Technical Evaluation Report

Operating Experience and Aging Assessment of ECCS Pump Room Coolers

D. E. Blahnik
R. L. Goodman

October 1986

Prepared for
U. S. Nuclear Regulatory Commission
under Contract DE-AC06-76RLO 1830
NRC FIN B2865

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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TECHNICAL EVALUATION REPORT

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Phase I Study

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ABSTRACT

This report provides a preliminary aging assessment of safety-related room coolers for the emergency core cooling system (ECCS) pump rooms in nuclear plants. The assessment conforms to the NRC Nuclear Plant Aging Research (NPAR) Program strategy. The assessment is based on limited information obtained through public and private data bases, equipment vendors, utility contacts, literature searches, and expert opinion.

The ECCS pump room cooler system description was determined by review of FSARs and vendor supplied information. Data from LERs, review of maintenance requests at a reactor plant, and discussions with personnel that have utility maintenance experience were used to determine the operating experience of pump room coolers. Failure modes, causes, frequency rates, and methods of detection are summarized from the operating experience. Maintenance actions and modifications needed as a result of the operator experience are addressed to the extent that information was available. Operational stressors are summarized, manufacturer recommendations for maintenance and surveillance are listed, and aging and service-wear monitoring are briefly evaluated.

ACKNOWLEDGMENTS

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A number of individuals assisted in collecting data, providing experienced opinions, making assessments and preparing and reviewing the report. The assistance was appreciated from the following individuals: Mano Subudhi, Brookhaven National Laboratory; George Murphy and Ray Borkowski, Oak Ridge National Laboratory, James Cleveland, SEA Consultants, Inc.; Dennis Pawlak, Ellis and Watts; Hunter McCluer and Mike Kippes, WPPSS; and John Vause, Robert Gruel, and Ben Johnson of Pacific Northwest Laboratory.

The assistance of David Hillard for editing and Lila Valdez and Pat Young for typing the report is also gratefully acknowledged.

EXECUTIVE SUMMARY

Pacific Northwest Laboratory conducted this review of pump room cooler operating experience under the U.S. Nuclear Regulatory Commission's Nuclear Plant Aging Research Program. The purpose of Phase I of this study is to make an interim aging assessment of emergency core cooling system (ECCS) pump room coolers based on actual operating experience data.

The ECCS pump room coolers prevent excessive temperatures in the room where the ECCS pumps are operating. The ECCS pumps are used in nuclear plants to provide reactor core cooling and primary coolant inventory makeup during emergencies such as a LOCA. The ECCS pumps and pump room coolers are both important safety-related equipment.

Pump room coolers were selected for the aging assessment because of safety concerns associated with the failure of a pump room cooler to perform its designated function. This study was performed to determine whether aging and service-wear effects substantially reduce safety margins for room cooling.

The equipment boundary selected for examination in this study is defined as the room cooler system components within the fan/coil enclosure. Most room coolers are quite similar within this boundary. Because elevated temperatures and humidities may occur in the pump rooms, electrical components within the boundary are usually limited to the drive motor and thermostats. The interfacing motor controls and other electrical and electronic components are located in the central motor control centers, where environmental conditions are more closely controlled. The water supply for the cooling coils and the pumps and valves that control the water flow are usually located in other areas.

Room cooler operating experience data obtained during this study suggest that pump room cooler operation has been relatively trouble-free. Room cooler fan motors are subject to more stressors than any other major component, but available data indicate that failure rates have been low. Not unexpectedly, the v-belts, a minor component, fail most frequently and cause the most maintenance problems.

Vibration is the largest cause of rapid aging in room coolers. The v-belt fan drives seem to be more prone to cause vibration than direct fan drives, but data are insufficient to substantiate this.

Licensee event report (LER) data indicate that room cooler failures are rare. Room cooler failures often develop outside the room cooler boundary in the motor control center electrical components or in the service water system chiller, valves, or pumps. These components are subjects of aging assessments in other NPAR Program tasks, and therefore no duplication of effort is being made. Motors are also being assessed in a separate task.

The lack of available data made it difficult to base the interim aging assessment of ECCS pump room coolers on operating experience. Part of the

reason for this lack of data is that ECCS pump room coolers were not incorporated into early plant designs. An increasing number of the plants that have come on line since 1972 have room coolers. Most plants coming on line in the near future will incorporate ECCS pump room coolers. Limited operating experience and largely trouble-free operation have resulted in a relatively small data base relating to room cooler service history.

Interim recommendations for minimizing the rate of room cooler aging are to follow manufacturer recommendations for maintenance and to monitor vibration, temperature, and sound, where practical. It is recommended that the aging, wear, and performance of pumps, valves, service water chiller, and other components associated with room cooler systems be investigated by the existing NPAR tasks to which the components are related. It is further recommended that Phase II of the ECCS pump room cooler aging assessment be delayed until NPAR systems assessments now underway have further addressed the significance of room coolers and more extensive operating experience is available.

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

BTU - British thermal units
BWR - boiling water reactor
cfm - cubic feet per minute
DBE - design basis earthquake
ECCS - emergency core cooling system
ESF - engineered safety features
FSAR - Final Safety Analysis Report
gpm - gallons per minute
HP - horse power
HPCI - high-pressure coolant injection
h - hour
HVAC - heating, ventilation and air conditioning
Hz - hertz (cycles per second)
IEEE - Institute of Electrical and Electronic Engineers
INPO - Institute for Nuclear Power Operations
IPRDS - In-Plant Reliability Data System
LER - Licensee Event Report
LOCA - loss of coolant accident
LPCI - low-pressure coolant injection
MCC - motor control center
NPAR - Nuclear Plant Aging Research
NPE - Nuclear Power Experience
NRC - Nuclear Regulatory Commission
NSIC - Nuclear Safety Information Center
ORNL - Oak Ridge National Laboratory
PSAR - Preliminary Safety Analysis Report
PWR - pressurized water reactor
RHR - residual heat removal

1.0 INTRODUCTION

Emergency core cooling system (ECCS) pumps are used in nuclear plants to ovide reactor core cooling and primary coolant inventory makeup during emerncies such as a loss-of-cooling accident. Pump room coolers are often used maintain room ambient air temperatures within acceptable limits for the pump tors. The coolers and their related heat exchanger systems also greatly duce the building heat accumulation and minimize the amount of air that must exhausted to the environment through filtered systems.

The Nuclear Plant Aging Research (NPAR) Program selected ECCS pump room olers for an aging assessment because of safety concerns associated with the ilure of coolers to perform their designated function (Davis et al. 1985). e present study was performed to determine whether aging and service-wear fects substantially reduce safety margins for room cooling. Phase I makes an terim assessment based on actual operating experience.

Pacific Northwest Laboratory (PNL) performed this study for the Nuclear gulatory Commission (NRC) Office of Research, Division of Engineering Techlogy, Electrical Engineering Branch as part of the NPAR Program. The NRC tablished the NPAR Program as a comprehensive research program to resolve sues related to the impact of aging and service wear of equipment and systems plant safety at commercial reactor facilities (US NRC 1985). The NPAR goals garding component and system aging are:

- to identify and characterize aging and service-wear effects that, if unchecked, could cause degradation of structures, components, and systems and thereby impair plant safety
- to identify methods of inspection, surveillance, and monitoring--or of evaluating residual life--of structures, components, and systems that will ensure timely detection of significant aging effects prior to loss of safety function
- to evaluate the effectiveness of storage, maintenance, repair, and replacement practices in mitigating the effects of aging and diminishing the rate and extent of degradation caused by aging and service wear.

accomplish these goals, the NPAR program strategy illustrated in Figure 1.1 being followed. The major program steps/deliverables are shown in circles, d the work activities required to accomplish these activities are provided in e boxes. The Phase I steps covered in this study are indicated by crosstching in the applicable circles and boxes.

This report contains a description of pump room cooler systems, an planation of sources for operating experience data, a listing of typical sting procedures, an analysis of operating experience, and a summary of operational stressors. These sections are followed by sections on manufacturer recommendations for maintenance and surveillance, aging and service-wear monitoring and assessment, expert opinion, and conclusions and recommendations.

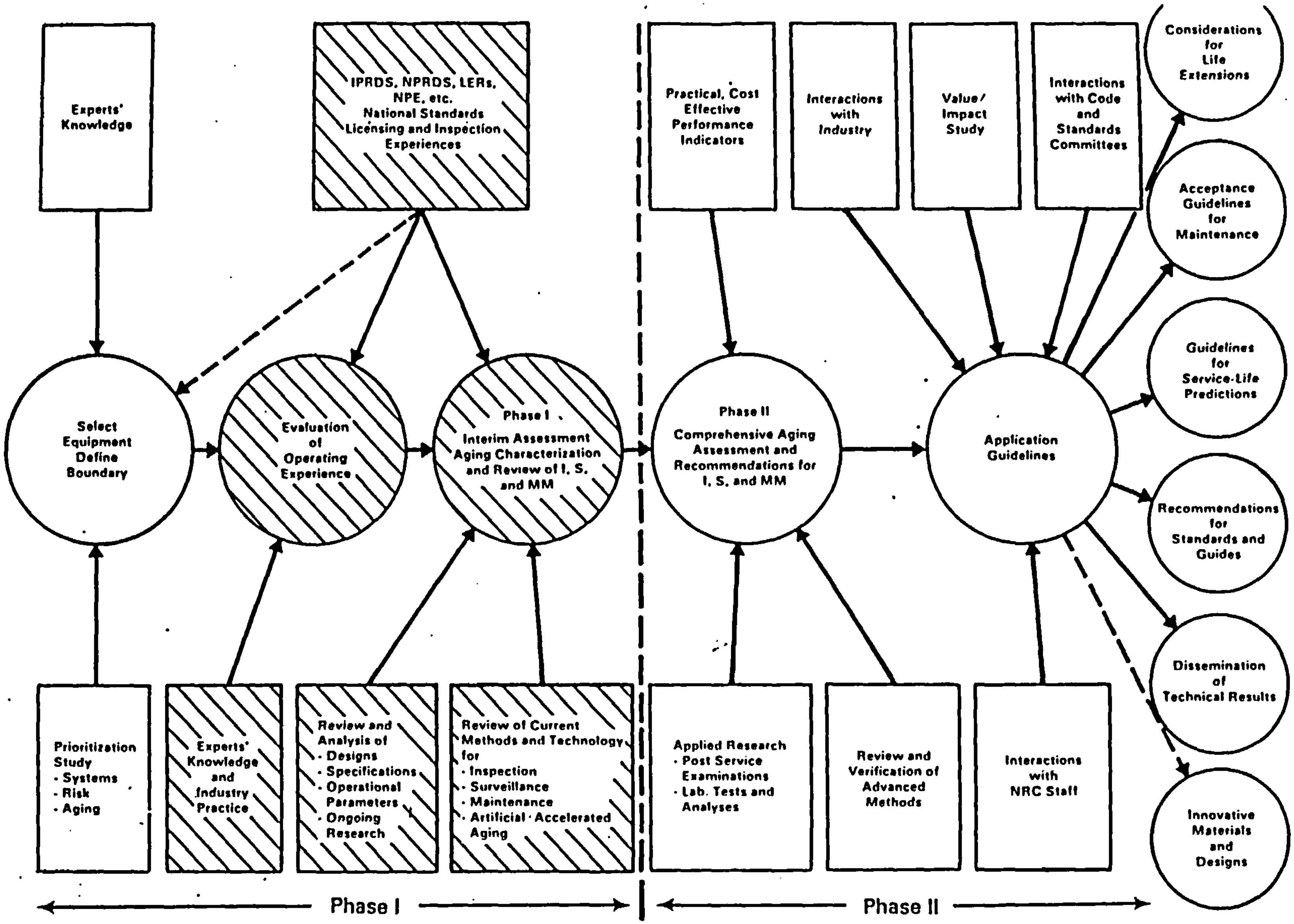


FIGURE 1.1. NPAR Program Strategy

2.0 PUMP ROOM COOLER SYSTEM DESCRIPTION

Older nuclear plants (15 to 25 years) do not have ECCS pump room coolers. Some intermediate-aged plants (5 to 15 yeas old) have room cooler systems, while others do not. New plants (0 - 5 years old) for all four of the U.S. reactor suppliers have pump room coolers with large cooling capacities to handle the higher power capacities of the newer reactors.

Designs for pump room cooling systems vary greatly among plants. Coolers are often interlocked with pumps and operate only when the pumps operate. Some coolers operate only during a loss-of-cooling while others are left on continuously. Other coolers operate only when room temperatures exceed the thermostat high setpoint.

The ECCS pump room coolers prevent excessive temperatures in the room where the ECCS pumps are operating. The ECCS pumps are used in nuclear plants to provide reactor core cooling and primary coolant inventory makeup during emergencies such as a LOCA. The ECCS pumps and pump room coolers are both important safety-related equipment.

The ECCS pump room coolers are basically safety-related fan coil units comprised of a steel housing containing an inlet opening, finned cooling coils, a fan-motor unit, and an outlet opening (Figure 2.1). Sometimes air inlets and outlets have louvers that can be adjusted to distribute and control air flow. Sometimes filters are placed in the inlet side.

The ECCS pump room cooling system includes the pump room cooler unit itself, plus a coolant supply system, motor control center and power supply, and other items, such as a room thermostat, manual switch, drain, and ventilation dampers.

ECCS room coolers are located in individual rooms housing the following types of ECCS pumps:

- high-pressure safety injection, charging, and core spray pumps.
- intermediate-pressure safety injection pumps.
- low-pressure safety injection and core spray pumps.
- residual or decay heat removal, pumps.
- containment spray pumps.

Pump names vary with the vintage and supplier of the individual plants. The ECCS pumps--sometimes called engineered safety feature (ESF) pumps--are safety-related equipment that perform an important function during a LOCA. The various ECCS pumps provide the primary cooling water system with high-pressure water injection for small-break LOCAs, low-pressure (high flow rate) water injection for large-break LOCAs, and long term core cooling once the reactor is depressurized and stable. The containment spray function also helps to depressurize and cool the containment and mitigate the spread of contamination. The ECCS pumps sometimes serve multiple purposes and need to function in normal operating and shutdown situations as well as emergency situations.

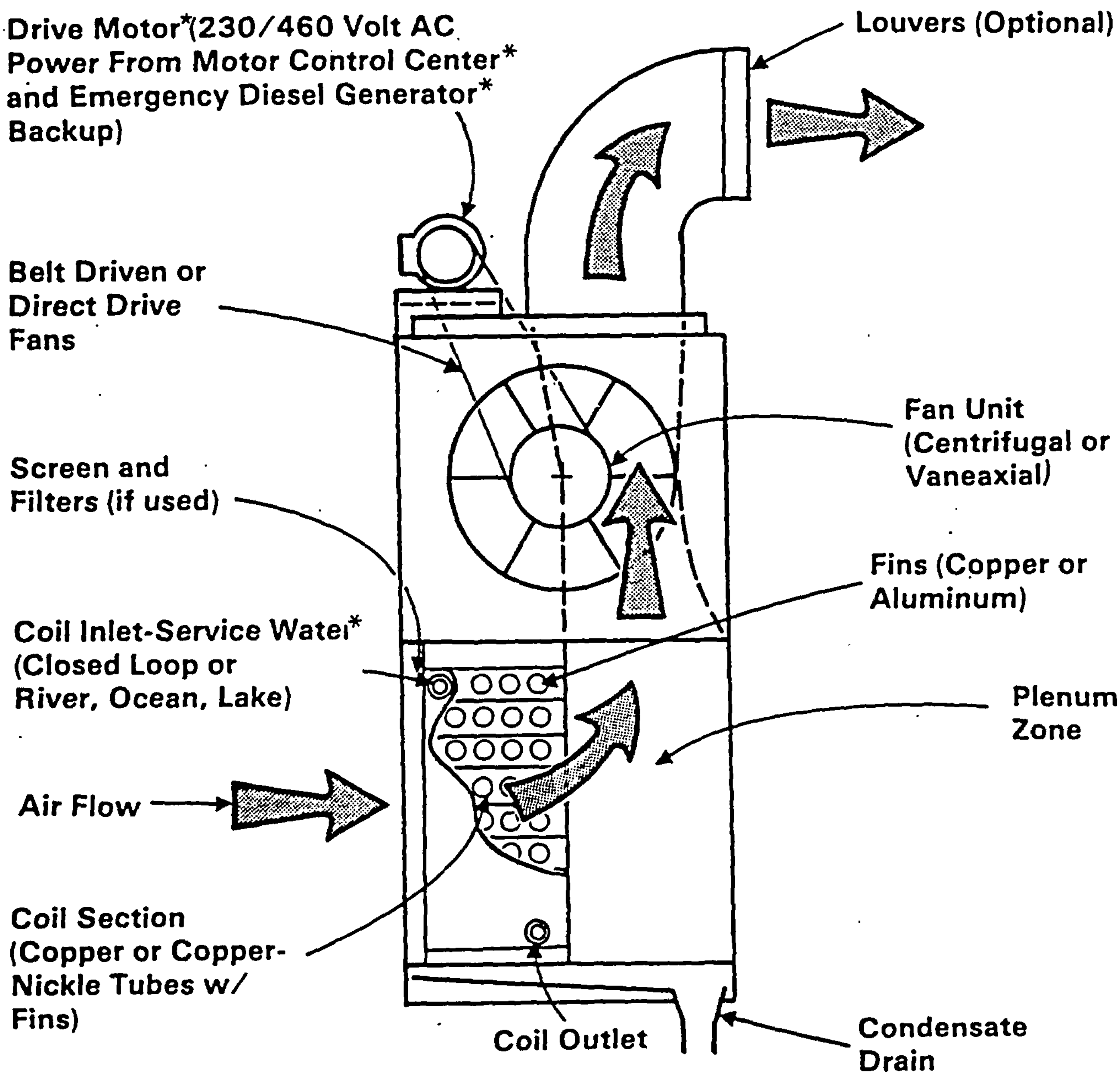


FIGURE 2.1. ECCS Pump Room Cooler Functional Design. Components indicated by (*) are being evaluated elsewhere in the NPAR program.

The room coolers protect the pumps from excessive ambient room temperatures, which are detrimental to the pump life. The room coolers usually meet Seismic Category I and Safety Class 3 requirements, which ensure that room coolers remain functional during and after a reactor shutdown on account of an earthquake. The room coolers are usually in redundant pump trains so that loss of a room cooler, although it may disable one train, will not jeopardize emergency operations. Room coolers are also usually on the emergency diesel generator safety busses so that they can operate during losses of offsite power.

ɜ only thing common among pump room cooling systems from plant to plant is ɜt they recirculate and cool the air within a given room. However, the :ual room cooler units within a given plant are often of the same or very nilar design and may be manufactured by a common vendor.

The rooms are normally heated and ventilated by the building central sysn. The ventilation system helps to keep the room cool and prevent excessive nidity buildup. During a radiation release in the room, either the central ɔm air exhaust is diverted to a central filtered exhaust system or the connninated room is isolated from the central air flow by closing room dampers.

The ECCS pump rooms are usually located outside of the primary containment ɜa. They are usually located in the secondary containment of BWR buildings in the auxiliary building of PWRs. The pump rooms are usually located in ɜ basements of buildings, so they are sometimes subject to cool, damp vironments created by sumps, condensation, etc. One plant reported that ɜam leaks were also of concern.

1 ROOM COOLER DESIGN

A typical pump room cooler is shown in Figure 2.1. Warm air flows in at e bottom left through a screen and medium density filter (if one is used). xt, the air passes through the cooling coils, where it is cooled. It contin-s through a plenum zone into a fan. The electric motor-driven fan moves the oled air into a short duct and returns it to the room through the outlet. metimes louvers are placed on the outlet to direct the air flow towards the CS pump and piping.

Filters are optional, although they are usually installed for at least the nstruction stage to protect internal components from dust and other debris. dium efficiency filters are sometimes used to protect the surface of the coil om dust and dirt when the room cooler is operating.

The cooling coil water is supplied either from a river, lake, ocean, or rough a recirculating closed loop system. In southern states, the closed op system uses a refrigerated chiller to remove the heat. In some cases, the ter flow through the coil is left on continuously. In other cases, it comes only when the ECCS pump comes on or the fan is manually started. Vents and ·ains are placed in the coil headers to provide a completely drainable, self-:nting coil. Drain pans are located below the coils to drain away the conden-ɜte water that results from the air cooling process. The power for the fan ɔtor is supplied from a motor control center located in a separate air-ɔnditioned room. Backup power is available from a safety-related emergency esel generator bus (same supply as for the ECCS pump it cools) when there is loss of offsite power.

Typical materials used in construction of the components are summarized in ɜble 2.1. The cooling coils are finned to improve cooling efficiency. The ɔils are usually made of seamless copper or copper-nickel tubing. The fin ɜterial is aluminum, copper, or 90/10 copper-nickel. The coil casing is

TABLE 2.1. Typical Materials Used in Component Construction

Component	Materials
Motor Stator	Copper, Steel, Silicon Steel, Aluminum, Insulating Materials
Motor Rotor	Copper, Steel, Insulating Materials
Motor Accessories	Steel, Cast Iron, Brass, Copper, Seals and Gaskets, Mica, Plastics, Cable, Insulating Material, Graphite
Motor and Fan Bearings	Steel, Brass, Bronze, Grease, Lube Oil
Fan	Galvanized, Carbon and Stainless Steel; Aluminum
Cooling Coil	Tubes--Copper and Copper-Nickel Headers--Copper and Copper-Nickel Fins--Aluminum, Copper, and Copper-Nickel Casing--Galvanized and Stainless Steel, Cast Iron Inlet/Outlet Connectors--Steel
Room Cooler Housing	Galvanized, Carbon, and Stainless Steel
Sheaves, Pulleys	Steel
V-Belts	Cord (cotton, rayon, synthetic, steel) Fabric, Rubber

usually constructed of stainless steel, cast iron, or galvanized steel. Headers are made of drawn copper or copper-nickel. They are brazed to the tubes, or the tubes are hydraulically expanded into die-formed collars in the fins. Lap joint steel stubs and flanges are used for the coil water supply and return connections.

The fan unit is usually either a centrifugal or vaneaxial type design. The fan is often constructed of galvanized or painted carbon steel. Fan blades are often constructed of aluminum or stainless steel. The fan bearings are standard anti-friction or sleeve types. The anti-friction type is available with either ball or roller bearings.

The fan is driven by a motor which is either directly coupled or indirectly coupled via a v-belt drive with sheaves. The fan is typically driven by a 60 Hz 3-phase horizontal induction-type motor. An excellent description of this motor is contained in a report, generated under the NPAR program, that summarizes aging characteristics of motors (Subudhi et al. 1985).

The room cooler air outlet may have a short section of duct or no duct at all. Small ducts or louvers can direct the cool air across the pump and related pipework.

The frame and housing cover for the room cooler are usually constructed of epoxy-coated carbon steel or galvanized steel, but stainless steel is used occasionally.

A photograph of a pump room cooler is provided by Figure 2.2. An example of room cooler layout is provided in Figure 2.3. The capacity of the unit shown is about 720,000 BTU/h based on a 29,000 cfm airflow and a 96 gpm coolant water flow rate. The centrifugal type fan is v-belt driven by a 20 HP motor.

2.2 ROOM COOLER DESIGN SPECIFICATIONS

The testing requirements for the room ECCS pump cooler and related systems are identified in U.S. NRC Regulatory Guide 1.68 in the category of heating, cooling, and ventilation systems that serve spaces housing engineering safety features. The room coolers are part of the systems reviewed in the Standard Review Plan, NUREG-0800, under Section 9.4.5 (Engineers Safety Feature Ventilation System). Room coolers are generally built to meet the quality assurance requirements of 10 CFR 50 Appendix B or ANSI N 45.2. The design codes and standards used for the room cooler components are listed below:

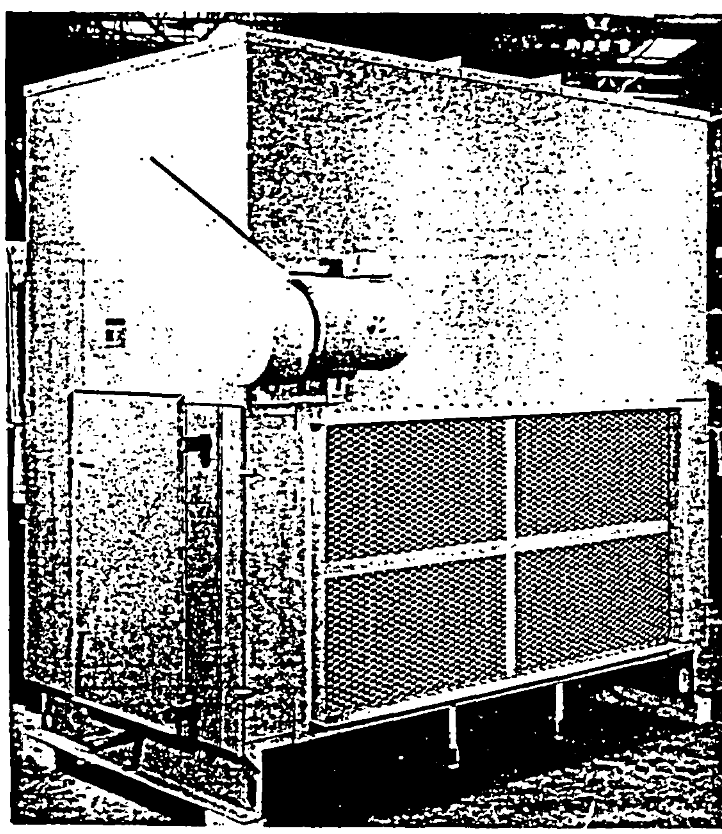


FIGURE 2.2. ECCS Pump Room Cooler (as supplied by Ellis and Watts)

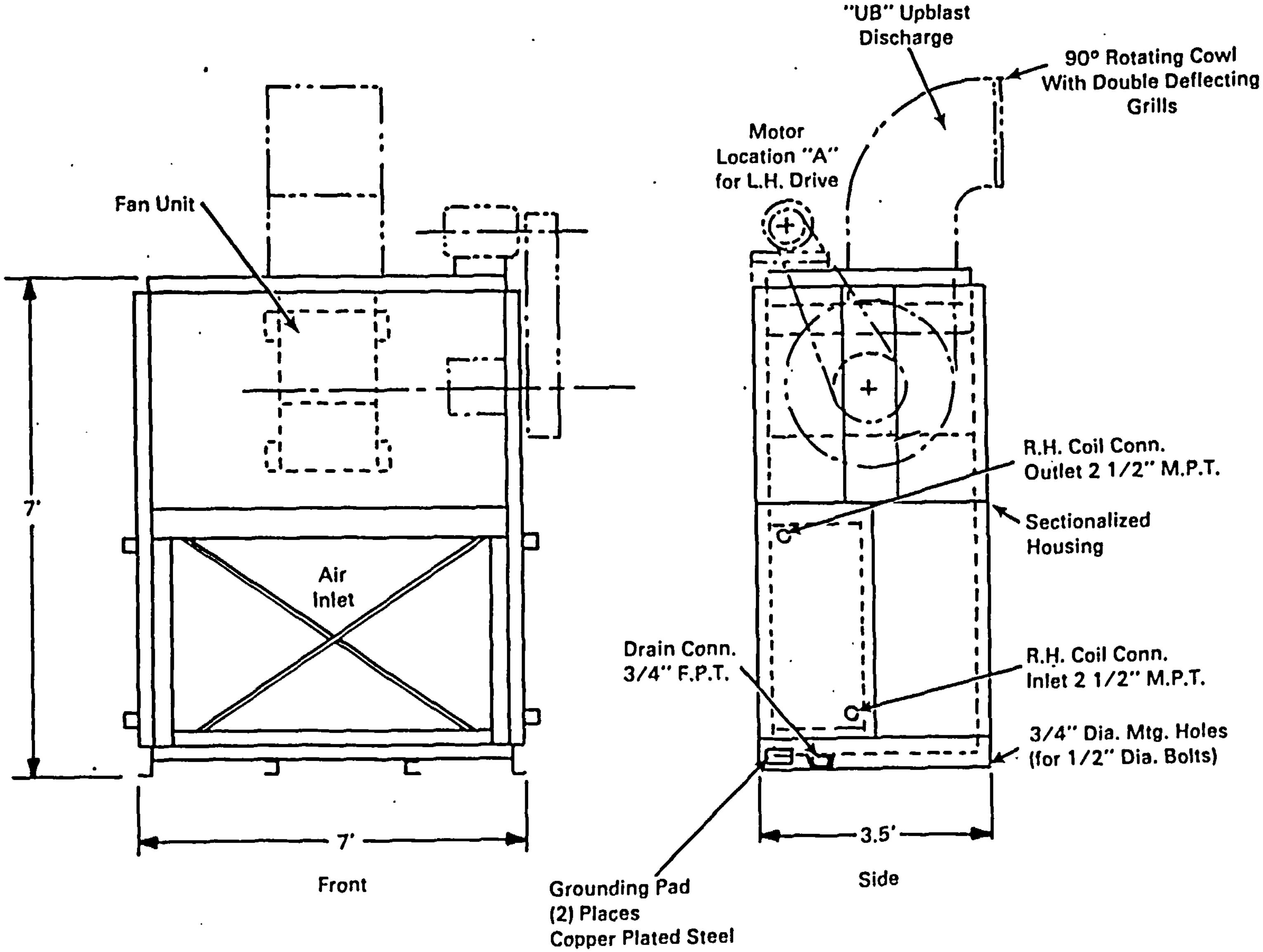


FIGURE 2.3. ECCS Pump Room Cooler Layout (as supplied by Ellis and Watts)

ans

Air Moving and Conditioning Association (AMCA)

- AMCA, Publication 99, Standards Handbook
- AMCA, Publication 201, Fan Application Manual: Fans and Systems
- AMCA, Standard 210, Laboratory Methods of Testing Fans for Rating Purposes
- AMCA, Publication 211, Certified Ratings Program Air-Performance
- AMCA Standard 300, Test Code for Sound Rating
- AMCA, Standard 500, Test Method for Louvers, Dampers and Shutters

Anti-Friction Bearing Manufacturers (AFBMA)

- ANSI/AFBMA, Standard 11, Load Ratings and Fatigue Life for Roller Bearings
- ANSI/AFBMA, Standard 9, Load Ratings and Fatigue Life for Ball Bearings

an Motors

National Electric Manufacturers Association (NEMA MG-1)

Institute of Electrical and Electronic Engineers (IEEE)

- IEEE Standard for Qualifying Class 1E[a] Equipment for Nuclear Power Generating Stations (IEEE-323)
- IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations (IEEE-344)

ooling Coils

Air-Conditioning and Refrigeration Institute (ARI 410 Standard for Forced-Circulation Air-Cooling and Air-Heating Coils)

American Society of Mechanical Engineers
(ASME Section III, Class 2 or 3, "N" stamped)

a) Class 1E - electrical equipment and systems that are essential for emergency reactor shutdown, containment isolation, reactor core cooling, etc. to prevent release of radioactive material into the environment.

2.3 PRINCIPAL TYPES AND USES OF ROOM COOLERS IN BWRS AND PWRS

Final Safety Analysis Reports (FSARs) and Preliminary Safety Analysis Reports (PSARs) for 49 U.S. nuclear power plants were reviewed to determine th types of ECCS pump room coolers and the extent of their use. The FSAR/PSAR Chapter 9.0, "Heating, Air Conditioning and Ventilation," was reviewed (See Appendix B).

Information gathered from the FSAR/PSARs indicates that pump room cooler system designs are plant-specific. Early nuclear plants do not have pump room per se, but large rooms that contain an entire train of each of the types of ECCS pumps. During a LOCA, all ventilation from nonessential areas in the building is forced through the ECCS pump area for cooling purposes. The evolu tion of ventilation and the pump room coolers is illustrated in Figure 2.4. Only a few of the ventilation room cooler schemes in use are illustrated.

In early plants, ventilation air is concentrated in the ECCS pump area if a LOCA occurs. Later plants used schemes with pump room coolers (shown in Con cepts B and C). In Concept B, ventilation continues even during a LOCA. In Concept C, the rooms can be isolated during a LOCA, with the pump room cooler performing all of the cooling.

The coolers are often interlocked with the ECCS pumps and operate only when the pumps operate. Some coolers operate only during a LOCA or other emergency. Others operate when the reactors are in operating, transient, and shutdown modes. Some are left on continuously. Others have the provision for manual operation to enable maintenance workers to work at lower temperatures. Some operate strictly by thermostat. Others operate by a combination of these modes.

Sometimes a cooler is in a separate room or cubicle with an individual pump. Other coolers serve more than one pumping system in a room or area. Th pump rooms are usually separated by a heavy wall to assure that a redundant pump train will not be affected by a local debilitating situation.

ECCS pump room cooler maximum airflow rates range between 1,600 and 30,000 cfm, and maximum heat removal rates range between 50,000 and 800,000 BTU/h. The cooling water flow rate for coolers varies between 15 and 100 gpm. The newer plants have the larger capacity cooler systems. The coole systems are designed to keep maximum pump room temperatures below 104 to 150°F (the maximum temperature varies from plant to plant but is usually in the 104 to 120°F range) after shutdown or isolation of other building ventilation and cooling systems. In a particular plant, the capacities and designs may be nearly identical for the different pump rooms (e.g., HPCS, LPCS, RHR, CS). Other plants have a broader range of cooler sizes and designs.

Sometimes, if the room is large and has additional equipment, the coolers have ductwork to the different equipment locations. In other cases there is n ductwork. If cooling is needed close to the pump, an outlet duct and/or louvers are focused on the pump and piping.

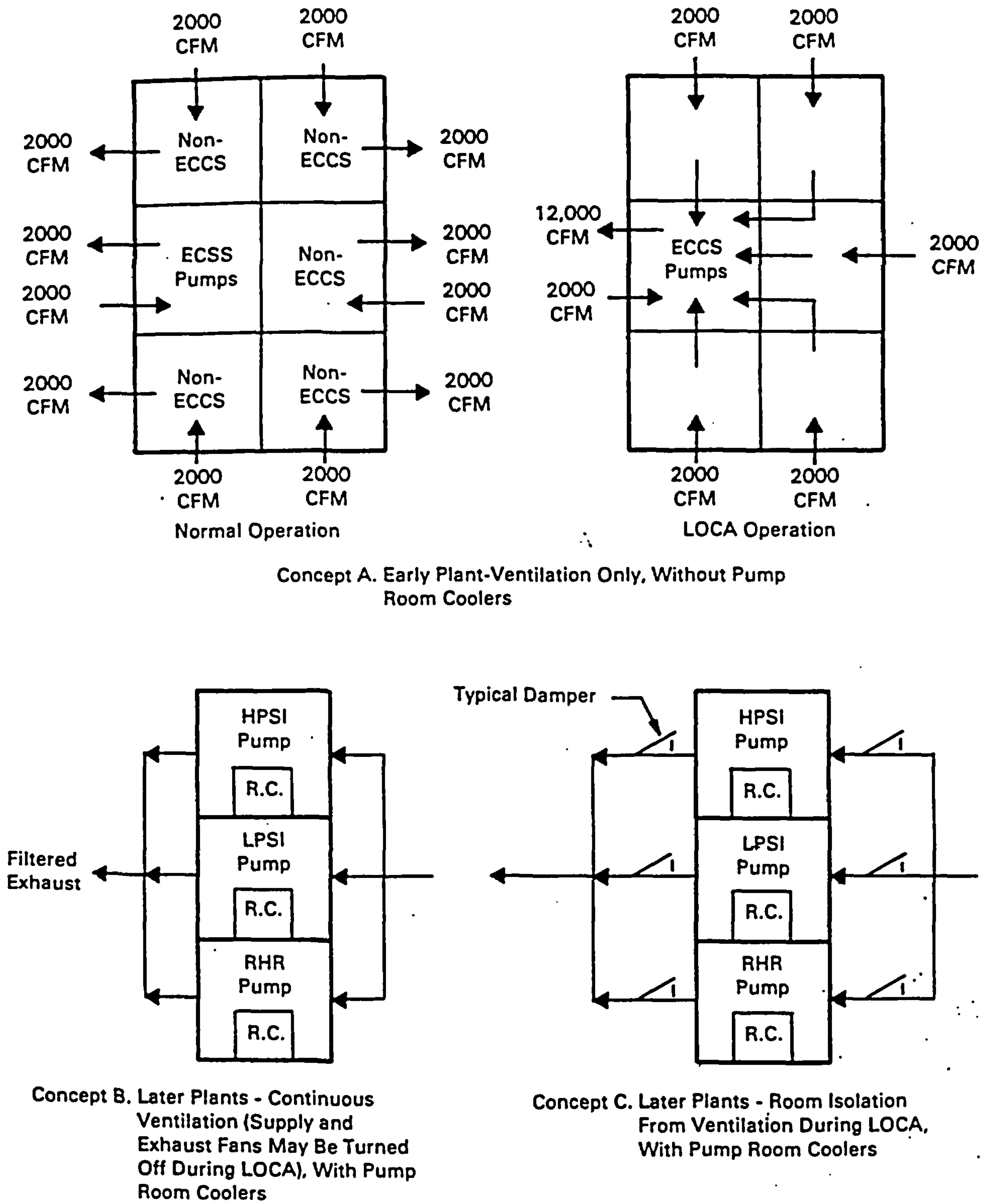


FIGURE 2.4. Examples of Building Ventilation and Room Cooler Concepts. (R. C. indicates room cooler).

The FSAR/PSAR review covered a wide spectrum of plant ages, sizes, and reactor suppliers (See Appendix B). The designs, layouts, and nomenclature room coolers vary from plant to plant. A total of 49 plants were reviewed, some were multiple reactor units at a single site. Plant age ranged from th that came on line as early as 1968 to some that recently went into commercia operation or may soon be going into operation. Plant sizes ranged from 470 1250 MWe. Plants designed by all four U.S. reactor suppliers were reviewed.

The review indicated that 26 of the 49 plants have ECCS pump room coole It is uncertain how many of the remaining 23 plants have them. One plant, which has a central cooling system for its pump rooms, did not have pump roo coolers. Some of the plants that had pump room coolers also had central ven lating sources. Appendix B summarizes by reactor vendor the plants that wer reviewed.

The newer plants all have pump room coolers with larger capacities to handle the higher reactor power capacities. Of the plants examined, most of the General Electric plants, over half of the Combustion Engineering plants, about one third of the Westinghouse plants, and one third of the Babcock and Wilcox plants definitely have pump room coolers.

Pump room coolers serve a variety of ESF and ECCS pump rooms in the reactors. The pumps they service are listed under the following names and acronyms:

<u>General Electric Reactors</u>
high-pressure core spray pump (HPCS)[a]
high-pressure coolant injection system pump (HPCIS)
low-pressure core spray pump (LPCS)
low-pressure coolant injection system pump (LPCIS)
residual heat removal pump (RHR)
decay heat removal pump (DHR)
core spray pump (CS)
reactor core isolation cooling pump (RCIC)

<u>Combustion Engineering Reactors</u>
high-pressure safety injection pump (HPSI)[a]
low-pressure safety injection pump (LPSI)
containment spray pump (CS)

<u>Westinghouse Reactors</u>
centrifugal charging pump (CC)[a]
safety injection pump (SI)
residual heat removal pump (RHR)
containment spray pump (CS)

(a) Most-common terminology for high-pressure injection pumps.

Babcock and Wilcox Reactors

high pressure injection pump (HPIP)[a]
low-pressure injection pump (LPIP)
emergency injection cooling pump (EIC)
reactor spray pump (RS)
decay heat removal pump (DHR)

2.4 EQUIPMENT BOUNDARY

The equipment boundary selected for the Phase I effort is the area within the fan/coil enclosure. The room cooler housing and its immediate attachments are included. Most room coolers have similar components within this boundary (Figure 2.5). Components include the following items:

- Frame Structure and Sheet Metal Housing
- Inlet Screen and Filter (Optional)
- Finned Cooling Coil
- Plenum Zone
- Fan Unit
- Fan Drive System
- Drive Motor
- Outlet Duct (Optional)
- Louvers (Optional).

Figure 2.5 shows the typical components located both inside and outside the chosen boundary. Because elevated temperatures and humidities may occur in the pump rooms, electrical components are usually limited to the drive motor and thermostats. The interfacing motor controls and other electrical and electronic components are located in the central motor control center (MCC), where environmental conditions are more closely controlled. Components in the motor control center include cables, wires, transformers, fuseboxes, breakers, switchgear, relays, and other electrical control and readout components. The offsite power and onsite emergency diesel generator busses also interface with the pump room cooler at the MCC. The water supply for the cooling coils, chillers, and the pumps and valves that control the water flow are usually located outside the room. Other items in the pump room, but outside the boundary, include a room thermostat, manual switch, drain, and ventilation dampers.

2.5 FUNCTIONAL REQUIREMENTS

The functions required of the ECCS pump room cooler are usually one or more of the following:

- Maintain the room ambient temperature low enough so that the ECCS pumps can respond properly in the event of a LOCA or Design Basis Earthquake (DBE).

(a) Most-common terminology for high-pressure injection pumps.

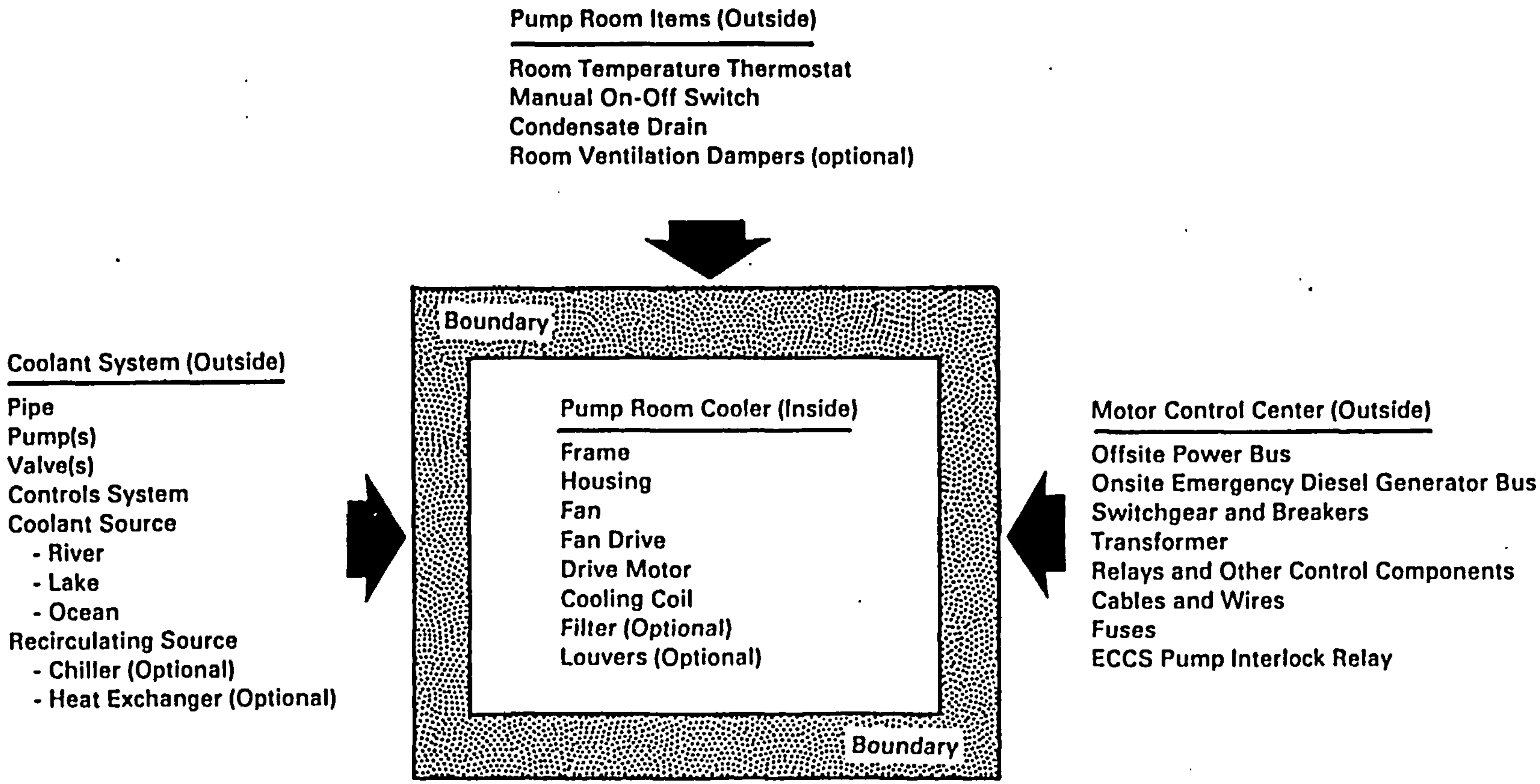


FIGURE 2.5. Components Located Inside and Outside the ECCS Pump Room Cooler Boundary

- Maintain the room ambient temperature low enough so that ECCS pump life is not degraded during normal operating and shutdown periods. Some ECCS pumps (e.g., RHR) operate during nonemergency periods also.
- Maintain room temperatures in a tolerable range for personnel to perform maintenance and surveillance work.
- Prevent building heat accumulation.
- Minimize the amount of air that must be exhausted to the environment through filtered systems.

3.0 DATA SOURCES FOR PUMP ROOM COOLER OPERATING EXPERIENCE

The sources of room cooler operating data are discussed in this section. In general, the data bases reviewed were not rich in information about the ECCS pump room coolers. The review of limited public and private information indicated that room cooler components within the defined boundary have not been a major problem in plant operations.

Data to assess aging of room coolers was sought from the following sources:

- Licensee Event Reports (LERs)
- In-Plant Reliability Data System (IPRDS)
- Nuclear Power Experience (NPE)
- Vendor Survey
- Utility Contacts
- Published Reports
- Ongoing Research
- Expert Opinion.

Each source will be briefly discussed in this section. Section 5.0 will discuss the operating experience data gathered from these sources.

3.1 LICENSEE EVENT REPORTS (LERs)

LERs are reports of significant operational events at nuclear power plants. The reports are submitted to NRC by licensees according to federal regulations. Prior to January 1984 LERs were filed based on NRC Regulatory Guide 1.16 and NUREG-0161 for the individual plant Technical Specifications. Since January 1984 the LERs are based on rule 10 CFR 50.73 and NUREG-1022. The new rule requires more detail and uniformity, but some of the component failure events previously reportable are no longer reportable. All LERs submitted under the old and new systems are computerized in an LER data file of the Nuclear Safety Information Center (NSIC) maintained by Oak Ridge National Laboratory (ORNL). A search of this file indicated that reported failures of the ECCS pump room coolers are rare and come from a small percentage of the plants.

3.2 IN-PLANT RELIABILITY DATA SYSTEM (IPRDS)

The ORNL-IPRDS data base is primarily for use in nuclear power plant probabilistic risk assessment and reliability studies. Maintenance work request records from representative operating commercial reactors were the source of data. The data on ECCS pump room coolers found in a search of the IPRDS were limited to one plant for a period of nine years.

3.3 NUCLEAR POWER EXPERIENCE (NPE)

The NPE data base is an accumulation of operating experience for U.S. light-water nuclear plants compiled by the S. M. Stoller Corporation. A very limited number of failure reports were obtained from this source.

3.4 VENDOR SURVEY

A telephone survey was the first attempt to acquire vendor information. Seven room cooler vendors were contacted, but very little information was obtained. The next approach was to send letters to 14 companies that have be involved in manufacturing of pump room cooler components and assemblies. Onl two companies responded with information in writing, and one company telephon a response. The three vendors who responded were very helpful in providing general design information; they expressed an interest in manufacturing equip ment in the future.

The market for pump room recirculating air coolers has dropped to virtually nothing, so most heating, ventilation, and air conditioning companies ar no longer in the room cooler business. Information and experienced personnel are difficult to locate. Some vendors indicated that they would provide the information only if under contract.

3.5 UTILITY CONTACTS

Utility personnel were contacted, but they were reluctant to provide information because of the procedures, time, and cost involved. Because of t wide range of cooling system designs, a significant number of utilities woulc have to be contacted, and cost arrangements would have to be worked out. Thi will be deferred until Phase II.

3.6 PUBLISHED REPORTS

No published reports addressing room coolers were found through several library searches.

3.7 ONGOING RESEARCH

No public information was found relating to ongoing research programs pertaining to room coolers.

3.8 EXPERT OPINION

Knowledgeable people from vendors and utilities were interviewed. This source is addressed in Section 9.0.

4.0 TESTING

Room cooler testing has been performed by the manufacturers and independent laboratories. Conformance to codes and standards for seismic and other safety requirements is determined by pre-operational testing or analysis calculations.

Usually, seismic qualification is established by testing a room cooler on a shake table to meet IEEE-344 performance requirements. The test is carried out in accordance with a seismic qualification test plan agreed to by the buyer and seller of the equipment.

After the room coolers are installed in the nuclear plant, the units are tested prior to startup to ensure that required design operating parameters are satisfied. One plant required that each cooling unit be tested as follows:

- Verify that control room panels work properly and indicate the corresponding equipment function (e.g., equipment running or stopped).
- Perform an audio/visual inspection of intake and discharge areas for excessive vibrations or obstructions.
- Measure and record the discharge air flow rate.
- Measure and record the fan total static pressure.
- Test fan and motor vibration at the bearings. Measure and record the axial, horizontal, and vertical vibration for each bearing.
- Measure and record the fan motor operating current and voltages.
- Verify MCC controls and interlock operability (e.g., ECCS pump interlock relay and emergency power breaker).
- Verify ECCS pump room temperature alarm settings performance.

5.0 OPERATING EXPERIENCE

As indicated in Section 3.0, only limited information is available regarding room cooler operating experience. Because room coolers are used more extensively in newer plants and in plants still under construction, eventually a broader data base will emerge. LOCA experience at Three Mile Island Unit 2 was reviewed, and it was determined that pumps were serviced by only a centralized ventilation system. In general, there appear to have been no significant room cooler aging problems, except for wear in bearings and sheaves caused by fan drive V-belts. Air-cooled equipment in other industrial sectors also appear to be relatively free of aging problems (Appendix A).

5.1 FAILURE MODES AND CAUSES

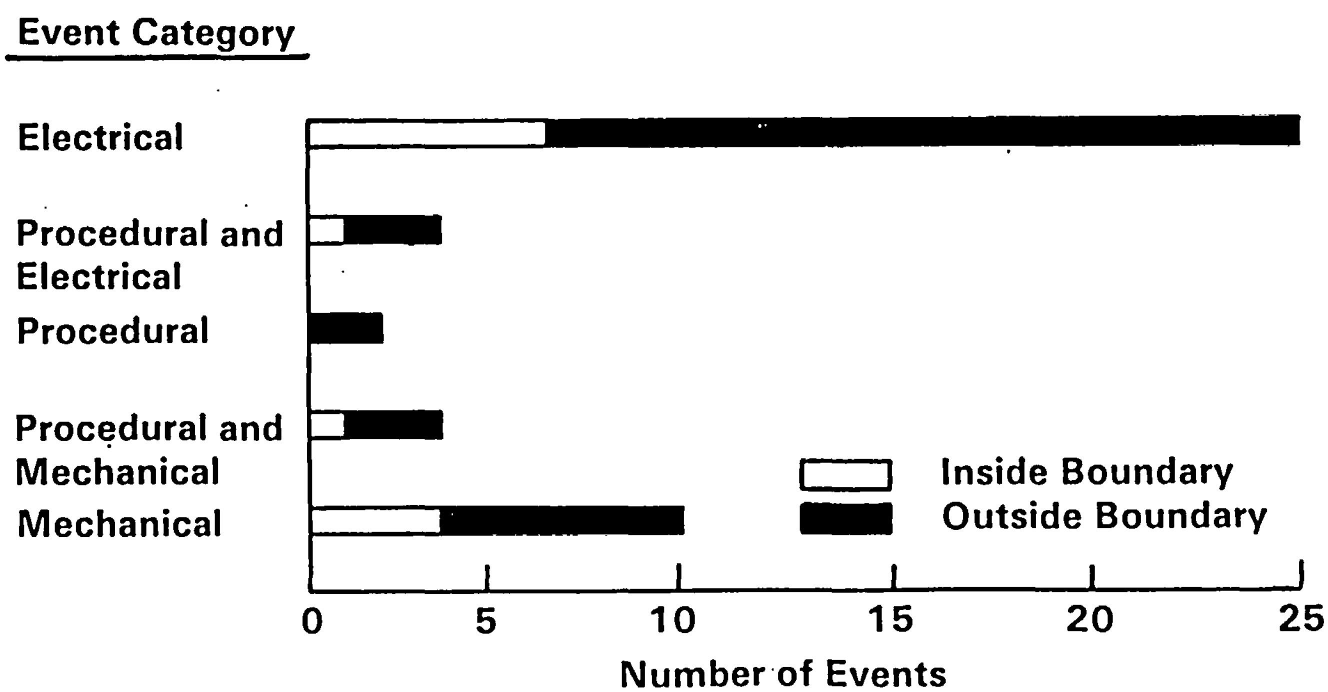
Results of the LER review are summarized in Figure 5.1. The LERs were accumulated from the RECON, SCSS, NPE and PDR data bases. The results indicate that most of the failures occurred outside the ECCS pump room cooler boundary. Most of the failures had electrical sources. A total of 45 reported failures occurred over about a 10-year period. Thirteen of the failures were within the room cooler boundary (a little more than one per year in the entire industry). Only 17 of the 83 operating plants have filed room cooler LERs. The majority, 31 of the 45 LERs (69%), were from 5 plants. Twenty-six of the 45 LERs occurred in BWRs; the balance occurred in PWRs. There is no apparent explanation for the concentration of LERs at a small percentage of the plants.

The bulk of the failures that could be linked to a particular system occurred in the RHR system, which is a heavily utilized system in most plants. It is usually used for normal decay-heat removal when the reactor is shutdown.

The LERs for events inside the boundary were attributed to a variety of causes. Three occurred as a result of small coil leaks, and three were due to thermostat problems. The rest were miscellaneous one-time occurrences.

The IPRDS data for one plant over a span of nine years indicated that 27 maintenance requests were made for a total of eight ECCS room coolers. It should be noted, however, that maintenance requests are usually written and action is taken before failures occur. Maintenance requests are often the result of preventive maintenance (PM) checks or surveillance activities. The requests were issued for the following items:

Drive Belt Adjustment or Replacement	10
Temperature Sensor Adjustment or Replacement	7
Coil Repair or Replacement	5
Coil Cleaning	2
Motor Control Center Service	2
Unknown	1
Total Requests	27



Boundary - Coil, motor, fan, drive system, housing and housing attachments.

FIGURE 5.1. ECCS Pump Room Cooler LER Review Summary

IPRDS data for the coolers used for rooms and areas outside of the ECCS pump rooms were also reported. The non-ECCS coolers are usually built to less stringent standards. Most had belt-driven centrifugal fans. Over 60 units were covered by 132 maintenance requests spaced over 9 years--about 0.25 requests/cooler/year. Again, this is a very low rate. The breakdown for maintenance requests is as follows:

	Quantity	Percentage
Belt Adjustment or Replacements	53	40%
Fan and Motor Bearing Replacements	17	13%
Coil Cleaning	15	11%
Sheave Repair or Replacement	10	8%
Coil Leak Repair	8	6%
Filter Change	8	6%
Mechanical, Miscellaneous	6	5%
Damper Adjustment or Repair	5	4%
Temperature Sensor Repair or Replacement	4	3%
Coil Replacement	3	2%
Electrical, Miscellaneous	3	2%
Total Maintenance Requests	132	100%

As with maintenance requests for ECCS coolers, the non-ECCS cooler maintenance involved drive belt and vibration-related items as the most frequent entries (61%). Sheave and bearing replacement is primarily due to vibration-related problems. Some bearing replacements were due to inadequate lubrication.

LER data from an ORNL search from 1976 to 1983 indicate that a total of 30 fan motor failures occurred in the following areas:

Stator	15
Bearing	8
Accessories	6
Rotor	1
Total LERs	30

The data were not sufficiently detailed for these fan motor failures to be identified with ECCS pump room coolers.

Room cooler analysis would benefit from the acquisition of maintenance data from more plants, especially from those that have more direct-driven, rather than belt-driven, fans. A comparison of vaneaxial and centrifugal fan experience would also be desirable, especially regarding vibration-induced problems.

A few utility contacts indicated that the primary maintenance concerns are with the belt-driven fans, which induce vibration. Direct-driven fans appear to have fewer vibration problems. Vibration generated from water flow through cooling coils does not appear to be a significant problem.

5.2 FREQUENCY OF FAILURES

The frequency of reported failures for ECCS pump room coolers is very More extensive surveys of utility experience may reveal some plants that ha experienced higher failure levels.

The available LERs cover a time span of about 9 years (1974 to 1983). that period, approximately 588 plant operating years were accumulated. It uncertain how many of the plants do not have ECCS pump room coolers. The frequency rate for LERs on ECCS pump room coolers is as follows:

	LERS	LER Frequency per Plant Operating Year
Within the Boundary	13	0.022
Outside the Boundary	32	0.054
Total Reported LERs	45	0.076

The LER failure frequency of 0.022 LERs per plant operating year appears to very low. The number of unreported failures is unknown.

The maintenance request rate, addressed by IPRDS data, was about 0.375 ECCS pump room cooler operating year. This is a very low maintenance volum and most of these maintenance requests did not concern a failed room cooler se. The non-ECCS cooler maintenance request rate was even lower. That rat was about 0.25 maintenance requests per non-ECCS cooler operating year.

The fan motor LER failure rate is difficult to assess. There are many safety-related fan motors in a nuclear plant in addition to the ECCS pump r cooler fan motors.

5.3 METHODS OF DETECTION

The primary failures and maintenance needs for ECCS pump room coolers ter around vibration problems created by units with belt-driven fans. Vibr tion causes excessive belt, sheave, and motor- and fan-bearing wear.

Such problems can usually be detected by vibration and acoustic testin equipment. The vibration and sound could also be continuously monitored fo deterioration trending. Poor alignment can sometimes be detected visually, alignment jigs can be used. Excessive vibration can also be seen or heard motor mounts and other fasteners start to fail or loosen. The IPRDS data indicated that most vibration and misalignment was detected by operators an craftsmen in the vicinity. Squawking, squealing, wailing and other noises usually indicate excessive wear and potential failure of V-belts, bearings, sheaves.

Slow coil leaks inside the housing may be hard to distinguish from ordi nary condensation. Larger leaks can be detected visually by inspection of t coil and the pump room cooler sight drain.

5.4 MAINTENANCE ACTIONS

The IPRDS information indicates that most maintenance actions are based on visual and noise observations by plant personnel. Fan and motor bearings are usually lubricated on a routine basis. It appears that coils are cleaned occasionally on a campaign basis.

Most room cooler maintenance can be performed before the deteriorating component fails. When there are downtime limitations listed in the technical specifications for room coolers, 12 hours to 14 days are generally allowed for repair of the equipment before a plant shutdown must be implemented. This amount of time--possible because of redundant ECCS pump trains--is sufficient to replace V-belts, a motor, a fan, or a coil.

Continued adherence to vendor maintenance recommendations will minimize maintenance work and equipment failure.

5.5 MODIFICATIONS RESULTING FROM FAILURES

If justified, monitors could be used to sense changes in vibration, sound, and temperature to provide faster response to a deteriorating or failed component. This phase of the study has not examined monitoring options closely. The sensors and transmitters used in this function would have to be designed for a variety of environmental conditions (e.g., high humidity, high temperature) in different plants and pump rooms. Simple peak vibration, acoustic, and temperature indicators may provide ample monitoring.

Actual modifications could not be identified in the data bases reviewed. No evidence was found where failures were severe enough to warrant design changes. Insufficient data was found to conclude that motor direct-drive fans would be substantially better than belt-driven fans.

6.0 SUMMARY OF OPERATIONAL STRESSORS

The stressors of primary concern are listed in Table 6.1. The degree of stress will vary according to the design and operation of specific plants and pump rooms. Many variations are described in Section 3, (e.g., the maximum room temperature limit varies from 104°F to 150°F). As seen in the table, vibration can effect all of the components; it is the principal stressor affecting room coolers. The motor is susceptible to the most stressors, and the motor insulation is particularly vulnerable.

6.1 MECHANICAL STRESSORS

Severe vibration is caused by moving components that are out of alignment or balance or by other sources of vibration that impact stability. The vibration can be externally or internally generated and can readily be transmitted to all components by the housing and drive system.

6.1.1 Fan Motor

The main effect of vibration on the fan motor is deterioration of the bearings. Vibrations can also loosen rotor bars, cause laminations in stator or rotor cores, cause chafing of insulation, and cause fatigue of metallic components because of cyclic stresses.

Loose motor mount bolts and armature unbalance can cause fan motor vibration and noise. Worn bearings can cause the armature to rub against the stator. Too little lubricant, too much lubricant, or the wrong lubricant can cause damage to the bearings.

Since the effects of mechanical and other stressors on motors are described thoroughly in another report generated under the NPAR program (Subudhi, M., E. L. Burns and J. H. Taylor, June 1985), they are not treated in depth in this report.

6.1.2 Coupling (For Direct Drive)

Direct couplings between the shafts of the motor and fan can transmit vibration from one to the other. If the shafts are misaligned the coupling can generate vibration itself. Misalignment between shafts can ultimately lead to failure of the coupling and parts in the motor and fan.

6.1.3 V-Belts and Sheaves (For Belt Drive)

The V-belts can transmit vibration between sheaves, and they can generate vibration if the sheaves are misaligned or if the belts are too tight or too loose. Excessive belt tension will reduce belt life and may cause bearing and shaft damage.

TABLE 6.1. Primary Stressors and Aging Mechanisms--Areas of Concern Within the Room Cooler Boundary

Component	Mechanical	Thermal	Environmental	Electrical	Radiation	Chemical
Fan Motor	Vibration Lubrication	Insulation Lubrication	Insulation Off-on Operation	Insulation Dielectric Strength	Insulation	Insulation Lubricant
Coupling	Vibration Misalignment	--	--	--	--	--
V-Belt & Sheaves	Vibration Misalignment Belt Tightness Start-Stop	Belt Temperature	--	--	Belt Material	--
Fan	Vibration Lubrication	Lubrication	Humidity	--	--	Lubricant
Cooling Coil	Vibration	--	Aluminum Fins	--	--	Salt in water water impurities Corrosion
Housing	Vibration	--	--	--	--	--

Multi-belt units that do not have uniform belt tension can also generate vibration. Vibration, misalignment, and improper tensioning cause V-belts to be the largest problem in the maintenance and operation of room coolers.

Sheaves and bearings can wear faster when they are misaligned. Starting and stopping (particularly heavy starting) decrease V-belt life. Frequent cycling will require more frequent adjustments and replacements.

6.1.4 Fan

Lack of proper static and dynamic balance in the fan can cause vibration throughout the room cooler unit. The fan bearings themselves are subject to deterioration because of vibration and improper lubrication.

6.1.5 Cooling Coil

The coil can generate vibration through water flow if it is not properly designed; however, experience does not suggest that coil vibration has been a problem. The most significant vibration is that transmitted from other room cooler components through the housing to the coil. Vibration can cause mechanical and brazed joints to fail and subsequently leak.

6.1.6 Housing

The housing can transmit vibration throughout the room cooler unit from other internal components or external sources. External vibration sources can be reduced some by using resilient floor mounts. Vibration generated from internal components cannot be isolated so easily, although resilient mountings may help in some cases.

Since it is designed to meet Class 1 seismic requirements, the housing should not deteriorate rapidly from vibration. Usually, loosening of bolts is the main concern.

6.2 THERMAL STRESSORS

The amount of thermal stress to room cooler components is somewhat plant-specific because maximum specified room temperatures vary between 104 and 150°F. During a LOCA, temperatures exceeding the maximum specifications are possible if the room coolers fail. This could be caused by the recycling of containment sump water, which can be above 200°F, through some or all of the ECCS pumps. During normal reactor shutdown, systems such as the RHR or LPCI pumps are used to recirculate and cool the reactor primary water, which can also reach relatively high temperatures. The pumps and fan motor also add heat to the rooms. Most pumps, however, have local coolers for their bearings and seals. Certain ECCS pumps in some plants are capable of operating in the 200 to 350°F range for limited periods, but the details are not clear and would have to be examined on a plant-specific basis with cooperation from the utilities.

6.2.1 Fan Motor

Fan motors must be designed to withstand room temperatures up to 150°F i some plants. Most plants require motor operation in ambient temperatures up the 104° to 120°F range. Subudhi, Burns, and Taylor (1985) elaborate on the effects of thermal stressors on motors. The report points out that temperatu is the key parameter that can affect motor performance over the long term--or for a short duration at excessive temperatures. As with vibration, high temperatures can be internally as well as externally generated. Manufacturers must design motors for specific temperature and humidity conditions, with amp margins of tolerance. Insulation material selection is very important to prevent temperature degradation.

Proper lubrication and lubrication material are important in preventing bearing burnout at high ambient temperatures. Insufficient or excessive lubrication can cause internally generated heat.

6.2.2 V-Belts

High ambient temperatures require selection of belts properly designed the application. Materials selection is particularly important when ambient temperatures approaching 140°F are anticipated.

6.2.3 Fan

Selection of high temperature bearing lubricant is required for ambient temperatures approaching 150°F. As with the motor bearings, the proper amou of lubricant is also important in minimizing internal heat generation.

6.3 ENVIRONMENTAL STRESSORS

The most important environmental concerns for room coolers are high tem ratures (previously discussed in Section 6.2) and high humidities. Pump roo are usually located at lower levels of the building, where water accumulates sumps, condensation forms on concrete walls, etc. increasing humidities abov those elsewhere in the building. Air that passes through the pump rooms is usually cleaned and conditioned by a central ventilating system. Air passes through only once in the ECCS pump rooms. Some plants control the humiditie at about 50%, but a survey of utilities would be necessary for an accurate assessment of humidity experience.

During a LOCA, humidity may increase because of leaks in containment pe tration seals or ECCS pumps and pipeworks, or from sump water accumulations. All of these items occurred to some extent at Three Mile Island-2.

6.3.1 Fan Motor

The room cooler component most affected by high humidity is the fan mot The presence of actual water in the insulation of a motor can accelerate the degradation process by reducing electrical life and dielectric strength. Bo the dissipation factor and the dielectric constant change considerably when an insulating material is exposed to humid air. Volume resistivity also declines at high relative humidities.

Humidity should be no problem for motors with heaters. Modern Class 1E motors windings with class B, F or H insulation, would be impervious to humidity unless extremely abused by thermal overload. Only a porous or hygroscopic winding would be significantly affected by humidity. Prolonged storage or idleness in an area of high humidity will cause corrosion of mounting bolts, lead connections, conduit boxes, bearings, and housing enclosures.

6.3.2 V-Belts

Data on V-belts in high humidities were not found. High humidities, especially when coupled with high temperatures, may cause problems in V-belts.

6.3.3 Fan

Varying humidities and condensation may cause problems with the bearings if lubrication is not properly maintained.

6.3.4 Cooling Coil

Some coils use aluminum fins on copper tubing. Experience with such coils in industrial areas with fumes and marine air have shown that aluminum fins may deteriorate, degrading their heat transfer capabilities (Appendix A). This has not seemed to be a problem in nuclear plants because the environment is usually clean, but aluminum fins should be monitored periodically.

6.4 ELECTRICAL STRESSORS

The fan motor is the only room cooler component subject to electrical stressors.

6.4.1 Fan Motor

Maintenance of dielectric strength is an important requirement for motor insulating material to perform its function. In most insulating materials, the ability to withstand electrical stress declines with increasing temperature, dust, dirt, and humidity. With an increasing combination of temperature, dust, dirt, and humidity the insulating capabilities of the dielectric is lost due to arcing (corona type discharge) across the surface area of the insulating material.

Voltages below or above specific ranges can cause rapid deterioration of the motor. An overload of the motor can cause high internal temperatures that will draw too much current and burn out the motor.

6.5 RADIATION STRESSORS

Radiation levels in pump rooms during normal operations vary from plan plant. During a LOCA, radiation levels may increase, and in some plants th design basis LOCA will cause radiation levels to greatly exceed safety limi for personnel. The radiation levels will increase greatly if some fuel mel down materials and water are pumped by the ECCS system from the containment sump or suppression pool. The FSAR of one plant indicated that radiation levels, on a 6-month integrated basis after a LOCA, could accumulate up to 3.1×10^6 rads in the RHR pump room.

An extended LOCA may cause deterioration of all organic materials used room coolers. V-belts, rubber motor mounts, and motor insulation are examp of these materials. Again, the fan motor would probably be stressed the mo:

6.5.1 Fan Motor

Since chemical changes rearrange the molecular structure of the materi. organic insulation in motors deteriorates both mechanically and electricall; a result of irradiation.

6.6 CHEMICAL STRESSORS

Chemical stressors primarily apply to the fan motor and cooling coil c ponents. Stressors occur from chemical changes that can be induced by exte: chemical effects and chemical change to the material itself. The most comm result of chemical stress is degradation of a material by oxidation (corrosion). Corrosion is discussed in greater depth in reference to dry cooling applications (Johnson, Pratt, and Zima 1976) and general behavior i air-cooled equipment (Appendix A).

6.6.1 Fan Motor

Insulation degradation, lube oil decomposition (i.e., viscosity break-down), and overall corrosion are the most significant forms which degrade m performance with time. Oxidation plays a major role in the breakdown of in: lation. Lubricant deterioration and contamination are also caused by the o dation process, which acidifies the lubricant medium and reduces the viscos Subsequently, metal-to-metal contact may degrade bearings.

6.6.2 Motor and Fan Bearings

Extended shutdowns can cause condensation that promotes corrosion. Special lubricant is needed for extended shutdown or intermittent operation

6.6.3 Cooling Coil

Corrosion of tubing and build up of scale can occur when salt and bracl water are used in some plants to cool the coils. Also, impurities in water pumped directly from rivers, lakes, etc. can cause corrosion. Plants with closed loop cooling water have treated water, which is less likely to cause corrosion. LERs have shown that corrosion is a problem in containment coolers, but the extent of corrosion in room coolers has not been determined.

6.7 PRINCIPAL VIBRATION CAUSES IN ROOM COOLERS

The largest source of stress and aging in room coolers appears to be vibration. In room coolers the principal sources of vibration are from the following conditions:

- Fan wheel out of balance due to damage, corrosion, or accumulated material
- Fan delivering more than the rated capacity
- Fan rotating in the wrong direction
- Motor out of balance or damaged
- Sheaves eccentric or out of balance
- Drive misalignment
- Bent shaft
- Belts too loose or too tight
- Mismatched drive belts
- Sheaves or fan wheel loose on shaft
- Worn coupling
- Loose bearings
- Loose mounting bolts
- Loose set screws
- Loose dampers
- Vibration isolators improperly adjusted
- Insufficient, excessive, or incorrect lubricant
- Unstable foundation
- Vibration from other equipment.

7.0 MANUFACTURER RECOMMENDATIONS FOR MAINTENANCE AND SURVEILLANCE

The general maintenance and surveillance guidelines recommended by manufacturers of room coolers are listed below:

- Establish a time schedule for routine inspection of all rotating parts and accessories. The inspection frequency depends on factors such as the severity of operations and environment. Initially, inspections should be frequent. With experience, the frequency can be optimized.
- Keep shafts and sheaves in good alignment.
- Check fan and motor bearings and lubricate according to the manufacturer recommendations. Do not over lubricate. If lubricant breaks down or becomes dirty, flush and replace it.
- Check the bearing pillow block temperatures while operating to ensure that it is within specifications.
- Check tightness of all bolts and set screws.
- Inspect fan wheel blades for accumulations of dust and dirt. Clean thoroughly. Check the wheel balance. Make certain the wheel turns in proper direction and that it turns no faster than the rated speed. Ensure that the fan does not turn hard. Hard turning may cause motor overload.
- Check belt wear, belt tension, and alignment of the sheaves. When multiple belts are used, replace all the belts simultaneously with new belts if one or more are deteriorated. Belts must be kept free of grease.
- Repaint the exterior and interior parts of fans and duct work as needed.
- Inspect motors and load condition occasionally.
- Blow out open type motor windings with low pressure air to remove dust and dirt.
- Check current and voltage against nameplate values and compare with previous readings.
- Keep motors dry. If motors are idle for extended times, space heaters or heater strips might be helpful to prevent water condensation on the windings.
- Screens and filters should be cleaned or replaced periodically. Ensure there are no obstructions to flow.

- Do not permit vibration. Check for misalignment, imbalance, loose bolts, bent shaft, etc.
- Periodically inspect, clean, and dry the cooling coil internal and external surfaces.
- Follow component manufacturer maintenance and surveillance guidelines.

8.0 AGING AND SERVICE-WEAR MONITORING AND ASSESSMENT

The information available to assess room cooler aging is limited, as pointed out in previous sections. Available evidence suggests that there are few failures and problems associated with the ECCS room coolers if they are properly installed and maintained.

Vibration is the stressor that causes the most maintenance problems, accelerated aging, and failures within the room cooler boundary. Vibration arises from several sources inside the room cooler. The room coolers are constructed to handle external vibrations (such as a seismic event), but internal vibration sources, perhaps caused by poor maintenance and surveillance practices, are the principal problem. If the manufacturers recommendations are followed closely, aging and wear are held to a minimum.

Vibration and acoustic monitoring of room coolers may reduce wear and failures in plants where surveillance by workers is not available every shift. Such monitoring would allow corrective action to be taken before failure or before component replacement is required. Periodic checks of motor and fan bearing pillow block temperatures would also help to prevent bearing failure. These monitoring steps would have to be implemented on a plant specific basis. Many plants with good ECCS room access and routine surveillance during normal operations may not need to use monitoring equipment. Monitoring of room coolers during and after LOCAs would be difficult in many of the plants.

9.0 EXPERT OPINION

Access to expert opinion was limited for this study. Vendor personnel involved in room cooler manufacturing, sales, and service were difficult to locate. The market for sales of ECCS room coolers has been nonexistent for several years, so personnel have left or are involved in other more active market areas. Vendors have not had many problems with their equipment in the field; they feel that if their maintenance instructions are followed, the equipment will be very reliable. Persons with utility experience indicated that room coolers have been relatively trouble-free and have experienced fewer problems than most other nuclear plant safety equipment. The only concern voiced was about vibration in belt-driven room coolers.

Because room cooler design and operation is plant-specific, the best approach to a more comprehensive assessment of room cooler aging would be to survey all of the utilities directly. Additional funding and authorization would be required to perform such a survey. Unless room coolers begin to develop more problematic operational history, a broader survey does not seem to be justified.

10.0 CONCLUSIONS AND RECOMMENDATIONS

Room coolers are important safety-related nuclear plant components, which serve other safety-related components such as ECCS pumps. The room cooler function is to maintain room ambient temperatures below specified limits. The limits differ for various plants and applications, but generally range from 104 to 120°F. The highest values are up to 150°F.

In LWR's of early design, component cooling is provided by centralized systems. Use of multiple smaller units, each directed to specific components (e.g., pumps) is a more recent development. Consequently, the time frame of room cooler experience is shorter than for other safety-related plant components such as pumps, valves and motors.

The boundary selected for this study involves the room cooler housing and includes the cooler frame, housing, fan, fan drive, drive motor, cooling coil, filter, and louvers. Other important equipment that influences room cooler operation includes the coolant supply system and motor control center. Most key equipment outside the boundary (service water system, pumps, valves, electrical components, etc.) and some inside the boundary (principally drive motors) are being addressed by aging studies elsewhere in the NPAR program (referenced in this study).

This investigation of room cooler aging employs a systematic strategy that is applied to nuclear plant components and systems addressed under the NPAR program. The major elements of the strategy applied to this investigation are:

- evaluation of operating experience
- interim assessment of aging characteristics.

Sources of operating experience include LERs, IPRDs, NPRDs, and NPE. The interim aging evaluation draws from vendors, utility contacts, and expert opinion. The experience survey resulted in limited data regarding room cooler operating problems. The limited data base appears to arise from two considerations:

- more recent incorporation of room coolers into plant designs
- room cooler operation that to date is relatively trouble-free, based on evidence from the survey.

The data suggest that vibration, particularly in units with belt-driven fans, has caused the most room cooler maintenance and aging problems. Fan motors are vulnerable to the greatest number of stressors. The LERs suggest that room cooler failures are rare. When they do fail to operate, it is usually because of malfunctions outside the room cooler boundary, in the interfacing motor control center or in the service water chiller, valves, or pumps.

Because the plant ECCS pump room cooler designs and operations vary so much from plant to plant, it is difficult to focus on specific aspects of equipment aging. Room cooler aging assessments must be performed essentially on a plant-specific basis. As plants get older, more aging-related problems may develop. However, cooperation by the utilities to provide assistance and data is needed if aging studies are to be successful.

10.1 RECOMMENDATIONS

Recommendations for minimizing the rate of aging of room cooler components within the defined equipment boundary are as follows:

- Follow manufacturer recommendations for installation, surveillance, and maintenance of parts, components, and assemblies.
- Add vibration isolation mounts (if practical) at locations where vibration is a problem.
- Where justified, use vibration, acoustic, and temperature monitoring methods. Use practical methods.
- Spot check vibration amplitudes and frequencies on a monthly basis. Also check bearing temperatures. Keep records to identify trending.
- Add strip heaters on motors and bearings if the room coolers are only used intermittently or infrequently in high-humidity rooms. The heater should operate only when the room cooler is idle.

10.2 FUTURE WORK

It is recommended that Phase II of the ECCS pump room cooler aging assessment be delayed until further study is justified by NPAR systems assessments regarding room cooler interactions in safety systems. Incorporation of containment coolers in future assessments or an independent assessment of containment-coolers should be considered. In some plants, containment coolers are important safety-related equipment for a design basis accident.

11.0 REFERENCES

Davis, T., A. Shafaghi, R. Kurth, and F. Leverenz. 1985. Importance Ranking Based on Aging Considerations of Components Included in Probabilistic Risk Assessments. NUREG/CR-4144 (PNL-5389), Battelle Columbus Laboratories, Columbus, Ohio.

Johnson, A. B. Jr., D. R. Pratt and G. E. Zima. 1976. A Survey of Materials and Corrosion Performance in Dry Cooling Applications. BNWL-1958, Pacific Northwest Laboratory, Richland, Washington.

Subudhi, M., E. L. Burns, and J. H. Taylor. 1985. Operating Experience and Aging-Seismic Assessment of Electric Motors. NUREG/CR-4156 (BNL-NUREG-51861), Brookhaven National Laboratory, Upton, New York.

Serada, P. J. 1974. Weathering Factors Affecting Corrosion of Metals in Corrosion in Natural Environments. ASTM STP 588, American Society for Testing and Materials.

Uhlig, H. H. 1967. Corrosion and Corrosion Control, p. 226. John Wiley and Sons, New York.

US NRC. 1985. Nuclear Plant Aging Research (NPAR) Program Plan. NUREG-1144. U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research.

APPENDIX A

GENERAL BEHAVIOR OF AIR-COOLED EQUIPMENT

APPENDIX A

GENERAL BEHAVIOR OF AIR-COOLED EQUIPMENT

In essence, room coolers in nuclear plants comprise finned tubes for heat transfer and fans to move air. In those respects, nuclear plant room coolers are similar to air-cooled equipment in other industrial applications. A survey of materials behavior in non-nuclear air-cooled equipment focused on equipment longevity and factors that contribute to air-cooled equipment deterioration (Johnson, Pratt, and Zima 1976). Results of the survey are briefly reviewed in respects potentially relevant to room cooler applications.

In benign (e.g. rural) environments, air coolers servicing gas pipe line pumps have been durable and reliable for service exceeding thirty years. The range of materials (Table A.1) largely parallels the range of nuclear room cooler materials (Table 2.1). The small number of units that were susceptible to severe fin corrosion were generally sited in marine environments, where industrial pollution was also a factor. An exception involved a case at a rural location where residual fin cleaning solution may have been the source of accelerated corrosion. Fin corrosion resulted in a gradual deterioration of heat transfer capacity.

A major factor in fin corrosion is the cooler operating cycle. While coolers operate at temperatures above the dew point, fin corrosion is minimized. During periods when coolers are out of service, the fins are more susceptible to corrosion. This is particularly true in humid environments, where moisture condensation occurs on fin surfaces. "Time-of-wetness" is recognized as an important atmospheric corrosion parameter (Serada 1974). Corrosion due to atmospheric moisture also may cause deterioration of other equipment that interfaces with room coolers, such as motors and electrical controls. However, those aspects are subjects of investigation in other elements of the NPAR program.

TABLE A.1. Materials in Conventional Dry Coolers

Dry Section	
Fins:	aluminum[a]
	steel
	stainless steel
	copper alloys
Tubes:	steel
	stainless steel
	copper nickel
	admiralty

(a) Coated fins can be specified.

Material selection is another important consideration in finned tube durability, particularly in environments where corrosion rates are significant (Uhlig 1967). Copper ions have a demonstrated accelerating effect on aluminum corrosion. Aluminum fins interface satisfactorily with copper tubes in relatively dry conditions. When moist conditions result in some dissolution of copper ions, accelerated corrosion of adjacent aluminum may result, depending on several factors, including time-of-wetness, temperature, and impurities in the environment. Under dry conditions, copper alloy tubes with aluminum fins have operated without problems over extended periods.

In coolers operating with good water quality control and flow design, water-side corrosion of tubes has not been a significant problem. Fouling of interior tube surfaces also has not limited thermal performance. If cooler water quality is marginal, or if sea water serves as the coolant, materials selection becomes a key consideration. The survey provides a review of corrosion behavior of candidate air cooler materials, including aqueous and air environments.

From the survey, additional problems and considerations in air-cooled equipment operation are summarized below:

- Vibration generally was due to loose supports and unbalanced fans.
- Fan motor failures were due to sub-standard motors and to inadequate maintenance; some motor bearing failures were indicated.
- Gear box failures have occurred due to shock loads and loss of lubricant.
- Some fan blade failures have occurred, principally from stress corrosion cracking of stainless steel blades; steel and plastic blades performed satisfactorily.
- Tube failures caused by freezing, and fouling of fin surfaces by airborne debris are not problems likely to be encountered by room coolers in nuclear plants.

From the standpoint of room cooler operation, the most relevant insights from the survey are:

- Air-cooled equipment has a history of high reliability over extended operation (>30 y).
- Slow, rather than sudden, deterioration of heat transfer capacity has occurred in the few cases where corrosion and fouling have been severe.
- Air-side corrosion generally was more significant when equipment was not operating, particularly in humid environments; the key aspect is water condensation on corrosion-prone surfaces; air contaminants also were important in cases of severe air cooler corrosion.

- For coolers with corrosion-prone materials or combinations of materials, periodic inspections are suggested (including inspection of contacts between fins and tubes when dissimilar metals are involved).

- Room cooler water quality is an important consideration; if sea water or other potentially aggressive waters are involved, a review of expected compatibility with tube materials is recommended. If tube corrosion and/or deposition is suspected or indicated, the need for further inspection or nondestructive evaluation is suggested.

REFERENCES

Johnson, A. B. Jr., D. R. Pratt and G. E. Zima. 1976. A Survey of Materials and Corrosion Performance in Dry Cooling Applications. BNWL-1958, Pacific Northwest Laboratory, Richland, Washington.

Serada, P. J. 1974. Weathering Factors Affecting Corrosion of Metals in Corrosion in Natural Environments. ASTM STP 588, American Society for Testing and Materials.

Uhlig, H. H. 1967. Corrosion and Corrosion Control, p. 226. John Wiley and Sons, New York.

APPENDIX B

LIST OF FSARs/PSARs REVIEWED

APPENDIX B

LIST OF FSARs/PSARs REVIEWED

The following list contains nuclear system suppliers and original nuclear plant FSARs/PSARs reviewed during the ECCS pump room cooler assessment:

General Electric

Arnold
Browns Ferry 1, 2, & 3
Brunswick 1 & 2
Fitzpatrick
Grand Gulf 1 & 2
Oyster Creek
Perry 1 & 2
Pilgrim

Babcock and Wilcox

Arkansas One -1
Davis Besse-1
Midland 1 & 2
Oconee 1, 2, & 3
Rancho Seco

Combustion Engineering

Arkansas One-2
Calvert Cliffs 1 & 2
Maine Yankee
Millstone 2
Palo Verde 1, 2, & 3
St. Lucie 1 & 2

Westinghouse

Beaver Valley 1 & 2
Byron 1 & 2
Connecticut Yankee
Farley 1 & 2
Ginna
Indian Point #3
Kewaunee
Point Beach 1 & 2
Salem 1
Sequoyah 1 & 2
Trojan
Turkey Point 3 & 4

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