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CONTRACTOR REPORT

Investigation of Potential Fire-Related Damage to Safety-Related Equipment in Nuclear Power Plants

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NOTICE

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INVESTIGATION OF POTENTIAL FIRE-RELATED DAMAGE TO SAFETY-RELATED EQUIPMENT IN NUCLEAR POWER PLANTS

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Sandia Project Monitor: Dennis L. Berry

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ABSTRACT

Based on a review of vendor information, fire damage reports, equipment qualification and hydrogen burn test results, and material properties, thirty-three types of equipment found in nuclear power plants were ranked in terms of their potential sensitivity to fire environments. The ranking considered both the functional requirements and damage proneness of each component. A further review of the seven top-ranked components was performed, considering the relative prevalence and potential safety significance of each. From this, relays and hand switches dominate as first choices for fire damage testing with logic equipment, power supplies, transmitters, and motor control centers as future candidates.

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by

Dennis L. Berry

Sandia National Laboratories

Background

The Fire Protection Research Program at Sandia National Laboratories is investigating for the U. S. Nuclear Regulatory Commission the phenomena associated with the occurrence, propagation, extinguishment, and control of fire in nuclear power plants and the ability of equipment and operators to cope with fire. Currently, the program emphasizes testing and analysis to provide a data base for fire risk assessments. This data base is needed, because probabilistic estimates of fire risk have appeared quite large relative to other accidents threatening nuclear power plants and because questions have arisen regarding the completeness and accuracy of the fire risk assessment results.

One topic which has received sparse treatment in fire risk assessments is the damage threshold of equipment. Except for assessing cable failures at an insulation autoignition temperature, little effort has been made to address failure mechanisms of equipment resulting from:

- high humidity conditions associated with suppression activities

- high temperatures below autoignition limits

- highly corrosive vapors given off by cable fires or gaseous suppression agents

The effects of high temperatures, corrosive vapors, high humidities, and exposure durations have not been determined for power plant safety equipment under fire conditions. As a result, fire risk assessments lack a supporting technical basis and often have been forced to make use of the sparse data that may be available.

Discussion

To address the lack of damageability data, equipment will be tested in the Fire Protection Research Program under the reproducible conditions of a fire simulation test chamber. However, because of the costs of testing and the large variety of components found in power plant safety systems, initial testing must focus on those pieces of equipment believed to be most functionally intolerant and most damage prone. In addition the importance of equipment to plant safety must be considered.

NUS Corporation, under contract to Sandia National Laboratories, developed a fire sensitivity ranking of thirty-three types of equipment found in nuclear power plant safety systems. The ranking process and its results are reported herein, representing a collection of vendor information, fire damage reports, equipment qualification and hydrogen burn survival test results, and material property reviews. At Sandia's request, NUS ranked the equipment on the basis of a relative overall numerical score which reflects the functional tolerance and damageability of each equipment type, based on all available information related to fire environments. The NUS rankings were developed without consideration of relative safety importance, consequences of failure, or testing costs. In addition, because of a lack of test information, the rankings assigned only 10% of the maximum ranking score to the possible damaging effects of smoke particles and corrosion, despite the fact that test data may later show these effects to be important.

As a result of their ranking process, NUS identified the following highest ranking components in terms of decreasing potential sensitivity to fire:

Recorders
Logic Equipment
Controllers
Power Supplies
Meters
Relays (Solid State and Electrical/Mechanical)
Hand Switches

For these and several other equipment types, NUS has developed in their report general guidelines for performing damageability testing. Where available, NUS has also provided sample procedures from operating nuclear power plants for calibrating and testing the components.

As a further refinement of the NUS ranking, Sandia assessed the above components in terms of:

- their prevalence in power plant safety systems
- their importance for automatic or manual operation of front-line systems
- their potential for effecting the loss of a complete safety function

Using the LaSalle Nuclear Power Plant as representative, Sandia*

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* Review performed by Mark J. Jacobus, Adverse Environment Safety Assessment Division 6447

reviewed equipment qualification lists of safety equipment to identify the number of components from the NUS ranking which are installed both generally in the plant and in front-line systems. The findings of this review, listed below, show a much higher occurrence of relays and hand switches in front-line systems than the other five components ranked above them as potentially more fire sensitive.

	Total Number	Number in LaSalle Front-Line Systems
Recorders	25	3
Logic Equipment	114	33
Controllers	93	1
Power Supplies	40	10
Meters	127	102
Relays	771	524
Hand Switches	446	322

For purposes of the above list, front-line systems included:

Auxiliary Power
Nuclear Pressure Relief
Reactor Recirculation
Control Rod Drive
Neutron Monitoring
Reactor Protection
Battery and Distribution
Residual Heat Removal (inc. service water)
Low Pressure Core Spray
High Pressure Core Spray
Reactor Core Isolation Cooling

Systems not considered front line included heating, ventilating, and air conditioning systems; gas treatment, leak detection, and drainage systems; and radiation monitoring, combustible gas control, and instrument nitrogen systems.

Conclusions

On the basis of a systematic assessment by NUS of thirty-three types of equipment found in nuclear power plants, a component ranking has been developed in terms of potential sensitivity to fire environments. The ranking has considered both the functional requirements and damage proneness of each component type, using vendor information, fire damage reports, equipment qualification and hydrogen burn test results, and material property reviews. Considering the relative prevalence and operational significance of the seven top-ranked components in power plant systems, relays and hand switches dominate as the first choices for fire damage threshold testing. Next to these components, other likely candidates for future testing include logic equipment, power supplies, transmitters, and motor control centers.

1.0 INTRODUCTION

The ability of fires to damage equipment is well known. The potential damage caused by fires in nuclear plants has resulted in Nuclear Regulatory Commission (NRC) regulations which strive to limit the damage to safety-related equipment caused by fires. These regulations are, however, non-mechanistic in that there is no attempt to quantify either the degree of functionality of equipment subjected to fire effects or the level of fire effects necessary to damage safety-related equipment. The purpose of this investigation is to establish, from existing utility documents, non-nuclear data sources, vendor data, and test reports, the relative sensitivity of nuclear plant safety-related equipment to fire damage mechanisms.

In order to define the fire-sensitive ranking of equipment, three major tasks were performed - 1) Equipment Identification and Functionality Determinations, 2) Literature Search and Vendor Data Gathering, and 3) Equipment Ranking. A fourth task, Testing Measurement Definition, was performed to ensure that the anticipated degree of equipment fire susceptibility will be measured by test and monitoring equipment during fire simulation testing. This task was arbitrarily placed under the third major task because it occurred during the latter stages of the project. Subtasks necessary to complete the three major task objectives are shown below:

Task 1) Equipment Identification and Functionality Determination
1) Fire Hazards Analysis Review
2) Final Safety Analysis Report Review
3) Supplementation of Equipment List Data using Equipment Qualification Reports
4) Technical Specifications Review
5) P & ID Review
6) Functionality Determination from Technical Specification Limiting Conditions for Operation
7) Vendor Contact to Obtain Catalog Information

Task 2) Literature Search and Vendor Data Gathering
1) Literature Search
2) NOMIS/FOMIS* Inquiry
3) Hydrogen Burn Tests Reports Review
4) Vendor Specification/Equipment Qualification Reports Review
5) Materials of Construction Evaluation

*Nuclear Operations Maintenance Information Service and Fossil Operations Maintenance Information Service - NUS Corporation Services, which provide for an interchange of ideas among utility operations and maintenance departments.

Task 3) Equipment Ranking

1) Measure of Worth Evaluation to Determine Dominant Expected Failure Causes
2) Failure Data Comparison
3) Testing Measurements Definition

The results of each task are discussed below. The final matrix used to determine the fire sensitivity is given in Table 8-1. This matrix is the major end product of the project. It ranks nuclear power plant equipment most likely to be damaged by fire effects.

2.0 EQUIPMENT IDENTIFICATION AND FUNCTIONALITY DETERMINATION

In order to choose representative equipment for evaluation with respect to fire damage potential, equipment types and their functions were obtained for four nuclear plants - one nonoperating pressurized water reactor (PWR), one operating PWR, one operating boiling water reactor (BWR), and one nonoperating BWR. In order to preserve anonymity and because only representative information was desired, the plants have been designated A, B, C, and D respectively.

2.1 FHS/FSAR REVIEW AND EQUIPMENT LIST SUPPLEMENTATION

Since the goal of the project is to determine the fire damageability of equipment and its effect on equipment functionality the Fire Hazards Analysis (FHA) for each plant was used to identify equipment necessary for safe plant shutdown during fires. In accordance with Nuclear Regulatory Commission (NRC) requirements, the nuclear plants studies had submitted an FHA which includes, to varying degree, the safety-related equipment needed to safely shut down each plant in the event of fire.

The FHA equipment lists contain system, tag number, and type of equipment without significant details about the manufacturer/model number, physical characteristics, or functional characteristics of the equipment. In order to obtain the missing data, other utility documents were queried. These documents included equipment qualification (EQ) reports, final safety analysis reports (FSAR), instrument lists, piping and instrumentation diagrams (P&ID), and other equipment identifying documents as necessary.

The results of the equipment identification process were compiled. A total of 219 major items were identified. In addition, about one-third of the major items had associated support equipment which was listed. A sample form is shown in Exhibit 2-1. The equipment information for plant D is summary in nature. The plant D data was obtained during the visit to the utility, because the FHA contained insufficient information to allow for completion of the system, tag number, and equipment type parameters. A safety-related equipment list supplemented plant D equipment data.

For the three plants having detailed FHA information, the FHA equipment parameters were supplemented by other data. In all three cases, only major equipment items were identified in the FHAs. Supporting equipment (see Exhibit 2-1) for plant A was determined through an instrument list and P&ID review. Supporting equipment for the other three plants (B, C, D) was not identified, but, since the major equipment types and manufacturers were similar among all fur plants, supporting equipment was assumed to be similar. Cost, scheduler and project scope constraints also limited the search for supporting equipment.

SAMPLE EQUIPMENT INFORMATION FORM

System: Shutdown Cooling

Tag Numbers: 2HV 9316

Equipment Type: Temperature Control Valve

Description:

Manufacturer: ITT

Model No: V621 UHE U9VALZZ
Rating: 250 psid, 400 deg F
Size:
Weight:

Qual. Temp:
Press:
Hum:
Op.Time:

Safety Function: Regulates Shutdown Cooling flow through to Low Pressure Safety Injection header.

Cold Shutdown

Operational
Success Criteria:

Operating Time:

Support Equipment: ZSH/L (NAMCO EA170-11302), Solenoid (ASCO HT-8316 65), Switch (MSC), Hand Controller (Foxboro 235 SM), E/I Converter (Foxboro 2AO-V2I), E/P Positioner (HD/C P51A100).

Vendor Information:

References: Inst. Index

Failure Mechanisms: Loss of Power

Location:

EXHIBIT 2-1

The supporting equipment review performed by NUS onsite personnel identified a large number of the panel-mounted and small electrical/electronic devices expected to be most susceptible to fire effects (see Section 8.0). In contrast, a review of the supporting equipment as determined from the equipment identification forms generated by utilities was not found to be as comprehensive for the major items. Since P & ID's don't contain information such as relays which control major items, indicating lights for position of major items, cable types which provide power and control functions to major items, etc., these types of supporting equipment were not listed on the equipment identification forms. The instrument indexes and equipment lists reviewed also do not have detailed information on supporting equipment. Therefore, much of the supporting equipment was inferred from the type of devices normally used in nuclear plants per NUS experience.

EQ reports and FSAR information were used to provide the operating time, shutdown, safety function, and qualification parameters listed on the Equipment Information Forms (see Exhibit 2-1). The Data Bank (EQDB) provided manufacturer/model number and equipment thermal and humidity withstand capability in the form of EQ test parameters and environmental specifications. THe Nuclear News Buyer's Guide was used to identify representative manufacturers/ model numbers where necessary.

2.2 TECHNICAL SPECIFICATIONS REVIEW

The functionality aspects of equipment were determined through a review of the Technical Specifications (TS) for plant A and a review of EQ reports and FSARs for the other plants. The functional requirements, as stated in the TS, were used to identify the necessary safety operations for the equipment and, sometimes, the duration of required operability. A sample TS is shown in Exhibit 2.2.

The TS and corresponding plant procedures define the appropriate tests and test frequencies to ensure that the safety function for the equipment is accomplished. By reviewing the TS/procedures, the important functionality aspects of equipment items were determined and recorded in tables. Only one set of TS was reviewed, since the functional success criteria and limiting conditions for operation (LCO) are similar for all nuclear plants. Also, the Standardized Technical Specifications used by NRC to review applications for plant operating licenses have nearly identical approaches to success criteria and limiting conditions for operation (LCO) when viewed from an equipmentspecific basis. For example, although valve stroke time may vary from about 10 to 60 seconds, valve operational success (as noted in TS) is measured by a change of state. The stroke time is mainly a function of equipment design rather than TS requirements. For example a Limitorque valve operator of a given size can be expected to perform as a function of design rather than requirement.

REACTIVITY CONTROL SYSTEMS

FLOW PATHS - OPERATING

LIMITING CONDITION FOR OPERATION

3.1.2.2 At least two of the following three boron injection flow paths shall be OPERABLE:

a. The flow path from the boric acid tanks via a boric acid transfer pump and a charging pump to the Reactor Coolant System.

b. Two flow paths from the refueling water storage tank via charging pumps to the Reactor Coolant System.

APPLICABILITY: MODES 1, 2, 3, and 4.#

ACTION:

With only one of the above required boron injection flow paths to the Reactor Coolant System OPERABLE, restore at least two boron injection flow paths to the Reactor Coolant System to OPERABLE status within 72 hours or be in at least HOT STANDBY and borated to a SHUTDOWN MARGIN equivalent to at least 1% delta k/k at 200°F within the next 6 hours; restore at least two flow paths to OPERABLE status within the next 7 days or be in COLD SHUTDOWN within the next 30 hours.

SURVEILLANCE REQUIREMENTS

4.1.2.2 At least two of the above required flow paths shall be demonstrated OPERABLE:

a. At least once per 7 days by verifying that the temperature of the heat traced portion of the flow path from the boric acid tanks is greater than or equal to (65)°F when it is a required water source.

b. At least once per 31 days by verifying that each valve (manual, power operated, or automatic) in the flow path that is not locked, sealed, or otherwise secured in position, is in its correct position.

c. At least once per 18 months during shutdown by verifying that each automatic valve in the flow path actuates to its correct position on a ___ test signal.

d. At least once per 18 months by verifying that the flow path required by Specification 3.1.2.2.a delivers at least ___ gpm to the Reactor Coolant System.

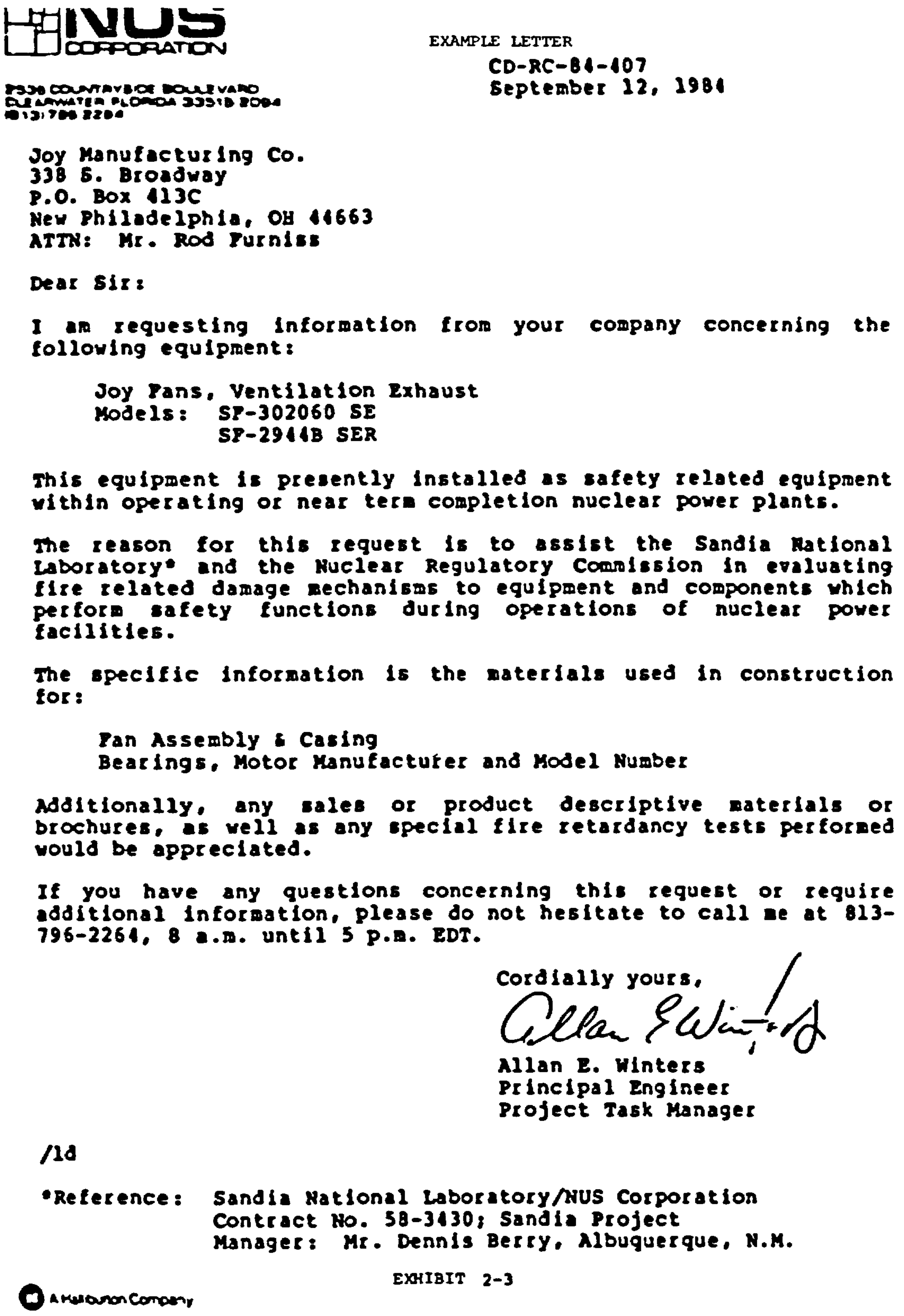
Only one boron injection flow path is required to be OPERABLE whenever the temperature of one or more of the RCS cold legs is less than or equal to (275)°F.

EXHIBIT 2-2

Exhibit 2-2 is a sample page from the Westinghouse Standard Technical Specifications (W-STS). Item C under the title "Surveillance Requirements" shows the W-STS success criteria of "...actuates to its correct position..." This level of detail is consistent throughout the TS for any plant. Equipment specification parameters, such as valve stroke time, valve operator torque output, tripping of valve operation internal limit switches, etc., must be determined from equipment specifications, rather than TS.

2.3 VENDOR CONTACT

Vendor contact was initiated as soon as the manufacturer and model number of the equipment was determined. The inclusion of this subtask in Major Task No. 1 was because of the long lead time expected for the return of vendor information. The results of the vendor contact will be discussed in Section 6.0. A sample vendor contact letter is shown in Exhibit 2-3.



NUS CORPORATION

2536 COUNTRYSIDE BOULEVARD
CLEARWATER FLORIDA 33515 2094
(813) 796 2264

EXAMPLE LETTER

CD-RC-84-407
September 12, 1984

Joy Manufacturing Co.
338 S. Broadway
P.O. Box 413C
New Philadelphia, OH 44663
ATTN: Mr. Rod Furniss

Dear Sir:

I am requesting information from your company concerning the following equipment:

Joy Fans, Ventilation Exhaust
Models: SF-302060 SE
SF-2944B SER

This equipment is presently installed as safety related equipment within operating or near term completion nuclear power plants.

The reason for this request is to assist the Sandia National Laboratory* and the Nuclear Regulatory Commission in evaluating fire related damage mechanisms to equipment and components which perform safety functions during operations of nuclear power facilities.

The specific information is the materials used in construction for:

Fan Assembly & Casing
Bearings, Motor Manufacturer and Model Number

Additionally, any sales or product descriptive materials or brochures, as well as any special fire retardancy tests performed would be appreciated.

If you have any questions concerning this request or require additional information, please do not hesitate to call me at 813-796-2264, 8 a.m. until 5 p.m. EDT.

Cordially yours,

Allan E. Winters

Allan E. Winters
Principal Engineer
Project Task Manager

/ld

*Reference: Sandia National Laboratory/NUS Corporation
Contract No. 58-3430; Sandia Project
Manager: Mr. Dennis Berry, Albuquerque, N.M.

EXHIBIT 2-3

A Halliburton Company

3.0 LITERATURE SEARCH

In order to identify damage mechanisms caused by actual fires, a literature search and expert opinion survey were performed. Numerous sources of data were queried without much beneficial information uncovered. Most of the fire reports are concerned with total loss of life and property. Practically no information exists on the degree of equipment function loss. The reports merely identify what failed. In addition, with the exception of a Duke Power report and a Consolidated Edison report, no indication of the nature of the equipment which successfully functioned during fires was identified. (Summaries of the literature/expert opinion search are shown in Exhibit 3.1)

A review of License Event Reports (LER's) was performed and summarized as shown in Exhibit 3.2. Note that each separate paragraph is a direct quote from LER summaries with plant identifiers deleted.

Public Document Reference (PDR), NUS Library, and NUS Licensing Information (LIS) literature sources were used for the literature search. Data bases were queried for fire, fire damage, smoke, smoke damage, heat, and heat damage keywords. A list of potentially useful documents was ordered through the PDR. A detailed list is shown in Exhibit 3-3.

In addition to the documents reviewed (see Exhibit 3-3), a few other documents were obtained and reviewed which contained little or no relevant information. Included in this category are: Proceedings from the International Symposiums on Combustion (1961 - 1976), Fire and Materials Magazines (1980 - 1983). The Nuclear Experience Data File was also reviewed for pertinent data on fire damage, but the data file was found to be redundant to the License Event Reports and EPRI NP-3179.

EXHIBIT 3.1

Literature/Expert Opinion Search

McDill Air Force Base, Tampa, Florida - Using VSM (microfilm) equipment, searched for Mil Specs and accident reports. Querried areas included fire, fire damage, fire retardancy, smoke, smoke damage, heat, damage reports. No information relative to project found.

Society of Fire Prevention, Boston, MA - Via telephone conversation, asked the society for any relative information related to project. No information available.

General Telephone Company (GTE), Tampa, Florida, GTE Regional Loss Prevention Unit - GTE has not had many fires within its operating equipment during the last seven years. GTE related that they have had computer and relay failures due to Halon Suppression System actuation during testing. Further details were not available as a contractor is responsible for clean-up and no formal report of any detail is filed.

Yankee Rowe Power Plant (YRPP), Mr. E. Sawyer, Fire Prevention Engineer - Mr. Sawyer is YRPP's Fire Prevention Engineer. He is presently completing his doctoral thesis on "Equipment Damage Due to Activation of Fire Suppression Systems." He indicated that he was not aware of any available information related to this project. He is addressing NRC Inspection and Enforcement Notice 83-41, "Actuation of Fire Suppression System Causing Inoperability of Safety-Related Equipment" but did not have, as yet, any information that would be of value to the project.

Institute of Nuclear Power Operations (INPO), Atlanta, GA - Various calls were placed to INPO to no avail. Personnel did not seem to know who would be the contact for any information or if information would be available for disclosure to an outside agency.

American Nuclear Insurers (ANI), Mr. M. Ferranti - Mr. Ferranti did not know of any investigations performed to the detail required. He also indicated that any ANI reports would be proprietary. ANI has a computer data bank but there is no "level of damage" keyword.

Florida State Fire Marshall, Mr. J. Martinez - Mr. Martinez indicated that Florida State fire reports are not detailed enough to be used in the project. The fire reports published by the Fire Marshall's office for industrial facilities primarily deal with arson origination or code violations.

University of Maryland, Dean of Fire Prevention Engineering, Dr. Bryan -Dr. Bryan was not aware of any type of information related to the project. He did not know of any reports or organizations having pertinent reports. He said that, normally, fire investigations deal with the fire cause. Equipment that was presumed damaged was replaced. He did indicate the EPRI may have completed some work, but was not sure what it was.

EXHIBIT 3.1 Continued

Factory Mutual Insurance, Mr. R. Brendal - Factory Mutual does not have any detailed information on fire damage. Factory Mutual primarily reviews and investigates fire causes related to their insurance and inspects for code and policy violations which may reduce insurance claims.

Factory Mutual Research, Mr. G. Weldon - Mr. Weldon was unaware of any information pertaining to the project. He indicated that Factory Mutual Research performs research in fire propagation, suppression, retardancy, and consumer product safety, and not fire damage per se.

National Fire Prevention Agency, NFPA Nuclear and Fossil Power Plan/Industrial Fire Prevention Engineer, Mr. Anderson - Mr. Anderson was not aware of any information but did suggest calling the NFPA Library. A literature list was sent by the library and reviewed by NUS. Literature was ordered as follows:

1) Hazardous Chemical Reactions Pub. No. 419M
2) Set of Fire Complications Pub. No. SET-55
3) Flash Point Index - 9th Ed. Pub. No. SPP-51
4) Surface Burning - Building Material Pub. No. 255
5) Flammable and Combustible Liquids Pub. No. 321
6) Properties of Flammable Liquids Pub. No. 325M
7) Test-Smoke Generated by Solid Materials Pub. 258

No pertinent data was found in any of the above publications.

EXHIBIT 3-2

LER SUMMARY 1969 TO 1984

(Note: Each paragraph below is a separate quote from the published LER summaries with plant identifiers deleted.

During normal plant operation, a control operator observed the "water spray" light for the 2A standby gas treatment train (SBGT) energized. The 2A SBGT fire detection had initiated a water deluge wetting the 2A SBGT filter.

When temperature switches TS5 and TS6 were removed for testing, it was noticed that condensate had formed in the switches and the switch junction box. A previous resistance reading across switch TS5, which was one third full of water, was 40K ohms. The source of condensation could not be found. Switches were replaced and sealed.

During normal operation, while hydrotesting the recently installed fire sprinkler system in reactor building, a gasket in a flow switch in a water line failed and water sprayed into 125 VDC starter racks for RCIC and RHR. One of the auxiliary contacts on starter for RCIC-MO-131 shorted and valve automatically opened. RCIC system was declared inoperable to repair shorted contact. Redundant emergency core cooling systems were operable, thus this event presented no adverse consequences from standpoint of public health & safety.

Fire sprinklers were hydrotested. As a result, a contact shorted in RCIC starter rack. Gasket and flow switch were reinstalled. Starter racks were cleaned and dried. Contact was replaced and correct operations of RCIC-MO-131 verified. Waterproofing of affected electrical equipment is being investigated.

It was discovered that an inadvertent actuation of the fire service deluge system resulted in damage to auxiliary building ventilation exhaust filter AHFL-2A in excess of two-thousand ($2,000) dollars. Auxiliary building ventilation was shifted to AHFL-2B at 1300. This is the first occurrence of this type reported. The cause of this event is attributed to personnel error. The inadvertent actuation occurred while attempting to reset a fire service panel alarm. Post replacement testing is scheduled.

Water seeped into the local actuation switch of fire protection water spray for charcoal filter associated with control room pressurization fans. This caused actuation of the fire spray system and lockout of the fans. The spray was valved off, but the fans would not reset until the local control box was drained and dried out.

Water in control cabinet shorted the auto start relay contact causing auto start block alarm. Water removed and cabinet dried. Required surveillance completed satisfactorily and the Diesel Generator demonstrated operable. The seams betweeen ceiling and U2 and U3 Diesel Generator Room vent, ductwork, have been sealed with RTV to prevent recurrence.

LER SUMMARY 1969 TO 1984

With Unit 1 at steady state power of 2272 MWT, Unit 2 transformer fire protection preoperational test on 2C startup transformer was being performed when arc occurred around the phase 2 230KV bushing. 230KV bus C overcurrent relay on phase 2 tripped instantaneously causing deenergization of startup transformers 1C & 2C. Exact cause of arc is not clearly understood although water spray from deluge system was major factor. One nozzle on deluge system was wetting phase 2 and phase 3 bushings and wind was blowing.

A fire occurred inside a temporary storage shed, in a warehouse storage area. A total of 14 valves were damaged in varying degrees. Electrical short in one of light fixtures in shed.

Controller and circuit breaker assembly were destroyed by fire. The equipment in question was Allis Chalmers 600-208 V motor control center. Cause was failure of contacts on the breaker assembly due to improper maintenance and handling. Corrective action involved training of plant personnel in proper maintenance & installation.

During normal operation an annuciator signal was received on a high pressure coolant injection (HPCI) valve overload/loss of control power. During investigation, a fire was found in BMCC6 for 23 MOV16. Initiated fire procedures and de-energized valve breaker. HPCI temporarily inoperative. Open manually 23 MOV16, restoring HPCI. Apparent Overload. Still being investigated.

During normal operation the 4160/480 volt, dry type, transformer feeding 480 volt essential bus 1A, failed and caught fire. Interruptible instrument power BUS 1C lost power and the main turbine generator tripped. The reactor was manually scrammed. The dry type ITE 4160/480 volt shorted turn-to-turn in one phase of the low voltage windings. Resulting fire extinguished by plant personnel using portable fire extinguishers. Transformer replaced in kind.

Near the end of the weekly thirty-minute run time of the turbine emergency oil pump, a fire alarm was received from the battery room. The plastic tops of two cells of "A" station battery were on fire and were extinguished by a short burst from a CO2 extinguisher. At no time did the battery lose power or give any indication of problems. The damage was contained to the top of the cell jars and does not appear to have hurt the cell internals. No electrolyte was lost. The cause of the fire appears to have been resistance heating of a strap-to-cell terminal connection during the heavy D.C. load of the emergency oil pump. All other connections were inspected and tested. Adequate capacity of 58 cells was verified and the battery was returned to service. New cells were ordered.

EXHIBIT 3-2 (Continued)

LER SUMMARY 1969 to 1984

With the plant in hot standby, a fire occurred in the "A" charging pump controller located in motor control center MCC 22-1E (B51) which is powered from 480V emergency BUS 22E. The fire was extinguished when MCC B51 was deenergized. The deenergization of B51 and its feeder to regulated instrument AC BUS IAC-1 resulted in the fire from electrical arcing of the controller to bus connection. Text is unclear about further details.

Fire in "A" charging pump controller resulted from arcing of supply lead to one of the bayonet fittings connecting the controller to BUS B51. Problems have been previously experienced with the G.E. type 1C7700 relay.

Transformer fire protection deluge system operation caused water to short out transformer and electrical protective circuits. Caused turbine lockout and scram. Reactor pressure peaked but one relief valve did not open. Similar malfunction of relief valve at this reactor occurred previously.

Leaking rainwater shorted deluge system. Target Rock relief valve malfunctioned caused by leak in bellows assembly.

During daily SRM operability check, SRM detector could not be withdrawn from the core. Investigation revealed that 18 relays in the SRM/IRM detector drive relay cabinet had suffered fire damage. Damaged relays and associated wiring were replaced and system was tested. One similar occurrence with this relay type was previously reported.

Apparent overheat and failure of coil of a GE type CR 120 relay caused flammable plastic contact retainer clips to catch fire. The fire was self-extinguishing.

Damage to portion of plant protection logic resulted from a partial short circuit in K-31 relay for residual heat removal (RHR)shutdown cooling isolation valve MO-10-18 which caused relay to overheat. The plastic contact arm retainer ignited and a minor fire communicated to adjoining relays. It was extinguished. Unit shutdown. No previous occurrence.

GE CR120A industrial control relay coil failed. Affected relays and equipment replaced and tested. No additional details provided.

Fire occurred in the motor control center in the auxiliary building. The fire was extinguished utilizing CO2 and dry chemicals. Cause was misaligned stabs resulting in electrical arcing subsequently igniting vertical insulating barrier. No further details provided.

EXHIBIT 3-2 (Continued)

LER SUMMARY 1969 to 1984

Misaligned stab assemblies connected to breaker associated with pump starter caused electrical arc to develop which subsequently ignited vertical insulating barrier.

Spurious fire protection system deluge actuation occurred in north cable riser area of control building. Cause unknown. No fire or smoke observed in area. No corrective action planned.

Deluge spray system inadvertently activated. Caused by accidental tripping of manual trip level. Fire watch established. Design change implemented.

Smoke detector panel failed to operate. Caused by water entering panel from concrete drilling operation. Work instructions revised to ensure fire alarm panels adequately protected.

Sprinkler system that protects diesel generator G-002 spuriously initiated leaving actuation fire detection sys inoperable until reset. Cause unknown. Firewatch established.

Fire observed in fire detection instrumentation panel 1FP3. Panel de-energized and several fire detectors rendered inoperable. Caused by failure of panel alarm buzzer relay. Relay replaced.

Fire detection system trouble alarms could not be cleared & EFA zones 63 and 64 declared inoperable. Caused by corrosion due to water leakage into data gathering panel. Failed components replaced.

Ionization smoke detector failed channel functional test. Caused by deterioration of integral printed circuitry due to boric acid deposits in Honeywell detector type TC 100A.

Pilot valve failure in fixed water spray system resulted in control room alarm. Caused by leakage past pilot valve seat due to corrosion and settling of pilot valve seat by fixed water spray system leakage. Corrosion removed.

Fire detection alarms & master solenoid relay found inoperable. Caused by defective wiring & moisture. Wiring changed & detector dried.

During normal operation, while hyrotesting reactor building fire sprinkler system gasket in a water line flow switch failed and water sprayed into 125 volt DC starter racks for reactor core isolation cooling.

EXHIBIT 3-2 (Continued)

LER SUMMARY 1969 to 1984

While securing a diesel generator from control room, two relays caught on fire. Cause undertermined. Relays were replaced, recalibrated, and checked.

Both control room pressurization fans were inoperable. Caused by water seepage into a fire protection system switch resulting in actuation of fire spray system and lockout of the fans.

EXHIBIT 3-3

LITERATURE SEARCH DOCUMENTS

1) Letter from A. C. Thies, Duke Power Company, to F. E. Kruesi, US Atomic Energy Commission, with attached report "1B2 Reactor Coolant Pump Motor Oil Leak and Fire, December 30, 1972," dated January 26, 1973.

2) Letter from W. F. Conway, Vermont Yankee Nuclear Power Corporation, to T. A. Ippolito, US Nuclear Regulatory Commission, dated March 14, 1980, (transformer fire).

3) Letter from A. C. Thies, Duke Power Company, to A. Giambusso, US Atomic Energy Commission, with attached report "Oconee Nuclear Station, March 6, 1973, 1A1 Reactor Coolant Pump Oil Fire Incident Report," dated May 4, 1973.

4) Letter from W. E. Caldwell, Consolidated Edison Company of New York, to P. A. Morris, US Atomic Energy Commission, with attached report "Indian Point Primary Auxiliary Building and Equipment," dated December 6, 1971.

5) Letter from J. P. O'Reilley, US Atomic Energy Commission, to W. W. Lapsley, Consolidated Edison Company of New York, dated January 19, 1972. (cable repair inspection.)

6) Letter from W. J. Caldwell, Jr., Consolidated Edison Company of New York, to J. P. O'Reilly, US Atomic Energy Commission, not dated. (restoration plan test results)

7) Letter from B. B. Stephenson, Commonwealth Edison Company, Quad-Cities Nuclear Power Station, to A. Giambusso, US Atomic Energy Commission, dated March 16, 1973. (hydrogen burn)

8) Letter from F. A. Palmer, Commonwealth Edison Company, Quad-Cities Nuclear Power Station, to J. F. O'Leary, US Atomic Energy Commission, dated July 24, 1972. (cable tray fire)

9) Cain, C. et al. Interim Report entitled "Program for Sampling, Analysis, and Cleanup of Residue on Affected Structures, Systems, and Components, dated May 22, 1975. (TVA Brown's Ferry fire)

EXHIBIT 3-3 (continued)

10) Beland, B., "Examination of Electrical Conductors Following a Fire, "Departmenty of Electrical Engineering, University of Sherbrooke.

11) Robinson, J. N. and Rau Jr., C. A. "Analyzing Failures - Some Advice and Examples, "Mechanical Engineering, July, 1984.

12) Dungan, K. W., and Lorenz, M. S., "Nuclear-Power-Plant Fire-Loss Data, "Professional Loss Control, Inc., prepared for Electric Power Research Institute, EPRI Report No. NP-3179, July, 1983.

13) Telephone Conversations with the following persons/organizations:

Name	Organization	Date
------------	Society of Fire Protection	June 13, 1984
E. Sawyer	Yankee Rowe	June 12, 1984
D. Perspacker	GTE Florida	June 13, 1984
------------	INPO	June 12, 1984
M. Ferrante	American Nuclear Insurers	June 11, 1984
J. Martinez	Florida State Fire Marshall	June 7, 1984
Dr. Bryan	Univ. of Md. Fire Prevention Dean	June 6, 1984
R. Brendal	Factory Mutual Insurance	June 6, 1984
G. Weldon	Factory Mutual Insurance	June 6, 1984
J. Anderson	NFPA	June 6, 1984
------------	Eastern Airlines	June 13, 1984
J. Kestler	Bay Area Rapid Transit	July 5, 1984

4.0 TEST DATA

Two sets of nuclear related test data were evaluated to determine temperature and moisture susceptibility of equipment during fire incidents - Equipment Qualification (EQ) and Hydrogen Burn Survivability Test Reports. Another source, (i.e., non-nuclear test data) obtained from a literature search, provided little data. The non-nuclear literature was not evaluated further. Both sets of nuclear related tests have been performed to assess equipment performance under high temperature. The EQ tests were performed in a steam environment, the hydrogen burn survivability tests used steam to heat up the test vessels to above ambient temperatures. Failures of equipment in either type of test could be the result of either heat or moisture effects or both.

4.1 NON-NUCLEAR TEST DATA

A search for non-nuclear test data which addressed the sensitivity of equipment located in mild environments, i.e., not subjected to high temperature and steam environments, was conducted through the literature contained in standard reference indexes. Few citations of fire-related damage to equipment were found. All published reports referred to either complete destruction of equipment or to financial loss, with the exceptions noted in the following paragraph.

Three promising non-nuclear citation titles were found however -1) "Electronic Vulnerability to Fire Related Carbon Fibers," 2) "Small Scale Laboratory Flammability Tests of Electronic Components," and 3) "Testing of Telecommunication Equipment." The first citation described tests performed on stereo amplifiers which showed the potential for carbon fibers to cause erroneous signals in electronic equipment. Soot, however, did not cause erroneous signals. The test was performed to study the effects of aircraft cable fires. The second citation merely discussed the flammability of electronic conponents without discussing the susceptibility of the components to external fire sources. The third citation was an oral technical presentation without any published record.

4.2 EQUIPMENT QUALIFICATION TESTS

An unpublished EPRI report on sealing methods employed to exclude moisture during EQ tests indicated moisture sensitivity for a few devices. Summaries of EQ experience along with indications of potential thermal and moisture sensitivities were published by NRC in Inspection and Enforcement (IE) Notices 81-29, 82-52, and 83-72. Other IE Bulletins (IEB) and Notices (IEN) which identified potential sensitivities were: IEB 84-01, IEN 82-04, IEN 82-13, IEN 84-20, and IEN 84-47. These documents along with engineering judgment applied to EQ test reports of qualified equipment were factored into the Functionality/Damageability Matrix of Section 8.0.

In addition, the EPRI Equipment Qualification Data Bank (EQDB) was queried for thermal test parameters of equipment qualified for harsh environments, i.e., equipment located inside containment or equipment subjected to elevated temperature because of steam line breaks. Equipment which passed EQ tests at elevated temperatures were judged more resistant to high temperatures and moisture than equipment not subjected to EQ tests unless other data (see Section 4.3) indicated a potential weakness.

4.3 HYDROGEN BURN SURVIVABILITY

The equipment listed in Tables 4-1, 4-2, 4-3, and 4-4 has either been analyzed for potential hydrogen burn failures or tested in actual hydrogen burns. Summaries of the failures predicted to occur or which have occurred are given below. A short description of the test conditions in each test is also included. Note that all equipment in the hydrogen burn tests below is Class 1E qualified for LOCA conditions. The limiting operating temperatures were obtained from the test data, other EQ tests, EQDB values and/or manufacturer's data. The temperatures are predicted not actual levels of operability in high temperature environments. Equipment located outside the containment in the auxiliary building or secondary containment is often identical to that located inside containment because the environments in the latter two areas is often nearly as severe as inside containment. Also many utilities make no distinction in specifying equipment located inside containment and outside containment.

Some of the equipment listed in the functionality matrix of Table 8-1 is located in control or electrical rooms and, therefore, not qualified to LOCA environments because, Regulatory Guide 1.89does not require that equipment located in mild environments be tested. Such equipment should be more likely to experience failures during fire conditions. Despite the fact that some equipment may be relatively more sensitive to fire, the failure modes occurring in the hydrogen burn test for the qualified equipment are indicative of failure modes for all equipment in a fire because hot and wet environments occur during both hydrogen burn tests and fires. However, it should be noted that successful operation during hydrogen burn tests does not imply successful operation in nuclear plant fires, although the relative sensitivity is addressed.

4.3.1 IDCOR - Equipment Survivability

The IDCOR (Industry Degraded Core Rulemaking), effort is an industry program to resolve questions raised by the TMI-2 incident. One purpose of IDCOR was to analytically evaluate the effects of hydrogen burn on the ability of safety-related equipment to perform. The assumptions included the specification of bounding temperature and pressure environments inside reactor containment buildings caused by hydrogen burn. Four nuclear plants (Zion, Sequoyah, Peach Bottom, and Grand Gulf) were used as reference plants. Computer codes, i.e., HEATING-5 for equipment response and MAPP for environment definition, were used to determine whether equipment could survive the predicted environments. Maximum conditions were calculated to be from 22 psia to 149 psia and from 220 F to 560 F depending on location of the equipment in the plant and the postulated accident sequence causing the release of hydrogen.

Table 4-1 is a list of equipment evaluated by IDCOR. The equipment predicted to fail is marked by an asterisk (*). All other equipment was predicted to survive the hydrogen burn environment. The survivability was generally predicted by calculating the maximum temperature rise of each equipment type using HEATING-5 and comparing the calculated rise to existing equipment qualification test data. In some cases, comparison of the temperature rise to equipment material heat resistance properties or analyses of time lag (insulation) properties of materials of construction were used to determine survivability.

Table 4-1

IDCOR Equipment Data

Equipment Type	Manufacturer	Model No.	Size (Approx.)	Weight (Approx.)	Limiting Operating Temp.
Check Valve	Not Given				
Motor Operator	Limitorque	SMB-2	46"x18"x16"	300 lbs	350-400°F
Thermocouple	Not Given				
Solenoid Valve	Target Rock	77J-001	24"x9"x18"	300 lbs	385-435°F
Level Transmitter	Barton	764	8"x8"x3"	15 lbs	380-420°F
Motor Operator	Limitorque	SMB-1	40"x18"x16"	250 lbs	350-400°F
* Fan Motor	Westinghouse	Frame 200 (200 HP) Class F			325°F WCAP-7829)
* Pressure Transmitter	Fisher & Porter	50 EP1041 BCXA-N			290°F
Solenoid Valve	Asco	LB-831654	6"x5"x2"	10 lbs	330°F
Motor Operator	Limitorque	SMB-000	24"x18"x15"	120 lbs	350-400°F
Level Transmitter	Barton	763	8"x8"x3"	15 lbs	380-420°F
Pump	Bingham				
Solenoid Valve	Automatic Valve Co.	AVC-C5450			340°F
* Connectors	Burndy	Hylink-SYV	3"x1"x1"	1 lb	338°F
Electrical Penetration	GE	Series 100	24"x12"x12"	500 lbs	900°F
Solenoid Valve	Asco	HTX8320A20	6"x5"x2"	10 lbs	330°F
Level Transmitter	Rosemount	1152	5"x5"x7"	5 lbs	350°F
Motor Operator	Limitorque (Reliance Motor)	SB-1-40	40"x18"x16"	250 lbs	350-400°F
* Electrical Penetration	Westinghouse (Okonite & Rockbestos Cables)	Modular Type B13	24"x12"x12"	500 lbs	340°F

* Equipment predicted by CLASIX analysis to fail.
Data from "IDCOR Task 17-Equipment Survivability in a Degraded Core Environment"

NOTE: No testing performed - all analysis using CLASIX Code.

4.3.2 EPRI Intermediate Scale Studies

The EPRI Intermediate Scale Equipment Surviability experiments were performed to assess the ability of safety-related equipment to perform when subjected to hydrogen burn in relatively small rooms. The test vessel used was a cylindrical tank, 17 feet high and 7 feet in diameter. The maximum internal air temperature in the equipment specimens installed in the vessel was 572 F. The maximum pressure inside the vessel was 49 psia. All Intermediate Scale tests used steam to preheat the vessel to 160 F prior to hydrogen ignition and water was sprayed inside the vessel during some tests.

Table 4-2 lists the equipment tested in this program. All equipment performed before and after the tests, however, some anomalies occurred during and shortly after the last and more severe test. The test engineer reported no indication of operation from the Limitorque limit switch contacts during the test, although the NAMCO limit switch indicated that the motor operator did function. Subsequent to the test, electrical arcing was observed at the Limitorque operator when the vessel was opened and the motor operator was energized. A few hours later, the arcing disappeared and the motor operator functioned properly.

The equipment in the test vessel was partially disassembled in a few minutes after the arcing disappeared. About one quart of water drained from the Limitorque operator upon disassembly. The Conax thermocouple connection head also had significant amounts of water inside. No electrical abnormality for the thermocouple was observed however. Trace amounts of water were found in the Asco solenoid valve, the Weed RTD connection head, and the Foxboro connection box. No water was found in the NAMCO limit switch or the Foxboro electronics enclosure.

There was no scorching, charring, or other thermal damage to the equipment observed. All anomalies including the failure of a cable to pass a post-burn electrical test were attributed to moisture intrusion. Preheating the vessel with steam and the use of water sprays in the test chamber contributed to the water found in the equipment. The O-rings used to seal the Foxboro transmitter and Weed RTD were effective. The flat gasket seals used to otherwise seal the equipment were only marginally effective at best. Equipment having drains which allowed no collection of water inside the equipment functioned properly. The Asco solenoid valve and the Foxboro transmitter connection box showed signs of water intrusion, but only trace amounts of condensation remained inside the equipment.

Table 4-2

EPRI Intermediate Scale Hydrogen Burn Equipment Data

Equipment Type	Manufacturer	Model No.	Size (Approx.) Inches	Weight (Approx.)	Predicted Limiting Operating Temp.
Motor Operator	Limitorque	SMB-000-2	24"x18"x15"	120 lbs	350/400°F
Pressure Transmitter	Foxboro	NE13DM	15"x12"x6"	30 lbs	350°F
Solenoid Valve	Asco	NP831654E	6"x6"x3"	5 lbs	300°F
Limit Switch	Namco Controls	EA180-11302	6"x3"x3"	10 lbs	400/450°F
Thermocouple	Conax Corporation	Dual Type E	12"x2"x2"	15 lbs	400°F
Resistance Temp. Detector	Weed Instruments	1B5D/611	18"x3"x3"	15 lbs	400/450°F
Hydrogen Ignitor	GM Glow Plug	AC-7G	8"x8"x6"	25 lbs	Unknown
Assembly-Box, Xfmr, Glow Plug	Xfmr. mfgr. unknown				Unknown
Thermocouples	Fabricated by Acurex				Unknown

Data extracted from EPRI Report No. NP-2953 - June, 1983 "Hydrogen Combustion and Control Studies in Intermediate Scale."

4.3.3 EPRI Large Scale Tests

The EPRI Large Scale tests were performed at the Nevada Test Site in a large spherical dewar, 52 feet in diameter. The maximum equipment temperature was 480 F. The vessel was preheated to 160 F and water sprays were used in the Intermediate Scale tests.

One difference between the Large Scale Tests and the Intermediate Scale Tests was that during the Large Scale Tests the equipment lead wires were enclosed in pressure tight hose rather than in flexible conduit as in the Intermediate Scale Tests. However, even though the hose was pressure tight water nevertheless intruded through equipment or fitting openings and collected in the equipment. Although this water collection problem was corrected through various means during the course of the test series, the indication is that water intrusion is a problem during hot and wet conditions.

Table 4-3 lists the equipment tested. The equipment with asterisks (*) experienced some failures/anomalies during the tests. The failures were attributed to multiple severe burn environments and water intrusion. The duration of the burn is short for hydrogen burns but the phenomenon of equipment temperature rise and moisture intrusion is anticipated to occur in other fire testing. Most of the data from the tests remain unpublished and therefore, only visual inspection results and assumed failure mechanisms can be given.

Although much of the equipment experienced anomalies or failures during the test series, many of the equipment types functioned during six or more severe tests. The first five tests of the series were scoping tests. Tests 7 through 15 are considered severe. Table 4-3 contains a breakdown of components which failed to function during three or more severe tests. These components are marked with two asterisks (**). A single asterisk (*) denotes failure in one test.

Preliminary data review seemed to indicate that the Veritrak transmitter is sensitive to high temperatures, while the NAMCO limit switch appeared to be sensitive to moisture intrusion. The Limitorque motor operator and Foxboro pressure transmitter were sensitive to water collection as shown by their successful operation subsequent to the corrective actions mentioned above. Comments by personnel involved in equipment qualification testing confirmed the sensitivity of some of the equipment to water intrusion.

The hydrogen burn data is germaine to potential fire damage to equipment because the environment produced by a hydrogen burn is a hot, wet environment which is typical of that produced by a fire with water suppression. The heat and moisture phenomena are expected to be similar to that experienced in a nuclear plant fire, although the pressure effects of a hydrogen burn are not expected during fires. It is recognized that the long duration and lower

Table 4-3

EPRI Large Scale Hydrogen Burn Equipment Data

Equipment Type	Manufacturer	Model No.	Size (Approx.)	Weight (Approx.)	Predicted Limiting Operating Temp.
* Pressure Transmitter	Barton	763	8"x8"x3"	15 lbs	380-420°F
* Pressure Transmitter	Foxboro	NE11GH	15"x12"x6"	30 lbs	300-370°F
* Pressure Transmitter	Rosemount	1153GD	5"x5"x7"	5 lbs	350°F
** Pressure Transmitter	Veritrak	32XX1	12"x4"x4"	15 lbs	Unknown
* Pressure Transmitter	Barton	764	8"x8"x3"	15 lbs	380-420°F
* Pressure Transmitter	Foxboro	NE13DM	15"x12"x6"	30 lbs	300-370°F
Pressure Transmitter	Rosemount	1153DB5	5"x5"x7"	5 lbs	350°F
** Pressure Transmitter	Veritrak	76	12"x4"x4"	15 lbs	Unknown
* Motor Operator	Limitorque	SMB-000-10	24"x18"x5"	120 lbs	350-400°F
Solenoid Valve	Asco	NP8316 65E	6"x5"x2"	10 lbs	330°F
Solenoid Valve	Valcor	V70900-21-3	8"x4"x4"	15 lbs	
** Limit Switch	Namco	EA-180-11303	6"x3"x3"	10 lbs	400-450°F
* Limit Switch	Allen-Bradley	802T ATP	3"x3"x4"	10 lbs	248°F
Ignitor	Tayco	-			-
** Ignitor	GM	-			-
Motor	Reliance	MTR-PWR			330-350°F
* Containment Penetration	Westinghouse	12X3MOD			340°F
Containment Penetration	Conax	Low Voltage			340-375°F
Resistance Temp. Detector	Minco	S8810	18"x3"x3"	15 lbs	250°F
Resistance Temp. Detector	Rosemount	186-29-1	18"x3"x3"	15 lbs	325-340°F
Resistance Temp. Detector	RDF	21204	18"x3"x3"	15 lbs	420°F

Manufacturer/Model No/Operability Data from "EPRI Quick Look Report on EPRI Hydrogen Burn Equipment Tests" by G. E. Sliter, dated December 19, 1983.

* Anomaly/Failure in single test
** Anomaly/Failure in more than one test

temperature produced by the burning of non-gaseous combustibles in a nuclear plant can produce different phenomena than hydrogen burning. However, the failure mechanisms from an equipment perspective are thought to be similar. Essentially no data exists on the severity or duration of fires and the time-related performance of equipment. Sensitivity to heat does not appear to be as large a problem as moisture intrusion, as long as semiconductor components are not overly affected by high temperatures. Both Foxboro and Rosemount transmitters contain semiconductors - Foxboro has discrete components, Rosemount uses integrated circuits. Both transmitters functioned well in severe hydrogen burns.

4.3.4 TVA (Fenwal) Tests and Analyses

These tests were performed in a spherical vessel about six feet in diameter (a small scale when compared to the EPRI tests.) Maximum equipment internal air temperature was about 230 F. Maximum vessel pressure was about 78 psia.

Table 4-4 indicates the equipment tested (five items) by a plus (+). The other equipment was analyzed (four items - not tested) by a utility sponsor of the tests (Mississippi Power and Light) based on the test results. All equipment functioned as designed during the tests.

Table 4-4

TVA (FENWAL) Hydrogen Burn Equipment Data

Equipment Type	Manufacturer	Model No.	Size (Approx.)	Weight (Approx.)	Limiting Operating Temp.
Containment Penetrations	Westinghouse	-	24"x18"x18"	500 lbs	3000°F for 20 min. (test)
+ Hydrogen Igniter Assembly	Not Given	-	8"x8"x6"	25 lbs	340°F (equip. qual.)
Pressure Transmitter	Rosemount	1153	9"x5"x5"	15 lbs	350°F (equip. qual.)
+ Pressure Transmitter	Barton	-	8"x8"x3"	30 lbs	380-420°F (equip. equal.)
Pressure Switch	Pressure Controls	A-17	8"x8"x4"	15 lbs	600°F
Radiation Monitor	Victoreen				350°F (equip. qual.)
Motor Operator					200°F
+ Solenoid Valve	Asco		6"x5"x2"	10 lbs	330°F
+ Limit Switch	Namco		8"x4"x3"	10 lbs	300°F (equip. qual.)
+ Regulator	Fischer		6"x6"x3"	10 lbs	-

+ Equipment tested - all others analyzed.

Data from MP&L letter to H. R. Denton of NRC on the subject of "Report on Equipment Survivability for a Hydrogen Generation Evaluation," dated January 19, 1982. Additional data from the "Quarterly Progress Report for the TVA Hydrogen Combustion Program" to NRC, dated December 15, 1980.

5.0 FUNCTIONALITY

The Technical Specifications (TS) for Plant A were reviewed for important safety functions. The results of that review were recorded in tables. The tabular information, in turn, was used to identify plant procedures which determined equipment testing requirements in compliance with the Technical Specifications. By this process, the relationship between procedures and the functional requirements necessary for plant safety can be related to equipment testing requirements.

It is important to note that the safety functional requirements of the TS are written from the perspective of what is necessary to accomplish, for example, safe shutdown. Equipment is selected to achieve the required functions. These safety functions may vary in requirement, although identical equipment may be specified to accomplish all similar functions. Equipment performance assessments, therefore, can be based on how well the equipment performance is maintained in terms of minimum manufacturer guarantees or specifications rather than TS. If minimum manufacturer specifications are maintained, the TS requirements should be addressed. Because of the enveloping of TS by manufacturer specifications, nuclear plants base their periodic surveillance testing on manufacturer data, while ensuring that such testing addresses TS requirements.

Only one plants's TS were reviewed because most of the safety functions are generic when viewed from equipment performance aspects. As mentioned above, equipment success criteria can be thought of as independent of system function for specific kinds of equipment. For example, although TS valve stroke time may vary due to different system functional requirements, causing different speed requirements for specific valve operators, the success criteria is how well the valve operator performs when compared to manufacturer specifications. If the stroke time is equal to or better than the manufacturer-specified maximum stroke time, the equipment success from system function through proper application of manufacturer specifications, allows for a single set of TS to be generically applicable for all general types of equipment addressed in the TS.

The plant procedures identified during the TS functional review have been factored into equipment test requirements discussed in Section 9.0

6.0 MATERIALS OF CONSTRUCTION/VENDOR CONTACT

Vendor data was collected from approximately 40 vendors (some large corporations have many vendor companies within them). The list of vendors is shown in Table 6-1. Materials data was sketchy except for some publicly available equipment qualification reports and vendor outline drawings which specified general materials of construction. Some vendors offered to sell materials information. These vendors would not supply any data beyond catalog information.

The factors mentioned above caused potential damageability sensitivity to be judged on manufacturer environment specifications and on thermal/moisture test data. Where materials data was obtained, an assessment of material susceptibility to fire effects was performed and the results were factored into the functionality/damageability matrix shown in section 8.0.

TABLE 6-1

VENDORS CONTACTED

G & D
Gould (GNB)
Solidstate Controls (SCI)
Conax
Raychem
Samuel Moore
Joy Manufacturing
Crosby
Wiegand (Chromalox)
Namco
Siemans-Allis (Allis Chalmers)
Allen-Bradley
ITE Imperial (Gould ITE)
Cutler-Hammer (Eaton)
Louis Allis
Reliance
Barksdale
Static-O-Ring
ITT Barton
Ingersol-Rand
Crane Deming
Goulds
Byron Jackson (Borg-Warner)
Rockbestos (Cerro)
Electroswitch
Target Rock
Automatic Switch Company (Asco)
Weed Instruments
Fenwal
Buchanan
Brown Boveri (ITE)
Foxboro
Rosemount
Westinghouse
General Electric
Bailey Controls
Struthers-Dunn
Velan
Borg-Warner
John Crane
Limitorque
Love Controls
Leeds and Northrup
Amerace (Agastat)

7.0 RELIABILITY DATA CHECK

The purpose of reliability data checking was to identify any reported failure modes which could be expected to be exacerbated by fire effects. It was assumed that sensitivity to heat, moisture, corrosive vapors, and particulates would be identified in reliability data sources as penalty factors applied to failure rates in normal environments.

Three reliability data sources were reviewed - IEEE 500-1984 "Reliability Data for Nuclear Power Generating Stations," MIL-HDBK-217C "Reliability Data, and NPRD-2 "Nonelectronic Parts Reliability Data." Some sensitivities to temperature, moisture, and corrosive vapors were identified, but the stated sensitivities are qualitative in nature and, therefore, the environmental sensitivities data did not substantially alter the rankings of Section 8.0.

IEEE 500 - 1984 initially appeared to have the most pertinent environmental factors information. Penalty factor tables were included in the standard. However, the high temperature and high humidity penalty factors given in IEEE 500 are questionable. The penalty factors tables often did not correspond to the failure rate data given. The identifiers given in the environmental data table did not, in many cases, match the equipment failure rate identifiers. This lack of correspondence is probably due to editorial errors.

In addition, the IEEE 500 penalty factors are applied differently for different groupings of equipment. For example, the high temperature penalty factor for induction motors is a "loss of life" factor and cannot be evaluated as a short term factor, such as that experienced during a fire. Induction motor transient capability during thermal excursions is excellent based on other IEEE standard testing methods (IEEE - 275, for example). On the other hand, the thermal penalty factor for a level controller is five times less than that of an induction motor and the considerations for establishing the penalty factor are unstated. Equipment specifications for sensitive devices, such as level controllers, are quite stringent concerning high temperature environments of even a transient nature. This and other similar examples of the disparity between penalty factors and the lack of correspondence mentioned above, made the use of this data source questionable. Therefore, IEEE 500 data was not factored into the Functionality/Damageability Matrix of Section 8.0.

Unlike IEEE 500, no penalty factors were given in the other two references. Some qualitative failure modes were discussed and the frequency of failure mode occurrence was given for a few small components. To the extent possible, the qualitative data was incorporated into the Section 8.0 matrix. Most of the data reinforced the preliminary conclusions listed in the matrix, therefore, the reliability references were used as confirmatory information and are not specifically listed as Section 8.0 matrix references.

8.0 EQUIPMENT FUNCTIONALITY/DAMAGEABILITY RANKING

Table 8-1 is the resulting equipment functionality/damageability rankings matrix for the equipment/equipment properties identified in Sections 1.0 through 7.0. The basis for making the selections is given in Table 8-2. Matrix references are recorded in Table 8-3.

The general process for determining the relative scores for equipment rankings was to conceptually identify what characteristics of equipment were likely to be affected by fire characteristics (heat, moisture, particulates or corrosive vapors). These effects of fires were determined to be dominant failure mechanisms for failures in any postulated fire. After identifying the failure mechanisms, the characteristics of equipment which would render it susceptible to the effects were assumed.

Engineering judgment was used to determine these "Functionality" characteristics which would be most likely to be affected by the mechanisms. The engineering judgment was enhanced by the fire data documented in Sections 2.0 through 7.0. The enhancement was light, however, since little data on function degradation was obtained.

The ranking scale was chosen after an extensive discussion of the relative importance of equipment/damage mechanism parameters. The ranking scale is comprehensive in that it covers all the identified equipment from nuclear plant equipment reviews (Section 1.0) and all the effects noted in Sections 3.0 through 7.0. The ranking criteria is relative because more dominant mechanism effects and more sensitive equipment produce a greater score (more likely to either fail or cause failures) and the subcategories have a similar structure with more dominant/sensitive parameters producing larger scores.

It should be noted that the ranking is based on inferred functionality and damageability of equipment from manufacturer's specifications, materials of construction, thermal/moisture test data, and most common location of the equipment in the nuclear plant. The ranking is not meant to be absolute, but relative. A few hundredths difference among components implies the same expected sensitivity to fire effects.

The ranking scale of 0 to 1.0 is a measure of worth percentage scale with 0 indicating no susceptibility to fire damage and 1.0 indicating highly sensitive equipment susceptible to virtually instantaneous failure because of any fire/suppression phenomena. Since all equipment has some degree of protection from damage caused by fires and resulting suppression, no equipment had a 1.0 score in the measure of worth rankings.

The ranking basis was initially broken down into functionality and damageability categories. The relative importance of the categories was set at 40 percent and 60 percent respectively because damageability was viewed as a direct and active effect, as opposed to the indirect functionality which is a secondary phenomenon only. Functionality loss is caused by a breakdown or an absence of damageability protection. For example, a meter could fail because of moisture damage to internal mechanisms caused by a seal failure. The internal moisture is a direct effect of fire suppression, the functional failure is an indirect effect of the seal failure.

For the functionality category, the measure of worth was established by assessing the relative importance of the ranking factors. Accuracy and complexity were viewed as having equal importance because the margin of error for each category is small when compared to the sensitivity category.

For the accuracy subcategory, the more accurate the specification, the harder it is to achieve and maintain the specification. Also, the accuracy normally can be affected quite easily by external phenomena and, hence, electrical tolerances/specifications are tight. The complexity subcategory is used to evaluate the number of parts or outputs. The larger the number of components or outputs, the more chance for failure.

It should be noted that the hydrogen burn data (Reference 14 in Table 8-1), used to rank certain components in Table 8-1 may reflect shorter durations and lower temperatures than those produced by the burning of nongaseous combustibles in power plants. However, essentially no other data exists which can be used to relate the performance of equipment in the hot, wet environments produced by a fire with water suppression. Despite this limitation, the equipment failure mechanisms observed under hydrogen burn conditions are thought to be similar to those which would occur during a conventional fire. It should be recognized, though that actual fire environment testing of equipment may produce failure mechanisms and damage sensitivities that differ from those observed during hydrogen burn test conditions and reflected under the "Hi Temp" column in Table 8-1.

Table 8-1

Equipment Functionability/Damageability Matrix

EQUIPMENT TYPE	Accuracy (REFS)	Complexity (REFS)	Sensitivity (REFS)	HiTemp (REFS)	Moisture* (REFS)	Particulates (REFS)	Corrosive Vapors (REFS)	TOTAL
Cables, non 1E	.08(23)	0(23)	.10(23)	.15(23)	0(23)	0(23)	0(23)	.33
Cables, 1E	.08(33)	0(33)	.10(33)	(33, 0 14)	(33, 0 14)	0(33)	0(33)	.18
Fans	0(34)	0(34)	0(34)	0(34)	.05(34)	0(34)	0(34)	.05
Pumps	0(22)	0(22)	0(22)	(22, 0 14)	(22, 0 14)	0(22)	0(22)	0
Solenoid Valves	0(22)	.03(22)	.02(22)	(22, .30 14)	(22, .04 14)	0(22)	0(22)	.34
Temperature Switches	.12(19)	.06(19)	0(19)	.18(19)	(19, .07 2)	0(19)	0(19)	.41
T/C and RTD's	.15(19)	0(19)	.10(19)	0(19)	(19, .08 14)	0(19)	0(19)	.33
MCC's	0(15)	.10(15)	0(15)	.27(15)1	(15, .10 2)	.01(15)	.01(15)	.49
Heaters	0(36)	0(36)	0(36)	0(36)	.02(36)	0(36)	0(36)	.02
Switchgear	0(16)	.10(16)	0(16)	.27(16)	.10(16)	.01	.01(16)	.49
Power Trans.	0(28)	.02(28)	0(28)	(28, .17 26)	(28, .05 2)	.02(28)	0(28)	.26
Control Trans.	0 (2)	.02(25)	0(25)	(25, .17 26)	(25, .08 2)	.02(25)	0(25)	.29
Batteries	0(18)	.01(18)	0(18)	.30(18)	.10(18)	0(18)	.03(18)	.44
Battery Chargers/ Inverters	.05(17)	.12(17)	0(17)	.23(17)	.08(17)	0(17)	.01(17)	.49
Distribution Panels	0(20)	.05(20)	0(20)	.23(20)	(20, .05 2)	(20, .03 9)	(20, .02 10)	.38
Recorders	.15 (3)	.15 (3)	.05 (3)	.30 (3)	.10 (3)	.02 (3)	.02 (3)	.79
Controllers	.15 (4)	.15 (4)	.09 (4)	.18 (4)	.10 (4)	.02 (4)	.02 (4)	.71
Power Supplies	.08 (5)	.15 (5)	.07 (5)	.23 (5)	.10 (5)	.02 (5)	.02 (5)	.67
Logic Equip.	.15 (1)	.15 (1)	.10 (1)	.23 (1)	.10(1,2)	.02 (1)	.02 (1)	.77

* USNRC Information Notice entitled "Actuation of Fire Suppression System Causing Inoperability of Safety-Related Equipment" (with AEOD Case Study CA02) and the LER's given in the LER Summary of Exhibit 3-1, indicate damageability of switches, starters, relays, panels (MCCs switchgear), and panel-mounted equipment (such as recorders, controllers, power supplies, and logic equipment). These references were considered when establishing the moisture damage susceptibility of the equipment. Specific sensitivity based on the references are shown in the matrix.

Table 8-1 (Continued)

Equipment Functionability/Damageability Matrix

EQUIPMENT TYPE	Accur-acy (REFS)	Complex-ity (REFS)	Sensi-tivity (REFS)	HiTemp (REFS)	Moisture* (REFS)	Particu-lates (REFS)	Corrosive Vapors (REFS)	TOTAL
Indicating Lights	0(21)	.01(21)	0(21)	.26(21)	(21, .10 2)	0(21)	0(21)	.37
Meters	.12 (6)	.10 (6)	.07 (6)	.23 (6)	.05 (6)	.03 (6)	.01 (6)	.61
Hand Switches/ Pushbuttons	0(11)	.08(11)	.05(11)	(11, .23 12)	.10(11)	(11, .02 12)	(11, .02 12)	.50
Gauges	.12(31)	.03(31)	.05(31)	0(31)	0(31)	0(31)	0(31)	.20
Electro/Mech. Relays/Contactors	0 (8)	.06 (8)	.06 (8)	.23(8,9)	.20(8,2)	.02(8,9)	(8, .02 10)	.59
Solid State Relays	0 (7)	.06 (7)	.09 (7)	.23 (7)	.20 (7)	.01 (7)	.01 (7)	.60
Position/Limit Switches	0(29)	.03(29)	0(29)	.02(29)	(29, .17 14)	.02(29)	.02(29)	.26
Valve Operators/ Positioners	0(30)	.15(30)	0(30)	(30, .03 14)	(30, .05 14)	.02(30)	.02(30)	.25
Transmitters (Press, Level, and Flow)	.15(13)	.10(13)	.10(13)	(13, .08 14)	(13, .07 14)	0(13)	0(13)	.50
Pressure Switches	.12(24)	.03(24)	.05(24)	0(24)	(24, .13 2)	0(24)	1 0(24)	.33
Motors (open)	0(26)	.03(26)	0(26)	(26, .12 14)	(26, .13 2)	0(26)	0(26)	.28
Motors (enclosed)	0(26)	.03(26)	0(26)	(26, .12 14)	.02(26)	0(26)	0(26)	.17
Valves	0(35)	.02(35)	0(35)	0(35)	0(35)	0(35)	0(35)	.02
Terminal Blocks	0(32)	0(32)	.03(32)	.03(32)	.08(32)	.02(32)	.02(32)	.18

TABLE 8-2

BASIS FOR EQUIPMENT MEASURE OF WORTH RANKINGS

FUNCTIONALITY
(.40)

Accuracy (.15 max)	
Binary and ≥ ± 10%	0
Non-specific or binary	
Output is D-C with minimum ripple reqt.	.05
≤ ± 10% and ≥ ± 2%	
Non-specific	.08
≤ ± 2%	
Extremely accurate (± 1/2%)	.15
Very accurate (± 1%)	.12
Accurate (± 2%)	.10
<u>Complexity (.15 max)</u>	
Low Complexity	
no moving parts/1 moving part/simple single output and few pieces	0
2-5 movements/parts, req'd to function/single simple output and few pieces	.03 - .06
Medium Complexity	
5 or more movements/parts/positions and simple binary output	.08 - .10
5 or more movements/parts/positions and simple variable output	.10 - .12
High Complexity	
Many interrelated movements/parts/positions with multiple variable outputs	.15

TABLE 8-2

BASIS FOR EQUIPMENT MEASURE OF WORTH RANKINGS
(Continued)

Sensitivity (.10 max)

High voltage or current	
≥ 125 VDC or 110 VAC + high current (over 10 amp)	0
≥ 125 VDC or 110 VAC + relatively low current (≥ 1 amp)	.01 - .03
Medium voltage or current	
≤ 125 VDC or 110 VAC and ≥ 25 VDC or 12 VAC + relatively low current (≥ 1 amp)	.05 - .07
Low voltage or current	
≤ 25 VDC or 12 VAC + milliamp current	.08 - .10

Damageability
(.60)

High Temperature (.35 max)

Temperature Insensitive	
Spec data or EQ data with temps above 300°F or no organic parts	0
Spec data or EQ data above 200°F or high temperature devices with few organic parts	.01 - .07
Spec data or EQ near 200°F but with many organic parts	.08 - .11
Temperature Medium Sensitivity	
Spec data between 140°F and 200°F	.12 - .18
Temperature Sensitive	
Spec data at 140°F or below	.19 - .23
Spec data for ambient (75-100°F)	.24 - .35

TABLE 8-2

BASIS FOR EQUIPMENT MEASURE OF WORTH RANKINGS
(Continued)

Moisture (.20 max)	
Moisture/Spray resistant Sealed devices or devices which can operate submerged	0
NEMA 4 (watertight) devices or devices which may be spray cleaned	.02 - .05
Unsealed devices which can withstand normal humidity and have some type of enclosure	.07 - .08
Sensitive to spray only. Devices subject to dripping or having open contact points	.10 - .15
Sensitive to both humidity and spray. Devices subject to corrosion by humid environments or requiring heaters to exclude moisture	.16 - .20
Particulates	
Devices with protected movable contacts or devices with no contacts	0
Devices with movable contacts, exposed terminals, unprotected contacts, or very small physical tolerances	.01 - .03
Corrosive Vapors	
AC devices with no exposed live electrical parts	0
DC devices with exposed live parts or sensitive movable metallic components	.01 - .02

TABLE 8-3

MATRIX REFERENCES

(1)	Bailey Controls	Product Specification E92-750; 1983.
	Bailey Controls	General Catalog, pp 80-107, 1982
	Foxboro Company	Technical Information, 2AI-180, 2AI-170, 2AI-140, 2AP-180, 2AP-140, 2AP-100, 2AO-113; 1973-1977.
	Rosemount	Product Data Sheet 2368; 1983.
(2)	AEOD/C402	NRC Case Study on Operating Experience Related to Moisture Intrusion in Electrical Equipment at Commercial Reactors; 1984.
(3)	Leeds & Northrup	CO.6215-FL, CO.7002-DS, and CO.7003-DS Publications; 1980, 1981.
	Bailey Controls	General Catalog, pp 148-155; 1982.
	Love Controls	Bulletin 9462; 1983.
(4)	Bailey Controls	General Catalog, pp 48-68; 1982.
	Love Controls	Bulletins 9472, 9466, 9478, 9473, 9453, 9465; 1981-1983.
(5)	Foxboro Company	Technical Information 2AR-102; 1977.
	Rosemount	Product Data Sheet 2491; 1983.
	Bailey Controls	General Catalog pp 141-143; 1982.
(6)	Bailey Controls	General Catalog, pp 175-178; 1982.
	Foxboro Company	Product Specifications PSS 9-7Cl A; 1980.
	General Electric	"Switchboard Instruments" Catalog.
(7)	Struthers-Dunn	Relay Catalog pp 89-94; no date.
	Westinghouse	Catalog Sections 8221, 8540, 8610; no date.
(8)	Struthers-Dunn	Relay Catalog; no date
	Cutler-Hammer	Industrial Control Catalog, pp. 123-135; 1983-1984 (information only).
	Electroswitch	"Auxiliary Relays for Power Industry Applications, no date.
	General Electric	General Catalog Section 7210, pp 1-4, Section 7211, p. 3; 1982-1984.
	Allen Bradley	Bulletin 705, 709, 715; 1969-1971.

TABLE 8-3 (Continued)

MATRIX REFERENCES

(9)	EPRI	NP-3179 Nuclear-Power-Plant Fire-Loss Data, p. 54, July 1983.
	IE Information Notice 82-13	"Failure of General Electric Type HFA Relays;" May 10, 1982.
	IE Information Notice 84-20	"Service Life of Relays in Safety-Related Systems," March 21, 1984.
	Letter from W.F. Conway	Vermont Yankee Nuclear Power Corporation to T. A. Ippolito, US Nuclear Regulatory Commission dated March 14, 1980 regarding a transformer fire.
(10)		Interim Report on TVA Brown's Ferry Fire "Program for sampling, Analysis, and Cleanup of Residue on Affected Structures, Systems, and Components;" November, 1975.
(11)	Westinghouse	General Section DB 25-100 pp. 2-8, Section 15-121, p.4, and Section 15-123, p. 3; no date.
	Westinghouse	General Catalog Section 34-251, pp. 2-8, no date.
	General Electric	General Catalog Section 7152, pp. 1-3, Section 7153, p. 1, Section 7154, p. 1, and Section 7156, p. 401; 1974-1976.
	Electroswitch	Series 20 and 40 Digest "Instrument and Control Switches;" no date.
(12)	EPRI	NP-3095 "Generic Qualification of Rotary Hand Switches," May, 1983.
(13)	Rosemount	Product Data Sheet 2260; 1978.
	Rosemount	Qualification Report E8300040, "... Pressure Transmitters Rosemount Model 1153 Series D, Rev A;" May, 1983.

TABLE 8-3 (Continued)

MATRIX REFERENCES

(13)	Rosemount	Qualification Report D8400102 "... Pressure Transmitter Model 1154;" May, 1984.
	Rosemount	Qualification Report 108025 "...Pressure Transmitters Rosemount Model 1153 Series B, Rev B;" February, 1981.
	Rosemount	Industrial Customer Catalog; April, 1983.
	Foxboro	Price Sheets 9-1B1, 9-1B2, 9-1B3, 9-1C1, 9-1Z1, 9-1Z9; September, 1978.
	Foxboro	Product Specification PSS-2A-1C1D "E13DM Series d/p Cell Transmitters;" 1980.
	Foxboro	Product Specification PSS-9-1B1A "NE11 and NE13 Series Nuclear Electronic Presure Transmitters;" 1981.
	Foxboro	Instructions Model E11GM Transmitter, Model E11GH Transmitter; 1971.
	Foxboro	"Environmental Test Report Summaries of Foxboro Products;" no date.
	ITT Barton	"Models 763 and 764, Electronic Transmitters Qualification Test Report Summary;" no date.
	ITT Barton	Product Bulletins 763-1 and 764-1; 1982.
(14)		Hydrogen Burn Survivability Test Data - See Section 4.2.
(15)	Siemens-Allis	"Value Line Mark 2 Motor Control Center Instructions;" April, 1978.
	Siemens-Allis	"Marq 21 Motor Control Centers;" no date.
	ITE Imperial	"Motor Control Center - Series 5600 Instructions, Specifications, Design and Application Guides," 1973.
	Westinghouse	General Catalog - Application Data Section 8260 pp. 2-4; no date.
	ITE Imperial	IB-6.10-1 "Series 9600 - Motor Control Center"

TABLE 8-3 (Continued)

MATRIX REFERENCES

(15)	General Electric	Buy Log; October, 1979.
	General Electric	General Catalog Section 2040, pp. 1-2; 1969.
(16)	General Electric	GET-6600D "Power/Vac Metalclad Switchgear Application Guide;" 1984.
	General Electric	General Catalog - Section 6771 pp. 1-4; 1977.
	Gould ITE	Bulletin 10.2-1D "...Low Voltage Metal Enclosed Switchgear...;" no date.
(17)	Solidstate Controls, Inc.(SCI)	Product Data Bulleting BCS, 1981.
	C & D Batteries (Allied Chemical)	"Auto Reg...ARR Series Float Chargers;" no date.
	C & D Batteries	"Factory Procedure" pp. 1-4; April 1976.
(18)	C & D Batteries	12-800 "Stationary Battery Installation and Operating Instructions;" Letter from F. M. Wagner, C & D Batteries, to A. E. Winters, NUS, dated September 4, 1984.
	Gould	"Stationary Battery Installation and Operating Instructions;" no date.
	GNB Batteries	Materials of Construction; 1984.
(19)	Transamerica Delaval(Barksdale)	Bulletin No. 690310-K "Temperature Switches: 1979.
	Transamerica Delaval(Barksdale)	Bulletin No. 790112-A "Econ-O-Temp Temperature Switch;" 1981.
	Transamerica Delaval(Barksdale)	Bulletin No. 801215 "Solid State Temperature Switches;" 1980.
	Weed Instruments	Temperature Measurement and Control Catalog; no date.
	Fenwal	Catalog 790; no date.

TABLE B-3 (Continued)

MATRIX REFERENCES

(19)	Wyant, F. J. and Minor, E. E.	NUREG/CR-3597-SAND 84-0938 "Equipment Qualification Methodology Research: Tests of RTD's;" September, 1984.
(20)	General Electric	Buy Log, October, 1979.
(21)	Cutler-Hammer	Industrial Control Catalog, pp. 145-200; 1983-1984.
(22)	ASCO	Catalog No. NP-1 with supplementary pages "3 and 4 Way Solenoid Vavles," 1978.
	ASCO	Certificates of Compliance Nos. VE2926R4 and VE3239R1; no dates.
	Target Rock	General Catalog; 1983.
(23)	Belden	"Electronic Wire and Cable;" 1983.
(24)	Transamerica Delaval (Barksdale)	Bulletin 730701-F, "Pressure Switches;" 1979.
	Transamerica Delaval (Barksdale)	Bulletin 680631-D "How to Select a Pressure Switch for Your Application;" no date.
	Static-O-Ring Pressure Switch Company	"Model Number System - How It Works;" 1975
	ITT Barton	Product/Bulletins 580-0/580-1, 581-0/581-1, 583-0/583-1 "...Differential Pressure Indicating Switches for Nuclear Safety-Related Inside/Outside Containment Applications;" 1980.
	Salazar, E.	NUREG/CR-3630-SAND83-2652 "Equipment Qualification Methodology Research: Tests of Pressure Switches;" March, 1984.
(25)	Square D	Digest 160; 1980.
(26)	Fink, D. G. and Beaty, H. W.	"Standard Handbook for Electrical Engineers," pp 10-41 to 10-44; 1978.

TABLE B-3 (Continued)

MATRIX REFERENCES

(27)	General Electric	GEP387A "Kinamatic Buyer's Guide;" 1978.
	General Electric	"Tri Clad Buyer's Guide;" no date.
	General Electric	General Catalog Section 336, pp. 101-104, Section 334, pp. 9 and 11; 1974 and 1976.
	General Electric	GEP-675 "Large A. C. Motors-Prices and Specifications, 1983.
	Westinghouse	Application Data 3170, pp. 1-8; 1971.
	Westinghouse	Descriptive Bulletins 3310-1 and 3310-2; 1970 and 1971.
	Reliance Electric (Joy Manufacturing)	Test Report Excerpt, no date.
	Bienko, W. J. and Stiffler, W. G.	"Qualification Test of a Fan and Motor Designed for Service in Nuclear Containment;" Presented at 10th Electrical Insulation Conference (IEEE); 1971.
	Reliance Electric	Industrial Motor Catalog - Condensed Edition; 1982-1983.
	Siemans-Allis	Nos. 2093B 1017-1 and 2093B 1040-1, no dates.
(28)	General Electric	Buy Log pp. 208-212, 1979.
	Brown Boveri (ITE)	Bulletin 5.1.1-1B "Dry-Type Transformers;" no date.
(29)	NAMCO	Qualification Test Reports for Models EA 180, EA 170, EA 750; 1978 and 1981.
	Cutler-Hammer	Industrial Control Catalog, pp. 204-226; 1983-1984.
	NAMCO	General Catalog; 1979.
(30)	Limitorque Corp.	Bulletin SMB1-82B "Type SMB Instruction and Maintenance Manual;" 1982.
	Limitorque Corp.	Bulletin SMB1-170 "Limitorque Valve Controls - Type SMB Instruction and Maintenance Manual;" 1977.

TABLE 8-3 (Continued)

MATRIX REFERENCES

(30)	Limitorque Corp.	Bulletin 871 "Type SMB Valve Controls;" 1971
	Limitorque Corp.	"IEEE 323 and IEEE 382 Nuclear Qualification Data for Safety-Related Service," November, 1977.
	Target Rock Corp.	"Electrically Positioned Control Valves;" no date.
	Foxboro/Jordan (Electrodyne)	Bulletin J-530 "TN-2 Series Rotary Actuator;" no date.
	Foxboro	"Instructions for Model 69TA Transducer," 1971.
(31)	Crosby	"Quality Gages, Precision Gages, Chemical Seals;" no date.
(32)	Westinghouse	General Catalog "Modular Terminal Blocks Type TBA;" no date.
	Buchanan(Amerace)	"Seismic and Radiation Tested Terminal Blocks;" February, 1981.
	Craft, C. M.	NUREG/CR-3418-SAND 83-1617 "Screening Tests of Terminal Block Performance in a Simulated LOCA Environment;" August, 1984.
(33)	Belden	"Electronic Wire and Cable;" 1983.
	Raychem	(Franklin Research Report F-C4033-3) "Tests of Raychem Thermofit Insulation Systems...;" 1975.
	Rockbestos Company (Cerro)	"Qualification of Firewall III Class 1E Electric Cables;" November, 1979.
	Rockbestos Company (Cerro)	RSS-3-021 "Firewall III Specification;" 1973.
	Rockbestos Company	RSS-6-005 "Firewall EP Specification;" (Cerro)1971.

TABLE 8-3 (Continued)

MATRIX REFERENCES

(33)	Rockbestos Comapny (Cerro)	(Franklin Research Center Reporet F-C3192) "Qualification Tests of Electrical Cables under Simulated Reactor Containment Conditions;" December, 1971.
	Rockbestos Company (Cerro)	"Pyrotrol III Radiation and Post-Accident Environmental Test Results;" 1971.
	Samuel Moore	"Dekorad Wire Specification Summaries;" no date.
(34)	Joy Manufacturing	Fan Construction Features; no date.
(35)	Velan	Engineering Data, no date.
	Anchor/Darling	Outline Drawings/Experience Data; no date.
	Crosby	"O" Ring Seat Design Data; no date.
	Borg Warner	Nuclear Valve Division Material Data; no date.
	Target Rock	"Self Contained Pressure Regulating Valves;" no date.
	John Crane	Catalog 70-14 "Mechanical Shaft Seals;" no date.
	John Crane	Bulletin No p-392-1 "Valve Stem Packings;" no date.
(36)	Chromalox (Edwin L. Wiegand)	"Industrial Heating Products;" no date.
	Chromolox (Edwin L. Wiegand)	"Immersion Elements;" no date.
(37)	Ingersoll-Rand	"The APKD/C Vertical Can Pumps...;" 1978.
	Crane Deming	Bulletin 4500 Section 40L "Sump Pumps;" no date.
	Goulds Pumps	Bulletin 725.1 "Model 3196 ANSI Standard Dimension Process Pumps;" January, 1980.
	Byron Jackson (Borg Warner)	Bulletin No. 123 "A Single Source for Your Complete Line of Reliable Pumps;" no date.

The sensitivity subcategory was viewed as less important than the previously mentioned subcategories because some variation in voltage or current can usually be tolerated. This subcategory is different from accuracy in that accuracy is an ultimate measure of the functional worth (throughput) where sensitivity is an inherent internal characteristic of the device itself. Accuracy is measured in deviation from the desired result. Sensitivity is the strength of the desired result. Stronger (higher power) outputs can tolerate more interference from external effects than weaker outputs.

For the damageability category, subcategories were ranked by dominant failure causes which have been reported as a result of fires. Since practically no reports of particulate or corrosive damage have been reported (except for soot cleanup and pitting of metals because of HCL), these two items were given low maximum scores with respect to thermal and moisture effects. In most fire reports, failures because of high temperature predominate over all other types of failures. Heat appears to be the major stress imposed during fires. Although moisture is not as dominant a failure stress as heat, recent NRC documents have indicated that moisture causes failures during normal operation and that fire suppression system actuation can cause equipment failures. Since moisture failures can occur, but few reports of actual failures relating to fire/suppression have been reported, the moisture subcategory was allocated a rather high maximum score, but lower than the high temperature subcategory.

The rankings were developed without consideration of relative safety importance of equipment or consequences of failure, size/weight, or cost considerations. Once the equipment was identified as being safety-related as determined by the FHA/FSAR/TS review, the equipment was assessed for functionality and damageability and incorporated into the matrix. All the equipment recorded in the matrix has been confirmed as being needed for safe shutdown by virtue of either its direct appearance in an FHA, or its functional connection (electrical/instrument loop) to FHA-specified equipment. The magnitude and duration of the fire was not considered, since the fire intensity and duration is an input variable to the planned equipment fire tests.

It is recognized that the potential size and duration of the fire varies throughout the plant and that more sensitive equipment may be better protected from large fires. This implication confirms that more sensitive equipment is, in fact, more prone to fire damage. It is the degree of fire sensitivity that will be established during the testing phase.

8.1 EQUIPMENT RANKING EXAMPLE

As an example, for electro-mechanical relays, the references in Table 8-3 item 8 and 9 were reviewed for the measure of worth parameters as described in Table 8-2. A zero (0) was assigned for the ACCURACY category because relay output is binary (on or off). A COMPLEXITY of .06 was assigned for complexity because there are approximately 4 major movable parts in relays (two or more contacts, coil mechanism core, timer, etc.) and output is simple. A value of 0.06 was chosen for the SENSITIVITY since electromechanical relays operate in the medium voltage and current range - all electromechanical relays have about 1 amp output at 110 VAC or 125 VDC.

The data in references 8 and 9 indicated a low thermal withstand capability of about 140°F as shown in manufacturer's data. The item 9 reference data especially I&E Information Notice 84-20 showed some thermal sensitivity due to short lives of relays attributed to accelerated thermal aging. A value of .23 was, therefore, assigned to the HIGH TEMPERATURE category. The moisture sensitivity of electromechanical relays was determined to be high (0.2) because most relays are not hermetically sealed and have open contact points. The item 2 reference contains evidence that con- tactors and devices with unsealed contacts are susceptible to moisture damage. PARTICULATE and CORROSIVE VAPOR susceptibility is based on the criteria of exposed, movable contacts and were scored .02 and .02 respectively.

8.2 EQUIPMENT SUMMARY RANKING

In order of decreasing potential sensitivity to fire effects, the equipment ranking is as follows:

Sensitivity Level	Equipment Type	Total Score
	Recorders	.79
	Logic Equipment	.77
	Controllers	.71
HIGH	Power Supplies	.67
	Meters	.61
	Solid State Relays	.60
	Electro Mechanical Relays/Contractors	.59
	Hand Switches/Pushbuttons	.50
	Transmitters (Press, Level, Flow)	.50
	Battery Chargers/Inverters	.49
MED. HIGH	Motor Control Centers	.49
	Switchgear	.49
	Batteries	.44
	Temperature Switches	.41
	Distribution Panels	.38
	Indicating Lights	.37
	Solenoid Valves	.34
	Thermocouples and Resistance Temp Detectors	.33
	Non-Class 1E Cables	.33
	Pressure Switches	.33
MED. LOW	Control Transformers	.29
	Motors (open)	.28
	Position/Limit Switches	.26
	Power Transformers	.26
	Valve Positioners/Opeators	.25
	Gauges	.20
	Terminal Blocks	.18
	Class 1E Cables	.17
	Motors (enclosed)	.17
	Fans	.05
LOW	Heaters	.02
	Valves	.02
	Pumps	.00

A score differential of between .07 and .10 is needed to discern any differences among component types. Levels of sensitivity can be segregated into high, medium to high, low to medium, and low categories as indicated in the table above. The categories can be sub-divided in this manner, since the scores are relative indicators of fire sensitivity rather than absolute indicators.

9.0 EQUIPMENT TEST RECOMMENDATIONS

9.1 GENERAL TEST RECOMMENDATIONS

The test specimen parameters measured during exposure to fire-related environments should be recorded for the duration of the testing. The variation of the input/output signals with time is crucial in determining the damage mechanism.

Internal temperature of the test specimen should be measured and recorded. Temperature sensitive lables of differing ratings should be used as a minimum. If possible, a mineral-insulated, metal sheathed thermocouple should measure internal equipment temperature caused by the fire enviroments. Internal temperature should be recorded.

Litmus paper or another acid/base indicator should be placed inside equipment to indicate whether corrosive vapor intrudes into the test specimen.

9.2 HIGH SENSITIVITY TEST RECOMMENDATIONS

The high potential sensitivity category equipment (See Section 8.1) is composed of devices which have testers specifically designed to assess the device performance. Relay testers and instrument test sets appropriate to the fire test specimens should be used to monitor equipment functional performance.

Since the test sets are sensitive in their own right, it will be difficult to monitor equipment performance during testing. However, if continuous monitoring during fire testing is desired, the cables and connectors used to transfer signals from the test specimen to the test set must be capable of performing in the fire environment. In order to ensure test set cable/connector integrity mechanical protection must be provided. The cable connector interface should be coated with fire retardant mastic. In addition, shrink-tube should be fitted around the cable/connector interface. Metallic steel conduit or pressure hose should be used to enclose the test set cable. If possible, sealing material should be applied at the connector/equipment interfaces. RTV may be used for this purpose.

In order to assess the physical damage caused by the fire/suppression effects, additional post-test exploratory measurements should be performed. In particular, contact resistance measurements should be made across any contacts showing visual signs of pitting, corrosion, or warping. Representative contact resistance measurements may be made across multipin connector interfaces.

Spring tension measurements of relay contacts and recorder meter pointers should be made to determine closing force required for relays and indicator pointer spring tension. The pen tension for recorders should be likewise measured. The spring tension values for these instruments are likely to be very small. Sensitive tension measuring devices should be used.

Where gaskets and O-rings have been employed by manufactureres to seal the equipment, the seals should be tested to determine tensile strength and elongation. Melting of thermoplastic materials of construction should be determined by visual inspection. Light intensity through recorder/meter faceplates should be measured using a light meter.

Equipment bearings for high sensitivity equipment are likely to be constructed of a hard, thermoplastic material (nylon, delrin, teflon, etc.). Degradation of thermoplastic bearings can be determined by either increased torque requirements to mechanically move an active component or by an increase in the amount of play between the active component and the bearing surface. It is, therefore, prudent to empirically assess the bearing surface condition by manually actuating the active device during the fire tests, if possible.

Since damage is often not quantifiable in absolute terms, it is necessary that at least two specimens are purchased for each device to be evaluated. The only way to characterize the damage imposed on devices subjected to adverse condition is to compare a post-test device to a new device. Pre-test equivalency of the specimens should be ascertained to the extent possible. Spare organic parts should be purchased in sufficient numbers to allow for destructive testing, such as tensile strength. Spare organic parts will allow for refurbishment of devices subsequent to fire testing. Refurbishment can characterize the degree of reversibility of the damage caused by fire effects.

9.3 MEDIUM SENSITIVITY TEST REQUIREMENTS

The medium high sensitivity equipment (See Section 8.1) for the most part, consists of physically large equipment which is difficult to test. Some of the equipment (transmitters, hand switches, pushbuttons, and temperature switches) are small and can be easily tested, however, Motor Control Centers, Switchgear and Battery Chargers/Inverters, although physically large, have some high sensitivity components included within the larger equipment.

Transmitters can be evaluated through electrical connection of the device, simulated process inputs, and output measurement. Organics within transmitters should be evaluated by comparison of tensile strength and elongation. Moisture intrusion effects can be determined by contact resistance measurements. Contact resistance measurements are especially important for the input/output terminals of the transmitter. Unlike high sensitivity devices, it is not necessary to protect transmitter interfaces beyond manufacturer-specified installation practices.

Spring tension and contact resistance tests should be used to evaluate hand switches, pushbuttons, and temperature switches. Tensile and elongation measurements are not required for these devices.

9.4 MEDIUM LOW SENSITIVITY TEST REQUIREMENTS

The medium low category contains both small and large equipment types. Distribution panels, power transformers, and some motors are large devices. Distribution panel sub-components are included in the high and medium high categories with the sole exception of indicating lights which are included in this (medium low) category. Control transformers have similar electrical characteristics to power transformers and similar sensitivity characteristics. Test results for transformers are expected to be likewise, similar.

Small motors also share similar characteristics with larger motors.

Most of the medium low equipment requires only 110/480 VAC power input. Function can only be determined by loss of input. Thermocouples/RTD's output signal strengths are low, but no voltage input is required. Loss of function can be measured by output interrruption. Percent error or accuracy can also be used to verify function if specifications and appropriate test sets are used.

Solenoid valves, gauges, and pressure switches require process air inputs. Limit switches require external actuation during and immediately after testing to determine functionality.

Organic material parameters should be measured for the following equipment components:

Solenoid Valve Gaskets
Thermocouple/RTD Gaskets
Non-Class 1E Cable Insulation
Pressure Switch Gaskets and Diaphragms
Position/Limit Switch Gaskets
Class 1E Cable Insulation

Post-test contact resistance and spring tension measurements should be made for the following:

Pressure Switches
Position/Limit Switches
Gauges (spring tension only)
Non-Class 1E Cables
Class 1E Cables
Terminal Blocks

Insulation resistance tests should be made for the following:

Non-Class 1E Cables
Class 1E Cables

Ammeter measurements (made during the tests) should be recorded for the following:

- Indicating Lights
- Solenoid Valves
- Control Transformers
- Motors
- Power Transformers

9.5 LOW SENSITIVITY TEST REQUIREMENTS

Since all low sensitivity equipment is made of metal with organics limited to bearings and gaskets, organic tensile and elongation measurements are the only necessary tests.

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Based on a review of vendor information, fire damage reports, equipment qualification and hydrogen burn test results, and material properties, thirty-three types of equipment found in nuclear power plants were ranked in terms of their potential sensitivity to fire environments. The ranking considered both the functional requirements and damage proneness of each component. A further review of the seven top-ranked components was performed, considering the relative prevalence and potential safety significance of each. From this, relays and hand switches dominate as first choices for fire damage testing with logic equipment, power supplies, transmitters, and motor control centers as future candidates.

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