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ENRICO FERMI ATOMIC POWER PLANT UNIT NO. 2 EVALUATION OF CONTAINMENT COATINGS

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THE DETROIT EDISON COMPANY
FERMI 2 NUCLEAR POWER PLANT

EVALUATION OF
CONTAINMENT COATINGS
FOR FERMI 2

REPORT NO. DECO-12-2191
REVISION 2

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1.0 INTRODUCTION

An evaluation of the Fermi 2 primary containment coatings was performed in response to comments expressed by the Nuclear Regulatory Commission and Duke Power Company as part of its Construction Assessment Inspection at Fermi 2 in June 1984. The comments raised primarily pertained to the repair and touch-up of damaged coatings, the amount of unqualified coatings and assessment of uncoated surfaces. It was further implied that failure of certain coatings could lead to degraded plant performance in accident conditions.

In response to these comments, Fermi 2 Engineering initiated a review of primary containment coating types and qualifications. This review encompassed the following subjects:

- . An analysis of the specific coating substances used for containment surfaces and components, and the rationale for their use
- . Original design and current regulatory standards for application and testing of coatings
- . Definition of qualified, safety-related coatings
- . Proper application of non-qualified coatings
- . Confirmation of test results

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- . Detailed as-built survey and inspection of primary containment coatings and determination of coating parameters and quantities
- . Analysis of failure modes of unqualified coatings and evaluation of safety concerns
- . Transport of coating debris and potential effects on plant systems performance
- . Additional test, surveillance and inspection programs to be implemented by Detroit Edison
- . Application of new coatings before and after fuel load

This evaluation determined that the applied containment coatings do not in any way degrade or affect the safe operation of the plant under normal or accident conditions.

The Fermi 2 FSAR and the coating specification will be appropriately revised to reflect the conclusions and as-built conditions discussed herein.

2.0 CONTAINMENT COATINGS

2.1 Drywell Interior

The original containment specification issued in 1969 included a requirement for coating of the interior

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pressure boundary surfaces in the drywell, with the primary objective being long-term corrosion protection. The industry standard at that time was to apply Carbo-Zinc 11 as manufactured by the Carboline Company in accordance with the manufacturer's recommendations. This type of coating has been successfully applied to most operating BWR's, and has stood up well over the years, even under a variety of adverse conditions. Most of the CZ-11 coating was originally applied to the Fermi 2 surfaces before the issuance of Regulatory Guide 1.54 and ANSI N101.4. However, the Fermi 2 QA Level 1 criteria was applied in the absence of definitive coating criteria.

2.2 Concrete Surfaces

Following erection, pressure testing and coating of the containment drywell, the drywell floor and RPV pedestal were poured to accept the reactor vessel. Erection of the sacrificial shield and drywell primary steel structures followed. The concrete surfaces of the drywell floor, and the exterior and interior of the pedestal, were coated with an Ameron Nu-clad surfacer 110AA and a finish coat of Ameron polyamide epoxy 66. This coating was applied in accordance with ANSI N101.4, and met the pull test requirements (200 psi) per ANSI 5.12, Section 6.2. Required DBA testing was conducted for these coating materials. The prime objective of the concrete coatings is to effectively seal the porous surfaces, to inhibit intrusion of

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radioactive contaminants and to facilitate easy washdown and decontamination if required.

2.3 Structural Steel

The primary structural steel within the drywell and the exterior steel surface of the sacrificial shield were coated with Carbo-Zinc 11. Surface preparation of these surfaces included blasting or hand power tooling to near-white metal. The purpose of the CZ-11 coating is to provide long-term protection against excessive corrosion and rusting, and to facilitate easy decontamination if required.

As a result of the new Mark 1 Program containment LOCA loads, new Safety Relief Valve discharge loads, and a general containment steel load reevaluation, substantial modifications were required to be implemented in two different phases. The two different time periods resulted in varying degrees of steel surface preparations. Approximately 250 tons of structural steel were added by means of welding to the existing structures. Welding and NDE operations required removal of the existing CZ-11 coating at the tie-in and welded connections. Due to the increased complexity of component placement and shrinking work space, as well as completed installation of much of the mechanical equipment, sandblasting and painting became more and more impractical and time consuming, affecting construction and preoperational testing progress. Therefore, coating of new structural steel and recoating of

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modified steel components was not routinely completed. The mill scale present on the uncoated and unblasted surfaces of the steel members is discussed in the debris evaluation within Section 6.0 of this report.

2.4 Suppression Chamber

The entire interior of the suppression chamber, including the vent system, ring girders, structures, mono-rail, piping and supports, is coated with Plasite 7155 manufactured by Wisconsin Protective Coating Company. The coating system is considered safety-related, QA Level 1, and was applied in accordance with Regulatory Guide 1.54 and ANSI N101.4. Some small areas (on the order of 1 inch²) which were subject to mechanical damage, newly-installed vacuum breaker flanges, and two RHR orifice flanges require repair and touch-up. In bays 15 and 16, the Plasite 7155 has been removed in 1 x 2 inch spots to facilitate installation of test instrumentation and strain gauges for the scheduled SRV test. These areas are to be repaired during the first refueling outage, when the instrumentation is removed.

3.0 EQUIPMENT COATINGS

3.1 Galvanized Surfaces

The drywell cooling system ducting and dampers are completely galvanized without any further coatings. At welded joints, the galvanized surface was ground off to clean metal, and in some locations these ground areas were touched up with Galvanox V, a zinc-rich coating

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similar in properties to CZ-11. In addition, all electrical conduit, terminal boxes, cable trays and supporting unistruts are galvanized. The only exceptions are some large flexible conduits made of stainless steel.

3.2 Hangers and Supports

Hanger and support components, including clamps, rods, spring cans, snubber attachments, pipe whip restraint components and secondary support steel, were originally coated with CZ-11. Significant changes in the hanger and support design resulted in the addition of secondary support steel and change-out of hanger components and welding of attachments. Coating repair and touch up of these areas is scheduled to be accomplished as time permits, to facilitate decontamination and provide long term corrosion protection.

3.3 Piping

Most of the piping within the drywell is insulated with reflective metallic insulation panels (Mirror Insulation), consisting of removable sections having an outer cover of stainless steel. No fibrous insulation has been used within the containment. Normally cold fluid system piping is not insulated or coated. The uninsulated carbon steel piping was shop coated with a protective varnish. Tight mill scale and some rust is apparent on the piping surfaces. The varnish and mill scale are considered unqualified coatings for the

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purpose of this evaluation and per Standard Review Plan 6.1.2. The design of the piping pressure boundary included a corrosion allowance of 0.125".

3.4 Miscellaneous Coatings

As part of a detailed coating survey within the containment, miscellaneous unidentified coatings were surveyed. These coatings consist largely of manufacturers' shop coatings and primers such as red lead, aluminum base, enamels, polymer and phenolic paints and yellow safety paint. These coatings are present on valve bodies, yokes and bonnets, motor and air operators, handwheels, handrails, electric motors, etc. Another category consists of identification marking and banding of electrical conduit, terminal boxes and trays. Only very small quantities of these coatings are present as shown on Table 1.

4.0 COATING SURVEY

A detailed coating survey was conducted of all surfaces within the primary containment, to assess type of coating, surface areas, and dry film thickness (DFT). This data was used to calculate total quantities of qualified and unqualified coatings. The results of this survey are summarized in Table 1.

5.0 COATING QUALIFICATIONS

The Plasite 7155 and Ameron 66 coatings have been applied in full compliance with the provisions of

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TABLE 1

SUMMARY OF PRIMARY CONTAINMENT COATINGS

<u>Type of Coating</u>	<u>Qual. Coatings</u>	<u>Average DFT* (mils)</u>	<u>Total Surface (ft²)</u>	<u>Approx. Dry Film Density (#/ft³)</u>	<u>Total Volume (ft³)</u>	<u>Total Mass (lbs)</u>
Carbo-Zinc 11	No	7	125,000	217	73	15,841
Plasite 7155	Yes	12	67,000	150	66.9	10,035
Ameron 66 and Surfacer	Yes	1/16" plus 10 mills	7,380	125	44.6	5,575
Galvanox V	No	5	775	202	0.36	73
Mill Scale and Varnish	No	3.4	89,000	350	25.22	8,827
Unqualified Paints	No	0.7 to 6.1	1,782	90 to 150	0.48	72

* DFT (Dry Film Thickness) measurements were taken with a Positector 2000 gauge, Serial #30531, calibrated with NBS shims #22272.

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Regulatory Guide 1.54 and ANSI N101.4 (1972). Pull tests have been performed in accordance with ANSI 5.12, Section 6.2 on the original coatings and the repaired areas. DBA testing was performed by the paint manufacturers as required under ANSI N5.9 and ANSI N101.2. These coatings are therefore considered fully qualified per the regulatory criteria of Standard Review Plan 6.1.2.

The Carbo-Zinc 11 coatings applied to the containment surfaces have also been subjected to extensive DBA testing for a variety of application techniques, and were found to be acceptable for use in BWR environments under LOCA conditions. The test results are contained in Report No. 56878 issued by the Carboline Company (Reference 1).

As discussed earlier, most of the CZ-11 on the containment pressure boundary was applied prior to the issuance of R.G.1.54 and ANSI N101.4. Even though a specific effort was made to document the CZ-11 application in accordance with the Fermi 2 QA Manual, a current inspection of the existing documentation reveals deficiencies when gauged against current criteria. These deficiencies in documentation, however, do not adversely affect the primary function of corrosion protection. The coatings have already successfully withstood more than 10 years of construction environment, wear and tear, and have undergone a substantial degree of thermal cycling, from

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direct summer sun exposure to near freezing winter conditions, without deleterious effects. For the purpose of this assessment, however, the CZ-11 coatings are evaluated as unqualified coatings.

Those containment surface areas which are severely damaged or worn (visible bare metal) are repaired by touch up, to ensure the continued long-term function of corrosion protection for the pressure boundary and to facilitate potential decontamination. The consequences of failures are evaluated in Section 8.0 of this report. These coatings are maintained under the Fermi 2 QA Level 1 criteria, to assure the long-term corrosion protection for the pressure boundary.

The remaining coatings listed in Table 1 are Galvanox V, Unqualified Paints, Mill Scale and Varnish. All of these coatings are non safety-related, and are considered unqualified by the definition of SRP-6.1.2-III. They are assumed to form solid debris under LOCA conditions for the purpose of this evaluation, though complete failure is not expected.

6.0 FAILURE MODES OF UNQUALIFIED COATINGS

Containment coatings are postulated to fail in one of two modes under extreme environmental conditions. Metallic type coatings, such as CZ-11, Galvanox V and aluminum based paints, without any top coating, have low tensile strength and are very brittle, such that any sizable flakes, separating from surfaces due to

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lack of proper adhesion, crumble into small particles. This failure mode has been identified as the most likely by the 4 largest manufacturers of inorganic type zinc coatings (Mobile, Ameron, Carboline and Napko). When directly impinged by steam or water, these coatings separate from the surface in small particles as a result of the scouring action.

Phenolic and polymer based paints when applied in thicknesses of approximately 3 mils and over are likely to separate from the surfaces in the form of peels, blisters, and flakes as a result of chemical breakdown and extreme temperature exposure.

Coatings of less than 3 mils generally are too thin to sustain the strain of peeling or blistering and the adhesion force, and are likely to separate in or disintegrate into small particles.

For the purpose of this evaluation and in estimating the total quantities of paint debris, 100% failure of all the unqualified coatings was conservatively assumed.

The DBA test report No. 56878 issued by Carboline (Reference 1) demonstrated that Carbo-Zinc 11 is not lost in flakes, but rather in particles of a size less than 20 microns. The report further states that the particles do not dissolve in water and do not clog screens. The density of CZ-11 dry film coatings is

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between 3 to 4 times that of water, and particles are expected to settle to the bottom of the drywell and the suppression pool, concentrating as sludge in low velocity areas. The particle separation mode is a result of continuous scouring action of steam and water spray as simulated in DBA testing programs. In a typical BWR containment, direct scouring occurs only in the immediate vicinity of the postulated pipe break and within a few feet of the containment spray headers (if used). The total affected surface area due to steam and water scouring is less than 10% of the CZ-11 coated areas. Temperature resistance of CZ-11 up to 750°F is considered excellent by the manufacturer, as described in Reference 2.

The failure mode for Galvanox V is considered similar to that of CZ-11, based on the physical properties provided by the manufacturer (Reference 3). However, no detailed test data exist to quantify the rate of deterioration. The tensile strength of Galvanox V dry film coating is such that if flaking occurs, the flakes will break up into small particles within a turbulent fluid or when subjected to gravity impact. The resulting debris can be classified as solid hydroxide as defined in NUREG-0897, Reference 4, in respect to ECCS pump and strainer performance.

Very small quantities of unqualified miscellaneous paints within the drywell are assumed to fail under LOCA conditions. In the absence of substantiating test

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subjected to 6 hours of steam atmosphere at 340°F, followed by 40 hours at 250°F. Mill scale did not separate, removal of rust was observed on the surfaces. Particles found in the container were in the form of sludge and water discoloration. Based on these results, it is postulated that some of the mill scale will spall off during postulated LOCA conditions. The density of mill scale is approximately 350 lbs/cu ft, and the scale is expected to settle in the drywell bottom and suppression pool as a sludge. The sludge is classified as hydroxide as defined in NUREG-0897.

Temperature resistance tests were also conducted for the varnish present on uncoated, uninsulated steel piping. Specimens were baked at 340°F in a dry oven, and the varnish was observed to soften but did not run or separate from the surfaces. No other deterioration was identified.

7.0 SAFETY EVALUATION OF COATINGS

The application of primary containment coatings has inherent positive and negative aspects. As discussed earlier, the desired positive qualities of long-term corrosion protection and decontamination must be balanced with the potential negative aspects of hydrogen evolution and debris generation during or following a postulated LOCA. This section, therefore, individually examines these aspects to assure that the applied coatings will not degrade or affect the safe operation of the plant.

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data, these paints are assumed to fail in the form of flaking and peeling. The resulting debris is considered similar in behavior to fibrous insulation material with a near neutral buoyancy. The detailed coating survey determined DFT (Dry Film Thickness) measurements between 0.7 and 6.1 mils, with 70% of the coatings less than 3 mils. A DFT of less than 3 mils is not expected to result in flaking or peeling, and the coating will disintegrate into small particles as discussed previously. Therefore, these assumptions are considered conservative.

Even though not considered a coating under standard definition, the mill scale present on some uncoated carbon steel surfaces was included in this evaluation. Mill scale exists on uncoated structural steel and on uncoated, uninsulated carbon steel piping. The piping has a thin varnish applied over the mill scale. To determine the failure mode under LOCA conditions, short-term simulation tests were conducted by the Engineering Research Department of Detroit Edison. These tests concluded that the mill scale remained adherent to the steel in a hot (210°F) dry nitrogen atmosphere. In a distilled water immersion test in a nitrogen environment, the mill scale spalled off within 72 hours at 210°F. The mill scale particles ranged in size from 4 to 60 microns and settled on the bottom of the test container. In addition, a LOCA simulation test was conducted, simulating the BWR LOCA conditions for an SBA event. The mill scale specimen was

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7.1 Corrosion Protection

Under normal operation, the Fermi 2 containment is nitrogen inerted and maintained at an operating temperature between 135 and 150°F. The drywell cooling system continuously removes excess moisture from the environment to maintain a dew point near the EECW/RBCCW water temperature (approximately 95°F). The drywell atmosphere is therefore substantially below saturation. Short-term, substantial corrosion during normal operation is therefore not expected, nor has it been observed in operating BWR's. The existing CZ-11 coating on the pressure boundary, together with repair and touch up coating, will adequately protect the containment from corrosion. Long-term effects, if any, will be monitored via visual inspections during refueling outages, and will be repaired in those areas where rusting or discoloration is apparent. Deterioration of the CZ-11 coating is anticipated during a postulated LOCA. Following the LOCA and containment depressurization, the onset of corrosion can be expected and will progress over time at a predictable rate. In the absence of significant concentrations (>25%) of acids and chlorides in the containment following a LOCA, a maximum corrosion rate of 0.02 to 0.05 inch per year is given in the literature, Reference 5. With a minimum shell thickness of 0.75 inch, containment integrity and leak tightness can be assured for years following the LOCA.

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7.2 Decontamination

The coatings within the containment also serve as a surface sealer to prevent contaminated fluids and particles from penetrating into porous materials and crevices. Washdown and other physical decontamination methods are made more effective and less time consuming, thereby promoting ALARA personnel exposure considerations. Decontamination itself is not considered a safety-related activity, but more specifically a normal plant maintenance item. It is an objective of Fermi 2 Nuclear Production to coat interior containment surfaces and maintain these coatings during the life of the plant for economic and ALARA reasons.

7.3 Hydrogen Evolution

The evolution of hydrogen from the corrosion of aluminum, zinc and zinc-base paints has been previously assessed in the Fermi 2 FSAR Section 6.2.5.3.1. The two hydrogen recombiner systems have been adequately sized to comply with the provisions of Regulatory Guide 1.7.

8.0 EFFECTS OF COATING DEBRIS

To evaluate the effects of coating debris generated by the postulated failure of unqualified coatings, both solid hydroxide type and fibrous debris (paint peels) are assessed separately in respect to their transport mechanisms and affect on ECCS performance. The

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assumptions used are extremely conservative for the purpose of this analysis.

8.1 Debris Transport

The debris generated from the failure of unqualified coatings and mill scale during and following a LOCA will be transported to the suppression pool by the flow of water, steam and noncondensable gases from the drywell. After initial surface separation, the coating particles will tumble to the drywell floor or other horizontal intervening surfaces by gravity. Pipe break flow or containment sprays will then flush most of the debris through the vent system into the suppression pool. High vent system flow velocities occur only during the initial 20 to 40 seconds following the DBA-LOCA while the reactor vessel depressurizes.

Coating debris which remains in the drywell after this initial transient can be transported to the pool by the ECCS flow or containment spray flow. Drywell floor and vent line/header flow velocities are very low and subject to gravity flow only. A pool of approximately 2 feet depth will develop on the drywell floor before excess water spills over to the vent lines into the vent system. Debris particles with densities significantly higher than water (such as CZ-11 and mill scale) will settle out in the drywell floor bottom. Particles which are swept over into the vent system will flow through the vent header and exit the downcomers near the center of the torus.

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Average water velocities within the torus following the initial transient are below 0.25 ft/sec, but approach 0.5 ft/sec within a 6 foot hemisphere of the largest suction strainers at maximum RHR pump capacity. Refer to Figure 1 for the dimension and arrangement within the torus. The maximum surface velocity at the strainer surface was calculated to be 2.5 ft/sec. The strainer intakes are located 9'-8" from the center of the torus and 5'-9" above dead bottom. For these pool velocities hydroxide type particles are therefore not postulated to reach the strainers in a realistic situation.

Unqualified paints that fail in a peeling or flaking mode are expected to float on the pool surface or remain suspended in water, where they could ultimately migrate toward the ECCS suction strainers.

8.2 ECCS Performance

To conservatively evaluate the postulated performance of plant systems and equipment, it was assumed that the hydroxide type debris, consisting of CZ-11 and mill scale particles, are completely suspended in the pool water during the early turbulent phase of the LOCA. Under this assumption, the total hydroxide particle concentration in the pool is calculated to be less than 0.35%. A more realistic assumption, using a 10% fraction of the debris as discussed in Section 6.0 would produce a hydroxide debris concentration of 0.035% in the pool water. In accordance with the conclusions and guidelines given in NUREG-0897, Section

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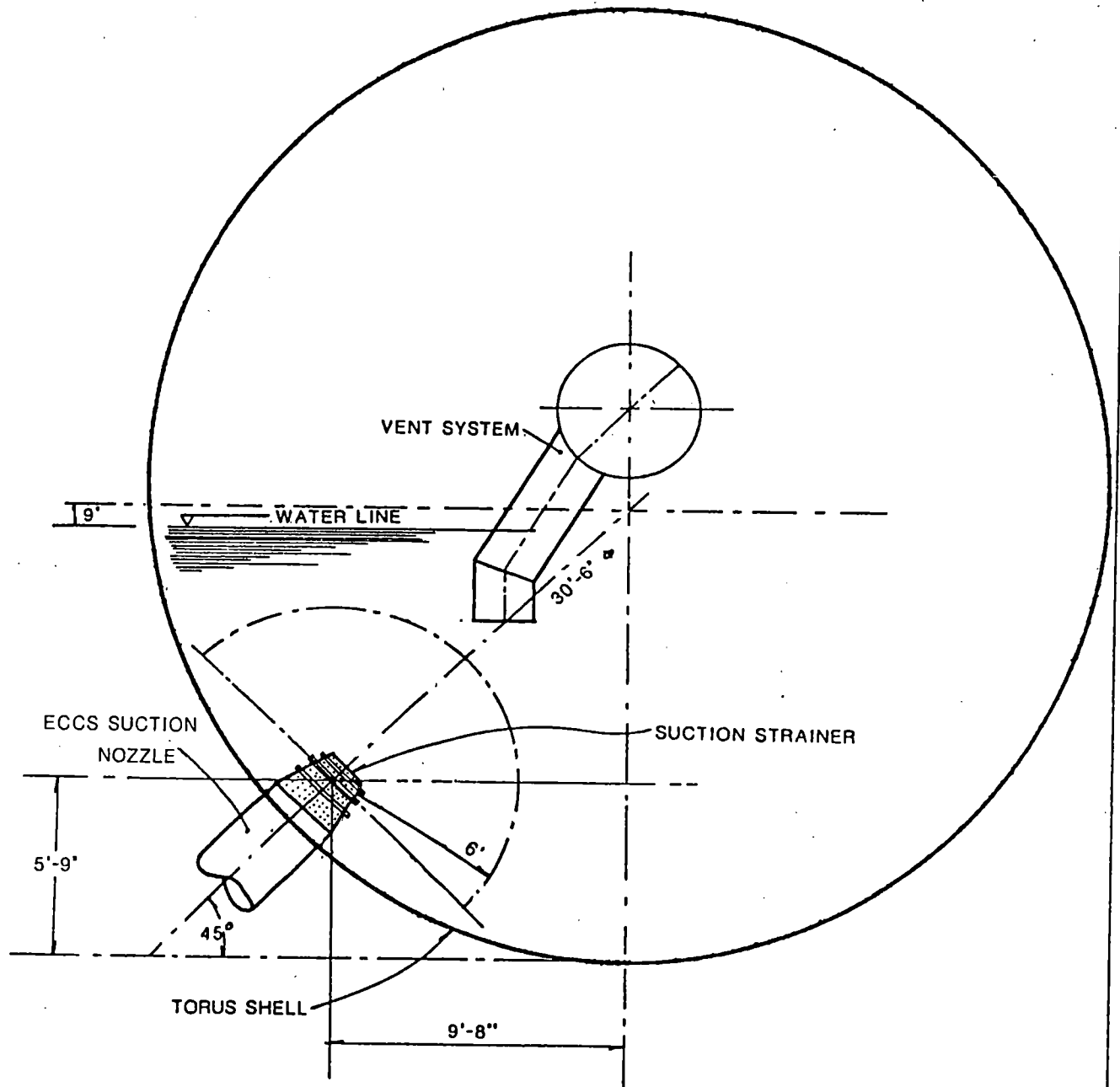
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ECCS SUCTION STRAINER LOCATION

FIGURE 1

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3.2.2.4, a solid hydroxide concentration of less than 1% of mass does not affect pump performance. The solid particles are less than 60 microns in size, and will therefore freely pass through the 1/8" holes in the suction strainers of the RHR, Core Spray and HPCI lines.

The fibrous debris, generated by failure of unqualified paints, is also transported to and distributed in the pool water volume. The total volume of 0.5 cu ft (72 pounds), as shown on Table 1, results in a volumetric concentration of $4.1 \times 10^{-4}\%$, well below the acceptable limits of 4% given in NUREG-0897 for fibrous debris. In addition, the ECCS pumps and system piping has been designed for a worst case assumption of 50% strainer blockage for the Design Basis Accident.

8.3 Containment Sprays

The Fermi 2 containment spray headers are equipped with a 1-1/2-7G25 fog nozzle as manufactured by Spraying Systems Company. The fog nozzle has a fleet passage of 0.125" which is of equal size to the ECCS strainer passage.

Solid particles which pass through the strainer are therefore expected to also pass through the fog nozzle, and no clogging or performance degradation occurs.

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The plant design basis does not require containment spray operation. This function, however, is desirable to mitigate the consequences of a LOCA.

8.4 RPV Core Spray and Feedwater Spargers

ECCS flow is injected into the reactor vessel directly via the RHR and Recirculation System piping and/or Core Spray piping. No intervening obstructions are located in the RHR flow path. Core spray flow is injected via the core spray spargers located directly above the fuel. The minimum flow passage through the sparger is more than 0.5 inch, which is larger than the strainer flow passage. Similarly, HPCI and RCIC flow is injected into the vessel via the feedwater system piping and spargers. The minimum flow passage in the feedwater spargers is more than 0.5 inch, and no flow blockage or performance degradation will occur.

The recirculation pumps are equipped with a demineralized water seal purge system, thereby preventing particle intrusion into the pump seal and bearing assembly.

8.5 Normal Operations

During normal plant operations, and as a result of operational vibrations, some coating and mill scale debris is expected to be generated. In the absence of any fluid flow between the drywell and torus, the particles will accumulate on the drywell floor and other horizontal surfaces. Some airborne particles may

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be transported via the vent system into the torus during purging and inerting operations, where they will settle to the bottom. The Torus Water Management System (TWMS) is designed to continuously process torus water through a demineralizer system to maintain water quality and to prevent gradual build-up of particles, contamination and sludge. The TWMS takes suction from the bottom of the torus. Normal operations, including ECCS testing, is therefore not impaired.

9.0 ADDITIONAL CONSIDERATIONS

9.1 Surveillance and Inspection

Following completion of the repair and touch-up of the qualified coatings and the CZ-11 coating on the containment pressure boundary, a thorough visual inspection will be conducted by Detroit Edison Nuclear Quality Assurance. After commercial operation is achieved, these same surfaces will be visually inspected during refueling outages to determine onset of corrosion, blistering or peeling, and coating discoloration. The extent of these inspections will be commensurate with the number of affected areas found. Suspect areas will be cleaned, including manufacturers' recommended surface preparations, and new coatings will be applied in accordance with the original application criteria.

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9.2 Additional New Coatings

As discussed earlier in this report, uncoated carbon steel surfaces will be coated as much as practical to reduce corrosion and facilitate decontamination. Surfaces will be prepared with hand power tool cleaning, and CZ-11 coatings will be applied in accordance with manufacturers' recommendations. These coatings will be applied on a schedule not interfering with the critical path. As time permits, coating activities will continue during refueling outages, when the containment is accessible.

10.0 CONCLUSION

After detailed evaluation of the coating qualities, quantities and potential failure modes, it is concluded that the Fermi 2 coatings currently applied within the primary containment do not adversely affect the safety of the plant, and will not impair normal or abnormal operation. The coatings are therefore classified as follows:

- Suppression Pool - Plasite 7155, qualified and safety related
- Drywell - Carbo-Zinc 11, unqualified, safety related, see Section 5.0, page 10
- Concrete Surfaces - Ameron 66, qualified and safety related
- Structural Steel - Carbo-Zinc 11, unqualified, not safety related*

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- Mill scale, unqualified, not safety related*
- Ducting - Galvanox V, unqualified, not safety related
- Carbon Steel Pipe - Mill scale/varnish, unqualified, not safety related*
- Misc. Coatings - Various enamel unqualified, not safety related*

* Surfaces to be coated and/or repaired per manufacturers' recommendations as time permits.

The Fermi 2 FSAR and applicable specifications will be revised to reflect the conclusions of this assessment.

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11.0 REFERENCES

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Bulletin No. 29 of June 1979, Galvanox Type V
4. NUREG-0897, Revision 1 Draft, USNRC, "Containment
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5. Perry's Chemical Engineers Handbook, Table 23-3,
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