APPENDIX 6A

SUMMARY DESCRIPTION

THREE MILE ISLAND NUCLEAR STATION UNIT 1

REACTOR BUILDING FAN COOLER ASSEMBLY

The material contained in Appendix 6A is a synopsis of American Air Filter's Topical Report to the Metropolitan Edison Co. covering Reactor Building Fan Assemblies for Three Mile Island Nuclear Station Unit 1.

(Originally issued with Amendment 17 to the FSAR, Dated 25, 1971)

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1.0 GENERAL

Three Reactor Building fan assemblies are installed in the Reactor Building of Three Mile Island Nuclear Station Unit 1 (TMI-1) to cool containment air volume during the normal operating environment as well as during emergency environmental conditions, should they occur. Section 2 of this report presents the description of the seismic design of the units, and Section 3 provides design summaries for the components of the Reactor Building fan cooling assembly.

Each assembly consists of fan, motor, normal cooling coils, separate emergency cooling coils, manifolds, drain sumps, mist eliminator pads (when present), pressure relief valves, and reinforced structural housing.

NOTE:
The AH-E-1C Mist Eliminator east bank has been removed (Reference 7).
AH-E-1A Mist Eliminator west bank has been removed (Reference 8).
AH-E-1B East and West Bank Mist Eliminator was removed per Reference 9.

A Reactor Building fan assembly unit is shown pictorially on Figure 6A-1.

1.1 OPERATING ENVIRONMENT

The Reactor Building fan units have a normal operating design life of 40 years. They are also designed for the once in a lifetime emergency load conditions which occur in eight to ten seconds. The structure will withstand a 2 psi pressure differential. The relief valves will permit rapid equalization of any pressure differential imposed on the structure over 1 psi.

The units are also designed so that there will be no loss of function during and after a prescribed seismic disturbance, as well as within the containment spray atmosphere, if utilized.

Original Purchase Specification Performance Data

> The following tabulation provides the normal and emergency designed performance parameters for the reactor building air coolers for original design conditions. This data is from the original design specifications for the system (information to which the RB Fan units were purchased), and is presented for historical reasons. This data does not represent actual system design performance, and is not to be used for accident analysis.

		Normal	Emergency
Airflow, cfm		108,000	54,000
Design cooling capacity, Btu/hr		2,150,000	80,000,000
Actual cooling capacity, Btu/hr		2,330,000	92,900,000
Inlet temperatures,	°F db	110.0	281.0
	°F wb	91.5	281.0
		(50% RH)	(Sat.)
Outlet temperatures,	°F db	88.4	255.0
	°F wb	87.3	255.0
		(96% RH)	(Sat.)
Mixture density, lb/ft^3		0.0685	0.180
Pressure, total absolute, psia		14.70	68.30
Inlet partial, vapor, psia		0.64	49.99
Inlet partial, air, psia		14.06	18.31
Outlet partial, vapor, psia		0.64	36.11
Outlet partial, air, psia	14.06	32.19	
Condensate rate, lb/hr		0.0	98,086.5
Coolant flow rate, gpm		430.0	1,780.0
Inlet coolant temperature, °F (85F Nominal)		85.1	84.8
Outlet coolant temperature, °F		95.6	183.0
Coolant side pressure drop, psi		4.9	8.7

Design Performance Data:

	Normal	Emergency
Air side static pressure drops, inch Hg		
Inlet losses	.17	.13
Filters	.06	.04
Dustload (maximum)	.50	.40
Normal coils	.37	.30
Emergency coils	.40	.36
External	3.50	2.50*
Air side static pressure, inch Hg	5.00	3.73
Air velocity pressure at cone discharge, inch wg	1.02	.74
Air side total pressure, inch Hg	6.02	4.47
Maximum Horsepower (at entering air density) lb/ft^3	150 @(.071)	75 @(0.21)

* External loss has been adjusted downwards as a square law resistance.

2.0 SEISMIC DESIGN DESCRIPTION

2.1 GENERAL APPROACH

The requirement to be completed was to design and build three air cooling units that would be capable of withstanding predicted seismic and overpressure forces.

Blast or overpressure resulting from a loss of coolant accident will be handled by the unit housing's capability of withstanding a 2 psi implosive load. Beyond that, numerous relief valves are provided to equalize exterior versus interior pressure.

A thorough seismic analysis would be dynamic, taking into account resonances the structure may have within the seismic spectrum. Such an analysis, however thorough, would still require considerable simplification. Therefore, static calculations (with margins of safety) are employed and realistic results are obtained.

2.1.1 CRITERIA

The unit must be capable of withstanding forces imposed by the predicted earthquake disturbances of 0.38g horizontal and 0.25g vertical, acting simultaneously, with allowable stresses not being exceeded.

In addition, simultaneous seismic factors of 0.76g horizontal and 0.51g vertical must be withstood without loss of function of the equipment (stresses below the yield point of the material).

Also, deformations and failures under the 2 psi loading condition must not result in loss of function of the equipment. (The assumption was made here that stresses should be kept under the yield point of the material).

2.2 METHOD

2.2.1 GENERAL

The units were initially designed on the basis of the 2 psi implosive loading which was correctly assumed to be the limiting condition.

Analysis was then accomplished under several loading conditions in order to prove structural integrity; since all three units are identical, only one analysis was made.

The loading conditions that were analyzed were the following:

a. Combined dead and 2 psi blast (wind).

b. Combined dead, downward vertical seismic and horizontal seismic acting on the side of the unit.

c. Combined dead, downward vertical seismic and horizontal seismic acting on the end of the unit.

d. Combined dead, downward vertical seismic, and horizontal seismic acting at 45 degrees on one corner of the unit.

Due to the symmetry of the units, it was assumed that these four loading conditions were fully representative of all possible load situations. (Upward vertical seismic was not considered due to the fact that the vertical factor is less than unity).

Seismic loading and wind (2 psi blast) loading were not considered to act simultaneously because an adequate time differential would exist between these loading conditions, even if the loss of coolant accident were caused by an earthquake.

When the analytical results of the original design were evaluated in terms of allowable stresses in each member and excessive displacements were encountered, certain structural changes were incorporated into the housings to satisfy design criteria.

2.2.2 PROCEDURE

Due to the size of the unit (i.e., the number of members versus core storage capacity of the computer used for the analysis), subdivisions were made along the split lines used for shipping (two end sections and one center section per housing). See Figures 6A-2, 6A-3, and 6A-4.

A full analysis was made on one end section while holding the joints common to both the end and center sections. Reactions were thus obtained in order to be reversed and applied to the center as joint loads (from each end section). These same joints were released in force and moment directions to allow movement in directions that motion may be assumed to occur.

This method of dealing with large structures is a realistic technique.

2.2.3 UTILIZATION

The structural analysis used was the IBM/360 version of the IBM/1130 STRESS computer program. It can analyze structures with prismatic properties (using the stiffness matrix method) in two or three dimensions, with pinned or rigid joints, and subjected to concentrated or (uniformly or linearly) distributed loads, support motions, or temperature effects. Loadings may be applied either on members or joints and only elastic deformation is considered. Outputs of this program include member forces and moments, support reactions, and joint displacements. This information can then be used to calculate deflections and beam stresses (to determine the possibility of safe limits being exceeded) (Reference 1).

Several supplemental computer programs were developed for use with IBM/STRESS in order to assist in application of loads and to test for allowable stresses.

Two such programs are the following:

SMDATA: Generates member input load data in a form acceptable to STRESS for a rectangular space frame, optionally panelled, with optional wind (blast) and seismic loads parallel to any global axis of the structure. It also punches a member data input deck for the post STRESS computer program MEMTST.

MEMTST (or STRESSA): Tests the member forces output of STRESS to determine whether allowable unit stresses on members of the structure have been exceeded (as per AISC Manual of Steel Construction, Sixth Edition).

2.2.4 DETAILED ANALYSIS

The right end section, reduced to a stick frame for use in the computer, is shown on Figure 6A-3. Such a stick frame allows all structural members to be represented by their centroidal axes. Some engineering judgment is involved in this reduction in order to minimize the number of members so that the STRESS program is capable of handling the structure. Therefore, certain assumptions (all of conservative tendency) were made for this housing. Five equally spaced interior roof beams, floor beams, and end vertical columns were used instead of six irregularly spaced members, and for the interior vertical columns on the center connecting face (members 27, 28, and 29), the intervals were adjusted so that they would connect with a roof or floor beam at a common joint.

At this point, the 7 gauge bottom or 11 gauge skin covering the structure is not given credit for adding structural support except in the following manner. The dashed members (69 and 70) are strategically located pseudobeams formed out of a 6 inch wide strip of skin and allowed to accept tensile loads only.

These realistically help to stiffen the structure under appropriate seismic directed loads. Tensile stress only in these members is insured by releasing the end moments (effectively pinning the ends instead of having a rigid joint) and assigning appropriate beam properties describing a member that will easily buckle under minimal compressive loads.

All other joints are assumed to be fully rigid in the analysis. Sufficient weld material exists at all joints for this assumption to be valid.

The SMDATA computer program begins at this point. Because the STRESS program defines all joint information in global coordinates and all member information in terms of its local coordinates, SMDATA must do the same. The global coordinate system is obvious from the diagram. Each member has its own local coordinate system with the local X axis running down the longitudinal axis of the member in the positive direction from its first named joint to its second named joint and always parallel with and in the same direction as one of the positive global axes. Both coordinate systems are right-handed, orthogonal Cartesian systems.

Prismatic properties (cross-sectional area, shear areas, moments of inertia, etc.) are assigned to each member by means of a beam code. Magnitudes of loading conditions (2 psi and six directed seismic factors) are fed into the program.

A member data deck is also an input that defines the member number, its end joint numbers, its length, the dimensions and weight of any attached panels of skin, its local blast loading direction, and its orientation to the global coordinate system.

Our SMDATA program takes all this input information and returns deck of IBM cards each for the dead load, wind load, and six directed seismic loads. This allows the selection of any separate loading situation as a separate input to STRESS after which STRESS combines the ones selected.

In its computation, SMDATA considers the weight of each member and distributes the weight of each panel to the surrounding members. Each member supports an area of the panel in direct relation to the ratio of its length to the total perimeter of the panel. The 2 psi blast load is directed perpendicularly against each panel and distributed to the surrounding members in the method discussed above. Seismic loads take the weight times the seismic factor and direct it in the appropriate direction. The assumption is made that these loads can logically be applied in a particular direction as either uniformly or linearly distributed directly to the member and not as small moments about the member's local X axis.

Loadings resulting from interior or exterior equipment on a housing (cooling coils, fan, and so forth) must be applied directly in the STRESS program.

In addition, SMDATA also accomplishes certain housekeeping chores such as generating information concerning which joints and which members are associated, each member's prismatic properties for use in STRESS, and a member data deck for use in the MEMTST program.

This application of the STRESS program uses the space frame type of structure, which allows all six possible degrees of freedom (X, Y, and Z forces and moments about the X, Y, and Z axes).

All bottom joints are held fully supported because they will be mounted on a heavy structural steel framework within the Reactor Building.

As previously explained, all joints common to both the end and center sections (on the interface between the two sections) were held only in specific directions, in order to obtain applicable reactions for application as joint loads to the center section. Therefore, end joints 3, 7, 13, 20, 24, 28, and 32 are labeled supports, but released in the Y and Z directions and the moment about the X axis. All equipment (coils, prefilters, and fan) was loaded directly on the applicable bottom members (either as a concentrated or uniform load) for dead and seismic loading conditions.

Computer printouts of the STRESS run on both the end and center sections are available, but are considered too cumbersome for inclusion in this report.

Maximum joint displacements proved to be end joint No. 40 (0.3856 in. in the negative Z direction) under the combined dead and wind (2 psi blast) load (without considering the existing roof stiffeners) and center joint No. 5 (0.3402 inch in the positive Z direction) under the same load.

Now, the MEMTST (or STRESSA) computer program is employed to check the most critical factor of member stresses having exceeded the criteria under any loading condition.

An explanation of this program follows:

The problem itself is based exclusively on the specifications contained in the American Institute of Steel Construction (AISC) Manual of Steel Construction (Sixth Edition).

Very basically, the criterion for allowable unit stress on a primary compression member at one of its joints is:

$$\frac{P/A}{Fa} + \frac{My/Sy \pm Mz/Sz}{Fb} < 1$$

Where: P = axial force

A = cross-sectional area

Fa = allowable compressive axial stress (Article 1.5.1.3 of AISC)

My and Mz = moments about member local Y and Z axes, respectively

Sy and Sz = section moduli of member

Fb = allowable compressive bending stress (Article 1.5.1.4 of AISC)

The MEMTST (or STRESSA) program uses the force and moment output of STRESS and member properties to compute the above information (or applicable information for tension members) and prints out the ratio of actual stress to allowable stress for each member at each joint.

Results of less than 1.33 are expected for this ratio under design earthquake loading conditions (Article 1.5.6 of AISC).

For the conditions of maximum earthquake and 2 psi blast (wind) where yield strength is the governing rather than allowable factor, allowable stresses of 0.6 of yield (on the average) are assumed and ratios under 2.2. are expected.

$$\frac{1.33}{0.6} = 2.2$$

Yield strength of our material is 36,000 psi (A 36 steel).

2.3 RESULTS

Our analysis indicated numerous raw beams having excessive stresses. All such situations were under the loading condition of dead plus the 2 psi wind (blast), and design earthquake seismic stresses proved to be small by comparison.

These members were then individually investigated. First, the 7 or 11 gauge skin which usually covered a member was taken into account structurally. This skin was solidly welded to a given member at its end joints (where maximum moment exists) and the usual practice employed a strip width of eight thicknesses extending either way beyond the cross-sectional limits. Other situations dictated combining both the properties and loads of adjacent end section and center section members on the interface between the two sections.

Further investigation proved necessary for those members still giving greater than a 2.2 test result for the 2 psi loading condition.

End section members 1, 4, 5, and 8 appeared to fail because of an apparent high value of local Y moment. This is non-representative of the actual stress distribution caused by the presence of several roof stiffeners running the length of the end section and not being included in the analysis. The assumption that these stiffeners will not allow failure of these members is valid because they provide lateral support in the direction of bending.

Members 15 and 20 of the end section will not cause loss function of any equipment if they fail at joints 18 and 35. Here again, the actual stresses involved are slightly less than those shown because there are actually six interior roof beams instead of the five used in the analysis.

All the members in the center section were determined to be satisfactory after analysis with skin attached or combined with end section members. However, since members 14 and 17 approached limiting conditions at joints 29 and 31, respectively, because of moments almost entirely about only one principal axis, a 2 1/2 by 2 1/2 by 1/4 angle roof stiffener was added to the center section to reduce the potential of a problem situation.

2.4 SUMMARY

Comprehensive analysis proves the structural integrity of the three air cooling units under the design basis earthquake and the 2 psi blast loading conditions. Since the loads of the maximum hypothetical earthquake are twice that of the design basis earthquake and the limiting criterion is yield strength instead of AISC allowable stresses (approximately 0.6 of yield), a check of the ratios of actual to allowable stresses under design basis earthquake loading clearly shows that the increased loads of the higher seismic factors will not be a critical condition.

In other words, for these housings, the 2 psi blast loading condition (which dictated the initial design) governs the strength of the members, and seismic considerations are not of a critical nature.

3.0 DESIGN SUMMARIES - MAJOR COMPONENTS

This section includes a brief summary of the design, operation, and testing of the major components for the Reactor Building fan cooler assemblies.

3.1 HOUSINGS

Housings for the fan assemblies are steel weldments, formed from structural angles and channels. Walls, floors, ceilings, and internal baffles of hot rolled steel are seam welded for these structural frames. Each housing is factory fabricated in three subsections, which are later assembled on the jobsite. Specifications of housing components are as follows:

Structural Frame: Standard ASTM A-36 structural angles and channels, seam welded at joints.

Walls and Ceiling: 11 gage hot rolled steel plate, seam welded.

Floor: 7 gage hot rolled steel plate, seam welded.

Doors: (Normal access, in walls) Marine bulkhead type, with twin locking lugs neoprene gasketed for no fume leakage up to 1 psi pressure differential. (Two doors per fan assembly, clear opening 20 by 50 inches).

Access Openings: Same as doors (two with clear openings 20 by 20 inches located in floor between emergency and normal coil banks, one with clear opening 30 by 30 inches located in floor in fan section).

Drains: 3 inch pipe, total five, one in fan section, and one upstream of each emergency coil bank and each normal coil bank; welded to housing floor, penetrating underframe.

Header Seals: Because of the difficulty of exactly aligning cooling coil headers, special sealing flanges are provided for each point where headers penetrate the housing walls. 'Aeroquip' 'Flexmaster' joints are incorporated in these flanges to seal between header pipes and the flanges; the flanges in turn are welded to the housing walls.

Fan Door: 11 gage hot rolled steel, attached to housing frame with eight 1/2 inch bolts. This door allows the entire fan and cone assembly to be withdrawn from the housing.

Lifting Lugs: Four per subsection, removable eyebolt type, 1 1/2 - 6 UNC 24 by 3 1/2 inches long.

Ringbolts: Eight mounted internal to each section, to allow insertion of guy wires and turnbuckles for shipping-shock protection.

Electrical Penetrations: One 3 inches, two 2 inches, and two 3/4 inches steel pipes, for motor power and control. Seamwelded to side wall under fan door.

Relief Valves: Total of 30 per fan cooler unit, and 14 are located in the housing walls upstream of each emergency cooling coil, two in the fan section.

Mist Eliminator Frames: Type of 304 stainless steel modular frames, 24 by 24 by 2 inches, bolted and riveted into two banks of 35 units each.

Painting: Undercoat is Phenoline No. 368 modified phenolic white primer; finish coat is Phenoline No. 368 finish coat, grey. Unit was touched up with these same paints after field welding was completed.

Housings are designed to withstand a maximum blast overpressure of 2 psi and the seismic accelerations listed in Section 2. Analysis of the effects of these loadings on the structure was carried out after final design of the housing.

3.2 RELIEF VALVES

Thirty fast-acting pressure relief valves are incorporated in the walls of each fan cooler unit to prevent its collapse in the event of a rapid pressure rise outside the unit. Each valve consists of a rectangular steel box having four ports on its top face. These ports are surrounded on the top side by a one-piece gasket of 1/4 inch foam rubber. Four circular valve cups press down on this gasket to seal the valve ports. The four cups are attached to a single steel flap approximately 20 by 5 by 1 inch which locates them and provides the required sealing force. This flap is welded to an axle which fits rather loosely into bearings formed by extensions of the ends of the valve box. When a sufficiently high pressure wave reaches the valve, it lifts the valve cups, and allows air to enter the housing. This prevents buildup of a pressure differential across the housing wall. When the differential decreases to a small value, the valve closes from its own weight.

The valve must maintain its seal during normal operation of the fan-cooler unit, yet respond quickly enough to follow the rapid pressure rise expected from a maximum hypothetical accident. The low moment of inertia of the valve flap combined with relatively heavy weight and sharp sealing edge make it meet these two requirements.

A prototype of the valve was tested under pressure-rise conditions postulated for TMI-1. The data gathered in this test sequence was entered into a computer simulation of the conditions of maximum hypothetical accident and demonstrated that the 30 valves in the fan cooler housings are indeed adequate to protect the housings from collapse.

3.3 MIST ELIMINATORS

Some fan coolers are equipped with a bank of mist eliminators through which all air must pass before entering, sequentially, the normal and emergency cooling coils. The function of the eliminators (when present) is to minimize the amount of treated water entrained in the return air (as a consequence of operation of the emergency spray system) that reaches the emergency cooling coil. The eliminators are considered to be desirable and precautionary but not essential to the emergency performance of the fan coolers for the reasons outlined below.

As shown in the tabulated Performance Data under Section 1.1 of this Summary Description, the emergency coil in each fan cooler will be condensing vapor at a rate in excess of 98,000 lb/hr. This quantity of distilled water will dilute any treated spray water that might be carried to the coil with the air.

The probability of air entrained water reaching the emergency coil is very low because to reach it the air must pass sequentially through return grilles, whence it makes a 90 degree turn into the duct, then through the duct system, where it passes through additional 90 degree elbows (which throw larger drops out by centrifugal action), through the mist eliminator bank (when present) and finally, through the 8-row-deep, 8-fins-per-inch normal cooling coil (where the velocity of 240 feet per minute is well below the moisture carryover velocity).

The spray water diminishing characteristics of the return duct system and the normal cooling coil plus the spray water diluting characteristics of the emergency coil are considered to provide a high degree of protection to the emergency coil. The mist eliminator bank (when present) is considered to be a redundant element in the chain through which the air passes.

The eliminator bank (when present) is constructed of AAFVM-154 pads, 305mm square. Each pad contains 450g of No. 35, Type 304 stainless steel wire crimped and distributed evenly over a 55 mm pad depth. The efficiency of this pad is predicted to be in excess of 95 percent based on a mean droplet size 50 micromillimeter diameter (References 2, 5, and 6). With larger particles, this efficiency would be expected to be even better.

The eliminator bank (when present) is expected to withstand the emergency pressure change from 14.7 psia to 68.3 psia in eight seconds. Relief valves on both the upstream and downstream side of the bank will keep the pressure differential to a minimum (Reference 3).

Although the above tests were favorable, they do not in any way represent a condition anticipated during emergency operation. There are four factors which operate to protect the emergency coil from exposure to treated building spray water entrained in air returning to the fan coolers. These are:

a. The return ducts with their 90 degree elbow

b. The mist eliminator bank (when present)

c. The normal duty cooling coil

d. The washing and diluting action of the high rate of condensation which occurs on the emergency coil

3.4 COILS

Cooling coils are arranged in two modular banks on opposite sides of the fan motor. Each of these banks is, in turn, divided into two sections, one for normal use and one for emergency use. Air flows first through the normal use coils, then through the emergency use coils.

Coil components are as follows:

Tubes: 0.625 inch OD, 0.527 inch ID, copper

Fins: 0.007 inch thick, copper

Manifolds: Copper tubing, 2-5/8 inch OD, brazed

Frames: Galvanized hot rolled steel

Emergency coils are of the plate fin, staggered row, single serpentine type, six fins per inch. Normal coils are the same, except that they are circuited half serpentine, and carry eight fins per inch. Tubes are hydraulically expanded to lock them into fins. Each coil module is 45 inches long (finned length) by 24 inches wide by 15 inches deep, has tube end fittings to allow brush cleanout, and is supplied with a drain pan to carry off excess condensate. Headers are brazed copper tubing, with 150 lb lap joint flanges for attachment to the coolant water supply and return.

A prototype of the emergency cooling coil was tested to determine its heat transfer parameters under conditions simulating a design basis accident. The data gathered from these tests were inserted into a computer program to predict the performance of the coil banks in the containment under DBA conditions. The required 80 x 10^6 Btu/hr capacity for each 54,000 ft^3/min fan cooler unit (consisting of 30 emergency use coil sections) was met. Qualitative tests were made exposing a coil type assembly of fins and tubes to an air spray mixture of the same chemical composition as will be used in the Reactor Building. No serious physical or structural degradation was apparent after an 8 day exposure, and therefore, the heat transfer characteristics were not adversely affected (Reference 4).

Although the above tests were favorable, they do not in any way represent a condition anticipated during emergency operation. There are four factors which operate to protect the emergency coil from exposure to treated spray water entrained in air returning to the fan coolers. These are:

a. The return ducts with their 90 degree elbows.

b. The mist eliminator bank (when present)

c. The normal duty cooling coil

d. The washing and diluting action of the high rate of condensation which occurs on the emergency coil

These factors are discussed more fully in section 3.3 of this Appendix, Mist Eliminators.

3.5 FAN MOTOR UNITS

3.5.1 FANS

The fans used are Joy Series 2000 units, type FF 11873. These are of axial flow design, with internal direct drive motors. Being two-speed units, they provide the following typical design performances (note that the following is manufacturer's shop test data used for design specification, and does not represent actual system design performance. This test data is not to be used for accident analysis):

Normal operation: 108,000 ft^3/min at 6 inches wg total pressure, 0.071 lb/ft^3 gas density (124 bhp, 3820 feet per minute outlet velocity)

Emergency operation: 54,000 ft^3/min at 4.4 inches wg total pressure (46 bhp, 1910 feet per minute outlet velocity)

The weight of the fan is carried on a welded framework which is mounted on four vibration isolators. These isolators make use of steel springs to carry the vertical (gravitational) load, and rubber pads to dampen horizontal excursions. Vibra-switches are mounted on the motor casings to sense out of balance conditions and transmit a signal outside the fan assembly.

Each fan is equipped with a discharge cone bolting to the fan door assembly. An inlet bell is mounted on the upstream end of the fan. A protective screen covers the open end of this bell. The casing for the fan is split to allow convenient disassembly.

The fan motor assembly underwent extensive runs under simulated hypothetical accident conditions as described below. The motor had been subjected to the special tests listed under Subsection 3.5.2 prior to undergoing the following test. These tests were carried out in a recirculatory pressure vessel system, as shown on Figure 6A-5.

The following tests were run in this duct:

a. Fan operation for 4 1/2 hour done in accordance with test cycles as contained in IEEE Proposed Guide to Qualification Tests for Class 1E Motors Installed Within the Containment of Nuclear Fueled Generating Stations, June, 1969. This test was conducted at approximately 75 psig, 280F ambient steam air mixture, with continuous spraying by a solution containing:

Sodium hydroxide	-	0.1 percent by weight
Sodium thiosulfate	-	1.0 percent by weight
Potassium hydroxide	-	(9×10^{-4}) percent by weight (= 4.5 ppm)
Boric Acid	-	3.4 percent by weight

b. Test of motor insulation resistance, using "Megger" insulation tester.

c. Repeat of Items a. and b., 4 additional cycles.

d. Seven days operation at 20 psig, with continuous spraying with the solution used in test a.

e. Meggering, disassembly, and inspection of the fan motor unit.

Inspection revealed that approximately 1 1/2 pints of water had reached the interior of the motor, but this did not cause a malfunction. The only apparent physical effects were to the surface coatings of the motor, fan housings, and fan blades; these were minor.

Following disassembly, motor and fan were completely reworked, with only mechanical parts (not electrical) being reused. Bearings and seals were also replaced.

3.5.2 MOTORS

Motors are totally enclosed, two-speed (600/1200 rpm) units, 75/150-hp, 460-V, 60-Hz, 3 phase squirrel cage induction motors, water cooled, General Electric type GEM-1000A. The motor stator is of double shell construction, with water circulating in a helical pattern around the diameter. The water circulation enclosure is bolted to the stator frame and sealed by 0-rings. Bearings are grease lubricated, using a special thermal and radiation resistant grease. Grease inlets and purgers are carried to the outside of the fan enclosure. The fan drive end has a roller bearing, the opposite end a ball bearing designed to take thrust loadings. Both bearings have calculated lives in excess of 100,000 hours.

The drive end bearing is protected by a shaft seal. This is a combination of a labyrinth type seal with a rotating bronze disk. The bronze disk acts to prevent the entry of large droplets of liquid. A series of restricted passages in the labyrinth seal resists the entry of other moisture. There is no physical contact between the rotating parts and the stationary parts of the seal.

Motor terminal connectors are ceramic insulated bushings. The following accessories are mounted in the motor stator housing:

Temperature Detector: Thermocouple, (copper constantan) mounted on motor stator end winding at top centerline opposite fan end.

Space Heater: 150 W, 117 V, GE Calrod type, to maintain internal temperature of motor slightly above ambient during motor shutdown periods.

Vibration Detector: Robertshaw Vibraswitch 366AWT-115 0-4.5 g acceleration trip point, factory set; feeds 117 V indicator.

Terminals and pipe conduits are provided for these accessories independent of the motor windings terminals.

Motor insulation is Class H, and has been demonstrated in prior documented testing, to have the ability to retain satisfactory insulating properties after radiation dosages of 10^{10} rads. Turn insulation is quadruple coated aromatic polymide; for ground insulation, coils are wrapped with mica-glass tape, dipped in silicone varnish, and baked. Connections are also mica-glass tape wrapped. Wedge and filler insulation is silicone-glass staple cloth. Coil ties are continuous filament glass fiber cord, silicone resin impregnated. The finished stator is multiple dipped in silicone varnish and baked after each dip.

The motor components have been individually tested as follows:

a. Insulation was tested for breakdown resistivity and power factor following approximately 10^{10} rads exposure.

b. Mica-glass tape was tested for abrasion resistance following combined temperature radiation exposure.

c. Resins were evaluated for gas release under radiation.

d. The shaft seals were tested for a cycle simulating LOCA conditions of pressure to be expected in the Reactor Containment Building. Temperature and radiation were not included as part of the testing as these would have very little, if any, effect upon the

bronze and steel used in the construction of the seal. Spray was not included in the testing since it has been determined that the chemicals in the containment spray would have minimal effects on the motor internal materials.

e. Grease was tested to 250F under MIL-G-7711A and MIL-G-18790A, and to approximately 10^8 rads.

In the above tests, no loss of function occurred.

The assembled motor was given the following standard tests:

a. Air gap

b. Insulation resistance (megger)

c. Resistance

d. No load current and power

e. Single-phase impedance

f. Open rotor bars

g. Starting volts

h. No load speed

i. Vibration

j. Short time overvoltage

k. End play, magnetic center, and end thrust

l. Lubrication leaks

m. Bearing run

n. Shaft volts

o. Phase rotation

p. Reed resonance

q. Runout and rotor displacement

r. Voltage ratio

s. High potential

In addition, the following special tests were made on the motor:

a. An aging test, simulating 40 years of use (245C for 100 hr). The motor was disassembled following this test and checked for electrical leakage and coil resistance. It was then reassembled and restarted.

b. After aging test "a.," the motor was subjected to vibration tests on a vibration table, including five 200-Hz resonance checks on two axes.

c. After test "b.," the motor was disassembled and carefully inspected.

In no case was there damage to the motor which would appear to make it fail the design requirements.

4.0 REFERENCES

1. "Structural Engineering System Solver (STRESS) for the IBM 1130, Model 2B (1130-EC-03X) Version 2, User's Manual," (H20-0340-2), Third Edition, 1967.

2. Letter from R. D. Rivers - AAF Manager of Research (3 pages), dated 7 December 1970 - Subject: Predicted Performance of AAF M-154 Moisture Separator Pad Used In Three Mile Island No. 1 Plant. (FSAR, Appendix 6A, Attachment 1)

3. Letter from B. Starr - AAF Product Engineer (1 page), dated December 3, 1970 Project No. 25-1300. (FSAR, Appendix 6A, Attachment 2)

4. Letter from J. York - AAF Senior Product Engineer (1 page), dated December 2, 1970 Project No. 25-1300. (FSAR, Appendix 6A, Attachment 3)

5. Moisture Separator Study, NYO-3250-6 by Richard D. Rivers and John Trinkle AEC Contract No. AT (30-1)-3250, June 1966.

6. Application of Particle-Size Analysis Data for the Determination of Air/Cleaner Performance, Lawrence J. Czerwonka and Jack M. Carey, ASME 65-CTP-6.

7. ECR 10-00307, Replace AH-E-1C Normal Cooling Coil East Bank

8. ECR 12-00166, Replace AH-E-1A Normal Cooling Coil West Bank

9. ECR 14-00469, Replace AH-E-1B Normal Cooling Coil East Bank