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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
Malcolm R. Knapp, Acting Director

In the Matter of	)	
	)	
WISCONSIN ELECTRIC POWER COMPANY (Point Beach Nuclear Plant)	))	Docket Nos. 50-266, 50-301, 72-5
	)	
CONSUMERS POWER COMPANY (Palisades Nuclear Plant)	))	Docket Nos. 50-255, 72-7
	)	
ENTERGY OPERATIONS, INC. (Arkansas Nuclear One)	))	Docket Nos. 50-313, 50-368, 72-13
	)	
SIERRA NUCLEAR CORPORATION	)	Docket No. 72-1007
	)	
	)	(10 CFR 2.206)

DIRECTOR'S DECISION UNDER 10 CFR 2.206

I. INTRODUCTION

On October 18, 1996, Don't Waste Michigan and the Lake Michigan Federation (Petitioners) filed a Petition pursuant to Section 2.206 of Title 10 of the Code of Federal Regulations (10 CFR 2.206) requesting that the U. S. Nuclear Regulatory Commission take the following action:

> Prohibit loading of Ventilated Storage Casks (VSC-24s) until the certificate of compliance (COC), the safety analysis report (SAR), and the safety evaluation report (SER) are amended following an independent, third-party review of the VSC-24 design, to address concerns raised by the Petitioners' engineering consultant, Dr. Rudolf Hausler

The Petition has been referred to me pursuant to 10 CFR 2.206. By letter dated December 10, 1996, to Dr. Mary Sinclair and Ms. Eleanor Roemer, on behalf of the Petitioners, NRC acknowledged receipt of the Petition and provided the NRC staff's determination that the Petition did not require

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immediate action by the NRC. Notice of receipt was published in the Federal Register on January 13, 1997 (62 FR 1783).

On the basis of the NRC staff's evaluation of the issues and for the reasons given below, I have determined that the Petitioners' request should be denied.

II. BACKGROUND

On May 28, 1996, a hydrogen gas ignition occurred during the welding of the shield lid after spent fuel had been loaded into a VSC-24 at the Point Beach Nuclear Plant. The hydrogen was formed by a chemical reaction between a zinc-based coating (Carbo Zinc 11) and the borated water in the spent fuel pool. On June 3, 1996, the NRC issued confirmatory action letters (CALs) to those licensees using or planning to use VSC-24s for dry storage of spent nuclear fuel, i.e., licensees for Point Beach Nuclear Plant, Palisades Nuclear Generating Plant, and Arkansas Nuclear One (ANO). The CAL issued to the licensee for ANO was supplemented on June 21, 1996, and the CALs issued to the licensees for Point Beach and Palisades were supplemented on June 27, 1996. The CALs, as supplemented, documented the licensees' commitments not to load or unload a VSC-24 without resolution of material compatibility issues identified in a forthcoming generic communication and subsequent NRC confirmation of corrective actions taken by the licensees. The generic communication was issued on July 5, 1996, in the form of NRC Bulletin 96-04, "Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks." NRC Bulletin 96-04 notified addressees about the potential for adverse chemical, galvanic, or other reactions among the materials of a spent fuel storage or transportation cask, its contents, and the environments the cask may encounter during use. The actions requested in

Bulletin 96-04 included reviewing the cask materials for potential adverse reactions, evaluating the short-term and long-term effects of any identified reactions, and determining the adequacy of cask operating procedures to minimize the consequences of any identified reactions. The NRC staff has acknowledged that the event demonstrated that the cask vendor's (Sierra Nuclear Corporation) SAR for the VSC-24 and related NRC review, as documented in the NRC staff's SER, did not adequately address the use of a zinc-based coating and its reaction with the acidic water in spent fuel pools.

In response to Bulletin 96-04 and to subsequent NRC staff inquiries, the licensees for ANO, Point Beach, and Palisades submitted to the NRC evaluations of possible material interactions and the effects of such interactions on cask performance and operation. The licensees also submitted information on the operating controls and limits that were implemented to prevent hazardous conditions which may result from adverse material interactions. The operating controls and limits included controls for the environments that the casks encounter during use, requirements for inspections and environmental sampling, and additional precautions for various cask operations.

The NRC staff evaluated the responses submitted by the licensee for ANO. As documented in the staff's safety evaluation dated December 3, 1996, the staff determined that the licensee's submittals provided the necessary level of confidence that the VSC-24 can be used to safely store spent fuel over the 20-year period of the certificate. The staff also determined that the operating controls and limits proposed by the licensee are acceptable and satisfy regulatory requirements. By a separate letter, also dated December 3, 1996, the staff informed the licensee for ANO that its corrective actions had

been verified by inspections performed by the NRC staff. Shortly thereafter, the licensee initiated cask loading activities.

The NRC staff also evaluated the responses submitted by the licensees for Point Beach and Palisades. As documented in the staff's safety evaluations dated respectively April 6, 1997, and June 12, 1997, the staff determined that the licensees' evaluations and proposed operating controls and limits are acceptable and satisfy regulatory requirements. However, the CALs placed on Point Beach and Palisades still remain in place until an NRC inspection is performed to verify that the licensees' corrective actions are properly implemented.

III. DISCUSSION

The Petition requests an NRC order to users of VSC-24s not to load additional casks until: (1) the COC, SAR, and SER are amended to contain operating controls and limits to prevent hazardous conditions; (2) an independent third-party review team has examined the safety issues raised by the Petitioners; (3) the potential impacts of all material aspects of the casks have been fully assessed; (4) there is experimental verification of temperature calculations and heat transfer assessments and other design assumptions; and (5) the safety of the material coatings on components and structures has been justified.

Item 1: Prohibit Loading of VSC-24s Pending Amendment of Documents

As noted in the NRC letter to the Petitioners on December 10, 1996, the Petitioners' request to amend the COC, SAR, and SER is similar to a request made by the Citizen's Utility Board (CUB) in a Petition dated September 30, 1996. The NRC staff denied the CUB petition on April 17, 1997, for the

reasons that are identical to the reasons stated here in denying the first part of the Petitioners' request.

The circumstances set forth above made clear that, following the event at Point Beach, the NRC staff recognized that additional evaluation of potential material interactions was warranted for all spent fuel transportation and storage casks. In regard to the VSC-24, the event and subsequent NRC inspections made it apparent that actual changes in the operating procedures or the design of the cask would be necessary. CALs were issued to confirm licensees' commitments to refrain from loading VSC-24s pending completion of the NRC staff's review of the responses to Bulletin 96-04 and verification of the associated corrective actions. As discussed, the CALs established a process by which the NRC staff could obtain confidence that operating controls and limits to address potential hazardous conditions are developed and implemented by each licensee using VSC-24s.

In particular, the CAL process ensures that licensees will incorporate the necessary operating controls and limits into revised plant procedures. Moreover, under existing NRC requirements, the licensee must adequately implement those revised procedures. For this reason, no changes to the COC or SAR are needed to ensure that enforceable operating controls and limits are in place to address potential hazardous conditions during the loading or unloading of a cask. Further, as previously indicated, the NRC staff has documented the process, information, and results of its review of the licensees' responses to Bulletin 96-04 for use of the VSC-24 at ANO, Point Beach, and Palisades in safety evaluations available for public review.

Although the actions taken as part of the CAL process provide adequate assurance that technical and regulatory compliance issues raised by the event

at Point Beach will be resolved before a licensee loads or unloads a VSC-24, the NRC staff agrees with the Petitioners that it would be beneficial if the SAR and other licensing basis documents accurately describe the identified chemical reaction and the associated operating controls and limits. The NRC staff is currently reviewing a proposed amendment to the SAR and COC for the VSC-24 design and will ensure that the information related to the identified chemical reaction and associated operating controls is adequately addressed in the appropriate licensing-basis documents. In addition, the NRC staff is processing a petition for rulemaking, PRM-72-3, that may lead to additional updating of independent spent fuel storage installation SARs and the inclusion of information on operating controls and limits implemented as a result of the event at Point Beach. However, the previously discussed controls to be implemented by the licensees and verified by the staff as part of the CAL process, and the enforceability of those controls under existing NRC requirements, make it unnecessary to require revision of the specific licensing documents cited by the Petitioners as a precondition for resuming cask operations at the facilities using VSC-24s. Therefore, there would be no regulatory basis for granting the first part of the Petition to require amendment of the COC, SAR, or SER before further loading of VSC-24s.

Item 2: Prohibit Loading of VSC-24s Pending Independent, Third-Party Review

Petitioners request the NRC to prohibit loading of VSC-24s until the COC, SAR and SER are amended following an independent, third-party review to address concerns raised by the Petitioners. The NRC staff performed a review of the VSC-24 design prior to certification in 1993. As a result of the review, the staff determined that the design and operation of the cask system is in compliance with 10 CFR Part 72. The staff also concluded, with a high

degree of assurance, that the VSC-24 will safely store spent fuel over the 20-year period of the certificate. Notwithstanding the staff's review and determination in 1993, the Petitioners are claiming that a new, independent review is needed before further VSC-24s are loaded.

While the event at Point Beach revealed the need for additional evaluation by licensees and NRC of potential material interactions in the VSC-24 (and other transportation and storage casks), the actions already taken, in the staff's judgment, provide an adequate response. In particular, Bulletin 96-04 was issued to request additional information from licensees using the VSC-24 on material interactions and compatibility in the VSC-24 and on the corrective actions implemented. The NRC staff then received and reviewed the responses submitted by the licensees for ANO, Point Beach, and Palisades. The staff's reviews (as well as the licensees') have been exhaustive and were performed by an inter-disciplinary team of engineers knowledgeable in materials, corrosion, metallurgy, chemistry, structural engineering, heat transfer, nuclear engineering, and other technical fields needed to perform the review. The results of the staff's reviews, including the necessary corrective actions, are documented and justified in the staff's December 3, 1996, April 8, 1997, and June 12, 1997, safety evaluations. These corrective actions include: cleanliness checks before placing the cask in the spent fuel pool, venting and monitoring of the air space beneath the VSC-24 shield lid during welding or cutting activities, discontinuing welding or cutting should the hydrogen concentration exceed 0.4% by volume (10% of the minimum amount necessary for a combustible concentration), and sampling the boron concentration in the spent fuel pool and multi-assembly sealed basket (MSB) water. While the staff agreed that the corrective actions were

necessary to prevent hazardous conditions during the loading and unloading of VSC-24s, the information submitted by the Petitioners does not raise any new issues or provide any reason for the staff to question its conclusion that the VSC-24 will safely store spent fuel over the 20-year period of the certificate.

In reaching this conclusion, the NRC staff evaluated the specific concerns raised by the Petitioners related to the design of the VSC-24. The staff believes that these concerns have already been addressed by the recent evaluations submitted in response to Bulletin 96-04, by information submitted to NRC to support the certification of the VSC-24 design in 1993, or by other information submitted in support of NRC review and inspection activities. Each of the Petitioners' specific concerns is addressed below.

(i) The Petitioners claim that the cask design allows for fuel elements to be in contact with the zinc primer creating a galvanic couple which will accelerate the corrosion of the zinc. The NRC staff considered galvanic effects between the Zircaloy fuel rods and the Carbo Zinc 11 coating. The staff agrees that a galvanic effect would increase the corrosion rate of the zinc, with a corresponding increase in the hydrogen gas generation rate, as the zinc in the Carbo Zinc 11 coating is polarized to a more active potential. However, in the VSC-24 design, several factors reduce the amount of zinc polarization such that there would not be a significant increase in hydrogen generation. One factor is the contact resistances between the stainless steel fuel assembly end-fittings and the Zircaloy fuel rods and between the end-fittings and the Carbo Zinc 11 paint. Another factor is the geometry of the VSC-24 and the fuel assemblies. The fuel assemblies are placed in fuel storage sleeves with a clearance of approximately 0.1 inch to 0.5 inch between

the sides of the fuel assembly and the sleeves. This clearance and the physical design of the fuel assemblies create shielding between the fuel rod surfaces and the Carbo Zinc 11 coating. This shielding effectively reduces the galvanic action between the Zircaloy fuel rods and the Carbo Zinc 11 coating. The Zircaloy fuel rods could contact the Carbo Zinc coated sleeves if the fuel assembly is not centered in the storage sleeves or if the fuel rods are bowed. However, the shielding effect and small Carbo Zinc/Zircaloy contact area would still prevent significant galvanic action. Hydrogen concentration measurements made at Point Beach and the hydrogen monitoring performed at ANO during loading of a VSC-24 in December 1996 (NRC Inspection Report Nos. 50-313/96-25 and 72-13/96-02) support the conclusion that significant galvanic action between the Zircaloy and zinc coating, and hence, increased hydrogen generation, is not occurring in the VSC-24. In addition, even if there was an increase in hydrogen generation because of the galvanic action, the staff has determined that the controls implemented by the licensees for ANO and Point Beach would prevent accumulation of a combustible concentration of hydrogen and its ignition. The staff will also review and verify the adequacy of the controls implemented by the licensee for Palisades.

(ii) The Petitioners claim that there were numerous discrepancies in the responses to Bulletin 96-04. As noted, the NRC staff completed its review of responses for ANO, Point Beach, and Palisades. The staff found these responses to be acceptable and found no discrepancies of concern. There were minor differences in the operating controls implemented at the three facilities. However, the staff reviewed these controls and concluded that all three sets of controls are adequate to preclude hazardous conditions during cask operation.

(iii) The Petitioners claim that the epoxy coating applied to the exterior of the Multi-Assembly Sealed Basket (MSB) could not withstand the temperatures developed during long-term storage. Technical data on the type of epoxy coating used on the MSB were provided by the licensees in their responses to Bulletin 96-04. The data show that the epoxy is temperature-resistant up to 350°F. The SAR for the VSC-24 (which the staff reviewed and accepted prior to certification in 1993) shows that under normal or off-normal storage conditions, the temperature of the MSB exterior will not exceed 300°F, for the maximum allowable heat load of 24 kW and, therefore, will not degrade the epoxy.

(iv) The Petitioners claim that the low-temperature specification in the COC for moving the VSC-24 MSB was not properly translated to the MSB shell material compositions. Low-temperature embrittlement of the MSB shell material was evaluated by the NRC staff during its safety review before certification of the VSC-24. The composition of the MSB shell material (SA516, Grade 70 carbon steel) is specified in the American Society for Mechanical Engineers, Boiler & Pressure Vessel Code, Section II, SA-516, "Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service." The impact testing requirements for the MSB material are found in American Society for Testing and Materials Specification A370 (ASTM A370), "Methods and Definitions for Mechanical Testing of Steel Products." As specified in the COC, SER, and SAR, each MSB shell material must be shown, during fabrication, by Charpy test per ASTM A370, to have 15 ft-lbs of absorbed energy at -50°F. Further, movement of the MSB must occur only at ambient temperatures of 0°F or above to avoid potential brittle

fracture of the MSB material[1]. The NRC staff considers the 50°F temperature difference to provide sufficient margin because it places the MSB material at a temperature that is significantly above the temperature where brittle fracture could occur. It should also be noted that the temperature of the MSB shell itself would actually be substantially higher than the ambient temperature (e.g., 20°F for 25-year-old fuel), thus providing an even higher margin. In addition, it is highly unlikely that any MSB movement activity would take place at temperatures below 0°F.

(v) The Petitioners claim that zinc-steel interaction at 800°F to 1000°F and possible steel embrittlement over a 20-year period were not considered. Zinc-steel interaction at the 800°F to 1000°F temperature range was not considered and is not a concern because, as documented in the VSC-24 SAR, temperatures in the MSB will not reach 800°F during storage. Maximum temperatures would be 688°F under normal conditions and 708°F under off-normal conditions, for the maximum allowable heat load of 24 kW. Furthermore, over the storage period, the temperatures within the MSB will continue to decrease as the heat load decreases due to the decay of the spent fuel.

(vi) The Petitioners claim that the effect of molten zinc on Zircaloy has not been verified experimentally. The NRC staff evaluated the durability and behavior of the zinc coating under the range of storage temperatures. The presence of molten zinc is not expected under the storage temperatures and

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[1]At Palisades, the licensee has administratively set a minimum ambient temperature of 10°F for moving the first four MSBs (CMSB-01 through 04) to be loaded because the shell material for these MSBs does not have 15 ft-lbs of absorbed energy at -50°F. Rather, these MSBs have 15 ft-lbs of absorbed energy at -40°F. Thus, to retain the 50°F temperature margin, the licensee has restricted movement of these four MSBs to an ambient temperature of 10°F or above. The NRC staff has reviewed and approved the licensee's administrative limit, as documented in NRC safety evaluation dated September 26, 1995.

conditions, thus the effect of molten zinc on Zircaloy is not a concern. However, as documented in the staff's safety evaluations for ANO (dated December 3, 1996), Point Beach (dated April 8, 1997), and Palisades (dated June 12, 1997), the staff did evaluate the potential interaction between zinc vapor and Zircaloy and the effect of this interaction. Based on the information provided in the responses to Bulletin 96-04, the staff concluded that the potential interaction between zinc vapor and Zircaloy presented no immediate or long-term safety concern for the spent fuel stored in the VSC-24.

(vii) The Petitioners claim that the vacuum-drying process does not seem to have been experimentally verified. Vacuum drying is a well-established, widely used method for removing moisture from spent fuel storage and transportation casks. The process used for the VSC-24 is a common process, which the NRC staff evaluated and determined to be acceptable during the safety review before certification in 1993. In the staff's judgment, experimental testing to verify a well-established process is unnecessary.

(viii) The Petitioners claim that the thermal analyses for the VSC-24 have not been experimentally verified. The thermal analyses for the VSC-24 contained conservative key assumptions, including a total heat generation of 1 kW per assembly (a total of 24 kW per cask). This assumption is conservative because it is highly unlikely that each assembly loaded in the cask will generate 1 kW of heat. In addition, the assembly and total cask heat loads will continually decrease over time as the spent fuel decays. In light of the conservatisms in the thermal analyses, the staff does not see the need for requiring experimental verification of the VSC-24 thermal analyses. Nevertheless, the COC requires that a thermal test be performed on the first VSC-24 to be loaded. The purpose of the test is to measure the heat removal

performance of the VSC-24 system. The licensee for Palisades performed such a test and summarized its results in a letter to NRC dated June 10, 1993. The temperatures measured during the test were lower than the predicted temperatures. The results thus indicate that the VSC-24 performs its intended heat removal function. The thermal test at Palisades was performed with a 12 kW heat load. To date, no VSC-24s have been loaded with greater than 12 kW heat load. As required by the COC, the thermal test must be performed for the first cask to use any higher heat loads, up to 24 kW.

The NRC staff believes, based on the foregoing, that an independent, third-party review is not warranted by the Petitioners' specific concerns. However, NRC review activities relating to the VSC-24 will nonetheless continue. In particular, NRC inspection activities at the facilities operated by the licensees, the VSC-24 vendor, and the VSC-24 fabricators may lead to additional reviews of the VSC-24. In addition, the staff is currently reviewing a proposed amendment, submitted by the VSC-24 vendor, to the SAR and COC for the VSC-24 design. This review will be performed in accordance with the staff's "Standard Review Plan for Dry Cask Storage Systems" (NUREG-1536) to ensure the thoroughness, quality, and consistency of the review. Where relevant, recent operational, technical, and safety issues related to the VSC-24 design will be considered by the staff in this review[2].

In addition, it is my judgment that the NRC staff is fully capable of fulfilling the responsibility for reviewing, approving, and certifying dry cask storage systems to be used under 10 CFR Part 72 which, by law, belongs to

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[2]Recent concerns relating to the MSB closure welds, as documented in NRC Inspection Report No. 72-1007/97-204, dated April 15, 1997, may result in further evaluations of the VSC-24 design and if necessary, appropriate regulatory action to ensure continued safe use of the VSC-24.

the NRC. In conducting its review, the NRC staff must have reasonable assurance that the cask system will safely store spent fuel over the period of the certificate. Further, the staff will assign the necessary resources and expertise to perform such reviews. When the NRC staff lacks either the resources or expertise to perform all or portions of the review in-house, the NRC may, and does, supplement its own ranks by using outside specialists.

Item 3: Prohibit Loading of VSC-24s Pending Assessment of Cask Materials

Petitioners request the NRC to prohibit loading of VSC-24s until the potential impacts of all material aspects of the casks have been fully assessed. As previously stated, Bulletin 96-04 was issued to request information on material interactions and compatibility in spent fuel storage and transportation casks. In response to this request, the licensees for ANO, Point Beach, and Palisades submitted evaluations on possible material interactions in the VSC-24 and the effects of such interactions on cask performance and operation. The only significant material interaction identified was between the zinc-based coating and the borated spent fuel pool water. As previously discussed, the operating controls and limits put in place by the licensees provide an adequate level of confidence to prevent the adverse effects of this interaction (generation and possible ignition of hydrogen gas and possible depletion of boron in the water). The staff reviewed these evaluations and, based on the information provided, concluded that none of the identified material interactions would adversely affect the VSC-24's ability to safely store spent fuel over the 20-year period of the certificate. The results of the staff's reviews are documented in the staff's December 3, 1996, April 8, 1997, and June 12, 1997, safety evaluations for ANO, Point Beach, and Palisades, respectively.

Item 4: Prohibit Loading of VSC-24s Pending Experimental Verification of Thermal and Other Design Assumptions

Petitioners request the NRC to prohibit loading of VSC-24s until there is experimental verification of temperature calculations and heat transfer assessments and other design assumptions. The thermal and other engineering and design analyses for the VSC-24 contained conservative key assumptions which are discussed in the SAR and SER. In addition, the acceptance criteria for these analyses have margins of safety that the staff considers to be sufficient. In light of the conservatisms and safety margins in the thermal and other analyses, the staff does not see the need for requiring experimental verification of the thermal and other design assumptions used in evaluating the VSC-24.

Item 5: Prohibit Loading of VSC-24s Pending Assessment of Material Coatings

Petitioners request the NRC to prohibit loading of VSC-24s until the safety of the material coatings on components and structures has been justified. As discussed above, material interactions within the VSC-24 and their effect on cask operations and performance were evaluated by the licensees in response to Bulletin 96-04 and reviewed by the staff. Specifically, the licensees evaluated, and the staff reviewed, the use of the zinc-based coating, its reaction with borated water and other cask environments, and the effect of the reaction or reaction products on cask operations and on the performance of the various cask components and structures. The staff concluded that use of existing VSC-24s with the zinc-based coating is acceptable in light of the operating controls and limits for preventing hazardous conditions that must be properly implemented by licensees during cask loading and unloading. Based on the information provided, the

staff also concluded that neither the coating itself, nor its reaction with borated water or other cask environments, would have an adverse effect on the performance of the cask components or structures during the period of spent fuel storage.

IV. CONCLUSION

The Petitioners requested that the NRC prohibit loading of VSC-24s until the COC, SAR, and SER are amended to contain operating controls and limits to prevent hazardous conditions. After reviewing each of the Petitioners' claims, I conclude that, for the reasons discussed above, no adequate basis exists for granting the Petitioners' request to prohibit licensees' use of the VSC-24 for dry cask storage of spent nuclear fuel at Palisades, Point Beach, or ANO pending: (1) revision of the SAR, SER, and COC for the VSC-24 to contain operating controls and limits to prevent hazardous conditions; (2) an independent third-party review to examine the safety issues raised by the Petitioners; and (3) experimental verification of temperature calculations and heat transfer assessments and other design assumptions. Furthermore, I conclude that the Petitioners' other two requests, an assessment of potential impacts of VSC-24 material aspects and a safety justification of material coatings on components and structures, have already been fulfilled through the staff's review of the licensees' responses to Bulletin 96-04.

A copy of this decision will be filed with the Secretary of the Commission for the Commission to review in accordance with 10 CFR 2.206(c).

As provided by this regulation, this decision will constitute the final action of the Commission 25 days after issuance, unless the Commission, on its own motion, institutes a review of the decision within that time.

Dated at Rockville, Maryland, this 18th day of June 1997

FOR THE NUCLEAR REGULATORY COMMISSION

Malcolm R Knapp

Malcolm R. Knapp, Acting Director
Office of Nuclear Material Safety
and Safeguards

w/Notes

EDO Principal Correspondence Control

FROM: DUE: 11/14/96 EDO CONTROL: GT96801
DOC DT: 10/18/96
FINAL REPLY:

Mary P. Sinclair, Don't Waste Michigan
Eleanor Roemer, Lake Michigan Federation

TO:

James Taylor

FOR SIGNATURE OF : ** GRN ** CRC NO:

DESC: ROUTING:

2.206 PETITION RE UNRESOLVED DESIGN PROBLEM OF THE USC-24 CASK

~~Taylor~~ Callan
~~Milhoan~~ Knapton
Thompson
Blaha
Miraglia, NRR
Paperiello, NMSS
Lieberman, OE

DATE: 10/22/96

ASSIGNED TO: CONTACT:

OGC Cyr

SPECIAL INSTRUCTIONS OR REMARKS:

AC

Don't Waste Michigan
5711 Summerset Dr.
Midland, MI 48640
(517) 835-1303
Lake Michigan Federation
59 E. Van Buren-Suite 2215
Chicago, Illinois 60605
Oct. 18, 1996
(312) 939-0838

James M. Taylor
Executive Director of Operations
U.S. Nuclear Regulatory Commission
1 White Flint North
11555 Rockville Pike
Rockville, Md. 20852

Dear Mr. Taylor:

On behalf of Lake Michigan Federation and Don't Waste Michigan , we are enclosing a petition pursuant to 10 CFR 2.206 of the Commission's regulations. This petition addresses new information on the unresolved design problems of the VSC-24 cask which have become known to the public as a result of the hydrogen ignition/explosion at the Point Beach, WI nuclear plant on May 28, 1996.

We have retained a highly competent corrosion engineer, Dr. Rudolf Hausler, to review the limited number of documents that are available to the public. The NRC denied our request for a detailed engineering design of the cask system.

Dr. Hausler points out the significant safety issues that have not been addressed by either the vendor or the NRC before the Certificate of Compliance for the VSC-24 cask was issued. The utilities have also failed to address these issues in response to NRC's recent requests for additional information . It is imperative that these issues be addressed at this time and incorporated in the SAR, the SER and the COC of the VSC-24 cask system.

Dr. Hausler is highly regarded in the nuclear field as well as in industry as a whole.

We appreciate the attention of the Commission to this petition.

Yours sincerely,

Mary P. Sinclair

Mary P. Sinclair, PhD
Co-chair, Don't Waste Michigan

Eleanor Roemer

Eleanor Roemer, Staff Attorney
Lake Michigan Federation

9612230230

EDO -- GT96801

DON'T WASTE MICHIGAN
LAKE MICHIGAN FEDERATION and
Petitioners

vs

UNITED STATES NUCLEAR
REGULATORY COMMISSION
Respondent

Petition

Pursuant to 10 CFR Part 2.206 of the Commission's regulations, LAKE MICHIGAN FEDERATION and DON'T WASTE MICHIGAN petition the Nuclear Regulatory Commission (NRC) to:

1) Prohibit the loading of any and all VSC-24 nuclear waste storage casks by users of the cask under the general license, until the NRC, following an independent third party review of the VSC-24 cask design, has amended the Safety Analysis Report (SAR), Safety Evaluation Report (SER), and Certificate of Compliance (COC) to address the significant safety concerns raised by corrosion engineer consultant, Dr. Rudolf Hausler, and listed below.

The following summary of unresolved corrosion issues affecting safety in the VSC-24 cask system (Full Report attached), associated with the Point Beach (Wisconsin Electric Power Co) hydrogen explosion, prepared by Dr. Rudolf Hausler, points out a range of short and long term critical issues in the VSC-24 cask system that have not been addressed by the vendor, the NRC or the utilities. (Dr. Hausler is a highly regarded corrosion consultant who was retained by the Electric Power Research Institute (EPRI) to develop and prove the effectiveness and safety of the corrosion inhibitor for off- line chemical cleaning inside reactors.) His conclusions on p. 5 and 6 of his Full Report are as follows:

"Some safety aspects of the Sierra Nuclear Fuel Storage System have been reviewed in the wake of the Point Beach (Wisconsin Electric Power Company) hydrogen explosion. Both short term and long term concerns are discussed.

(i) The storage configuration allows for the fuel elements to be in contact with zinc (metal) primer which is applied to all internal steel surfaces of the MSB. This creates a galvanic element between the zinc and the Zircaloy which in turn accelerates the corrosion of the zinc. No tests have been performed simulating this galvanic situation. Calculations relating to the hydrogen evolution rate and SPF water contamination rate, which are based on the available tests, have therefore little relevance.

(ii) Numerous discrepancies in the responses submitted by the various companies to the NRC request for additional assessment of safety concerns reveal an alarming lack of consensus.

(iii) The epoxy coating applied to the outside of the MSB cannot possibly withstand the temperatures said to develop on long term storage. This will result in an expensive SFP water contamination during unloading of the radioactive material.

(iv) The NRC has published temperature specifications relating to low temperature embrittlement of the structural carbon steels used in the Sierra Nuclear spent fuel storage system. These specs have not been translated properly to the corresponding material composition specifications (for the steels in question), thereby creating additional hazards in handling the storage casks under possible emergency situations.

(v) The zinc-steel interaction at 800 to 1000 degrees F. and possible steel embrittlement over a period of 20 years has not been considered, again creating an additional hazard for handling the MSB in the future.

(vi) Similarly, the effect (or the absence thereof) of molten zinc on Zircaloy has not been verified experimentally. The possible failure of the cladding could make unloading of the spent fuel rods impossible.

(vii) The vacuum drying process does not seem to have been experimentally verified relative to residual water remaining in the MSB. All calculated data relating to pressure in the MSB

during storage, and continued integrity of the seal welds are therefore open to questioning.

(viii) None of the temperature calculations and heat transfer assessments have been experimentally verified. There has never been a field test of this storage system. It is not apparent that the storage system has been instrumented in order to verify the design assumptions."

Evaluate Based on max heat Load - or cask loaded w/ max heat Load.

Facts

1. The NRC issued a Certificate of Compliance 72-1007 for the Ventilated Storage Cask VSC-24, May 7, 1993.

2. Casks of the Model VSC-24 are used by Consumers Power Co.'s, WEPCo's and Entergy's general license issued pursuant to 10 CFR 72.210, subject to the conditions specified by 10 CFR 72.212 and the conditions for Cask Use contained in the Certificate of Compliance 72-1007.

3. The VSC-24 cask is a dry storage system for utilizing a concrete storage cask, and a carbon steel, seal-welded multi-assembly basket (MSB) to store irradiated nuclear fuel. The VSC system includes:

(i) Ventilated Concrete Cask (VCC)
(ii) 24 -Assembly Multi-Assembly Sealed Basket (MSB)
(iii) MSB Transfer Cask (MTC) for on site use
(iv) Vacuum drying and Helium Back-fill System
(v) Engineered Cask Transporter for on site use

4. At 2:45 a.m. (CDT) on May 28, 1996, hydrogen gas ignited during closure welding of a VSC-24 multi-assembly sealed basket loaded with spent fuel at WEPCo's nuclear power plant at Point Beach, Wisconsin. The hydrogen gas ignition displaced the MSB shield lid weighing about 6,390 pounds, leaving it in place but tipped at an angle, with one edge about 3 inches higher than normal. (U.S NRC Information Notice 96:34, May 31, 1996)

Zinc 11 coating when in contact with the borated water in the spent fuel pool. (July 3, 1996, NRC Issues Augmented Inspection Team Report on Hydrogen Gas Burn in Spent Fuel Cask at Point Beach Plant)

6. An NRC Augmented Inspection Team (AIT), at a June 7, 1996, Exit Meeting, also concluded that the source of the hydrogen gas was a chemical reaction between boric acid in the spent fuel pool water and zinc in a coating on the carbon steel interior of the MSB.

7. Neither WEPCo nor the NRC have satisfactorily addressed the significance of the galvanic reaction between the zinc coating and the Zircaloy cladding of the fuel rods and its effect of generating increased levels of hydrogen. [Hausler, III (2) (b)]

8. Specific operational controls and limits necessary to prevent criticality, maintain confinement, shielding, heat removal, and structural integrity under normal and accident operations must be identified and supported in the SAR. (draft NUREG-1536, 12-3, Feb., 1996. Emphasis added).

9. The Safety Analysis Report (SAR) for the Ventilated Storage Cask System prepared by PSNA and SNC, October, 1991, concluded that the materials from which the VSC is constructed will not experience significant chemical, galvanic, or other reactions in a water atmosphere. (SAR, section 3.4.1)

10. The conclusions of the October, 1991, SAR, for the VSC-24 do not identify 1) the potential for hydrogen gas formation as a result of reactions between coatings used on components important to safety and spent fuel pool water; 2) the potential of this hydrogen gas formation to ignite as a result of operations performed on the MSB shield lid during loading and unloading operations; and (3) the potential for boron depletion as a result of the reaction between the MSB coatings and the spent fuel water and the resulting potential impact on criticality; (4) the potential for charring of the epoxy coating on the MSB and the resulting impact on spent fuel pool water when unloading; (5) the potential for steel embrittlement; and (6) the galvanic corrosion element between the zinc and the Zircaloy cladding of the fuel rods.

11. The SER of April 28, 1993,and the Certificate of Compliance issued by the NRC on May 7, 1993, did not identify any of the issues described in No. 10 above.

12. MSB coatings were not classified as important to safety even though the coating is applied to the inside of the MSB basket which is classified as important to safety. (NRC Inspection Team Leader at SNC, June 5, 1996, notes.)

13. The NRC concluded that the designers of the VSC-24 cask never considered fire or explosion due to hydrogen. (Ibid.)

14. SNC design review of VSC did not include a corrosion engineer or environmental effects specialist. (Ibid.)

15. The NRC's AIT teams review of the SAR for the VSC System showed that consideration of the temporary condition of the cask being immersed in borated water was not assessed. (NRC AIT Review of the May 28, 1996, Hydrogen Gas Ignition During Dry cask Storage Welding Operations Reports No. 50-266/96005; 50/301/96005, July 1, 1996)

16. The occurrence of the hydrogen ignition event at Point Beach, WI, on May 28, '96, provides clear evidence that the VSC-24 vendor and licensees did not adequately address material reactions and material compatibility with possible environments, in the design and design review of the VSC-24 cask. (Ibid., p. 11-12)

17. The NRC did not consider material reactions and material compatibility in its licensing review of the VSC-24 cask. (SER, April 28, 1993, COC May 7, 1993, NRC Bulletin, July 5,1996, p. 4)

18. The NRC issued NRC Bulletin 96-04 on July 5, 1996, requiring all holders of operating licenses for power reactors to submit information to the NRC regarding the susceptibility of their cask to chemical, galvanic, or other reactions on the casks ability to maintain the structural integrity and retrievability of the spent fuel through the term of the license; an evaluation of the effects of the reaction among Carbo Zinc 11 or other equivalent coatings and the water environment the cask may

encounter, and an evaluation of the procedures for unloading a cask to consider the likely presence of hydrogen gas inside the MSB and the possible adverse effects of the hydrogen gas on cask handling and performance.

19. The nuclear facilities, including WEPCo, CPCo, and Entergy have responded to the NRC's request for information, but, as Dr. Hausler points out in the attached report, the materials performance questions do not address the significant safety issues, and there are numerous discrepancies in the companies' responses.

20. The descriptions of the cask use and design contained in the VSC-24 SAR and associated SER have not been reviewed to the extent necessary to assure prevention of hazardous conditions caused not only by the reaction between MSB coatings and the spent fuel pool water, but by certain other metallurgical, chemical reactions and temperature effects as pointed out by Dr. Hausler in the attached report.

21. Corrosion Consultant Dr. Rudolf Hausler in his Preliminary Report, based on the limited number of documents available to him, has nevertheless, been able to identify a number of these key issues for the NRC which an independent third party review team should explore in greater detail to establish parameters for the safe operation of the VSC-24 cask system. These include:

(i) questions regarding the impact of the galvanic reaction between the zinc coating and the zircaloy cladding;

(ii) discrepancies in responses submitted by utilities and the vendor to the NRC's July 5 memorandum;

(iii) questions regarding the impacts of long term storage on the epoxy coating;

(iv) risk scenarios related to low temperature embrittlement of the structural steels used in the Sierra Nuclear spent fuel storage system;

(v) risk scenarios related to zinc-steel interaction at 800-1000 degrees F. and possible steel embrittlement over a period of 20 years;

(vi) experimental verification of temperature calculations and heat transfer assessments.

Conclusions

22. The VSC-24 SAR and the associated SER do not contain:

(i) documentation of the conditions produced by the reaction between the MSB coatings and the spent fuel pool water, including the formation of ignitable, and explosive quantities of hydrogen and its impact on the boron concentration; cask performance; temperature effects on materials performance; and verification of temperature calculations, heat transfer assessments, and design assumptions;

(ii) adequate operating controls and limits to prevent hazardous conditions from being caused by reactions between MSB coatings and the spent fuel pool water; the potential impact of molten zinc and the Zircaloy cladding; and consideration of temperature effects and metal embrittlement;

(iii) justification that the conditions produced by the reaction between MSB coatings, spent fuel pool water, and other material performance issues do not result in unsafe cask operation.

23. Specific operational controls and limits necessary to prevent criticality, and maintain confinement, shielding, heat removal and structural integrity under normal and accident operations must be identified and supported in the SAR and SER.

24. The COC for the VSC-24 was issued on the basis of a review of the vendor's SAR and the determination that the cask design

meets the applicable requirements of 10 CFR Part 72 as discussed in the NRC's SER. Because the vendor's SAR did not address the potential consequences of MSB coatings reaction with the spent fuel pool water, as well as other metallurgical issues and chemical reactions, as well as temperature related issues, as pointed out by Dr. Hausler, it is inadequate to provide the basis for a Certificate of Compliance.

25. The COC for the VSC-24 does not contain operating controls and limits that prevent hazardous conditions caused by chemical and galvanic reactions. It does not confirm any experimental verification of temperature calculations and heat transfer assessments, and other design assumptions.

26. In order for the VSC-24 dry cask storage system to be used in a manner which protects public health and safety and allows for the safe operation of the cask over its licensed lifetime, the VSC-24 cask system should not be used until:

(i) an independent third party review team has explored and satisfactorily resolved the safety issues raised by Dr. Hausler in the attached report;

(ii) the identification of the potential impacts of all the materials performance of the cask have been fully assessed;

(iii) there is experimental verification of temperature calculations and heat transfer assessments and of other design assumptions;

(iv) justification of the safe use of the material coatings on components and structures important to public health and safety has been made;

(v) the SAR, SER and COC are amended by the NRC to include the necessary operating controls and limits to direct the safe use of the VSC-24 cask.

THEREFORE, petitioners, Lake Michigan Federation and Don't Waste Michigan, petition the NRC to order users of the VSC-24 system not to load VSC-24 casks until the COC, SAR and SER of the VSC-24 are amended to contain the operating controls and limits that prevent hazardous conditions, including but not limited to the generation of explosive gases, due to VSC-24 materials reactions with environments encountered during loading, storage, and unloading of the VSC-24.

An independent third party interdisciplinary review team that includes corrosion engineers, metallurgists, chemical engineers and others must determine the operating controls and limits which should be clearly documented and justified in the technical review sections of the SAR and associated SER for the VSC-24 cask, and incorporated in a revised COC.

Date: October 18, 1996

Eleanor Roemer, Staff Attorney
Lake Michigan Federation

Mary P. Sinclair, PhD
Co-Chair, Don't Waste Michigan

(This petition under 10 CFR 2.206 should not be interpreted as a petition for rulemaking, including emergency rulemaking).

cc. Chairperson Shirley Jackson, NRC
Carol Browner, Adm. EPA
Valdus Adamkus, EPA
Senator Carl Levin
Senator Joseph Lieberman
Senator Paul Simon
Senator Russell Feingold
Senator Paul Wellstone
Attorney Gen. F. Kelley, MI
Attorney Gen. J. Doyle, WI
Michigan Public Service Commissioners

Vice-President Al Gore
Secy of Energy, Hazel O'Leary
Senator Frank Murkowski
Senator Spencer Abraham
Congressman Fred Upton
Senator Carol Moseley Braun
Senator Herbert Kohl
Dinah Bear, Gen. Counsel, CEQ
Governor John Engler, MI
Governor Tommy Thompson, WI
Wisconsin Public Service Commissioners

Corro Consulta

Rudolf H. Hausler
7804 Pencross Lane, Dallas, TX 75248
Tel: 214 490 8605 Fax: 214 490 8878

Dr. Mary Sinclair
5711 Summerset Dr.
Midland, MI 48640

October 6, 1996

Subject: Preliminary Review of Documentation relating to the Safety Evaluation of the Use of the Sierra Nuclear Corporation's Dry Fuel Storage System

I. Scope

This analysis is based on the documentation available at the time of the analysis (see references attached as Appendix II). The primary focus is corrosion and materials performance both during the loading process of the dry storage system components and during long term storage. It is assumed that the reader is familiar with the components of this system (Ventilated Storage Cask System, VCS) and its components (Multi-Assembly Sealed Basket, MSB; Multi-Assembly Transfer Cask, MTC, and the Ventilated Storage Cask, VSC). Therefore a detailed description of these components is omitted here.

II. Background

The issues relating to corrosion and materials performance of the ISFSI (Independent Spent Fuel Storage Installation System) arose when an explosion occurred during the welding of the lid onto the MSB. Subsequent to this incident, the NRC issued Bulletin 96-04 requesting information on the "Chemical, Galvanic, or other Reactions in Spent Fuel Storage and Transportation Casks" dated July 5 1996. The responses to this request, as well as the responses to subsequent Confirmatory Action Letters (CAL's) by the NRC are reviewed.

The immediate concerns relate to the nature of the explosive gas which apparently was generated inside the MSB, possible means to avoid such incidences in the future, and questions relating to the behavior of materials associated with the MSB and the VSC on long term exposure to high temperatures.

III. The Evolution of Hydrogen.

The MSB, consisting of a cylindrical storage can containing 24 rectangular sleeves (designed to hold one fuel rod assembly each) is fabricated from heavy steel sheet. The outside of the MSB is coated with a zinc primer covered by an epoxy coating. All inside steel surfaces are coated only with a zinc primer. This includes the inside wall of the MSB as well as all surfaces of the sleeves. As a consequence, the Zircaloy fuel rods are in electrical contact with primer coated surfaces and form a galvanic corrosion element.

minimal contact
Zirc. contact would be w/ spacer grids
∃ contact resistance

pH periodically (typical) monitored at Pt. Beach; trend from 4.5 to 5.7

III. 1 Boric Acid Chemistry

The spent fuel pool (SFP)water contains 2850 ppm of boron or 16,310 ppm of boric acid. (There is no indication in the available literature that the solution might be buffered with sodium borate). The pH of this solution can be calculated as 4.86 (see Appendix I). Contrary to a comment by Wisconsin Electric Power Company (WEPCO) the boric acid in pure water does not increase the pH but reduces it from the pH of water; therefore the corrosion of zinc is accelerated, not reduced (see ref. 11, pg. 2, last par.)

It appea[illegible]ever, that the low pH of the borated SFP water has been recognized and is qu[illegible]ing about 4.5 in several other documents.

III. 2 Corrosion of Zinc in Borated Water

The corrosion rate of zinc primer applied to steel coupons appears to have been measured by NWT and by Entergy (Ref. 7) These tests seem to have focused on the rate of hydrogen generation and precipitate formation. No corrosion rate data are available, nor have the tests been described in any detail in the available documents. It is being said that the results from NWT Corporation (San Jose, CA) "appear to be fairly consistent with those from Entergy Company", but about 8 times higher than the rate indicated by WEPCO. WEPCO assumed a zinc corrosion rate of 0.028 inches per year (ipy) based on literature data quoted in Uhlig's Handbook of Corrosion. However, no effort was made by WEPCO to translate that into a hydrogen evolution rate. Rather, WEPCO chose to assume a hydrogen evolution rate based on some measurements (Ref. 9) These measurement indicate that the solution was saturated with hydrogen at a partial pressure of one atmosphere. The reported concentration of 15 cc H_2/kg H_2O corresponds to saturation of the water with hydrogen gas at of 1 ata and a temperature of 25 $^{\circ}$C. One does not know from the report, where the water was sampled and how the analysis was made. However, if the water in the MSB became saturated with hydrogen at 1 ata, the hydrogen evolution was no doubt quite fast and the atmosphere above the water must have been very rich in hydrogen. None of these factoids are useful for the assessment of the zinc corrosion rate and the associated H_2-evolution rate under use conditions.

There are several effects which must be taken into consideration in the design and evaluation of corrosion tests, or when comparing literature results.

a. The data quoted by WEPCO (from Uhlig) were obtained on solid zinc samples and hence apportioned to a measurable surface area. The zinc primer consists of zinc powder in an inorganic matrix. Depending on the particle size and the zinc content in the primer, a surface area many times the apparent area may be exposed to the corrosive medium. Because of the small size of the particles, corrosion is very likely accelerated over that measured on solid coupons. Furthermore, the hydrogen evolution rate would be proportionately larger at the ratio of the apparent, or geometric, surface area to the real surface area of the zinc particles. Literature data, such as those quoted by Uhlig, have no relevance with respect to zinc particle corrosion in paint primers.

b. Galvanic Corrosion: The Zircaloy surfaces of the fuel elements inside the sleeves of the MSB are in electrical contact with the zinc primer, with which the inside surfaces of the sleeves are coated. It has been amply demonstrated, e.g., that the Inconel tubes in a steam generator galvanically accelerate the corrosion of the carbon steel walls of the generator during chemical cleaning (Ref. 12) . (The effect on the welds is even larger). There is no reason to assume that Zircaloy will not similarly accelerate the corrosion of

zinc. As a consequence, this fact must be considered in tests which purport to evaluate the behavior of the zinc primer when in contact with the SFP water during loading of the MSB and subsequent operations.

The NRC has repeatedly called for comments regarding galvanic reactions. This question has not been answered to date. WEPCO indicates (ref. 9) that the "rate of galvanic corrosion of the zinc from the Carbo Zinc 11 SG may be three times higher than in neutral (pH 7) water". Clearly this comment does not answer the question since the galvanically accelerated corrosion rate at the low pH is not specified. The same reference, pg. 2, indicates that "Published data were found for the kinetics of zinc corrosion in boric acid". However, no reference is given and no data are quoted.

c. Corrosion Kinetics: All metals which can form a solid corrosion product when corroding in an aqueous medium exhibit passivation behavior. This means that the corrosion rate observed on the bare metal upon immersion into the corrosive fluid gradually decreases with time. The initial corrosion rate, immediately upon immersion, may be orders of magnitude higher than the average rate for the duration of the test. The extent and the rate to which this decrease of the rate occurs depends on the nature of the corrosion product. Therefore, an average corrosion rate result (such as weight loss) which has been obtained in a long term test is not representative of the possible short term corrosion rate and is a function of the test duration.

Furthermore, a test such as the one performed by ANO (Ref. 10) may be misleading in other ways. The test protocol called for increasing the temperature from 120 °F, following immersion of a primer coated coupon into the borated water, to 200 °F, followed again by a slow cool down to the starting temperature. The duration of the test was 75 hrs. It is known that increasing temperature promotes passivation. The corrosion rate in borated water may actually decrease with increasing temperature. (The phenomenon is well documented for CO_2 corrosion). Hence the temperature cycle performed in ANO tests may not be representative of the worst case condition. In view of the importance, physically and financially, of the question of the rate of hydrogen generation and associated SFP water contamination, it would seem that a full evaluation of the zinc corrosion under all possible conditions of actual use in the application under consideration should be conducted.

Test "simulate cask loading"

d. The Nature of the Zinc Primer.

Ref. 8 (WEPCO) discusses the use of zinc primer from the point of view of contamination introduced into the SFP water. Here it is stated that the primer contains "25,000 ppm of zinc and 530 ppm of lead". All other specifications for the zinc level in the primer indicate 85% (850,000 ppm). If the lead contamination of the zinc in the primer were indeed 2%, as indicated by the WEPCO numbers, then the the amount of lead introduced into the SFP water through corrosion of the zinc would be 34 times larger than what WEPCO assumed it to be. This discrepancy, it would seem, calls for a re-evaluation of the lead impurities which could be introduced into the SFP water, in light of the limiting amount of lead which can be tolerated according to the Westinghouse specifications (ibid).

III. 3 Conclusions

It would appear from the above that the question of corrosion of the zinc in the primer has not been resolved quantitatively, neither from the point of view of hydrogen evolution, nor from the point of view of SFP water contamination.

The NRC request for review of the materials performance questions by a corrosion specialist does not seem to have been fulfilled.

IV. Additional Concerns Relating to Materials Performance

IV. 1. Temperature and Epoxy Coating

Specifications for the Epoxy coating to be applied to the outside surface of the MSB are presented in Ref. 11. It is noted that no temperature performance limits are specified. In view of the fact that the temperature in the MSB on long term storage may be as high as 800 to 900 °F (in the extreme as much as 1000 °F) the performance of the Epoxy top coat becomes a concern. It is recognized that the space between the MSB and the VCC is air cooled. This suggests that the lowest overall heat transfer coefficient is given by the natural convection of the air through the annular space. As a consequence, the temperature of the epoxy would be expected to be very little below the values quoted. Degradation by carbonization of the organic material can, therefore, be expected. No surface temperature has been calculated for the outside of the MSB. Since the unloading of the VCS is part of the safety evaluation, and since it would also have to be performed in the SFP, the corrosion of the residual zinc on the outside of the MSB in contact with charred epoxy paint becomes a real concern.

While extensive simulations and calculations of the heat transfer rates from the MSB to the environment have been made it should be recognized that the heat transfer coefficients for radiation, conduction, and natural convection are afflicted with uncertainties. It is therefore suggested that confidence limits be given for all such calculations and be reviewed by a third party. Clearly the heat transfer cannot be very efficient if the temperatures in the MSB can rise to 1000 °F. Common uncertainties in the coefficients of 20 to 50% (particularly with respect to thermal conductivity through coatings) can alter the calculations significantly.

IV. 2. Zinc-Steel Interactions

The melting point of zinc is 786 °F, or well below the anticipated temperatures inside the MSB. This raises a serious concern about liquid metal embrittlement. While such phenomena are not generally observed following the galvanizing process of steel, it must be recognized also that during galvanizing, steel is in contact with molten zinc for a very short time only. The exposure of steel at 800 °F to molten zinc over a period of years is totally uncharted territory and needs to be seriously investigated.

IV. 3. Zinc-Zircaloy Interactions

The continued integrity of the Zircaloy cladding over the 20 year licensing period is imperative if the fuel rods are to be unloaded any time in the future. In this context at least two issues need to be reviewed relating to stress corrosion cracking and liquid metal embrittlement. It has been reported (Ref. 14) that concentrated methanol and organic solvents containing small amounts of chloride can cause stress corrosion of zirconium. Generic specification of cleaning solvents should therefore not be permissible, since many such solvents either contain methanol, are chlorinated hydrocarbons, or contain chlorinated hydrocarbons.

Similarly, liquid metal embrittlement has been reported for zirconium in contact with molten cesium or when exposed to liquid sodium or cadmium. The effect of zinc metal in contact with Zircaloy at 800 to 1000 °F must therefore also be examined since zinc, like cadmium and mercury is also a 2b transition metal. Liquid embrittlement of metals by mercury is well known.

Most Zircaloys behave very similar to zirconium because the alloying constituents are present in the Zircaloy in small amounts only.

IV. 4. Performance of Steels at Low Temperatures

a. Manganese Steels: The generic specification of structural steels such as A-36 and A-516 is unsatisfactory from the point of view of cold temperature behavior. The embrittlement temperature is very dependent on the manganese content in the steel as well as on other alloying elements which are not included in the generic compositional specifications of these steels (Ref. 13). A-516, e.g., has a Mn spec of 0.8 to 1.2 %. In view of the fact that the NRC has specified a temperature 50 °F above the embrittlement temperature, efforts must be made to develop more precise specifications for the steels to be used in order to assure safe handling of the storage cask under all possible conditions including emergencies.

b. Welds: It is noted that no specifications relative to the embrittlement temperatures have been defined for welds. The absence of such specifications is considered very dangerous.

IV. 5. Residual Corrosion of the Zinc in the MSB and Resulting Pressure on Long Term Storage

It has been proposed that following closure of the MSB (welding of the seal lid) the water is drained from the inside of the basket. Complete drying is then attempted by a vacuum process. There appears to be no verification of the residual water which may remain in the basket. Such verification is essential in order to determine the pressures which might develop in the basket, particularly if these pressures need to be used in the evaluation of the structural integrity of the basket on long term storage.

Evaluated during certification

V. Summary

Some safety aspects of the Sierra Nuclear Fuel Storage System have been reviewed in the wake of Point Beach (Wisconsin Electric Power Company) hydrogen explosion. Both short term and long term concerns are discussed.

- The storage configuration allows for the fuel elements to be in contact with zinc (metal) primer which is applied to all internal steel surfaces of the MSB. This creates a galvanic element between the zinc and the Zircaloy which in turn accelerates the corrosion of the zinc. No tests have been performed simulating this galvanic situation. Calculations relating to the hydrogen evolution rate and the SFP water contamination rate, which are based on the available tests, have therefore little relevance.
- Numerous discrepancies in the responses submitted by the various companies to the NRC request for additional assessment of safety concerns reveal an alarming lack of consensus.
- The epoxy coating applied to the outside of the MSB cannot possibly withstand the temperatures said to develop on long term storage. This will result in an expensive SPF water contamination during unloading of the radioactive material.

- The NRC has published temperature specifications relating to low temperature embrittlement of the structural carbon steels used in the Sierra Nuclear spent fuel storage system. These specs have not been translated properly to the corresponding material composition specifications (for the steels in question), thereby creating additional hazards in handling the storage casks under possible emergency situations.
- The zinc-steel interaction at 800 to 1000 °F and possible steel embrittlement over a period of 20 years has not been considered, again creating a n additional hazard for handling the MSB in the future.
- Similarly, the effect (or the absence thereof) of molten zinc on Zircaloy has not been verified experimentally. The possible failure of the cladding could make unloading of the spent fuel rods impossible.
- The vacuum drying process does not seem to have been experimentally verified relative to residual water remaining in the MSB. All calculated data relating to pressure in the MSB during storage, and continued integrity of the seal welds are therefore open to questioning.
- None of the temperature calculations and heat transfer assessments have been experimentally verified. There has never been a field test of this storage system. It is not apparent that the storage system has been instrumented in order to verify the design assumptions.

Corro-Consulta

Rudolf H. Hausler

R.H. Hausler

APPENDIX I

Determination of pH of Boric acid solution:

Solution: Distilled water @ room temperature
Boron content 2850 ppm; 16,310 ppm boric acid; 0.264 mol/L boric acid
$(K_a)^1$ (boric acid) = 7.3×10^{-10}

Therefore:

$$7.3 \cdot 10^{-10} = \frac{[H^+] \cdot [H_2BO_3]}{[H_3BO_3]}$$

since: $$[H^+] = [H_2BO_3]$$

and $$[H^+]^2 = 7.3 \cdot 10^{-10} \cdot 0.264$$

$$pH = 4.86$$

APPENDIX II.

References:

1. *Safety Analysis Report* (SAR), October 1989; Section 3: Principal Cask Design Criteria

2. *Safety Evaluation Report* ; NRC March 29, 1991

3. *Safety Evaluation Report;* NRC April 1993

4. *Notice of Non-Conformance;* NRC, June 7 1996

5. *Initial Responses to CAL 4-96-002*; Entergy Operations, June 2, 1996

6. *Request for additional Information regarding Bulletin 96-04, "Chemical, Galvanic, or other Reactions in Spent Fuel Storage Casks"*, Letter from NRC to WEPCO 9/4/96

7. *SNC response to NRC Bulletin 96-04 for VSC-24 Dry fuel Storage System;* Sierra Nuclear Corp., August 16, 1996

8. *Use of Carbozinc Paint as a primer for the Multi-assembly Storage Basket*, Internal Memo, Wisconsin Electric Power, July 18 1995

9. *WEPCO response to NRC Bulletin 96-04 for VSC-24 Dry fuel Storage System;* WEPCO August 16, 1996

10. *Consumers Power response to NRC Bulletin 96-04 for VSC-24 Dry fuel Storage System: Galvanic, or other Reactions in Spent Fuel Storage and Transportation Cask;* August 19, 1996

11. *WEPCO response to NRC request for additional information relating to: Bulletin 96-04 for VSC-24 Dry fuel Storage System: Galvanic, or other Reactions in Spent Fuel Storage and Transportation Cask;* September 6 1996

12. *Non Proprietary Corrosion Inhibitors for Solvents to Clean Steam Generators*; R.H. Hausler, EPRI report NP 3030, 1983.

13. *Metals Handbook*; 9th Edition, Vol. 1, Properties and Selection of Irons and Steels, American Society for Metals, 1978, pg. 689

14. *Metals Handbook; Desk Edition;* American Society for Metals, 1985, pg. 20-35

Rudolf H. Hausler

7804 Pencross Lane • Dallas, Texas 75348

(214) 490-8605 or (806) 495-3808 Telephone • (214) 490-8878 or (806) 495-4035 Fax

SUMMARY

Over 20 years planned, conducted, and directed advanced chemical research focused on oil production and processing additives. Acquired expertise in corrosion prevention, inhibition and materials selection, failure analysis trouble shooting and economic analysis. Proficient in German, French and Italian.

EXPERIENCE

Mobil Oil Company (Dallas Research Center), Dallas, TX 1991-1995

Senior Engineering Advisor

Developed corrosion testing facilities for basic research and to meet specific oil field requirements.

- Planned and developed H_2S corrosion test facility.
- Planned safety and wrote safety manual.
- Developed unique continuous Flow-Through corrosion Test Facility (1.5 MM$).
- Developed test protocols and supervised operations of the FTTF.
- Extensive consultation with Affiliates on problem solving and chemical usage.
- Established supplier relationships and consulted with Affiliates on establishing Enhanced Supplier Relationships.
- Developed theory and practice of novel approach to autoclave testing.

Petrolite Corporation, St. Louis, MO 1979-1991

Research Associate (1986-1991)

Directed and conducted the development of novel corrosion inhibitors for extreme operating conditions.

- New corrosion inhibitor to combat erosion corrosion of carbon steel in gas condensate wells.
- Extensive studies on CO_2 corrosion aimed at establishing predictive corrosion model.

Special Assistant to Executive Vice President (1985-1987)

Special Assignments focused at supporting International Sales.

- Extensive travel to secure major accounts in Europe, Russia and East Asia.
- Monitored out-sourced R&D in Germany and England.

Senior Research Scientist (1979-1985)

- Developed novel chemical composition under contract with EPRI for corrosion inhibition of cleaning fluids used in nuclear steam generators and methodology of application (only effective formulation still used today).
- Developed unique corrosion model for CO_2 corrosion in oil and gas wells.
- Conducted numerous detailed field studies to establish case histories of chemical performance and applications technology.

Gordon Lab, Inc., Great Bend, KS 1976-1979

Technical Director

Responsible for all technical issues involving formulation, application and sales of stripper well production chemicals (corrosion, emulsion, scale, bacteria).

- Conducted failure analysis for customers and developed pertinent reports.
- Supervised service laboratory.
- Established technical training of sales and support personnel.
- Developed technical sales literature and company brochure.

UOP (Division of Signal Companies), Des Plaines, IL 1963-1976

Research Associate (1972-1976)
Associate Research Coordinator (1967-1972)
Research Chemist (1963-1967)

To conduct research in electrochemistry, analytical methods development, heat exchanger fouling processes and refinery process additives.

- Developed novel organic electrochemical synthesis procedure.
- Developed unique (patented) test apparatus for measuring anti-foulant activity.
- Introduced statistical design and evaluation of experiments to R&D department.
- Developed full 3 credit hour corrosion course to be taught at IIT and DeSoto Chemical company.
- Developed 20 hour course on statistics.

EDUCATION

Ph.D. Chemical Engineering, Swiss Federal Institute of Technology, Zurich, Switzerland
BS, MS Chemical Process Technology, Swiss Federal Institute of Technology, Zurich, Switzerland

PROFESSIONAL ASSOCIATIONS

American Chemical Society
The Electrochemical Society
Society of Petroleum Engineers
NACE International (Corrosion Engineers)
American Society of Metals (ASM)
Active in NACE on local, regional and national level

HONORS, AWARDS, RECOGNITIONS

17 patents, 55 publications and more than 100 technical presentations
NACE Technical Achievement Award (1990)
Registered Professional Engineer (Corrosion Branch, California)
NACE Certified Corrosion Specialist

PUBLICATIONS

1. ELECTROCHEMICAL PRINCIPLES IN CORROSION
   R. H. Hausler, Heating, Piping, Air Conditioning, 41. (#9) 11(1969)

2. THE USE OF STATISTICAL DESIGN AND ANALYSIS IN THE DEVELOPMENT OF A CORROSION INHIBITOR TEST
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3. CONTRIBUTION TO THE FILMING AMINE THEORY
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4. CONTRIBUTION TO THE MECHANISM OF HYDROGENSULFIDE CORROSION INHIBITION.
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5. CORROSION CONTROL IN CRUDE UNIT OVERHEAD SYSTEMS
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   R. H. Hausler, R. C. Kunzelman, Materials Protection and Performance, 11, (#11) 27 (1972).

7. PROCESS CORROSION AND CORROSION INHIBITORS IN THE PETROLEUM INDUSTRY
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8. FOULING STUDIES IN HYDROCARBON STREAMS IN THE PETROLEUM INDUSTRY
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9. FREE ENERGY AND ENERGY FUNCTIONS
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10. SYSTEMS APPROACH TO CORROSION ENGINEERING IN THE CHEMICAL INDUSTRY

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11. FOULING AND CORROSION IN FEED EFFLUENT EXCHANGER

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12. SOME CONSIDERATIONS REGARDING THE USE OF ELECTROCHEMICAL CORROSION MEASUREMENTS IN THE PRESENCE OF CORROSION PRODUCT LAYERS

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13. INSTRUMENT MEASURES PROCESS FOULING, ETC.

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14. CONTRIBUTION TO THE UNDERSTANDING OF FOULING PHENOMENA IN THE PETROLEUM INDUSTRY 16TH NATIONAL HEAT TRANSFER CONFERENCE

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16. CORROSION INHIBITION AND INHIBITORS

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17. ECONOMICS OF CORROSION CONTROL

R. H. Hausler, Materials Performance 17, (#6) 9, 1978

18. OIL TREATING CHEMICALS - EMULSIONS

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19. SCALING AND SCALE CONTROL IN OILFIELD BRINES

R. H. Hausler, Oil & Gas Journal, Sept. 18, 1978.

20. CORROSION INHIBITION AND GALVANIC COUPLES IN THE OILFIELD

R. H. Hausler, Paper presented NACE: CORROSION/79, Atlanta, Georgia, 1979, paper #17

21. PREVENTING SCALE AND EMULSION PROBLEMS IN OIL PRODUCTION
R. H. Hausler, Invited paper presented before the International Petroleum Exhibition, Tulsa, Oklahoma, Sept. 1979

22. CORROSION MONITORING IN CHEMICAL CLEANING SOLUTIONS
R. H. Hausler, J. M. Jevec, W. S. Leedy; NACE: Corrosion/83 1983 Paper No. 227 p. 13.

23. LABORATORY INVESTIGATIONS OF THE CORROSION MECHANISM AS APPLIED TO HOT DEEP GAS WELLS
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24. THE COPRA CORRELATION - A QUANTITATIVE ASSESSMENT OF DEEP HOT GAS WELL CORROSION AND ITS CONTROL
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25. THE ROLE OF HYDRAZINE IN EDTA CONTAINING CHEMICAL CLEANING SOLVENTS
R. H. Hausler; NACE: Corrosion/82 1982 Paper No. 30, 12 p.

26. CORROSIVENESS OF EDTA CHEMICAL CLEANING SOLUTION
R. H. Hausler, A. L. Savage; NACE: Corrosion/82 1982 Paper No. 31, 15 p.

27. INHIBITION OF CORROSION REACTION BY CORROSION PRODUCT LAYERS OF TYPE METAL ION CHELATING AGENTS
R. H. Hausler; NACE: Corrosion/81, 1981 Paper No. 252, 17 p.

28. CORROSION INHIBITION AND GALVANIC COUPLES IN THE OILFIELD
R. H. Hausler, NACE: Corrosion/79 1979 Paper No. 17

29. NONPROPRIETARY CORROSION INHIBITORS FOR SOLVENTS TO CLEAN STEAM GENERATORS
R. H. hausler, EPRI Final Report (346 pp) #NP-3030), Project S-148, June 1983.

30. THE IMPORTANCE OF THE INTERPHASE IN THE CONTROL OF CORROSION IN EDTA SOLUTIONS
R. H. Hausler, Presented before the International Conference on Corrosion Inhibition, NACE May 1983, published in CORROSION INHIBITION, NACE-7, p. 132 (1988).

39. STUDIES RELATING TO THE PREDICTIVENESS OF CORROSION INHIBITOR EVALUATIONS IN LABORATORY AND FIELD ENVIRONMENTS
R. H. Hausler, D. W. Stegmann, EUROPEC/88, London, SPE paper #18369, 1988, accepted for publication in Petroleum Production Engineering, 1990.

40. LABORATORY STUDIES ON FLOW INDUCED LOCALIZED CORROSION IN CO_2/H_2S ENVIRONMENTS, I. DEVELOPMENT OF TEST METHODOLOGY
D. W. Stegmann, R. Hausler, C. I. Cruz, H. Sutanto, presented at 6th Asian Pacific Corrosion Control Conference, Singapore, September 1989; also accepted for CORROSION/90, NACE 1990, paper #90005.

41. LABORATORY STUDIES ON FLOW INDUCED LOCALIZED CORROSION IN CO_2H_2S ENVIRONMENTS, II. PARAMETRIC STUDIES ON THE EFFECTS OF H_2S, CONDENSATE, METALLURGY AND FLOWRATE.
R. H. Hausler, D. W. Stegmann, C. I. Cruz, D. Tjandroso, ibid.

42. LABORATORY STUDIES ON FLOW INDUCED LOCALIZED CORROSION IN CO_2/H_2S ENVIRONMENTS, III. CHEMICAL CORROSION INHIBITION
R. H. Hausler, D. W. Stegmann, C. I. Cruz, D. Tjandroso, ibid.

43. THE COPRA CORRELATION REVISITED
R. H. Hausler, T. D. Garber, accepted for presentation at CORROSION/90, NACE 1990, paper #90045.

44. CO_2 CORROSION AND ITS INHIBITION UNDER EXTREME SHEAR STRESS
G. Schmitt, T. Simon, R. H. Hausler, accepted for presentation at CORROSION/90, NACE 1990 paper #90022.

45. CHEMICAL INHIBITION OF FLOW INDUCED LOCALIZED CORROSION IN CO_2 CONTAINING MEDIA
R. H. Hausler, D. W. Stegmann, Proceedings of the 7th European Symposium on Corrosion Inhibitors, p. 1247, 1990, Ferrara, Italy, Sept. 1990.

46. INTERPRETATION OF LINEAR POLARIZATION MEASUREMENTS
(Discussion Contribution) DECHEMA Monograph, Vol. 101, Electrochemical Corrosion Testing, p. 109-114, 1986.

BOOKS

1. CORROSION IN OIL AND GAS PRODUCTION
   L. E. Newton, R. H. Hausler, NACE, Houston, TX. 1983.

2. ADVANCES IN CO_2 CORROSION VOL. 1
   R. H. Hausler, H. L. Godard, NACE, July 1985.

3. CORROSION INHIBITION
   R. H. Hausler, NACE-7, 1988.

AWARDS AND RECOGNITION

1. NACE Technical Achievement Award, May, 1990.

2. Plenary Lecture, 6th Asian Pacific Corrosion Control Conference, Singapore, Sept. 1989.

3. Plenary Lecture, 7th European Symposium on Corrosion Inhibitors, Ferrara Italy, Sept. 1990.

4. Plenary Lecture, 5th Middle East Corrosion Conference, Bahrain, Jan. 1991.

PAPERS PRESENTED BEFORE TECHNICAL MEETINGS

by R. H. Hausler

1. Corrosion in H_2S Containing Media, before the NACE, T8-2 Committee, January, 1970.

2. Corrosion and Corrosion Inhibition in H_2S and Cl^- Containing Media, before the Montreal, Canada, Section of the NACE, December 8, 1970.

3. Time Effects on Polarization Measurements, before the Chicago Section of the NACE, May 18, 1971.

4. Rust Inhibition and Inhibitor Testing, before the North Central-Northeast NACE Regional Conference, October 16-18, 1972.

5. Process Side Fouling of Heat Exchangers, before the NACE T8-2 Committee, Chicago, March 8, 1973.

6. On the Mechanism of Hydrochloric Acid Inhibition by Organic Molecules; Presented at the Gordon Research Conference on Corrosion, July 1974.

7. On the Mechanism of Corrosion Inhibition by Organic Chemicals before the Chicago Section of the Electrochemical Society, January 9, 1975.

8. Seminar on Corrosion and Fouling in the Petroleum Industry. Full day seminar given before the engineers of the Peruvian Petroleum Company (Petroperu) upon invitation, June 22, 1975, Lima, Peru.

9. Linear Polarization Technique, Paper presented before NACE-Corrosion/76, Houston, Texas, March 22-26, 1976.

10. Corrosion Inhibition. Presented as ACS/NACE/ECS sponsored short course on Chemistry in Corrosion, Chicago, February 24, 1976.

11. Corrosion Inhibitors and Sulfide Corrosion, presented before the NACE Western Kansas Section, Great Bend, KS., May 7, 1976.

12. Cooling Water Treatment, Presented before the first annual Corrosion Control Seminar Sponsored by the Kansas Section of the NACE, November 9, 1977, Great Bend, KS.

13. Economics of Corrosion Control, Dinner Talk before the first annual Corrosion Control Seminar sponsored by the NACE Great Bend, KS. Section.

14. Corrosion Inhibition and Galvanic Couples in the Oilfield, NACE North Central Regional Meeting, October 19-21, (1981).

15. Mechanism of Corrosion Inhibition with Reference to Automotive Coolants, NACE North Central Regional Meeting, Octo er 19-21 (1981).

16. CO_2 Corrosion in the Oil and Gas Production, and Overview, NACE South Central Regional Meeting, Oklahoma City, October, 1983.

17. CO_2 Corrosion in Oil and Gas Production, An Overview, presented before the Corrosion Center of the University of Manchester Institute of Technology, July 4, 1985.

18. New Mechanism for Pitting of Carbon Steel in Inhibited Hydrochloric Acid, presented before the faculty of the Materials Engineering Department of the University of Ferrara, June 24, 1985.

19. Metallurgical Effects on Corrosion Inhibition, presented before the faculty of the Corrosion Center of the Institute for Technical Chemistry and Petroleum Chemistry at the University of Aachen, June 28 (1985).

20. CO_2 Corrosion and Prevention. Formal seminar presentation at NAM-Assen (Holland) June 20 (1985).

21. Systems Approach to Corrosion Engineering as Applied to Oil and Gas Production, presented before the ALL-Union Union Oil Institute, Krasnodar, Russia, June 1985.

22. The Effect of Ohmic Resistance on Linear Polarization Measurements for Corrosion Rate Determination, presented before the NACE Chicago Section, October, 1973.

23. Corrosion Monitoring in Sweet Production, NACE, Canadian Region Western Conference, Calgary, Febr. 25 (1986).

24. Overview of the CO_2 Corrosion Mechanism and Inhibition of Erosion Corrosion, NACE South Central Region Committee, Lafayette, Nov. 16-18, 1987.

25. Novel Approach Toward Assessing Inhibitor Cost for CO_2 Corrosion: Example of a CO_2 Flood, ibid.

26. Systems Approach to Corrosion Inhibition of Gas and Gas Condensate Producing Facilities, Gulf Coast Corrosion Seminar Febr. 1987.

27. Predicting Corrosion Inhibitor Performance - Laboratory Evaluations vs. Field Performance, New Orleans NACE Section Meeting, Jan. 22, 1990.

PATENTS

USP 3 790 496	R. H. Hausler;	Alkylene Polyamine Polymeric Reaction Product Corrosion Inhibitor
USP 3 609 549	R. H. Hausler,	R. W. Sampson; Corrosion Measuring Device
USP 3 810 009	R. H. Hausler,	R. W. Sampson; Apparatus for Measuring Fouling of a Test Specimen
USP 3 731 187	R. H. Hausler,	R. W. Sampson; Temperature Compensated Fouling Measuring Method and Apparatus
USP 3 705 109	R. H. Hausler,	L. A. Goeller; Corrosion Inhibiting Composition and Use Thereof
USP 3 622 503	R. H. Hausler;	Hydrogen Transfer Agent for Slurry Processing of Hydrocarbonaceous Black Oil
USP 3 562 138	R. H. Hausler;	Structural Element for Use in an Electrolytic Cell
Swiss Patent 4393/62	V. Spreter,	R. H. Hausler; Electrode pour Element Galvanique
USP 3 696 049	R. H. Hausler,	L. A. Goeller; Corrosion Inhibiting Composition and use Thereof
USP 3 696 048	R. H. Hausler,	L. A. Goeller; Corrosion Inhibiting Composition and use Thereof
USP 3881 957	R. H. Hausler;	Electrochemical Cell Comprising a Catalytic Electrode of a Refractory Oxide and a Carbonaceous Pyropolymer
USP 3 913 378	R. H. Hausler;	Apparatus for Measuring Fouling on Metal Surfaces
USP 3 923 606	R. H. Hausler;	Prevention of Corrosion
USP 3 972 732	R. H. Hausler;	Electrochemical Cell
USP 4 454 006	R. H. Hausler,	L. Savage, J. B. Harrell; Method and apparatus for Measuring Total Corrosion Rate

USP 4 495 336	R. H. Hausler,	N.E.S. Thompson; Mercapto-Polycarboxylic Acids
EP 027 5651	R. H. Hausler,	B. A. Alink, M. E. Johns, D. W. Stegmann; Carbondioxide Corrosion Inhibiting Composition and Method of Use Thereof.
EP 927 5646	R. H. Hausler,	Carbon Dioxide Corrosion Inhibiting Composition and Method of Use Thereof.

EDUCATIONAL LECTURES

by R. H. Hausler

1. Electrochemistry - a Modern Challenge: presented December 1966 to Science Seminar at Taylor University, Marion, Indiana. February 1970, to Science Seminar of the ACS Student Affiliate Chapter at University of Illinois, Circle Campus, Chicago.

2. Corrosion-5 Billion Dollar Business, presented to an advanced Science Class as Hillcrest High School, Country Club Hills, Illinois, December 13, 1972.

3. Discussion on Cathodic Protection, together with Harry E. Kroon of Illinois Bell Telephone, presented at an Educational Seminar of the Chicago Section, NACE, May 1970.

4. Application of Potentiostatic Techniques in Corrosion Research, presented at an Educational Seminar of the Chicago Section, NACE, October 24, 1970.

5. Electrical Methods for Determining Corrosion Rates, at the 4th Annual Seminar on Fundamentals of Corrosion, Milwaukee School of Engineering, November 23, 1971.

6. Organic Corrosion Inhibitors and,

7. Corrosion Prevention in the Chemical Process Industry, both presented at the Summer Engineering Conference on Corrosion Engineering, University of Michigan, Ann Arbor Michigan, June 19-23, 1972, published in the Proceedings.

8. Chemistry of Corrosion, course taught at the Illinois Institute of Technology, Evening Division (Chem 544), 3 credit hours, Jan-May, 1975.

9. Chemistry of Corrosion, course taught for DeSoto, Inc. Research Centre, started Nov. 1975, 15 2-hour lectures.

10. Statistical Design and Evaluation of Experiment, 20 2-hour lectures with examples and applications presented in-house at UOP.

11. Corrosion Engineering, (Course based on MIT Video Tapes), organized 20 seminars at Petrolite and 1/2 hour discussion sessions following review of tapes.

CONTINUED PROFESSIONAL EDUCATION

1. Short Course on Corrosion, University of California Extension, Los Angeles, June 26-30, 1967,.

2. Short Course on Statistical Design and Evaluation of Experiments, University of Detroit, Summer 1966.

3. Engineering Summer Short Course on Statistical Experimental Design, University of Wisconsin Extension, Madison Wisc. June 24-28, 1968.

4. Evolutionary Operations and Non-Linear Estimating, Short Course, Chicago, 1967.

5. R&D and New Venture Management, University of Wisconsin Extension, Madison, Wisconsin, May 15-16, 1969.

6. Industrial Research Institute, Mid-Management Groups Seminar, New York, October 28-30, 1973.

7. Gordon Research Conferences: Electrochemistry 1965, 1966, 1967, 1968; Corrosion 1969, 1971, 1973.

8. Two Phase Gas-Liquid Flow, University of Houston, February 22-26, (1982).

PROFESSIONAL ACTIVITIES

THE ELECTROCHEMICAL SOCIETY

Member since 1964

• Chicago Section	Secretary	1964-1965
	Treasurer	1966-1967
	Vice-Chairman	1966-1967
	Chairman	1967-1968
	Councilor	1972-1976
• National Meeting 1968	Co-Treasurer	
• National Meeting 1973	Hospitality Chairman	

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Member since 1968

• Chicago Section	Treasurer	1971-1973
	Vice-Chairman	1973-1974
	Chairman	1974-1976
• National Meeting 1974	General Chairman	
• North Central Region	Program Chairman Regional Meeting	1972
	Education Chairman	1982-1985
• Unit Committee T-3A	Chairman	1973-1975
• Research Committee	Member	1975-1978
	Vice-Chairman	1983-1984
	Liaison Education Committee	1982-1984
	Liaison TPC	1981-1983
• Education Committee	Member	1983-1985
• Awards Committee	Member	1984-1986

- Group Committee T-1 | Member 1976-
  Vice Chairman
  T-1-3 1981-1984
  Various T-1 Unit Committees and Task Groups

- Organized numerous conferences, among others:

  - International Conference on Corrosion Inhibition, Dallas, 1983

  - International Symposium on CO_2 Corrosion, Los Angeles, 1983

- Co-Editor Advances in Corrosion Inhibition (in preparation).

<u>THE CHICAGO TECHNICAL SOCIETIES COUNCIL</u>

Member 1968

Treasurer	1970-1972
Vice-Chairman	1972-1974
Chairman	1974-1975
Awards Jury	1970-1976