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Three Mile Island Unit 1 Probabilistic Risk Assessment

DATA ANALYSIS REPORT

Project Director
B. John Garrick

Project Manager
Douglas C. Iden

Principal Investigator
Frank R. Hubbard

Task Leaders
Mardyros Kazarians
Ali Mosleh
Harold F. Perla
Martin B. Sattison
Donald J. Wakefield

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Pickard, Lowe and Garrick, Inc.
Engineers • Applied Scientists • Management Consultants
Newport Beach, CA Washington, DC

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LIST OF ACRONYMS

Abbreviation	Definition
ACR	air-cooled reactor
ADV	atmospheric dump valve
AOV	air-operated valve
ATOG	abnormal transient operational guidelines
ATWS	anticipated transient without scram
BOP	balance of plant
Btu	British thermal unit
BWR	boiling water reactor
BWST	borated water storage tank
CARS	condenser air removal system
CAS	chemical addition system
CBVS	control building ventilation system
CCF	common cause failure
CFT	core flooding tank
CIV	containment isolation valve
CSF	conditional split fraction
CST	condensate storage tank
CRO	control room operator
CWS	circulating water system
DHCCW	decay heat closed cooling water
DHR	decay heat removal
DHRS	decay heat removal system
DHRW	decay heat river water
EFW	emergency feedwater
EOF	emergency operations facility
EPRI	Electric Power Research Institute
ESD	event sequence diagram
ESAS	engineered safeguards actuation system
ETC	event tree code
FSAR	Final Safety Analysis Report
FTAP	Fault Tree Analysis Program
GCR	gas-cooled reactor
GPUN	GPU Nuclear Corporation
HCR	human cognitive reliability
HPI	high pressure injection
HPIS	high pressure injection system
HVAC	heating, ventilating, and air conditioning
ICCS	intermediate closed cooling system
ICCW	intermediate closed cooling water
ICS	integrated control system

LIST OF ACRONYMS (continued)

Abbreviation	Definition
LBIS	line break isolation system
LCO	limiting condition for operation
LER	Licensee Event Report
LOCA	loss of coolant accident
LOFW	loss of main feedwater
LONS	loss of nuclear services
LORI	loss of reactor coolant system inventory
LORW	loss of river water
LOSP	loss of offsite power
LPI	low pressure injection
LPIS	low pressure injection system
LSS	low speed stop
MCC	motor control center
MFPT	main feedwater pump trip
MFW	main feedwater
MGL	multiple Greek letter
MOV	motor-operated valve
MSIV	main steam isolation valve
MSLB	main steam line break
MSS	main steam system
MSSV	main steam safety valve
MSV	main steam valve
MUP	makeup and purification
NPE	Nuclear Power Experience
NRC	U.S. Nuclear Regulatory Commission
NSCCS	nuclear services closed cooling system
NSCCW	nuclear services closed cooling water
NSRW	nuclear services river water
NSSS	nuclear steam supply system
OPM	Operations Plant Manual
OTSG	once-through steam generator
PCL	panel center left
PCR	panel center right
PDS	plant damage state
PLF	panel left front
PLG	Pickard, Lowe and Garrick, Inc.
P&ID	piping and instrumentation drawing
PORV	power-operated relief valve
PRA	probabilistic risk assessment
PRF	panel right front
PSHX	primary to secondary heat transfer
PSV	pressurizer safety valve
PWR	pressurized water reactor

LIST OF ACRONYMS (continued)

Abbreviation	Definition
RBCU	reactor building cooler unit
RBEC	reactor building emergency cooling
RBD	reliability block diagram
RBS	reactor building spray
RBSS	reactor building spray system
RCDT	reactor coolant drain tank
RCP	reactor coolant pump
RCS	reactor coolant system
RPS	reactor protection system
SCCW	secondary closed cooling water
SCM	subcooled margin
SGTR	steam generator tube rupture
SLB	steam line break
SLRDS	steam line rupture detection system
SRO	senior reactor operator
SRW	secondary river water
SSCCS	secondary services closed cooling system
SSE	safe shutdown earthquake
SSS	support state system
STA	shift technical advisor
TBV	turbine bypass valve
TMI-1	Three Mile Island Nuclear Generating Station, Unit 1
ULD	unit load demand

1. INTRODUCTION

This report presents the data developed in support of the TMI-1 PRA systems and plant analyses and provides a discussion of the techniques used and steps taken in developing the data base.

The following four general areas define the scope of the data analysis as presented in this report:

1. Component Failure Rates
2. Common Cause Failure Parameters
3. Component Maintenance Frequency and Duration
4. Initiating Event Frequencies

Several other types of data such as component fragility curves used in the seismic analysis, fire frequencies used in the fire analysis, and human actions are developed and presented elsewhere in the TMI-1 PRA report.

The TMI-1 data are developed by combining in a Bayesian update the cumulative experience from a large population of nuclear power plants documented in the PLG proprietary data base with the comprehensive plant-specific data base developed from a detailed review of the TMI Unit 1 records of several years of operation.

The proprietary PLG generic data base has evolved from all of the PRAs that PLG has performed to date. It is based on data collected from U.S. reliability data sources and from operating data of U.S. light water reactors evaluated in past PLG PRAs.

The following sections describe in detail the methodology used for data analysis followed by a detailed discussion of the collected plant-specific data. The resulting distributions are presented in tabular form for each of the five categories of data supported by a series of appendices at the end of the report that provide the detailed plant-specific data. All plant-specific distributions are stored in a computer data base that includes a brief summary of the collected data, the generic distributions used, and several important characteristics of the distributions.

2. DATA ANALYSIS APPROACH

This section provides a discussion of the techniques used in developing the TMI-1 data base. As mentioned earlier, the data was developed by updating generic information with TMI-specific information, using Bayesian techniques.

Familiarity with certain basic concepts of Bayesian analysis is essential in understanding the content of this section. These concepts are briefly reviewed in the following.

The methodology used to develop the data for this study is based on the Bayesian interpretation of probability and the concept of "probability of frequency" (Reference 2-1). In this context, for example, component failure rates are treated as measurable quantities whose uncertainty is dependent on the state of knowledge of the investigation. The "state of knowledge" is presented in the form of a probability distribution over the range of possible values of that quantity. The probability associated with a particular numerical value of an uncertain but measurable quantity indicates the likelihood that the numerical value is the correct one.

A key issue in developing state-of-knowledge distributions for the parameters of the PRA models is to assure that the information regarding each parameter, its relevance, and its value as viewed by the analyst are presented correctly and that various pieces of information are integrated coherently. "Coherence" is preserved if the final outcome of the process is consistent with every piece of information used and with all assumptions made. This is done by utilizing the fundamental tool of probabilistic inference; i.e., Bayes' theorem (Reference 2-2). Mathematically, Bayes' theorem is written as

$$P(x|E,E_0) = k^{-1} L(E|x,E_0)P(x|E_0) \qquad (2.1)$$

where

$P(x|E,E_0)$ ≡ probability of x being the true value of an unknown quantity in light of new evidence E and prior body of knowledge E_0.

$L(E|x,E_0)$ ≡ likelihood of the new evidence E assuming that the true value is x.

$P(x|E_0)$ ≡ probability of x being the true value of the unknown quantity based on the state of knowledge E_0 prior to receiving E.

Finally, k is a normalizing factor defined as

$$k \equiv \int_{\text{all } x} L(E|x,E_0)P(x|E_0)dx \qquad (2.2)$$

In the context of a plant-specific PRA, there are three types of information available for the frequency of elemental events.

E_0 = general engineering knowledge such as that of the design and manufacture of equipment.

E_1 = the historical information from other plants similar to the one in question.

E_2 = the past experience in the specific plant being studied.

The information of types E_0 and E_1 together constitute the "generic" information, and E_2 is the "plant-specific" or "item-specific" information.

Since the TMI-1 plant has several years of operating experience, the data developed for the TMI-1 PRA are based on generic as well as plant-specific information. Any additional plant-specific information collected in the course of operating TMI units in the future can be incorporated into the existing data by applying Bayes' theorem.

It is very important to note that the information E_0 brings an element of plant specificity in the generic data developed for a plant-specific PRA. In general, decisions regarding the relevance and applicability of different pieces of information in developing each generic distribution are made based on type E_0 information. Therefore, a piece of information may be judged as being relevant in developing the generic data in one PRA and not in another. As a result, generic distributions for different plant-specific studies could be significantly different.

2.1 COMPONENT FAILURE RATES

2.1.1 GENERIC FAILURE RATE DISTRIBUTIONS

To discuss the way the failure rate distributions were developed based on different types of information, we consider the following cases.

- Type 1. Failure data from operating experience at various nuclear power plants.

- Type 2. Failure rate estimates or distributions contained in various industry compendia, such as WASH-1400 (Reference 2-3) and IEEE-500 (Reference 2-4).

By type 1 information, we mean a set of failure and success data collected from the performance of similar equipment in various power plants. Reference 2-5, for example, provides a detailed list of reported valve failures at various U.S. commercial nuclear power plants for a 2-year period. Also given in this reference are the number of demands and total operating time for the valves at each power plant.

Type 2 information, which could be called processed data, are estimates ranging from the opinion of experts with engineering knowledge about the design and manufacturing of the equipment to estimates based on observed performance of the same class of equipment in various applications. For instance, Reference 2-4 provides failure estimates based on the opinion of several experts. Estimates of Reference 2-5, on the other hand, are based on recorded failures of equipment at various nuclear power plants.

Normally, type 2 data are either a point estimate usually referred to as the "best estimate," or a range of values centered about a "best estimate." In some cases, a distribution is provided covering a range of values for the failure rate with the mean or median representing the "best estimate" of the source. For instance, IEEE-500 provides a "low," "high," and "recommended" for the failure rates under normal conditions and a "maximum" value under extreme environments. WASH-1400, on the other hand, assesses a probability distribution for each failure rate to represent the variability of the available data from source to source. Such distributions are normally centered around a median value judged to be most representative of the equipment in question for nuclear applications.

The methodology used to develop the TMI-1 failure rate data uses both types of information to generate generic probability distribution for the failure rates. Such distributions represent variability of the failure rates, from source to source (for type 2 information) and/or from plant to plant (for type 1 information). Obviously, as applied to TMI-1, these distributions are in fact, prior state-of-knowledge curves for the failure rate of components. The following discussion helps to understand the distinction and serves as a prelude to the discussion of the methodology.

Suppose that we have 100 plants and that for each plant the exact value of the failure rate of a particular type of pump is known. Let λ_i be the failure rate of the pump at the ith plant. Suppose further that the λi's can be grouped into a limited number of discrete values, say λ_1^*, through λ_5^*, with 20 of the λ_i's being equal to λ_1^*, 35 equal to λ_2^*, 25 equal to λ_3^*, 15 equal to λ_4^*, and finally, 5 equal to λ_5^*. The frequency distribution of the λ_i's is then given by the histogram shown in Figure 2-1.

This histogram represents the "population variability" of the λ_i's because it shows how the failure rate of the particular type of pumps under consideration varies from plant to plant. It is an exact and true representation of the variability of the failure rate at the 100 plants in the population without any uncertainty or ambiguity because the distribution is based on presumed perfectly known failure rates at each and every one of those plants.

Consider now, the case where only estimates and not the exact values of the failure rates are available for some but not all of the 100 plants in the population. With this state of knowledge, obviously we are not able to know the exact population variability distribution (Figure 2-1). The question is how one can use this more limited information to estimate the population variability curve and how close the estimate will be to the true distribution as given in Figure 2-1.

To answer the question, first note that the desired distribution is a member of the set of all histograms. Because of our limited information, we are uncertain as to which member of that set is in fact the true distribution. This situation can be represented by a probability distribution over the set of all possible histograms expressing our state of knowledge about the nature of the true histogram.

For instance, if the entire space, H, of all possible histograms is composed of only n histograms; i.e., if

$$H \equiv \{h_1, h_2, \ldots, h_n\}$$

where h_i represents the ith histogram, the evidence regarding the pump failure rates at different power plants can be used to assess a prob bility distribution over H as follows

$$P(H) = \{p_1, p_2, \ldots, p_N\} \qquad \text{with} \sum_{i=1}^{n} P_i = 1 \tag{2.3}$$

where p_i is the chance that h_i is the true histogram.

Figure 2-2 depicts the situation where the variable λ is considered to be continuous and the desired distribution is a density function.

For a perfect state of knowledge, we would be able to say which h_i is the true distribution; consequently, the corresponding p_i would be equal to 1 and all others equal to 0. However, based on the state of knowledge expressed by Equation (2.3), our estimate of the true histogram is

$$\overline{h} = \sum_{i=1}^{n} p_i \; h_i \tag{2.4}$$

which is called the "expected distribution." Another histogram of interest is one which is assigned the highest chance of being the true histogram. We call that the "most likely distribution," h_m, and we have

$$p_m = \max \{p_i \quad i=1,\ldots,n\} \tag{2.5}$$

The problem of obtaining P, defined by Equation (2.3), is formulated in the Bayesian context as follows [see Equation (2.1)]

$$P(h_i|E) = k^{-1} \; L(E|h_i)P_0(h_i) \tag{2.6}$$

where $P_0(h)$ is the prior state of knowledge regarding the set H defined by Equation (2.3) and $P(h_i|E)$ is the posterior state of knowledge in light of the evidence E. The evidence is incorporated via the likelihood term $L(E|h_i)$ which is the probability of observing the evidence given that the true histogram is h. Finally, k is a normalizing factor defined as [see Equation (2.2)]

$$k = \sum_{i=1}^{n} L(E|h_i)\, P_0(h_i) \qquad (2.7)$$

The expected distribution, Equation (2.4), is our estimate of the true population variability of the failure rate. It shows how the failure rates of similar pumps are distributed among plants in the population. Now if all we know about a specific pump before we have any experience with it is that it is one member of the population, the population variability curve also becomes our state-of-knowledge distribution for the failure rate of that specific pump. In other words, generic distributions representing the population variability can also be used to predict the expected behavior of any member of the population if no other information is available.

For this reason, the generic frequency distributions developed based on type 1 and type 2 information are used as the state-of-knowledge distributions for the components at the TMI-1 plant prior to incorporating the site-specific information.

The following sections describe how types 1 and 2 information can be used to develop generic distribution.

2.1.1.1 Generic Distributions Based on Actual Performance Records (Type 1)

The following discussion is based on the method presented in Reference 2-6. Consider the case where the following set of information is available about the performance of a generic component in N plants

$$I_1 = \{<k_i, T_i>;\ i=1,\ldots,N\} \qquad (2.8)$$

where k_i is the number of failures of the component in the ith plant in a specific period of time, T_i.

The desired information is, $\phi(\lambda)$, the distribution of the failure rate of the component, λ, in light of evidence I_1. This distribution represents the variation of λ from one plant to another, and is analogous to Figure 2-1.

Following our discussion in Section 2.1.1, we would like to express a posterior state of knowledge about the true nature of the function $\phi(\lambda)$. To make matters practical, it is assumed that $\phi(\lambda)$ belongs to a particular parametric family of distributions. Let θ be the set of m parameters of $\phi(\lambda)$

$$\theta = \{\theta_1, \ldots, \theta_m\}$$

For each value of θ, there exists a distribution $\phi(\lambda|\theta)$ and vice versa. Therefore, the state-of-knowledge distribution over the space of all possible $\phi(\lambda|\theta)$s is the state of knowledge over all possible values of θ and vice versa.

Bayes' theorem in this case is written as [see Equation (2.6)]

$$P(\theta|I_0 I_1) = k^{-1} L(I_1|\theta,I_0)\ P_0(\theta|I_0) \tag{2.9}$$

where

$P(\theta|I_0 I_1)$ = posterior state of knowledge about θ in light of evidence I_1 and prior information I_0.

$L(I_1|\theta,I_0)$ = the likelihood of evidence I_1 given that the actual set of parameters of $\phi(\lambda)$ is θ.

$P_0(\theta|I_0)$ = prior state of knowledge about θ based on general engineering knowledge I_0.

and k is a normalizing factor

$$k^{-1} = \int_\theta L(I_1|\theta,I_0)P_0(\theta|I_0)d\theta$$

The likelihood term is the (conditional) probability of observing the evidence, I_1, given that the data are based on an underlying population variability curve $\phi(\lambda|\theta)$ with θ as the value of its parameters

$$L = P(<k_i,T_i>;\ i=1,\ \ldots,N|\theta,I_0) \tag{2.10}$$

Note that L is also conditional on the prior state of knowledge I_0.

If we assume that the length of operating hours, T_i's, at different plants are independent of one another and that the observed failures, k_i's, also have no dependence (according to our model, each k_i is based on a different underlying failure rate) the joint probability distribution given by Equation (2.10) can be reduced to the product of the marginal distributions as follows

$$L(I_1|\theta,I_0) = \prod_{i=1}^{N} P_i(k_i,T_i|\theta,I_0) \tag{2.11}$$

where

$P_i(k_i,T_i|\theta,I_0) \equiv$ probability of observing k_i failures of the equipment in question during the period T_i in the ith plant assuming that the set of parameters of the underlying population variability curve is θ.

If the failure rate, λ_i, at the ith plant is known exactly, using a Poisson model, the likelihood of observing k_i in T_i can be calculated from

$$P(k_i,T_i|\lambda_i) = \frac{(\lambda_i T_i)^{k_i}}{k_i!} \exp(-\lambda_i T_i) \tag{2.12}$$

However, λ_i is not known. All we know is that λ_i is one of possibly many values of variable λ which represents the variation of the failure rate from plant to plant. In addition, according to our model, λ is distributed according to $\phi(\lambda|\theta)$ with θ being unknown. For this reason, we calculate the probability of observing the evidence, $\langle k_i, T_i \rangle$, by allowing the failure rate to assume all possible values. This is achieved through averaging Equation (2.12) over the distribution of λ

$$P_i(k_i, T_i|\theta,I_0) = \int_0^\infty P_i(k_i,T_i|\lambda)\,\phi(\lambda|\theta)d\lambda$$

$$= \int_0^\infty \frac{(\lambda T_i)^{k_i}}{k_i!} e^{-\lambda T_i}\,\phi(\lambda|\theta)d\lambda \tag{2.13}$$

Depending on the parametric family chosen to represent $\phi(\lambda|\theta)$, the integration in Equation (2.13) can be carried out analytically or by numerical techniques. For example, if $\phi(\lambda|\theta)$ is assumed to be a gamma distribution which has the following form

$$\phi(\lambda|\alpha,\beta) = \frac{\beta^\alpha}{\Gamma(\alpha)} \lambda^{\alpha-1} e^{-\beta\lambda} \tag{2.14}$$

with α and β, both nonnegative, as its parameters, the integral can be done analytically resulting in (Reference 2-5)

$$P_i(k_i,T_i|\alpha,\beta) = \frac{T_i^{k_i}}{k_i!} \frac{\beta^\alpha}{\Gamma(\alpha)} \frac{\Gamma(\alpha+k_i)}{(\beta+T_i)^{\alpha+k_i}} \tag{2.15}$$

In developing failure rate distributions, $\phi(\lambda|\theta)$ is assumed to be lognormal with μ and σ as its parameters

$$\phi(\lambda|\mu,\sigma) = \frac{1}{\sqrt{2\pi}\,\sigma\lambda} \exp\left\{-\frac{1}{2}\left(\frac{\ell n\,\lambda-\ell n\,\mu}{\sigma}\right)^2\right\} \tag{2.16}$$

In [illegible], Equation (2.13) is calculated numerically.

The total likelihood for all N plants can now be found by using Equation (2.13) in Equation (2.11)

$$L(I_1|\theta,I_0) = \prod_{i=1}^{N} \left\{ \int_0^{\infty} d\lambda \phi(\lambda|\theta) \frac{(\lambda T_i)^{k_i}}{k_i!} \exp(-\lambda T_i) \right\} \tag{2.17}$$

The posterior distribution resulting from using the likelihood of Equation (2.17) in Bayes' theorem, Equation (2.9), is a probability distribution over the m-dimensional space of θ. Any point, θ, in this space has a one-to-one correspondence with a distribution, $\phi(\lambda|\theta)$, in the space of $\phi(\lambda|\theta)$. Figure 2-3 is an example of $P(\theta|I_0,I_1)$ constructed for $\theta = \{\alpha,\beta\}$, the two parameters of gamma distribution based on the pump data from all U.S. nuclear power plants (Reference 2-7).

The "expected distribution" is obtained from [see Equation (2.4)]

$$\overline{\phi}(\lambda) = \int_{\theta} \phi(\lambda|\theta)P(\theta|I_0,I_1)d\theta \tag{2.18}$$

The quantity $\overline{\phi}(\lambda)$ "summarizes" the information about λ and is used in this study as the model for generic failure distributions.

Sometimes it is also useful to obtain the "most likely distribution" [see Equation (2.4)]. According to the definition, the most probable distribution of λ is the one whose parameters maximize $P(\theta|I_0 I_1)$. These parameters are, therefore, the solution of the following system of m equations

$$\left.\frac{\partial P(\theta|I_0 I_1)}{\partial \theta_i}\right|_{\theta_{i,max}} = 0; \qquad i=1,\ldots,m \tag{2.19}$$

The methodology discussed above also applies to failure on demand type of data where the evidence is of the form

$$I_1 = \{\langle k_i, D_i \rangle,\ i=1,\ldots,N\} \tag{2.20}$$

where k_i and D_i are the number of failures and demands in the ith plant, respectively. This can be done if the Poisson distribution used in Equation (2.13) is replaced by the binominal distribution

$$P(K_i,D_i|\lambda) = \frac{D_i!}{k_i!(D_i-k_i)!} \lambda^{k_i} (1-\lambda)^{D_i-k_i} \tag{2.21}$$

Example

For motor-operated valve failure to start on demand, the following data from six plants were available.

Plant	Number of Failures (k)	Number of Demands (D)
1	10	$1.65 \times 10^{+4}$
2	14	$1.13 \times 10^{+4}$
3	7	$1.73 \times 10^{+3}$
4	42	$6.72 \times 10^{+3}$
5	3	$1.26 \times 10^{+3}$
6	31	$9.72 \times 10^{+3}$

These data, which form a set of type 1 information, I_1, were used in mode 1 of the computer code BEST4 (Reference 2-8), which calculates Equations (2.13) and (2.17) and generates $\Phi(\lambda)$ based on Equation (2.18). The result was a 20-bin discrete probability distribution with the following characteristics:

5th Percentile: 6.10×10^{-4}
50th Percentile: 1.05×10^{-3}
95th Percentile: 3.19×10^{-3}
Mean: 2.26×10^{-3}

2.1.1.2 Generic Distributions Using Estimates of Available Sources of Generic Data (Type 2)

As mentioned earlier, generic data frequently are not in the fundamental form given by Equations (2.7) and (2.20). Rather, most sources report point or interval estimates or even distributions for failure rates (type 2 information). These estimates are either judgmental (expert opinion), or based on standard estimation techniques used by the analysts to translate raw data into point or interval estimates, and sometimes into a full distribution.

An example of such estimation techniques is the well known maximum likelihood estimator given by

$$\lambda_M = \frac{k}{T} \tag{2.22}$$

where k is the total number of failures in T units of operating time. Most data sources report λ_M and not k and T.

To develop a model for constructing generic distributions using this type of data, the following cases are considered.

2.1.1.2.1 Estimating an Unknown Quantity Having a Single True Value

The following method is adopted from Reference 2-9. Suppose there are M sources, each providing its own estimate of λ, which has a single true, but unknown value λ_t. An example is the failure rate of a particular component at a given plant. The true value of that failure rate, λ_t, will be known at the end of the life of the component. Before then, however, the failure rate may be estimated by one or more experts familiar with the performance of the component. Let

$$I_2^* = \{\lambda_i^*; i=1,\ldots,M\} \tag{2.23}$$

be the set of such estimates where λ_i^* is the estimate of the ith expert for λ_t.

The objective is to use information I_2^* and obtain a state-of-knowledge distribution for λ_t. Obviously, when everything is known about λ_t; such a state-of-knowledge distribution is a delta function centered at λ_t

$$P(\lambda | \text{Perfect Knowledge}) = \delta(\lambda - \lambda_t) \tag{2.24}$$

Note that in Equation (2.24), λ is used as a variable representing the unknown failure rate.

Assuming a prior state of knowledge, $P_0(\lambda)$, about the quantity λ, Bayes' theorem can be utilized to incorporate information I_2^* into the prior and obtain an "updated" state of knowledge about λ

$$P(\lambda | \lambda_1^*, \ldots, \lambda_N^*) = k^{-1} L(\lambda_1^*, \ldots, \lambda_N^* | \lambda) P_0(\lambda) \tag{2.25}$$

For N independent sources of information the likelihood term, $L(\lambda_1^*, \ldots, \lambda_N^* | \lambda)$ can be written as

$$L(\lambda_1^*, \ldots, \lambda_N^* | \lambda) = \prod_{i=1}^{N} P_i(\lambda_i^* | \lambda) \tag{2.26}$$

where

$P_i(\lambda_i^* | \lambda)$ = the probability that the estimate of the ith source is λ_i^*, when the true value of the unknown quantity is λ.

The case of dependent sources of information is discussed in Reference 2-9. Obviously, if the ith source is a perfect one,

$$P_i(\lambda_i^* | \lambda) = \delta(\lambda_i^* - \lambda) \tag{2.27}$$

which means the estimate, λ_i^*, is the true value. The posterior, $P(\lambda | \lambda_1^*, \ldots, \lambda_N^*)$, in this case will be entirely determined by the estimate of this source

$$P(\lambda | \lambda_1^*, \ldots, \lambda_N^*) = \delta(\lambda - \lambda_i^*) \tag{2.28}$$

In another extreme, when it is believed that the source is totally unreliable,

$$P_i(\lambda_i^*|\lambda) = C \tag{2.29}$$

where C is a constant. This means that if the true value is λ, the estimate of the ith source can be anything. Using a likelihood of this form in Equation (2.25), will show that the estimate of this source, as expected, has no effect on shaping the posterior state of knowledge.

The likelihood term in this approach is the most crucial element. It reflects the analysts' degree of confidence in the sources of information, their accuracy, and the degree of applicability of their estimates to the particular case of interest.

As can be seen, the subjective nature of evaluating and "weighting" of the evidence from different sources fits very well in the above formulation. This becomes clearer in discussing the following models for the likelihood functions in Equation (2.26).

Suppose in estimating the true value of λ_t the ith source makes an error of magnitude E. Two simple models relating λ_t, E, and λ_t^* are

$$\lambda_i^* = \lambda_t + E \tag{2.30}$$

$$\lambda_i^* = \lambda_t \cdot E \tag{2.31}$$

In the model of Equation (2.30), if a normal distribution is assumed for the error term of the estimate of each source, the likelihood function will be a normal distribution with mean equal to $\lambda_t + b_i$, where b_i is the expected error or, in other words, a "bias" term about which the error of the ith source is propagated.

Formally, we have

$$P(\lambda_i^*|\lambda_t) = \frac{1}{\sqrt{2\pi}\,\sigma_i} \exp\left\{-\frac{1}{2}\left(\frac{\lambda_i^*-(\lambda_t+b_i)}{\sigma_i}\right)^2\right\} \tag{2.32}$$

The variance of the likelihood, σ_i^2, is the variance of the error distribution. Values of b_i and σ_i are assessed by the data analyst subjectively and reflect the credibility and accuracy of the source as viewed by the data analyst. Sometimes, certain information provided by the source such as the uncertainty bound for the estimate can be used to assess σ_i.

If, in addition to a normal likelihood function, a normal prior distribution representing the state of knowledge of the data analyst is assumed for λ_t with mean λ_0 and variance σ_0^2, the posterior distribution in Equation (2.25) will also be normal with mean, λ_p, given by

$$\lambda_p = \sum_{i=0}^{N} w_i(\lambda_i^* - b_i) \qquad (2.33)$$

and variance

$$\sigma_p^2 = \sum_{i=0}^{N} \frac{1}{\sigma_i^2} ^{-1} \qquad (2.34)$$

where w_i, defined as

$$w_i = \frac{\sigma_p}{\sigma_i}^2 \qquad (2.35)$$

is the weight given to the ith source.

Note that

$$\sum_{i=0}^{N} w_i = 1 \qquad (2.36)$$

The mean, therefore, is a weighted average of the individual estimates after correcting for their expected biases. Also, as can be seen from Equation (2.35), smaller values of σ_i result in higher weights, implying that the source which is believed to make errors of smaller magnitudes (σ_i is the variance of E) is assigned a higher weight; something which is intuitively expected. Extreme cases are when $\sigma_i = 0$ (highest degree of confidence in the ith estimate), for which $w_i = 1$, and when $\sigma_i = \infty$ (no confidence at all) for which $w_i = 0$.

If, instead of the model of Equation (2.30), the model of Equation (2.31) is applied and the logarithm of the error is assumed to be normally distributed, the likelihood function for the ith source becomes a lognormal distribution

$$P_i(\lambda_i^* | \lambda_t) = \frac{1}{\sqrt{2\pi}\, \sigma_i \lambda_i^*} \exp\left\{-\frac{1}{2}\left(\frac{\ell n\lambda_i^* - (\ell n\lambda_t + \ell n b_i)}{\sigma_i}\right)^2\right\} \qquad (2.37)$$

where $\ell n b_i$ is the logarithmic mean error about the logarithm of the true value, $\ell n\lambda_t$, and σ_i is the multiplicative standard deviation. Again, $P_i(\lambda_i^*|\lambda_t)$ is the probability that the estimate of the ith source is λ_i^* when the true value of the failure rate is λ_t. Some evidence in support of the lognormality of $P_i(\lambda_i^*|\lambda_t)$ are provided in References 2-9 and 2-10.

By using the model of Equation (2.37) for individual likelihoods in Bayes' theorem, Equation (2.25), and assuming a lognormal prior distribution for λ_t the posterior state of knowledge will also be a lognormal with the following median value

$$\lambda_{50,p} = \prod_{i=0}^{N} \left(\frac{\lambda_i^*}{b_i}\right)^{w_i} \tag{2.38}$$

where w_i is defined as in Equation (2.35).

The median, then, is a weighted geometric average of the individual estimates after correcting for the multiplicative biases. Note that the usual arithmetic and geometric average methods frequently used in the literature are special cases of these Bayesian normal and lognormal models. For instance, Reference 2-4 uses the following geometric average of the estimates provided by several experts

$$\overline{\lambda} = \left(\prod_{i=1}^{N} \lambda_i\right)^{1/N} \tag{2.39}$$

which assumes equal weights ($W_i = \frac{1}{N}$), no bias ($b_i = 1$), no prior information, and does not show any uncertainty about the resulting value.

Example

Reference 2-5 provides a point estimate of 5.60×10^{-3} for the demand failure rate of motor-operated valves. We would like to use this estimate and obtain a state-of-knowledge distribution for the MOV failure rates. We use the lognormal model of Equation (2.37) to express our confidence in the estimated value

$$P(\lambda_1^*|\lambda_t) = \frac{1}{\sqrt{2\pi}\,\sigma_1\lambda_1^*} \exp\left\{-\frac{1}{2}\left(\frac{\ell n\lambda_1^* - (\ell n\,\lambda_t + \ell n b_1)}{\sigma_1}\right)^2\right\} \tag{2.40}$$

where λ_1^* is the estimate (5.60×10^{-3}) and λ_t is the assumed true value of the failure rate which remains an unknown variable at this point. Our subjective judgment about the magnitude of error of the data source is expressed by assigning numerical values to the "bias" term b_1 and the logarithmic standard deviation σ_1.

We assume that there is no systematic bias (b_1=1). We estimate σ_1 with the aid of range factor (RF) which is a more understandable quantity. Unless otherwise indicated, the range factor here is defined as the ratio of the 95th to the 50th percentiles of the lognormal distribution. Therefore, given the range factor, the value of σ_1 is obtained from the following equation

$$\sigma_1 = \frac{\ln RF}{1.645} \qquad (2.41)$$

For our example, we assume a range factor of 3. Normally, such a range factor represents a relatively high degree of confidence and means that the source's estimate could be a factor of 3 higher or smaller than the true failure rate and such a statement is made with 90% confidence. Using this range factor in Equation (2.41) results in a value of 0.67 for σ_1.

If we now use the likelihood of Equation (2.40) in Bayes' theorem, Equation (2.25), and assume a flat prior distribution, $P_0(\lambda_t)$, the posterior distribution will be

$$P(\lambda|\lambda_1^* = 5.6 \times 10^{-3}) = 106.65 \exp\left\{-\frac{1}{2}\left(\frac{\ln \lambda - \ln 5.6 \times 10^{-3}}{0.67}\right)^2\right\} \qquad (2.42)$$

which has the following characteristics:

5th Percentile: 1.87×10^{-3}

50th Percentile: 5.6×10^{-3}

95th Percentile: 1.68×10^{-2}

Mean: 7.01×10^{-3}

2.1.1.2.2 Estimating Distributions Using Point Estimates of Various Sources

We now go back to our original problem which was estimating the generic failure rate distribution $\phi(\lambda|\theta)$. This time, however, we assume that instead of having the set of $<k_i, T_i>$ defined in Equation (2.8) from various plants, we are given one estimate, λ_i^*, for each plant. That is, the evidence is of the form

$$I_2 = \{\lambda_i^* \; i=1, \ldots, N\} \qquad (2.43)$$

The model to be used is a combination of the methods presented in Sections 2.1.3.1 and 2.1.3.2.1 and is fully discussed in References 2-7 and 2-11. A particular family of parametric distributions, $\phi(\lambda|\theta)$, is assumed for λ and the information I_2 is used in Bayes' theorem to obtain a posterior distribution over the entire set of possible values of θ and consequently over all possible distributions $\phi(\lambda|\theta)$. Formally

$$P(\theta|I_2, I_0) = k^{-1} L(I_2|\theta, I_0) P_0(\theta|I_0) \qquad (2.44)$$

See the set of definitions immediately following Equation (2.9) for interpretation of the terms in Equation (2.44).

The total likelihood function in the present case when λ_i's are independently estimated can be written as [see Equation (2.11)]

$$L(I_2|\theta, I_0) = \prod_{i=1}^{N} P_i(\lambda_i^*|\theta, I_0) \tag{2.45}$$

where

$P_i(\lambda_i^*|\theta, I_0) \equiv$ probability that the estimate provided for the ith plant is λ_i^* if the parameter of the population variability distribution of the failure rates is θ. (2.46)

To make matters clearer, note that we are assuming that the ith source of data is providing an estimate for the failure rate at a particular plant and all we know is that failure rates vary from plant to plant according to the variability curve $\phi(\lambda|\theta)$. Each λ_i, therefore, is an estimate of one point in that distribution. As a result, there are two sources of variability in the estimates. First, estimates of individual sources are not necessarily perfect; i.e., they could involve errors and biases as discussed in Section 2.1.1.2.1. Second, even if all the sources were perfect, the estimates would still be different due to the actual variation of the failure rate from plant to plant.

Based on our discussion in the previous section, the confidence that we have in the accuracy of the estimate λ_i^* for the failure rate at the ith plant can be modeled by a lognormal distribution [see Equation (2.37)]. Assuming no bias, we have

$$P_i(\lambda_i^*|\lambda_i) = \frac{1}{\sqrt{2\pi}\,\sigma_i\lambda_i^*} \exp\left\{-\frac{1}{2}\left(\frac{\ln\lambda_i^* - \ln\lambda_i}{\sigma_i}\right)^2\right\} \tag{2.47}$$

where λ_i is the true value of the failure rate at the ith plant. Again, we really do not know λ_i but we assume that it belongs to $\phi(\lambda|\theta)$, the distribution representing the variability of λ_i's from plant to plant. The relation between $P_i(\lambda_i^*|\theta, I_0)$ and $\phi(\lambda|\theta)$ is shown in Figure 2-4.

Therefore, as we did in the case of Equation (2.13) we write

$$P_i(\lambda_i^*|\theta, I_0) = \int_0^\infty P_i(\lambda_i^*|\lambda)\, \phi\,(\lambda|\theta) d\lambda \tag{2.48}$$

As it was mentioned earlier, in developing the failure rate distributions $\phi(\lambda|\theta)$ is assumed to be lognormal defined by Equation (2.16). With this assumption, the integration in Equation (2.48) can be done analytically and the result is

$$P_i(\lambda_i^\star|\theta,I_0) = \frac{1}{2\pi\sqrt{\sigma_i^2 + \sigma^2}\ \ \lambda_i^\star\lambda} \exp\left\{-\frac{1}{2}\frac{(\ell n\lambda_i^\star - \ell n\mu)^2}{\sigma_i^2 + \sigma^2}\right\} \tag{2.49}$$

Equation (2.44), Bayes' theorem, is now written as:

$$P(\theta|\lambda_1^\star, \ldots, \lambda_N^\star) = k^{-1} \prod_{i=1}^{N} P_i(\lambda_i^\star|\theta, I_0)\ \ P_0(\theta|I_0) \tag{2.50}$$

The most probable and expected distributions of λ can be found in the same way as discussed in Section 2.1.1.1. The expected distribution is calculated by using the result of Equation (2.47) in Equation (2.18). The parameters of the most likely distribution are shown to be solutions of the following system of equations (Reference 2-12)

$$\ell n\mu = \sum_{i=0}^{N} \frac{(\sigma_i^2 + \sigma^2)^{-1}}{\sum_{i=0}^{N}(\sigma_i^2 + \sigma^2)^{-1}} \ell n\lambda_i^\star \tag{2.51}$$

$$\sum_{i=1}^{N}\left[\frac{1}{\sigma_i^2 + \sigma^2} - \left(\frac{(\ell n\lambda_i^\star - \ell n\mu)}{\sigma_i^2 + \sigma^2}\right)^2\right] = 0 \tag{2.52}$$

For perfect sources of information (i.e., $\sigma_i = 0$), the above equations simplify and result in the following solution

$$m = \left(\prod_{i=1}^{N} \lambda_i^\star\right)^{\frac{1}{N}} \tag{2.53}$$

$$\sigma^2 = \frac{1}{N}\sum_{i=0}^{N} (\ell n\ \lambda_i^\star - \ell n\ \mu)^2 \tag{2.54}$$

Note that Equations (2.53) and (2.54) are similar to the conventional results for fitting a lognormal distribution to a set of estimates. It should also be mentioned that the results of this section apply to any set of failure rate estimates from various sources where a true variability is suspected to exist among the actual values being estimated by each source. For instance, if several generic sources of data provide estimates for a particular type of equipment and it is known or suspected that each source's estimate is based on a different subset of the population, the methods of this section can be applied to obtain a generic distribution representing the "source to source" variability of the failure rate.

Example

The following set of estimates are available for the demand failure rate of MOVs.

Source	Estimate
WASH-1400 (Reference 2-3)	1.00×10^{-3}
N-1363 (Reference 2-5)	5.60×10^{-3}
GCR (Reference 2-12)	1.00×10^{-3}

To use the model of this section, we need to assign range factors to each source as a measure of our confidence in the estimate provided by that source. In this way, we will be able to determine $P_i(\lambda_i^*|\lambda_i)$, Equation (2.47), for each source.

Following our discussion in the example of Section 2.1.1.2.1, we assign a range factor of 3 to the estimate of N-1363. For the estimate of WASH-1400, we assign a range factor of 5 which results in a broader likelihood, $P_i(\lambda_i^*|\lambda_i)$, for that source and represents a less degree of confidence as compared to N-1363. This is due to the fact that the estimate of N-1363 appears to be based on a larger sample of MOV failures in nuclear applications than the estimate of WASH-1400. The latter provides a range factor of 3 for the lognormal distribution whose median (1.00×10^{-3}) we have taken as the estimate. Assigning a larger range factor of 5 also means that we believe WASH-1400 has overstated its confidence in the estimated median value.

The idea of broadening some of WASH-1400 distributions when used as generic curves was introduced in an early site-specific PRA study (References 2-13 and 2-14) where the WASH-1400 curves (as given) were used as generic prior distributions. It was then found that several posterior distributions, reflecting the evidence of the specific plant, lay in the tail region of the prior distributions on the high side. These results led us to the conclusion that the generic curves had to be broadened to reflect greater uncertainty.

References 2-15 and 2-16 provide further support to our decision. In Reference 2-15, the authors review experimental results that test the adequacy of probability assessments, and they conclude that "the overwhelming evidence from research on uncertain quantities is that people's probability distributions tend to be too tight. The assessment of extreme fractiles is particularly prone to bias." Referring to the Reactor Safety Study, they state "The research reviewed here suggests that distributions built from assessments of the 0.05 and 0.95 fractiles may be grossly biased."

Commenting on judgmental biases in risk perception, Reference 2-16 states:

> A typical task in estimating uncertain quantities like failure rates is to set upper and lower bounds such that there is a 98% chance that the true value lies between them. Experiments with diverse groups of people making many different kinds of judgments have shown that, rather than 2% of true values falling outside the 98% confidence bounds, 20 to 50% do so (Reference 2-15). Thus, people think that they can estimate such values with much greater precision than is actually the case.

The numerical effect of using a larger range factor is illustrated in the following table

Distribution	5th Percentile	Median	Mean	95th Percentile	Range Factor
WASH-1400	3.3×10^{-4}	1.0×10^{-3}	1.2×10^{-3}	3.0×10^{-3}	3
Broadened Distribution	2.0×10^{-4}	1.0×10^{-3}	1.6×10^{-3}	5.0×10^{-3}	5

We see here that the medians are the same and the mean value increases slightly reflecting the extension of the high side tail of the curve.

For the cases where WASH-1400 was the only source used for a failure rate, the above methodology was used to generate a broader generic curve from the distribution of WASH-1400. The applied range factor, however, was not necessarily the same for each case. Several examples of this situation can be found in the detailed failure rate description of Reference 2-17.

Similarly, we assign a range factor of 10 for the GCR estimate. This reflects a lower degree of confidence in the estimate of Reference 2-12.

These range factors can be used to obtain the corresponding σ_i values by using Equation (2.41). The results are σ_1=0.67, σ_1=0.98, and σ_3=1.40, for WASH-1400, N-1363, and GCR, respectively. These values as well as the estimate from the three sources were used as the main input to the mode 2 of the computer code BEST that calculates Equations (2.47) through (2.50) and obtains an expected curve based on an integration similar to Equation (2.18).

The resulting histogram has the following characteristics:

5th Percentile: 8.4×10^{-4}

50th Percentile: 1.5×10^{-3}

95th Percentile: 7.4×10^{-3}

Mean: 2.0×10^{-3}

2.1.1.3 Generic Distributions Based On a Mixture of Type 1 and Type 2 Data

An obvious extension of the situations discussed in Sections 2.1.3.1 and 2.1.3.2 is the case where a mixture of I_2 and I_1 information is available. In this case, the equivalent of Equations (2.9) and (2.44) is

$$P(\theta|I_2,I_1,I_0) = k^{-1} L(I_2,I_1|\theta,I_0)P_0(\theta|I_0) \quad (2.55)$$

If I_1 and I_2 are independent pieces of information

$$L(I_2,I_1|\theta,I_0) = L(I_2|\theta,I_0)L(I_1|\theta,I_0) \quad (2.56)$$

where the terms in the right-hand side of the equation are defined by Equations (2.11) and (2.45).

The expected distribution of λ can now be found from

$$\bar{\phi}(\lambda) = \int_0^\infty \phi(\lambda|\theta)\ P\ (\theta|I_2,I_1,I_0)d\theta \quad (2.57)$$

Example

As an example, we use the combination of the data given in the examples in Sections 2.1.1.1 and 2.1.1.2.2. This information was used as the main input to mode 3 of the computer code BEST3 which calculates Equations (2.55) through (2.57). The resulting discretized distribution has the following characteristics:

5th Percentile:	7.49×10^{-4}
50th Percentile:	2.84×10^{-3}
95th Percentile:	1.05×10^{-2}
Mean:	4.30×10^{-3}

2.1.1.4 Development of Generic Failure Rate Distributions

Developing a generic data base requires a thorough review, analysis, and tabulation of the available generic data for each of the identified component failure modes. The PLG generic data base is proprietary. It was updated to its current form during the Seabrook PRA (Reference 2-18), and it is documented in Reference 2-17, a PLG proprietary report. This PLG generic data base was used as the generic data basis for the TMI-1 PRA. In addition to generic data sources, several well documented site-specific failure rate data from power plants examined in previous or ongoing risk studies were used in the development of the generic data base. This assures that the final failure rate distributions accurately reflect all information currently available.

A practical difficulty in using the available generic estimates in the process of developing generic distributions was the lack of standardization in the generic literature. This dictates that utilizing generic sources involves much more than a simple catalog of published failure rate estimates. Each source presents its own unique set of advantages and drawbacks, and these factors must be carefully evaluated before a meaningful comparative analysis may be performed. Typical problems encountered include incompatibility between failure and test data, inclusion of failures due to other than hardware related causes, exclusion of failures due to licensing based reporting criteria, and a general lack of specific documentation of assumptions made, boundary conditions, and methodologies applied. Often it is simply not possible to discern the reasons for significant differences among several sources publishing data for the same component failure mode.

Because of the inherent difficulty in ascertaining the direct comparability among these various estimates, the only practical approach to the problem is the assignment of subjective "weighting factors" to each piece of data, based upon the perceived compatibility of the source with the desired failure rate information. These weights are assigned by assessing either a range factor or σ parameter for the likelihood functions for each source according to the models discussed in Section 2.1.2. This process is computerized via the computer code BEST3, which takes as input various point estimates and corresponding subjective range factors as well as plant-specific experience of the component in question at various plants. The code then performs Bayesian calculations based on the models and generates an average distribution for the failure rate representing source to source and/or plant to plant variability of the data. This process involved several iterations in running the code and reviewing the results to ensure that the range of discrete probability distribution was a reasonable representation of the input information and that the binning of the distribution (20 bins or less) was done properly.

In other cases, where only one source of data was available for the component, failure rate distributions were represented as lognormal. In general, these failure rate distributions were derived by defining the median value and range factor as the two most physically meaningful parameters of the lognormal distribution (the range factor is defined here as the ratio of the 95th percentile to the median, or the square root of the ratio of the 95th and 5th percentiles). In order to provide traceable documentation of the data sources used in this analysis, the median value of such distributions was based on published data. The range factor was subjectively assigned such that the resulting 5th and 95th percentiles of the distribution represent realistic bounds for expected or observed component failure rates.

The relative magnitudes of the range factors developed for the various distributions were influenced by a set of consistent evaluation criteria. In general, range factors significantly greater than 10 (i.e., a span of more than 100 in failure frequency between the 5th and 95th percentiles) were considered to produce distributions so broad as to convey a nearly uninformed state of knowledge and, therefore, would be of marginal utility in any quantification process. The mean value of such a broad distribution, while defined mathematically, is virtually meaningless as a representation of expected component performance because, in truth, very little is known about how the entire population behaves. Some distributions were assigned range factors on the order of 10. Typically, these distributions were characterized by sparse generic data not closely correlated to the desired component failure mode and a relatively low degree of confidence in the available source. It is felt that a distribution this broad conveys only marginal knowledge as to the behavior of a population and is generally indicative of the application of good engineering judgment to minimal prior information. Some distributions were assigned range factors on the order of 3 to 5 (i.e., spans of approximately 10 to 25 between the 5th and 95th probability percentiles). While these distributions are still relatively broad, they represent a higher degree of confidence in the failure rate estimate used as the median value.

Treatment of the generic distributions from IEEE STD-500 (Reference 2-4) is discussed in the following. This reference contains data for electronic, electrical, and sensing components. The reported values were mainly synthesized from the opinions of some 200 experts (a form of the Delphi procedure was used). Each expert reported a "low," "recommended," and "high" value of the failure rate under normal conditions and a "maximum" value which would be applicable under all conditions (including abnormal ones). The pooling of the estimates was done using geometric averaging technique, e.g.,

$$\lambda_{max} = \left(\prod_{i=1}^{N} \lambda_{max,\, i} \right)^{1/N} \tag{2.58}$$

This method of averaging was considered a better representation of the expert estimates, which were often given in terms of negative powers of 10. In effect, the usual arithmetic averages of the exponents were used, which, as discussed in Section 2.1.1.2.1, is a special case of the Bayesian model presented in this report.

Reference 2-4 does not recommend a distribution. The method of averaging, however, suggests that the authors have in mind a lognormal distribution. Our task now is to determine this distribution from the given information.

The recommended value is suggested to be used as a "best" estimate. The word "best" is, of course, subject to different interpretations. We have decided to use it as the median value mainly for two reasons. First, for skewed, lognormal type distributions, the median is a more representative measure of central tendency than the mean, which is very sensitive to the tails of the distribution. Thus, we suspect that the experts who submitted their "recommended" estimates actually had in mind median values. Experimental evidence (Reference 2-19) also indicates that assessors tend to bias their estimates of mean values toward the medians. The second reason is that this choice is conservative, since the mean value of our resulting distribution is then larger than the "recommended" value. The "maximum" value is taken to be the 95th percentile of the lognormal distribution.

For the majority of the components for TMI-1 PRA, generic component failure rates were taken from PLG Generic Data Base (Reference 2-17). In a few cases additional generic distributions had to be developed for some specific types of equipment. Reference 2-17 provides a detailed documentation of the generic distributions used in this study. The mean value of the generic distributions are listed in Section 3 in conjunction with the TMI-specific failure rate distributions.

2.1.2 DATA SPECIALIZATION

Data specialization or the development of plant specific failure rate distribution is achieved by applying Bayes' theorem as follows

$$P(\lambda|E_2) = k^{-1} L(E_2|\lambda) P_0 (\lambda) \qquad (2.59)$$

where $P(\lambda|E_2)$ is the plant-specific failure rate distribution reflecting the plant-specific experience E_2, and the generic distribution $P_0(\lambda)$ as prior state of knowledge about the failure rate of the component in question. The likelihood term, $L(E_2|\lambda)$, takes the form of a Poisson distribution when λ is the rate of failure per unit time and the evidence E_2 is k failures in T time units

$$P(k_1T|\lambda) = \frac{(\lambda T)^k}{k!} e^{-\lambda T} \qquad (2.60)$$

If λ is a demand failure frequency and E_2 is k failures in D demands, then $L(E_2|\lambda)$ is a binomial distribution

$$P(k_1D|\lambda) = \frac{D!}{(D-k)!\ k!} (1-\lambda)^{D-k} \lambda^k \qquad (2.61)$$

The magnitude of the effect of adding plant-specific data depends on the relative strength of the data compared with the prior level of confidence expressed in the form of the spread of the prior distribution. Typically both the location and the spread of the posterior or updated distribution is affected by the plant-specific evidence. The mean value of the updated distribution could be higher or lower than the mean of the generic prior but adding the plant-specific data normally reduces the spread of the distribution, as shown in the following example. The generic distribution for the MOV demand failure frequency presented in the example of Section 2.1.1.3 was updated with 15 failures in 5,315 demands. Calculations were performed using mode 4 of the computer code BEST3. The following table compares some basic characteristics for the generic prior and updated distributions.

Distribution	Mean (per demand)	5th Percentile	Median	95th Percentile
Generic	4.30×10^{-3}	7.49×10^{-4}	2.84×10^{-3}	1.05×10^{-2}
Updated	2.88×10^{-3}	1.83×10^{-3}	2.82×10^{-3}	1.71×10^{-3}

2.2 COMMON CAUSE FAILURE PARAMETERS

In the TMI-1 PRA, dependent failures such as common cause failures at the systems level are treated either explicitly by means of identifying causes of dependent failure and incorporating them in the systems or event sequence models, or implicitly by using certain parameters to account for their contribution to the systems' unavailability. Examples of the first category are sharing of common components, fires, floods, and certain types of human error during test and maintenance. This section deals with the second category, addressing common cause failures that are not covered in the first category, such as design errors, construction errors, procedural deficiencies, and unforeseen environmental variations.

The parametric model used in this study to quantify the effect of the second category of dependent failures is known as the multiple Greek letter method (Reference 2-20) which is an extension of the beta factor method (Reference 2-21). The following is an overview of the method and the Bayesian technique used in developing state-of-knowledge distributions reflecting various sources of uncertainty in estimating the parameters of the method.

2.2.1 OVERVIEW OF THE MGL METHOD

In the MGL method, the total failure probability of each component is determined from all independent and common cause contributions for that component. For instance, for a component in a system of three redundant and identical components we have

$$Q_c = Q_1 + 2Q_2 + Q_3 \tag{2.62}$$

where Q_i is the frequency of simultaneous failure of i components.

The common cause parameter, β, is then defined for each component as the conditional probability of a common cause event involving a second or third unit, given that a specified component failure occurs.

$$\beta \equiv \frac{2Q_2 + Q_3}{Q_1 + 2Q_2 + Q_3} \tag{2.63}$$

A second common cause failure parameter, γ, is defined for each component as the conditional probability that a common cause failure involving that component involves all three components in the system

$$\gamma \equiv \frac{Q_3}{2Q_2 + Q_3} \tag{2.64}$$

An important observation about the MGL model that is useful in collecting data and estimating parameters is that, for systems having identical components and identical conditions and environments acting on the components but with different numbers of components, the only parameters that are "conserved" (i.e., invariant among systems with different component populations) are Q and Q_1. All the remaining parameters (Q_2, Q_3, β, γ) are a function of the number of identical components in the system. For example, consider two systems, one with two components and one with three components. In the two-component system, all common cause events are modeled by Q_2 inasmuch as no more than two components can fail. However, some of the common cause events in the two-component system might cause all three components to fail in a three-component system. Therefore, despite the fact that each component experiences the same causes of independent and common cause events, we have

$$Q_2(\text{first system}) \neq Q_2(\text{second system})$$

$$Q_3(\text{first system}) = 0 \neq Q_3(\text{second system})$$

$$Q_2(\text{first system}) = 2Q_2(\text{second system}) + Q_3(\text{second system})$$

To avoid problems, it is recommended that when parameters are estimated, all data are interpreted to assess the impact of each event in the particular system under investigation. This technique will be illustrated later.

After rearranging Equations (2.62), (2.63), and (2.64), the following identities are obtained

$$Q_3 = \gamma\beta Q_C$$

$$Q_2 = \frac{1}{2}(1 - \gamma)\beta Q_C$$

$$Q_1 = (1 - \beta)Q_C \qquad (2.65)$$

These parameters can now be used to calculate system unavailability due to both independent and dependent failures. For example, the following MGL models are obtained for two system configurations. For the one-out-of-three system

$$Q(1/3) \simeq \gamma\beta Q_c + \frac{3}{2}(1 - \gamma)(1 - \beta)\beta Q_c^2 + \frac{3}{4}(1 - \gamma)^2\beta^2 Q_c^2 + (1 - \beta)^3 Q_c^3 \qquad (2.66)^*$$

that, to the third order in β and Q, can be further simplified to

$$Q(1/3) \simeq \gamma\beta Q_c + \frac{3}{2}(1 - \gamma)\beta Q_c^2 + Q_c^3 \qquad (2.67)^*$$

The first term on the right side of Equation (2.67) accounts for a triple-component common cause failure, the second accounts for a

*Approximation comes from the "rare event" approximation.

double-component common cause event in combination with a single independent failure, and the third represents the case of triple independent failures.

For a two-out-of-three system

$$Q(2/3) \simeq \frac{3}{2}(1 - \gamma)\beta Q_c + \gamma\beta Q_c + 3(1 - \beta)^2 Q_c^2 \qquad (2.68)^*$$

which to the third order in β and Q_c, is simplified to

$$Q(2/3) \simeq \frac{1}{2}(3 - \gamma)\beta Q_c + 3(1 - 2\beta)Q_c^2 \qquad (2.69)^*$$

2.2.2 ESTIMATORS FOR THE PARAMETERS OF THE MGL MODEL

To develop estimators for the parameters of the MGL method, we start with the following general formula for the failure frequency Q_c of a component in a system of m (identical and redundant) units

$$Q_c \simeq \sum_{j=1}^{m} \frac{(m-1)!}{(m-j)!\,(j-1)!} Q_j \qquad (2.70)$$

where

$Q_j \equiv$ Failure frequency of simultaneous failure of j components in the system.

For instance, for a component in a three-unit system (m = 3), we have

$$Q_c = \sum_{j=1}^{3} \frac{2!}{(3-j)!\,(j-1)!} Q_j$$

$$= \frac{2!}{2!\,0!} Q_1 + \frac{2!}{1!\,1!} Q_2 + \frac{2!}{0!\,2!} Q_3$$

$$= Q_1 + 2Q_2 + Q_3 \qquad (2.71)$$

An estimator for Q_j is

$$Q_j^* = \frac{n_j}{\frac{m!}{(m-j)!\,j!} N_D} \qquad (2.72)$$

*Approximation comes from the "rare event" approximation.

where

$n_j \equiv$ number of events involving j components in failed state.

$N_D \equiv$ number of demands on the entire system of m components.

Replacing Q_j in Equation (2.70) with the corresponding estimator yields

$$Q_c^{\star} = \frac{1}{m\ N_D} \sum_{j=1}^{m} j n_j \tag{2.73}$$

In the following, we develop estimators for the first three parameters of the MGL model for a system of m components. Estimators for the higher order parameters can be developed in a similar fashion. Based on the definition of β as the conditional probability that given a specified component failure, at least one other component also failed due to the same cause, we have

$$\beta = \frac{1}{Q_c} \sum_{j=2}^{m} \frac{(m-1)!}{(m-j)!\ (j-1)} Q_j \tag{2.74}$$

The parameter γ is defined as the conditional probability that given a common cause failure of two components, at least a third unit also failed due to the same cause. Therefore,

$$\gamma = \frac{1}{\beta Q_c} \sum_{j=3}^{m} \frac{(m-1)!}{(m-j)!\ (j-1)} Q_j \tag{2.75}$$

Similarly

$$\delta = \frac{1}{\beta\gamma Q_c} \sum_{j=4}^{m} \frac{(m-1)!}{(m-j)!\ (j-1)} Q_j \tag{2.76}$$

Therefore, using Equations (2.72) and (2.73), we obtain

$$\beta = \left(\sum_{j=2}^{m} j n_j\right) \Bigg/ \left(\sum_{j=1}^{m} j n_j\right) \tag{2.77}$$

$$\gamma = \left(\sum_{j=3}^{m} j n_j\right) \Bigg/ \left(\sum_{j=2}^{m} j n_j\right) \tag{2.78}$$

$$\delta = \left(\sum_{j=4}^{m} j n_j\right) \Bigg/ \left(\sum_{j=3}^{m} j n_j\right) \tag{2.79}$$

For instance, for a three-unit system ($m = 3$), we have

$$\beta_3 = \frac{2n_2+3n_3}{n_1+2n_2+3n_3} \quad (2.80)$$

$$\gamma_3 = \frac{3n_3}{2n_2+3n_3} \quad (2.81)$$

2.2.3 ASSESSMENT OF UNCERTAINTY

Point estimators developed in the previous section only provide single values for the parameters of the MGL model. However, since the estimates are typically based on limited information, the true value of a parameter may actually differ from the point estimate. The objective of uncertainty analysis is to assess the range of values of each parameter based on the available information and various sources of uncertainty. Variation of the value of a parameter could be due to one or a combination of the following reasons:

1. Size of the data sample.
2. Uncertainty in data classification.
3. Variation among the plants in equipment systems and operational philosophy.

The following sections describe how each of the above sources of uncertainty was treated in this study.

2.2.3.1 Assessment of Uncertainty Due to Data Sample Size

The first of these sources of uncertainty is a well-known subject in statistics. Larger sets of failure and success data would result in estimates with higher degrees of confidence simply because they are more represenative of the general population. For instance, in Equation (2.77), the larger the total number of failures given by the term

$$N_t = \sum_{j=1}^{m} jn_j$$

the more accurate the estimated value of β. The mathematical models presented in the following Bayesian method provides a mechanism for handling this source of uncertainty. We will limit the discussion to a two-parameter MGL model which applies to a system of three components. Extension of the results to higher order parameters will be a simple task.

Based on the definition of β and γ, [Equations (2.63) and (2.64)], we define

$Z_1 \equiv 1-\beta$ conditional probability of component failure being a single failure.

$Z_2 \equiv \beta(1-\gamma)$ conditional probability of a component being involved in a double failure.

$Z_3 \equiv \beta\gamma$ conditional probability of a component being involved in a triple failure.

Note that

$$Z_1 + Z_2 + Z_3 = 1 \qquad (2.82)$$

as expected.

The likelihood of observing n_1 single failures, $2n_2$ component failures due to common cause, and $3n_3$ component failures due to common cause, can be modeled by a multinomial distribution for Z_i's

$$P(n_1, 2n_2, 3n_3, |Z_1, Z_2, Z_3) = C\, Z_1^{n_1}\; Z_2^{2n_2}\; Z_3^{3n_3} \qquad (2.83)$$

where C is the binomial coefficient. Rewriting Equation (2.83) in terms of β and γ gives

$$P(n_1, 2n_2, 3n_3|\beta,\gamma) = C\, \beta^{2n_2+3n_3}\, (1-\beta)^{n_1}\, \gamma^{3n_3}\, (1-\gamma)^{2n_2} \qquad (2.84)$$

We now write Bayes' theorem as follows

$$\pi(\beta,\gamma|n_1, 2n_2, 3n_3) = k^{-1} P(n_1, 2n_2, 3n_3|\beta,\gamma)\pi_0(\beta,\gamma) \qquad (2.85)$$

where π_0 and π are the prior and posterior distribution of β and γ and k is a normalizing factor defined as

$$k = \iint P\,(n_1, 2n_2, 3n_3|\beta,\gamma)\pi_0(\beta,\gamma)d\beta d\gamma \qquad (2.86)$$

As the prior one can use a multinomial distribution

$$\pi_0(\beta,\gamma) = k\, \beta^{A_0-1}\, (1-\beta)^{B_0-1}\, \gamma^{C_0-1}\, (1-\gamma)^{D_0-1} \qquad (2.87)$$

where k is a normalizing factor.

A noninformative flat prior distribution is obtained by setting

$$A_0 = B_0 = C_0 = D_0 = 1$$

Using Equation (2.87) in Equation (2.85) results in a posterior distribution for β and γ which is also multinomial with parameters

$$A = A_0 + 2n_2 + 3n_3$$

$$B = B_0 + n_1$$

$$C = C_0 + 3n_3$$

$$D = D_0 + 2n_2 \tag{2.88}$$

The mode of the posterior distribution occurs at

$$\beta_{mode} = \frac{A-1}{A+B-2} \tag{2.89}$$

$$\gamma_{mode} = \frac{C-1}{C+D-2} \tag{2.90}$$

The mean values are calculated from

$$<\beta> = \frac{A}{A+B} \tag{2.91}$$

$$<\gamma> = \frac{C}{C+D} \tag{2.92}$$

Note that for a noninformative prior, the mode of the posterior distribution is

$$\beta_{mode} = \frac{2n_2+3n_3}{n_1+2n_2+3n_3} \tag{2.93}$$

$$\gamma_{mode} = \frac{3n_3}{2n_2+3n_3} \tag{2.94}$$

which correspond to the point estimates developed in Section 2.2.2 for $m = 3$.

The variance of the posterior distribution for β and γ are

$$V(\beta) = \frac{AB}{(A+B)^2(A+B+1)} \tag{2.95}$$

$$V(\gamma) = \frac{CD}{(C+D)^2(C+D+1)} \tag{2.96}$$

For instance, for a noninformative prior

$$v(\beta) = \frac{(2n_2+3n_3+1)(n_1+1)}{(n_1+2n_2+3n_3+2)^2(n_1+2n_2 3n_3+3)} \tag{2.97}$$

As we can see, the variance decreases as the total number of failures ($n_. = n_1+2n_2+3n_3$) increases. Since smaller variance means smaller range of uncertainty, the larger the number of failures in the data sample, the higher the confidence in the estimated value.

2.2.3.2 Assessment of Uncertainty Due to Data Classification

An important source of uncertainty is the judgments that are made in the process of classification of data for use in quantifying common cause parameters. Treatment of this type of uncertainty and several other aspects of data classification that have direct impact on the assessment of common cause parameters are discussed below.

Of fundamental importance in a meaningful assessment of the contribution of common cause events to the system unavailability is a detailed review and systematic classification of failure events experienced in the nuclear industry. The data used for this study are based on review and classification of several thousand failure events reported by U.S. nuclear power plants, as well as TMI-specific component failure events. The data classification approach was that of Reference 2-22. In short, events were classified into one of two categories of dependent and independent events. Dependent events are those that involve several component abnormalities that are casually related. All other events are classified as independent. Abnormal states of components are classified as either failed or functionally unavailable where, in both cases, the component is not capable of performing its function according to a given success criterion. The failed state applies to cases where, in order to restore the component to operability, some kind of repair or replacement action on the component is necessary. A functionally unavailable component, however, is capable of operating but the function normally provided by the component is unavailable due to loss of input such as motive power, command signal, cooling water, air, etc.

Sometimes, even though a given success criterion has been met and the component has performed its function according to the success criterion, some abnormalities are observed that indicate that the component is not in its perfect or nominal condition. Although a component in such a state may not be regarded as unavailable, there may exist the potential of the component becoming unavailable with time due to changing conditions, or due to more demanding operational modes. Events involving these potentially unavailable states provide valuable information about causes and mechanisms of propagation of failures and thus should not be ignored. The concept of potentially unavailable states also serves a practical need to enable the consistent classification of "grey area" cases and difficult-to-classify situations. The "potentially unavailable" component state category is defined for this situation. It refers to the cases where the component is capable of performing its function according to a success criterion but an incipient or degraded condition, as defined below, exists.

- Degraded. The component is in such a state that it exhibits reduced performance but insufficient degradation to declare the component unavailable according to the specified success criterion. Examples of degraded states are relief valves opening prematurely outside the technical specification limits but within a safety margin and pumps producing less than 100% flow but within a stated performance margin.

- Incipient. The component is in a condition that, if left unremedied, could ultimately lead to a degraded or unavailable state. An example is the case of an operating charging pump which is observed to have excessive lube oil leakage. If left uncorrected, the lube oil would reach a critical level and result in severe damage to the pump.

A key to distinguishing between degraded and incipient conditions is the knowledge that an incipient condition has not progressed to the point of a noticeable reduction in actual performance, as is the case with a degraded condition.

It is important to recognize that potentially unavailable is not synonymous with hypothetical. Both incipient and degraded conditions are indicative of observed, real component states that, without corrective action, would likely lead to unavailable component states.

Dependent events were further grouped into events in which the cause of failure of the component(s) of interest is the failure of another component (component-caused events) and those where the cause(s) of failure(s) is something other than the state of another component (root-caused events). Finally, events in the dependent category were screened based on a set of criteria for applicability to PRA type systems analysis in general and the TMI-1 PRA in particular. The events that are not screened out in this process are named "common cause events" and are used to estimate the common cause model parameters.

In estimating the parameters of the MGL model, a particular system size must be considered. The next step is to calculate the number of component failures for each of the various "system impact" categories. System impact category refers to the number of components being affected in an event. For instance, if in an event two components are failed, the system impact category for that event is 2. We explain this step with the aid of a hypothetical example.

Suppose that we want to estimate the common cause contribution to the unavailability of a system of three identical redundant components. Therefore, we need to estimate β and γ in addition to the failure rate of the component. Suppose, further, that the data after screening indicate that there have been 88 independent events involving 70 actual and 18 potential failures. In addition, assume that there have been three common cause events:

- Event 1. Common cause failure of two components in a system of two components. However, the cause of failure is such that if a similar event occurred in our example system, it would most likely affect all three components.

- Event 2. Two components failed within a short period of time but it cannot be determined, based on the event description, whether the two failures shared the same failure cause.

- <u>Event 3</u>. One component failed and another in degraded condition (potential failure) due to the same cause.

Event 1 involves a situation where the data from a two-component system should be "extrapolated" by postulating the impact of the cause of the event on a three-component system. Therefore, with regard to the "system impact" of this event, there are two hypotheses: (1) the cause only affects two of the three components, and (2) it affects all three. Weights can be assigned to each of the two hypotheses that reflect the analyst's judgment regarding the two hypotheses. In Table 2-1, this situation is represented by weights of 0.05 and 0.95 assigned to the first and second hypothesis, respectively.

Event 2 also involves two hypotheses: (1) two components were affected independently, and (2) the event is a common cause failure of two components. In Table 2-1 a weight of 0.9 is assigned to the first hypothesis, while the second one is given a weight of 0.1.

In event 3, we are dealing with a common cause situation. However, only one component actually failed, while the state of the other one was "potentially failed." If we assign a weight of 0.10 to the potential failure, the effective number of failures in the event is 1 + (0.1)(1) = 1.1, as can be seen in Table 2-1. Note also that there is only one hypothesis regarding the system impact of the cause.

Table 2-1 summarizes the information obtained for the common cause events in the form of effective number of component failures in each event for each hypothesis. This effective number can be calculated for the jth event from

$$\bar{n}_{ji} = \sum_{k=1}^{i} w_{jik} \qquad (2.98)$$

where

i ≡ "system impact" index, which is defined as the number of components assumed to be affected by the cause.

w_{jik} ≡ the weight assigned to the state of the kth component in the event j for system impact index i.

In our example, for the independent events the effective number of failures is 70 + (0.1)(18) = 71.8, where 0.1 is the weight given to potential failures.

In addition to the effective number of components per hypothesis, Table 2-1 lists the weight given to each hypothesis. Finally, the last column of Table 2-1 provides the effective number of failures for each system impact category. For category i, this number is calculated from

$$\bar{n}_i = \sum_{j=1}^{J} p_{ji}\, \bar{n}_{ji} \equiv \text{effective number of component failures for system impact category } i \qquad (2.99)$$

where p_{ji} is the weight given to the ith hypothesis regarding event j.

We are now ready to calculate point estimates for β and γ using $\bar{n}_i$'s

$$\beta^* = \frac{\bar{n}_2 + \bar{n}_3}{\bar{n}_1 + \bar{n}_2 + \bar{n}_3} \quad (2.100)$$

$$\gamma^* = \frac{\bar{n}_3}{\bar{n}_2 + \bar{n}_3} \quad (2.101)$$

For the present example, based on the values provided in Table 2-1, we have

$$\beta^* = \frac{0.41 + 2.85}{74.59 + 0.41 + 2.85} = 0.04$$

$$\gamma^* = \frac{2.85}{0.41 + 2.85} = 0.87$$

The above estimators reflect the uncertainty due to data classification. The value of $\bar{n}_i$'s could also be used in the likelihood of Bayes' theorem discussed in Section 2.2.3.1 to obtain the combined effect of uncertainties due to data classification as well as data sample size.

2.2.3.3 Plant-to-Plant Variability of the MGL Parameters

The third source of uncertainty is the variation of the value of the parameters from plant to plant. This type of variability stems from the fact that similar equipment and systems in various plants may show inherently different failure rates due to a variety of reasons, such as minor design differences within the same category of equipment and variation in system designs and operating philosophies leading to different coupling mechanisms.

There are two approaches for dealing with this issue. One approach is to assess the variability of the parameters based on statistical evidence from all plants without screening events based on their applicability to the situation under consideration. This results in a wider range of possible values for the parameters. In the second approach, failure events from various plants are reclassified and events not considered to be applicable to the plant or system of interest are excluded from the data base. The result is the formation of a data sample much larger than one based only on the records of the specific plant under consideration. The resulting uncertainty range for the estimated parameters will obviously be smaller in this case as compared with a distribution representing differences in plants. This reduction in uncertainty is the result of applying the additional information about the specific characteristics of the system being analyzed. This was the approach taken in this study to quantify the common cause parameters.

2.2.4 GENERIC COMMON CAUSE PARAMETER DATA BASE

Based on the approach described in the previous section, the generic data is normally screened for applicability to the particular systems analyses being considered. In that sense, the industry-wide data is specialized to the TMI-1 plant even at the "generic" level. The generic data used for this study and the result of event screening are documented in Reference 2-17. The data base included common cause events for several key components such as reactor trip breakers, diesel generators, pumps, and valves. Mean values of the generic distributions are provided in Section 3, in conjunction with the updated distributions.

2.3 COMPONENT MAINTENANCE DATA

Maintenance activities which remove components from service and alter the normal configurations of mechanical systems can provide a significant contribution to the overall unavailability of those systems. This section describes how generic and plant-specific maintenance data are used to develop the distribution of component maintenance unavailability.

These distributions apply to maintenance performed during unit noncold shutdown operating periods (i.e., at power operation or in some cases, at hot shutdown). These include the regularly scheduled preventive maintenance. The specific causes leading to these maintenance activities are not delineated; they include repairs of component failures experienced during operation, repairs of failures during periodic testing, removal from service for special testing or inspection, minor adjustments, hardware modifications, etc.

To quantify maintenance unavailabilities, both the frequency and duration of maintenance are necessary; the frequency of maintenance defines the rate at which components are removed from service while the duration and frequency combined determine the component unavailability to be applied in the quantification of system unavailability.

The unavailability due to maintenance is calculated from

$$Q_M = \frac{f \cdot \tau}{1 + f \cdot \tau} \qquad (2.102)$$

where f is the maintenance frequency and τ is the mean duration or, as it is frequently called, mean time to repair.

When $f \cdot \tau \ll 1$, then

$$Q_M \simeq f \cdot \tau \qquad (2.103)$$

Therefore, in order to obtain a state-of-knowledge distribution for the unavailability, Q_M, one needs to have state-of-knowledge distributions

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for both f and τ. Such distributions are developed as described in the following.

2.3.1 FREQUENCY OF MAINTENANCE

The component maintenance frequency distributions for this study were developed by updating generic maintenance frequency distributions using TMI-specific maintenance frequency data. The method of updating was the same used in updating failure rates described in Section 2.1.2. Five generic maintenance frequency distributions were developed for five general component categories based on the component type, its normal service duty, and the applied technical specifications inoperability limitations. The basis for these distributions is described in Reference 2-16 and their mean values are presented in Section 3 in conjunction with the TMI-specific distributions.

2.3.2 DURATION OF MAINTENANCE

As applied in this data base, the duration of a maintenance event includes the entire time period during which the affected component is unavailable for operation. This period is defined from the time when the component is originally isolated or otherwise removed from service to the time when the component is returned to service in an operable state and, in many cases, it may be only weakly dependent on the actual time required for maintenance personnel to effect the repairs.

Five generic distributions for the maintenance duration were used from the PLG proprietary data base documented in Reference 2-17. The distributions for the TMI-specific mean maintenance duration were developed based on the five generic maintenance duration distributions, updated with TMI-specific component repair times. The following explains the Bayesian technique that was used to develop these distributions.

The following analytical model is used to model the variability of the repair times from plant to plant or from occasion to occasion.

Let t denote the actual repair time in any instance, and imagine that the value of t has been recorded for many, many occasions where this repair operation was performed. From these records, one would be able to plot a curve $\phi(t)$, showing the frequency distribution of t. The desired mean duration, τ, could be immediately computed from this distribution

$$\tau = \int_0^{\infty} t\, \phi(t) dt \qquad (2.104)$$

To know τ, therefore, we need to know $\phi(t)$. The problem, of course, is that in real life, one does not usually have the curve $\phi(t)$. Usually, all one has is a small set, E, of values

$$E = \{t_i;\ i = 1,\ldots,N\} \qquad (2.105)$$

where the t_i's represent the observed repair times.

Within the Bayesian framework, the solution to this problem is straightforward. One imagines the true distribution, $\phi(t)$, as embedded within a parametric distribution space, $\phi(t|\theta)$, and the probability distribution is erected on this space using Bayes' theorem and evidence E

$$P(\theta|E,E_0) = k^{-1}L(E|\theta,E_0)\ P_0(\theta|E_0) \tag{2.106}$$

where E is given by Equation (2.105) and $P(\theta|E,E_0)$ is the posterior probability distribution over θ, the set of parameters of $\phi(t)$.

It is assumed that there is a minimum repair time, t_0, and that the actual repair times are mostly distributed about an average value, with a few much longer than the average. In other words, it is assumed that

$$x = t - t_0 \tag{2.107}$$

is approximately lognormally distributed

$$\phi(x|\mu,\sigma) = \frac{1}{\sqrt{2\pi}\ \sigma x} \exp \left\{ \frac{1}{2} \left(\frac{\ell n x - \ell n\ \mu}{\sigma} \right)^2 \right\} \tag{2.108}$$

If x is distributed according to Equation (2.108), the likelihood of observing a particular value, x_i, where

$$x_i \equiv t_i - t_0 \tag{2.109}$$

is

$$\phi_i(x_i|\mu,\sigma) = \frac{1}{\sqrt{2\pi}\ \sigma\ x_i} \exp \left\{ \frac{1}{2} \left(\frac{\ell n x_i - \ell n \mu}{\sigma} \right)^2 \right\} \tag{2.110}$$

consequently, $L(E|\theta,E_0)$, the total likelihood in Equation (2.106) for $\theta = \{\mu,\sigma\}$, becomes

$$L(x_1,x_2,\ldots,x_N|\mu,\sigma,E_0) = \prod_{i=1}^{N} \phi_i(x_i|\mu,\sigma) \tag{2.111}$$

The posterior, $P(\mu,\sigma|E,E_0)$, which can now be calculated from Equation (2.106), is the probability distribution for different pairs of μ and σ and consequently for different $\phi(x|\mu,\sigma)$ given by Equation (2.108). Each such distribution has a mean value, $\bar{x}$, which is given by

$$\bar{x} = \mu \exp\left(\frac{1}{2}\sigma^2\right) \tag{2.112}$$

Therefore, the posterior distribution on μ and σ is also a probability distribution about $\overline{x}$ which is related to the mean repair time by

$$\tau = \overline{x} + t_0 \tag{2.113}$$

We now have a probability distribution for τ (t_0 is a constant) which represents our state of knowledge about the mean repair time in light of the observed repair times as given in Equation (2.105).

The generic information enters the picture through the prior distribution $P_0(\sigma|E_0)$ in Equation (2.106) that for a lognormal maintenance distribution takes the form $P_0(\mu 1\sigma|E_0)$. Therefore, for each category of component the prior state of knowledge needs to be expressed in terms of a probability distribution for μ and σ. This is done by transforming the probability distribution over the generic distribution of the actual repair times to a distribution over the parameters of lognormal distribution (μ, σ). This is done with the aid of computer code RTIME2 (Reference 2-23), which transforms state-of-knowledge distributions over the 5th and 95th percentiles of the generic lognormal distribution into a discretized grid for μ and σ. The details of the development of the five generic maintenance frequency distributions are provided in Reference 2-17. The mean values of the generic distributions are tabulated in Section 3 together with the updated distributions.

2.4 INITIATING EVENTS FREQUENCIES

The initiating events are divided into two groups according to the method using for quantifying their frequencies. The first set is composed of those events for which the available data from other nuclear power plants are judged to be relevant. This includes essentially all initiating events except those involving failure of systems that have configurations unique to the TMI-1 plant, requiring a plant-specific analysis of those systems.

The methodology used to develop the generic and plant-specific distribution of the frequencies of the initiating events in the first group is similar to one used for component failure rates, as described in Section 2.1. The details of the development of the generic frequencies and the compiled raw data are described in Reference 2-17.

The details of the development of the frequency of the initiating events in the second group (i.e., those requiring plant-specific analysis of the systems involved) are presented in Section 3.5 of this report.

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TABLE 2-1. EXAMPLE OF THE CALCULATION OF THE EFFECTIVE NUMBER OF FAILURES FOR VARIOUS SYSTEM IMPACT CATEGORIES

System Impact Category*	Independent Events		Dependent Events						Effective Number of Failures††
			Event 1		Event 2		Event 3		
	p**	$\bar{n}$†	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	1.0	71.8	0.0	0	0.9	2	0.9	1.1	$\bar{n}_1$ = 74.59
2	0.0	0	0.05	2	0.1	2	0.1	1.1	$\bar{n}_2$ = 0.41
3	0.0	0	0.95	3	0.0	0	0.0	0	$\bar{n}_3$ = 2.85

*Refers to the number of components affected in the event.
**Weight assigned to various hypotheses.
†Effective number of component failures for each event for each hypothesis (Equation 2.98).
††Total effective number of component failures for each system impact category (Equation 2.99).

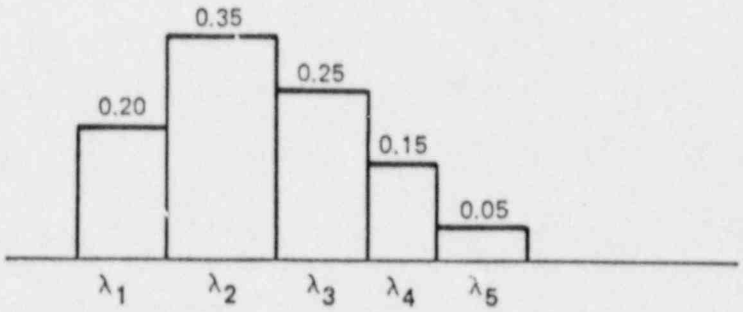

FIGURE 2-1. POPULATION VARIABILITY OF THE FAILURE RATE

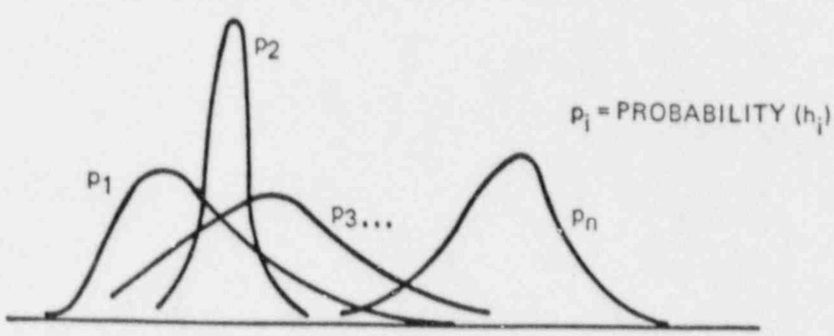

FIGURE 2-2. STATE-OF-KNOWLEDGE DISTRIBUTION OVER THE SET OF FREQUENCY DISTRIBUTIONS

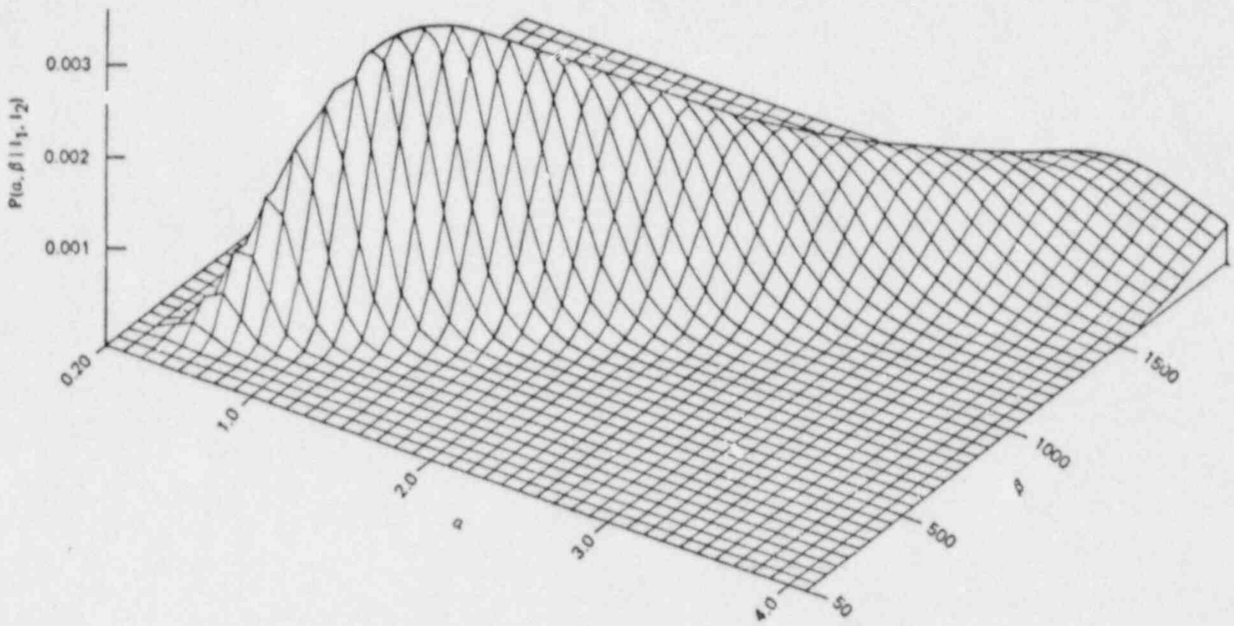

FIGURE 2-3. POSTERIOR DISTRIBUTION FOR THE PARAMETERS OF THE DISTRIBUTION OF PUMPS' FAILURE TO START ON DEMAND RATES

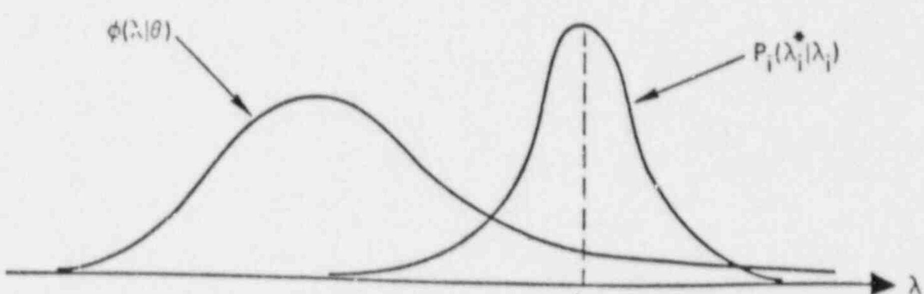

FIGURE 2-4. THE RELATION BETWEEN THE POPULATION VARIABILITY CURVE AND UNCERTAINTY ABOUT INDIVIDUAL ESTIMATES

3. TMI PLANT-SPECIFIC DATA BASE

3.1 INTRODUCTION

A comprehensive and well-documented summary of the TMI-1 operating experience provides the cornerstone for the Bayesian analysis of the data developed for this study. This section explains the process of plant-specific data collection in the areas of (1) component failures, (2) common cause events, (3) component maintenance, and (4) initiating events. It also provides the summary of collected data as well as the resulting updated distributions for each of the above four categories. Detailed listings of the plant-specific data are provided in a series of four appendices at the end of this report.

The TMI-1 plant started up on September 2, 1974. The data collection effort covered the period from the date of the beginning of commercial operation through June 30, 1984, even though the plant has been shut down since February 17, 1979. Table 3-1 lists the primary documents and operating records used during the plant data collection task. Each of the documents and sources of information are described in more detail under the corresponding topic in the following sections. For component failure data, the entire period from September 2, 1974, through June 30, 1984, was covered. For reasons explained later, the maintenance data had to be limited to the noncold shutdown periods. Table 3-2 provides the history of TMI-1 cold shutdown outages including reasons for such shutdowns. The initiating events data were collected for the period September 2, 1974, through February 17, 1979.

3.2 COMPONENT FAILURE RATES

Quite simply, the collection of plant-specific failure rate data requires the analyst to count and record, for each component and failure mode being modeled, the number of failures and the corresponding number of demands or operating hours. Unfortunately, these data are virtually never found together in the same plant records. The solution to this problem demands a judicious accounting for each type of data to ensure accurate and consistent failure rates.

3.2.1 COMPONENT FAILURE DATA

3.2.1.1 Definition of Failure

The data presented in this section are used in the system analyses to quantify the frequency of hardware failures that prevent a system from meeting success criteria defined by the event tree models. Several failure causes are evaluated in each analysis, and all causes are combined to determine overall system unavailability for each set of success criteria. The failure rate data must be comparable with these applications. The failures must include all events that functionally disable a component for the failure mode being evaluated. This ensures completeness of the failure rate data base. However, failures due to causes other than internal equipment malfunctions must be closely examined to determine whether they are evaluated separately in the system model. This avoids potential double-accounting for failures in the system analysis results.

For example, if a normally closed motor-operated valve must open and remain open for a system to operate properly, equipment failures that prevent the valve from closing after it opens are not relevant for the valve data base. However, these failures are relevant data for a valve that must reclose. If one of the failures occurred because test personel left a circuit breaker open, and if this failure cause is evaluated separately in the valve model, the event applies to the evaluation of test personnel error rates. It is not included in the valve hardware failure rate data because doing so would double-account for the test personnel errors. However, if testing errors are not evaluated separately in the valve model, the event is included as a valve hardware failure to ensure complete accounting for all the plant-specific evidence.

A component failure is thus an event in which a piece of equipment fails to perform a function required by the system model. The event is included in the hardware failure rate data base if its cause is not evaluated explicitly in a separate part of the model. If the cause is quantified separately, the event is used as evidence for the appropriate failure cause.

The equipment operating records document a large number of component malfunctions. Many are clearly component failures that should be included in the data base. For example, a motor-operated valve may fail to close because of loose limit switch contacts, or a pump may fail to start because its circuit breaker closing coil has burned out. However, a large number of events documented as malfunctions require additional investigation and subjective evaluation to determine whether they should be included as functional failures. For example, pump shaft vibration is indicative of possible damage to the pump bearings. Severe vibration is normally included in the data base as functional failure of the pump during operation because shaft seizure or other failures will occur within a few hours if the pump remains running. Observation of minor vibration or bearing noise may be the reason for pump inspection, additional lubrication, or corrective maintenance. These minor problems are sometimes considered as failure "precursors" because they will eventually progress to pump damage if left unattended. However, they are not normally included in the failure data base because the pump will continue to run for several hours or days before experiencing severe damage. Additional information about the types of repairs made, the parts replaced, and the urgency of the repairs often provides important insight about the severity of these malfunctions. Preventive and corrective maintenance is performed to stop the progression of minor problems, and only the events that actually cause equipment damage are correctly included as failures. The effects on component availability from inspections, preventive maintenance, and minor repairs are included in the maintenance data base described in Section 3.4.

The first step in collecting failure data for a component is to determine the failure modes and failure causes to be included in the data base.

These are defined by the success criteria and types of analyses performed for the system models. The second step is to include only those malfunctions that cause functional component failure for each failure mode being evaluated. This requires close examination of the plant records, discussions with cognizant operating and maintenance personnel, and experienced interpretation of the functional severity of "borderline" events.

3.2.1.2 Failure Data Sources

Several sources of information were consulted for collecting equipment failure data. All major equipment malfunctions are documented on either a "Work Request" or "Job Ticket" form. Combined together, there are about 40,000 work requests and job tickets covering the period September 2, 1974, through June 30, 1984. Approximately 21,000 such records are on computer for the period 1977 through June 1984. About 19,000 work requests dated prior to 1977 are recorded in a logbook by date of issue and work request number. The majority of logbook entries include a few words about the nature of the problem and the component designation for the components involved. To obtain more detailed information, the original work requests recorded on microfilms had to be reviewed.

A work request or job ticket is written whenever significant maintenance is required on any piece of mechanical or electrical equipment. Minor adjustments may be made without work requests, but all work requiring equipment disassembly, repair, or replacement is documented on a work request or job ticket form. The work requests thus provide a complete history of all significant adjustments, repairs, and replacements of TMI-1 mechanical and electrical components. They are less complete as a source for documenting electronic and control equipment malfunctions.

Each work request identifies the specific component affected, the observed problem, and the desired maintenance activities. Work requests and job tickets are written for both "safety-related" and "nonsafety-related" equipment, and they are written during all plant operating modes. They are, in a sense, the most "pure" and complete documentation of component malfunctions available. Since each work request or job ticket is assigned a unique identification number, they also afford easy traceability for all failures recorded in the data base.

Use of the work requests and job tickets to collect equipment failures greatly simplifies the collection of compatible component operating time and demand data. Work requests are written for all component malfunctions, regardless of the plant or equipment operating conditions when the problem is observed. The data analyst can, therefore, include all the equipment operating experience as relevant "success" data for the failure rate calculation. Use of more restrictive failure records, such as failures reported only during periodic testing, or failures while the reactor is at power would have required a corresponding reduction of the experience base to provide consistent failure rate data. By restricting the data base, the analyst is also forced to subjectively assess each piece of demand and operating time data to determine its applicability to the limited failure experience.

Another important advantage afforded by the work requests and job tickets is that they provide a record of the component malfunction and the corresponding repairs on a single form. In many cases, both types of information are required for the analyst and plant personnel to determine the relative severity and functional effects of a "borderline" malfunction.

Two drawbacks of the work requests are the large volume of records that must be reviewed and the lack of detail in some of the malfunction and repair descriptions. Each work request form had to be examined first to determine if it applied to a component being modeled in the study. If it did, a more thorough review was performed to determine the exact failure mode and any available information about the cause of failure. Several hundred work requests were actually found to be relevant for the failure data base. Because descriptions of the malfunctions and repairs are often quite brief and abbreviated, it was occasionally difficult for even experienced plant operations and maintenance personnel to reconstruct a specific malfunction. Unless the event could be conclusively discounted as not degrading equipment performance, it was retained in the data base as a functional failure of the component.

All component failures collected for the TMI-1 plant-specific data base are documented on the data sheets in Appendix A. Each data sheet includes the specific component affected, the observed failure mode, a brief description of the failure cause, the date of the failure, and the corresponding work request or job ticket identification number.

3.2.2 COMPONENT DEMANDS AND OPERATING HOURS

One of the most difficult tasks in the development of a comprehensive data base is to ensure that the failure events and the successes have been derived from compatible data sources. The documents reviewed for component failure events do not contain any information about the corresponding component success data. Therefore, other documents were used for information about component demands and operating hours.

3.2.2.1 Demand Data Sources

The two most important sources for TMI-1 component demand data are the periodic test procedures and the plant operating procedures. Since the work requests and job tickets provide information about component failures during all modes of plant operation, it was not necessary to restrict the demand data to tests or operations performed only during certain plant conditions. Therefore, the TMI-1 success data include information obtained from all modes of operation between September 2, 1974, and June 30, 1984.

Table 3-2 summarizes the cold shutdown outages for the TMI-1 plant. This information is important for the development of component demand data from the periodic test reports, because many of the testing schedules change when the reactor is placed in cold shutdown.

Many of the periodic test procedures are also used to verify redundant equipment operability during maintenance and to verify repaired equipment operability after maintenance. The component maintenance records described in Section 3.4 and the operability testing requirements were used to estimate the number of additional performances of each test for maintenance outages.

Of the 134 test procedures reviewed in detail for the study, 64 provided information about relevant mechanical and electrical equipment operations for the component failure rate data base. Table 3-3 lists these tests by number and summarizes the number of performances for each test during the data base period.

For many of the failure modes in the data base (e.g., failure of motor-driven pump to start on demand), specific operations performed during a test provide direct evidence of component response; e.g., start pump X. For a large number of failure modes, however, no analagous specific operations are included to directly verify successful component performance. In many cases, observed flow rates, pressures, temperatures, or levels can be used as evidence that components have operated successfully or are aligned in their normal positions. As an example of this method of test data synthesis, consider the component failure mode "manual valve transfers closed". Referring to the example in Figure 3-1, a system flow test is performed to verify the operability of pump X by closing motor-operated valve A and running the pump on recirculation flow. Successful performance of the test requires that the pump start and that adequate flow is observed at flow gauge F. This test, in addition to verifying pump X operability to start and run, provides the following test data:

- Motor-operated valve A closes and reopens on demand.
- The piping from the suction source through the recirculation line is not plugged.
- Check valve C opens successfully.
- Manual valves M1, M2, and M3 are open.

The test does not provide any information about the status of the flow path through motor-operated valve A and manual valve M4. The test would detect failures to close valve A if a flow path were available downstream from valve A, if valve M4 had not failed in the closed position, and if the leakage through valve A were sufficient to degrade the measured flow at gauge F. However, the internal status of valve M4 cannot be determined from the test. If the valve disc had separated from the valve stem, the flow path would be blocked, but since motor-operated valve A is closed throughout the test, this failure mode cannot be detected during normal test conditions. Therefore, the test is not included in the success data for valve M4. This general process was applied to all systems tested during the periodic tests to develop additional information about the demands on, and the operating status of, components not specifically addressed in the periodic test performance steps.

Reactor plant and turbine unit startups and shutdowns also provide an important source of component demand data. The TMI-1 operating procedures were reviewed to identify equipment routinely cycled during these evolutions. Operating records from the monthly reports document all reactor plant and turbine unit power changes. The demands from routine plant operations were added to the test performances to complete the demand data base for each component.

3.2.2.2 Operating Hours Data Sources

The operating hours for several large motor-driven components at TMI-1 are provided by Operations Surveillance OPS-594 which has monthly readings of run-time meters for loads on buses D and E. These run time meters provided a source of information on operating hours for most of the large motor-driven pumps and ventilation units in the plant-specific data base.

To calculate plant-specific failure rates for component failure modes like "valve transfers closed" or "heat exchanger plugs during operation," the data analyst needs the corresponding number of component operating hours in the unfailed state. For example, if one spurious closure of a motor-operated valve had been experienced in the plant valve population, the data analyst would need to know how many valves were included in the population and, for each valve, how many hours it had remained open. Detailed success data for these generally passive component failure modes are not directly available from any plant records and are extremely difficult to estimate. The TMI-1 plant-specific data were obtained from a detailed analysis of the normal plant operating procedures and paractices and from a review of the periodic test records.

A normal flow path alignment was identified for each system in the plant model. Operation of the system in this alignment verfies that all the associated valves, piping, and heat exchangers are open and functioning properly. The plant power operating records and the equipment run time meter logs were used to determine the total number of successful operating hours for each component in the flow path. For example, normal operation of a system might provide continuous flow through a series of three motor-operated valves and a heat exchanger. If the run time meter records indicated that the system had been operated for 1,000 hours, the evidence for the plant data base was 3,000 open valve hours and 1,000 open heat exchanger hours. This accounting process was used to estimate all the passive component operating success hours for normally running systems and for systems operated in a specific alignment during certain plant modes; e.g., the decay heat removal system.

Some systems, such as the reactor building spray system, are operated only during periodic tests but remain unchanged between tests. Each of these systems was also analyzed for component success data. Although these systems are normally in standby, the periodic tests verify the status of several of their components. This testing provides sufficient information to include these components in the success data base if their status remains the same between tests. For example, if a normally open valve was verified to be open because of the flow path established during a test, and if the valve remained open between tests, the total number of hours between the tests was included in the success data for the valve.

If the valve failed in the closed position during or between the tests, its failure would have been discovered during the periodic test and would have been documented in a work request. Therefore, these standby system component hours were also added to the success data for normally operating systems.

3.2.3 UPDATED COMPONENT FAILURE RATE DISTRIBUTION

As described earlier, the TMI-1 component failure rate distributions were developed by combining two pieces of information; namely, the generic distributions described in Section 2.1 and the plant-specific failure data presented in the previous section as well as Appendix A. The updating process was based on the methods discussed in Section 2 and, in particular, Equation (2.59). The computer code BEST4 (Reference 3-1) was used to perform the calculations. Basic characteristics of the resulting distributions are listed in Table 3-4. Also presented in the table are the plant-specific failure and success data for each component, as well as the mean values of the generic distributions. In cases where no plant-specific data were collected, no updating was performed and the listed distributions are generic.

3.3 COMMON CAUSE FAILURE PARAMETERS

Several common cause events were identified in the course of the component failure data collection task, as described in Section 3.2. These events are summarized in Appendix B. Appendix B also provides detailed tables of the screened generic common caused events used to quantify the common cause parameters for this study (see discussion in Section 2.2; especially, Table 2.1). The common cause parameter distributions listed in Table 3-5 were developed by combining the generic and plant-specific data using the approach discussed in Section 2.2. The computations were performed with the aid of the computer code BETA (Reference 3-2).

3.4 COMPONENT MAINTENANCE DATA

3.4.1 DEFINITION OF MAINTENANCE

In this study, component maintenance includes much more than unscheduled repairs of equipment failures. A component is considered to be out of service for maintenance whenever it is disabled for special inspections, routine preventive maintenance, scheduled overhaul, modifications, replacement, or repairs. The frequency of these maintenance events is substantially higher than most component failure rates, because the failure rates include only those events that cause severe functional damage to the equipment. The maintenance event durations also depend on the type of activity. The effective "mean time to repair" a component may be only weakly correlated to actual maintenance personnel hours spent repairing failures.

The only maintenance events included in the data base are those that remove a component from service in a manner that prevents it from performing the function analyzed in its system model. For example, a normally closed motor-operated valve may be required to open automatically and remain open for successful system response to an initiating event. Any activity that removes the valve from service in the closed position and prevents it from opening is counted as a maintenance event affecting the availability of the valve. If, however, the valve was deenergized in the open position while the motor was replaced, the event would not be included in the maintenance data base because it did not prevent the valve from satisfying its required function.

The duration of a maintenance event lasts from the time a component is tagged out of service to the time it is returned to service in an operable condition. In many cases, this period is only weakly correlated to the actual number of maintenance personnel hours spent working on the equipment. Factors which make the observed event duration longer than the actual repair time include time for the plant operators to align the system for maintenance and to realign it after the work is completed, time to perform required operability testing, delays for spare parts, time for coffee breaks and meals, and overnight or weekend periods when maintenance personnel may not be scheduled to work, and where no conflict with technical specifications develops.

3.4.2 MAINTENANCE DATA SOURCES

The most accurate information about component unavailabilities due to maintenance at TMI-1 is found in the "Switching and Tagging Orders." The plant-specific maintenance data are derived from a review of all switching and tagging orders written between September 1974 and February 1979.

When a component is realigned in an abnormal configuration, tags are posted locally and in the control room to inform personnel of the equipment status. These tags denote the repositioned valves, disconnected circuit breakers, special control switch positions, and other actions required to isolate a component from its system so that personnel may work on it safely. The equipment is considered to be functionally disabled whenever the tags are in place, and it is available for normal service when the tags are removed.

The switching and tagging orders contain all the information necessary to determine the effect of each maintenance event on functional component availability. A brief description of the reason for maintenance and the specified position for each component realigned for the job are included on each form. The orders also contain signature blanks for work authorization and job clearance. The dates and times of these signatures denote the full period that the component was unavailable for service.

All switching and tagging orders were screened according to the TMI-1 cold shutdown outage periods listed in Table 3-2. Equipment removed from service during cold shutdown was not included in the data base because the nature and duration of these maintenance events do not represent maintenance performed during the operating periods of interest in this study. Some maintenance events were initiated before the reactor was placed in cold shutdown or extended beyond the reactor startup time. These were included in the data base for the duration of time above cold shutdown, because they affected component availability during the pertinent reactor operating modes. The TMI-1 plant-specific maintenance data are summarized in Appendix C which provide information about the date of each maintenance event, the corresponding tag order, component affected, and work performed and its duration.

3.4.3 UPDATED COMPONENT MAINTENANCE DISTRIBUTION

As discussed in Section 2, component maintenance unavailability distribution for each component is developed as the distribution of the product of maintenance frequency and maintenance duration for that component. Therefore, separate updated distributions were developed for component maintenance frequencies and durations based on the generic distributions discussed in Section 2.3 and plant-specific data presented in Appendix C.

3.4.3.1 Updated Maintenance Frequency Distributions

Table 3-6 provides basic characteristics of the updated maintenance frequency distributions. These distributions were developed with the aid of mode 4 of the computer code BEST4 (Reference 3-1), which was used to perform the updating calculations based on Equation (2.59). Table 3-6 also lists the plant-specific data in the form of the number of maintenance events and the total number of component hours for each component.

3.4.3.2 Updated Maintenance Mean Duration Distributions

Maintenance duration distributions were developed based on the procedure described in Section 2.3.2. Each distribution was developed by establishing a prior distribution for the two parameters of the assumed lognormally distributed maintenance durations based on generic information. This prior parameter grid was then updated using the plant-specific data with the aid of RTIME2 computer code (Reference 3-3). The distributions listed in Table 3-7 are the resulting uncertainty distributions of the mean maintenance durations. A total of 48 mean maintenance durations was developed for 47 components. The table shows that, for NSRW pumps, two distributions were developed: one for short-duration maintenance activities and another for long-duration maintenance. This was done to acknowledge that for that component, a single unimodal distribution, such as lognormal, could not represent the data.

3.5 INITIATING EVENT GROUP FREQUENCIES

Table 3-8 lists the internal initiating event groups chosen for the TMI-1 plant analysis. Each group contains one or more specific initiating events believed to result in the same general plant response as modeled in the plant event trees.

Details of the selection and grouping of initiators are provided in Section 2 of the Plant Model Report. As was discussed in Section 2.5, the internal initiating event groups are divided into two general sets. The first set is composed of those events for which the available data from other nuclear power plants are judged to be relevant. This group includes all initiating event groups except groups 5, 13, 14, 18, and 19. The available generic and plant-specific data were input to the Bayesian data analysis process to generate a frequency distribution for each of the initiating event groups.

For the second set the data from other power plants could not be used. This is due to the fact that the systems involved have designs and specifications unique to the TMI-1 plant, which require a plant specific analysis. For this reason, the frequency of groups 5, 13, 14, 18, and 19 were quantified by analyzing the corresponding systems and scenarios. The following sections describe how the frequency of each category was developed.

3.5.1 EVENTS QUANTIFIED, BASED ON GENERIC AND PLANT-SPECIFIC DATA

The generic frequency distributions were developed, based on the industry experience with PWRs in general and B&W plants in particular. The loss of offsite power data base covers the PWR as well as BWR experience. Details of how these generic frequencies are developed are provided in Reference 3-4. The mean values of the generic distributions are given in Table 3-8.

Among the sources for the generic plant population event data for initiating events was the Electric Power Research Institute study of pressurized water reactor transients (Reference 3-5). The study summarizes the events initiating forced shutdowns at 36 PWR units from their initial year of operation until January 1981.

The 41 initiating event data categories listed in the EPRI study for PWRs were reviewed and 27 of those categories were summed for 4 of the event groups chosen for this analysis as shown in Table 3-9. To the extent possible, the data from the EPRI study was carefully examined. In some cases, incidents not included in the EPRI study were added to the data base, while in other cases, further consultation with other sources resulted in removal of incidents from the data base. The final result of this process is given in Reference 3-4, where the plant population data for these initiating event categories are listed for each of the 36 PWR units included in the data base.

The EPRI study, because it was done for ATWS analysis, does not provide any data for causes of losses of RCS inventory (groups 1, 2, 3, and 4) or for steam line breaks (groups 6 and 7). These initiators include events which are either the direct result of pipe failures or which have the same effect on plant response as would a pipe failure. Catastrophic pipe failures have occurred in a variety of industrial and nonnuclear power generation facilities. However, the types of piping involved and their operating temperature, pressure, and flow conditions are generally quite different from those of interest in these initiating events. The industry experience adds to the general understanding of pipe failure phenomena, but evaluation of its direct applicability to this data base requires a much more detailed comparative engineering and design analysis than was possible within the scope of this study.

Several sources of nuclear industry data including Nuclear Power Experience (Reference 3-6) were consulted to obtain plant population data for these initiators. No events applicable to categories 1 and 2 were reported for PWRs. However, the investigation provided information about several events which were judged to be applicable to the data base for groups 3, 4, and 7. These events and the resulting plant population data are described in Reference 3-4.

In the case of large and medium LOCAs (groups 1 and 2) it was judged that there is little, if any, plant-to-plant variation in the frequency since the primary piping systems are essentially designed according to the same codes and manufactured based on similar standards. Moreover, these piping systems are not affected as much by the variation of operating practices among plants as are other components and systems. Therefore, it was decided to use the cumulative experience at U.S. PWRs (zero events in 428 reactor years) as evidence in a one-stage Bayesian updating process.

The loss of offsite power initiating event (group 7) data was based on extensive review of the history of losses of offsite power at all nuclear power plants in the United States, the details of which are reported in Reference 3-4.

For the loss of air systems initiating event (group 13), the plant population data were obtained from review of Nuclear Power Experience (NPE) (Reference 3-6) for the period 1970 through 1985. No evidence of total loss of air system was found in this review. Furthermore, it was observed that air contamination has always only resulted in isolated component failures without any significant impact on the operation of the air system, as a whole, or on the plant operation.

For steam generator tube rupture (group 8), loss of ATA power (group 15), and loss of one DC power train (group 16), NPE was reviewed and several events were judged to be applicable to the data base.

In the case of steam generator tube rupture initiating event, the review of the industry experience did not reveal any major tube rupture events that did not result in an automatic plant trip.

The plant population data for the excessive feedwater flow (group 9) is based on the review of the operating history of B&W plants (Reference 3-7).

For TMI-1 plant-specific initiating events, data was collected by reviewing plant records, such as monthly operating reports and weekly reports for the period of September 2, 1974, through February 19, 1979. The NRC Gray Books were also reviewed for the same period.

Appendix D summarized the collected data for each of the quantified initiating event categories, based on generic and plant-specific data.

The statistical information is summarized in Table 3-8. Bayesian calculations were done using computer code BEST4 (Reference 3-1). The table also presents the initiating event frequency distributions resulting from updating the generic distributions with plant-specific data.

3.5.2 INITIATING EVENTS WHOSE FREQUENCIES WERE QUANTIFIED BY PLANT-SPECIFIC ANALYSIS

3.5.2.1 Loss of River Water

The frequency of loss of river water system is believed to be dominated by external causes that prevent flow of river water to pump intake. The blockage of river water flow has in fact happened in the past at the TMI site. The most severe occurrence happened in February 1979 when, following a heavy rainfall, debris was washed down the river in large quantities and resulted in plugging of the intake screens for 6 hours. Unit 2 was operating at the time, and Unit 1 was shut down for refueling. The Unit 2 intake screens were the only ones plugged during this event. The flow of river water to the intake stucture was virtually reduced to zero. The source of water for the 6-hour period before the screens were finally cleaned was the water already in the pump house when the blockage occurred.

Events of this type form the basis for the calculation of the frequency of the loss of river water initiating event (ϕ_{RW}). This frequency is calculated based on the site-specific data for the frequency (f_{SP}) of severe plugging of the intake screens (one event in 12 site-years) and the chance of recovery, given plugging of the screens.

The time available to unplug the screens depends on the volume of water available in the intake structure (assuming no water flowing from the river) and the number of pumps operating.

The volume of available water ranges between 1.4×10^5 to 4.1×10^5 cubic feet, depending on the river water level, ranging from a normal level at 278 feet to a high level of 303.5 feet. Assuming two river water pumps operating at full capacity (7,250 gpm), the time available for recovery action ranges from 1.3 to 4 hours. For one pump operating, this time is doubled.

The following probability distribution is assessed for the frequency of failure of the recovery action HRE4.

Mean:	1.78×10^{-1}
5th Percentile:	3.02×10^{-2}
50th Percentile:	3.45×10^{-2}
95th Percentile:	9.86×10^{-1}

For a discussion of the derivation of the duration of HRE4, see the TMI-1 Human Actions Analysis Report.

A distribution was developed for f_{SP} based on a uniform prior and evidence of one event in 12 years. The basic characteristics of this distribution are:

Mean: 8.43×10^{-2}

5th Percentile: 9.06×10^{-3}

50th Percentile: 6.12×10^{-2}

95th Percentile: 1.74×10^{-1}

The frequency of the loss of river water is then calculated from

$$\phi_{RW} = f_{SP} \cdot HRE4$$

The main characteristics of the distribution of ϕ_{RW} are listed in Table 3-8.

3.5.2.2 Loss of Nuclear Services Closed Cooling Water

For detailed discussion of the calculation of the frequency of this initiator, see Section 4 of the Systems Analysis Report. Table 3-8 lists the basic characteristics of the distribution.

3.5.2.3 Loss of Control Building Ventilation

For detailed discussion of the calculation of the frequency of loss of control building ventilation, see Section 6 of the Systems Analysis Report. Basic characteristics of the distribution are provided in Table 3-8.

3.5.2.4 Inadvertent Opening of DHR Valves (V-Sequence)

The following two scenarios are considered to be the most likely ways of an outside containment LOCA.

- Scenario 1. Failure of two series check valves in the cold leg injection lines of LPI/DHR, followed by failure of lower pressure downstream piping.
- Scenario 2. Failure of three normally closed series motor-operated valves in the hot leg suction path of DHR, followed by failure of lower pressure downstream piping.

3.5.2.4.1 Scenario 1 (LPI Cold Leg Injection)

Figure 3-2 shows the simplified LPI cold leg injection path arrangement of the LPI/DHR system at TMI-1.

In general, the frequency of failure for two valves, V_1 and V_2, in series (V_1 is assumed to be nearest to the RCS) can be expressed as

$$\lambda_S = \lambda(V_1) \cdot P(V_2|V_1) + \lambda(V_2) \cdot P(V_1|V_2) \qquad (3.1)$$

where

λ_s = the frequency of failure of both series valves.

$\lambda(V_1)$ = the frequency of random, independent failure of valve V_1.

$P(V_2|V_1)$ = the conditional likelihood that V_2 is failed, given that V_1 fails.

$\lambda(V_2)$ = the frequency of random, independent failure of V_2 (events per hour).

$P(V1|V2)$ = the conditional probability that V_1 is failed, given that V_2 fails.

$P(V_2|V_1)$ and $P(V_1|V_2)$ are composed of both random, independent, and demand type failures of the second valve.

In some cases, the random, independent failure frequencies and conditional probabilities for the two valves will be approximately equal, but in other cases, they will not. For example, if V_1 leaks slightly but V_2 does not, V_2 would be exposed to the differential pressure loading to which V_1 is normally exposed. In this situation, V_1 would have RCS pressure on both sides of the disc and would be expected to have a lower failure rate than V_2, which is exposed to a greater differential pressure. Thus, Equation (3.1) could be written as

$$\lambda_s = \lambda(V_1) \cdot P(V_2|V_1) \cdot (1-P_I) + \lambda'(V_1) \cdot P'(V_2|V_1) \cdot P_I + \lambda(V_2) \cdot P(V_1|V_2) \cdot (1-P_I) + \lambda'(V_2) \cdot P'(V_1|V_2) \cdot P_I \qquad (3.2)$$

where

P_I = the probability that the space between valves is pressurized to RCS pressure.

$\lambda'(V_1)$ = the frequency of a random, independent failure of V_1, given that the space between valves is pressurized (events per hour).

$P'(V_2|V_1)$ = the conditional probability that V_2 fails, given that V_1 has failed and the space between valves is pressurized.

$\lambda'(V_2)$ = the frequency of a random, independent failure of V_2, given that the space between valves is pressurized.

$P'(V_1|V_2)$ = the conditional probability that V_1 fails, given that V_2 has failed and the space between valves is pressurized.

On the basis of the loadings across the valve discs, the following assumptions appear to be reasonable for the lines that contain the check valves.

1. $\lambda'(V_2) \simeq \lambda(V_1)$.

2. $\lambda'(V_1)$ is small compared to $\lambda(V_1)$.

3. $\lambda(V_2)$ is small compared to $\lambda'(V_2)$.

4. $P'(V_1|V_2) \simeq P(V_2|V_1)$.

Substituting for $\lambda'(V_2)$ and $P'(V_1|V_2)$

$$\lambda_s \simeq \lambda(V_1) \cdot P(V_2|V_1) \cdot (1-P_I) + \lambda'(V_1) \cdot P'(V_2|V_1) \cdot P_I \quad (3.3)$$

$$+ \lambda(V_2) \cdot P(V_1|V_2) \cdot (1-P_I) + \lambda(V_1) \cdot P(V_2|V_1) \cdot P_I$$

or

$$\lambda_s \simeq \lambda(V_1) \cdot P(V_2|V_1) + \lambda'(V_1) \cdot P'(V_2|V_1) \cdot P_I \quad (3.4)$$

$$+ \lambda(V_2) \cdot P(V_1|V_2) \cdot (1-P_I)$$

The third term in Equation (3.4) is small compared to the first; therefore

$$\lambda_s \simeq \lambda(V_1) \cdot P(V_2|V_1) + \lambda'(V_1) \cdot P'(V_2|V_1) \cdot P_I \quad (3.5)$$

As a conservative upper bound, it can be argued that

$$\lambda_s \simeq \lambda(V_1) \cdot P(V_2|V_1) \cdot (1+P_I) \quad (3.6)$$

Because only a minute amount of leakage is required to pressurize the space between valves, it is assumed that P_I approaches 1.0. Therefore

$$\lambda_s \simeq 2 \cdot \lambda(V_1) \cdot P(V_2|V_1) \quad (3.7)$$

Given that V_1 has failed independently, V_2 could fail upon demand (due to the sudden pressure challenge), or it may fail randomly in time, sometime after failure of V_1. The latter failure mode is represented by the standby redundant system model. Equation (3.7) conservatively reflects the potential for discovery of the outboard valve rupture before the next testing opportunity of the inboard valve because of the ability to alarm and indicate this condition to the operator via the accumulator pressure sensors.

The term $P(V_2|V_1)$ in Equation (3.7) contains two components: one representing random failures of the second valve, given that the first valve has failed, and the second representing a demand failure at the time the first valve failed.

The determination of the frequency of occurrence of random failures is facilitated by assuming that the two series check valves in each path represent a standby redundant system, and failure of the downstream check valve cannot occur until failure of the check valve nearest to the reactor coolant system loop has occurred. The probability of random failure (unreliability) for a single injection path is given by

$$Q_{path} \approx 1 - e^{-\lambda t} (1 + \lambda t) \tag{3.8}$$

where λ is the appropriate failure rate of a single check valve. This expression was then used to derive a failure (or hazard) rate for the path. That is,

$$\lambda_{path}(t) = \frac{-1}{(1 - Q_{path})} \frac{d}{dt} [1 - Q_{path}] \tag{3.9}$$

or

$$\lambda_{path}(t) = \frac{\lambda}{(1 + \frac{1}{\lambda t})} \tag{3.10}$$

The plant is expected to go to cold shutdown at least once every 1.5 years at which time these valves will be inspected. If it is determined that the system is not functioning, it is repaired at that time. Therefore, the time-dependent failure rate is bounded at 1.5 years. The average failure rate over a time period, T, is given by

$$\langle\lambda_{path\ per\ reactor\ year}\rangle = \frac{1}{T} \int_0^T \frac{\lambda dt}{(1 + \frac{1}{\lambda t})} = \frac{1}{T} [\lambda T - \ell n (1 + \lambda T)] \tag{3.11}$$

When $\lambda T << 1$, this result can be expanded to obtain

$$\langle\lambda_{path}\rangle = \frac{1}{2} \lambda^2 T \tag{3.12}$$

The demand component of the path failure frequency is merely the product of λ and the demand failure rate, λ_d. Thus,

$$\langle\lambda_{path}\rangle = \lambda [\frac{\lambda T}{2} + \lambda_d] \tag{3.13}$$

Finally, the above expression for $\langle\lambda_{path}\rangle$ is multiplied by a factor of 2 to account for the logic used in developing Equation (3.7). This logic is that the two valves can fail in either sequence because of an assumed high likelihood of inboard valve leakage and pressurization of the space between valves. Thus, the final expression for the series valves in the injection lines is

$$<\lambda_{path}> = 2\lambda\ [\frac{\lambda T}{2} + \lambda_d] \qquad (3.14)$$

As an upoer bound, the check valve fail to operate on demand, V7F, will be used for λ_d. For λ, it was assumed that even though the disc rupture mode of failure is extremely unlikely, it is implicitly included in the check valve leak data. The following distribution was developed for the disc rupture mode of failure (V7R) based on extensive review of PWR, ECCS, and RPS check valve leakage data.

95th Percentile	3.2×10^{-8}
Mean	8.3×10^{-9}
Median	2.3×10^{-9}
5th Percentile	1.6×10^{-10}

Therefore

$$<g_{path}> = 2 \cdot V7R\ [\frac{V7R \cdot T}{2} + V7F]$$

since there are two injection paths, then the annual frequency of scenario 1 is

$$\phi_1 = 2 <\lambda_{path}>$$

A point estimate for ϕ_1, using the mean values for V7R and V7F and T = 1.5 years is 7.8×10^{-8}/year

3.5.2.4.2 Scenario 2 (DHR Hot Leg Suction Line)

This scenario involves failure of three series MOVs, DH-V1, DH-V2, and DH-V3. Given that such failures occur, the low pressure piping and the RHR system components downstream of these MOVs would be exposed to RCS pressure.

The sequential failure of all three values due to random causes is judged to be very unlikely. The frequency of this scenario, ϕ_2, is then calculated based on assuming (1) sequential failure of V1 and V2 followed by failure of V3 due to failure of V1 and V2, and (2) rupture of V1 disc, followed by failure of V2 due to V1 failure and finally failure of V3 due to V2 failure. Therefore

$$\phi_2 = 2\lambda(\frac{\lambda T}{2})\ \lambda_d + \lambda\ \lambda_d^2$$

In this case, we use V1F and V7R for λ_d and λ, respectively. Therefore

$$\phi_2 = 2 \cdot V7R \cdot V1F\left(\frac{V7R \cdot T}{2}\right) + V7R \cdot (V1F)^2$$

A point estimate using mean values for V7R and V1F and with T = 1.5 years is $\phi_2 = 9.3 \times 10^{-10}$/year.

Finally, the annual frequency of the V-sequence is given by

$$\phi = \phi_1 + \phi_2$$

The distribution of ϕ is provided in Table 3-8.

3.5.2.5 Loss of Air System

For detailed discussion of the calculation of the frequency of this initiator, see Section 18 of the Systems Analysis Report. Table 3-8 lists the basic characteristics of the distribution.

3.6 REFERENCES

3-1. Pickard, Lowe and Garrick, Inc., "Bayesian Estimation Computer Code 4 (BEST4) Users Manual," PLG-0460, December 1985.

3-2. Pickard, Lowe and Garrick, Inc., "BETA Computer Code Users Manual," PLG-0389, January 1985.

3-3. Pickard, Lowe and Garrick, Inc., "RTIME2 (Repair Time) Computer Code Users Manual," PLG-0439, December 1985.

3-4. Pickard, Lowe and Garrick, Inc., "PRA Proprietary Data."

3-5. Electric Power Research Institute, "ATWS: A Reappraisal, Part III, Frequency of Anticipated Transients," EPRI NP-2230, January 1982.

3-6. Nuclear Power Experience, published by S. M. Stoller Corporation, updated monthly.

3-7. B&W Owners Group Probabilistic Evaluation of Pressurized Thermal Shock - Phase 1 Report - BAW-1791, Babcock & Wilcox, June 1983.

TABLE 3-1. TMI-1 RECORDS CONSIDERED IN DATA SEARCH

Source	Data
Monthly Operating Report	Plant Power History, Forced and Scheduled Shutdowns, Initiating Events, Vital Equipment Failures
Weekly Reports	Initiating Events
Maintenance Request Logbooks	Component Failures
Work Requests (microfilm)	Component Failures
Job Tickets (microfilm)	Component Failures
Computerized Work Requests and Job Tickets	Component Failures
Switching and Tagging Orders	Component Maintenance Events
Component Run-Time Record	Component Operating Hours

TABLE 3-2. TMI-1 COLD SHUTDOWN OUTAGES

From	To	Reason	Duration (Hours)
October 20, 1974	October 30, 1974	Repair Pressurizer Valve Leaks	[illegible]
November 17, 1974	November 21, 1974	Replace Faulty Control Rod Drive Motor	98
April 5, 1975	April 14, 1975	Repair Control Rod Drive Cable Connector	205
May 25, 1975	June 11, 1975	Repair DR Pump 1B and Control Rod Drive	389
September 27, 1975	October 8, 1975	Repair RCP 1A	285
October 16, 1975	October 19, 1975	Repair Control Rod Drive Stator	84
November 12, 1975	November 24, 1975	Repair Control Rod Drive Stator and Turbine Valve	295
December 17, 1975	December 21, 1975	Repair Makeup Valve	81
January 16, 1976	January 17, 1976	Replace Control Rod Stator	35
February 21, 1976	May 24, 1976	Refueling Outage	2,215
November 6, 1976	December 2, 1976	Miscellaneous Repair	638
March 19, 1977	May 15, 1977	Refueling Outage	1,296
September 16, 1977	September 25, 1977	Miscellaneous Repairs	224
March 18, 1978	April 30, 1978	Refueling Outage	1,053
June 21, 1978	June 29, 1978	RCP Seal Failure	173
February 17, 1979	March 27, 1979	Refueling	912
March 28, 1979	October 2, 1985	TMI-2 Accident	46,116

NOTES:

1. Unit 1 started commercial operation on September 2, 1974.
2. Data based on TMI monthly operating reports (January 1, 1975 to August 31, 1977) and NRC "Gray Book" Reports, 1974 through 1978.

TABLE 3-3. TEST PROCEDURES CONSIDERED FOR SUCCESS DATA DEVELOPMENT

Procedure Number	Title	Number of Tests Performed*
1300-3A A/B	Reactor Building Spray Pump Functional Test Recirculation Mode and Reactor Building Spray System	18/25
1300-3B A/B	Decay Heat Removal Pump Functional Test and Decay Heat Removal System Valve Operability Test	32/37
1300-3C	Decay Heat Closed Cooling Water Pumps Functional Test Surveillance Frequency - 92 Days	41
1300-3D	Decay Heat River Water Pump Functional Test and Decay Heat River Valve Operability Test	48
1300-3E	Spent Fuel Cooling Pump Functional Test Surveillance Frequency - 92 Days	**
1300-3F A/B	Motor-Driven Emergency Feedwater Functional Verification and Valve Operability	20/17
1300-3G A/B	Turbine-Driven Emergency Feedwater Pump Functional Test and Valve Test/Valve Lineup Operability Test	26/35
1300-3H A/B	Makeup Pump and Valve Functional Tests	13/17
1300-3I A/B	NSRW Pump Functional Test and Valve Operability Test	31/40
1300-3J	Nuclear Service Closed Cooling Water Pump and Valve Functional Test	40

*Numbers separated by "/" (e.g., 18/25) correspond to the procedures separated by "/" in the procedure number column; e.g., 1300-3A A/B.
**Test procedure reviewed but did not involve components of interest in data analysis.

TABLE 3-3 (continued)

Sheet 2 of 7

Procedure Number	Title	Number of Tests Performed*
1300-3K A/B	Reactor Building Emergency Cooling Pump Functional Test and Reactor Building Emergency Cooling System	30/41
1300-3N	Chilled Water Pump (AH-P-3A/B) Functional Test and Valve Operability Test	44
1300-3P	IST of Check Valves During Shutdown	10
1300-3Q	Quarterly Inservice Testing of Valves During Normal Plant Operations	**
1300-3R	IST of Valves Shutdown and Remote Indication Check	**
1300-3T	Pressure Isolation Test of CF-V-4A/B, CF-V-5A/B, and DH-V-22A/B	3
1300-4A	Hydrostatic Test for ISI	**
1300-4C A/B	NSRW Pump Functional Test and Valve Operability Test	4/1
1300-4E	Nuclear Services Closed Cooling Water Pump and Valve Functional Test During Refuelings	5
1301-1	Shift and Daily Checks	**
1301-4.1	Weekly Surveillance Checks	**
1301-4.4	Borated Water Storage Tank	**
1301-4.6	Station Storage Batteries Required Interval - Weekly	**

*Numbers separated by "/" (e.g., 18/25) correspond to the procedures separated by "/" in the procedure number column; e.g., 1300-3A A/B.

**Test procedure reviewed but did not involve components of interest in data analysis.

TABLE 3-3 (continued)

Sheet 3 of 7

Procedure Number	Title	Number of Tests Performed*
1301-5.8	Station Batteries Required Interval - Monthly	**
1301-6.7	Monitoring of Silt Buildup in River Water Screen House	**
1301-8.2	Diesel Generator Annual Inspection	**
1301-9.7	Intake Pump House Floor, Silt Accumulation	**
1301-10.1	Internal Vent Valve Inspection and Exercise	**
1301-13.1	Emergency Equipment Readiness	**
1302-5.1 and 1302-5.5	Reactor Coolant Temperature Channels and Pressure/Temperature Comparator	**
1302-5.2 and 1302-5.3	RPS High and Low RC Pressure Channels Required Interval - Refueling Interval	**
1302.5-4	Reactor Coolant Flux Flow Comparator Required Interval - Refueling Interval	
1302-5.6	RPS Pump/Flux Comparator and RCP Power Monitor Surveillance Calibration	**
1302-5.7	High Reactor Building Pressure Channel	**
1302-5.8	High and Low Pressure Injection Analog Channels	**
1302-5.10	Reactor Building 4 psig Channels Required Interval - Refueling Interval	**

*Numbers separated by "/" (e.g., 18/25) correspond to the procedures separated by "/" in the procedure number column; e.g., 1300-3A A/B.
**Test procedure reviewed but did not involve components of interest in data analysis.

Procedure Number	Title	Number of Tests Performed*
1302-5.11	Reactor Building 30 psig Pressure Channels Required Interval - Refueling Interval	**
1302-5.18	High and Low Pressure Injection Flow Channel	**
1302-5.19	Borated Water Storage Tank Level Indicator	**
1302-5.25	Reactor Building Sump Level Required Interval - Each Refueling Period	**
1302-5.26	OTSG Level Channel Calibration	**
1302-5.30	Diesel Generator Protective Relaying Required Interval - Refueling Interval	7
1302-5.31A	4,160V D and E Bus Degraded Grid Undervoltage Relay System Calibration	**
1302-5.31B	4,160V D and E Bus Loss of Voltage Relay System Calibration	
1302-5.31C	4,160V ID Bus Loss of Voltage/Degraded Grid Auxiliary Timer Calibration	3
1302-5.31D	4,160V 1E Bus Loss of Voltage/Degraded Grid Auxiliary Timer Calibration	3
1302-5.34	Reactor Trip on Loss of Feedwater/Main Turbine Trip Required Interval - Refueling Interval	**
1302-6.3	EFW Flow Instrumentation Calibration Required Interval - Refueling	**

*Numbers separated by "/" (e.g., 18/25) correspond to the procedures separated by "/" in the procedure number column; e.g., 1300-3A A/B.

**Test procedure reviewed but did not involve components of interest in data analysis.

TABLE 3-3 (continued)

Procedure Number	Title	Number of Tests Performed*
1302-6.16	PORV Setpoint and Remote Position Check Required Interval - Refueling Interval	**
1303-1.1	Reactor Coolant System Leak Rate	**
1303-4.1	Reactor Protection System	140/Channel
1303-4.11	HPI and LPI Logic and Analog Channels	**
1303-4.13	Reactor Building Emergency Cooling and Isolation System Analog Channels	**
1304-4.14	Reactor Building 30 psig Analog Channels	
1303-4.16	Emergency Power System	200 DGA, 177 DGB
1303-4.17	Main Steam Isolation Valves Required Interval - Monthly	**
1303-4.18	4 kV ES Bus Undervoltage Relay Test Required Interval - Monthly	**
1303-4.19	HPI and LPI Analog Channels	**
1303-5.1	Reactor Building Cooling and Isolation System Logic Channel and Component Test	**
1303-5.2	Loading Sequence and Component Test and High Pressure Injection Logic Channel Test	23
1303-5.5	Control Room Emergency Filtering System Operation Test	7

*Numbers separated by "/" (e.g., 18/25) correspond to the procedures separated by "/" in the procedure number column; e.g., 1300-3A A/B.

**Test procedure reviewed but did not involve components of interest in data analysis.

TABLE 3-3 (continued)

Procedure Number	Title	Number of Tests Performed*
1303-5.12	Control Building Emergency Ventilation System Air Distribution Test	**
1303-6.1	Reactor Building Integrated Leak Rate Test	3
1303-8.4	Reactor Building Spray System Compressed Air Test	2
1303-10.1	Reactor Building Purge System Required Interval - No More than Once a Week Prior to Refueling Operation	**
1303-11.2	Pressurizer Code Safety Valves Setpoint Verification	8
1303-11.3	Main Steam Safety Valves	7
1303-11.8	High Pressure Injection	7
1303-11.9	Reactor Building Emergency Cooling System	7
1303-11.10	Engineered Safeguards System Emergency Sequence and Power Transfer Test	8
1303-11.11	Station Batteries Load Test	**
1303-11.13	Control Room Filtering System Test	**
1303-11.14	Reactor Building Purge Exhaust	**
1303-11.16 (A, D/B, C/E)	Decay Heat Removal System Leakage	**
1303-11.19	Turbine Overspeed Testing	211/6/6

*Numbers separated by "/" (e.g., 18/25) correspond to the procedures separated by "/" in the procedure number column; e.g., 1300-3A A/B.

**Test procedure reviewed but did not involve components of interest in data analysis.

TABLE 3-3 (continued)

Procedure Number	Title	Number of Tests Performed*
1303-11.21	Core Flooding System Valve Operability Test	8
1303-11.22	Main Steam Isolation Valves	**
1303-11.26	Reactor Building Isolation Valve Cycle Test Required Interval - Cold Shutdown	**
1303-11.27	Makeup and Purification System Leakage Check	2
1303-11.39	Emergency Feedwater Pump Automatic Start	10
1303-11.42	Emergency Feedwater Flow Test From Condensate Storage Tank Surveillance Frequency	3
1303-11.45	PORV Setpoint Check	**
1303-11.50	Reactor Building Spray System Leakage Check	5
1303-11.53	Emergency Feedwater Flow	**
1303-11.54	Low Pressure Injection	2
1303-12.3	Venting of MU Pumps and HPI Lines	**
1303-12.4	Venting of DH Pumps and LPI Lines	**

*Numbers separated by "/" (e.g., 18/25) correspond to the procedures separated by "/" in the procedure number column; e.g., 1300-3A A/B.
**Test procedure reviewed but did not involve components of interest in data analysis.

TABLE 3-4. TMI-1 COMPONENT FAILURE RATE DATA BASE

Designator	Component Description	Failure Mode	TMI-1 Experience		Generic Mean	TMI-1 Specific Distribution			
			Failures	(hours/demands)		Mean	5th Percentile	Median	95th Percentile
ACR	Air Compressor	Failure during Operation	7	8.61+4 Hours	9.81-5	8.10-5	2.82-5	7.49-5	1.24-4
ACS	Air Compressor	Failure To Start on Demand		*	3.29-3	3.29-3	2.22-4	1.64-3	1.01-2
AD1	Air Dryer - Compressed Air System	Failure during Operation	0	8.61+4 Hours	1.69-7	1.66-7	1.85-8	9.19-8	4.24-7
AF1	Air Filter (ventilation)	Failure during Operation		*	5.83-6	5.83-6	1.90-7	1.87-6	1.78-5
AF2	Air Filter (oil removal)	Failure during Operation		*	1.76-5	1.76-5	5.73-7	5.62-6	5.37-5
AF3	Air Filter (compressed air system)	Failure during Operation		*	3.54-5	3.54-5	1.15-6	1.13-5	1.08-4
BC	Battery Charger	Failure during Operation	9	5.17+5 Hours	1.86-5	1.63-5	8.49-6	1.35-5	2.83-5
BISF	Bistable	Failure To Operate on Demand		*	4.40-5	4.40-5	2.89-6	1.95-5	1.27-4
BTO	Battery (125V DC)	Failure of Output during Operation	5	1.72+5 Hours	7.53-7	1.29-5	6.02-6	1.18-5	2.38-5
BTD	125V DC Battery	Failure of Output on Demand		*	4.84-4	4.84-4	7.51-5	3.26-4	1.15-3
BUS	Electrical Bus	Failure during Operation		*	4.98-7	4.98-7	7.73-8	3.36-7	1.17-6
CB1FC	Circuit Breaker (AC 480V and above)	Failure To Close on Demand		*	1.61-3	1.61-3	2.80-4	1.22-3	3.23-3
CB1FO	Circuit Breaker (AC 480V and above)	Failure To Open on Demand		*	6.49-4	6.49-4	5.95-5	3.67-4	1.41-3
CB1TO	Circuit Breaker (AC 480V and above)	Transfers Open during Operation		*	8.28-7	8.23-7	5.08-8	3.99-7	2.36-6
CB2FC	Circuit Breaker (AC 480V and above)	Failure To Close on Demand		*	2.27-4	2.27-4	6.48-6	8.89-5	6.52-4
CB2TO	Circuit Breaker (AC or DC, LT. 480V)	Transfers Open during Operation		*	2.68-7	2.68-7	2.50-8	1.41-7	9.11-7
CB4FO	Circuit Breaker (reactor trip)	Failure To Open on Demand	1	876 Demands	4.66-3	2.50-3	1.04-3	2.32-3	4.72-3
CFR	Single Control Rod Assembly	Failure on Demand	0	610 Demands	3.20-5	3.11-5	1.80-6	1.41-5	1.07-4
CVF	Cavitating Ventori	Failure during Operation		*	2.66-6	2.66-6	8.68-8	8.52-7	8.14-6
DGS	Diesel Generator	Failure To Start on Demand	14	869 Demands	2.14-2	1.58-2	1.04-2	1.51-2	2.38-2
DGR1	Diesel Generator	Failure during First Hour of Operation	6	983 Hours	1.70-2	6.58-3	3.48-3	6.84-3	1.13-2
DGR2	Diesel Generator	Failure after First Hour of Operation		*	2.50-3	2.50-3	2.43-4	1.60-3	5.80-3
D1F	Pneumatic Damper	Failure To Operate on Demand		*	1.52-3	1.52-3	2.83-4	1.14-3	3.16-3
D1T	Pneumatic Damper	Transfers Open/Closed during Operation		*	2.67-7	2.67-7	1.78-8	1.20-7	6.71-7
D2T	Fire Damper	Inadvertent Actuation		*	4.20-8	4.20-8	1.69-9	1.41-8	1.31-7
D3F	Gravity Damper	Failure To Operate on Demand		*	1.52-3	1.52-3	2.83-4	1.14-3	3.16-3
EFVCC	EFW Valve Control Circuit	Failure on Demand		*	2.41-4	2.41-4	1.39-5	1.10-4	7.67-4
EFENAB	EFW Enable	Failure during Operation		*	4.54-5	4.54-5	5.35-6	2.75-5	1.37-4
EFACT	EFW Actuation Circuit	Failure on Demand		*	2.41-4	2.41-4	1.39-5	1.10-4	7.67-4
EFWLSW	EFW Level Switch	Failure during Operation		*	5.69-6	5.69-6	2.70-6	5.22-6	9.94-6
EFWSI	EFW Signal Isolator	Failure during Operation		*	8.75-6	8.75-6	2.25-6	6.90-6	2.06-5
EFSIG	EFW Actuation Control Signal	Failure during Operation		*	2.07-5	2.07-5	6.89-6	1.57-5	4.60-5
EJF	Expansion Joint	Failure during Operation		*	1.64-6	1.64-6	1.00-8	2.24-7	6.96-6
FCD	Feedwater Hand/Auto Station	Failure To Switch to Manual Control on Demand		*	8.07-4	8.07-4	8.94-5	4.46-4	2.15-3
FCS	Feedwater Hand/Auto Station	Failure during Operation		*	1.30-5	1.30-5	1.44-6	7.20-6	3.47-5
FSP	River Water Screen	Plugs during Operation	0	12 Hours	1.14-1	4.51-2	2.01-3	2.35-2	9.47-2
FT	Flow Transmitter	Failure during Operation		*	6.25-6	6.25-6	6.03-7	4.18-6	1.41-5
FWM	ICS Feedwater Module	Failure during Operation		*	1.30-4	1.30-4	1.44-5	7.20-5	3.47-4
FZ	Fuse	Failure during Operation		*	9.20-7	9.20-7	2.83-8	3.16-7	2.83-6
F1R	Ventilation Fan	Failure during Operation	13	2.58+5 Hours	7.89-6	3.63-5	2.37-5	3.39-5	5.27-5
F1S	Ventilation Fan	Failure To Start on Demand	5	932 Demands	4.84-4	2.94-3	8.58-4	2.28-3	5.87-3
HXP	Heat Exchanger	Plugs during Operation	0	1.59+6 Hours	1.95-6	7.49-7	1.41-7	5.82-7	1.53-6
HXR	Heat Exchanger	Leaks/Ruptures during Operation	0	1.59+6 Hours	1.95-6	7.49-7	1.41-7	5.82-7	1.53-6
IMM	ICS Integrated Master Module	Failure during Operation		*	5.21-5	5.21-5	5.78-6	2.88-5	1.39-4
INV	Inverter	Failure during Operation		*	1.83-5	1.83-5	1.73-6	1.14-5	4.16-5
LC	Steam Generator Water Level Controller	Failure during Operation		*	2.66-5	2.66-5	8.68-7	8.52-6	8.14-5

*No plant-specific data collected.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 8.61+4 = 8.61×10^4; 9.81-5 = 9.81×10^{-5}.

TABLE 3-4 (continued)

Sheet 2 of 3

Designator	Component Description	Failure Mode	TMI-1 Experience		Generic Mean	TMI-1 Specific Distribution			
			Failures	(hours/demands)		Mean	5th Percentile	Median	95th Percentile
LS	ESAS Load Sequencer	Failure To Operate on Demand		*	2.40-6	2.40-6	7.84-8	7.69-7	7.34-6
LSW	Limit Switch	Failure To Operate on Demand		*	4.28-4	4.28-4	6.83-5	2.83-4	1.10-3
LT	Level Transmitter	Failure during Operation		*	1.57-5	1.57-5	3.51-6	1.12-5	3.34-5
MLT	Manual Loader	Failure during Operation		*	2.66-5	2.66-5	8.68-7	8.52-6	8.14-5
NP	Reactor Building Spray Nozzles	Plug during Operation		*	7.06-8	7.06-8	2.70-9	3.02-8	2.00-7
OGF	Offsite Grid	Failure on Demand, Given Plant Trip		*	2.66-4	2.66-4	8.68-6	8.52-5	8.14-4
PB	Pushbutton Switch	Fail To Operate on Demand		*	2.40-5	2.40-5	8.29-7	7.90-6	7.32-5
PP1	Piping, GE, 3-inch Diameter	Failure per Section		*	8.60-10	8.60-10	1.98-12	1.80-10	2.02-9
PP2	Piping, < 3-Inch Diameter	Failure per Section per Hour		*	8.60-9	8.60-9	1.98-11	1.80-9	2.02-8
PS	Power Supply	Failure during Operation		*	1.71-5	1.71-5	1.18-6	7.25-6	4.39-5
PSW	Pressure Switch	Failure To Operate on Demand		*	2.69-4	2.69-4	1.41-5	1.25-4	7.69-4
PT	Pressure Transmitter	Failure during Operation		*	1.57-5	1.57-5	3.51-6	1.12-5	3.34-5
P1S	Normally Operating Motor-Driven Pump	Failure To Start on Demand	2	393 Demands	2.35-3	3.49-3	8.61-4	2.67-3	8.16-3
P1R	Normally Operating Motor-Driven Pump	Failure during Operation	0	1.56+5 Hours	3.36-5	6.69-6	1.27-6	4.76-6	1.45-5
P2S	Standby Motor-Driven Pump	Failure To Start on Demand	3	1731 Demands	3.29-3	1.83-3	5.29-4	1.69-3	2.96-3
P2R	Standby Motor-Driven Pump	Failure during Operation	6	1.07+5 Hours	3.42-5	4.48-5	2.06-5	3.84-5	6.93-5
P3ES	Turbine-Driven Emergency Feed Pump	Failure To Start on Demand	0	119 Demands	3.31-2	3.31-2	5.75-3	2.50-2	7.10-2
P3ER	Turbine-Driven Emergency Feed Pump	Failure To Run	0	33 Demands	1.03-3	9.30-4	5.98-5	4.46-4	2.52-3
P3S	Turbine-Driven Main Feed Pump	Failure To Start	2	120 Demands	3-31-2	2.23-2	7.49-3	2.03-2	3.74-2
P3R	Turbine-Driven Main Feed Pump	Failure during Operation	3	6.36+4 Hours	1.03-3	6.90-5	2.70-5	6.04-5	1.25-4
P4S	Normally Operating River Water Pump	Failure To Start	2	430 Demands	2.35-3	3.05-3	7.58-4	2.80-3	5.99-3
P4R	Normally Operating River Water Pump	Failure during Operation	4	1.18+5 Hours	3.36-5	3.02-5	1.22-5	2.45-5	5.30-5
P5S	Standby River Water Pump	Failure To Start	4	814 Demands	3.29-3	4.11-3	1.46-3	3.58-3	7.20-3
P5R	Standby River Water Pump	Failure during Operation	3	5.45+4 Hours	3.42-5	4.41-5	1.27-5	3.99-5	8.56-5
P6S	Vacuum Pump	Failure To Start		*	2.35-3	2.35-3	2.51-4	1.44-3	6.42-3
P6R	Vacuum Pump	Failure To Run		*	3.36-5	3.36-5	2.75-6	1.64-5	9.00-5
RD	Relay	Failure To Operate on Demand		*	2.41-4	2.41-4	1.41-5	1.35-4	6.40-4
RO	Relay	Failure during Operation		*	4.20-7	4.20-7	2.83-8	1.90-7	1.41-6
RSC	Reactor Sump	Clogs/Fails during Operation		*	1.00-5	1.00-5	3.46-7	3.29-6	3.05-5
SF	Service Water Strainer	Failure during Operation	2	6.02+5 Hours	6.21-6	3.23-6	7.44-7	2.50-6	6.06-6
SIF	Seal Injection Line Filter	Plugging during Operation		*	3.23-6	3.23-6	3.58-7	1.79-6	8.59-6
SMF	Signal Modifier	Failure during Operation		*	2.94-6	2.94-6	4.66-7	2.04-6	6.42-6
STC	Shunt Trip Coil	Failure To Operate on Demand		*	1.40-4	1.40-4	3.27-5	1.05-4	2.94-4
TCF	Timing Circuit	Failure To Operate on Demand		*	2.40-6	2.40-6	7.84-8	7.69-7	7.34-6
TDD	Time Delay Relay	Failure To Operate on Demand		*	2.41-4	2.41-4	1.41-5	1.35-4	6.40-4
TE	Temperature Element	Failure during Operation		*	7.50-7	7.50-7	1.67-8	1.99-7	2.31-6
TEB	Turbine Exhaust Boot	Failure during Operation		*	2.66-6	2.66-6	8.68-8	8.52-7	8.14-6
TM	Temperature Monitor Loop	No Output		*	3.41-6	3.41-6	3.14-8	5.67-7	1.02-5
TR	Tank	Rupture during Operation	0	6.89+5 Hours	2.66-8	2.45-8	7.59-10	1.04-8	6.86-8
ULD	ICS Unit Load Demand Module	Failure during Operation		*	1.43-4	1.43-4	1.58-5	7.91-5	3.81-4
VCS	Ventilation Chiller	Failure To Start on Demand	5	375 Demands	8.07-3	1.11-2	4.72-3	1.02-2	2.00-2
VCR	Ventilation Chiller	Failure during Operation	3	8.61+4 Hours	9.44-5	4.86-5	2.27-5	4.33-5	7.80-5
V1F	Motor-Operated Valve	Failure To Operate on Demand	50	1.42+4 Demands	4.30-3	3.51-3	2.78-3	3.40-3	4.25-3
V1T	Motor-Operated Valve	Transfers Open/Closed during Operation		*	9.27-8	9.27-8	1.03-8	5.02-8	2.37-7
V2F	Solenoid Valve	Failure To Operate on Demand		*	2.43-3	2.43-3	7.64-5	9.79-4	6.94-3
V2T	Solenoid Valve	Transfers Open/Closed during Operation	0	8.12+5 Hours	1.27-6	4.94-7	3.09-8	2.83-7	1.41-6

*No plant-specific data collected.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 2.40-6 = 2.40×10^{-6}; 1.56+5 = 1.56×10^{5}.

TABLE 3-4 (continued)

Designator	Component Description	Failure Mode	TMI-1 Experience		Generic Mean	TMI-1 Specific Distribution			
			Failures	(hours/demands)		Mean	5th Percentile	Median	95th Percentile
V3F	Air-Operated Valve	Failure To Operate on Demand	7	2.72+3 Demands	1.52-3	2.16-3	1.40-3	2.13-3	3.43-3
V3M	Air-Operated Valve	Failure To Modulate to Control Pressure		*	1.62-2	1.62-2	3.99-3	1.20-2	3.50-7
V3T	Air-Operated Valve	Transfers Open/Closed during Operation	7	1.56+6 Hours	2.67-7	3.24-6	1.36-6	2.87-6	4.78-6
V3TC	Air-Operated Valve	Transfers Open/Closed during Operation	0	1.72+4 Hours	2.67-7	2.62-7	1.50-8	1.10-7	7.85-7
V3FP	Air-Operated Valve	Failure To Transfer to Failed Position		*	2.66-4	2.66-4	7.57-6	1.04-4	7.62-4
V4F	Electrohydraulic Valve	Failure To Operate on Demand		*	1.52-3	1.52-3	2.83-4	1.14-3	3.16-3
V4T	Electrohydraulic Valve	Transfers Open/Closed during Operation		*	2.67-7	2.67-7	1.78-8	1.20-7	6.71-7
V6F	Stop Check Valve	Failure To Operate on Demand		-	9.13-4	9.13-4	7.01-5	4.21-4	2.35-3
V6T	Stop Check Valve	Transfers Open/Closed during Operation		*	1.04-8	1.04-8	2.43-9	7.80-9	2.19-8
V7F	Check Valve (other than stop)	Failure To Operate on Demand	1	4.96+3 Demands	2.69-4	2.11-4	7.14-5	1.41-4	3.72-4
V7FI	Check Valve (intermediate cooling)	Failure To Operate on Demand	1	276 Demands	2.69-4	5.09-4	1.37-4	2.45-4	1.41-3
V7FR	Check Valve (river water)	Failure To Operate on Demand	10	3.48+3 Demands	2.96-4	2.08-3	1.16-3	1.79-3	3.22-3
V7L	Check Valve (other than stop)	Gross Reverse Leakage during Operation	1	2.04+5 Hours	5.36-7	9.78-7	1.41-7	5.45-7	2.56-6
V7LI	Check Valve (intermediate cooling)	Gross Reverse Leakage during Operation	7	3.18+4 Hours	5.36-7	1.91-4	8.53-5	1.62-4	3.05-4
V7LR	Check Valve (river water)	Gross Reverse Leakage during Operation	1	1.40+5 Hours	5.36-7	1.06-6	1.43-7	5.66-7	2.86-6
V7R	Check Valve	Gross Reverse Leakage during Operation		*	7.24-5	7.24-5	1.20-6	1.65-5	2.23-4
V7T	Check Valve (other than stop)	Transfers Closed; Plugs during Operation	0	1.23+6 Hours	1.04-8	1.03-8	2.43-9	7.80-9	2.15-8
V7TI	Check Valve (intermediate cooling)	Transfers Closed; Plugs during Operation	0	1.91+5 Hours	1.04-8	1.04-8	2.43-9	7.80-9	2.18-8
V7TR	Check Valve (river water)	Transfers Closed; Plugs during Operation	0	1.74+5 Hours	1.04-8	1.04-8	2.43-9	7.80-9	2.18-8
V8F	Manual Valve	Failure To Open on Demand		*	7.40-4	7.40-4	1.80-4	4.86-4	1.89-3
V8T	Manual Valve	Transfers Open/Closed during Operation	0	9.47+6 Hours	4.20-8	2.14-8	1.41-9	1.41-8	5.66-8
V9F	Relief Valve (other than PORV or safety)	Failure To Open on Demand		*	2.42-5	2.42-5	7.55-7	9.72-6	6.92-5
V9O	Relief Valve (other than PORV or safvty)	Premature Open		*	6.06-6	6.06-6	1.08-6	3.94-6	1.73-5
V10FS	Press::rizer Safety Valve	Failure To Open on Demand (passing steam)	0	131 Demands	3.28-4	2.92-4	1.34-5	1.41-4	8.98-4
V10FW	Pressurizer Safety Valve	Failure To Open on Demand (passing water)	0	131 Demands	3.28-4	2.92-4	1.34-5	1.41-4	8.98-4
V10RS	Pressurizer Safety Valve	Failure To Reseat on Demand (passing steam)	0	131 Demands	2.87-3	1.53-3	8.84-5	1.07-3	4.30-3
V10RW	Pressurizer Safety Valve	Failure To Reseat on Demand (passing water)		*	1.01-1	1.01-1	2.88-3	1.20-1	2.50-1
V10T	Pressurizer Safety Valve	Transfers Open/Closed		*	3.03-6	3.03-6	5.38-7	1.97-6	8.65-6
V11FS	PORV	Failure To Open on Demand (passing steam)	0	18 Demands	4.27-3	4.10-3	9.95-4	3.20-3	8.28-3
V11FW	PORV	Failure To Open on Demand (passing water)	0	18 Demands	4.27-3	4.10-3	9.95-4	3.20-3	8.28-3
V11RS	PORV	Failure To Open/Reseat on Demand (passing steam)	0	18 Demands	2.50-2	2.05-2	5.85-3	1.77-2	3.85-2
V11RW	PORV	Failure To Reseat on Demand (passing water)	0	18 Demands	1.01-1	1.01-1	2.88-3	1.20-1	2.50-1
V11T	PORV	Transfer Closed during Operation		*	3.03-6	3.03-6	5.38-7	1.97-6	8.65-6
V12F	Turbina Stop/Control Valve	Failure To Operate on Demand		*	1.25-4	1.25-4	2.92-5	9.37-5	2.63-4
V13T	Pressure Controlled Regulating Valve	Transfer Closed during Operation		*	1.69-5	1.69-5	1.88-6	9.37-6	4.51-5
V14F	Air Compressor Transfer Valve	Failure to Operate on Demand		*	1.52-3	1.52-3	2.85-4	1.03-3	3.57-3
YS	Y-Type Strainer	Failure during Operation		*	2.66-6	2.66-6	8.68-8	8.52-7	8.14-6
X1F	Transformer (GST/UAT/RAT)	Failure during Operation	0	1.72+5 Hours	1.56-6	1.26-6	2.83-7	9.89-7	2.45-6
X2F	Transformer (Station Service/480V to 4,160V)	Failure during Operation	G	1.38+6 Hours	6.87-7	4.28-7	7.06-8	3.46-7	8.37-7
X3F	Transformer (instrument/120V to 480V)	Failure during Operation		*	1.55-6	1.55-6	7.44-8	6.57-7	4.18-6

*No plant-specific data collected.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 2.72+3 = 2.72×10^3; 1.52-3 = 1.52×10^{-3}.

TABLE 3-5. TMI-1 COMPONENT COMMON CAUSE PARAMETER DATA BASE

Designator	Parameter	Component	Failure Mode	Distribution			
				Mean	5th Percentile	Median	95th Percentile
BACR	Beta Factor	Air Compressor	Fails during Operation	5.00-2	5.11-3	2.98-2	1.28-1
BACS	Beta Factor	Air Compressor	Fails To Start on Demand	1.00-1	1.02-2	6.98-2	2.49-1
BBISF	Beta Factor	Bistable	Fails To Operate on Demand	5.00-2	5.11-3	2.98-2	1.28-1
BCB4FO	Beta Factor	Circuit Breaker (R.T.)	Fails To Open on Demand	1.85-1	9.74-2	1.76-1	2.58-1
BDGS	Beta Factor	Diesel Generator	Fails To Start on Demand	4.93-2	2.51-2	4.65-2	7.01-2
BDGR1	Beta Factor	Diesel Generator	Fails during First Hour of Operation	4.09-2	1.59-2	3.75-2	6.39-2
BDGR2	Beta Factor	Diesel Generator	Fails after First Hour of Operation	4.09-2	1.59-2	3.75-2	6.39-2
BD1F	Beta Factor	Pneumatic Damper	Fails To Operate on Demand	1.00-1	1.02-2	6.98-2	2.49-1
BF1R	Beta Factor	Ventilation Fan	Fails during Operation	5.00-2	5.11-3	2.98-2	1.28-1
BF1S	Beta Factor	Ventilation Fan	Fails To Start on Demand	5.00-2	5.11-3	2.98-2	1.28-1
BHXP	Beta Factor	Heat Exchanger	Plugs during Operation	5.00-2	5.11-3	2.98-2	1.28-1
BP1S	Beta Factor	Normally Operating Motor-Driven Pump	Fails To Start on Demand	5.63-2	9.06-3	4.72-2	1.07-1
BP1R	Beta Factor	Normally Operating Motor-Driven Pump	Fails during Operation	1.39-2	8.20-4	9.47-3	3.38-2
BP2S	Beta Factor	Standby Motor-Driven Pump	Fails To Start on Demand	1.62-1	8.44-2	1.54-1	2.28-1
BP2R	Beta Factor	Standby Motor-Driven Pump	Fails during Operation	3.35-2	5.25-3	2.80-2	6.41-2
BP3S	Beta Factor	Turbine-Driven Pump	Fails To Start on Demand	2.43-2	6.05-4	1.48-2	6.39-2
BP3R	Beta Factor	Turbine-Driven Pump	Fails during Operation	3.17-2	1.82-3	2.16-2	7.67-2
BP4S	Beta Factor	Normally Operating River Water Pump	Fails To Start on Demand	5.63-2	9.06-3	4.72-2	1.07-1
BP4R	Beta Factor	Normally Operating River Water Pump	Fails during Operation	1.39-2	8.20-4	9.47-3	3.38-2
BP5S	Beta Factor	Standby River Water Pump	Fails To Start on Demand	5.63-2	9.06-3	4.72-2	1.07-1
BP5R	Beta Factor	Standby River Water Pump	Fails during Operation	1.39-2	8.20-4	9.47-3	3.38-2

NOTE: Exponential notation is indicated in abbreviated form; i.e. 5.00-2 = 5.00 x 10^{-2}.

TABLE 3-5 (continued)

Sheet 2 of 3

Designator	Parameter	Component	Failure Mode	Distribution			
				Mean	5th Percentile	Median	95th Percentile
BS	Beta Factor	EFW Pump (pump portion)	Fails To Start on Demand	2.56-2	6.37-4	1.56-2	6.71-2
BR	Beta Factor	EFW Pump (pump portion)	Fails during Operation	3.42-2	1.97-3	2.34-2	8.26-2
BRD	Beta Factor	Relay	Fails To Operate on Demand	1.00-1	1.02-2	6.98-2	2.49-1
BSF	Beta Factor	Service Water Strainer	Fails during Operation	1.00-1	1.02-2	6.98-2	2.49-1
BTDD	Beta Factor	Time Delay Relay	Fails To Operate on Demand	5.00-2	5.11-3	2.98-2	1.28-1
BVCS	Beta Factor	Ventilation Chiller	Fails To Start on Demand	5.00-2	5.11-3	2.98-2	1.28-1
BVCR	Beta Factor	Ventilation Chiller	Fails during Operation	1.00-1	1.02-2	6.98-2	2.49-1
BV1F	Beta Factor	Motor-Operated Valve	Fails To Operate on Demand	8.07-2	6.29-2	7.99-2	9.41-2
BV6F	Beta Factor	Stop Check Valve	Fails To Operate on Demand	1.00-1	1.02-2	6.98-2	2.49-1
BV9F	Beta Factor	Relief Valve (not PORV or safety)	Fails To Open on Demand	1.00-1	1.02-2	6.98-2	2.49-1
BV10FS	Beta Factor	Pressurizer Safety Valve	Fails To Open on Demand (steam)	5.00-2	5.11-3	2.98-2	1.28-1
BV10FW	Beta Factor	Pressurizer Safety Valve	Fails To Open on Demand (water)	5.00-2	5.11-3	2.98-2	1.28-1
BV10RS	Beta Factor	Pressurizer Safety Valve	Fails To Reseat on Demand (steam)	5.00-2	5.11-3	2.98-2	1.28-1
BV10RW	Beta Factor	Pressurizer Safety Valve	Fails To Reseat on Demand (water)	5.00-2	5.11-3	2.98-2	1.28-1
GACR	Gamma Factor	Air Compressor	Fails during Operation	5.00-1	2.11-1	5.20-1	7.60-1
GACS	Gamma Factor	Air Compressor	Fails To Start on Demand	5.00-1	2.11-1	5.20-1	7.60-1
GBISF	Gamma Factor	Bistable	Fails To Operate on Demand	5.00-1	2.11-1	5.20-1	7.60-1
GCB4FO	Gamma Factor	Circuit Breaker (R.T.)	Fails To Open on Demand	4.29-1	1.77-1	4.08-1	6.27-1
GF1R	Gamma Factor	Ventilation Fan	Fails during Operation	5.00-1	2.11-1	5.20-1	7.60-1
GF1S	Gamma Factor	Ventilation Fan	Fails To Start on Demand	5.00-1	2.11-1	5.20-1	7.60-1
GHXP	Gamma Factor	Heat Exchanger	Plugs during Operation	5.00-1	2.11-1	5.20-1	7.60-1
GP1S	Gamma Factor	Normally Operating Motor-Driven Pump	Fails To Start on Demand	2.50-1	7.18-5	1.81-1	5.84-1
GP1R	Gamma Factor	Normally Operating Motor-Driven Pump	Fails during Operation	5.26-1	4.23-2	4.88-1	9.21-1
GP2S	Gamma Factor	Standby Motor-Driven Pump	Fails To Start on Demand	3.66-1	1.37-1	3.44-1	5.56-1
GP2R	Gamma Factor	Standby Motor-Driven Pump	Fails during Operation	2.49-1	8.12-3	1.80-1	5.81-1

NOTE: Exponential notation is indicated in abbreviated form; i.e, 2.56-2 = 2.56 x 10^{-2}.

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TABLE 3-5 (continued)

Sheet 3 of 3

Designator	Parameter	Component	Failure Mode	Distribution			
				Mean	5th Percentile	Median	95th Percentile
GP4S	Gamma Factor	Normally Operating River Water Pump	Fails To Start on Demand	2.50-1	7.18-5	1.81-1	5.84-1
GP4R	Gamma Factor	Normally Operating River Water Pump	Fails during Operation	5.26-1	4.23-2	4.88-1	9.21-1
GRD	Gamma Factor	Relay	Fails To Operate on Demand	5.00-1	2.11-1	5.20-1	7.60-1
GTDD	Gamma Factor	Time Delay Relay	Fails To Operate on Demand	5.00-1	2.11-1	5.20-1	7.60-1
GV1F	Gamma Factor	Motor-Operated Valve	Fails To Operate on Demand	2.01-1	1.23-1	1.94-1	2.64-1
GV9F	Gamma Factor	Relief Valve (not PORV or or safety)	Fails To Open on Demand	5.00-1	2.11-1	5.20-1	7.60-1
GV10RS	Gamma Factor	Pressurizer Safety Valve	Fails To Reseat (steam)	5.00-1	2.11-1	5.20-1	7.60-1

NOTE: Exponential notation is indicated in abbreviated form; i.e, 2.50-1 = 2.50×10^{-1}.

TABLE 3-6. TMI-1 COMPONENT MAINTENANCE FREQUENCY

Sheet 1 of 2

Designator	Component	TMI-1 Experience*		Generic Mean (events/hour)	TMI-1 Specific Distribution			
		Events	Hours		Mean (events/hour)	5th Percentile	Median	95th Percentile
MFCD1	Main Steam ADV	6	6.36+4	2.75-5	3.25-5	2.23-5	3.10-5	4.08-5
MFCD2	Pressurizer Spray Valve	2	9.54+4	2.75-5	2.68-5	1.81-5	2.55-5	3.45-5
MFCF1	Reactor Building Fan	41	9.54+4	2.19-4	4.02-4	2.94-4	3.85-4	4.89-4
MFCF2	Motor-Operated Cooler Inlet Valve		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFCF3	Motor-Operated Cooler Outlet Valve		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFCF4	Reactor Building Cooling Unit		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFCF5	Reactor River Water Pump	73	6.36+4	8.42-5	1.06-3	8.44-4	1.03-3	1.24-3
MFCF6	Motor-Operated River Water Discharge Valve		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFCF7	Reactor River Pump Minimum Flow Valve		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFCF8	Reactor River Strainer	2	6.36+4	2.19-4	7.38-5	4.06-5	6.53-5	1.21-4
MFCF9	RR-V5		**		2.75-5	1.85-5	2.62-5	3.67-5
MFCF10	Fan Motor Cooler		**		2.75-5	1.85-5	2.62-5	3.67-5
MFCI1	Letdown Isolation Valve	2	9.54+4	2.75-5	2.68-5	1.81-5	2.55-5	3.45-5
MFCS1	Reactor Building Spray Pump	11	6.36+4	2.19-4	1.78-4	1.15-4	1.75-4	2.47-4
MFCV1	Control Tower Instrument Air Compressor	13	1.27+5		1.08-4	6.80-5	1.16-4	1.46-4
MFCV2	Control Building Fan	32	1.27+5	2.19-4	2.33-4	1.70-4	2.30-4	2.75-4
MFCV3	Chilled Water Train (pump and chiller)	17	6.36+4	2.19-4	2.53-4	1.60-4	2.43-4	3.39-4
MFC31	MU-V26		**		2.75-5	1.85-5	2.62-5	3.67-5
MFC32	MU-V25		**		2.75-5	1.85-5	2.62-5	3.67-5
MFDA1	Station Battery	0	6.36+4	2.75-5	2.55-5	1.77-5	2.44-5	3.35-5
MFDA2	Battery Charger	2	1.91+5	2.75-5	2.44-5	1.77-5	2.33-5	3.15-5
MFDH1	DHR Pump	30	6.36+4	8.42-5	3.41-4	2.43-4	3.27-4	4.41-4
MFDH2	DHR Cooler		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFDH3	DHR MOV	10	1.26+5	2.75-5	3.49-5	2.46-5	3.35-5	4.60-5
MFDH4	LPI/HPI Cross-Connect Strainer	5	6.36+4	2.19-4	1.10-4	5.74-5	1.06-4	1.60-4
MFEF1	EFW Pump	24	9.54+4	2.19-4	2.43-4	1.79-4	2.42-4	3.14-4
MFEF2	EFW Pump Steam Supply Valve	10	1.59+5	2.75-5	3.35-5	2.35-5	3.26-5	4.16-5
MFEF3	EFW Logic Channel		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFFW1	Condensate Pump	19	9.54+4	1.26-4	1.76-4	1.14-4	1.68-4	2.30-4
MFFW2	Condensate Booster Pump	36	9.54+4	1.26-4	3.19-4	2.37-4	3.09-4	4.00-4
MFGA1	Diesel Generator	102	6.36+4	2.75-5	1.57-3	1.29-3	1.53-3	1.82-3
MFGA2	Fuel Oil Transfer Pump	2	6.36+4	2.75-5	2.77-5	1.94-5	2.65-5	3.66-5
MFHA1	DHRW Pump	78	6.36+4	8.42-5	1.13-3	9.28-4	1.12-3	1.32-3
MFHA2	DHRW Discharge Valve		**	2.75-5	2.75-5	1.85-5	2.52-5	3.67-5
MFHA3	River Water Strainer	5	6.36+4	2.19-4	1.10-4	5.74-5	1.08-4	1.61-4
MFHA4	Decay Heat Cooler	5	1.27+5	2.75-5	2.90-5	2.00-5	2.78-5	3.84-5
MFHA5	Decay Heat CCW Pump	14	6.36+4	8.42-5	1.58-4	9.93-5	1.58-4	2.21-4
MFHA6	Decay Heat Service Cooler (scheduled)		**		2.75-5	1.85-5	2.62-5	3.67-5
MFHL1	DH-V3	2	3.18+4	2.75-5	2.88-5	1.97-5	2.75-5	3.87-5
MFHP1	Normally Running Makeup Pump	14	3.18+4	1.26-4	2.84-4	1.87-4	2.79-4	3.96-4

*TMI-1 experience is based on the maintenance events documented on maintenance summary sheets (Appendix C).
**No plant-specific data collected.

NOTE: Exponential notation is indicated in abbreviated form; i.e. 6.36+4 = 6.36 x 10^4; 2.75-5 = 2.75 x 10^{-5}.

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TABLE 3-6 (continued)

Sheet 2 of 2

Designator	Component	TMI-1 Experience*		Generic Mean (events/hour)	TMI-1 Specific Distribution			
		Events	Hours		Mean (events/hour)	5th Percentile	Median	95th Percentile
MFHPA	Maintenance Frequency - Two MU Pumps under Maintenance		**		2.75-5	1.85-5	2.62-5	3.67-5
MFHP2	Standby Makeup Pump	27	6.36+4	8.42-5	3.07-4	2.19-4	2.92-4	3.98-4
MFNS1L	NSRW Pump - Long Duration	8	9.54+4	2.75-5	3.37-5	2.33-5	3.28-5	4.28-5
MFNS1S	NSRW Pump - Short Duration	86	9.54+4	1.26-4	8.71-4	7.20-4	8.61-4	9.74-4
MFNS2	MOV		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFNS3	NSCCW Pump	23	9.54+4	1.26-4	2.10-4	1.49-4	2.03-4	2.70-4
MFNS4	Single Auxiliary Building	12	1.27+5	2.19-4	1.10-4	6.78-5	1.05-4	1.48-4
MFNS5	Nuclear Services Cooler	0	3.[illegible]+4	2.75-5	2.65-5	1.77-5	2.52-5	3.45-5
MFOP1	Auxiliary Station Service Transformer		**	1.26-4	1.26-4	5.48-5	1.10-4	2.15-4
MFPO1	Frequency that PORV Is Declared Inoperable with Reactor at Power		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFPO2	Frequency that PORV Block Valve Is Declared Inoperable with Reactor at Power		**	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFRT1	RPS Channel		**	8.42-5	8.42-5	3.65-5	7.34-5	1.44-4
MFSE1	ICCW Pump	5	6.36+4	1.26-4	9.74-5	5.36-5	9.30-5	1.44-4
MFSR1	Sump Isolation Valve	0	0	2.75-5	2.75-5	1.85-5	2.62-5	3.67-5
MFSR2	DH-V5		**		2.75-5	1.85-5	2.62-5	3.67-5

*TMI-1 experience is based on the maintenance events documented on maintenance summary sheets (Appendix C).
**No plant-specific data collected.

NOTE: Exponential notation is indicated in abbreviated form; i.e, 6.36+4 = 6.36×10^4; 2.75-5 = 2.75×10^{-5}.

TABLE 3-7. TMI-1 MEAN MAINTENANCE DURATION DATA BASE

Sheet 1 of 2

Designator	Component	Generic Mean (hours)	TMI-1 Specific Distribution*			
			Mean (hours)	5th Percentile	Median	95th Percentile
MDCD1	Main Steam ADV	5.6	1.37+1	6.70+0	1.59+1	1.70+1
MDCD2	Pressurizer Spray Valve	5.6	6.48+0	3.57+0	5.58+0	1.10+1
MDCF1	Reactor Building Fan	20.9	1.74+1	1.57+1	1.60+1	2.14+1
MDCF2	Motor-Operated Cooler Inlet Valve	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDCF3	Motor-Operated Cooler Outlet Valve	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDCF4	Reactor Building Cooling Unit	20.9	2.09+1	1.23+1	1.90+1	2.79+1
MDCF5	Reactor River Water Pump	20.9	1.46+1	1.15+1	1.42+1	1.82+1
MDCF6	Motor-Operated River Water Discharge Valve	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDCF7	Reactor River Pump Minimum Flow Valve	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDCF8	Reactor River Strainer	20.9	2.05+1	1.07+1	1.80+1	3.26+1
MDCF9	RR-V5	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDCF10	Fan Motor Cooler	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDCI1	Letdown Isolation Valves	5.6	8.85+0	4.39+0	7.60+0	1.30+1
MDCS1	Reactor Building Spray Pump	20.9	1.70+1	1.04+1	1.61+1	2.36+1
MDCV1	Instrument Air Compressor	20.9	2.04+1	1.91+1	1.92+1	2.48+1
MDCV2	Control Building Fan	40.4	2.49+1	1.82+1	2.23+1	3.51+1
MDCV3	Chilled Water Train (pump and chiller)	40.4	3.29+1	1.91+1	2.76+1	5.85+1
MDC31	MU-V26	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDC32	MU-V25	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDDA1	Station Battery	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDDA2	Battery Charger	5.6	4.74+0	3.03+0	4.35+0	7.02+0
MDDH1	DHR Pump	20.9	1.29+1	1.04+1	1.24+1	1.56+1
MDDH2	DHR Cooler	20.9	2.09+1	1.23+1	1.90+1	2.79+1
MDDH3	DHR MOV	5.6	1.18+1	6.32+0	1.17+1	1.70+1
MDDH4	LPI/HPI Cross-Connect Strainer	20.9	2.14+1	1.22+1	1.87+1	3.28+1
MDEF1	EFW Pump	20.9	1.43+1	1.12+1	1.25+1	1.92+1
MDEF2	EFW Pump Steam Supply Valve	5.6	1.62+1	8.95+0	1.70+1	1.70+1
MDEF3	EFW Logic Channel	10.8	1.08+1	6.91+0	9.54+0	1.58+1
MDFW1	Condensate Pump	116.4	8.96+1	2.78+1	9.91+1	1.35+2
MDFW2	Condensate Booster Pump	116.4	4.62+1	2.56+1	3.55+1	9.91+1
MDFW3	MFW Pump	40.4	3.69+1	1.67+1	2.77+1	6.21+1
MDFW4	Feedwater Pump	40.4	1.28+2	2.30+1	6.26+1	3.29+2
MDFW5	Feedwater Isolation Valves	40.4	7.76+0	4.26+0	6.97+0	1.20+1
MDGA1	Diesel Generator	40.4	2.17+1	1.81+1	2.16+1	2.44+1
MDGA2	Fuel Oil Transfer Pump	40.4	3.98+1	1.74+1	3.08+1	7.02+1
MDHA1	DHRW Pump	20.9	1.60+1	1.22+1	1.55+1	1.88+1
MDHA2	DHRW Discharge Valve	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDHA3	Maintenance Duration - River Water Strainer	20.9	2.14+1	1.22+1	1.87+1	3.28+1

*TMI-1 experience consists of individual outage durations documented on component maintenance summary sheets (Appendix C).

NOTE: Exponential notation is indicated in abbreviated form: i.e., 1.37+1 = 1.37 x 10^1.

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TABLE 3-7 (continued)

Sheet 2 of 2

Designator	Component	Generic Mean (hours)	TMI-1 Specific Distribution*			
			Mean (hours)	5th Percentile	Median	95th Percentile
MDHA4	Decay Heat Service Cooler	20.9	5.70+1	2.78+1	5.45+1	7.25+1
MDHA5	Decay Heat CCW Pump	20.9	1.98+1	1.90+1	1.92+1	2.21+1
MDHA6	Decay Heat Service Cooler (scheduled)	20.9	5.70+1	2.78+1	5.45+1	7.25+1
MDHL1	DH-V3	5.6	5.14+0	3.13+0	4.73+0	7.22+0
MDHP1	One MU Pump	20.9	1.30+1	1.11+1	1.24+1	1.55+1
MDHP2	Two MU Pump	20.9	2.09+1	1.23+1	1.90+1	2.79+1
MDNS1L	NSRW Pump - Long Duration	116.4	3.93+2	3.00+2	3.57+2	4.76+2
MDNS1S	NSRW Pump - Short Duration	5.6	1.23+1	1.15+1	1.20+1	1.34+1
MDNS2	MOV	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDNS3	NSCCW Pump	116.4	9.84+1	3.49+1	9.91+1	1.15+2
MDNS4	Single Auxiliary Building Ventilation Train	20.9	2.43+1	1.25+1	2.34+1	3.31+1
MDNS5	Nuclear Services Cooler	20.9	5.70+1	2.78+1	5.45+1	7.25+1
MDOP1	Auxiliary Station Service Transformer	116.4	1.17+2	1.60+1	[illegible].87+1	2.77+2
MDPO1	Duration between Cold Shutdowns	**	2.50+3	1.35+3	2.07+3	3.99+3
MDRT1	RPS Channel	5.6	5.56+0	3.20+0	5.48+0	7.50+0
MDSE1	ICCW Pump	116.4	5.88+1	1.58+1	2.84+1	1.68+2
MDSR1	Sump Isolation Valve	5.6	5.[illegible]+0	3.20+0	5.48+0	7.50+0
MDSR2	BWST Isolation Valve	5.6	5.56+0	3.20+0	5.48+0	7.50+0

*TMI-1 experience consists of individual outage durations documented on component maintenance summary sheets (Appendix C).

**Based on TMI-1 cold shutdown outage history (Table 3-3). No generic distribution was used.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 5.70+1 = 5.70×10^1.

TABLE 3-8. TMI-1 INITIATING EVENT FREQUENCY DATA BASE

Designator	Initiating Event Category	Generic Mean*	Plant-Specific Data		Distribution			
			Events	Years	Mean*	5th Percentile	50th Percentile	95th Percentile
LL	1. Large LOCA	2.66-4	0	4.5	1.91-4	7.30-6	7.36-5	5.21-4
ML	2. Medium LOCA	8.00-4	0	4.5	4.20-4	1.91-5	1.86-4	1.32-3
SB	3. Small LOCA	3.56-3	0	4.5	3.25-3	2.66-5	9.43-4	1.06-2
VSB	4. Very Small LOCA	5.19-3	0	4.5	5.05-3	2.19-4	2.55-3	1.37-2
VS	5. Inadvertent Opening of DHR Valves	**	0	4.5	1.00-7	4.58-10	6.38-9	1.66-7
SLI	6. Steam Line Break in Intermediate Building	8.00-4	0	4.5	4.20-4	1.91-5	1.86-4	1.32-3
SLT	7. Steam Line Break in Turbine Building	6.86-3	0	4.5	6.34-3	1.79-4	2.84-3	1.58-2
TR	8. Steam Generator Tube Rupture	1.39-2	0	4.5	1.13-2	3.95-4	6.43-3	2.82-2
EXC	9. Excessive Feedwater Flow	2.32-1	0	4.5	1.18-1	2.09-2	7.87-2	2.78-1
FW	10. Total Loss of Main Feedwater	5.48-1	0	4.5	2.33-1	5.11-2	1.83-1	4.81-1
RT	11. Reactor Trip	6.64+0	3	4.5	1.38+0	6.66-1	1.39+0	2.24+0
TT	12. Turbine Trip	1.89+0	7	4.5	1.64+0	7.75-1	1.53+0	2.32+0
LA	13. Loss of Air System	**	0	4.5	6.00-3	2.00-4	1.87-3	1.89-2
LC	14. Loss of Control Building Ventilation	**	0	4.5	1.95-4	5.37-5	1.35-4	4.17-4
ATA	15. Loss of ATA Power	7.16-2	0	4.5	5.42-2	5.18-3	3.61-2	1.73-1
LD	16. Loss of DC Power Train A	3.33-2	0	4.5	2.77-2	3.73-3	1.87-2	5.99-2
AC	17. Loss of Offsite Power	1.28-1†	0	4.5	7.10-2†	1.91-2	5.30-2	1.54-1
LNS	18. Loss of Nuclear Services Closed Cooling Water	**	0	4.5	1.43-2	4.59-3	1.10-2	2.74-2
LR	19. Loss of River Water	**	0	12.0	7.41-3	3.51-4	1.26-3	2.25-2

*Events per calendar year.
**Event frequency quantified based on analysis of the system(s) involved.
† Frequency per site-year.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 2.66-4 = 2.66 x 10^{-4}.

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TABLE 3-7. GROUPING OF EPRI EVENT CATEGORIES INTO TMI-1 INITIATING EVENT GROUPS

Sheet 1 of 3

Plant Specific Initiating Event Group	NP-2230 Initiating Event Category Used
1. Large LOCA	None.
2. Medium LOCA	None.
3. Small LOCA	None.
4. Very Small LOCA	None.
5. Inadvertent Opening of DHR Valves	None.
6. Steam Line Break in Intermediate Building	None.
7. Steam Line Break in Turbine Building	None.
8. Steam Generator Tube Rupture	None.
9. Excessive Feedwater Flow	None.
10. Total Loss of Main Feedwater	16. Total loss of feedwater flow (all loops). This transient occurs when a simultaneous loss of all main feedwater occurs, excluding that due to loss of station power (see NP-2230 category 35).
	24. Loss of condensate pumps (all loops). This transient occurs when all condensate pumps fail, causing a loss of feedwater flow.
	25. Loss of condenser vacuum. This transient occurs when either a complete loss or decrease in condenser vacuum results from a hardware or human error.
	27. Condenser leakage. This transient occurs when excessive secondary system leakage occurs in the condenser.
	30. Loss of circulating water. This transient occurs when circulating water is not available to the plant.
11. Reactor Trip	1. Loss of RCS flow (one loop). This transient occurs when an inadvertent hardware or human error interrupts the flow in one loop of the reactor coolant system.
	2. Uncontrolled rod withdrawal. This transient occurs when one or more control rods are withdrawn inadvertently.
	3. CRDM problems and/or rod drop. This transient occurs when failures in the control rod drive mechanism (CRDM) occur which lead to out of tolerance conditions in the primary system. The transient may include dropping of one or more control rods into the core as part of the CRDM failure.
	8. High pressurizer pressure.
	11. CVCS malfunction - boron dilution. This transient occurs when hardware or operator error results in a CVCS malfunction such that reactor power is affected.
	12. Pressure, temperature, power imbalance. This transient occurs when various primary systems signals indicate pressure, temperature, or power imbalances.
	14. Total loss of RCS flow. This transient occurs when a hardware or operator error causes a loss of reactor coolant system flow.

TABLE 3-9 (continued)

Sheet 2 of 3

Plant Specific Initiating Event Group	NP-2230 Initiating Event Category Used
	15. Loss or reduction in feedwater flow (one loop). This transient occurs when one feedwater pump trips or when another occurrence results in an overall decrease in feedwater flow.
	17. Full or partial closure of MSIV (one loop). This transient occurs when one MSIV closes, the rest remain open, or the partial closure of one or more MSIVs occurs.
	21. Feedwater flow instability - operator error. This transient occurs when feedwater is being controlled manually, usually during startup or shutdown, and excessive or insufficient feedwater flow occurs.
	22. Feedwater flow instability - miscellaneous mechanical causes. This transient occurs when excessive or insufficient feedwater flow results from hardware failures in the feedwater system.
	23. Loss of condensate pumps (one loop). This transient occurs when one condensate pump fails, reducing feedwater flow.
	28. Miscellaneous leakage in secondary system. This transient occurs when excessive leakage occurs in the secondary system, other than the condenser (see NP-2230 category 27).
	36. Pressurizer spray failure.
	37. Spurious auto trip - no transient condition. This transient occurs when an auto scram is initiated by a hardware failure in instrumentation or logic circuits and no out of tolerance condition exists.
	38. Auto/manual trip due to operator error. This transient occurs when an auto scram or manual scram is initiated by human error and no out of tolerance condition exists.
	39. Manual trip due to false signals. This transient occurs when an operator initiates a scram based on information from erroneous instrumentation.
	40. Spurious trips - cause unknown. This transient occurs when a scram occurs and no out of tolerance condition can be detected, nor cause of scram determined.
	6. High or low pressurizer pressure. This transient occurs when the pressurizer pressure is outside of the required operating limits.
12. Turbine Trip	33. Turbine trip, throttle valve closure, EHC problems. This transient occurs when a turbine trip occurs or if turbine problems occur which, in effect, decrease steam flow to the turbine, causing a rapid change in the amount of energy removed from the primary system.
	34. Generator trip or generator caused faults. This transient occurs when the generator is tripped due to electrical grid disturbances or generator faults.
	18. Closure of all MSIVs. This transient occurs when any one of various steam line or nuclear system malfunctions requires termination of steam flow from the vessel, or by operator action.
13. Loss of Air System	None.

TABLE 3-9 (continued)

Sheet 3 of 3

Plant Specific Initiating Event Group	NP-2230 Initiating Event Category Used
14. Loss of Control Building Ventilation	None.
15. Loss of ATA Power	None.
16. Loss of DC Power Train A	None.
17. Total Loss of Offsite Power	None.
18. Loss of Nuclear Services Closed Cooling Water	None.
19. Loss of River Water	None.

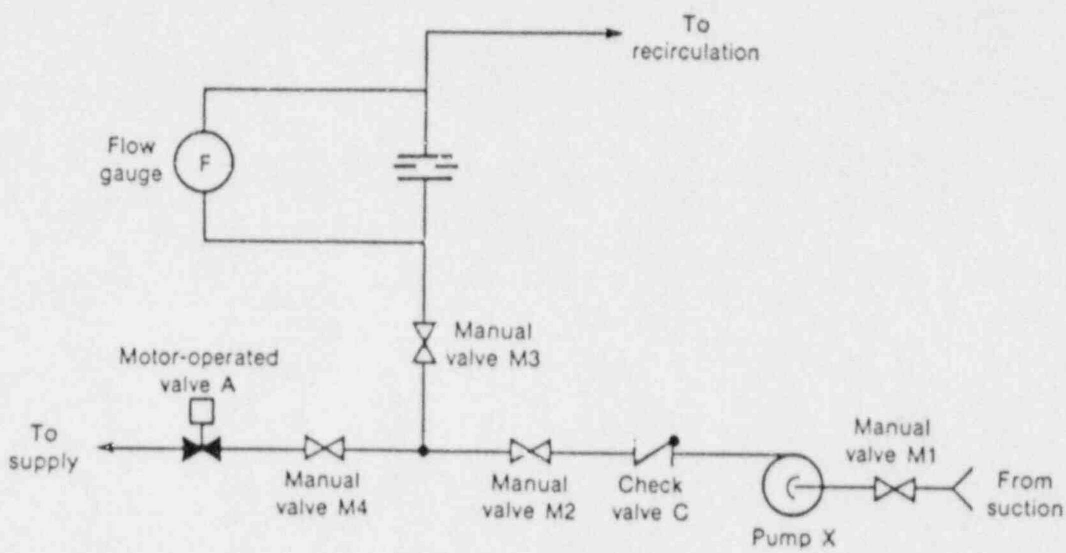

FIGURE 3-1. EXAMPLE SYSTEM FOR FLOW TEST DATA

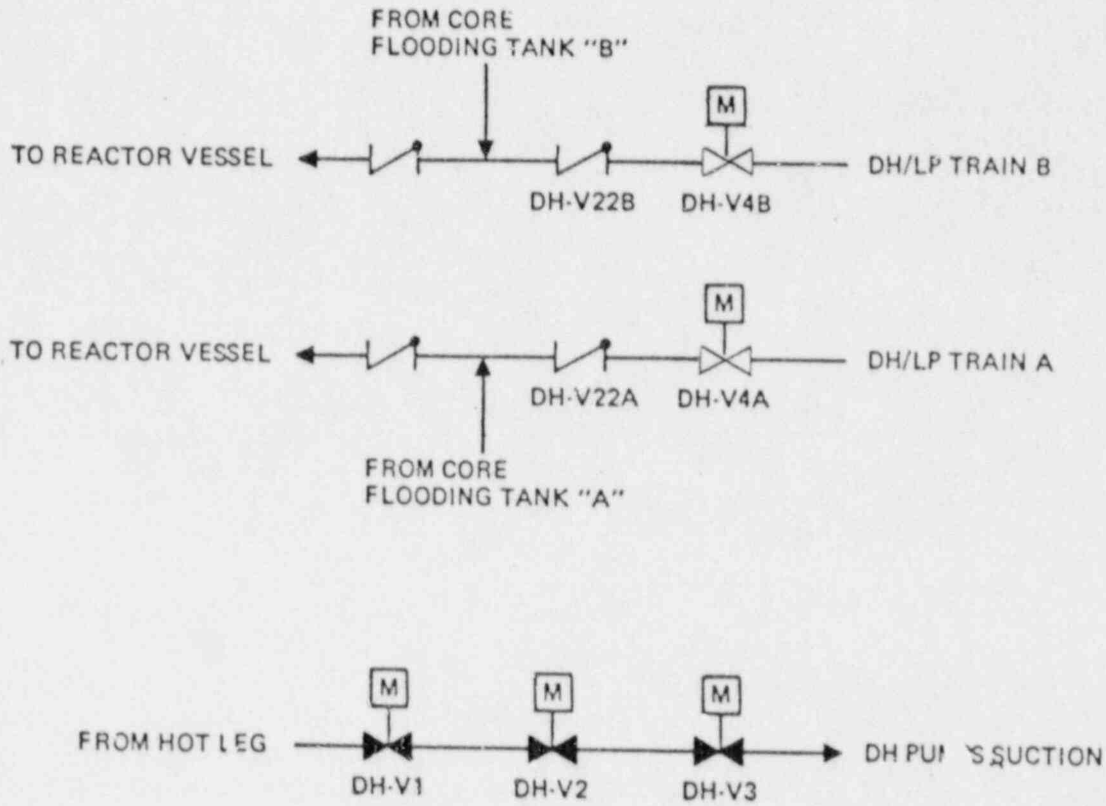

FIGURE 3-2. COLD LEG INJECTION PATH AND HOT LEG SUCTION PATH S'MPLIFIED DIAGRAM

APPENDIX A

TMI-1 COMPONENT FAILURE RATE DATA

APPENDIX A

TMI-1 COMPONENT FAILURE RATE DATA

The data sheets in this appendix summarize the failure events and the corresponding number of demands or operating hours used for the TMI-1 plant-specific component failure rate estimation. The failure events were obtained from a review of Work Requests (WR) and Job Tickets (JT). The reference WR or JT number is listed by each event. Component demands and operating hours were obtained from plant operating records, periodic tests, and run-time meter log. This appendix is divided into two subsections:

- Appendix A.1: Component Failure Data Summary Sheets
- Appendix A.2: Component Success Data Summary Sheets

The data in each section are organized by component type and failure mode as listed in Table 3-4 of this report.

APPENDIX A.1

COMPONENT FAILURE DATA SUMMARY SHEETS

TMI-1
COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: ACR

SYSTEM: Instrument Air

COMPONENT TYPE: Air Compressor

FAILURE MODE: Failure During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Seven Failures

Date	Reported Failure	Cause
4-21-83	(JT-CA618) IA-P1A	Leaking discharge valve--system pressure could not be maintained.
5/5/83	(JT-C2284) IA-P1B	"Knocking" piston touching the bottom of cylinder.
9/10/74	(WR-4220) IA-P1A	Tripped--would not start.
12/9/74	(WR-6061) IA-P1A	Tripped on overload.
12/11/74	(WR-6089) IA-P1B	Leads leaving breaker badly burned.
5/10/76	(WR-15356) SA-P-1A	Bad bearing--replaced.
10/18/77	(WR-21679) SA-P-1A	Tripped on thermal overload--replaced motor.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: ACS

SYSTEM: Instrument Air, Service Air

COMPONENT TYPE: Compressor

FAILURE MODE: Fail To Start

Site-Specific Data

- Failure Data for Given Failure Mode: Four Failures

Date	Reported Failure	Cause
6/24/76	(WR-15934) IA-P1B	Failed to load--cleaned in next attempt.
6/24/82	(JT-C8702) IA-P1B	Would not load at desired setpoint--control switch problem.
10/8/76	(WR-17189) SA-P1A	Would not start.
	(JT-C6041) IA-P1B	Fails to unload and load properly.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: AD1

SYSTEM: Compressed Air System

COMPONENT TYPE: Air Dryer

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: BC

SYSTEM: Electric Power

COMPONENT TYPE: Battery Charger

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Nine Failures

Date	Reported Failure	Cause
1/5/82	(JT-C7570) B	Breaker tripped, replaced two control boards, adjusted current limit.
8/25/81	(JT-C6631) 1A	Would not pick up load.
1/21/80	(JT-C2324) 1B	Bad AC input breaker.
10/31/79	(JT-C1984) 1B	AC breaker tripped.
8/3/81	(JT-C6456) 1D	Would not carry load.
3/22/77	(WR-19436) 1C, 1E	1C tripped off, 1E could not be controlled.
8/17/77	(WR-21089) 1A	Tripped on high voltage.
4/9/78	(WR-23422) 1A	Tripped on high voltage--float and equalizer out of adjustment.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: BTO

SYSTEM: Electric Power

COMPONENT TYPE: Station Battery

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Five Failures

Date	Reported Failure	Cause
1/28/81	(JT-C5092) B	Zero ground.
2/33/81	(JT-C5320) A	Grounds < 50 kΩ--relay in 1P bus grounded.
12/28/75	(WR-13119) A	Grounded.
12/26/76	(WR-18265) A	A - 70 kΩ grounds.
	(WR-18265) B	B - 50 kΩ grounds.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: CB4FO

SYSTEM: RPS

COMPONENT TYPE: Trip Breaker

FAILURE MODE: Fail To Open on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
9/1/76	(WR-16622) CB2	Failed to trip during test.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: CRF

SYSTEM: Reactor Protection System

COMPONENT TYPE: Single Control Rod Assembly

FAILURE MODE: Fail To Insert on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: DGR1

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

FAILURE MODE: Failure To Run during First Hour of Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Six Failures

Date	Reported Failure		Cause
5/9/77	(WR-19890)	DG-1A	Low oil pressure.
9/13/78	(WR-25197)	DG-1B	Governor failure.
9/14/78	(WR-25214) (WR-25197)	DG-1B	Governor failure.
2/17/79	(JT-C0512)	DG-1B	Tripped on overspeed.
10/8/79	(JT-C1863)	DG-1A	Governor linkage failure.
2/11/82	*	DG-1B	Breaker tripped open.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

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*Event listed in GPU memorandum on "Audit of Generator Start Failure Data," December 4, 1984.

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: DGS (Sheet 1 of 2)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: 14 Failures

Date	Reported Failure	Cause
2/22/79	(JT-C0630) DG-1A	Starting air compressor would not load.
4/11/79	(JT-C0870) DG-1B	Failed to start.
2/17/76	(WR-14048) DG-1B	Starting compressor would not load.
2/21/76	(WR-14132) DG-1B	Breaker would not close--adjusted governor.
3/16/76	(WR-14404) DG-1A	Would not start from control.
3/24/76	(WR-14509) DG-1A	Open air start compressor breaker.
6/28/76	(WR-15955) DG-1B	Start compressor failed to start.
8/17/76	(WR-16494) DG-1A	Start compressor failed to start.
8/23/76	(WR-15124) DG-1A	Would not start.
10/20/76	(WR-17407) DG-1B	Start compressor would not start.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: DGS (Sheet 2 of 2)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: 16 Failures

Date	Reported Failure	Cause
11/8/77	(WR-21871) DG-1A	Low lube oil pressure.
4/27/78	(WR-23610) DG-1B	Governor failure.
6/12/80	* DG-1A	No voltage control.
8/20/80	* DG-1B	No governor control.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

*Event listed in GPU memorandum on "Audit of Generator Start Failure Data," December 4, 1984.

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: F1R

SYSTEM: Air Handling

COMPONENT TYPE: Fan Unit

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: 13 Failures

Date	Reported Failure	Cause
6/24/75	(WR-9777) AH-E-19A	Short circuit.
8/17/78	(WR-24944) AH-E-1C	Fan motor failure.
9/29/78	(WR-21489) AH-E-1C	Excessive vibration--tripped.
2/3/83	(JT-CA110) AH-E-1C	Blown fuse.
3/25/83	(JT-CA466) AH-E 1A	Fan overloaded.
4/27/82	(JT-C8265) AH-E-1A	Motor seal failed--bad design.
1/19/79	(JT-C0302) AH-E-1B	Motor failed.
3/22/82	(JT-C8069) AH-E-1B	Water leakage into motor.
5/16/79	(JT-C1016) AH-E-1C	Water leakage into motor.
5/28/80	(JT-C3270) AH-E-17A	"Outer fan belt is off."
12/29/82	(JT-C9906) AH-E-17A	Fan tripped on overload--wiring error.
5/12/81	(JT-C5968) AH-E-95B	Breaker tripped on thermal overload.
1/19/77	(WR-18569) AH-E-17B	Fan belts flew off.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: F1S

SYSTEM: Air Handling

COMPONENT TYPE: Fan

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Five Failures

Date	Reported Failure	Cause
3/19/75	(WR-7962) AH-E-32	Breaker tripped--replaced faulty overload block.
1/7/81	(JT-C4883) AH-E-17A	Fan tripped after starting.
5/21/77	(WR-20096) AH-E-19B	Would not start.
7/22/77	(WR-20789) AH-E-17B	Would not start--damper interlock; damaged damper.
6/16/76	(WR-15841) AH-E-17A	Fan belts off.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: HXP, HXR

SYSTEM: All

COMPONENT TYPE: Heat Exchangers

FAILURE MODE: Excessive Leakage, Rupture

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P1R

SYSTEM: Nuclear Services Secondary Water

COMPONENT TYPE: Pump

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm a .. computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P1R

SYSTEM: Makeup

COMPONENT TYPE: Pump 1B (normally operating)

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1
COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P1S

SYSTEM: Nuclear Services Secondary Water

COMPONENT TYPE: Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Two Failures

Date	Reported Failure	Cause
4/1/78	(WR-23330) NS-P-1A	Breaker failure.
7/1/83	(JT-CB174) NS-P-1B	Relay failed to pick up after breaker closure.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P1S

SYSTEM: Makeup

COMPONENT TYPE: Pump 1B (normally operating)

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Makeup

COMPONENT TYPE: Pumps 1A and 1C

FAILURE MODE: Failure During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Two Failures

Date	Reported Failure	Cause
2/17/79	(JT-C0513) MU-P-1C	Tripped-repaired stator winding.
10/10/74	(WR-4905) MU-P-1A	Burned off motor lead.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Decay Heat

COMPONENT TYPE: Pump

FAILURE MODE: Failure During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Two Failures

Date	Reported Failure	Cause
9/19/79	(JT-C1875) DH-P-1A	"Broken."
7/3/79	(JT-C1329) DH-P-B	Pump tripped--motor grounded.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfi' and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Decay Heat Closed Cooling

COMPONENT TYPE: Pump

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Two Failures

Date	Reported Failure	Cause
10/21/81	(JT-C7083) DC-P-1A	Shaft sleeve replaced.
2/19/82	(JT-C7880) DC-P-1A	Packing smoked--replaced.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Building Spray

COMPONENT TYPE: Pump

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1
COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Motor-Driven EFW Pump

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Makeup

COMPONENT TYPE: Pumps 1A and 1C

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Two Failures

Date	Reported Failure	Cause
10/17/74	(WR-5069) MU-P-1C	Tripping latch spring out of position.
1/3/75	(WR-6471) MU-P-1C	Did not start on engineered safeguards signal--breaker failure.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Decay Heat

COMPONENT TYPE: Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Decay Heat Closed Cooling

COMPONENT TYPE: Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Building Spray

COMPONENT TYPE: Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: EFW

COMPONENT TYPE: Motor-Driven Pump

FAILURE MODE: Fail To Start

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
7/8/82	(JT-C8778) Pump 2A	Failed to start during SP 1303-11.39--fuse failure.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P3R

SYSTEM: Main Feedwater

COMPONENT TYPE: Pump

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Three Failures

Date	Reported Failure	Cause
10/7/74	(WR-4870) Pump B	Worn lube oil drive gear.
5/22/77	(WR-20102) Pump A	Auxiliary oil pump failure.
7/29/83	(JT-CB423) Pump A	Bearing failure.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P3ER

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Turbine-Driven Pump

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P3S

SYSTEM: Main Feedwater

COMPONENT TYPE: Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Two Failures

Date	Reported Failure	Cause
4/18/78	(WR-23527) P-B	Dirty contact on pressure switch.
10/3/79	(JT-C1832) P-B	Turbine trip.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P3ES

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Turbine-Driven Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P4R

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Four Failures

Date	Reported Failure	Cause
1/7/76	(WR-13311) NR-P-1A	Broken end bell on motor.
6/29/77	(WR-20501) NR-P-1C	Broken pump coupling.
8/29/79	(JT-C1645) NR-P-1A	Noisy shaft--pump replaced.
2/23/79	(JT-C0549) NR-P-1C	Motor failed.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P4S

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Two Failures

Date	Reported Failure	Cause
5/17/79	(JT-C1034) NR-P-1A	Breaker failed.
9/22/83	(JT-CC012) NR-P-1A	Tripped upon start--contacts adjusted.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P5R

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Pump

FAILURE MODE: Failure During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Three Failures

Date	Reported Failure	Cause
4/30/79	(JT-C0931) DR-P-1A	Excessive vibration (overhauled).
5/14/80	(JT-C3172) DR-P-1A	Excessive vibration--new bearings installed.
12/5/79	(JT-C2113) DR-P-1B	High vibration--rebuilt pump.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P5R

SYSTEM: Reactor Building Emergency Cooling

COMPONENT TYPE: Pump

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P5S

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
9/22/83	(JT-CB991) DR-P-1B	Pump will not rotate because diver's desilting hose stuck in pump.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: P5S

SYSTEM: Reactor Cooling Emergency Cooling

COMPONENT TYPE: Pump

FAILURE MODE: Fail To Start on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Three Failures

Date	Reported Failure	Cause
1/3/75	(WR-6477) RR-P-1B	Did not start on engineered safeguards signal.
12/15/77	(WR-22179) RR-P-1A	Cause unspecified.
3/15/77	(WR-18558) RR-P-1B	Control switch failure.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: SF

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Strainer

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
12/9/83	(JT-CC648) 1A	Clogged--would not clear by being backwashed.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: SF

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Strainer

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
7/25/81	(JT-C6380) S1C	Clogged.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: TR

SYSTEM: All

COMPONENT TYPE: Surge Tanks

FAILURE MODE: Rupture During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: VCR

SYSTEM: Control Building Chiller Unit

COMPONENT TYPE: Chiller

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Three Failures

Date	Reported Failure	Cause
2/3/79	(JT-C0436) AH-C-4B	Kept tripping.
4/12/79	(JT-C0858) AH-C-4B	Tripped on low oil pressure.
4/2/75	(WR-8197) AH-C-4B	Would not run.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: VCS

SYSTEM: Chilled Water

COMPONENT TYPE: Chiller Unit

FAILURE MODE: Fail To Start

Site-Specific Data

- Failure Data for Given Failure Mode: Five Failures

Date	Reported Failure	Cause
11/29/78	(WR-26068) 4A	Low oil pressure--no electric power to oil heater.
3/4/79	(JT-C0646) 4A	Antirecycle interlock would not clear.
8/29/79	(JT-C1644) 4A	Purge unit failed to start.
10/24/79	(JT-C1958) 4A	Vane control motor failure.
6/5/80	(JT-C3359) 4A	Low oil pressure.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: Reactor Building Emergency Cooler

COMPONENT TYPE: Motor-Operated Outlet Isolation Valve

FAILURE MODE: Fail To Operate on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
12/13/74	(WR-23964) RR-V-4A	Would not close.
5/23/78	(WR-6140) RR-V-4B	Faulty torque switch.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: Intermediate Cooling

COMPONENT TYPE: MUV

FAILURE MODE: Fail To Operate on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: Main Steam

COMPONENT TYPE: MOV

FAILURE MODE: Fail To Open or Close on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Six Failures

Date	Reported Failure	Cause
7/1/78	(WR-244.6) MS-V-5A* (WR-24456) MS-V-5B*	Both valves failed to operate with operator--both tripped on overload.
5/16/75	(WR-9037) MS-V-10B	Burned contacts in opening and closing circuits.
2/12/80	(JT-C2523) MS-V-8A	Motor tripped after only 10% open.
11/12/83	(JT-CC484) MS-V-10A	Stuck on seat--would not open electrically or manually.
3/11/79	(JT-C0688) MS-V-10B	Replaced contacts in close starter.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

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*Possible common cause failure.

TMI-1
COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: MOV

FAILURE MODE: Fail To Open or Close on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: 14 Failures

Date	Reported Failure	Cause
1/6/76	(WR-21535) NR-V-1A	Operator failed.
10/4/77	(WR-21535) NR-V-1A	Valve disc broken.
5/16/75	(WR-9055) NR-V-1B	Would not operate.
9/17/75	(WR-11383) NR-V-4A	Dirty contact on electrical interlock.
8/8/79	(JT-C1516) NR-V-1C	Dirty contact and relay.
10/17/83	(JT-CC261) NR-V-2	Valve operator.
10/2/82	(JT-C9?35) NR-V-8A	Stuck-open auxiliary contact.
4/9/83	(JT-CA547) NR-V-8C	Limtorque out of adjustment.
9/5/79	(JT-C1680) NR-V-10B	Motor.
5/18/83	(JT-CA871) NR-V-15B	Tripped on thermal overload.
7/3/81	(JT-C6286) NR-V-16C	Would not open.
2/22/78	(WR-22933) NR-V-1A (WR-21535)	Would not close or open during test.
7/16/75	(WR-10151) NR-V-1B	Would not close or open.
8/8/75	(WR-10565) NR-V-1B	Broken auxiliary block contractor.

- Failure Data Sour[illegible] [illegible]intenance Request Logbook
  [illegible]k Requests (microfilm and computer file)
  [illegible]o Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: Decay Heat

COMPONENT TYPE: MOV

FAILURE MODE Fail To Open or Close on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Eight Failures

Date	Reported Failure	Cause
3/6/80	(JT-C2729) DH-V2	Improperly set torque switch.
5/31/83	(JT-CA940) D[illegible]-V4A	Torque switch opened up when valve traveled partly open.
1/12/79	(JT-C0204) DH-V5B	Breaker tripped.
11/7/80	(JT-C4463) DH-V5B	Breaker tripped.
12/5/83	(JT-CC613) DH-V-7	Improperly set torque switch.
3/24/76	(WR-14493) DH-V1	Valve failed to open fully--replaced stem.
4/20/76	(WR-15048) DH-V2	Replaced operator, straightened valve stem.
12/3/74	(WR-6403) DH-V5A	Breaker tripped.

- Failure Data Source: [illegible]ntenan[illegible]est Logbook
  [illegible]crofilm and computer file)
  [illegible]rofilm and computer file)

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COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: Feedwater

COMPONENT TYPE: MOV

FAILURE MODE: Fail To Open or Close on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Seven Failures

Date	Reported Failure	Cause
11/19/74	(WR-5676A) FW-V-5A	Motor would not run--adjusted limit switch.
11/17/76	(WR-17769) FW-V-5A	Would not close from control room.
7/17/80	(JT-C3652) FW-V-5B	Would not stay open.
9/8/82	(JT-CB802) FW-V-1B	Replaced motor.
11/19/78	(WR-25988) FW-V-1B (WR-25966)	Would not operate electrically.
9/6/83	(JT-CB945) FW-V-92B	Hard packing--burned or overheated; repacked 10 rings.
11/6/78	(WR-25968) FW-V-5A	Would not open electrically.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: EFW

COMPONENT TYPE: MOV

FAILURE MODE: Fail To Open or Close on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
11/3/76	(WR-17565) EF-V-2A	Would not open or close electrically.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: Makeup

COMPONENT TYPE: MOV

FAILURE MODE: Fail To Open or Close on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Eight Failures

Date	Reported Failure	Cause
4/17/78	(WR-23510) MU-V-16D	Breaker tripped upon opening or closing.
7/25/79	(JT-C145L) MU-V-25	Blew control fuses--loose wires.
5/6/77	(WR-19852) MU-V-2A	Motor tripped--leads pinched.
10/31/74	(WR-5336) MU-V-16	Improper torque setting--would not open from control.
11/14/75	(WR-12440) MU-V-12	Operator could not engage valve.
5/21/76	(WR-15525) MU-V-2B	Would not close--stem.
5/21/76	(WR-15501) MU-V-1A	Operator could not engage valve--corrected itself.
3/29/77	(WR-19501) MU-V-1A	Would not operate electrically.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1T

SYSTEM: All

COMPONENT TYPE: Motor-Operated Valve

FAILURE MODE: Transfer Open or Closed

Site Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V3F

SYSTEM: All

COMPONENT TYPE: Air-Operated Valve

FAILURE MODE: Fail To Operate on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Ten Failures

Date	Reported Failure	Cause
1/12/81	(JT-C4897) MU-V-3	Valve binding--lack of lubrication.
2/17/83	(JT-CA226) MU-V-3	Improper alignment of solenoid valves.
1/16/81	(JT-C4949) MU-V-20	Air not bleeding off.
8/21/83	(JT-C8595) MU-V-26	Failed solenoid.
9/6/77	(WR-21198) MU-V-17	Would not respond on manual.
9/27/77	(WR-21424) MU-V-17	Stuck 70% open.
9/27/77	(WR-21425) FW-V-17B	Valve did not stroke.
6/20/83	(JT-C8130) IC-V-3	Stem to packing tight--would not open fully.
6/18/79	(JT-C0526) IC-V-3	Would not open fully.
5/30/79	(JT-C1147) IC-V-3	Opened half-way.
8/20/79	(WR-10775) MS-V-13B	Would not open or stay open--temperature and pressure switches replaced.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V3T

SYSTEM: All

COMPONENT TYPE: Air-Operated Valves

FAILURE MODE: Transfer Closed or Open During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Seven Failures

Date	Reported Failure	Cause
5/4/82	(JT-C8475) DC-V-65B	Broken air line.
5/2/79	(JT-C2715) FW-V-17B	Would not stay shut--air controller leaked.
4/4/83	(JT-CA606) FW-V-17B	Air leak in air regulator.
3/3/83	(JT-CA307) FW-V-17A	Air leak.
5/2/79	(JT-C0945) FW-V-17B	Packing leak.
11/5/74	(WR-5408) MS-V-3C	Body to bonnet leak caused vacuum leak.
1/17/76	(WR-13517) MS-V-3C	Air leakage.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7F

SYSTEM: All (except intermediate closed cooling and river water systems)

COMPONENT TYPE: Check Valve

FAILURE MODE: Fail To Operate on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
7/2/83	(JT-C8203) MU-V-95	Did not seat.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7FI

SYSTEM: Intermediate Closed Cooling

COMPONENT TYPE: Check Valve

FAILURE MODE: Fail To Operate on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
3/21/77	(WR-19431) IC-V-13B	Stuck open.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7FR

SYSTEM: River Water Systems

COMPONENT TYPE: Check Valve

FAILURE MODE: Fail to Operate on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: 10 Failures

Date	Reported Failure	Cause
7/29/81	(JT-C6401) DR-V-21B	Stuck closed--cleaned.
3/19/79	(JT-C0759) DR-V-22A	Did not close.
4/21/80	(JT-C3004) DR-V-22A	Stuck in closed position.
3/13/79	(JT-C0693) DR-V-6B	Made loud noise, replaced disk.
6/4/79	(JT-C1120) DR-V-6A	Stuck open--replaced clapper arm.
5/6/81	(JT-C5939) DR-V-6A	Hung open--worn internals.
12/12/79	(JT-C2150) DR-V-6B	Valve did not seat--internals replaced.
7/16/78	(WR-24559) NR-V-20B	Would not close.
7/16/75	(WR-10154) NR-V-20B	Would not close.
9/15/82	(JT-C9234) NR-V-20A	Would not close.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7L

SYSTEM: All (except intermediate closed cooling and river water systems)

COMPONENT TYPE: Check Valve

FAILURE MODE: Gross Reverse Leakage, Transfer Open

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
12/7/79	(JT-C2127) DH-V-14A	Loose disc.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7LI

SYSTEM: Intermediate Closed Cooling

COMPONENT TYPE: Check Valve

FAILURE MODE: Gross Reverse Leakage, Transfer Open

Site-Specific Data

- Failure Data for Given Failure Mode: Six Failures

Date	Reported Failure	Cause
8/11/83	(JT-CB534) IC-V-13A	Leaked allowing reverse rotation of pump.
9/16/83	(JT-CB906) IC-V-13A	Worn disc armhole.
12/21/79	(JT-C0336) IC-V-13A	Leaked back--replaced valve.
1/30/80	(JT-C2241) IC-V-13A	Leaked at 200 GPM--repaired.
6/12/81	(JT-C6146) IC-V-13A	Leaked--replaced valve inner parts.
9/8/81	(JT-C6744) IC-V-13A	Leaked through--repaired.
12/11/80	(JT-C4688) IC-V-13A	Leaked through.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7LR

SYSTEM: River Water Systems

COMPONENT TYPE: Check Valve

FAILURE MODE: Gross Reverse Leakage, Transfer Open

Site-Specific Data

- Failure Data for Given Failure Mode: One Failure

Date	Reported Failure	Cause
8/4/78	(JT-C0694) NR-V-20B	Leaked back through.

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7T

SYSTEM: All (except intermediate closed cooling and river water systems)

COMPONENT TYPE: Check Valve

FAILURE MODE: Plug/Transfer Closed during Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7TI

SYSTEM: Intermediate Closed Cooling

COMPONENT TYPE: Check Valve

FAILURE MODE: Plug/Transfer Closed during Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V7TR

SYSTEM: River Water Systems

COMPONENT TYPE: Check Valve

FAILURE MODE: Plug/Transfer Closed during Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V8T

SYSTEM: All

COMPONENT TYPE: Manual Valve

FAILURE MODE: Transfer Closed

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V10FS, V10FW

SYSTEM: RCS

COMPONENT TYPE: Code Safety Valve

FAILURE MODE: Fail To Open on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V10FS, V10FW

SYSTEM: Main Steam

COMPONENT TYPE: Code Safety Valve

FAILURE MODE: Fail To Open on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V10RS

SYSTEM: RCS

COMPONENT TYPE: Code Safety Valve

FAILURE MODE: Fail To Reseat After Opening (passing steam)

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V1ORS

SYSTEM: Main Steam

COMPONENT TYPE: Code Safety Valve

FAILURE MODE: Fail To Reseat After Opening (passing steam)

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V11FS, V11FW

SYSTEM: Pressurizer, Main Steam

COMPONENT TYPE: PORV

FAILURE MODE: Fail To Open

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

TMI-1
COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: V11RS, V11RW

SYSTEM: Pressurizer, Main Steam

COMPONENT TYPE: PORV

FAILURE MODE: Fail To Reseat on Demand

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: X1F

SYSTEM: Electric Power

COMPONENT TYPE: Main Transformer

FAILURE MODE: Fail During Operation

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

COMPONENT FAILURE DATA SUMMARY SHEET

DESIGNATOR: X2F

SYSTEM: Electric Po.er

COMPONENT TYPE: Station Trar 'ormer

FAILURE MODE: Fail During Opera ^n

Site-Specific Data

- Failure Data for Given Failure Mode: Zero Failures

Date	Reported Failure	Cause
	None	

- Failure Data Source: Maintenance Request Logbook
  Work Requests (microfilm and computer file)
  Job Tickets (microfilm and computer file)

APPENDIX A.2

COMPONENT SUCCESS DATA SUMMARY SHEETS

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: ACR

SYSTEM: Instrument Air

COMPONENT TYPE: Compressor

FAILURE MODE: Fail During Operation

One of two compressors is operating at all times. This leads to a total of 8.61×10^4 hours of operation for the two compressors.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: AD1

SYSTEM: Compressed Air System

COMPONENT TYPE: Air Dryer

FAILURE MODE: Fail During Operation

One of two air dryers operate at all times. This results in 8.61×10^4 hours of operation for the two air dryers.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: BC

SYSTEM: Electric Power

COMPONENT TYPE: Battery Charger

FAILURE MODE: Failure During Operation

Number of Chargers:	6
Number of Chargers on Line:	4
Number of Hours per Charger:	8.61×10^4
Total Hours:	$4 \times 8.61 \times 10^4 = 3.44 \times 10^5$

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: BTO

SYSTEM: Electric Power

COMPONENT TYPE: Battery

FAILURE MODE: Fail During Operation

Number of Batteries:	2
Number of Hours per Battery:	8.61×10^4
Total Hours:	$2(8.61 \times 10^4) = 1.72 \times 10^5$

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: CB4FO

SYSTEM: RPS

COMPONENT TYPE: Reactor Trip Breaker

FAILURE MODE: Fails To Open on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-4.1	6	140	840

There were 6 reactor trips during commercial operation of the unit, resulting in 36 breaker demands. Total number of breaker demands is then 876.

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: CRF

SYSTEM: Reactor Protection System

COMPONENT TYPE: Single Control Rod Assembly

FAILURE MODE: Fail To Insert on Demand

There have been six trips and four tests. The number of assemblies challenged in each demand is 61. Therefore, total number of demands is 10 x 61 = 610.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: DGS

SYSTEM: Emergency Diesel Generator Services

COMPONENT TYPE: Diesel Generator

FAILURE MODE: Fail To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-11.10	8	8	64
1302-5.30	2	7	14
1303-4.16	1	377	377
1303-5.2	18	23	414
			869

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: DGR1

SYSTEM: Emergency Diesel Generator Services

COMPONENT TYPE: Diesel Generator

FAILURE MODE: Fail During Operation

Test	Number of Hours Run Time per Test	Number of Tests	Total Run Time-Hours
1303-11.10	0.67	8	11
1302-5.30	0.50	7	4
1303-4.16	0.25	377	94
1303-5.2	4.50	23	104
			213

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: F1R

SYSTEM: All Air Handling Systems

COMPONENT TYPE: HVAC Fan

FAILURE MODE: Fail During Operation

One train of control room air handling with three fans is continuously running during unit operation and shutdown. This run time is much greater than the successful run times during scheduled tests. Total run time calculated in this way is 2.58×10^5.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: F1S

SYSTEM: All Air Handling Systems

COMPONENT TYPE: HVAC Fan

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1300-3N*	1	44	44
1303-5.5	12	71	852
1303-11.13	6	6	36
			932

*It is assumed for this test that the standby train is started, and the operating train is stopped and left in this configuration until the next test.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: HXP, HXR

SYSTEM: All

COMPONENT TYPE: Heat Exchanger

FAILURE MODE: Leak Rupture, Plugs

System	Number of Heat Exchangers	Number of Successful Hours	Time Span	Total Hours
Decay Heat Closed Cooling System	2	8.61×10^4	One train in use during cold shutdown.	1.72×10^5
Decay Heat Removal System	2	8.61×10^4	One train in use during cold shutdown.	1.72×10^5
Nuclear Services River Water System	4	8.61×10^4	Two trains in use during cold shutdown.	2.58×10^5
Nuclear Services Closed Cooling System	6	8.61×10^4	Six room coolers in continuous operation.	4.90×10^5
Reactor Building Emergency Cooling System	3	8.61×10^4	Last test June 1984.	2.58×10^5
Intermediate Cooling System	2	3.18×10^4	One heat exchanger during power operation.	6.36×10^4
Chilled Water System	2	8.61×10^4	One in use continuously.	1.72×10^5
				1.59×10^6

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P1R

SYSTEM: Nuclear Services Closed Cooling

COMPONENT TYPE: Nuclear Services Closed Cooling Pump

FAILURE MODE: Fail During Operation

Two pumps are operating continuously during normal unit operation, and one pump is operating during cold shutdown. Total pump run time is 1.18×10^5 hours.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P1R

SYSTEM: Makeup

COMPONENT TYPE: Normally Operating Makeup Pump

FAILURE MODE: Fail During Operation

One pump is operating continuously during unit power operation. It is assumed that this is the B makeup pump for most of the time. There is not sufficient information on the operation of makeup pumps during cold shutdown. When only the run time during power operation is considered a total of 3.18×10^5 hours is obtained. However, run meter has recorded 2.21×10^4 hours of run time for the B pump between November 1, 1976 and July 2, 1984. Extrapolation to the period September 2, 1974, through November 1, 1976, yields an additional 1.59×10^4 hours of operation for pump B. The total hours is then

$$2.21 \times 10^4 + 1.59 \times 10^4 = 3.8 \times 10^4 \text{ hours.}$$

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P1S

SYSTEM: Nuclear Services Closed Cooling

COMPONENT TYPE: Nuclear Services Closed Cooling Pump

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-11.10	6	8	48
1300-4E	3	5	15
1300-3J	3	40	120
1303-5.2	6	23	138
			321

One pump is operating continuously during cold shutdown, and two pumps are operating during power operation of the unit. This requires one pump to start every time the unit is started from cold shutdown. Total number of demands is then 337.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P1S

SYSTEM: Makeup

COMPONENT TYPE: Normally Operating Makeup Pump

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-11.10	1	8	8
1300-3H A/B	1	30	30
1303-11.27	1	2	2
			40

The B makeup pump is started every time the unit is started up from cold shutdown. There have been 16 startups from cold shutdown. Total number of demands on the B makeup pump is then 56.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Decay Heat Removal

COMPONENT TYPE: Decay Heat Removal Pump

FAILURE MODE: Fail During Operation

One train of decay heat removal system is in use continuously during cold shutdown. This time far exceeds the run time of the pumps during the scheduled testing. Total run time is 5.43×10^4 hours.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Makeup

COMPONENT TYPE: Standby Makeup Pumps (A and C)

FAILURE MODE: Fail During Operation

Test	Run Hours per Test	Number of Tests	Total Run Hours
1303-11.10	2.0	8	16
1300-3HA	0.50	13	7
1300-3HB	1.17	17	20
1303-11.8	1.0	7	7
1303-5.2	2.0	23	46
1303-11.27	2.0	2	4
			100

Run meters have recorded 1.13×10^3 hours of run time on the A and C makeup pumps between November 1, 1976, and July 2, 1984. Extrapolation of the run time to the period September 21, 1974, through November 1, 1976, yields a total of 3.79×10^3 hours for these pumps. This value was used in the quantification.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Decay Heat Closed Cooling

COMPONENT TYPE: Decay Heat Closed Cooling Pump

FAILURE MODE: Fail During Operation

One train of decay heat closed cooling system is in use continuously during cold shutdown. This time exceeds the run time of the pumps during the scheduled testing. Total run time is 5.43 x 10^4 hours.

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Reactor Building Spray

COMPONENT TYPE: Reactor Building Spray Pump

FAILURE MODE: Fail During Operation

Test	Run Hours per Test	Number of Tests	Total Number of Hours
1300-3A A/B (pump test)	0.50	32	16
1300-3A A/B (pump and bearing test)	1.17	11	13
1303-5.2	1.50	23	35
1303-11.10	1.00	8	8
1303-11.50	2.0	5	10
			82.0

Run meters have recorded 9.79×10^1 hours on both pumps between November 1, 1976, and July 2, 1984. Extrapolation of the run time to the period September 2, 1974, through November 1, 1976, yields a total of 121.3 operating hours. This value was used in the analysis.

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2R

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Motor-Driven Emergency Feedwater Pump

FAILURE MODE: Fail During Operation

Test	Run Hours per Test	Number of Tests	Total Number of Hours
1303-11.10	1.00	5*	5
1300-3FA/B	0.67	32	21
1300-3FB	1.33	20	27
1300-11.42	1.00	3	3
1300-11.39	0.67	10	7
			63

Run meters recorded 200.00 hours run time between November 1, 1976 and July 2, 1984. Extrapolation of run time to the period September 2, 1974, through November 1, 1976, yields a total of 248 hours of operation. This value was used in the analysis.

*Eight tests have been conducted, but only five include starting motor-driven emergency feedwater pumps.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Makeup

COMPONENT TYPE: Standby Makeup Pumps (A and C)

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1303-11.10	8	8	64
1300-3H A/B	2	30	60
1303-11.8	4	7	28
1303-5.2	8	23	184
1303-11.27	2	2	4
			340

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Decay Heat Removal

COMPONENT TYPE: Decay Heat Removal Pump

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-11.10	6	8	48
1303-11.54	2	2	4
1303-11.27	2	2	4
1300-38 A/B	2	69	138
1300-5.2	8	23	184
			338

The decay heat removal system is put into operation at each cold shutdown. There have been 16 cold shutdowns at this plant. Alternating the operation of the two trains is assumed to be carried out at the time the tests are performed. Total number of demands is then 354.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Decay Heat Closed Cooling

COMPONENT TYPE: Decay Heat Closed Cooling Pump

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1303-11.10	6	8	48
1303-11.50	2	5	10
1300-3A A/B	2	43	86
1303-11.54	2	2	4
1300-3B A/B	2	69	138
1300-3C	2	41	82
1300-3H A/B	2	30	60
1303-11.8	4	7	28
1303-5.2	6	23	138
			594

One train of decay heat closed cooling is started for operation during cold shutdowns. There have been 16 cold shutdowns of the unit. Total number of demands is then 604.

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COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Reactor Building Spray

COMPONENT TYPE: Reactor Building Spray Pump

FAILURE MODE: Fail To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1300-3A A/B	2	43	86
1303-5.2	6	23	138
1303-11.10	6	8	48
1303-11.50	2	5	10
			282

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P2S

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Motor-Driven Emergency Feedwater Pump

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1303-11.10	6	5*	30
1300-3F A/B	2	37	74
1300-11.42	3	3	9
1300-11.39	4	10	40
			153

*Eight tests have been conducted, but only five include starting motor-driven emergency feedwater pumps.

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P3R

SYSTEM: Main Feedwater

COMPONENT TYPE: Main Feedwater Pump

FAILURE MODE: Fail During Operation

The feedwater system is not in operation during cold shutdown. It is operating at every other time. The number of hours of operating time for each feedwater component is 3.18×10^4 hours. Two main feedwater pumps are operated for a major portion of the time. Total run time for main feedwater pump is then 6.36×10^4 hours.

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P3ER

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Turbine-Driven Emergency Feedwater System

FAILURE MODE: Fail During Operation

Test	Run Time per Test	Number of Tests	Total Run Time-Hours
1300-11.42	0.25	3	1
1303-11.39	0.5	10	5
1303-3G A	0.25	26	7
1300-3G B	0.58	35	20
			33

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P3S

SYSTEM: Main Feedwater

COMPONENT TYPE: Main Feedwater Pump

FAILURE MODE: Fails To Start on Demand

The number of demands on the feedwater system are based on an estimated system startup rate of 10 per calendar year in addition to 16 startups of the unit from cold shutdown. Total number of demands ≈ 60. Two main feedwater pumps are operated for a major portion of the time the unit is operating. Total number of demands on the main feedwater pump is then 120.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P3ES

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Turbine-Driven Emergency Feedwater System

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1300-11.42	1	3	3
1303-11.39	2	10	20
1300-3G A	1	26	26
1300-3G B	2	35	70
			119

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P4R

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Nuclear Services River Water Pump

FAILURE MODE: Fail During Operation

Two pumps are operating continuously during normal unit operation, and one pump is operating during cold shutdown. Total pump run time is then 1.18×10^5 hours.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P4S

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Nuclear Services River Water Pump

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1303-11.10	6	8	48
1300-4C A/B	3	5	15
1300-3I A/B	3	71	213
1303-5.2	6	23	138
			414

One pump is operating continuously during cold shutdown, and two pumps are operating during power operation of the unit. This requires one pump to start every time the unit is started from cold shutdown. Total number of demands is then 430.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P5R

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Decay Heat River Wat..r Pump

FAILURE MODE: Fail During Operation

One train of the decay heat river water system is continuously in use during cold shutdown. This run time exceeds the run time for pumps during scheduled testing. Total run time is then 5.43×10^4 hours.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P5R

SYSTEM: Reactor Building River Water

COMPONENT TYPE: Reactor Building River Water Pump

FAILURE MODE: Fail During Operation

Test	Number of Hours per Test	Number of Tests	Total Number of Run Hours
1300-3k A	0.50	30	15
1300-3k B	1.17	41	48
1300-11.9	0.67	7	5
1303-5.2	1.50	23	35
1303-11.10	1.00	8	8
			111

Run meters have recorded 210 hours of pump run time between November 1, 1976, and July 2, 1984. Extrapolation of the run time to the period September 2, 1974, through November 1, 1976, yields a total of 249 hours of operation. This value was used in the analysis.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P5S

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Decay Heat River Water Pump

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1303-11.10	6	8	48
1303-11.50	2	5	10
1300-3A A/B	2	43	86
1303-11.54	2	2	4
1300-3D	2	48	96
1300-3HA/B	2	30	60
1303-11.8	2	7	14
1303-5.2	6	23	138
			456

The decay heat river water system is started up at cold shutdown together with decay heat removal system. There have been 16 cold shutdowns at the unit. Total number of demands is then 472.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: P5S

SYSTEM: Reactor Building River Water

COMPONENT TYPE: Reactor Building River Water Pump

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1300-3K A/B	2	71	142
1303-11.9	2	7	14
1303-5.2	6	23	138
1303-11.10	6	8	48
			342

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: SF

SYSTEM: All

COMPONENT TYPE: Screen, Filter

FAILURE MODE: Plug During Operation

System	Number of Screens	Number of Operating Hours	Time Span Description	Total Hours
Decay Heat River Water System	2	8.61×10^4	One train in use during cold shutdown.	1.72×10^5
Nuclear Services River Water System	3	8.61×10^4	One train in use during cold shutdown.	2.58×10^5
Reactor Building River Water Systems	2	8.61×10^4	Last test verified screens on June 1984.	1.72×10^5
				6.02×10^5

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: TR

SYSTEM: All

COMPONENT TYPE: Surge Tank

FAILURE MODE: Ruptures

System	Number of Tanks	Number of Successful Hours (power operation and cold shutdown)	Total Hours
Decay Heat Closed Cycle System	2	8.61×10^4	1.72×10^5
Reactor Coolant System	2	8.61×10^4	1.72×10^5
Intermediate Closed Loop Cooling System	1	8.61×10^4	8.61×10^4
Nuclear Services Closed Cooling System	1	8.61×10^4	8.61×10^4
Emergency Feedwater System	2	8.61×10^4	1.72×10^5
			6.89×10^5

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: VCR

SYSTEM: Chilled Water

COMPONENT TYPE: Chiller

FAILURE MODE: Fails During Operation

One train of the chilled water system is continuously in operation during power operation and cold shutdown. Total operating hours is then 8.61×10^4.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: VCS

SYSTEM: Chilled Water

COMPONENT TYPE: Chiller

FAILURE MODE: Fails To Start on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1300-3N*	1	44	44
1300-5.5*	1	71	71
			115

In addition, the chillers are alternated every other week. This adds another 26 starts for every year. For the 10-year period covered by the data collection, the total number of demand is 260 + 115 = 375.

*For the tests, the standby chiller is started, and the operating pump is stopped.

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: All Systems

COMPONENT TYPE: Motor-Operated Valve

FAILURE MODE: Fail To Open on Demand

Test/System	Number of Demands Per Test	Number of Tests	Total Number of Demands	Other Demands
1300-3P	2	10	20	
1303-11.50	2	5	10	
1300-3A A/B	2	43	86	
1300-11.54	2	2	4	
1302-6.16	1	3	3	
1300-3D	2	48	96	Plus 16 from Unit Shutdowns
1303-11.42	4	3	12	
1303-11.39	4	10	40	
1300-3 G A	3	26		
1300-3 G B	4	35	218	
1300-3H A/B	7	17	179	
1303-1127	10	2	20	
1303-11.8	12	7	84	
1303-11.21	2	8	16	
1300-3R	15	20	300	
1300-4C A/B	3	5	15	
1300-3C A/B	3	71	213	Plus 32 from Unit Startups
1300-3K A/B	7	71	287	
1303-11.9	8	7	56	
1300-3Q	4	40	160	
1303-11.10	20	8	160	
1303-11.26	5	24	120	
1305-5.2	84	23	1,932	
Decay Heat Removal System	--	--	--	48 from Unit Shutdowns
Decay Heat River Water System	--	--	--	16 from Unit Shutdowns

Total Number of Demands = 4.43×10^3

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V1F

SYSTEM: All Systems

COMPONENT TYPE: Motor-Operated Valve

FAILURE MODE: Fail To Close on Demand

Test/System	Number of Demands Per Test	Number of Tests	Total Number of Demands	Other Demands
1300-31	2	10	20	
1300-11.50	2	5	10	
1300-3A A/B	2	43	86	
1300-11.54	2	2	4	
1302-6.16	1	3	3	
1300-3D	2	48	96	Plus 16 from Unit Startups
1303-11.42	4	3	12	
1303-11.39	4	10	40	
1300-3G A	3	26		
1300 3G B	4	35	218	
1300 3H A/B	17	17	179	
1303-11.27	10	2	20	
1303-11.8	12	7	84	
1303-11-21	2	8	16	
1300-3R	15	20	300	
1300-4C A/B	3	5	15	
1300-3L A/B	3	71	213	Plus 32 from Unit Shutdowns
1300-3k A/B	7	71	287	
1300-11.9	18	7	56	
1300-3Q	4	40	160	
1303-11.10	20	8	160	
1303-11.26	5	24	120	
1305-5.2	84	23	1,932	
Decay Heat Removal System				48 from Unit Startups
Decay Heat River Water System				16 from Unit Startups

Total Number of Demands = 4.43×10^3

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V1T

SYSTEM: All Systems

COMPONENT TYPE: Motor-Operated Valve

FAILURE MODE: Transfers Closed

System	Number of Valves	System Last Tested/Operated	Number of Verified Valve Hours	Total Valve Hours
Main Steam	4	2/79	3.18×10^4	1.27×10^5
Makeup	14	2/79	3.18×10^4	4.45×10^5
Reactor Building Spray	2	5/84	8.61×10^4	1.72×10^5
Decay Heat River Water	1	Open During Shutdown	5.43×10^4	5.43×10^4
Decay Heat Removal	4	Open During Shutdown	5.43×10^4	2.17×10^5
Emergency Feedwater	5	6/84	8.61×10^4	4.31×10^5
Nuclear Services	13	Power Operation	3.18×10^4	7.94×10^5
River Water	7	Cold Shutdown	5.43×10^4	
Nuclear Services Closed Cooling	3	2/79	3.18×10^6	9.56×10^6
Reactor Coolant	1	2/79	$3/18 \times 10^4$	3.18×10^4
Inter-mediate Closed Cooling	5	2/79	3.18×10^4	1.59×10^5
Feedwater	18	2/79	3.18×10^4	5.72×10^5
Reactor Building River Water	3	5/84	8.16×10^4	2.58×10^5

Total Valve Hours = 3.36×10^6

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V1T

SYSTEM: All Systems

COMPONENT TYPE: Motor-Operated Valve

FAILURE MODE: Transfers Open

Test/System	Number of Valves	System Last Tested/Operated	Number of Verified Valve Hours	Total Valve Hours
1303-11.27 Makeup System and Decay Heat Removal System	8	8/83	3.93×10^4	3.14×10^5
1300-3A A/B Reactor Building Spray	2	5/84	8.61×10^4	1.72×10^5
Nuclear Services	4	Power Operation	3.18×10^4	5.62×10^5
River Water	8	Shutdown Operation	5.43×10^4	
Intermediate Cooling System	1	2/79	3.18×10^4	3.18×10^4
Main Steam System	2	2/79	3.18×10^4	6.36×10^5

Total Valve Hours = 1.15×10^6

Note: Although there are many normally closed MOVs at TMI-1, only a few are verified as staying closed.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V3F

SYSTEM: All Systems

COMPONENT TYPE: Air-Operated Valve

FAILURE MODE: Fail To Open on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1300-3Q	5	40	200
1303-5.2	6	23	138
1303-11.42	3	3	9
1300-3G A/B	2	61	122
1303-11.9	2	7	14
1303-11.10	6	8	48
Feedwater System Startups*	9	60	590
1303-1126	12	24	288
			1,359

*There have been 60 feedwater startups, based on an estimate of 10 per calendar year plus 16 cold shutdowns.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V3F

SYSTEM: All Systems

COMPONENT TYPE: Air-Operated Valve

FAILURE MODE: Fails To Close on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1300-3Q	5	40	200
1303-5.2	6	23	138
1303-11.42	3	3	9
1300-3G A/B	2	61	122
1303-11.9	2	7	14
1303-11.10	6	8	48
Feedwater System Startups*	9	60	590
1303-11.26	12	24	288
			1,359

*There have been 60 feedwater startups, based on an estimate of 10 per calendar year plus 16 cold shutdowns.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V3T

SYSTEM: All Systems

COMPONENT TYPE: Air-Operated Valve

FAILURE MODE: Transfers Closed

System Test	Number of Valves	System Last Operated/ Tested	Number of Verified Valve Hours	Total Number of Valve Hours
Makeup System	5	2/79	3.18×10^4	1.59×10^5
Nuclear Services Closed Cooling System	6 1 6 (90% time) 2 (10% time)	2/79 6/84 Cold Shut-down	3.18×10^4 8.61×10^4 5.43×10^4	1.91×10^5 8.61×10^4 3.04×10^5
Feedwater System	9	2/79	3.18×10^4	2.86×10^5
Decay Heat Closed Cycle	2	6/84	8.61×10^4	1.72×10^4
Emergency Feedwater System	3	6/84	8.61×10^4	5.17×10^5

Total Valve Hours = 1.56×10^6

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7F (Sheet 1 of 2)

SYSTEM: All Systems (except intermediate closed cooling and river water systems)

COMPONENT TYPE: Check Valve

FAILURE MODE: Fails To Operate on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1300-3H A/B	12	30	392 (includes 16 unit startups)
1303-11.27	40	2	80
1303-11.8	22	7	154
1303-11.54	8	2	16
1300-3P	8	10	80
1300-3A A/B	8	43	344
1303-11.50	4	5	20
1300-3B A/B	12	69	860 (includes 16 unit shutdowns)
1300-3G A	8	26	208
1300-3G B	20	35	700
1300-3F	10	37	370
1300-11.42	24	3	72
1300-3N	2	44	88

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7F (Sheet 2 of 2)

SYSTEM: All Systems (except intermediate closed cooling and river water systems)

COMPONENT TYPE: Check Valve

FAILURE MODE: Fails To Operate on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1300-3J	6	40	272 (includes 16 startups)
1300-11.21	4	8	32
Feedwater System	16	60 Start-ups	960
1303-11.39	28	10	280

Total Number of Demands = 4,928

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7FR

SYSTEM: River Water System

COMPONENT TYPE: Check Valve

FAILURE MODE: Fails To Operate on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
1300-3D	4	48	224 (includes 16 unit shutdowns)
1300-4C A/B	6	5	30
1300-3I A/B	6	71	426
1300-4E	6	5	32
1300-3K A/B	4	71	284
1303-11.9	4	7	28
OPS-S227	2	--	1,212
OPS-S52	2 (power operation) 4 (cold shutdown)	--	1,246

Total Number of Demands = 3,480

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7FI

SYSTEM: Intermediate Closed Cooling

COMPONENT TYPE: Check Valve

FAILURE MODE: Fails To Operate on Demand

Test	Number of Demands per Test	Number of Tests	Total Number of Demands
Operation of System	12	16 startups and 7 failures of operating pump train	276

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7L

SYSTEM: All Systems (except intermediate closed cooling and river water systems)

COMPONENT TYPE: Check Valve

FAILURE MODE: Transfers Open, Gross Reverse Leakage

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Makeup System	2	Power Operation	3.18×10^4	6.36×10^4
Nuclear Services Closed Cooling	1 2	Power Operation Shutdown	3.18×10^4 5.43×10^4	1.40×10^5

Total Valve Hours = 2.04×10^5

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7LI

SYSTEM: Intermediate Closed Cooling

COMPONENT TYPE: Check Valve

FAILURE MODE: Transfers Open, Gross Reverse Leakage

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Intermediate Closed Cooling	1	6/84	4.23×10^4	4.23×10^4

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7LR

SYSTEM: River Water Systems

COMPONENT TYPE: Check Valve

FAILURE MODE: Transfers Open, Gross Reverse Leakage

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Nuclear Services River Water	1	Power Operation	3.18×10^4	1.40×10^5
	2	Shutdown	5.43×10^4	

Total Valve Hours = 1.40×10^5

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7T

SYSTEM: All Systems (except intermediate closed cooling and river water systems)

COMPONENT TYPE: Check Valve

FAILURE MODE: Transfers Closed

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Makeup System	12	2/79	3.18×10^4	3.82×10^5
Decay Heat Removal	3	Cold Shutdown	5.43×10^4	1.63×10^5
Chilled Water System	1	6/84	8.61×10^4	8.61×10^4
Nuclear Services Closed Cooling System	3 1	Power Operation Shutdown	3.18×10^4 5.43×10^4	1.49×10^5
Feedwater System	8	2/79	3.18×10^4	2.54×10^5

Total Valve Hours = 1.03×10^{6}

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7TI

SYSTEM: Intermediate Closed Cooling

COMPONENT TYPE: Check Valve

FAILURE MODE: Transfers Closed

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Intermediate Closed Cooling	6	6/84	4.23×10^4	2.54×10^5

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V7TR

SYSTEM: River Water Systems

COMPONENT TYPE: Check Valve

FAILURE MODE: Transfers Closed

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Decay Heat River Water	1	Cold Shutdown	5.43×10^4	5.43×10^4
Nuclear Services River Water	6 1	Power Operation Shutdown	3.18×10^4 5.43×10^4	1.18×10^5
Decay Heat River Water	1	OPS-S227	702	702
Nuclear Services River Water	1	OPS-S52	623	623

Total Valve Hours = 1.74×10^5

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V8T (Sheet 1 of 2)

SYSTEM: All Systems

COMPONENT TYPE: Manual Valve

FAILURE MODE: Transfers Closed

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Makeup System	28	2/79	3.18×10^4	8.90×10^5
Decay Heat Removal System	12	6/84	8.61×10^4	1.03×10^6
Auxiliary Spray Line	2	2/79	3.18×10^4	7.36×10^4
Decay Heat Closed Cooling System	10	6/84	8/61 x 10^4	8.61×10^5
Decay Heat River Water System	2	6/84	8.61×10^4	1.72×10^5
Reactor Building Spray System	10	5/84	8.61×10^4	8.61×10^5
Chilled Water System	34	6/84	8.61×10^4	1.08×10^6
Inter-mediate Cooling System	8	2/79	3.18×10^4	2.54×10^5

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V8T (Sheet 2 of 2)

SYSTEM: All Systems

COMPONENT TYPE: Manual Valve

FAILURE MODE: Transfers Closed

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Nuclear Services Closed Cooling System	32	During Plant Operation	3.18×10^4	1.02×10^6
	5	During Shutdown	5.43×10^4	1.60×10^5
	20	Continuous Operation	8.61×10^4	1.63×10^6
Emergency Feedwater System	7	6/84	8.61×10^4	6.03×10^5
Feedwater System	13	2/79	3.18×10^4	4.13×10^5

Total Number of Valve Hours = 9.05×10^6

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V8T

SYSTEM: All Systems

COMPONENT TYPE: Manual Valve

FAILURE MODE: Transfers Open

System	Number of Valves	System Last Tested/Verified	Number of Verified Hours	Total Number of Valve Hours
Nuclear Services Closed Cooling	2	6/84	8.61×10^4	1.72×10^5
	2	Power Operation	3.18×10^4	6.36×10^4
	1	Cold Shutdown	5.43×10^4	5.43×10^4
Inter-mediate Cooling System	1	2/79	3.18×10^4	3.18×10^4
Makeup System	3	2/79	3.18×10^4	9.54×10^4

Total Number of Valve Hours = 4.17×10^5

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V10FS, V10FW

SYSTEM: RCS

COMPONENT TYPE: Code Safety Valve

FAILURE MODE: Fails To Open on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-11.2	6	16	96

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V10FS, V10FW

SYSTEM: Main Steam

COMPONENT TYPE: Code Safety Valve

FAILURE MODE: Fails To Open on Demand

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-11.3	5	7	35

The relief valves may open on large steam demand reductions and after reactor trips. No record is kept of how many opened. These demands have not been included. Total number of main steam relief valve demands is then 35.

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V1ORS

SYSTEM: RCS

COMPONENT TYPE: Code Safety Valve

FAILURE MODE: Fails To Reseat after Opening (passing steam)

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-11.2	6	16	96

TMI-1

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V1ORS

SYSTEM: Main Steam

COMPONENT TYPE: Code Safety Valve

FAILURE MODE: Fails To Reseat after Opening (passing steam)

Test	Number of Demands per Test	Number of Tests	Total Demands
1303-11.3	5	7	35

The relief valves may open on large steam demand reductions and after reactor trips. No record is kept of how many opened. These demands have not been included.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V11FS, V11FW

SYSTEM: Pressurizer, Main Steam

COMPONENT TYPE: PORV/ADS

FAILURE MODE: Fail To Open on Demand

There are three power-operated relief valves: one on pressurizer and two on main steam. They are demanded to open on reactor trips. There have been a total of six trips, leading to a total of 18 demands on PORV/ADS.

TMI-1
COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: V11RS, V11RW

SYSTEM: Pressurizer, Main Steam

COMPONENT TYPE: PORV/ADS

FAILURE MODE: Fail To Reseat after Opening

A total of 18 power-operated relief valve demands to reseat after opening is estimated, based on 18 demands to open. (See notes on fail to open on demand success data summary sheet.)

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: X1F

SYSTEM: Electric Power

COMPONENT TYPE: Main Transformers 1A and 1B

FAILURE MODE: Fail During Operation

Both transformers (1A and 1B) operate at all times. Total hours per transformer = 8.6×10^4. Total transformer hours of operation is then 1.72×10^5.

COMPONENT SUCCESS DATA SUMMARY SHEET

DESIGNATOR: X2F

SYSTEM: Electric Power

COMPONENT TYPE: Station Service Transformer

FAILURE MODE: Fail During Operation

All 16 transformers operate at all times. Total operating hours per transformer = 8.6×10^4. Total transformer hours of operation is then 1.38×10^6.

APPENDIX B

TMI-1 COMPONENT COMMON CAUSE FAILURE DATA SUMMARY SHEETS

TMI-1

SITE-SPECIFIC COMPONENT COMMON CAUSE FAILURE DATA SUMMARY SHEET

SYSTEM: All

COMPONENT TYPE: Motor-Operated Valve

FAILURE MODE: Fails To Operate on Demand

Site-Specific Data

Date	Reported Failure	Cause
7/1/78	(WR-24456) MS-V-5A, MS-V-5B	Both valves failed to operate--both tripped on overload.

Failure Data Source: Maintenance Request Logbook
Work Requests (microfilm and computer file)
Job Tickets (microfilm and computer file)

TMI-1

COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Standby Motor-Driven Pump (MU, CBS)
FAILURE MODE: Fails To Start on Demand

Sheet 1 of 2

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	26.5																			$\bar{n}_1$ = 26.5
2				1.0	2															$\bar{n}_2$ = 2.0
3		1	1.2			1.0	3													$\bar{n}_3$ = 4.2
4																				$\bar{n}_4$ = 0.0

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2.22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Salem 1 (November 1979), NP-3967, p. 3-96.
Event 2: Robinson 2 (July 1973), NP-3967, p. 3-98.
Event 3: Robinson 2 (November 1977), NP-3967, p. 3-98.

TMI-1

COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Standby Motor-Driven Pump (DHR, DHCC)
FAILURE MODE: Fails To Start on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	35.45																			$\bar{n}_1$ = 35.45
2		1	2	1	2	1	2													$\bar{n}_2$ = 6.0
3																				$\bar{n}_3$ = 0.0
4																				$\bar{n}_4$ = 0.0

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Peach Bottom 2 (April 1978), NP-3967, p. 3-109.
Event 2: Brunswick 1 (April 1979), NP-3967, p. 3-109.
Event 3: Browns Ferry 1 (September 1974), NP-3967, p. 3-110.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: River Water Pump
FAILURE MODE: Fails To Start on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	49.3																			$\bar{n}_1$ = 49.3
2		1.0	2																	$\bar{n}_2$ = 2.0
3																				$\bar{n}_3$ = 0.0
4																				$\bar{n}_4$ = 0.0

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Oyster Creek (November 1978), NP-3967, p. 3-141.

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TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Standby Motor-Driven Pump (DHR, DHCC)
FAILURE MODE: Fails during Operation

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	33.75																			$\bar{n}_1$ = 33.75
2		1	.02																	$\bar{n}_2$ = .02
3																				$\bar{n}_3$ = 0.0
4																				$\bar{n}_4$ = 0.0

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Beaver Valley 1 (January 1978), NP-3967, p. 3-107.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: River Water Pump
FAILURE MODE: Fails during Operation

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	87.9	.9	5																	$\bar{n}_1$ = 92.40
2		.05	2																	$\bar{n}_2$ = .10
3		.03	3																	$\bar{n}_3$ = .09
$\geq$ 4		.02	4	1.0	.05															$\bar{n}_4$ = .13

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Pilgrim (May 1974), NP-3967, p. 3-140.
Event 2: Hatch 1 (August 1979), NP-3967, p. 3-141.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: EFW Pump (pump portion)
FAILURE MODE: Fails during Operation

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	
1	35.7																			$\overline{n}_1$ = 35.7
2																				$\overline{n}_2$ = 0
3		1.0	.3																	$\overline{n}_3$ = .3
4																				$\overline{n}_4$ = 0

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Kewaunee (November 1975), NP-3967, p. 3-127.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: EFW Pump (pump portion)
FAILURE MODE: Fails To Start

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	37.1																			$\bar{n}_1$ = 37.1
2																				$\bar{n}_2$ = 0
3																				$\bar{n}_3$ = 0
4																				$\bar{n}_4$ = 0

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3967 report, Reference 2-22. None of the events listed in Table 3-28 of NP-3967 involving EFW pumps was considered applicable to TMI-1 for this failure mode of EFW pumps.

TMI-1

COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Diesel Generator
FAILURE MODE: Fails To Start on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	245.8																			$\bar{n}_1$ = 245.8
2		1.0	2	1.0	.2			1.0	.2	1.0	2	1.0	2	1	2					$\bar{n}_2$ = 8.4
3						1.0	3													$\bar{n}_3$ = 3.0
4																1.0	4			$\bar{n}_4$ = 0.4

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Fort Calhoun (July 1973), NP-3967, p. 3-24.
Event 2: Zion (July 1974), NP-3967, p. 3-26.
Event 3: Peach Bottom 2 and 3 (June 1977), NP-3967, p. 3-27.
Event 4: Farley 1 (September 1977), NP-3967, p. 3-28.
Event 5: Cook 1 (December 1977), NP-3967, p. 3-29.
Event 6: North Anna (February 1981), NP-3967, p. 3-30.
Event 7: Three Mile Island 1 (April 1974), NP-3967, p. 3-30.
Event 8: Browns Ferry 1 and 3 (May, June 1981), NP-3967, p. 3-31.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Diesel Generator
FAILURE MODE: Fails during Operation

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	173									.9	2									$\bar{n}_1$ = 174.8
2		1.0	2			1.0	2	1.0	.2	.1	2									$\bar{n}_2$ = 4.4
3				1.0	2.1															$\bar{n}_3$ = 2.1
$\geq$ 4																				$\bar{n}_4$ = 0.0

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Salem (July 1977), NP-3967, p. 3-25.
Event 2: Yankee Rowe (August 1977), NP-3967, p. 3-25.
Event 3: Millstone 2 (May 1977), NP-3967, p. 3-27.
Event 4: Peach Bottom 2 (February 1978), NP-3967, p. 3-28.
Event 5: Arkansas One 1 (August 1979), NP-3967, p. 3-29.

TMI-1

COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Standby Motor-Driven Pump (MU, CBC)
FAILURE MODE: Fails during Operation

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	
1	52.3																			$\overline{n}_1$ = 52.3
2		1	2																	$\overline{n}_2$ = 2.0
3																				$\overline{n}_3$ = 0.0
4																				$\overline{n}_4$ = 0.0

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: North Anna 1 (July 1978), NP-3967, p. 3-97.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Reactor Trip Breaker
FAILURE MODE: Fails To Open on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	
1	53.1																			$\overline{n}_1 =$ 53.1
2		1	2	1	2			1	2	1		1	.2	1	.2	1	.2			$\overline{n}_2 =$ 6.6
3																		1	.3	$\overline{n}_3 =$ .3
4						1	4			1	.4									$\overline{n}_4 =$ 4.4

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Connecticut Yankee (December 1981), NP-3967, p. 3-12.
Event 2: Oconee 1 (February 1979), NP-3967, p. 3-12.
Event 3: St. Lucie (November 1980), NP-3967, p. 3-12.
Event 4: Salem 1 (February 1983), NP-3967, p. 3-13.
Event 5: Calvert Cliffs 1 (March 1983), NP-3967, p. 3-14.
Event 6: Calvert Cliffs 2 (March 1983), NP-3967, p. 3-14.
Event 7: McGuire 1 (March 1983), NP-3967, p. 3-14.
Event 8: Maine Yankee (March 1983), NP-3967, p. 3-14.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Motor-Operated Valves
FAILURE MODE: Fail To Operate on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures**
		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6		Event 7		Event 8		Event 9		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1	847.7																			
2				1.0	2	1.0	2							1.0	2	1.0	.2	1.0		
3		1.0	1.2									1.0	1.2							
$\geq$ 4								1.0	1.3	1.0	1.3									

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 1: Cook 2 (January 1979), NP-3967, p. 3-38.
Event 2: Turkey Point (April 1979), NP-3967, p. 3-38.
Event 3: Arkansas One (April 1980), NP-3967, p. 3-38.
Event 4: Palisades (June 1971), NP-3967, p. 3-39.
Event 5: Oconee 2 (October 1975), NP-3967, p. 3-39.
Event 6: Trojan (October 1976), NP-3967, p. 3-40.
Event 7: North Anna (August 1978), NP-3967, p. 3-40.
Event 8: Kewaunee (September 1975), NP-3967, p. 3-41.
Event 9: Zion 2 (October 1975), NP-3967, p. 3-41.

**See sheet 5 for total failures.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Motor-Operated Valves
FAILURE MODE: Fail To Operate on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures**
		Event 10		Event 11		Event 12		Event 13		Event 14		Event 15		Event 16		Event 17		Event 18		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1																				
2		1.0	2	1.0	2	1.0	2	1.0	2	1.0	2			1.0	2	1.0	2			
3																				
≥ 4												1.0	5					1.0	2.2	

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 10: Arkansas One 1 (August 1981), NP-3967, p. 3-42.
Event 11: Oconee 1 (November 1975), NP-3967, p. 3-42.
Event 12: Oconee 2 (December 1975), NP-3967, p. 3-42.
Event 13: Rancho Seco (November 1976), NP-3967, p. 3-42.
Event 14: Cook 1 (November 1977), NP-3967, p. 3-44.
Event 15: Oconee 2 (June 1979), NP-3967, p. 3-46.
Event 16: Oconee 2 (December 1979), NP-3967, p. 3-47.
Event 17: Cook 1 (March 1981), NP-3967, p. 3-47.
Event 18: Monticello (July 1972), NP-3967, p. 3-48.

**See sheet 5 for total failures.

COMMON CAUS' PARAMETER SUMMARY SHEET

COMPONENT: Motor-Operated Valves
FAILURE MODE: Fail To Operate on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures**
		Event 19		Event 20		Event 21		Event 22		Event 23		Event 24		Event 25		Event 26		Event 27		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1																				
2		2	1.1		1	1.0	2	1.0	2			1.0	2	1.0	.2	1.0	2	1.0	1.1	
3																				
≥ 4				1.0	1.3					1.0	1.3									

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event :): Browns Ferry 3 (Ma y 1975), NP-3967, p. 3-48.
Event 20: Robinson 2 (Janu.ry 1981), NP-3967, p. 3-49.
Event 21: Surry 2 (July 1981), NP-3967, p. 3-49.
Event 22: Dresden 2 (August 1973), NP-3967, p. 3-50.
Event 23: Browns Ferry 2 (December 1974), NP-3967, p. 3-51.
Event 24: Pilgrim (September 1974), NP-3967, p. 3-51.
Event 25: Vermont Yankee (May 1976), NP-3967, p. 3-52.
Event 26: Dresden 3 (September 1975), NP-3967, p. 3-52.
Event 27: Browns Ferry 1 (September 1974), NP-3967, p. 3-53.

**See sheet 5 for total failures.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Motor-Operated Valves
FAILURE MODE: Fail To Operate on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures**
		Event 28		Event 29		Event 30		Event 31		Event 32		Event 33		Event 34		Event 35		Event 36		
		p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	p	$\bar{n}$	
1																				
2		1.0	2	1.0	2	1.0	2	1.0	2	1.0	2	1.0	.2	1.0	2	1.0	1.1	1.0	2	
3																				
≥ 4																				

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 28: Hatch 2 (September 1978), NP-3967, p. 3-53.
Event 29: Pilgrim (July 1979), NP-3967, p. 3-54.
Event 30: Hatch 2 (May 1980), NP-3967, p. 3-54.
Event 31: Hatch 2 (May 1982), NP-3967, p. 3-54.
Event 32: Dresden 2 (October 1973), NP-3967, p. 3-54.
Event 33: Arnold (March 1976), NP-3967, p. 3-55.
Event 34: Dresden 2 (May 1975), NP-3967, p. 3-56.
Event 35: Cooper (October 1980), NP-3967, p. 3-56.
Event 36: Vermont Yankee (September 1976), NP-3967, p. 3-56.

**See sheet 5 for total failures.

TMI-1
COMMON CAUSE PARAMETER SUMMARY SHEET

COMPONENT: Motor-Operated Valves
FAILURE MODE: Fail To Operate on Demand

System Impact Category	Independent Events	Dependent Events*																		Effective Number of Failures**
		Event 37		Event 38		Event 39		Event 40		Event 41		Event 42		Event 43		Event 44		Event 45		
		p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	p	$\overline{n}$	
1																				$\overline{n}_1$ = 799.7
2		1.0	2	1.0	2	1.0	.2			1.0	2									$\overline{n}_2$ = 55.7
3								1.0	3											$\overline{n}_3$ = 5.4
$\geq$ 4																				$\overline{n}_4$ = 5.2

*For a complete listing of all dependent events considered in screening for applicability to TMI-1, see EPRI-NP-3697 report, Reference 2-22. The following provides cross-references between events listed in this table and those reported in NP-3967 by plant name and date of occurrence:

Event 37: Dresden 2 (August 1973), NP-3967, p. 3-56.
Event 38: Dresden 1 (October 1978), NP-3967, p. 3-57.
Event 39: Pilgrim (October 1981), NP-3967, p. 3-58.
Event 40: Millstone 1 (May 1971), NP-3967, p. 3-59.
Event 41: Pilgrim (April 1973), NP-3967, p. 3-59.

**See sheet 5 for total failures.

APPENDIX C

TMI-1 COMPONENT MAINTENANCE
DATA SUMMARY SHEETS

APPENDIX C

TMI-1 COMPONENT MAINTENANCE DATA SUMMARY SHEETS

The data sheets in this appendix summarize the component maintenance events used for the TMI-1 plant-specific maintenance frequency and duration updates. The maintenance events were obtained from a review of the plant tagout orders. The data in this appendix are organized by component type as listed in Tables 3-6 and 3-7.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCD1

SYSTEM: Main Steam

COMPONENT TYPE: Main Steam Atmosphere Dump Valve

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.63×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5420	MS-V-4A	11/16/74	1.75	Calibrate positioner.
6048, 6050, 6059, 6125, 6141	MS-V-4A	2/20/75	294.75	Repair seat.
8167	MS-V-4A	10/9/75	3.5	Check electric/ pneumatic converter and strike valve.
8502	MS-V-3E	11/20/75	125.0	Calibrate.
8721	MS-V-3E	12/30/75	9.0	Repair actuator.

- Maintenance Data Source: Switching and Tagging Orders

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDC2

SYSTEM: Reactor Coolant

COMPONENT TYPE: Pressurizer Spray Valve

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 9.54×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5454	RC-V-1	11/21/74	2.0	Troubleshoot valve.
5871, 5875	RC-V-1	1/23/75	19.5	*

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF1 (Sheet 1 of 3)

SYSTEM: Reactor Building Emergency Cooling

COMPONENT TYPE: Containment Fan Cooler

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 9.54×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5007	AH-E-1A	9/17/74	5.5	Change overload block.
5137	AH-E-1C	10/15/74	1.3	Drain water out of motor.
5471	AH-E-1C	11/23/74	2.5	Check moisture detector on fan motor.
5475, 5476	AH-E-1C	11/25/74	4.67	Correct problem with water detector alarm.
5491	AH-E-1B	11/26/74	0.5	*
5498	AH-E-1C	11/27/74	6.75	Clear alarm.
5517	AH-E-1B	12/1/74	1.3	Clear alarm on moisture detector.
5589	AH-E-1B	12/13/74	6.75	Valve RR-V-4B deenergized closed.
6218	AH-E-1B	3/15/75	0.3	Valve RR-V-4B deenergized closed.
6306	AH-E-1C	3/21/75	0.6	Inspect breaker wiring.
6319	AH-E-1C	3/22/75	2.16	Inspect breaker wiring.
6322	AH-E-1B	3/22/75	2.16	*
8912	AH-E-1C	2/10/76	0.8	Clear vibration alarm.

*No information provided in t.., order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF1 (Sheet 2 of 3)

SYSTEM: Reactor Building Emergency Cooling

COMPONENT TYPE: Containment Fan Cooler

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
432	AH-E-1B	8/2/76	3.5	Repair.
434	AH-E-1B	8/4/76	25.2	Repair.
1624	RR-V-4B	1/31/77	48.3	Repair per WR-18072.
649	AH-E-1A	5/14/77	72.0	Remove contactor.
1115	AH-E-1C	9/30/77	15.40	Vibration reading.
1196	AH-E-1C	10/25/77	4.45	Replace vibration switch.
1214	AH-E-1B	10/31/77	4.0	Install new leak detector relay.
1216	AH-E-1B	11/1/77	14.1	Install new leak detector relay.
1224	AH-E-1A	12/2/77	6.0	Install new leak detector relay.
1230	AH-E-1C	11/3/77	7.0	Install new leak detector relay.
7	AH-E-1C	12/13/77	5.45	Adjust vibration switch.
11	AH-E-1C	12/14/77	7.0	Install new vibration switch.
830	AH-E-1A AH-E-1B AH-E-1C	6/23/78	59.0	Grease motor. Grease motor. Grease motor.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF1 (Sheet 3 of 3)

SYSTEM: Reactor Building Emergency Cooling

COMPONENT TYPE: Containment Fan Cooler

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1030, 1033	AH-E-1C	8/18/78	82.0	Test breaker, check rotation.
1034, 1035	AH-E-1C	8/21/78	5.3	Repair motor, amp readings.
1151	AH-E-1A	9/23/78	111.3	Megger motor.
1174	AH-E-1A	9/25/78	14.35	Remove motor.
1287	AH-E-1B	10/18/78	4.1	Grease motor.
1314	AH-E-1B	10/30/78	4.45	Dry water detector.
140[illegible]	AH-E-1A	11/27/78	5.50	*
1417	AH-E-1C	12/1/78	11.0 (estimated)	*
1419	AH-E-1C	12/2/78	443.0	*
1485	AH-E-1C	12/22/78	133.0	*
--	AH-E-1C	12/28/78	435.0	*
1557	AH-E-1C	1/15/79	0.45	*
1569	AH-E-1C	1/18/79	5.50	*
1576, 1577	AH-E-1B	1/19/79	2.20	*
1587	AH-E-1B	1/22/79	24.0 (estimated)	*

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF5 (Sheet 1 of 6)

SYSTEM: Reactor Building Emergency Cooling River Water

COMPONENT TYPE: Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5808	RR-P-1B	1/15/75	5.0	*
5860	RR-P-1A	1/22/75	2.5	*
5945	RR-P-1A	2/3/75	1.0	Inspect breaker.
5947	RR-P-1B	2/3/75	2.0	Inspect breaker.
6231	RR-P-1B	2/16/75	0.25	Discharge valve V-1B deenergized closed.
6308	RR-S-1A	3/21/75	3.5	Inspect wiring
6350	RR-P-1A	3/24/75	2.0	Megger.
6431	RR-P-1A	3/31/75	7.5	Repair and clean rotometer; clean lines.
6455	RR-P-1B	4/2/75	4.5	Repair and clean.
6655	RR-P-1B	4/21/75	5.2	Repair ESAS.
6664	RR-P-1B	4/22/75	3.0	Check control switch.
6724	RR-P-1A	4/29/75	5.0	Inspect breakers.

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF5 (Sheet 2 of 6)

SYSTEM: Reactor Building Emergency Cooling River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
7281	RR-P-1A	6/14/75	0.7	Check keyway on motor shaft.
7524	RR-P-1B	7/27/75	1.2	Megger windings.
7619	RR-P-1B	8/14/75	2.5	Change oil.
7654	RR-P-1A	8/18/75	8.0	Change oil in motor bearings.
8579	RR-P-1B	12/3/75	0.5	Megger.
8618	RR-P-1A	12/11/75	4.3	Lube motor.
8623	RR-P-1B	12/11/75	4.25	Lube motor.
8890	RR-P-1B	2/5/75	3.0	RR-P-2B deenergized.
267	RR-P-1A	6/21/75	10.0	Replace gasket.
375	RR-P-1A	7/20/76	7.0	Repack.
1472	RR-P-1A	12/20/76	220.0	Remove silt from around pump.
1546A	RR-P-1B	1/12/77	39.17	Tagged "as is" for silt removal.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF5 (Sheet 3 of 6)

SYSTEM: Reactor Building Emergency Cooling River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1733	RR-P-1B	2/23/77	3.58	Clean strainer.
720	RR-P-1A RR-P-1B	6/10/77	5.30	Megger motors.
756	RR-P-1A	6/21/77	3.0	Megger motors.
1106	RR-P-1B	9/28/77	6.0	Renew expansion joints.
1112	RR-P-1B	9/29/77	11.35	Renew expansion joints.
1220	RR-P-1B	11/2/77	8.20	Oil change.
74	RR-P-1A	1/5/78	3.15	Oil change.
109	RR-P-1A	1/13/78	24.0	Replace strainer.
121	RR-P-1A	1/17/78	9.0	Replace strainer.
133	RR-P-1B	1/19/78	6.15	Replace strainer.
911	RR-P-1A	7/14/78	6.40	General maintenance.
1001	RR-P-1B	8/9/78	30.0	General maintenance.
1056	RR-P-1A	8/27/78	60.0	Divers removing silt.
1058	RR-P-1A	8/30/78	12.30	Divers removing silt.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF5 (Sheet 4 of 6)

SYSTEM: Reactor Building Emergency Cooling River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1061	RR-P-1A	8/31/78	15.0	Divers removing silt.
1063	RR-P-1A	9/1/78	7.3	Divers removing silt.
1068	RR-P-1A	9/5/78	13.0	Divers removing silt.
1075	RR-P-1A	9/6/78	16.0	Divers removing silt.
1079	RR-P-1A	9/7/78	17.20	Divers removing silt.
1082	RR-P-1A	9/8/78	15.40	Divers removing silt.
1100	RR-P-1A	9/12/78	14.0	Divers removing silt.
1104	RR-P-1A	9/13/78	5.3	Divers removing silt.
1071	RR-P-1A	9/5/78	9.15	Repair RR-V-12A.
1145	RR-P-1A	9/20/78	6.0	Installation of lube water modification.
1152	RR-P-1B	9/21/78	10.0	Installation of lube water modfication.
1171	RR-P-1B	9/25/78	11.0	Divers removing silt.
1178	RR-P-1B	9/26/78	14.15	Divers removing silt.
1197	RR-P-1B	9/28/78	13.0	Divers removing silt.
1214	RR-P-1B	10/2/78	15.3	Divers removing silt.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF5 (Sheet 5 of 6)

SYSTEM: Reactor Building Emergency Cooling River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1223	RR-P-1B	10/4/78	15.4	Divers removing silt.
1231	RR-P-1B	10/5/78	13.0	Divers removing silt.
1241	RR-P-1B	10/9/78	17.45	Divers removing silt.
1248	RR-P-1B	10/10/78	16.45	Divers removing silt.
1251	RR-P-1B	10/11/78	15.20	Divers removing silt.
1256	RR-P-1B	10/12/78	11.30	Divers removing silt.
1268	RR-P-1B	10/16/78	20.15	Divers removing silt.
1275	RR-P-1B	10/17/78	16.15	Divers removing silt.
1282	RR-P-1B	10/18/78	20.25	Divers removing silt.
1293	RR-P-1A	10/23/78	15.3	Divers removing silt.
1296	RR-P-1A	10/24/78	15.15	Divers removing silt.
1297	RR-P-1A	10/25/78	14.0	Divers removing silt.
1305	RR-P-1A	10/26/78	16.0	Divers removing silt.
1313	RR-P-1A	10/30/78	14.3	Divers removing silt.
1316	RR-P-1A	10/31/78	14.3	Divers removing silt.
1320	RR-P-1A	11/1/78	14.3	Divers removing silt.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF5 (Sheet 6 of 6)

SYSTEM: Reactor Building Emergency Cooling River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1324	RR-P-1A	11/2/78	14.5	Divers removing silt.
1327	RR-P-1A	11/6/78	11.45	Divers removing silt.
1333	RR-P-1A	11/7/78	15.0	Divers removing silt.
1339	RR-P-1A	11/9/78	8.15	Divers removing silt.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCF8

SYSTEM: Reactor Building Emergency Cooling River Water

COMPONENT TYPE: Reactor Building River Water Strainer

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
468	RR-S-1A	8/14/76	1.25	Change oil.
470	RR-S-1B	8/15/76	2.1	Change oil.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MOCI1

SYSTEM: Makeup

COMPONENT TYPE: Letdown Isolation Valves

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 9.54×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
6342	MU-V-2B	3/24/75	8.5	Inspect wiring in MCC.
6341	MU-V-2A	3/24/75	30	Inspect wiring in MCC.

- Maintenance Data Source: Switching and Tagging Orders

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCS1

SYSTEM: Reactor Building Spray

COMPONENT TYPE: Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5811	BS-P-1B	1/16/75	29.5	*
5971	BS-P-1A	2/6/75	1.7	Check and inspect breaker.
6343	BS-P-1B	3/24/75	8.5	Inspect wiring for BS-V-3B for MCC.
6345	BS-P-1B	3/24/75	6.2	Inspect wiring.
6433	BS-P-1A	3/31/75	6.C	Change oil.
6436	BS-P-1B	3/31/75	4.0	Change oil.
6457	BS-P-1A	4/2/75	10.0	Troubleshoot indicating light.
6729A	BS-P-1A	4/29/75	5.5	Inspect breaker.
301	BS-P-1A	6/24/76	3.0	Megger.
33	BS-P-1B	3/9/77	58.0	Check breaker.
778	BS-P-1B	6/27/77	6.5	Maintenance.

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCV1

SYSTEM: Control Building Instrument Air System

COMPONENT TYPE: Compressor

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 1.27×10^5

Tag Order	Component	Date	Duration (hours)	Work Done
5858	AH-P-9A	1/22/75	24.0	*
6031	AH-P-9A AH-P-9B	2/18/75	19.5 19.5	Repair relief valve on air receiver.
6074	AH-P-8A AH-P-8B	2/24/75	0.65 0.65	Test safety valve.
6175	AH-P-9A AH-P-9B	3/10/75	0.4 0.4	Change control switch.
6418	AH-P-8A Ah-P-8B	3/27/75	2.12 2.12	Inspect and repair.
7563	AH-P-9A AH-P-9B	8/6/75	0.5 0.5	Change oil.
872	AH-P-9A AH-P-9B	9/14/76	0.5 0.5	Preventive maintenance.

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCV2 (Sheet 1 of 3)

SYSTEM: Control Building Ventilation

COMPONENT TYPE: Control Building Ventilation Fans 17A/B, 18A/B

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 1.27×10^5

Tag Order	Component	Date	Duration (hours)	Work Done
5093	AH-E-18B	10/7/74	36.0	Repair pressure indicator.
6407	AH-E-18B	3/27/74	5.2	Inspect breaker.
680	AH-E-17B	5/8/75	4.0	Filter change.
6420	AH-E-17A	3/27/75	23.0	Inspect, tighten, and repair.
7336	AH-E-17A	6/24/75	4.5	Filter change.
7833	AH-E-17A	9/8/75	2.5	Weld supports onto motor base frame.
8308	AH-E-18B	10/28/75	427.0	Test AH-F-3B.
8538	AH-E-17A	11/26/75	3.2	Investigate and repair cause for tripping.
237	AH-E-17A	6/16/76	3.75	Install new belts.
1581	AH-E-17B	1/21/77	4.3	General maintenance.
1724	AH-E-18A	2/19/77	31.3	Install flow totalizer.
1736	AH-E-18A	2/20/77		
1745	AH-E-18A	2/24/77	5.35	Install flow totalizer.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCV2 (Sheet 2 of 3)

SYSTEM: Control Building Ventilation

COMPONENT TYPE: Control Building Ventilation Fans 17A/B, 18A/B

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
6	AH-E-18A	3/2/77	4.2	Inspect; calibrate.
8	AH-E-18A	3/2/77	1.1	Inspect; calibrate.
13	AH-E-18A	3/4/77	7.0	Adjust damper.
39	AH-E-18A	3/10/77	5.15	Megger.
40	AH-E-18B	3/10/77	5.15	Megger.
56	AH-E-18A AH-E-18B	3/14/77	4.25	Test.
821	AH-E-17B AH-E-18B	7/10/77	3.4	Modify drain plate.
833	AH-E-17B AH-E-18B	7/16/77	3.2	Repair leaks.
834	AH-E-17A AH-E-18A	7/16/77	6.3	Modify drain plate.
842	AH-E-17B AH-E-18B	7/19/77	83.0	Provide access for condensate removal.
854	AH-E-17B	7/22/77	7.0	Repair damper.
865	AH-E-17B	7/25/77	14.0	Repair damper.
867	AH-E-17A AH-E-18A	7/26/77	50.3	Provide better water drainage.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCV2 (Sheet 3 of 3)

SYSTEM: Control Building Ventilation

COMPONENT TYPE: Control Building Ventilation Fans 17A/B, 18A/B

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
881	AH-E-17B AH-E-18B	7/29/77	7.2	Repair float.
1034	AH-E-17A	9/14/77	4.25	Check belts.
1280	AH-E-17B	11/23/77	4.1	Check motor trips.
1289	AH-E-17A	11/30/77	4.0	Install new breaker.
1290	AH-E-17A	11/30/77	4.2	Test.
1110	AH-E-18A	9/15/78	3.0	Vibration reading.
1502	AH-E-17A	1/1/79	19.3	Vibration reading.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCV3 (Sheet 1 of 2)

SYSTEM: Chilled Water System

COMPONENT TYPE: Chilled Water System Train (pump and chiller)

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
6614	AH-C-4B	4/15/75	5.5	Megger motor.
6618	AH-C-4B	4/16/75	7.15	Investigate loss of oil.
6685	AH-C-4A	4/25/75	15.75	Preventive maintenance.
6733	AH-C-4A	4/30/75	9.75	Preventive maintenance.
6904	AH-C-4B	5/23/75	48.0	Preventive maintenance.
7268	AH-C-4B	6/12/75	153.6	Replace motor.
7299	AH-C-4A	6/18/75	20.0	Oil change.
256, 258, 259, 268, 289	AH-C-4A	6/19/76	116.0	Turbopack teardowr.
362	AH-C-4A	7/16/76	3.3	Repair purge unit.
496	AH-C-4A	8/25/76	2.5	Repair control circuit.
820	AH-C-4A	9/1/76	3.0	Replace purge unit.
1105	AH-C-4B	9/13/78	7.2	Calibrate condenser purge gauge.
1656	AH-C-4B	2/12/79	5.2	*

*Information provided in tag order forms.

T[illegible]I-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDCV3 (Sheet 2 of 2)

SYSTEM: Chilled Water System

COMPONENT TYPE: Chilled Water System Train (pump and chiller)

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
6191	AH-P-3A	3/12/75	2.3	Lubricate motor.
7307	AH-P-3A	6/19/75	2.0	Inspect breaker.
7680	AH-P-3A	8/22/75	4.7	Lubricate motor.
824	AH-P-3A	9/14/76	1.25	Inspect motor.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDDA2

SYSTEM: Electric Power

COMPONENT TYPE: Battery Charger

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 1.91×10^5

Tag Order	Component	Date	Duration (hours)	Work Done
957	1A	8/18/77	1.0	Replace trip switch.
736	1E	5/31/78	1.3	Trouble shoot.

- Maintenance Data Source: Switching and Tagging Orders

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDDH1 (Sheet 1 of 2)

SYSTEM: Decay Heat

COMPONENT TYPE: Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5368	DH-P-1A	10/14/74	2.0	Change oil.
5371	DH-P-1B	11/7/74	4.5	Change oil.
5578	DH-P-1A	12/12/74	2.0	*
5635	DH-P-1B	12/19/74	3.25	*
5812	DH-P-1B	1/15/75	2.5	*
5849	DH-P-1B	1/21/75	12.0	*
5919	DH-P-1A	1/29/75	3.2	*
6318	DH-P-1A	3/22/75	2.0	Inspect breaker wiring for V-5B.
--	DH-P-1B	3/22/75	4.16	Inspect breaker wiring for V-4B.
6321	DH-P-1B	3/22/75	1.5	Replace breaker wiring for V-6B.
6351	DH-P-1B	3/24/75	7.0	Replace breaker wiring for V-4B.
6727	DH-P-1A	4/29/75	5.0	Inspect breaker.
7460	DH-P-1B	7/16/75	3.0	Lubricate.
7477	DH-P-[illegible]	7/17/75	2.0	Change oil.
8546	DH-P-1[illegible]	12/1/75	0.3	Megger.

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDDH1 (Sheet 2 of 2)

SYSTEM: Decay Heat

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
151	DH-P-1B	5/27/76	7.0	Change oil and clean sight glass.
157	DH-P-1B	5/28/76	6.2	Change oil and clean sight glass.
1003	DH-P-1B	9/3/77	19.15	Inspection.
1004	DH-P-1A	9/4/77	6.45	Inspection.
1103	DH-P-1B	9/28/77	43.50	Align coupling.
1120	DH-P-1A	10/3/77	9.45	Align coupling.
1221	DH-P-1A	11/1/77	19.45	Align coupling.
1226	DH-P-1B	12/2/77	8.40	Align coupling.
1228	DH-P-1A	11/3/77	10.50	Check coupling.
1286	DH-P-1A	11/29/77	7.30	Oil change.
1287	DH-P-1B	11/30/77	12.15	Oil change.
1301	DH-P-1A	12/5/77	9.20	Monthly inspection.
1304	DH-P-1B	12/6/78	12.50	Monthly inspection.
104	DH-P-1A	1/12/78	15.0	Check coupling.
199	DH-P-1B	2/13/78	5.3	Check coupling.

- Maintenance Data Source: Switching and Tagging Orders

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDDH3

SYSTEM: Low Pressure Injection

COMPONENT TYPE: Low Pressure Injection Line Valves

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5596	DH-V-4A	12/16/74	30	*
5617	DH-V-4B	12/17/74	2	*
5707	DH-V-4B	12/31/74	49	*
7337A	DH-V-4B	6/24/75	4	Breaker wires replaced.
6226A	Dh-V-7B	3/16/75	2.25	Inspect wiring size on breaker.
6604	DH-V-7B	4/14/75	4.5	Reweld fitting.
6609	DH-V-7A	4/15/75	17.5	Reweld fitting.
7411	DH-V-7A	7/11/75	18.5	Repair two welds on vent line.
7677	DH-V-7A	8/21/75	13.75	Repair vent line connection.
8285	DH-V-7A	10/21/75	11.5	Repair weld leak upstream of NU-V-156A.

- Maintenance Data Source: Switching and Tagging Orders

*No information provided i tag order forms.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDDH4

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Strainer

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5753	DR-S-1A	1/7/75	28.25	*
5948	DR-S-1B	2/3/75	4.0	Check control circuit and test motor.
6001	DR-S-1A	2/12/75	11.0	Open breaker and rotate strainer by hand.
6005	DR-S-1A	2/12/75	7.3	Repair.
7221	DR-S-1A	6/6/75	48	Clean and repair.

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDEF1 (Sheet 1 of 2)

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Pump (motor-driven EF-P-2A and 2B, turbine-driven EF-P-1)

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 9.54×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5056	EF-P-2A	9/26/74	1.5	Change oil in motor.
5058	EF-P-2B	9/26/74	2.5	Change oil in motor.
5066	EF-P-2A EF-P-2B	9/30/74	2.75	Change oil.
5820	EF-P-2A	1/16/75	0.67	*
5821	EF-P-2B	1/16/75	1.25	*
5917	EF-P-2A	1/29/75	3.3	*
5920	EF-P-2B	1/29/75	3.5	*
5958	EF-P-2A EF-P-2B	2/5/75	2.2	Change oil.
5995	EF-P-2A	2/11/75	2.5	Quarterly preventive maintenance.
6160	EF-P-2A EF-P-2B	3/6/75	4.0	Change oil in motors.
6402	EF-P-1	3/27/75	10.5	Inspect breaker V-1B.
6403	EF-P-1	3/27/75	10.5	Inspect breaker V-2B.
6735	EF-P-1	4/30/75	2.25	Oil change.
7757A	EF-P-2B	5/29/75	4.25	Megger motor for preventive maintenance.

*No information provided in tag order forms.

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COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDEF1 (Sheet 2 of 2)

SYSTEM: Emergency Feedwater

COMPONENT TYPE: Pump (motor-driven EF-P-2A and 2B, turbine-driven EF-P-1)

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
7899	EF-P-1	9/16/75	4.75	Valves MS-10A, 10B, 13A, and 13B deenergized closed.
8724	EF-P-2A	1/2/76	1.0	Change oil.
8725	EF-P-2B	1/2/76	1.5	Change oil.
1079	EF-P-2A	10/29/76	3.5	Change oil.
1080A	EF-P-2B	10/29/76	1.5	Change oil.
1081	EF-P-1	10/29/76	3.0	Change oil.
966	EF-P-1	8/22/77	4.30	Change oil.
1229	EF-P-1	10/4/77	5.4	Change oil.
930	EF-P-2A	8/10/77	1.3	Change oil.
937	EF-P-2B	8/12/77	2.3	Change oil.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDEF2

SYSTEM: EFW

COMPONENT TYPE: Pump Steam Supply Valve

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 1.59×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
9309	MS-V-10B	3/5/75	1,319.3	Disconnect wiring to replace gasket.
6849	MS-V-10B	5/16/76	863.5	Correct problem.
7662, 7663, 7679, 7668, 7674	MS-V-13B	8/20/75	29.00	Repair, troubleshoot control circuit.
462	MS-V-10A	8/13/76	1.0	Troubleshoot control circuit and motor.
822, 517	MS-V-10B	8/31/76	8.0	Megger.
873	MS-V-10A	9/14/76	4.5	Preventive maintenance.
1704	MS-V-10A	2/17/77	34.0	Electrical maintenance.
981	MS-V-10B	8/24/77	5.35	Electrical maintenance.
984	MS-V-10B	8/24/77	0.3	Test.
985	MS-V-10A	8/25/77	19.0	Electrical maintenance.

- Maintenance Data Source: Switching and Tagging Orders

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDFW1 (Sheet 1 of 2)

SYSTEM: Main Feedwater

COMPONENT TYPE: Condensate Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 9.54×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
4946	CO-P-1A	9/5/74	0.67	Clean suction strainer.
5069	CO-P-1C	9/30/74	1.75	Change oil.
5075	CO-P-1B	10/1/74	1.50	Change oil.
5083	CO-P-1A	10/2/74	1.50	Change oil.
6336	CO-P-1C	3/22/75	1.50	Lube flow indication.
7613	CO-P-1A	8/14/75	7.25	Change oil.
7742	CO-P-1A	8/28/75	1.30	Megger motor for preventive maintenance.
7745	CO-P-1B	8/28/75	2.0	Megger motor for preventive maintenance.
7746	CO-P-1C	8/28/75	1.50	Megger motor for preventive maintenance.
8544	CO-P-1C	12/1/75	1.60	Megger motor for preventive maintenance.
515	CO-P-1A	8/31/76	1.50	Change oil.
888	CO-P-1A	9/16/76	0.50	Megger motor.
1401, 1404, 1405, 1411, 1412, 1495, 1497, 1502	CO-P-1A	12/3/76	618.2	Remove and install motor.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDFW1 (Sheet 2 of 2)

SYSTEM: Main Feedwater

COMPONENT TYPE: Condensate Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1507	CO-P-1A	12/30/76	5.25	Adjust packing.
1517	CO-P-1A	1/3/77	4.40	Change oil.
1521	CO-P-1B	1/3/77	3.50	Change oil.
1525	CO-P-1C	1/4/77	3.15	Change oil.
1528	CO-P-1C	1/4/77	4.00	Check alignment.
1036	CO-P-1A	9/14/77	4.15	Repair suction.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDFW2 (Sheet 1 of 3)

SYSTEM: Main Feedwater

COMPONENT TYPE: Condensate Booster Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 9.54×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
4968, 4969	CO-P-2C	9/10/74	20.5	Repair leak.
5448	CO-P-2C	11/20/74	34.0	Maintenance.
5459	CO-P-2C	11/22/74	2.2	Change oil.
5470	CO-P-2A	11/33/74	1.5	Change oil.
5672	CO-P-2A	12/26/74	2.15	*
5684	CO-P-2B	12/27/74	78.0	*
5702	CO-P-2A	12/31/74	5.0	*
6173	CO-P-2B	3/10/75	4.0	Change oil.
6177	CO-P-2A	3/11/75	3.75	Change oil.
6186	CO-P-2C	3/11/75	1.0	Change oil.
6487	CO-P-2A	4/3/75	3.1	Change oil.
6494	CO-P-2A	4/4/75	1.5	Change oil.
6496A	CO-P-2A	4/5/75	2.0	Change oil.
6840	CO-P-2A	5/15/75	3.6	Investigate low oil pressure.
7570	CO-P-2C	8/7/75	1.6	Reset relief valve.

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDFW2 (Sheet 2 of 3)

SYSTEM: Main Feedwater

COMPONENT TYPE: Condensate Booster Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
7605	CO-P-2A	8/13/75	2.6	Work on pump motor outboard bearings thermocouple.
7743	CO-P-2A	8/[illegible]/75	0.6	Megger motor for preventive maintenance.
7791	CO-P-2C	9/2/75	10.0	Repair CO-P-9C.
7880	CO-P-2A	9/12/75	1.6	Oil change.
7886	CO-P-2B	9/12/75	4.6	Oil change.
8224, 8229, 8274	CO-P-2A	10/16/75	55	Repair pump.
8290, 8291	CO-P-2A	10/23/75	13.5	Repair seal.
8525	CO-P-2A	11/25/75	2.0	Repair seal.
8535	CO-P-2A	11/26/75	8.5	Repair seal.
876	CO-P-2B	9/14/76	2.25	Change oil in motor.
894	CO-P-2A	9/16/76	1.30	Preventive maintenance.
897	CO-P-2C	9/17/76	1.0	Preventive maintenance.
1731	CO-P-2B	2/23/77	0.4	Change oil.
1732	CO-P-2C	2/23/77	1.50	Change oil.
666	CO-P-2B	5/18/77	3.45	Change oil.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDFW2 (Sheet 3 of 3)

SYSTEM: Main Feedwater

COMPONENT TYPE: Condensate Booster Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
987	CO-P-2B	8/26/77	3.20	Change oil.
688	CO-P-2A	5/15/78	184.0	Repair seal.
1478	CO-P-2B	12/20/78	4.10	*
1483	CO-P-2B	12/21/78	6.30	*
1511	CO-P-2B	1/3/79	26.0	*
1521	CO-P-2B	1/4/79	94.0	*

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA1 (Sheet 1 of 8)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5320, 5325, 5335, 5337, 5338, 5343	DG-1B	10/28/74	56.0	Inspection.
5359	DG-1A	11/4/74	4.5	Pull piston.
5757, 5758, 5771	DG-1A	1/8/75	53	Start air valve EG-V-15A closed.
5785, 5787	DG-1A	1/13/75	13.5	*
5800, 5801, 5802	DG-1B	1/14/75	80	Start air valve EG-V-15B closed.
5830	DG-1B	1/17/75	5.5	Start air valve EG-V-15B closed.
5831	DG-1A	1/18/75	2.67	Start air valve EG-V-15A closed.
5842	DG-1B	1/20/75	9.5	Start air valve EG-V-15B closed.
5848	DG-1B	1/21/75	10.5	Start air valve EG-V-15B closed.
5854	DG-1B	1/22/75	10.0	Start air valve EG-V-15B closed.
5863	DG-1A	1/27/75	107.25	Start air valve EG-V-15A closed.

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA1 (Sheet 2 of 8)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
5952	DG-1B	2/4/75	8.0	Start air valve EG-V-15B closed.
5979	DG-1A	2/7/75	5.5	Start air valve EG-V-15A closed.
6098	DG-1B	2/27/75	10.0	Adjust injection pumps; repair leaks.
6138, 6143	DG-1B	3/4/75	13.0	Repair governor.
6660	DG-1B	4/22/75	4.0	Connect governor motor.
6745	DG-1A	5/1/75	2.0	Inspect breaker.
7287	DG-1B	6/16/75	5.6	Change governor.
7297	DG-1B	6/17/75	1.0	Change megawatt meter.
7399	DG-1A	7/8/75	51.3	Inspect blower drive gear.
7418	DG-1B	7/14/75	53.0	Inspect blower drive gear.
7453	DG-1A	7/16/75	4.95	Inspect intake air piping.
7466	DG-1B	7/17/75	2.25	*
7604	DG-1B	8/13/75	8.0	Clean and check relay cab.

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA1 (Sheet 3 of 8)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
7612	DG-1A	8/14/75	3.5	Clean and check relay cab.
8202	DG-1A	10/14/75	9.0	Starting air compressor deenergized.
8777, 8776, 8765	DG-1B	1/9/76	100.67	Preventive maintenance, calibrate instrument.
8815	DG-1B	1/19/76	17.0	Calibrate instrumentation.
8846	DG-1A	1/24/76	4.5	--*
8847	DG-1B	1/24/76	3.75	Preventive maintenance.
8823, 8842	DG-1B	1/23/76	5.0	Surveillance.
8854, 8853	DG-1A	1/26/76	70.0	Repair.
8869	DG-1A	1/29/76	2.0	Inspect CAM.
8871, 8874	DG-1A	1/30/76	7.0	Calibrate instrumentation.
8880	DG-1B	2/2/76	36.75	Repair leaks in exhaust system.
8892	DG-1B	2/6/76	2.75	Change gasket on exhaust.

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA1 (Sheet 4 of 8)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
8928	DG-1A	2/13/76	5.0	Clean oil on engine.
8843, 8941	DG-1B	2/17/76	7.5	Repair.
242	DG-1A	6/16/76	4.5	Starting air receivers vented.
419	DG-1A	7/30/76	13.0	Replace coolant.
455	DG-1A	8/8/76	4.5	Set governor, change oil.
458	DG-1B	8/11/76	4.0	Set governor, change oil.
1534	DG-1A	1/7/77	9.50	Yearly inspection.
1546	DG-1A	1/11/77	17.45	WR-18139.
1547	DG-1A	1/11/77	26.30	Yearly inspection.
1575	DG-1A	1/20/77	20.25	Install servo motor.
1577	DG-1A	1/20/77	20.25	Install resistors.
1585	DG-1A	1/22/77	6.0	Test relays.
1593	DG-1A	1/24/77	1.2	Generator maintenance.
1594	DG-1A	1/24/77	8.15	Generator maintenance.
1596	DG-1A	1/25/77	3.2	Generator maintenance.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA1 (Sheet 5 of 8)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1603	DG-1B	1/26/77		Preventive maintenance.
1604	DG-1B	1/26/77	27.0	Preventive maintenance.
1607	DG-1B	1/27/77		Relay timing.
1627	DG-1B	1/31/77	16.50	Annual preventive maintenance.
1642	DG-1B	2/3/77	14.35	Annual preventive maintenance.
1665	DG-1B	2/8/77	10.50	Annual preventive maintenance.
1671	DG-1B	2/9/77	9.55	Annual preventive maintenance.
37	DG-1B	3/10/77	6.0	Fuel leak.
1030	DG-1B	9/13/77	72.0	Install automatic voltage control.
1121	DG-1A	10/3/77	7.45	Repair air box.
1137	DG-1A	10/5/77	4.25	Install rheostat.
1160	DG-1A	10/12/77	5.0	Repair starting circuit.
1202	DG-1A	10/27/77	11.30	Install new resistors in excitor.
1205	DG-1B	10/28/77	7.20	Install new resistors in excitor.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA1 (Sheet 6 of 8)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1236	DG-1A	11/4/77	47.5	Annual calibration.
1240	DG-1B	11/6/77	38.4	Annual calibration.
1307	DG-1B	12/6/77	53.0	Preventive maintenance.
5	DG-1B	12/12/77	26.15	Preventive maintenance.
10	DG-1B	12/12/77	2.4	Annual inspection.
13	DG-1B	12/12/77	4.45	T mers test.
28	DG-1A	12/18/77	29.0	Preventive maintenance.
33	DG-1A	12/20/77		
66	DG-1B	1/3/78	10.15	Clean filters.
70	DG-1B	1/4/78	3.2	Inspect leak.
72	DG-1A	1/4/78	17.4	Preventive maintenance.
84	DG-1A	1/6/78	4.45	Replace heat shields.
113	DG-1B	1/15/78	5.10	Check timing.
184	DG-1A	2/8/78	27.55	Set injectors.
251	DG-1B	3/11/78	13.3	Surveillance.
253	DG-1B	3/12/78	3.3	Replace switch.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA1 (Sheet 7 of 8)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
916	DG-1A	7/17/78	26.45	Wiring changes.
947	DG-1B	7/25/84	11.3	Wiring changes.
1107	DG-1B	9/13/78	12.0	Repair governor.
1131	DG-1B	9/18/78	6.0	Install new governor.
1177	DG-1B	9/25/78	6.0	Replace governor.
1325	DG-1A	11/3/78	5.35	Calibration.
1560, 1562	DG-1B	1/16/79	119.0	*
1586	DG-1B	1/22/79	8.15	*
1596, 1597	DG-1A	1/24/79	83.0	*
1613	DG-1A	1/28/79	7.3	*
1618	DG-1A	1/29/79	14.0	*
1647	DG-1B	2/7/79	5.0	*
1649	DG-1A	2/7/79	2.3	*
1653	DG-1A	2/9/79	3.15	*
1659	DG-1B	2/12/79	26.0	*
1666	DG-1B	2/13/79	24.3	*

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA1 (Sheet 8 of 8)

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1582	DG-1A	1/21/77	2.0	Calibrate instrumentation.
1719	DG-1A DG-1B	2/18/77	1.5	Change oil.
34	DG-1A	3/9/77	0.3	Replace belts.
1314	DG-1B	12/8/77	2.15	Calibration.
21	DG-1B	12/16/77	6.3	*
893	DG-1B	7/6/78	1.2	Replace belts.
1140	DG-1A	9/19/78	3.0	Reset relief valve.
1233	DG-1A	10/5/78	3.15	Repair leak.

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDGA2

SYSTEM: Electric Power

COMPONENT TYPE: Diesel Generator Fuel Oil Transfer Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5141	1C	10/16/74	1.25	Test on/off switch.
5559	1B	12/9/74	3.25	Check contacts on auxiliary relay.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA1 (Sheet 1 of 6)

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5008	DR-P-1A	9/16/74	5.0	Lubricate motor.
5042	DR-P-1B	9/23/74	1.0	Change oil and lubricate motor.
5768	DR-P-1A	1/10/75	27.75	*
5905	DR-P-1B	1/28/75	25.50	*
6239	DR-P-1A	3/17/75	2.3	Lubricate motor.
6359	DR-P-1B	3/19/75	7.6	Lubricate motor.
6365	DR-P-1B	3/25/75	8.0	Inspect breaker wiring (DR-S-1B).
6366	DR-P-1B	3/25/75	8.0	Inspect breaker wiring (DR-P-2B).
6367	DR-P-1B	3/25/75	8.0	Inspect breaker wiring (DR-V-1B).
6465	DR-P-1B	4/3/75	3.5	Repair and clean lines.
6488	DR-P-1A	4/3/75	1.2	Repair and clean lines.
6902	DR-P-1B	5/21/75	7.45	Deenergized.
6902	DR-P-1B	5/23/75	48	Repair shaft.
7275	DR-P-1B	6/13/75	4.75	*

*No information provided in tag order forms.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA1 (Sheet 2 of 6)

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
7279	DR-P-1A	6/14/75	0.5	*
7302, 7309	DR-P-1B	6/19/75	35.5	Remove motor, repair.
8884	DR-P-1B	2/4/76	3.25	Clean and repair check valve (DR-P-2B).
8891	DR-P-1A	2/5/75	2.0	Unclog drain line.
7279	DR-P-1A	6/14/76	24.0 (estimated)	*
467	DR-P-1B	8/13/76	3.0	Clean strainer (DR-S-2B).
871	DR-P-1A	9/14/76	4.75	Semiannual preventive maintenance.
1059	DR-P-1A	10/28/76	6.0	Repack strainer.
1472	DR-P-1A	10/20/76	220.0	*
1546A	DR-P-1A	1/12/77	39.20	Tagged "as is" for silt removal.
58	DR-P-1A	3/14/77	2.5	Repack pump.

*No information provided in tag order forms.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA1 (Sheet 3 of 6)

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
873	DR-S-1A	7/27/77	10.3	Change oil.
876	DR-S-1B	7/28/77	3.3	Change oil.
905	DR-P-1A	8/4/77	4.0	Change oil.
907	DR-P-1B	8/4/77	3.0	Change oil.
1213	DR-P-1A	10/31/77	3.2	Repair strainer.
1285	DR-P-1A	11/29/77	10.3	Replace end bell on motor.
1317	DR-P-1B	12/9/77	17.4	Repack pump.
963	DR-P-1A	7/31/78	5.45	Clean tubes.
986	DR-P-1A	8/4/78	1.25	Megger.
944	DR-P-1B	8/7/78	55.0	Clean tubes.
1010	DR-P-1A	8/13/78	2.45	Unplug drain valve.
1110	DR-P-1B	9/13/78	7.20	Divers removing silt.
1113	DR-P-1B	9/14/78	14.0	Divers removing silt.
1100	DR-P-1A	9/12/78	14.0	Divers removing silt.
1100	DR-P-1B	9/12/78	14.0	Divers removing silt.
1104	DR-P-1A	9/13/78	5.3	Divers removing silt.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA1 (Sheet 4 of 6)

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1104	DR-P-1B	9/13/78	5.3	Divers removing silt.
1130	DR-P-1B	9/18/78	17.2	Divers removing silt.
1137	DR-P-1B	9/19/78	14.35	Divers removing silt.
1144	DR-P-1B	9/20/78	17.3	Divers removing silt.
1150	DR-P-1B	9/21/78	6.0	Divers removing silt.
1134	DR-P-1B	9/18/78	12.0	Lube water modification.*
1171	DR-P-1A	9/25/78	11.0	Divers removing silt.
1178	DR-P-1A	9/26/78	14.15	Divers removing silt.
1193	DR-P-1A	9/27/78	7.3	Lube water modification.
1197	DR-P-1A	9/28/78	13.0	Divers removing silt.
1214	DR-P-1A	10/2/78	15.3	Divers removing silt.
1223	DR-P-1A	10/4/78	15.4	Divers removing silt.
1231	DR-P-1A	10/5/78	13.0	Divers removing silt.
1241	DR-P-1A	10/9/78	17.45	Divers removing silt.

*Overlap with tag order 1130.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA1 (Sheet 5 of 6)

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1248	DR-P-1A	10/10/78	16.45	Divers removing silt.
1251	DR-P-1A	10/11/78	15.2	Divers removing silt.
1256	DR-P-1A	10/12/78	11.30	Divers removing silt.
1268	DR-P-1A	10/16/78	20.15	Divers removing silt.
1275	DR-P-1A	10/17/78	16.15	Divers removing silt.
1282	DR-P-1A	10/18/78	20.25	Divers removing silt.
1285	DR-P-1B	10/19/78	15.30	Divers removing silt.
1293	DR-P-1B	10/23/78	15.30	Divers removing silt.
1296	DR-P-1B	10/24/78	15.15	Divers removing silt.
1297	DR-P-1B	10/25/78	14.0	Divers removing silt.
1305	DR-P-1B	10/26/78	16.0	Divers removing silt
1313	DR-P-1B	10/30/78	14.3	Divers removing silt.
1316	DR-P-1B	10/31/78	14.3	Divers removing silt.
1320	DR-P-1B	11/1/78	14.3	Divers removing silt.
1324	DR-P-1B	11/2/78	14.5	Divers removing silt.
1327	DR-P-1B	11/6/78	11.45	Divers removing silt.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA1 (Sheet 6 of 6)

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1333	DR-P-1B	11/7/78	15.0	Divers removing silt.
1339	DR-P-1B	11/8/78	8.15	Divers removing silt.
1357	DR-P-1A	11/30/78	4.0	Test.
1391	DR-P-1A	11/21/78	5.0	Inspection.
1409	DR-P-1A	11/28/78	7.3	*
1521	DR-P-1A	1/8/79	3.5	*
1530	DR-P-1A	1/8/79	10.0	*

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA3

SYSTEM: Decay Heat River Water

COMPONENT TYPE: Strainer

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5753	DR-S-1A	1/7/75	28.25	*
5948	DR-S-1B	2/3/75	4.0	Check control circuit and test motor.
6001	DR-S-1A	2/12/75	11.0	Open breaker and rotate strainer by hand.
6005	DR-S-1A	2/12/75	7.3	Repair.
7221	DR-S-1A	6/6/75	48	Clean and repair.

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA4

SYSTEM: Nuclear Services Closed Cooling System

COMPONENT TYPE: Nuclear Services Coolers

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 1.27×10^5

Tag Order	Component	Date	Duration (hours)	Work Done
639	NS-C-1A	5/1/78	84.0	Clean tubes.
690	NS-C-1B	5/15/78	183.0	Clean tubes.
709	NS-C-1C	5/22/78	213.0	Clean tubes.
756	NS-C-1D	6/5/78	1,274.0	Clean tubes.
948	NS-C-1D	7/26/76	2.0	Clean tubes.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHA5

SYSTEM: Decay Heat Close Cycle

COMPONENT TYPE: Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5031	DC-P-1A	9/20/74	3.8	Repair ground in circuit.
6835	DC-P-1A	5/14/75	0.33	Change oil.
7927	DC-P-1A	9/19/75	3.5	Change oil.
7929	DC-P-1B	9/19/75	2.0	Change oil.
6206	DC-P-1A	3/14/75	1.0	Lubricate motor.
6209	DC-P-1B	3/14/75	1.0	Lubricate motor.
6830	DC-P-1B	5/13/75	0.8	Change oil.
8360	DC-P-1A	11/10/75	0.25	Lubricate motor.
8361	DC-P-1A	11/10/75	0.25	Lubricate motor.
8545	DC-P-1B	12/1/75	3.0	Megger.
8567	DC-P-1A	12/3/75	1.5	Megger.
8584	DC-P-1A	12/4/75	1.3	Install new secondary contact block on breaker.
1045	DC-P-1B	10/23/76	1.7	Change oil.
1067	DC-P-1A	10/30/76	1.0	Change oil.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHL1

SYSTEM: DHR

COMPONENT T'P Leg Suction Line Valves V1 and V2

Site-Speci.

Data include ntenance performed during periods when the reactor was not in col down.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5130	DH-V1	10/14/74	4.75	Remove V1 automatic interlock bistable, repair.
5378	DH-V1, DH-V2	10/14/74	2.50	Replace triac in ESASS system.

- Maintenance Data Source: Switching and Tagging Orders

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHP1, MDHP2 (Sheet 1 of 4)

SYSTEM: Makeup

COMPONENT TYPE: Pumps A, B, and C*

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: Pump B = 3.18×10^4; Pumps A and C = 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5112, 5113, 5120	MU-P-1A	10/10/74	34.75	Repair pump motor.
5150	MU-P-1C	10/17/74	1.67	Test breaker.
5590, 5591	MU-P-1C	12/13/74	1.25	**
5592	MU-P-1C	12/13/74	4.0	**
5726	MU-P-1C	1/3/75	3.2	**
5762	MU-P-1C	1/8/75	3.0	**
5813	MU-P-1C	1/15/75	5.0	**
5923	MU-P-1B	1/30/75	2.0	**
6003	MU-P-1C	2/12/75	1.0	Inspect BDD for loose connections, nuts, etc.
6006	MU-P-1A	2/12/75	0.5	Inspect BDD.
6045	MU-P-1B	2/11/75	1.0	Inspect BDD.
6157	MU-P-1C	3/6/75	5.5	Repair bearing oil leak.

*Used pump B data for MDHP1 and pumps A and C data for MDHP2.
**No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHP1, MDHP2 (Sheet 2 of 4)

SYSTEM: Makeup

COMPONENT TYPE: Pumps A, B, and C*

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
6266, 6279	MU-P-1A	3/19/75	7.25	Replace lube oil cooler temperature indicator.
6310	MU-P-1B	3/21/75	1.0	Inspect breaker wiring.
6604	MU-P-1C	4/14/75	4.5	Reweld fitting.
6609	MU-P-1A	4/15/75	17.5	Reweld fitting.
6728	MU-P-1B	4/29/75	5.0	Inspect breaker.
6730	MU-P-1A	4/29/75	8.0	Inspect breaker.
6738	MU-P-1C	4/30/75	8.67	Change oil and check leaks.
6748	MU-P-1C	5/2/75	1.0	Change oil.
6759	MU-P-1A	5/5/75	6.2	Change oil and repair leak.
6787	MU-P-1B	5/7/75	3.15	Change oil.
6802, 6803	MU-P-1C	5/11/75	5.3	Repair suction valve.
6869	MU-P-1B	5/18/75	3.2	Repair auxiliary oil pump pressure switch.

*Used pump B data for MDHP1 and pumps A and C data for MDHP2.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHP1, MDHP2 (Sheet 3 of 4)

SYSTEM: Makeup

COMPONENT TYPE: Pumps A, B, and C*

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
7411	MU-P-1A	7/11/75	18.5	Repair two welds on vent line.
7614	MU-P-1B	8/14/75	7.5	Repair oil leaks.
7677	MU-P-1A	8/21/75	13.75	Repair weld leak.
8166	MU-P-1B	10/9/75	2.0	Repair oil leak.
8285	MU-P-1A	10/21/75	11.5	Repair weld leak upstream of MU-V-156A.
8311	MU-P-1B	10/29/75	2.6	Repair oil.
8901	MU-P-1A	2/9/76	1.75	Replace broken green field connection.
1057	MU-P-1B	10/28/76	4.2	Change oil.
1058	MU-P-1A	10/28/76	3.0	Change oil.
1061	MU-P-1C	10/29/76	3.2	Change oil.
670	MU-P-1A	5/19/77	7.35	Change oil.
1187	MU-V-14B	10/22/77	8.0	Repack valve.
50, 52	MU-P-1B	12/27/77	31.0	**

*Used pump B data for MDHP1 and pumps A and C data for MDHP2.
**No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDHP1, MDHP2 (Sheet 4 of 4)

SYSTEM: Makeup

COMPONENT TYPE: Pumps A, B, and C*

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
124	MU-P-1A	1/18/78	14.3	Repair, replace nipple; repack valve MU-V-74A.
962	MU-P-1A	7/31/78	12.0	Repair vent line nipple.
1013	MU-V-14B	8/14/78	4.0	Set limits.
1684	MU-P-1C	2/17/78	33.0	**

- Maintenance Data Source: Switching and Tagging Orders

*Used pump B data for MDHP1 and pumps A and C data for MDHP2.
**No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS1L, MDNS1S* (Sheet 1 of 8)

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 9.54×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5009	NR-P-1C	9/17/74	4.0	Preventive maintenance M-1.
5657	NR-P-1C	12/23/74	7.0	**
5692	NR-P-1A	12/28/74	6.0	Screen wash pump 2A deenergized.
6316	NR-P-1A	3/21/75	0.5	Repair automatic vent.
6373	NR-P-1C	3/25/75	22.5	Inspect wiring on breaker NR-S-1C.
6374	NR-P-1C	3/25/75	22.5	Inspect wiring on breakers.
6430	NR-P-1A	3/31/75	7.5	Repair and clean lines.
6438	NR-P-1C	4/1/75	4.0	Repair and clean lines.
6448	NR-P-1B	4/1/75	5.0	Repair and clean lines.
6814	NR-P-1A	5/12/75	9.0	Repack.
6839	NR-P-1A	5/15/75	8.0	Adjust and repack.

*Maintenance duration less than 100 hours.

**No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS1L, MDNS1S (Sheet 2 of 8)

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
7214	NR-P-1A	6/6/75	392.5	Pull motor.
7363	NR-P-1A	6/27/75	462.75	Replace motor.
7442	NR-P-1C	7/15/75	2.5	Change oil and lubricate motor.
7452	NR-P-1B	7/15/75	4.0	Change oil.
7574	NR-P-1B	8/11/75	8.7	Repair check valve.
7580	NR-P-1B	8/12/75	1.5	Repair relay.
7588	NR-P-1B	8/12/75	3.4	Inspect check valve NR-V-20B.
8566	NR-P-1C	12/2/75	1.5	Megger.
8751, 8744, 8759, 8808, 8820	NR-P-1A	1/8/76	312	Repair valve.
146	NR-P-1A	5/26/76	389	Lubricate motor bearings.
202	NR-P-1A	6/10/76	3.5	Check clearance on check valve hinge pins (NR-V-20A).
341	NR-P-1B	7/8/76	2.0	*
493	NR-P-1C	8/24/76	8.50	Investigate control power fuse failure.

*No information provided in tag order forms.

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COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS1L, MDNS1S (Sheet 3 of 8)

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1062	NR-P-1A	10/29/76	3.5	Repack pump NR-P-2A.
1472	NR-P-1A	10/29/76	220	*
1548	NR-P-1C	1/14/77	27.45	Pump tagged "as is."
2	NR-P-1B	3/2/77	1.30	Repack pump.
19	NR-P-1A	3/5/77	5.0	Preventive maintenance, lubricate motors.
	NR-P-1B			Preventive maintenance, lubricate motors.
	NR-P-1C			Preventive maintenance, lubricate motors.
61A	NR-P-1B	3/14/77	17.40	Repair strainer.
788, 789	NR-P-1C	6/29/77	64.50	Repair coupling.
799	NR-P-1C	7/5/77	386.3	Check pump shaft.

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS1L, MDNS1S (Sheet 4 of 8)

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
851, 852	NR-P-1C	7/21/77	127.30	Megger motor, couple motor and pump.
855	NR-P-1C	7/22/77	138.50	Remove motor.
871	NR-P-1C	7/27/77	2.15	Check current.
875	NR-P-1C	7/28/77	3.0	Check current.
1291	NR-P-1B	12/1/77	16.15	Replace pump coupling.
94	NR-P-1C	1/9/78	105.0	Repack pump; replace strainer.
917	NR-P-1A	7/17/78	12.15	Replace joint.
938	NR-P-1A	7/24/78	5.45	General maintenance.
980	NR-P-1B	8/3/78	8.0	General maintenance.
982	NR-P-1C	8/4/78	16.0	General maintenance.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS1L, MDNS1S (Sheet 5 of 8)

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1028	NR-P-1A	8/29/78	33.2	Repair, calibrate.
1056	NR-P-1A	8/27/78	60.0	Divers removing silt.
1058	NR-P-1A	8/30/78	12.3	Divers removing silt.
1061	NR-P-1A	8/31/78	15.0	Divers removing silt.
1063	NR-P-1A	9/1/78	7.3	Divers removing silt.
1068	NR-P-1A	9/5/78	13.0	Divers removing silt.
1075	NR-P-1A	9/6/78	16.0	Divers removing silt.
1079	NR-P-1A	9/7/78	17.2	Divers removing silt.
1082	NR-P-1A	9/8/78	15.4	Divers removing silt.
1100	NR-P-1A	9/12/78	14.0	Divers removing silt.
1104	NR-P-1A	9/13/78	5.3	Divers removing silt.
1110	NR-P-1B	9/13/78	7.2	Divers removing silt.
1113	NR-P-1B	9/14/78	14.0	Divers removing silt.
1130	NR-P-1B	9/18/78	17.2	Divers removing silt.
1137	NR-P-1B	9/19/78	14.35	Divers removing silt.
1144	NR-P-1B	9/20/78	17.3	Divers removing silt.
1150	NR-P-1B	9/21/78	6.0	Divers removing silt.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS1L, MDNS1S (Sheet 6 of 8)

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1114	NR-P-1B	9/14/78	9.2	Install lube water modification.
1119	NR-P-1A	9/15/78	7.50	Install lube water modification.
1133	NR-P-1C	9/18/78	9.4	Repair valve NR-V-20B.
1171	NR-P-1C	9/25/78	11.0	Divers removing silt.
1178	NR-P-1C	9/26/78	14.15	Divers removing silt.
1197	NR-P-1C	9/28/78	13.0	Divers removing silt.
1214	NR-P-1C	10/2/78	15.3	Divers removing silt.
1223	NR-P-1C	10/4/78	15.4	Divers removing silt.
1231	NR-P-1C	10/5/78	13.0	Divers removing silt.
1241	NR-P-1C	10/9/78	17.45	Divers removing silt.
1248	NR-P-1C	10/10/78	16.45	Divers removing silt.
1172	NR-P-1C	9/25/78	10.0	Lube water modification.
1220	NR-P-1B	10/3/78	6.45	Rebuild check valve.
1251	NR-P-1B	10/11/78	15.2	Divers removing silt.
1256	NR-P-1B	10/12/78	11.3	Divers removing silt.
1268	NR-P-1B	10/16/78	20.15	Divers removing silt.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS1L, MDNS1S (Sheet 7 of 8)

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1275	NR-P-1B	10/17/78	16.15	Divers removing silt.
1282	NR-P-1B	10/18/78	20.25	Divers removing silt.
1265	NR-P-1A	10/14/78	1.15	Repair valve NR-V-22A.
1285	NR-P-1B	10/19/78	15.30	Divers removing silt.
1293	NR-P-1B	10/23/78	15.3	Divers removing silt.
1296	NR-P-1B	10/24/78	15.15	Divers removing silt.
1297	NR-P-1B	10/25/78	14.0	Divers removing silt.
1305	NR-P-1B	10/26/78	16.0	Divers removing silt.
1313	NR-P-1B	10/30/78	14.3	Divers removing silt.
1316	NR-P-1B	10/31/78	14.3	Divers removing silt.
1320	NR-P-1A	11/1/78	14.3	Divers removing silt.
1324	NR-P-1A	11/2/78	14.5	Divers removing silt.
1327	NR-P-1A	11/6/78	11.45	Divers removing silt.
1333	NR-P-1A	11/7/78	15.0	Divers removing silt.
1339	NR-P-1A	11/9/78	8.15	Divers removing silt.
1347	NR-P-1B	11/9/78	3.4	Divers removing silt.
1422	NR-P-1C	12/5/78	23.0	*

*No information provided in tag order forms.

TMI-1

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS1L, MDNS1S (Sheet 8 of 8)

SYSTEM: Nuclear Services River Water

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1429	NR-P-1B	12/7/78	5.1	*
1674	NR-P-1B	2/15/79	24.0 (estimated)	*

o Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS3 (Sheet 1 of 2)

SYSTEM: Nuclear Services Closed Cycle

COMPONENT TYPE: Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 9.54×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
5054	NS-P-1A	9/25/74	0.6	Change oil on bearings.
	NS-P-1B		0.6	Change oil on bearings.
	NS-P-1C		0.6	Change oil on bearings.
577	NS-P-1A	1/10/75	10.0	*
5782	NS-P-1A	1/10/75	187	Repack pump.
6842	NS-P-1C	5/15/75	0.67	Change oil.
6843	NS-P-1A	5/15/75	0.4	Change oil.
6844	NS-P-1B	5/15/75	0.5	Change oil.
7304	NS-P-1C	6/19/75	28.8	Test thermal overload relay 49X.
7804	NS-P-1B	9/4/75	6.5	Megger motor for preventive maintenance.
8542	NS-P-1A	12/1/75	3.2	Megger.
8557	NS-P-1C	12/2/75	1.0	Megger.
8578	NS-P-1B	12/3/75	0.5	Megger.
343	NS-P-1B	7/9/76	3.2	Preventive maintenance.

*No information provided in tag order forms.

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS3 (Sheet 2 of 2)

SYSTEM: Nuclear Services Closed Cycle

COMPONENT TYPE: Pump

Site-Specific Data

Tag Order	Component	Date	Duration (hours)	Work Done
1536	NS-P-1B	1/7/77	5.2	Megger control circuit.
1726	NS-P-1B	2/20/77	1.0	Oil change.
1730A	NS-P-1B	2/23/77	1.2	Oil change.
48	NS-P-1B	3/11/77	3.0	Bearing.
49	NS-P-1A	3/12/77	4.3	Bearing.
142	NS-P-1A	1/23/78	10.0	Repack.
1689	NS-P-1B	2/13/77	1.15	Change oil.
1307	NS-P-1B	10/26/78	16.10	Repack pump.
1309	NS-P-1A	10/27/78	3.35	Change oil.

- Maintenance Data Source: Switching and Tagging Orders

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS4

SYSTEM: Air-Handling

COMPONENT TYPE: Auxiliary Building Ventilation Fans

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 1.27×10^5

Tag Order	Component	Date	Duration (hours)	Work Done
5659	AH-E-15A	12/23/74	11.3	*
5690	AH-E-15A AH-E-15B	12/28/74	1.5	*
5856	AH-E-15B	1/22/75	7.1	*
6250	AH-E-15A	3/17/75	0.5	Inspect breaker and strainer.
6383	AH-E-15B	3/26/75	0.75	Inspect breaker.
6778	AH-E-15B	5/7/75	26.5	Check noise.
1568	AH-E-15B	1/18/77	2.0	General overhaul.
1637	AH-E-15B	2/2/77	10.45	Check vibration.
1073	AH-E-15A	9/5/78	29.30	Change CS12.
1070	AH-E-15B	9/6/78	9.30	Change CS12.

- Maintenance Data Source: Switching and Tagging Orders

*No information provided in tag order forms.

TMI-1
COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDNS4

SYSTEM: Emergency Feedwater Ventilation

COMPONENT TYPE: Ventilation Fans

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
6421	AH-E-24A	3/27/75	3	Inspect, tighten, repair.
879	AH-E-24A AH-E-24B	9/15/76	6	Lubricate motors.

- Maintenance Data Source: Switching and Tagging Orders

COMPONENT MAINTENANCE DATA SUMMARY SHEET

DESIGNATOR: MDSE1

SYSTEM: Intermediate Cooling Closed Loop

COMPONENT TYPE: Pump

Site-Specific Data

Data include only maintenance performed during periods when the reactor was not in cold shutdown.

- Total noncold shutdown hours for reporting period: 6.36×10^4

Tag Order	Component	Date	Duration (hours)	Work Done
4917	IC-P-1B	9/4/74	3.5	Test molded case breaker.
5985	Filter F1A	2/7/75	2.0	Valves V-14 and V-15 closed; valves V-53 and V-54 open.
5989	Filter F1A	2/10/75	2.0	Valves V-14, V-15, V-53, and V-54 closed; change gasket.
6389	IC-P-2	3/26/76	22.25	Inspect breakers.
678	RM-L9	5/21/77	6.50	Close IC-V-44, V-45, V-65, and V-75.

- Maintenance Data Source: Switching and Tagging Orders

APPENDIX D

TMI-1 INITIATING EVENTS DATA SUMMARY SHEETS

APPENDIX D

TMI-1 INITIATING EVENT DATA SUMMARY SHEETS

The data sheets in this appendix summarize the initiating events that have occurred at TMI-1 during the period covered by the data collection effort. The data sheets are organized by initiating event categories as listed in Table 3-8.

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: LL

EVENT CATEGORY: Large LOCA

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: ML

EVENT CATEGORY: Medium LOCA

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: SB

EVENT CATEGORY: Small LOCA

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: VSB

EVENT CATEGORY: Very Small LOCA

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: VS

EVENT CATEGORY: Inadvertent Opening of DHR Valves

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: SLI

EVENT CATEGORY: Steam Line Break in Intermediate Building

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: SLT

EVENT CATEGORY: Steam Line Break in Turbine Building

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: TR

EVENT CATEGORY: Steam Generator Tube Rupture

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: EXC

EVENT CATEGORY: Excessive Feedwater Flow

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: FW

EVENT CATEGORY: Total Loss of Main Feedwater

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: RT

EVENT CATEGORY: Reactor Trip

NUMBER OF EVENTS: 3

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
6/25/75	Reactor tripped because control rod swap group 7 phase bus bar faulted to neutral, causing group 7 to drop into the cone. (This was followed by a turbine trip due to water in high pressure turbine - see turbine trip event summary sheet).
5/27/76	Reactor trip on high neutron flux due to operator switching error in nuclear instrumentation (trying to shift the neutron flux input jacks to the ICS with a large neutron error signal present).
11/14/77	ICS component malfunctioned, causing reactor trip.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: TT

EVENT CATEGORY: Turbine Trip

NUMBER OF EVENTS: 7

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
1/23/75	High moisture separator drain tank level caused turbine trip. Reactor did not trip (reduced to 10^{-8} amps).
3/30/75	A faulty relay gave an erroneous signal that indicated loss of DC power to the turbine EHC system. The signal tripped the turbine. The reactor tripped from high reactor coolant pressure.
5/9/75	Turbine tripped due to a mechanical failure in the "B" moisture separator high-level trip device, which allowed moisture into the switch, causing the switch to short.
6/18/75	A brush recorder monitoring the turbine EHC system caused erroneous voltage spikes resulting in rapid load reduction and reactor trip on high pressure.
6/25/75	Turbine tripped offline due to water in high pressure turbine.
12/21/75	Turbine trip due to actuation of deluge system. The switch was actuated to test the flood valve for the main turbine generator deluge system.
11/15/78	Momentary loss of DC power to the EHC control system caused a turbine trip. The reactor was kept about 15 to 20% at power.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: LA

EVENT CATEGORY: Loss of Air System

NUMBER OF EVENTS:

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: LC

EVENT CATEGORY: Loss of Control Building Ventilation

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: ATA

EVENT CATEGORY: Loss of ATA Power

NUMBER OF EVENTS: 0

REACTOP YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: LD

EVENT CATEGORY: Loss of DC Power Train A

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1

INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: AC

EVENT CATEGORY: Total Loss of Offsite Power

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: LNS

EVENT CATEGORY: Loss of Nuclear Services Closed Cooling Water

NUMBER OF EVENTS: 0

REACTOR YEARS: 4.5

Event Summary

Date	Event Description
	None.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book

TMI-1
INITIATING EVENTS DATA SUMMARY SHEET

DESIGNATOR: LR

EVENT CATEGORY: Loss of River Water

NUMBER OF EVENTS: 0

REACTOR YEARS: 12

Event Summary

Date	Event Description
	See discussion on plugging of intake screens in Section 3.5.

Data Sources: Monthly Operating Reports
Weekly Reports
Gray Book