component in which a piece part is installed), driver (the component driven by a driver-type component), enclosure type, external environment, external location, facility (NSSS vendor for fuel assemblies), instrumentation (the parameter being monitored), instrument type (analog or digital), internal environment, relay function, voltage level, and valve (the valve design for valve-valve operator components). The application categories appropriate for each type of component are defined in Appendix F. For each defined category of application, exactly one specific application is listed. Codes are provided below for specific applications, including the case where the specific application is not given in the data source.

Code	Description
C	COMPONENT APPLICATIONS
DRIV	DRIVER APPLICATIONS
DRIVDM	Damper Driver
DRIVGN	Generator Driver
DRIVPM	Pump Driver
DRIVVL	Valve Driver
DRIVXX	Unknown Driver
DRIVZZ	Other Driver
ENCL	ENCLOSURE TYPE APPLICATIONS
ENCLEC	Enclosed in Conduit
ENCLED	Enclosed in Duct
ENCLES	Enclosed in Sealed Enclosure
ENCLET	Enclosed in Cable Tray
ENCLEX	Enclosed in Unknown
ENCLEZ	Enclosed in Other
ENCLNE	Not Enclosed
ENCLXX	Unknown Enclosure
EXTE	EXTERNAL ENVIRONMENT APPLICATION
EXTEBN	Benign (within NEMA MG-1 envelope) Ext.
EXTECL	Cold External Environment
EXTECO	Corrosive External Environment
EXTEDT	Dirty/Dusty/Greasy External Environment
EXTEHD	Humid/Damp External Environment
EXTEHR	High Radiation External Environment
EXTEHT	Hot (> 40 degrees C) Ext. Environment
EXTEVB	Vibration External Environment
EXTEWF	Wet (fresh water) External Environment
EXTEWS	Wet (salt water/other electrolyte) Ext.
EXTEXX	Unknown External Environment
EXTEZZ	Other External Environment
EXTL	EXTERNAL LOCATION APPLICATION
EXTLNB	Control Building/Control Complex
EXTLNC	Emergency Onsite Power Supply Building
EXTLND	Emergency Operations Facility (Offsite)
EXTLNE	Fuel Building
EXTLNF	Radwaste Building
EXTLNG	Auxiliary Building
EXTLNH	Reactor Building (BWR)
EXTLNM	Reactor Containment Building
EXTLNN	Turbine Building

Hardware Component Application Codes

Code	Description
EXTLNO	Circulating Water Structures
EXTLNP	Primary Containment
EXTLNS	Secondary Containment
EXTLXT	External to Buildings
EXTLXX	Unknown
EXTLZZ	Other
FACL	FACILITY APPLICATIONS
FACLAC	Allis-Chalmers Facility
FACLBW	Babcock-Wilcox Facility
FACLCE	Combustion Engineering Facility
FACLGA	General Atomic Facility
FACLGE	General Electric Facility
FACLWH	Westinghouse Facility
FACLXX	Unknown Facility
FACLZZ	Other Facility
INST	INSTRUMENTATION APPLICATIONS
INSTAC	Acceleration Instrumentation
INSTAN	Analysis Instrumentation
INSTCD	Conductivity Instrumentation
INSTCU	Current Instrumentation
INSTDP	Differential Pressure Instrumentation
INSTFL	Flow Instrumentation
INSTFN	Flux/Neutron Level Instrumentation
INSTFQ	Frequency Instrumentation
INSTFS	Fire/Smoke Instrumentation
INSTGD	Ground Instrumentation
INSTIN	Intrusion Instrumentation
INSTLM	Limit Instrumentation
INSTLV	Level Instrumentation
INSTMG	Magnetism Instrumentation
INSTMH	Moisture/Humidity Instrumentation
INSTMV	Multi-variable Instrumentation
INSTPD	Speed Instrumentation
INSTPR	Pressure Instrumentation
INSTPW	Power Instrumentation
INSTPX	Proximity Instrumentation
INSTRD	Radiation Instrumentation
INSTRS	Resistance Instrumentation
INSTTF	Torque/Force Instrumentation
INSTTG	Toxic Gas Instrumentation
INSTTI	Time Instrumentation
INSTTP	Temperature Instrumentation
INSTVB	Vibration Instrumentation

Hardware Component Application Codes

Code	Description
INSTVT	Voltage Instrumentation
INSTXX	Unknown Instrumentation
INSTZZ	Other Instrumentation
INTE	INTERNAL ENVIRONMENT APPLICATIONS
INTEAR	Air Internal Environment
INTECG	Compressed Gas Internal Environment
INTECL	Chlorine Internal Environment
INTECS	Chemical Solution other than Boric Acid
INTEHG	Hydrogen Internal Environment
INTEIG	Inert Gas Internal Environment
INTEOL	Oil Internal Environment
INTEST	Steam Internal Environment
INTEWB	Water, Borated Internal Environment
INTEWC	Water, High Purity/Demineralized - Int.
INTEWD	Water, Silt/Particle Entrained - Int.
INTEWS	Water, Brackish Sea Internal Environment
INTEXX	Unknown Internal Environment
INTEZZ	Other Internal Environment
RELY	RELAY FUNCTION APPLICATIONS
RELY02	Time Delay, starting/closing relay func.
RELY03	Checking or Interlocking relay function
RELY12	Overspeed relay function
RELY14	Underspeed relay function
RELY15	Speed/Frequency, matching relay function
RELY23	Temperature Control Relay Function
RELY27	Undervoltage Relay Function
RELY32	Directional Power Relay Function
RELY40	Field Relay Function
RELY46	Phase Balance Negative Sequence Relay
RELY47	Phase Sequence Voltage Relay Function
RELY48	Incomplete Sequence Relay Function
RELY49	Thermal Relay Function
RELY50	Instantaneous Overcurrent Relay Function
RELY51	AC Time Overcurrent Relay Function
RELY59	Overvoltage Relay Function
RELY62	Time Delay, stopping Relay Function
RELY63	Pressure Relay Function
RELY64	Ground Protective Relay Function
RELY67	AC Directional Overcurrent Relay Functn.
RELY81	Frequency Relay Function
RELY86	Locking-out Relay Function
RELY87	Differential Protective Relay Function
RELY98	Overload Relay Function

Hardware Component Application Codes

Code	Description
RELY99	Unknown Relay Function
TYPE	INSTRUMENTATION TYPE APPLICATION
TYPEAN	Analog Instrumentation Type
TYPEDG	Digital Instrumentation Type
TYPEXX	Unknown Instrumentation Type
TYPEZZ	Other Instrumentation Type
VALV	VALVE APPLICATIONS
VALVAN	Angle Valve
VALVBF	Butterfly Valve
VALVBL	Ball Valve
VALVDP	Diaphragm Valve
VALVGL	Globe Valve
VALVGT	Gate Valve
VALVND	Needle Valve
VALVPL	Plug Valve
VALVXX	Unknown Valve
VALVZZ	Other Valve
VTAC	VOLTAGE LEVEL APPLICATIONS - AC
VTACAA	< 125 VAC (single voltage)
VTACAB	< 249 VAC (voltage range)
VTACAC	< 599 VAC (voltage range)
VTACAD	< 4.74 kVAC (voltage range)
VTACAI	< 125 VAC - > 169 kVAC (voltage range)
VTACBB	125 - 249 VAC (single voltage)
VTACBC	125 - 599 VAC (voltage range)
VTACCC	250 - 599 VAC (single voltage)
VTACCD	250 VAC - 4.74 kVAC (voltage range)
VTACDD	600 VAC - 4.74 kVAC (single voltage)
VTACDE	600 VAC - 8.24 kVAC (voltage range)
VTACDI	> 600 VAC (voltage range)
VTACEE	4.75 - 8.24 kVAC (single voltage)
VTACEF	4.75 - 14.9 kVAC (voltage range)
VTACFF	8.25 - 14.9 kVAC (single voltage)
VTACFG	8.25 - 72.4 kVAC (voltage range)
VTACGG	15.0 - 72.4 kVAC (single voltage)
VTACGH	15.0 - 168 kVAC (voltage range)
VTACHH	72.5 - 168 kVAC (single voltage)
VTACHI	> 72.5 kVAC (voltage range)
VTACII	> 169kVAC (230,345kVAC,greater classes)
VTACXX	Voltage level Unknown - AC

Hardware Component Application Codes

Code	Description
VTDC	VOLTAGE LEVEL APPLICATIONS - DC
VTDCAA	< 125 VDC (single voltage)
VTDCAB	< 250 VDC (voltage range)
VTDCBB	125 - 250 VDC (single voltage)
VTDCBC	> 125 VDC (voltage range)
VTDCCC	> 250 VDC (single voltage)
VTDCXX	Voltage level Unknown - DC
VTXX	VOLTAGE LEVEL APPLICATIONS - UNKNOWN
VTXXAA	< 125 V (single voltage)
VTXXAB	< 249 V (voltage range)
VTXXBB	125 - 249 V (single voltage)
VTXXBC	125 - 599 V (voltage range)
VTXXCC	250 - 599 V (single voltage)
VTXXCD	250 V - 4.74 kV (voltage range)
VTXXDD	600 V - 4.74 kV (single voltage)
VTXXDE	600 V - 8.24 kV (voltage range)
VTXXEE	4.75 - 8.24 kV (single voltage)
VTXXEF	4.75 - 14.9 kV (voltage range)
VTXXFF	8.25 - 14.9 kV (single voltage)
VTXXFG	8.25 - 72.4 kV (voltage range)
VTXXGG	15.0 - 72.4 kV (single voltage)
VTXXGH	15.0 - 168 kV (voltage range)
VTXXHH	72.5 - 168 kV (single voltage)
VTXXHI	> 72.5 kV (voltage range)
VTXXII	> 169 kV (single voltage)
VTXXXX	Voltage level Unknown (Unknown VAC/VDC)

APPENDIX H

FACILITY IDENTIFIER (FID) CODES

APPENDIX H

FACILITY IDENTIFIER (FID) CODES

Facility identifier codes identify the plant, or plants, at which the data originated. As many as four codes may be listed. A single code suffices for data from a single station (e.g., ZIS for ZIS1/ZIS2). All plants for which data has been entered in NUCLARR are listed below, alon with their respective NUCLARR Facility Identifier codes (FIDs). As new plants or plant groupings are added, this listing will be updated.

PLANT UNIT NAME	FID
ARKANSAS 1	ANO1
ARKANSAS 2	ANO2
PROPRIETARY PRA A	APRA
PROPRIETARY REL A	AREL
ADV.TEST REACTOR	ATR
PROPRIETARY PRA B	BPRA
PROPRIETARY REL B	BREL
BEAVER VALLEY 1	BVS1
BEAVER VALLEY 2	BVS2
BIG ROCK POINT	BRP1
BRAIDWOOD 1	BRS1
BROWNS FERRY 1	BRF1
BROWNS FERRY 2	BRF2
BROWNS FERRY 3	BRF3
ALL BRUNSWICK	BEP
BRUNSWICK 1	BEP1
BRUNSWICK 2	BEP2
BYRON 1	BYS1
BYRON 2	BYS2
CALLAWAY	CAY1
CALVERT CLIFFS 1	CCN1
CALVERT CLIFFS 2	CCN2
CATAWBA 1	CNS1
CATAWBA 2	CNS2
CLINTON 1	CPP1
COOK 1	DCC1
COOK 2	DCC2
COOPER STATION	CPR1
CRYSTAL RIVER 3	CRP3
UNPUBLISHED PRA C	CPRA
ALL COMANCHE PEAK	CPS
DAVIS-BESSE	DBS1
DIABLO CANYON 1	DCP1
DIABLO CANYON 2	DCP2
ALL DRESDEN	DRS
DRESDEN 1	DRS1
DRESDEN 2	DRS2
DRESDEN 3	DRS3
DUANE ARNOLD	DAC1
UNPUBLISHED PRA D	[illegible]RA
EUROPEAN COMM.	E[illegible]
UNFINISHED PRA E	EPRA
ALL FARLEY	JMF
FARLEY 1	JMF1
FARLEY 2	JMF2
FAST FLUX TEST FAC.	FFTF
FERMI 2	EFP2

PLANT UNIT NAME	FID
FITZPATRICK	JAF1
FORT CALHOUN	FCS1
FORT ST. VRAIN	FSV1
PROPRIETARY PRA F	FPRA
GINNA	REG1
GRAND GULF	GGS1
UNFINISHED PRA G	GPRA
HADDAM NECK	HNP1
HATCH 1	EIH1
HATCH 2	EIH2
HOPE CREEK	HCS1
HUMBOLDT BAY 3	HMB3
INDIAN POINT 2	IPS2
INDIAN POINT 3	IPS3
KEWAUNEE	KNP1
LA CROSSE	LBR1
ALL LASALLE	LSC
LASALLE 1	LSC1
LASALLE 2	LSC2
LASALLE 3	LSC3
LIMERICK	LGS1
MAINE YANKEE	MYP1
MCGUIRE 1	MGS1
MCGUIRE 2	MGS2
MILLSTONE 1	MNS1
MILLSTONE 2	MNS2
MILLSTONE 3	MNS3
MONTICELLO	MNP1
NINE MILE PT. 1	NMP1
NINE MILE PT. 2	NMP2
NORTH ANNA 1	NAS1
NORTH ANNA 2	NAS2
OCONEE 1	NEE1
OCONEE 2	NEE2
OCONEE 3	NEE3
OYSTER CREEK	OCP1
PALISADES	PAL1
PALO VERDE 1	PAV1
PALO VERDE 2	PAV2
PALO VERDE 3	PAV3
PEACH BOTTOM 2	PBS2
PEACH BOTTOM 3	PBS3
PERRY	PNP1
PILGRIM	PPS1
ALL POINT BEACH	PBH
POINT BEACH 1	PBH1

PLANT UNIT NAME	FID
POINT BEACH 2	PBH2
ALL PRAIRIE ISL.	PIN
PRAIRIE ISLAND 1	PIN1
PRAIRIE ISLAND 2	PIN2
ALL QUAD CITIES	QAD
QUAD CITIES 1	QAD1
QUAD CITIES 2	QAD2
RANCHO SECO	RSS1
RINGHALS 2 (SWED)	RGLS
RIVER BEND	RBS1
ROBINSON 2	HBR2
SALEM 1	SGS1
SALEM 2	SGS2
SAN ONOFRE 1	SOS1
SAN ONOFRE 2	SOS2
SAN ONOFRE 3	SOS3
SEABROOK	SBK1
SEQUOYAH 1	SNP1
SEQUOYAH 2	SNP2
SHEARON HARRIS 1	SHS1
SHOREHAM	SNS1
ST. LUCIE 1	SLS1
ST. LUCIE 2	SLS2
SUMMER	VCS1
ALL SURRY	SPS
SURRY 1	SPS1
SURRY 2	SPS2
ALL SUSQUEHANNA	SES
SUSQUEHANNA 1	SES1
SUSQUEHANNA 2	SES2
THREE MILE ISL. 1	TMI1
THREE MILE ISL. 2	TMI2
TROJAN	TNP1
ALL TURKEY POINT	TPS
TURKEY POINT 3	TPS3
TURKEY POINT 4	TPS4
VERMONT YANKEE 1	VYS1
VOGTLE 1	AWV1
WASH. NUCLEAR 2	WNP2
WATERFORD 3	WGS3
WOLF CREEK	WCS1
YANKEE-ROWE	YKR1
PLANT X (SAIC)	X
PLANT Y (1ST U)	Y1
PLANT Y (2ND U)	Y2
ALL ZION	ZIS
ZION 1	ZIS1
ZION 2	ZIS2

IPRDS Plant 1 -- IP1
IPRDS Plant 2 -- IP2
IPRDS Plant 3 -- IP3
IPRDS Plant 4 -- IP4
IPRDS Plant 5 -- IP5

Identifiers for Stations

The plant unit identifier listed above with the plant unit number omitted. For example, ZIS for Zion Station (both Unit 1 and 2).

Identifiers for Utilities

For groups of plants operated by a single utility, the three-letter Nuclear Plant Reliability Data System utility codes with the last character blank. For example, FPL for Florida Power and Light Co.

Special Identifiers for Groups of Plants

GROUP	FID
All PWRs	PWR
All BWRs	BWR
All Babcock & Wilcox	B&W
All Combustion Eng.	CE
All General Electric	GE
All Westinghouse	WEST
All Plants	ALLP

APPENDIX I

HARDWARE COMPONENT FAILURE DATA SYSTEM CODES

APPENDIX I

HARDWARE COMPONENT FAILURE DATA SYSTEM CODES

HCFD system codes identify the system(s) represented by the set of components whose experience is described by a single record. Up to five included or excluded systems may be listed for a record. Most of the system codes given in this Appendix are taken from IEEE Standard 805-1984, which provides system drawings and guidance for determining a component's system. For example, heat exchangers are listed in the system in which they perform a heating or cooling function; instruments are in the systems in which they sense; actuators and circuit breakers are in the systems containing the controlled equipment; valves are assigned to the system in which they control fluid; and transformers are assigned to the lower voltage system. Special codes are provided for Class 1E electrical systems; for data from sources that are not specific, the associated more general system codes may also include data for Class 1E components.

The code AL is provided for all systems; however, this code is used only when the data source emphasizes that the data combined to provide a failure rate represent all systems. The code ZZ (not specified) is selected in preference to AL if the source does not make a system distinction. For system code XX (other), the actual system is explained in the comments field.

Code	Description
AA	CONTROL ROD DRIVE SYSTEM
AB	REACTOR COOLANT SYSTEM (PWR)
AC	REACTOR CORE SYSTEM
AD	REACTOR RECIRCULATION SYSTEM (BWR)
AE	REACTOR COOLANT SYSTEM - HELIUM (HTGR)
AL	ALL SYSTEM (BALANCE OF PLANT) [SPECIAL NON-EIIS CODE]
AP	PRESSURIZER SYSTEM (PWR) [SPECIAL NON-EIIS CODE]
AS	STEAM GENERATING SYSTEM (PWR) [SPECIAL NON-EIIS CODE]
AV	REACTOR VESSEL SYSTEM [SPECIAL NON-EIIS CODE]

BA AUXILIARY/EMERGENCY FEEDWATER SYSTEM (PWR)
BB CONTAINMENT COMBUSTIBLE GAS CONTROL SYSTEM
BC CONTAINMENT ICE CONDENSER/REFRIGERATION SYSTEM (PWR)
BD CONTAINMENT LEAKAGE CONTROL SYSTEM
BE CONTAINMENT SPRAY SYSTEM (PWR)
BF CONTAINMENT VACUUM RELIEF SYSTEM
BG HIGH PRESSURE CORE SPRAY SYSTEM (BWR)
BH EMERGENCY/STANDBY GAS TREATMENT SYSTEM
BI ESSENTIAL SERVICE WATER SYSTEM
BJ HIGH PRESSURE COOLANT INJECTION SYSTEM (BWR)
BK CONTAINMENT FAN COOLING SYSTEM (PWR)
BL ISOLATION CONDENSER SYSTEM (BWR)
BM LOW PRESSURE CORE SPRAY SYSTEM (BWR)
BN REACTOR CORE ISOLATION COOLING SYSTEM (BWR)
BO LOW PRESSURE COOLANT INJECTION SYSTEM (BWR)
BP LOW PRESSURE SAFETY INJECTION SYSTEM (PWR)
BQ HIGH PRESSURE SAFETY INJECTION SYSTEM (PWR)
BR STANDBY LIQUID CONTROL SYSTEM (BWR)
BS ULTIMATE HEAT SINK SYSTEM
BT SUPPRESSION POOL MAKEUP SYSTEM (BWR)
BU LOOP ISOLATION/SHUTDOWN (HTGR) [SPECIAL NON-EIIS CODE]
BV CONTAINMENT PURGE SYSTEM [SPECIAL NON-EIIS CODE]
BW INTERMEDIATE HEAD INJECTION (PWR) [SPECIAL NON-EIIS CODE]
BX UPPER HEAD INJECTION (PWR) [SPECIAL NON-EIIS CODE]
BY AUTOMATIC DEPRESSURIZATION SYSTEM [SPECIAL NON-EIIS CODE]

CA BORON RECYCLE SYSTEM (PWR)
CB CHEMICAL AND VOLUME CONTROL/MAKEUP AND PURIFICATION SYSTEM (PWR)
CC CLOSED/COMPONENT COOLING WATER SYSTEM
CD CONTROL ROD DRIVE COOLING SYSTEM (PWR)
CE REACTOR WATER CLEANUP SYSTEM (BWR)
CF REACTOR SERVICES SYSTEM
CG SUPPRESSION POOL PURIFICATION SYSTEM (BWR)
CH RESIDUAL HEAT REMOVAL SYSTEM (BWR) [SPECIAL NON-EIIS CODE]
CI RESIDUAL HEAT REMOVAL SYSTEM (PWR) [SPECIAL NON-EIIS CODE]

DA FUEL POOL COOLING AND PURIFICATION SYSTEM
DB NUCLEAR FUEL SERVICES SYSTEM
DC DIESEL FUEL OIL SYSTEM
DE FUEL OIL RECEIVING, STORAGE, AND TRANSFER SYSTEM
DF NUCLEAR FUEL TRANSFER SYSTEM

EA MEDIUM-VOLTAGE POWER SYSTEM (601V THROUGH 35 KV)
EB MEDIUM-VOLTAGE POWER SYSTEM - CLASS 1E
EC LOW-VOLTAGE POWER SYSTEM (600V AND LESS)
ED LOW-VOLTAGE POWER SYSTEM - CLASS 1E
EE INSTRUMENT AND UNINTERRUPTIBLE POWER SYSTEM
EF INSTRUMENT AND UNINTERRUPTIBLE POWER SYSTEM - CLASS 1E
EI DC POWER SYSTEM
EJ DC POWER SYSTEM - CLASS 1E
EK EMERGENCY ONSITE POWER SUPPLY SYSTEM
EL MAIN GENERATOR OUTPUT POWER SYSTEM
EX AC POWER (SPECIAL NON-EIIS CODE)

FA CABLE RACEWAY SYSTEM
FB CATHODIC PROTECTION SYSTEM
FC GROUNDING AND LIGHTNING PROTECTION SYSTEM
FD HEAT TRACING SYSTEM
FE HEAT TRACING SYSTEM - CLASS 1E
FF NORMAL AC LIGHTING SYSTEM
FG STANDBY AC LIGHTING SYSTEM
FH EMERGENCY DC LIGHTING SYSTEM
FI COMMUNICATIONS SYSTEM
FJ STATION GENERATION TELEMETERING SYSTEM
FK SWITCHYARD SYSTEM

IA SECURITY SYSTEM
IB ANNUNCIATOR SYSTEM
IC FIRE DETECTION SYSTEM
ID COMPUTER SYSTEM
IG INCORE/EXCORE NEUTRON MONITORING SYSTEM
IH CORE VIBRATION MONITORING SYSTEM
II LOOSE PARTS MONITORING SYSTEM
IJ LEAK MONITORING SYSTEM
IK CONTAINMENT ENVIRONMENTAL MONITORING SYSTEM
IL RADIATION MONITORING SYSTEM
IM TEMPERATURE MONITORING SYSTEM
IN SEISMIC MONITORING SYSTEM
IO PERFORMANCE MONITORING SYSTEM
IP POST-ACCIDENT MONITORING SYSTEM

IQ SEQUENCE OF EVENTS MONITORING SYSTEM
IR TELEVISION SYSTEM
IS ENVIRONMENTAL/METEOROLOGICAL MONITORING SYSTEM
IT MAIN TURBINE INSTRUMENTATION SYSTEM
IU DISPLAY CONTROL SYSTEM
IV VIBRATION MONITORING SYSTEM

JA INTEGRATED CONTROL SYSTEM
JB FEEDWATER/STEAM GENERATOR WATER LEVEL CONTROL SYSTEM
JC PLANT PROTECTION SYSTEM
JD REACTOR POWER CONTROL SYSTEM
JE ENGINEERED SAFETY FEATURES ACTUATION SYSTEM
JF TOXIC GAS ISOLATION SYSTEM [SPECIAL NON-EIIS CODE]
JG SOLID STATE CONTROL SYSTEM/AUXILIARY LOGIC CONTROL SYSTEM
JI TURBINE STEAM BYPASS CONTROL SYSTEM
JK FEEDWATER PUMP TURBINE INSTRUMENTATION AND CONTROL SYSTEM
JL PANELS SYSTEM
JM CONTAINMENT ISOLATION CONTROL SYSTEM
JN LOW TEMP/OVERPRESSURE PROTECTION SYSTEM (PWR) [SPECIAL NON-EIIS CODE]
JR RECIRCULATION ACTUATION SYSTEM [SPECIAL NON-EIIS CODE]
JS ANTICIPATED TRANSIENT W/O SCRAM SYSTEM (BWR) [SPECIAL NON-EIIS CODE]
JT STEAM AND FEEDWATER RUPTURE CONTROL SYSTEM (B&W) [SPL NON-EIIS CODE]
JU FEED ONLY GOOD STEAM GENERATOR SYSTEM (B&W) [SPL NON-EIIS CODE]

KA CONDENSATE STORAGE AND TRANSFER SYSTEM
KB TURBINE BUILDING CLOSED COOLING WATER SYSTEM
KC DEMINERALIZED WATER STORAGE AND TRANSFER SYSTEM
KD CONDENSATE AND FEEDWATER CHEMISTRY CONTROL SYSTEM
KE HEAT REJECTION SYSTEM
KF HEAT REJECTION CHEMICAL TREATMENT SYSTEM
KG NONESSENTIAL SERVICE WATER SYSTEM
KH WATER FILTRATION SYSTEM
KI RAW WATER MAKEUP SYSTEM
KJ MAKEUP DEMINERALIZER SYSTEM
KK PORTABLE WATER DISTRIBUTION SYSTEM
KL REMOVAL CHEMICAL CLEANING SYSTEM
KM CHILLED WATER SYSTEM
KN SAMPLING AND WATER QUALITY SYSTEM
KO GLAND SEAL WATER SUPPLY SYSTEM
KP FIRE PROTECTION SYSTEM (WATER)
KQ FIRE PROTECTION SYSTEM (CHEMICAL)
KR FIRE PROTECTION SYSTEM (PASSIVE) [SPECIAL NON-EIIS CODE]
KS REACTOR WATER STORAGE TANK [SPECIAL NON-EIIS CODE]

LA DIESEL LUBE OIL SYSTEM
LB DIESEL COOLING WATER SYSTEM
LC DIESEL GENERATOR STARTING AIR SYSTEM
LD INSTRUMENT AIR SUPPLY SYSTEM
LE ESSENTIAL AIR SYSTEM
LF SERVICE AIR SYSTEM
LG WELDING GAS SYSTEM
LH BREATHING AIR SYSTEM
LJ HYDROGEN SUPPLY SYSTEM
LK NITROGEN SUPPLY SYSTEM
LL LUBE OIL SYSTEM
LM LUBE OIL STORAGE AND TRANSFER SYSTEM
LN INSULATING OIL SYSTEM
LP LABORATORY GAS SYSTEM
LQ LABORATORY EQUIPMENT SYSTEM
LR MATERIAL AND EQUIPMENT HANDLING SYSTEM
LS PLANT SHOP SYSTEM
LT RECORD STORAGE SYSTEM
LU YARD HANDLING AND MAINTENANCE SYSTEM
LV PLANT HOT WATER SYSTEM
LW CARBON DIOXIDE SUPPLY SYSTEM

MA ADMINISTRATION BUILDING
MB INDUSTRIAL/SANITARY WASTE TREATMENT BUILDING
MC MAINTENANCE AND WAREHOUSE BUILDING
MD MAKEUP WATER INTAKE STRUCTURE
MF SERVICE BUILDING
MG WASTEWATER OUTFALL STRUCTURE
MH WATER TREATMENT BUILDING
MJ VISITORS CENTER
MK ESSENTIAL SERVICE WATER PUMP BUILDING
MS MAIN STEAM ISOLATION VALVES [SPECIAL NON-EIIS CODE]

NA CONTROL BUILDING/CONTROL COMPLEX
NB EMERGENCY ONSITE POWER SUPPLY BUILDING
NC EMERGENCY OPERATIONS FACILITY (OFFSITE)
ND FUEL BUILDING
NE RADWASTE BUILDING
NF AUXILIARY BUILDING
NG REACTOR BUILDING (BWR)
NH REACTOR CONTAINMENT BUILDING
NM TURBINE BUILDING
NN CIRCULATING WATER STRUCTURES
NO NO SYSTEMS INVOLVED [SPECIAL NON-EIIS CODE]

NP PRIMARY CONTAINMENT [SPECIAL NON-EIIS CODE]
NS SECONDARY CONTAINMENT [SPECIAL NON-EIIS CODE]
NT DRYWELL (SPECIAL NON-EIIS CODE)

PM PLANT MANAGEMENT [SPECIAL NON-EIIS CODE]
PS PLANT STAFFING [SPECIAL NON-EIIS CODE]

SA AUXILIARY STEAM SYSTEM
SB MAIN/REHEAT STEAM SYSTEM
SD CONDENSATE SYSTEM
SE STEAM EXTRACTION SYSTEM
SF CONDENSATE DEMINERALIZER SYSTEM
SG CONDENSER SYSTEM
SH CONDENSER VACUUM SYSTEM
SI CONDENSER TUBE CLEANING SYSTEM
SJ FEEDWATER SYSTEM
SK FEEDWATER PUMP INJECTION AND MISCELLANEOUS SYSTEM
SL FEEDWATER PUMP TURBINE LUBE OIL SYSTEM
SM LP HEATER DRAINS AND VENTS SYSTEM
SN HP HEATER AND MSR DRAINS AND VENTS SYSTEM

TA MAIN TURBINE SYSTEM
TB MAIN GENERATOR SYSTEM
TC TURBINE STEAM SEAL SYSTEM
TD TURBINE LUBE OIL SYSTEM
TE MISCELLANEOUS TURBINE VENTS SYSTEM
TF TURBINE DRAINS AND MISCELLANEOUS PIPING SYSTEM
TG MAIN TURBINE CONTROL FLUID SYSTEM
TH MAIN GENERATOR GAS PURGE SYSTEM
TI MAIN GENERATOR SEAL OIL SYSTEM
TJ MAIN GENERATOR STATOR COOLING SYSTEM
TK MAIN GENERATOR HYDROGEN COOLING SYSTEM
TL MAIN GENERATOR EXCITATION SYSTEM

UA PUMPING STATION ENVIRONMENTAL CONTROL SYSTEM
UB WATER TREATMENT BUILDING ENVIRONMENTAL CONTROL SYSTEM
UC SERVICE BUILDING ENVIRONMENTAL CONTROL SYSTEM
UD ADMINISTRATION BUILDING ENVIRONMENTAL CONTROL SYSTEM

UE SECURITY BUILDING ENVIRONMENTAL CONTROL SYSTEM
UF TECHNICAL SUPPORT CENTER ENVIRONMENTAL CONTROL SYSTEM
UG EMERGENCY OPERATIONS FACILITY ENVIRONMENTAL CONTROL SYSTEM
UH VISITORS CENTER ENVIRONMENTAL CONTROL SYSTEM

VA REACTOR BUILDING ENVIRONMENTAL CONTROL SYSTEM
VB DRYWELL ENVIRONMENTAL CONTROL SYSTEM (BWR)

VC SHIELD ANNULUS RETURN AND EXHAUST SYSTEM
VE ACCESS CORRIDORS ENVIRONMENTAL CONTROL SYSTEM
VF AUXILIARY BUILDING ENVIRONMENTAL CONTROL SYSTEM
VG FUEL BUILDING ENVIRONMENTAL CONTROL SYSTEM
VH RADWASTE BUILDING ENVIRONMENTAL CONTROL SYSTEM
VI CONTROL BUILDING/CONTROL COMPLEX ENVIRONMENTAL CONTROL SYSTEM
VJ EMERGENCY ONSITE POWER SUPPLY BUILDING ENVIRONMENTAL CONTROL SYSTEM
VK TURBINE BUILDING ENVIRONMENTAL CONTROL SYSTEM
VL PLANT EXHAUST SYSTEM

WA CASK DECONTAMINATION SYSTEM
WB SOLID WASTE MANAGMENT SYSTEM
WD LIQUID WASTE MANAGEMENT SYSTEM
WE GASEOUS WASTE MANAGEMENT SYSTEM (PWR)
WF OFFGAS SYSTEM (BWR)
WG SANITARY WASTE PROCESSING SYSTEM
WH WASTEWATER DISPOSAL SYSTEM
WI STEAM GENERATOR BLOWDOWN SYSTEM (PWR)
WJ SLUDGE WASTE DEWATERING SYSTEM
WK EQUIPMENT AND FLOOR DRAIN SYSTEM

XC ECCS (SPECIAL NON-EIIS CODE)
XX OTHER KNOWN SYSTEM - SEE COMMENT FIELD [SPECIAL NON-EIIS CODE]
XY MULTIPLE KNOWN SYSTEM - SEE COMMENT FIELD [SPECIAL NON-EIIS CODE]

ZP PRIMARY CONTAINMENT - UNDETERMINED SYSTEM [SPECIAL NON-EIIS CODE]
ZS SECONDARY CONTAINMENT - UNDETERMINED SYSTEM [SPECIAL NON-EIIS CODE]
ZZ UNKNOWN SYSTEM [SPECIAL NON-EIIS CODE]

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Walter E. Gilmore
Cindy D. Gentillon
David I. Gertman
Gretchen H. Beers
William J. Galyean
B. Gay Gilbert
Wendy J. Reece

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