UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION III
799 ROOSEVELT ROAD
GLEN ELLYN, ILLINOIS 60137

December 7, 1983

MEMORANDUM FOR: John W. Clark, Chief
Management Analysis Branch, Office of Resource Management

FROM: W. S. Little, Chief
Engineering Division, Branch 2 - Region III

SUBJECT: 10 CFR 50.55(e) ITEM REGARDING MIDLAND CONTAINMENT PROTECTIVE COATING DEFICIENCY

This is to express our appreciation of the technical assistance which Messrs. L. Abramson and D. Lurie of your staff provided to Region III.

Their assistance was instrumental in our assessment of Consumer Power Company's statistical methodology relative to the testing of potentially defective protective coatings.

Again, thank you for your assistance in this matter.

W. S. Little, Chief
Engineering Division, Branch 2

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Who did this work?
Condry
Williams
Horton
Gardeman
Hopkins

Consumers Power Company

James W Cook
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December 17, 1982

79-12 #11

Mr J G Keppler, Regional Administrator
US Nuclear Regulatory Commission
Region III
799 Roosevelt Road
Glen Ellyn, IL 60137

MIDLAND NUCLEAR COGENERATION PLANT
DOCKET NOS 50-329 AND 50-330
CONTAINMENT INTERNAL STRUCTURES COATING DEFICIENCY
FILE: 0.4.9.37 SERIAL: 20649

References: 1) J W Cook letter to J G Keppler, same subject, dated October 30, 1981, Serial 14598

2) NRC Inspection Report No 50-329/82-10 and 50-330/82-10, dated July 28, 1982

Reference 1 was our final 50.55(e) report on the containment internal structures coating deficiency. During the NRC site visit to close out this item (see Reference 2), it was determined that supplementary information was required to be developed to allow the NRC final closure. The attachment to this letter is a supplementary final report and provides the information that was necessary.

James W. Cook

JWC/WRB/lr

Attachment: MCAR 35, Revised Final Report Revision 2, dated November 10, 1982

CC: Document Control Desk, NRC
Washington, DC

RJCook, NRC Resident Inspector
Midland Nuclear Plant

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Attachment to
Serial 20649
79-12 #11

Bechtel Associates Professional Corporation

Management Corrective Action Report (MCAR)

SUBJECT: MCAR 35 (issued 11/13/79)
Containment Internal Concrete Structures Coating

FINAL REPORT REVISION 2

DATE: November 10, 1982

PROJECT: Consumers Power Company Midland Plant Units 1 and 2 Bechtel Job 7220

1.0 INTRODUCTION

During a planned coating inspection in November 1979, a Consumers Power Company engineer noted that there was a loss of adhesion between multiple coats of a decontaminable surfacing system used on concrete walls. The coating system was specified as System 9 in Specification 7220-A-15(Q), Technical Specification for Subcontract for Epoxy or Phenolic Decontaminable Surfacer for the Midland Plant Units 1 and 2, Consumers Power Company, Midland, Michigan. J.L. Manta, Inc, was the coatings subcontractor responsible for installing and inspecting decontaminable coatings included in the specification.

Nonconformance Report M-01-4-9-132 was written on November 8, 1979, requiring identification of the cause and extent of the nonconforming work. All concrete coated with System 9 was subject to testing. Inspection indicated that the loss of adhesion could be detected in the containments and other plant buildings. No apparent cause could be identified. The adhesion failure occurred between unspecified multiple coats of NuKlad 117(N), surfacer, resulting in disbondment of a final surfacing coat and the two finish coats. The first surfacer coat was firmly bonded to the concrete.

Preliminary analysis indicated that a potential safety problem existed. Should coatings be removed during a reactor accident that initiated the containment spray system, the failed coating from some areas might be carried to the sump and cause screen blockage. As a result of this analysis, MCAR 35 was written November 13, 1979. It was determined that the criteria contained in this MCAR were reportable under 10 CFR 50.55(e). This report incorporates or provides references to data furnished previously in MCAR 35, Interim and Final Reports, which were submitted in accordance with reporting requirements of 10 CFR 50.55(e).

It includes a description of corrective action that has been implemented to replace defective coating in containment Units 1 and 2. The reporting format follows the guidelines of Bechtel Engineering Department Procedure (EDP) 4.60, Rev 1, Section 2.0.

2.0 DESCRIPTION OF DEFICIENCY

Coating System 9 includes four application steps of a thin film surfacing system recommended by Ameron Protective Coatings Division. NuKlad 117(N) was first applied as required to fill voids 3/4 inch or less. A continuous surfacing coat was then applied to provide a pinhole-free surface using a rubber-faced trowel to spread and smooth the coating. Following a specified cure period, Amercoat 90 finish was applied at approximately 5 mils thickness. Pinholes were repaired with NuKlad 117(N) or Amercoat 90 before the final 5 mil coat of Amercoat 90 was applied.

Delamination occurred between two coats of NuKlad 117(N). Contrary to Ameron's data sheet (R3/78), which was incorporated in J.L. Manta's quality assurance manual, two complete coats had been applied. J.L. Manta confirmed that this practice was followed during most of the work and was permitted by Ameron in a revised data sheet (November 1978). However, this revised data sheet was never submitted for approval to Bechtel. Containment coating systems at Midland must be prequalified to Midland design basis accident criteria in accordance with Specification 7220-A-45. System 9 was prequalified as a single surfacing coat; requalification of multiple coats would be required before approval for use. This factor resulted in a potential nonconformance status of all System 9 coating that had been applied, and no further work was permitted in containment. From November 11, 1979, to November 30, 1979, random adhesion tests by knife verified that the delamination problem was significant enough to preclude a cause based on a unique set of circumstances, such as local contamination or poor mixing of components. A preliminary evaluation program was developed by J.L. Manta and Bechtel to systematically inspect all surfaces coated with System 9 to determine the extent of the failure. It was known at this time that all coating System 9 did not delaminate and that the problem was most severe on interior shield walls at the lower elevations of the Unit 2 containment.

When the coating deficiency was identified, the investigation was subdivided in the following manner:

a. Location of specific boundaries of sound and unsound coating System 9

b. Determination of the root cause of the delamination

c. Investigation of corrective procedures for removal and replacement of failed coating System 9 with an acceptable coating system

These requirements made it necessary to establish a schedule of evaluations in which each activity was assigned and completed independently. Preliminary investigations provided a basis for programmed work by Bechtel, Consumers Power Company and consultant laboratories. It required approximately 2 years to complete all investigations and perform analysis of tests and data. It was discovered that the cause of delamination was related to several factors, each of which could independently or collectively lead to coating failure.

3.0 SUMMARY OF INVESTIGATION AND HISTORICAL BACKGROUND

3.1 PRELIMINARY INVESTIGATION

3.1.1 Adhesive Properties of Epoxy Base Products - Generic

Each coating system specified for application to concrete surfaces is composed of one or more epoxy coating materials, each with a defined function within the composite coating system. When multiple coats are applied over each other, each coat must adhere to the previous coat. The first coat must bond to the cementicious substrate. Adhesive properties to the substrate and between coats are measurable by test. However, because the epoxy coating system strength exceeds the concrete tensile strength by an appreciable margin, it is unusual to have adhesive failure within the coating system. Failure analysis requires that the source of bond strength be examined. Generally, the adhesive strength of coatings is a result of the following factors:

a. Partial solubility and wetting of the previous coat

b. Mechanical interlocking to a porous or rough surface, or previous coat

c. Bonding due to polar or electrical attraction of molecular groups typical of each generic type of resin used in the coating vehicle

Epoxy base products can be designed to adhere by one or all of the above factors. Because no failure occurred at the substrate interface, it was apparent that the problem was related to wetting and proper bonding of a second coat of NuKlad 117(N) to a partially cured NuKlad 117(N) surface. A reliable bond can be obtained to a previous coat if the surface is uncontaminated. The degree of cure of the previous coat has a definite influence on maximum bond strength. NuKlad 117(N) is not recoatable following 1 week cure at 73F based on Ameron data. Furthermore, any surface condition resulting from contamination or exudate that may occur during cure of the first coat can partially or completely eliminate adhesion between coats.

The preliminary and programmed investigation was designed to methodically evaluate potential causes of reduced adhesion between multiple coats of NuKlad 117(N). It was known in the initial stages of the investigation that at least two coats of NuKlad 117(N) were applied contrary to the specification, but approved by Ameron. This constituted the as-built condition, and spot checks on adhesion verified that all coating work was not deficient. The principal concern was related to location of failed areas and, if possible, determining why certain areas failed and adjacent locations were acceptable.

3.2 EVALUATION OF INSTALLED COATING SYSTEM 9

3.2.1 Testing of Coating Failure -Knife Test Method

The identification of failed coating required that a method be selected or developed for evaluation of adhesion. Adhesion test methods available are described in ASTM procedures. Few of these methods are designated for field testing of thick films with high tensile strength. The elcometer method, using a bonded aluminum test dolly, appeared to be the most accurate method, but this method had some limitations in areas where access was restricted. By experimenting with knife tests, it was determined that 3-inch parallel cuts 1/4 inch apart (through the coating to the substrate) provided a reproducible method of determining disbondment. If the coating system delaminated, the cut area could be removed by separating layers of the coating using a knife as a probe. The coating could not be separated if adhesion was tight. In a trial area in the auxiliary building, a comparison with elcometer tests showed that the knife test failed corresponding with elcometer readings of 200 psi or less [minimum specified in ANSI N5.12(1974) for acceptable bond to concrete].

J.L. Manta prepared Test Procedure JLM 450-A-5 on the basis of these results, and this procedure was used for determination of pass/fail areas on subsequent testing.

3.2.2 Mapping - Extent of Coating Failure

Initially, it was important to determine the amount and location of failure, and if there was correlation between the failed area with documented application variables. A single unit of NuKlad 117(N) covers approximately 100 square feet at the recommended coverage rate of 5 to 10 mils dry film thickness. Material losses due to limited pot life after mix reduce the practical coverage to under 100 square feet/unit. A 100-square-foot-test area representing a single mix was therefore selected as the initial test area. Sketches were prepared to divide all concrete surfaces into 100 ft^2 grids. SKA-205 through SKA-216 were issued for Containment 2 tests. When Unit 2 testing was complete, SKA-217 to SKA-228 were similarly issued for Containment 1 tests.

Knife tests were performed at a site within the boundaries of each test grid and the test location was marked. This provided an assessment of the approximate percentage of failed area - 18% in

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Unit 2 and 6% in Unit 1. Although this test did not locate the extremities of coating failure, the number of tests and the test rationale provided a basis for planned corrective action. It appeared that there was sufficient sound coating to justify repair rather than complete removal and recoat. The total mapping program required several months to complete.

3.2.3 <u>Correlation of Application Variables with Failed Areas</u>

During Unit 2 mapping and testing, the daily documentation records for the initial application of System 9 were tabulated. This included the following:

a. Mapping of areas coated on each day for each coat of System 9, including two or more surfacer coats and two or more finish coats.

b. Batches of each coat used were plotted on the area covered daily by each batch.

c. Time between coats for each coat was identified (1 week, 1 to 3 weeks, over 3 weeks).

d. Temperature recorded for the surface during application was plotted.

3.2.4 When this data was superimposed over the pass/fail grids on sketches, it was possible to compare application variables with failed areas. Although no correlation was evident, certain deviations from specified requirements were noted.

a. Two full coats of NuKlad 117(N) were applied in most cases. In some instances, more than two coats were applied.

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b. Several areas were identified in which the time between coats exceeded manufacturer's recommendations.

c. In a few isolated areas, Amercoat 90 was "sandwiched" between coats of NuKlad 117(N).

d. In some cases documentation was incomplete or inaccurate. Relative humidity, although listed on forms used by J.L. Manta, was not recorded except for a few months after work commencement.

3.2.5 Preliminary Evaluation - Coating Removal

Methods available for removal of failed coating were limited because the problem was identified in the advanced stage of construction. Sandblasting was not practical because of potential damage to walls and adjacent installed equipment. Although water blast by high-pressure laser could remove the failed coating, it was not compatible with other construction activities. Minnesota Mining and Manufacturing (3M) produces an impact cleaning tool called a Roto Peen. Trial demonstrations using this equipment verified that delaminated System 9 was removed from a sound layer of NuKlad 117(N). If delamination did not occur, additional cleaning effort was required to remove the entire coating system. Generally, a fresh concrete surface was exposed. NuKlad 117(N) residue remained in pits and depressions. Corners and areas with limited access were cleaned to bare concrete using a needle gun.

The Roto Peen method was adopted for removal because it provided a clean delineation between delaminated areas. These areas generally occurred between steel embeds. This supported the conclusion that an application variable was responsible for delamination. The embed spacing provided a logical boundary to terminate application during vertical drops from upper to lower elevations, and was evidently used to assign work to the painters.

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All subsequent testing was performed by reapplication of coating systems to surfaces cleaned by Roto Peen. Final cleaning by sanding or Clean-N-Strip Wheels was required.

3.3 REVIEW OF SPECIFICATION 7220-A-15(Q) AND SUBCONTRACTOR QA PROGRAM AND PROCEDURES

3.3.1 Specification 7220-A-15(Q), Technical Specification for Subcontract for Epoxy or Phenolic Decontaminable Surfacer, was issued for bids on February 17, 1976. The initial work performed by Bagwell Coatings was limited to non-Q-listed work in the Units 1 and 2 auxiliary buildings. An Ameron coating identified as NuKlad 1871 was used in System 9. J.L. Manta was awarded the contract for all surfacing work not completed by Bagwell Coatings. J.L. Manta's quality assurance program and procedures were prepared on the basis of the products originally specified. The sub-contractor was also required to bid alternative surfacing systems of other manufacturers with products equivalent to Ameron systems. Based on evaluation of bids, the Carboline alternative bid by J.L. Manta was not accepted. Therefore, Ameron surfacing systems were used.

Shortly after application was started by J.L. Manta, a safety problem was identified in the Ameron surfacing systems. This required a change in the epoxy convertor used, and revised products were tested and approved at Oak Ridge National Laboratories (ORNL) using the new systems recommended by Ameron. The specification was revised to incorporate the product changes NuKlad 110AAB Green in Systems 7 and 8, and NuKlad 117(N) in System 9.

3.3.2 J.L. Manta Concrete Coatings Procedure JLM-450-A-1 was issued and attached to J.L. Manta's Quality Assurance Manual Job 7220, Midland Project, Subcontract 7220-A-15. Section 6.4.0 contains instructions for application of NuKlad 117(N) and requires sealing pinholes before topcoating by using either NuKlad 117(N) or Amercoat 90 depending on the size of the pinhole.

The quality assurance manual and procedures incorporates the specific revision of the manufacturers data sheets that apply to each individual type of coating; the manufacturer's instructions are mandatory.

3.3.3 Nonconformance Identification - Two Complete Coats of NuKlad 117(N)

a. A review of the documents listed in Sections 3.3.1 and 3.3.2 indicated that NuKlad 117(N) applied as two coats was nonconforming. Neither the specified manufacturers data sheet or J.L. Manta's procedures permitted two complete coats. The tested configuration and most recent revision of J.L. Manta's quality assurance program permitted one complete coat. In November 1978, Ameron issued a new data sheet on NuKlad 117(N) describing conditions under which two coats were permitted. This data sheet was never submitted to Bechtel for approval and incorporation, but was evidently used by J.L. Manta as a work-controlling document.

b. Other nonconformances are identified as follows:

   1) Failure to record all information required or complete all forms on JLM forms, which are copies of ANSI N101.4(1972) documentation. This includes records of relative humidity and dew point calculations on certain forms.

   2) Excessive time between coats was documented on daily application records (see Section 3.2.3).

3.3.4 Investigations by J.L. Manta and Ameron

Ameron Protective Coatings Division was requested by J.L. Manta to assist in evaluation of the problem. Ameron's participation included site visits by technical personnel and laboratory work at their Buffalo Laboratory. The correspondence and test reports are summarized below.

a. Ameron reported that a solvent odor could be detected in areas where no topcoat had been applied. This was apparent immediately following film separation. If topcoat had been applied, it was possible for solvents from the finish to collect at the interface where delamination occurred. However, in accordance with the specification and manufacturers' data sheets, solvent was not permitted in the surfacer.

b. Ameron reported that the film was soft, indicating incomplete cure. A pink discoloration in the NuKlad 117(N) film was questioned. This was later identified as an iron oxide contaminant in the silica filler used in NuKlad 117(N).

c. Ameron furnished Laboratory Report 405 on January 29, 1980. The report tended to eliminate two potential causes of delamination, which were subsequently proven to significantly contribute to the problem - moisture and Amercoat 6 thinner used in the NuKlad 117(N).

3.4 PROGRAMMED INVESTIGATION

During the preliminary investigation, it was determined that the probable root cause of delamination could be traced to one or more potential variables during application of System 9. Nonconformances identified did not completely define the extent or location of delamination. Before making repairs, it was essential that the cause of delamination be established. Laboratory and controlled plant tests were required to provide data for analysis and resolution of this problem. The following studies of application variables were scheduled between May 1980 and August 1981:

a. Controlled study of the effect of time between coats conducted by KTA-Tator, Inc.

b. In-plant testing of solvent additions to first and second coat of NuKlad 117(N). Initial testing included all solvents and thinners used onsite. Final testing included xylol and Amercoat 6 thinner with application scheduled at intervals following mixing of components.

c. Laboratory tests at Consumers Power Laboratories at Jackson, Michigan. These included thinned and unthinned sample preparations to test mixing variables, contamination, and effect of application to wet surfaces.

d. Contracted evaluation tests by Imco Laboratories, Buffalo, New York. Imco was requested to do sufficient application tests to comment on the selection of NuKlad 117(N) as a decontaminable surfacer coating.

e. Analysis of existing coating at Midland compared with prepared samples of known composition (KTA-Tator, Inc.). These tests were run by KTA-Tator, Inc. to verify the type and amount of solvent added to NuKlad 117(N) by J.L. Manta.

f. Tests conducted by Bechtel in Ann Arbor to determine the influence of relative humidity during the cure of each coat.

3.5 RATIONALE

The rationale in proceeding with the corrective action investigation was as follows:

3.5.1 All System 9 was nonconforming because of use of unqualified procedures utilizing two coats of NuKlad 117(N). Therefore, the two-coat work in the as-built condition was processed through design basis accident (DBA) testing before a decision was made regarding the status of System 9 in areas where delamination did not occur.

3.5.2 A replacement system was required for areas where delaminated coating was removed. Because all residues of NuKlad 117(N) could not be removed without damage to concrete surfaces, the replacement system also required requalification under DBA test conditions.

3.5.3 Bechtel construction took over the coatings work and implemented its own quality control program. Field coatings engineers were also provided to monitor and direct the work at the jobsite. Consumers Power Company was responsible for the quality assurance program to provide the required over-inspections and other necessary functions when the Q-listed work began. A specification was prepared by project engineering incorporating procedures and controls to prevent recurrence of the delamination problem. The specification provided types of controls, such as surface preparation, application procedures, points of inspection, material storage, and certification of painters. When the specification was issued, Bechtel construction was able to perform the coatings work. Because the root cause was unknown, all specification requirements were evaluated in non-Q-listed areas where surfacing was required. Repairs in containment were not performed until the cause was determined.

3.5.4 Statistical test methods were available to provide a basis for sampling to established levels of reliability. Regardless of the root cause, unacceptable work could be segregated.

3.6 ACCEPTABILITY OF UNFAILED SYSTEM 9

3.6.1 Specification 7220-A-55(Q) was prepared to determine the acceptability of those portions of System 9 that had not delaminated. This specification was designed to provide the following information:

a. Reliability of the knife adhesion test

b. Provide a statistically selected series of core samples suitable for design basis accident (DBA) tests at ORNL to Midland criteria specified in Specification 7220-A-45.

3.6.2 Specification 7220-A-55(Q) was implemented to provide at least 95% reliability that at least 95% of the samples collected were representative of the area tested. The following summarizes the sampling procedures:

a. All failed areas as determined in preliminary testing and mapping of 100 ft^2 grids were excluded from tests.

b. Sample sites were statistically selected from approximately 500 test grids providing 80 samples.

c. Each sample site was tested for delamination by knife on four sides of the immediate site for core sampling. One knife test was run using 1/8-inch spacing between parallel cuts. This accentuated the tendency for delamination.

d. Special samples were taken in both pass and failed areas and tested by immersion in 180 to 200F spray solution at Consumers Power Laboratory. This test confirmed that blistering, cracking, and peeling can occur during the final immersion stage of simulated DBA testing in accordance with Specification 7220-A-45. Samples that pass the knife test passed the immersion test and samples that fail the knife test failed.

e. DBA testing was conducted on samples collected under Section 3.6.1.b. Neither irradiated or unirradiated samples failed. A few panels blistered. However, this was attributed to the fact that panels were not prepared in a laboratory and represented an as-built plant condition.

3.7 REPLACEMENT OF SYSTEM 9 IN FAILED AREAS - COATING SYSTEM TESTS

3.7.1 Four principal coating manufacturers that supply prequalified coating system for concrete surfacing were selected as potential suppliers of replacement coating in failed areas. Specification 7220-A-57(Q) was prepared to provide and control sample preparation and collection of potential System 9 replacement specimens. This specification included the following requirements:

a. Use of delaminated coating removal methods and follow-up cleaning by procedures proposed for plant use

b. Surface preparation of wall areas in a room in Containment 2 that had exhibited extensive delamination

c. Selection of sample sites typical of retained NuKlad 117(N) residue, and masked "window" areas to permit recording (photographically) the surface condition under new coatings in the sampled area

d. Sufficient area of each system applied in one, two, three, or four coats to permit selection of alternative systems that best meet the functional requirements

e. Application under fully documented conditions with (optional) technical assistance by the coating manufacturer

f. Test the use of Amercoat 90 as a finish coat over all other coating systems

3.7.2 Sample areas were prepared and sample sites selected after preparation. Core samples were collected for DBA testing in accordance with Specification 7220-A-45. Samples were DBA-tested at ORNL and are reported.

3.7.3 All samples tested were acceptable. Based on compatibility with existing System 9, a coating system was selected that required a mist coat of Amercoat 90 over the cleaned surface, which had a NuKlad 117(N) residue. Following this, a surfacer coat of NuKlad 117(N) was applied and cured followed by a finish coat of Amercoat 90. This coating system was placed in the technical specification for reapplication in areas where coating has been removed.

3.8 PREPARATION OF TECHNICAL SPECIFICATION FOR APPLICATION OF DECONTAMINABLE COATINGS TO CONCRETE

3.8.1 Specification 7220-A-56(Q)

This specification was issued on April 14, 1981, to replace Specification 7220-A-15(Q), previously used for subcontracted work. Before implementation, draft procedures for Coating Systems 6, 7, 8, and 9 in Specification 7220-A-15(Q) were prepared and verified by application in non-Q-listed areas before preparation of Specification 7220-A-56(Q). This specification incorporated rigid environmental controls to preclude further problems.

3.8.2 Revisions to Specification 7220-A-56(Q)

When the root cause of System 9 failure was determined and a replacement system tested, appropriate revisions were made to Specification 7220-A-56(Q). These include the following items:

a. Decrease relative humidity permitted to 80% for all surfacer systems

b. Incorporate replacement System 9

c. Incorporate testing procedure for location, verification, and removal of failed coating (this item is described in detail under Corrective Action)

The replacement System 9 was applied in accordance with the requirements of the revised Specification 7220-A-56(Q).

4.0 ANALYSIS OF SAFETY IMPLICATION

4.1 The total System 9 coating that now exists in containment Units 1 and 2 is comprised of portions from the original subcontractor-applied System 9 (old coating) [Specification 7220-A-15(Q)], which has been qualified by the testing process, and portions from the new Bechtel-applied System 9 (new coating) [Specification 7220-A-56(Q)]. It is not considered feasible that under accident conditions this existing System 9 coating can degrade performance of the containment sump or sprinkler head system for the following reasons:

4.1.1 The 95/95 testing plan used to qualify the "old System 9" (subcontractor-applied) coating results in a 95% confidence that a minimum of 95% of this coating will be good (i.e., not delaminate). Using this as the most conservative approach, the resulting 5% of the old System 9 coating equals approximately 2,349 square feet in Unit 1 and 524 square feet in Unit 2. According to the actual test results, 472 grids were tested in Unit 1 with 5 grids that failed, resulting in a minimum of 97.8% of the old System 9 that will be good. In Unit 2, because of the smaller amount of remaining old System 9 coating, 118 grids were tested with 1 grid that failed, resulting in a minimum of 96% of the old System 9 that will be good. Therefore, the actual resulting percentage of 2.2% in Unit 1 equals approximately 1,034 square feet, and the 4% in Unit 2 equals 419 square feet of old System 9 coating that may possibly delaminate. When the reliability of the current System 9 coating (old plus new) is analyzed, Unit 1 results in a 95% confidence that 98.4% of the System 9 coating will be good, and in Unit 2, a 95% confidence that 99.4% of the System 9 coating will be good.

4.1.2 As described in the Midland Final Safety Analysis Report, Revision 44, Subsections 6.2.2 and 1.2.2, and Table 6.2-23, each containment sump is designed in accordance with Regulatory Guide 1.82

criteria. The sump is designed to maintain a water flow approach velocity to the fine mesh sump screens at less than 0.2 ft/sec with the floor level in the immediate vicinity of the sump sloped gradually down, away from the sump. These design features allow for settlement of debris with a specific gravity greater than 1.05 before reaching the sump screens (refer to Regulatory Guide 1,82, June 1974, Section B). Each of the System 9 components [Amercoat 90 and NuKlad 117(N)] has a specific gravity greater than 1.4 (based on tests done by Consumers Power Company Laboratory). If an accident condition occurred and lack of adhesion was exhibited by the System 9 coatings, the debris would settle during flow to the sump, rather than becoming entrained in the sump screens.

5.0 PROBABLE CAUSE

5.1 Each of the test programs provided positive indications that the delamination between coats of NuKlad 117(N) could be duplicated by application conditions, which were representative of unusual circumstances that could have occurred during the work.

5.1.1 If the time interval between coats of NuKlad 117(N) was extended beyond 7 days, the frequency of delamination increased. However, the results of this test did not conclusively indicate that this variable in itself accounted for the amount or location of delamination that occurred at the Midland plant.

5.1.2 Reports by KTA-Tator, Inc. (supported by Bechtel tests) indicated that NuKlad 117(N) applied at the end of the useful pot life increased the potential for adhesion loss if warm material was applied to a cooler surface. This reduced the flow property of the applied coat due to a rapid increase in viscosity or solidification at the cold surface.

5.1.3 Solvent addition extended the apparent pot life and in severe cases caused delamination. Some solvents appeared to cause additional exothermic heat when added to the mix, indicating reactivity with the amine convertor.

5.1.4 Both KTA-Tator, Inc. and Imco Laboratories concluded that delamination increased at high levels of relative humidity. This observation was made independently by both laboratories performing application tests. This occurred with and without solvent addition. This work provided important evidence needed to explain the delamination in the plant.

5.1.5 When the results from Section 5.1.4 were reported, Bechtel performed tests to determine the percentage of relative humidity that was detrimental. The results of this testing were as follows:

a. Without solvent (Amercoat 6), relative humidity above 80% was detrimental to adhesion between two coats of NuKlad 117(N).

b. With the use of Amercoat 6 thinner, delamination does not occur until most solvent has evaporated. This requires 6 to 8 weeks and did occur at relative humidity below 80%.

5.1.6 It was concluded that the major root cause of delamination was due to high levels of relative humidity during the cure of the first coat of NuKlad 117(N). Cure was retarded and delamination was not readily apparent because of the unauthorized addition of Amercoat 6 thinner to NuKlad 117(N). This solvent addition also extends the apparent pot life and, because of hygroscopic properties, makes the uncured coating more susceptible to high relative humidity. Variations in film thickness accounted for differences in solvent retention. This could have accounted for the failure to observe this problem while application was under way. It is estimated that total loss of adhesion between coats may require up to 6 months on thinned Nuklad 117(N).

5.2 The sequence of events typical of the installation of System 9 is listed below to provide logical explanation for the location of delaminated NuKlad 117(N).

5.2.1 Surfacing of all concrete was scheduled during 1978 and 1979. To avoid interference with other crafts, work was normally started at 4:00 a.m. and proceeded until noon. Areas cleaned on the previous day were coated early on the following day. During most of this time interval, the temporary construction openings (doors) were closed when coating work was in progress. At 7:00 a.m., when other crafts started work, the construction opening was in use and the temperature and relative humidity of the air gradually changed to reflect outside ambient conditions. Coating work was then stopped in cold weather due to restrictions specified for surface temperature. Air flow during the cure of freshly applied surfacer was from lower elevations where the humidity was greatest to the upper levels through the shield wall area.

5.2.2 Units 1 and 2 were scheduled for coating work based on availability of the uncoated areas. However, Unit 1 had less construction work in progress and environmental conditions were reported to be more stable. This accounts for the fact that delamination was not as extensive in Unit 1. The construction opening on Unit 1 was also shielded to some extent by other buildings whereas Unit 2 construction opening faced the river.

5.2.3 The probable cause of delamination has been traced to high relative humidity. The separation of coats of NuKlad 117(N) did not occur until the first coat had cured. Complete cure was delayed for months due to unspecified thinning of NuKlad 117(N) with Amercoat 6 thinner. High relative humidity causes the water sensitive amine convertor to migrate to the coating surface. This is further enhanced by water soluble solvent residues of the type that can react with free amine groups preventing complete cure within the limits predicted for maximum hardness. At the surface of the coating, any amine exudate can also react with carbon dioxide forming complex incompatible products on the surface. Delaying the time between coats and prolonged pot life may have influenced delamination, but could not account for the extensive failures observed.

5.2.4 Although the second coat of NuKlad 117(N) may have been thinned in the same manner as the first coat, it was not necessary to apply as heavy a film. The second coat was used to completely fill surfacer pinholes, and there were no heavy deposits required to fill the concrete depressions and undercut areas. The thinner film was able to cure more quickly and release the solvent through Amercoat 90 finish coats.

6.0 CORRECTIVE ACTION

6.1 Nonconforming System 9 included all System 9 applied by subcontract in containment buildings 1 and 2. Therefore, all System 9 was subject to removal or testing to resolve the nonconformance. Previous tests of 10' x 10' grids provided information on the location of failed areas, but did not provide the failure boundaries. When delaminated System 9 was removed by impact tools, such as the Roto Peen, it was possible to segregate sound coating by observing the difficulty of removal. Starting at known failed test areas, coating was removed to the point of intersection with sound coating. Field engineering determined the total area of coating removal based on further knife tests and consolidation of removed coating into logical areas for reapplication of System 9.

6.2 Specification 7220-A-56(Q), Section 12.0, defines the removal and reapplication of System 9. Sections 13.7 and 13.8 provide inspection and testing criteria for selection of random sample sites by a scientific sampling plan. The implementation of these sections of Specification 7220-A-56(Q) require removal and replacement of System 9 or requalification of System 9 installed under subcontract and allowed to remain. The results of this program are tabulated in Appendix A. The procedure for implementation was as follows:

6.2.1 Drawings A-1000(Q) through A-1015(Q) were issued to subdivide all coated concrete walls in containment buildings 1 and 2. Each containment

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area represented by a drawing was a unit for statistical testing.

6.2.2 Each drawing was further marked off in 2' x 2' grids for use as special sample sites.

6.2.3 Bechtel project engineering performed a walkdown of each area before issuing the drawing to construction. All removed coating and areas inaccessible to testing were identified on the drawing. Other coating systems applied in conformance to the subcontract Specification 7220-A-15(Q) were marked. The resulting 2' x 2' grids constituted the population of sample sites for statistical sampling of System 9.

6.2.4 Bechtel reliability engineering generated random grid numbers for performance of knife test adhesion. The criterion used provided 95% confidence that a minimum of 95% of the unremoved coatings in each containment could not delaminate. Grids were designated A, B, or C.

a. Testing of 59 "A" grids permitted no failure

b. Testing of 59 "A" grids and 34 "B" grids allowed one adhesion failure

c. Testing of 59 "A" grids, 34 "B" grids, and 31 "C" grids allowed two adhesion failures

6.2.5 Teams consisting of a Bechtel field engineer and a Bechtel quality control engineer performed adhesion tests under a quality control inspection plan. Based on test performance, results were documented and reported as "pass" or "fail." If the area failed, additional coating removal was permitted. A revised drawing was issued and retested by repeating Steps 3 and 4 above. If in the judgment of field engineering the area represented by the drawing did not justify retest, all coating was removed.

6.2.6 After July 1, 1982, testing was limited to "A" grids only. This eliminated the need to locate the boundaries of failure represented by permitted failures of "B" and "C" grids.

6.2.7 All corrective action was completed by September 15, 1982. This includes the reapplication of System 9 to areas where delaminated coating was removed. Final touchup of areas where rework is being performed will be completed after other construction activities are complete.

7.0 REPORTABILITY

Based on the safety implication analysis of this report, the described deficiency was considered reportable in accordance with the Code of Federal Regulation, 10 CFR 50.55(e).

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CORRECTIVE ACTION-SYSTEM 9 TEST AND REPLACEMENT

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Drawing Number	Final Revision	Grids Tested	Area No	Elevation	Unit No	Total Coating Removed (Sq. Ft.)	Total Coating Remaining (Sq. Ft.)	Remarks
A-1000(Q)	1	A-B	1	685' to 659'	2	718	5,990	
A-1001(Q)	4	A-B	1	685' to 659'	1	1,755	4,953	
A-1002(Q)	2	A	2	659' to 640'	2	1,683	4,479	
A-1003(Q)	2	A-B-C	2	659' to 640'	1	283	5,879	
A-1004(Q)	3	-	3	685' to 640'	2	12,434	0	All Coating Removed
A-1005(Q)	3	A-B	3	685' to 640'	1	1,728	10,706	
A-1006(Q)	6	-	4	640' to 626'	2	4,130	0	All Coating Removed
A-1007(Q)	2	A-B	4	640' to 626'	1	1,149	2,981	
A-1008(Q)	10	-	5	626' to 593'-6"	2	12,050	0	All Coating Removed
A-1009(Q)	1	A	5	626' to 593'-6"	1	1,534	10,516	
A-1010(Q)	1	-	6	640' to 593'-6"	2	10,958	0	All Coating Removed
A-1011(Q)	0	A	6	640' to 593'-6"	1	712	10,246	
A-1012(Q)	0	-	7	Misc	2	6,824	0	All Coating Removed
A-1013(Q)	1	A	7	Misc	1	5,126	1,698	
A-1014(Q)	5	-	7B	Misc	2	7,131	0	All Coating Removed
A-1015(Q)	5	-	7B	Misc	1	7,131	0	All Coating Removed
Totals For Unit No 1						19,418	46,979	
Totals For Unit No 2						55,928	10,469	
Total For Units 1 & 2						75,346	57,448	
Total Area Of Concrete (System 9) per Unit = 66,397								

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Other Inspection Areas

A followup inspection (reference IE Reports No. 50-329/82-10; 50-330/82-10) was conducted relative to the Consumers Power 50.55(e) item regarding ~~the~~ Units 1 and 2 containment internal structures coating deficiencies. The final Consumers Power report on the resolution of the item was transmitted to Region III ~~by~~ ~~Consumers Power~~ on December 17, 1982.

The report was reviewed to verify the satisfactory resolution of the identified Service Level I coating deficiencies. Particular emphasis was placed on Consumer Power's analysis of potential safety implications and the completion of specified corrective action.

Based on this review, we have concluded that ~~the~~ appropriate measures have been effected by Consumers Power relative to this issue and the item is considered closed.