May 27, 2008

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
Entergy Nuclear Generation Co. and	)	
Entergy Nuclear Operations, Inc.	)	Docket No. 50-293-LR
	)	
	)	ASLBP No. 06-848-02-LR
(Pilgrim Nuclear Power Station)	)	

NRC STAFF RESPONSE IN OPPOSITION TO (1) PILGRIM WATCH MOTION TO STRIKE TESTIMONY and (2) MOTION TO INCLUDE AS PART OF THE RECORD EXHIBITS ATTACHED TO PILGRIM WATCH MOTION TO STRIKE TESTIMONY

INTRODUCTION

Pursuant to 10 C.F.R. §§ 2.323(c) and 2.1204(a), the staff of the Nuclear Regulatory Commission ("Staff") hereby files it response to Pilgrim Watch Motion to Strike Incorrect and Misleading Testimony from the Record ("Motion"), filed May 15, 2008, and Pilgrim Watch Motion to Include as Part of the Record Exhibits Attached to Pilgrim Watch Motion to Strike Incorrect and Misleading Testimony from the Record ("Exhibit Motion"), filed May 27, 2008. For the reasons stated below, the Staff opposes both motions.[1] The Staff's response is supported by the affidavit of James A. Davis, PhD, attached hereto.

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[1] On May 27, 2008, the Staff was served with the Exhibit Motion. The Staff opposes that motion based on the same reasons discussed in the instant response. In addition to the reasons cited in this response, none of the exhibits Pilgrim Watch seeks to enter into evidence are admissible. Neither the letter signed by Mr. Fitzgerald nor the e-mails from the various employees/owners of cathodic protection companies rise to the level of affidavit or testimony, in that they are not under oath or affirmation. Moreover, none of the exhibits are admissible because the other parties were not given an opportunity to rebut the assertions made therein, and the proponents were not produced at hearing and made available for examination by the Board.

(continued. . .)

BACKGROUND

In the Motion, Pilgrim Watch requests that certain Staff and Applicant testimony given on April 10, 2008, at the hearing on this matter be stricken because it is "either inaccurate, incomplete or . . . misleading." Motion at 1. In the alternative, Pilgrim Watch requests that the hearing be reopened. *Id.* Pilgrim Watch states that the testimony could "materially affect" the Atomic Safety and Licensing Board's ("ASLB") decision. *Id.* Specifically, Pilgrim Watch alleges that testimony presented by Entergy regarding the cured in place liner (CIPP) was misleading and inaccurate, and attaches a paper written by a representative of the vendor that installed the liner as evidence of Entergy's alleged perfidy.[2] Pilgrim Watch also seeks to strike Entergy's testimony regarding pipe coatings. *Id.* at 7-8. Finally, Pilgrim Watch seeks to strike the testimony of Staff expert Dr. James A. Davis regarding cathodic protection as incorrect and

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(. . .continued)

Pilgrim Watch asserts in the Exhibit Motion that the hearing has not been closed. Exhibit Motion at 1. Apparently, based on that conclusion, Pilgrim Watch believes that it has carte blanche to supplement the record at will. The Staff submits that Pilgrim Watch is mistaken. While it is true that, technically, the record is open, when the Board decided to keep the hearing open at the close of the April 10th evidentiary hearing, it was for the sole purpose of compliance with the First Circuit's decision in the *Massachusetts v. NRC* case. *See Massachusetts v. NRC*, Nos. 07-1482, 07-1483 (1st Cir. Apr. 8, 2008). As the Board stated in its May 12, 2008 Order (Setting Deadlines for Provisional Proposed Findings and Conclusions on Contention 1 and for Pleadings to Pilgrim Watch's Recent Motion Regarding CUFs), the hearing was not closed just in case a need for further findings should arise "based on the current stay or related activities." Order at 3. The hearing was held open to accommodate any action taken by the Massachusetts Attorney General to enter this case as an interested state. Thus, any attempt by Pilgrim Watch to supplement the record is not "appropriate or necessary", *Id.,* and should not be permitted. The Staff also notes that the Commission has instructed the Board to close the record. *See* Memorandum and Order, CLI-08-09, 67 NRC __, slip op. at 5 (May 16, 2008). Furthermore, the Commission acknowledged that the stay was solely for the purpose of preventing "the adjudication to reach a point where it would no longer allow Massachusetts to seek participant status and request a suspension of the proceedings." *Id.* at 3-4.

[2] *Id.* at 2, citing Raymer, Jonathan, *Pilgrim Nuclear Power Station: Salt Service Water Discharge Piping Trenchless Rehabilitation Challenges*, presented to the North American Society for Trenchless Technology, March 2004 ("NASTT Paper").

misleading. *Id.* at 8-16. As support for that request, Pilgrim Watch relies on a letter from John Henry Fitzgerald and e-mails from several cathodic protection company employees or owners.

As discussed more fully below, the Staff opposes the Motion on the grounds that the information in the Motion is inexcusably late in that it was not produced at the hearing or in prefiled testimony and rebuttal testimony and the Motion is a thinly veiled attempt to enter into evidence information that should have been presented prior to or at hearing. Second, Pilgrim Watch has failed to demonstrate why the objection to Entergy's testimony regarding the pipe coatings should not be considered waived since it was not made at the time the testimony was presented. Third, the information presented regarding cathodic protection is not relevant or material to the decision that the Board must make in this matter: *i.e.*, whether the aging management program ("AMP") for the underground pipes that may contain radioactive liquid is adequate. Fourth, to the extent that it is a Motion to reopen the record,[3] it fails to meet the criteria for reopening the record. Finally, the information is incompetent as evidence.

The Staff also opposes the Exhibit Motion, which requests that the exhibits filed with the Motion be admitted into evidence, for the same reasons.

DISCUSSION

Pilgrim Watch seeks to strike testimony that it claims is incorrect, incomplete or misleading.

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[3] Although the Board left the record open at the close of the hearing on April 10, 2008, as explained in footnote 1, above, the record was kept open for the sole purpose of complying with the First Circuit's direction in *Massachusetts v. NRC.* It should be considered closed for all other purposes and motions to supplement the record or "open" the record, should be required to meet criteria for reopening the record.

A. <u>The Motion is Untimely</u>

In support of its Motion, Pilgrim Watch submitted the 2004 NASTT Paper, e-mails from owners or employees of cathodic protection companies, and a letter and curriculum vitae (CV) from John H. Ftizgerald, III. *See* Motion and attachments thereto. The NASTT Paper was submitted in support of the Motion as it pertains to testimony regarding the CIPP liner. The e-mails, letter and CV were submitted to support the claims regarding the testimony relating to cathodic protection.

The NASTT Paper was presented in March 2004. Yet Pilgrim Watch provides no explanation why it was not produced in its case-in-chief or in rebuttal. A petitioner in an NRC proceeding has an "ironclad obligation" to examine publicly available evidence in support of its contention. *See Duke Energy Corp.* (Oconee Nuclear Station, Units 1, 2, & 3), CLI-99-11, 49 NRC 328, 338 (1999). It was, therefore, incumbent on Pilgrim Watch to search for publicly available evidence that supported its contention. Clearly, the document was available on the NASTT website. See Motion at 2 n.2. Moreover, it was no surprise that much of the testimony at the hearing concerned the pipe lining. It was apparent from the contention, the disclosures, the prefiled testimony, and the Board's various orders that the condition of the piping was a major area of consideration in this case. Therefore, Pilgrim Watch cannot, and has not, claimed that it could not anticipate that there would be testimony regarding the installation of the CIPP liner. In fact, the issue was discussed in Pilgrim Watch's prefiled testimony. Pilgrim Watch should have been prepared in its testimony and at hearing to address Entergy's testimony regarding the CIPP liner. It was not, and it should not be heard now to complain that its failure to effectively challenge Entergy's testimony was somehow Entergy's fault for not supplying a document that was in the public domain and may not have been in Entergy's possession. Therefore, the motion to strike Entergy's testimony regarding the CIPP should be denied.

Pilgrim Watch also seeks to strike Entergy's testimony regarding coatings, based upon an asserted contradiction between the testimony and an exhibit. *Id.* at 7-8. Objections to evidence must be made in a timely fashion and failure to object essentially bars later objection. *See, e.g., Florida Power & Light Co.* (St. Lucie Nuclear Power Plant, Unit 2), ALAB-335, 3 NRC 830, 842 n.26 (1976). Because Pilgrim Watch did not move to strike during the hearing, it has effectively waived its right to object to the testimony. Therefore, the motion to strike should be denied as to the coatings testimony.

Finally, Pilgrim Watch wants Dr. Davis' testimony regarding cathodic protection to be stricken. *Id.* at 7-16. The request is based on information Pilgrim sought and received *after* the evidentiary hearing in this matter.[4] Yet, Pilgrim Watch offers no reason why this information was not obtained in a timely manner and offered in its case-in-chief, its rebuttal, or even at the hearing. Again, it could come as no surprise that the issue of cathodic protection, an issue first raised by Pilgrim Watch in its initial statement of position and pre-filed testimony,[5] would be addressed at hearing. In fact the issue was raised again at the hearing by Mr. Gundersen, Pilgrim Watch's witness.[6] Thus, Pilgrim Watch should have been prepared to address any issues regarding cathodic protection at the hearing. It should not be permitted to return after the hearing is over and present evidence that it should have presented, at the very latest, at the

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[4] *See* Motion at 9-15 and exhibits 2,3. Exhibit 3 contains e-mails from Pilgrim Watch's representative, Mary Lampert to various cathodic protection companies. All of the e-mails from Ms. Lampert are dated May 5, 2008, some 25 days post-hearing. Exhibit 2, the letter from Mr. Fitzgerald is dated May 12.

[5] *See* Pilgrim Watch Presents Statements of Position, Direct Testimony and Exhibits Under 10 CFR 2.1207 [Modified Per Request ASLB Order of February 21, 2008, section c, page 2] at 42-43, 64, 66, 69, 84, Exhibit 1, Declaration of Arnold Gundersen Supporting Pilgrim Watch's Petition for Contention 1 at 5, 8, 9, 13, 19.

[6] *See* Transcript of the April 10, 2008 hearing ("T") at 761, line 11 to 763, line 6.

hearing. Pilgrim Watch did not fulfill its "ironclad obligation" to examine publicly available evidence in support of its contention. *See Oconee*, CLI-99-11, 49 NRC at 338.

Moreover, pursuant to 10 C.F.R. §§ 2.1204 and 2.323, motions must be filed within ten days of the occurrence of the event or circumstances giving rise to the motion. Much of the testimony Pilgrim Watch seeks to strike was filed in March, 2008, and the remaining testimony was given at the hearing on April 10, 3008. The information that Pilgrim Watch filed in support of the Motion was available and attainable well before the filing of testimony and the hearing. Thus, the Motion is untimely because it was not filed within ten days of the testimony or within ten days of the supporting documentation becoming available.

In sum, the objections raised by Pilgrim Watch in its Motion are untimely and are based on information obtained in an untimely manner. Therefore, the Motion and the Exhibit Motion should be denied.

B. Information Concerning Cathodic Protection is not Relevant or Material to the Issue to be Decided

Pilgrim Watch claims that the alleged inaccurate testimony regarding cathodic protection "could materially affect" the Board's decision. Motion at 1. The Staff disagrees. The issue to be decided in this case is whether the Aging Management Program ("AMP") for buried piping and tanks that may contain radioactive water is adequate.[7] Since cathodic protection is not

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[7] *See, e.g.,* Order (Denying Pilgrim Watch Motion for Reconsideration) at 6-7 (Jan. 11, 2008) (The determination that the Agency must make is "whether or not the Applicant has programs and procedures in place which enable it to determine whether buried pipes and tanks containing radioactive fluids are able to satisfy their intended safety functions despite leaks - i.e. to determine that there are not leaks at such great rates so as to cause those pipes or tanks to fail to satisfy those safety functions. The programs and procedures of the Applicant which enable it to make that determination are within the sole discretion of the Applicant, although they must ultimately satisfy the Agency's requirements. Thus it is erroneous to assert that information regarding monitoring wells, or any other particular widget, is relevant to this hearing unless the Applicant expressly determines it intends to utilize such wells or widgets to make the subject determination.") *See also* Memorandum and Order (Ruling on Entergy's Motion for Summary Disposition of Pilgrim Watch Contention 1, Regarding Adequacy of Aging Management (continued. . .)

being credited in the AMP for the piping, information regarding cathodic protection is not relevant to the Board's decision whether the AMP is adequate as written. Nor is cathodic protection required by the Commission's regulations. Therefore, evidence about cathodic protection is not material or relevant to the Board's decision, and the motion to strike Dr. Davis' testimony should be denied.

In addition to its immateriality, the information in the Motion is incorrect, as demonstrated in the affidavit of Dr. James A. Davis, attached hereto, or it is based on a misunderstanding of Dr. Davis' testimony. The Staff submits that it is highly unlikely that the new information could have an effect on the decision of the Board. Thus, the Motion and the Exhibit Motion should be denied.

C. The Exhibits Appended to the Motion are Inadmissible as Evidence

In support of the Motion and the Exhibit Motion, Pilgrim Watch submitted: a paper given at a conference, a letter, and several e-mails. None of the exhibits are sworn or attested to. The paper is not sponsored or certified to be accurate or complete. The exhibits are, therefore inadmissible as evidence. Pursuant to 10 C.F.R. § 2.1207, written testimony (in this case, the letter and e-mails) is required to be supported by affidavits. 10 C.F.R. § 2.1207(a)(1). *See also*

(. . .continued)

Program for Buried Pipes and Tanks and Potential Need for Monitoring Wells to Supplement Program) at 18 (Oct. 17, 2007) ("the only issue remaining before this Licensing Board regarding Contention 1 is whether or not monitoring wells are necessary to assure that the buried pipes and tanks at issue will continue to perform their safety function during the license renewal period — or, put another way, whether Pilgrim's existing AMPs have elements that provide appropriate assurance as required under relevant NRC regulations that the buried pipes and tanks will not develop leaks so great as to cause those pipes and tanks to be unable to perform their intended safety functions."); Order (Revising Schedule for Evidentiary Hearing and Responding to Pilgrim Watch's December 14 and 15 Motions) at 1 (Dec. 19, 2007) ("only challenges to errors or omissions from the Applicant's Aging Management Program (AMP) are properly within the scope [of the contention]. The single admitted contention relates to whether or not Applicant's AMPs are sufficient to enable it to determine whether or not certain buried pipes and tanks are leaking at such great rates that they cannot satisfy their respective intended safety functions.").

10 C.F.R. § 2.326. Exhibits submitted in support of motions filed under § 2.323 should also be in the form of evidence, and exhibits that contain assertions by witnesses should be in affidavit form. *See* 10 C.F.R. § 2.323(b) (motions are to accompanied by "affidavits or other *evidence* relied on.").

Pilgrim Watch's exhibits fail to meet any criteria for admissibility. Therefore the Motion and the Exhibit Motion should be denied.

D. Pilgrim Watch's Motion Does Not Satisfy the Commission's Requirements for Reopening the Record

Pilgrim Watch is also requesting that, in the alternative, the Board reopen the record. While the Staff acknowledges that the evidentiary record is technically "open", as explained in footnotes 1 and 3 of this response, it is open only for compliance with the First Circuit's direction regarding any request by the Massachusetts Attorney General to participate as an interested state. As to additional testimony or evidence from Pilgrim Watch regarding Contention 1, it should be considered closed. Consequently, Pilgrim Watch should be required to meet the criteria for reopening the record, pursuant to 10 C.F.R. § 2.326.[8]

Pilgrim Watch has failed to meet a number of the requirements it must satisfy in order to reopen the record in this proceeding and gain admission of the additional information. Pursuant to 10 C.F.R. § 2.326(a), a motion to reopen a closed record to consider additional evidence will not be granted unless *all* of the following criteria are satisfied:

> (1) The motion must be timely, except that an exceptionally grave issue may be considered in the discretion of the presiding officer even if untimely presented.

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[8] Considering the Commission's rationale in CLI-08-09 in ordering the Board to close the record, there is a question as to whether the record should have been closed on April 10th at the close of the hearing. Therefore, Pilgrim Watch should be required to meet the criteria for reopening the record. *See Texas Utilities Elec. Co.* (Comanche Peak Steam Elec. Station, Units 1 and 2), LBP-84-10, 19 NRC 509, 530 n.64 (1984).

> (2) The motion must address a significant safety issue.
>
> (3) The motion must demonstrate that a materially different result would be or would have been likely had the newly proffered evidence been considered initially.

10 C.F.R. § 2.326(a). *See also Pacific Gas & Electric Co.* (Diablo Canyon Nuclear Power Plant, Units 1 & 2), LBP-94-35, 40 NRC 180 (1994).

In addition to the standards of 10 C.F.R. § 2.326(a), the motion must be accompanied by one or more affidavits—given by "competent individuals with knowledge of the facts alleged" or by experts in the appropriate disciplines—which set forth the factual or technical bases, or both, for the movant's claims. 10 C.F.R. § 2.326(b). *See also Public Service Co. of New Hampshire* (Seabrook Station, Units 1 & 2), LBP-89-38, 30 NRC 725, 734 (1989), *aff'd on other grounds*, ALAB-949, 33 NRC 484 (1991). The new material in support of a motion to reopen must be set forth with a degree of particularity in excess of the basis and specificity requirements contained in 10 C.F.R. § 2.309(f) for admissible contentions. *See Pacific Gas and Electric Co.* (Diablo Canyon Nuclear Power Plant, Units 1 & 2), ALAB-775, 19 NRC 1361, 1366 (1984), *aff'd sub. nom. San Luis Obispo Mothers for Peace v. NRC*, 751 F.2d 1287 (D.C. Cir. 1984), *aff'd on reh'g en banc*, 789 F.2d 26 (1986). Furthermore, the supporting information must be more than a mere allegation; it must be tantamount to evidence. *See id.; Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 and 4), LBP-87-21, 25 NRC 958, 963 (1987). To satisfy this requirement, it must possess the attributes set forth in 10 C.F.R. § 2.337(a), which defines admissible evidence as "relevant, material, and reliable." *Diablo Canyon*, ALAB-775, 19 NRC at 1366-67.

As the Commission has recognized, these reopening requirements pose a "stiff test" for parties seeking to reopen closed adjudicatory records. *Private Fuel Storage, LLC* (Independent Spent Fuel Storage Installation), CLI-06-03, 63 NRC 19, 25 (2006). Indeed, this "heavy burden" created by the regulations is intentional. *See* Criteria for Reopening Records in Formal Licensing Proceedings (Final Rule), 51 Fed. Reg. 19,535, 19,538 (May 30, 1986). The Licensing Boards and the Atomic Safety and Licensing Appeal Board ("Appeal Board") have also noted that the reopening requirements apply to all issues for which reopening is sought, meaning that the reopened record is open solely to those matters which have been found to satisfy the § 2.326 reopening requirements. *Houston Lighting and Power Co.* (South Texas Project, Units 1 and 2), LBP-85-19, 21 NRC 1707, 1720 (1985) (*citing Metropolitan Edison Co.* (Three Mile Island Nuclear Station, Unit 2), ALAB-486, 8 NRC 9, 22 (1978)).[9]

The burden is on the moving party to meet the standards for reopening, and "the movant is not entitled to engage in discovery in order to support a motion to reopen." *Metropolitan Edison Co.* (Three Mile Island Nuclear Station, Unit 1), CLI-85-7, 21 NRC 1104, 1106 (1985).

1. <u>Pilgrim Watch's Motion does not address a significant safety issue</u>

Pilgrim Watch's Motion does not satisfy the requirements set forth in 10 C.F.R. § 2.326(b), because the Motion is not accompanied by affidavits setting forth factual or technical bases that would demonstrate that the issue raised is a significant safety issue. The "most important of the three [§ 2.326(a) elements]" to be addressed is that the motion raises a safety (or environmental) issue that is <u>significant.</u> *Public Service Company of New Hampshire* (Seabrook Station, Units 1 and 2), ALAB-940, 32 NRC 225, 243-44 (1990).[10] Pilgrim Watch's failure to make this demonstration via affidavit or otherwise necessitates denial of their Motion.

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[9] Thus, if the Board grants this motion, the record would only be reopened to allow additional evidence on the issues raised by Pilgrim Watch's Motion. If Pilgrim Watch sought to raise any other issues, they would have to satisfy § 2.326 as to those issues as well.

[10] This case interpreted the former 10 C.F.R. § 2.734, which contained the same three factors, in substantially identical form, that are now found at 10 C.F.R. § 2.326(a). The only difference between the two sets of factors is a minor grammatical change that broke up the one-sentence-long 10 C.F.R. § (continued. . .)

The supporting documentation provided by Pilgrim Watch - the NASTT Paper, the Fitzgerald Letter and the e-mails from employees and owners of cathodic protection companies - never explain the safety significance of the issues raised. In fact, the only claim that is made in Pilgrim Watch's entire pleading is that the challenged testimony is "inaccurate, incomplete or gave a misleading impression." Motion at 1. The supporting documentation accompanying the Motion, therefore, completely fails to show that the Motion is raising a "significant safety issue." Thus, the § 2.326(b) affidavit requirement with respect to the most important of the three mandatory § 2.326(a) criteria is not satisfied and the motion to reopen the record must be denied.

In addition, none of the supporting documentation meets the requirement that the motion be accompanied by affidavits. Nor does it meet the requirements that the evidence in the affidavits meet admissibility standards and address each criterion of section 2.326 separately "with a specific explanation why it has been met." 10 C.F.R. § 2.326(b).

2. <u>Pilgrim Watch's Motion to reopen is not timely</u>

As discussed in Section A, above, the Motion to strike is not timely. To the extent that the Motion seeks to reopen the record it is similarly untimely, and does not present the sort of exceptionally grave issue that could exempt it from the timeliness requirements applicable to reopening records. Accordingly, it does not satisfy 10 C.F.R. § 2.326(a)(1).

"[F]or a reopening motion to be timely presented, the movant must show that the issue sought to be raised could not have been raised earlier." *Diablo Canyon*, ALAB-775, 19 NRC at

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(. . .continued)

2.734(a)(1) into two sentences to form the current § 2.326(a)(1). *Compare* 51 Fed. Reg. at 19,539 (containing text of § 2.734(a)(1)) *with* 10 C.F.R. § 2.326(a)(1).

1366. In addition, parties to NRC proceedings have "an ironclad obligation" to examine the application, and other publicly available documents, with sufficient care to uncover any information which could serve as the foundation for a contention. *Oconee*, CLI-99-11, 49 NRC at 338.

Pilgrim Watch does not address the timeliness requirement in the Motion. Yet, as discussed in Section A, above, all the information contained in the documentation accompanying the Motion was available and attainable well before the filing of the testimony and the hearing in this matter. The consequences of Pilgrim Watch's decision not to seek information that pertains to issues it raised, should be borne by Pilgrim Watch and the motion to reopen should, therefore, be denied for failure to satisfy 10 C.F.R. § 2.326(a)(1).

3. Pilgrim Watch has not demonstrated that a materially different result may be reached due to the "new" information

Pilgrim Watch's Motion further fails to satisfy § 2.326(b) because it fails demonstrate via affidavit that the proposed contention would "likely" lead to a "materially different result" in the Pilgrim license renewal proceedings, as is required under § 2.326(a)(3). While the Motion contains a statement that the alleged incorrect testimony "could materially affect the decision of the [Board] in this proceeding," there is no "specific explanation" of why, or even how, the criterion to demonstrate that a materially different result would be likely has been met. Therefore, Pilgrim Watch has not demonstrated that reopening the record to permit additional evidence regarding coatings, linings and cathodic protection would be likely to lead to a materially different result in these proceedings.

In sum, Pilgrim Watch has completely failed to meet the criteria to reopen the record. Therefore, the motion to reopen should be denied.

CONCLUSION

Based on the foregoing, the Staff submits that the Motion and the Exhibit Motion should be denied.

Respectfully submitted,

/RA/
Susan L. Uttal
Counsel for NRC staff

Dated at Rockville, Maryland
this 27th day of May, 2008

May 23, 2008

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
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Entergy Nuclear Generation Co. and Entergy Nuclear Operations, Inc.	)	Docket No. 50-293-LR
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	)	ASLBP No. 06-848-02-LR
(Pilgrim Nuclear Power Station)	)	

AFFIDAVIT OF DR. JAMES A. DAVIS IN RESPONSE
TO PILGRIM WATCH MOTION TO STRIKE TESTIMONY

I, James A. Davis, do hereby declare under penalty of perjury that the following statement is true and correct to the best of my knowledge and belief:

1. I am employed by the U.S. Nuclear Regulatory Commission ("NRC") as a Senior Materials Engineer in the Office of Nuclear Reactor Regulation ("NRR"), Division of License Renewal. I am filing this affidavit in response to Pilgrim Watch's May 15, 2008 motion to strike testimony I gave at the April 10, 2008 evidentiary hearing on this case regarding cathodic protection.

2. I have previously submitted my *curriculum vitae* to the Licensing Board and the parties. As indicated in my *curriculum vitae* and in my prefiled testimony in this case, I have years of experience with pipeline corrosion issues. I have attached hereto as Attachment 1, a copy of a paper, entitled *Electrochemical Principles Applied to Operating Pipelines*,[1] I presented at a conference on corrosion in 1989, sponsored by National Association of Corrosion Engineers (NACE).

3. Pilgrim Watch's motion was supported by a letter from John H. Fitzgerald III that disputed my testimony about cathodic protection ("Fitzgerald Letter"). I will address his

[1] J.A. Davis, J.D. Kellner, *Electrochemical Principles Applied to Operating Pipelines,* Corrosion 89, New Orleans, Louisiana, April 17-21, 1989, Paper Number 412 ("NACE Presentation").

comments one by one.

4. Mr. Fitzgerald disputes my testimony that "Cathodic protection is something like a battery in that there is a current flow from an anode to a cathode." *See* Fitzgerald Letter at 1; April 10, 2008 Hearing Transcript ("Tr") at 769, lines 24-25 to 770, line 1.

His response to my testimony is:

> The protective current does not really supply a DC charge to the pipe as stated by Dr. Davis in line 25. There is, however, a flow of electrons from the Rectifier (power source) through connecting cables and bonds (not through the soil) to the protected structure. These electrons then take part in electrochemical cathodic reactions on the surface of the protected structures.
>
> In lay terms, it can be said that corrosion is caused by DC currents that flow from one point to another on a structure because of voltage differences that exist between these points; cathodic protection current overcomes these corrosion currents and stops corrosion. In electrochemical terms, cathodic protection neutralizes the voltage differences on the structure, thus eliminating the corrosion currents.

Fitzgerald Letter at 1.

Mr. Fitzgerald later stated that current flows from the groundbed to the buried structure (See Mr. Fitzgerald's statement in 7 below). Here, he is confusing electron flow with current flow. By American convention, electrons flow in the direction opposite that which current flows. When a current is impressed on a buried steel component such as buried piping, the current causes the piping voltage to become more negative (also called cathodic). This is where the term cathodic protection comes from.

In relation to his second comment about the voltage differences that exist on a structure, Mr. Fitzgerald is incorrect. The steel that is used to construct the pipe is a good conductor and cannot support the voltage differences that Mr. Fitzgerald proposes.

Fontana and Greene state on page 205 of their text book titled "Corrosion Engineering,"[2] that "Cathodic protection as achieved by supplying electrons to the metal structure to be protected." They go on to say, "If current is considered to flow from (+) to (-), as in conventional electrical theory, then a structure is protected if current enters it from the electrolyte. . . . [C]urrent passes to the metallic structure and corrosion is suppressed." I have attached these references as Attachment 2. In my NACE Presentation I discuss in detail the basis for establishing cathodic protection. I state that the only valid way to cathodically protect a steel pipeline is to hold the potential of the pipeline more negative than equilibrium potential where the rate of reduction of iron is equal to the rate of oxidation of iron (the redox potential). As Fontana and Greene state above, at this point, net current enters the pipeline when this condition is satisfied. NACE Presentation at 3.

5. Mr. Fitzgerald's next comment relates to my testimony at Tr, page 770 lines 1-2, where I stated that "[t]here are no cathodes involved." This testimony was in response to Pilgrim Watch's witness Mr. Gundersen's testimony at Tr, page 762-763 as follows:

> I mean this morning we talked about coming from the inside out, but should abrasion affect that outside liner, GALL suggests that cathodic protection is a good idea and I would agree. If it were a new plant, you would cathodically protect the whole pipe and I am not suggesting that, but you can backfit – it's called impressed current cathodic protection system by putting anodes and **cathodes** along the pipe at intervals of about 40 feet so maybe five on each pipe would go a long way to protecting the pipe from outside in.

Tr at 762-763. I responded by stating that cathodes are not installed as part of the cathodic protection system, the pipe is the cathode. Mr. Fitzgerald states that "the statement that there are no cathodes involved is incorrect." Fitzgerald Letter at 1. Perhaps he did not read Mr. Gundersen's testimony.

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2 Mars G. Fontana and Norbert D. Greene, *Corrosion Engineering*, McGraw-Hill, Inc. 1967.

I agree with Mr. Fitzgerald that more than one anode may be required to protect all of the buried piping. But, it should be remembered that the only piping we are talking about here is the salt service water discharge piping, not all of the buried piping at the site. Also, there is no NRC requirement to install a cathodic protection system on buried structures at nuclear power plants. It is the licensee's responsibility to ensure that the buried components such as piping and tanks can perform their intended safety function and it is the licensee's responsibility to determine how to accomplish this feat. Cathodic protection is only one possible method. Another method is to coat the buried component. A third method is to construct the components out of material that is not subject to aging in a soil environment.

6. Mr. Fitzgerald's next comment refers to my testimony at Tr page 770, lines 5-6, where I stated that cathodic protection is "like" plating the pipe. Mr. Fitzgerald misread my testimony, and apparently concluded that I stated that cathodic protection is a plating process. *See* Fitzgerald Letter at 2. That is incorrect. I did not say that cathodic protection was a plating process, I said it was *like* a plating process. My point was that both cathodic protection and plating involve passing a current from an anode to a cathode.

7. Mr. Fitzgerald's next comment is:

> Page 770. 7-9: The statements in these lines are confusing and do not make sense. Cathodic protection does prevent the iron (or other metal) from going into solution, but that prevention occurs electrically, as explained above under Page 769, lines 24 & 25. It has nothing whatsoever to do with plating.

Fitzgerald Letter at 2. My testimony at the hearing was ". . . *ions* cannot go into solution thermodynamically. It can only plate, if there's any iron *ions* . . ." Unfortunately, the transcript contains an error in that "ions" was left out of the transcript. *See* Tr, page 770, lines 7-9. It is more likely that either hydrogen ions or oxygen atoms will be reduced at the piping surface.

8. Mr. Fitzgerald's next two comments discuss my testimony regarding problems that may be caused if rectifiers are inoperable. I stated: "They were concerned that if they used a rectifier or put the rectifier as safety-related and it went down for some reason, they would go

into a limited condition of operation and they would have to shut down the plant because the rectifier failed." Tr page 770, line 10-14. Mr. Fitzgerald responded as follows:

> Unless there is a NRC rule requiring this, there is no reason to have to shut down the plant if the rectifier should go off. If the cathodic protection system is properly maintained each rectifier will be inspected every month. If one should be found to be out of operation, it will not have been out for more than 30 days. Even if it took a week or more to get it back in service, only minute if any corrosion will occur in that length of time. There are cathodic protection rectifiers in the three nuclear power station in which I have worked and no one at any of those stations had any concerns about this.

Fitzgerald Letter at 2. I also testified as follows: "And I might also add that cathodic protection is used very extensively, particularly on cross-country pipelines, oil, gas, slurry, all different kinds. It's fairly easy to apply cathodic protection in that situation." Tr page 770, line 25 to page 771, line 4. Mr Fitzgerald responded, "Cathodic protection is indeed used in the applications noted. None of these operators are concerned if a rectifier is out of service for a short time for the very same reasons cited in the paragraph above." Fitzgerald Letter at 2.

In fact, there are NRC rules that would govern rectifiers. When an aging management program is used as part of the basis for license renewal, the program elements 7, 8, and 9 of the aging management program are "corrective actions," "confirmation processes," and "administrative control." These elements mean that the components included in the aging management program become part of the facility's 10 CFR Appendix B Quality Assurance Program (Appendix B Program). Measures must be established to ensure that conditions adverse to quality, such as failures, malfunctions, deviations, defective material and equipment, and nonconformances, are promptly identified and corrected. Therefore, the rectifier and groundbed anodes and all associated equipment for the cathodic protection would be covered by the Appendix B Program. If a licensee does not purchase the rectifiers as safety related, and if they use the cathodic protection as part of an aging management program, then the rectifiers may have to be made safety related by either ordering new rectifiers or commercially dedicating the existing ones. If the rectifiers fail, a plant would enter a limited condition of operation and may have to shut down if the rectifier was not repaired or replaced within a certain time (*i.e.,* the time specified in the technical specifications).

9. Mr. Fitzgerald's next comment refers to my testimony at Tr page 771, lines 5-15 and page 772, line 1, regarding problems with backfitting cathodic protection. Mr. Fitzgerald states:

> These statements are blatantly untrue. There is nothing at all dangerous about installing cathodic protection in complex facilities like power stations. It simply requires proper design to ensure effective protection. It is important to realize that, with the possible exception of buried or submerged piping or tanks unique to nuclear power, the underground structures at a nuclear plant are no different from those at fossil fuel plants.

Fitzgerald Letter at 2.

Perhaps the term I used - "dangerous" - is a bit strong. A better choice of words would be "caution should be exercised when backfitting a cathodic protection system to avoid stray current corrosion."

Mr. Fitzgerald goes on to say:

> The statements in this section concerning the flow of current are also untrue. The current does flow from the rectifier to the groundbed and thence to the underground structures. It returns to the rectifier on the buried structures, not through the soil, and will not put holes in the piping. The piping (The cathode!) does need to be electrically continuous, however, as discussed immediately below.

As shown in Attachment 2, *Corrosion Engineering* at 206, Figure 6-1, the current flows from the rectifier to the anode in the groundbed and to the pipeline then back to the rectifier when stray current corrosion is not occurring.

But, when another set of piping is near the pipe being protected, stray current can occur when some of the current from the anode enters the nearby piping and then exits, as shown in Attachment 2, *Corrosion Engineering* at 210, Figure 6-6. Accelerated corrosion occurs at the point where the current leaves the nearby pipe. I misspoke during my testimony at the hearing and reversed the source of the current. *See* Tr page 771 line 8-12). I meant to say that the current enters the nearby piping on the way from the anode to the intended piping and where it exits the piping is where accelerated corrosion occurs.

10. Mr. Fitzgerald's final comment refers to my testimony at Tr page 771, lines 16-25, where I stated that "[y]ou have to know where every single pipe is on your facility and then you have to bond these together and that's extremely difficult to do –" Mr. Fitzgerald states:

> This is basically true, although it is presented in a manner that not only gives the impression that achieving electrical continuity among the plant piping is extremely difficult, but that cathodic protection is actually dangerous, as erroneously stated on Page 771, line 6.
>
> In lines 23-25 & Page 772, line 1, Dr. Davis is partially correct in saying that bonding, that is, electrical continuity, is necessary. Line 24 & 25 are misleading, however, because the protective current still flows through the soil to the underground structures. What really happens here is that if the current encounters a structure that is not electrically continuous with the protection system, the current can flow along that structure and discharge back into the soil. At the point of discharge, corrosion will indeed occur; this is called stray current corrosion.
>
> The strong impression that one gets from lines 16-25 is that achieving electrical continuity of underground structures in a complex facility is extremely difficult. It is not….

I agree with Mr. Fitzgerald that as long as a cathodic protection system is properly designed, it will protect the piping. My point was that retrofitting cathodic protection can cause stray current corrosion and bonding can be used to avoid stray current corrosion. Bonding is shown in Attachment 2, *Corrosion Engineering* at 210, Figure 6-7 as a means of avoiding stray current corrosion. Improper design of a retrofitted cathodic protection system that does not consider nearby buried piping can result in stray current corrosion.

This affidavit was executed this 23rd day of May, 2008, at Rockville, Maryland.

/Original Signed By/

____

James A. Davis

Entergy Nuclear Generation Co. and Entergy Nuclear Operations, Inc.

Pilgrim Nuclear Power Station

Docket No. 50-293-LR

ASLBP No. 06-848-02-LR

AFFIDAVIT OF DR. JAMES A. DAVIS IN RESPONSE TO

PILGRIM WATCH MOTION TO STRIKE TESTIMONY

ATTACHMENT 1

"Electrochemical Principles Applied to Operating Pipelines",

by J.A. Davis and J.D. Kellner

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ELECTROCHEMICAL PRINCIPLES APPLIED TO OPERATING PIPELINES

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ABSTRACT

The kinetic and thermodynamic treatment of electrochemical reactions are reviewed as they apply to operating pipelines under cathodic protection. The five criteria for cathodic protection of pipelines outlined in NACE publication RP 01-69 are examined in the light of the electrochemical principles discussed. Even when given a few specific assumptions, only one criterion is shown to be fully consistent with the theoretical basis of electrochemistry.

INTRODUCTION

Recent pipeline accidents have prompted a renewed investigation into the proper application of cathodic protection to buried pipelines. Although the cathodic protection of steel pipelines has been extensively and successfully used for many years, misconceptions of the technical basis for cathodic protection have become firmly entrenched. This paper will present the electrochemical basis for cathodic protection of steel pipelines in an attempt to dispell some of these misconceptions.

Mears and Brown(1) wrote a classic paper on cathodic protection of pipelines in 1938. In this paper, the authors state that cathodic protection is achieved when the local anodes are polarized to a potential more active (more negative) than the potential of the local cathodes. The interpretation of this statement has resulted in most of the confusion in modern cathodic protection circles. In order to determine the technical basis for protection criteria, we will examine the thermodynamic and the kinetic equations governing corrosion reactions.

THERMODYNAMIC CONSIDERATIONS

The driving force for any chemical reaction to occur is a free energy change that results in a lower free energy for the system. This principal applies to electrochemical reactions and the free energy change can be expressed as an electrical potential change. The expression for this relation is :

$$\Delta G = -nF\Delta E \qquad (1)$$

where ΔG=the free energy change, n=the number of electrons transferred during the reaction, F=Faraday's Constant, and ΔE=the potential change.

The ΔE is the cell potential relative to a standard potential. It is normally convenient to divide electrochemical reactions into half cell reactions. For instance, iron in water may react as follows:

$$2Fe + O_2 + 4H^+ \rightarrow 2H_2O + 2Fe^{++} \qquad (2)$$

Then the half cell reactions would be:

$$O_2 + 4H^+ + 4e \rightarrow 2H_2O \qquad (3)$$

$$2Fe \rightarrow 2Fe^{++} + 4e \qquad (4)$$

The standard oxidation-reduction (redox) potential sometimes called the standard electrode potential is the potential at which the forward and reverse rates of reaction for a given half cell are equal at 25 C and with all reactants and products at unit activity. At potentials more noble (positive) than the standard redox potential, the oxidation reaction is favored and at more active (negative) potentials, the reduction reaction is favored. The standard redox potential for eqn.(4) is -0.440v (Normal Hydrogen Electrode) at 25 C. The standard redox potential for iron going to the ferrous state using the copper/copper sulfate reference electrode scale is -0.756v ($Cu/CuSO_4$). If the reactants and products are not at unit activity, the redox potential becomes:

$$E = E_{std} + 2.3\ RT/nF \log\left(a_{oxid} / a_{red}\right) \qquad (5)$$

where R=the ideal gas constant, T=the absolute temperature, a_{oxid}=the activity of the oxidized species, and a_{red} = the activity of the reduced species.

The reduced species in this case is the iron and by definition, the activity of a solid is unity. The activity of the ferrous ions will be roughly equivalent to the concentration of ferrous ions in solution. For a two electron transfer reaction, the redox potential shifts by 29.5 mv in the active or negative direction for a ten fold decrease in activity (concentration) of reactants. Soil containing ferrous ions at 0.01 normal concentration will cause a shift in the redox potential of -0.059 V giving a half cell redox potential of −0.815v ($Cu/CuSO_4$). As corrosion occurs and ferrous ions build up, the redox potential will approach the −0.756v ($Cu/CuSO_4$) value. Barlo and Berry(2) compared clean versus mill scale coated steel and found that the overvoltage for protection of the mill scaled steel was 100 to 200 mv more noble (more positive) than the bare steel. Since the mill scaled steel will have a ready supply of ferrous ions present at the steel-electrolyte boundary, a more noble half cell redox potential would be predicted from equation 5.

Other species such as sulfate reducing bacteria that affect the half cell reaction will produce a change in the redox potential. Experimentally, a potential of −0.95v ($Cu/CuSO_4$) is required to cathodically protect steel in the presence of sulfate reducing bacteria(2).

Increasing the temperature will shift the redox potential for the half cell reaction in proportion to the ratio of the new temperature to the standard temperature (298 K). This produces a shift of about one millivolt in the active direction for each ten degree rise in temperature in degrees C.

Holding the potential of a pipeline or any other buried iron based structure more negative than the redox potential for the iron/ferrous reaction is the only valid way to satisfy the Mears and Brown(1) criteria for cathodic protection. At potentials more active than the iron/ferrous redox potential, the reduction of ferrous ions to elemental iron is thermodynamically favored over the reverse reaction. In the absence of other reactive species, this potential can range from −0.75 to −0.85v ($Cu/CuSO_4$) at 25 C, depending on the ferrous ion concentration in the soil and at pH values less than about 9.5(3). At higher pH, the redox potential becomes more negative, being about −1.3v ($Cu/CuSO_4$) at pH 14.

KINETIC CONSIDERATIONS

Stern and Geary(4,5,6) have described the kinetics of electrochemical reactions in a series of papers. Much of what Stern and Geary describe is critical to the understanding of cathodic protection of pipelines. A brief review of the Stern and Geary work will be presented in this section.

If an electrochemical reaction rate is under activation control, the dependence of current on overvoltage is expressed as:

$$i = i_0 \exp(\pm\eta/\beta') \qquad (6)$$

where i=the current flow in the oxidation or rèduction reaction, i_0=the corresponding exchange current, η=the overvoltage, β'=the Tafel constant. This expression is commonly written as:

$$\eta = \pm\beta \log(i/i_0) \qquad (7)$$

where $\beta=2.3(\beta')$. These relations are presented graphically in Figure 1 where the overvoltage is plotted vs the logarithm of the current for the oxidation reaction and the reduction reaction.

Of main concern for cathodic protection is the cathodic polarization diagram for the system of interest. In this case, the expression for an activation controlled reaction is written as:

$$\eta = -\beta \log(i/i_0) \qquad (8)$$

where i=the total current flow as externally measured and $i=i_{red} + i_{oxid}$.

The cathodic polarization diagram will appear as shown in Figure 2, where the overvoltage is plotted vs logarithm of the current using equation (8) with a β value of 0.1. This curve deviates from Tafel behavior only at low currents where the i_{oxid} becomes significant compared to i_{red}. One of the criteria for cathodic protection in NACE's standard RP 01-69[7] is that the applied potential be in the Tafel region of the cathodic polarization diagram. This criterion has no basis, since Tafel behavior occurs when i_{red} / i_{oxid} is greater than about 100. This ratio is all that is important and cathodic Tafel behavior does not depend on the

magnitude of i_{oxid}. Logan[8] proposed that Mears and Brown's[1] criterion (local anodes polarized to a potential more negative than local cathodes) would be satisfied at a break in the cathodic polarization diagram associated with the onset of cathodic Tafel behavior and that the start of cathodic Tafel behavior indicates that no anodic reaction is occurring. While it is true that in the Tafel region, the anodic current is much smaller than the cathodic current, there is no significance to the onset of cathodic Tafel behavior. In spite of this, the criterion is still used in cathodic protection and is still part of RP 01-69 and Department of Transportation[9] (DOT) requirements even though there is no technical basis for the criterion.

Stern and Geary report that two additional types of polarization can affect the linear region of the Tafel curve and therefore, the ability to measure activation polarization. The first is concentration polarization and the second is resistance polarization. Concentration polarization occurs when the rate determining step becomes the diffusion of reactants to the electrode surface or the diffusion of products away from the surface. Resistance polarization occurs when there is a resistance between the reference electrode and the metal surface. Concentration polarization is given by the expression:

$$\eta = -\beta \log(i/i_0) + 2.3\ RT/nF \log[(i_L - i)/i_L] \qquad (9)$$

where i_L = the limiting diffusion current.

The combined effect of activation polarization and concentration polarization is shown graphically in Figure 3. At currents much below i_L, the behavior is similar to that shown in figure 2. However, when i approaches 0.1 i_L, the concentration polarization has the effect of limiting the current that can be passed, regardless of the voltage applied.

For resistance polarization, the overvoltage is a linear function of current:

$$\eta = iR \qquad (10)$$

where R = the resistance. The measured electrode potential will be a combination of the activation polarization, the concentration polarization, and the resistance polarization. The expression for overvoltage becomes:

$$\eta = -\beta \log(i/i_0) + 2.3\ RT/nF \log\left((i_L - i)/i_L\right) - iR \qquad (11)$$

The first two terms in this expression represent the true polarized potential of the electrode of interest. The third term represents an iR drop in the measurement circuit and gives the impression that the electrode is polarized to a potential more active than is actually achieved. This is shown graphically in Figure 4, where the overvoltage is plotted vs the three current terms as in equation (11). As can be seen in Figure 4, the voltage expected from the Tafel slope extrapolation is more noble (positive) than is actually the case. Since the magnitude of the iR drop is difficult to estimate on a buried pipeline, it is important to eliminate the iR portion of the potential from any measurement of polarized potential. If the current is turned off, the iR portion drops to zero instantly, while the activation controlled and concentration controlled parts of equation (11) decay exponentially with time. If it is not possible to interrupt the current, then it is important to obtain a good estimate of the iR portion of the measured potential.

RP 01-69 AND DOT CRITERIA VS ELECTROCHEMICAL PRINCIPLES

Five criteria have been included in RP 01-69[7] and the Department of Transportation Office of Pipeline Safety regulations[9] and these criteria are currently being reviewed for the newest version of RP 01-69. The criteria with comments on their scientific basis are:

1. "A negative (cathodic) voltage of at least 0.85 volt as measured between the structure surface and a saturated copper-copper sulfate reference electrode contacting the electrolyte. Determination of this voltage is to be made with the protective current applied." DOT adds that IR drops must be considered.

This criteria is probably the closest to an adequate criteria of any of the five. The NACE criteria should be changed so that IR drops are not included in the measurement. Also, cautions should be added that this criteria is only valid up to a pH of 9.5 at a temperature of 25 C in the absence of reactants that affect the redox potential for the iron/ferrous reaction. Barlo and Berry[2] found that this criteria is generally valid and in many cases, a more noble potential is adequate.

It would be desirable to change this requirement to : " A negative (cathodic) voltage that is more negative than the redox potential for the iron/ferrous half cell reaction." However, it is difficult to determine this redox potential in a laboratory and even more difficult on an operating pipeline. The -0.85v ($Cu/CuSO_4$) is a conservative estimate of the redox potential for the iron/ferrous half cell reaction. History has shown that a potential that is more negative than -0.85v ($Cu/CuSO_4$) is generally adequate for cathodic protection.

2. "A minimum negative (cathodic) voltage shift of 300 millivolts, produced by the application of protective current. The voltage shift is measured between the structure surface and a stable reference electrode contacting the electrolyte. This criterion of voltage shift applies to structures not in contact with dissimilar metals."

There is no thermodynamic or kinetic justification for this criterion. This measurement necessarly includes any IR drops in the measuring circuit and as Barlow and Berry[2] point out, this inclusion affects the reliability of the measurement. This criterion works very well if the starting potential is more active (more negative) than -0.550v ($Cu/CuSO_4$), IR drops are not included in the 300 mv polarization, the pH is below 9.5, and the redox potential for the iron/ferrous reaction is not affected by additional reactions.

Barlo and Berry[2] found this criteria to be the least reliable of the first four criteria. It is difficult to determine the amount of resistance polarization included in the measurement; hence, the validity of this criteria is in question.

3. "A minimum negative (cathodic) polarization voltage shift of 100 millivolts measured between the structure surface and a stable reference electrode contacting the electrolyte. This polarization voltage shift is to be determined by interrupting the protective current and measuring the polarization decay. When current is initially interrupted, an immediate voltage shift will occur. The voltage reading after the immediate shift, shall be used as the base reading from which to measure polarization decay."

There is no thermodynamic or kinetic justification for this criterion either. This criterion works very well if the potential after the decay is more active (more negative) than -0.750v ($Cu/CuSO_4$). IR drops are eliminated from this measurement; therefore, when the current is interrupted, the potential should be compared to the -0.85v ($Cu/CuSO_4$) criterion if the pH is below 9.5, and the redox potential for the iron/ferrous reaction is not affected by additional reactions.

Barlo and Berry[2] found that this criteria was the most reliable of the four criteria that they examined. It is likely that the bare steel surface is being cathodically cleaned during cathodic protection and that an electrochemically active and reproducable surface is produced. Jones[10] points out that the anodic rate of reaction decreases by an order of magnitude for cathodic polarization equal to the anodic Tafel constant. Since the anodic Tafel constants are often 50 mv or less, polarization by 100 mv will reduce the corrosion rate by 100 times or more and the corrosion rate could be below detection limits.

4. "A structure-to-electrolyte voltage at least as negative (cathodic) as that originally established at the beginning of the Tafel segment of the E-log-I curve. This structure-to-electrolyte voltage shall be measured between the structure surface and a stable reference electrode contacting the electrolyte at the same location where voltage measurements were taken to obtain the E-log-I curve."

This criterion is a classic mis-interpretation of a method to satisfy the Mears and Brown[1] criterion for cathodic protection. The assumption is made that when Tafel behavior is achieved, that the iron to ferrous ion reaction is no longer occurring. In reality, Tafel behavior indicates that the rate of the cathodic reaction is approximately two orders of magnitude higher than the rate of the anodic reaction. The rate of the anodic reaction can be significant as long as the rate of cathodic reaction is about two orders of magnitude higher.

Barlow and Berry[2] observed that the beginning of Tafel behavior has no relation to conditions that control corrosion. This observation is in agreement with theoretical considerations.

5. "A net protective current from the electrolyte into the structure surface as measured by an earth current technique applied at predetermined current discharge (anodic) points of the structure."

This criterion states that the rate of cathodic reaction be greater than the rate of anodic reaction. Again, the rate of anodic reaction could be significant.

CONCLUSIONS

Of all of the criteria in RP 01-69, only the first criterion is based on scientific principals of thermodynamics if the IR drop is eliminated from the measurement and if no reactions are occuring that affect the redox potential for the iron/ferrous reaction. The remaining criteria are only effective if the resulting applied potential is more active than the redox potential for the iron/ferrous half cell reaction. In general, these criteria are conservatively applied and the resulting potential is more active than the redox potential for the iron/ferrous reaction and cathodic protection is acheived. However, it is possible that these criteria can be applied to an underground structure and significant corrosion can occur.

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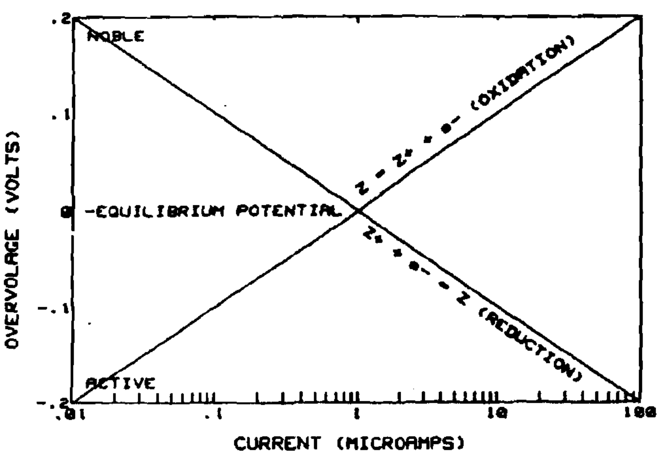

Figure 1. Overvoltage vs log current for the oxidation and reduction half-cell reactions.

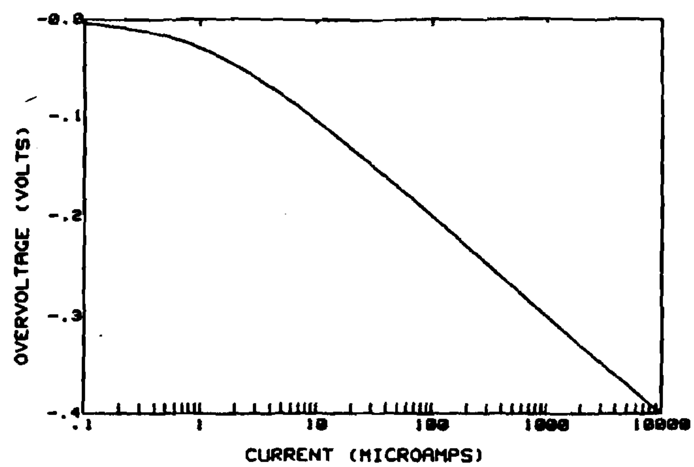

Figure 2. Overvoltage vs log current with activation control only.

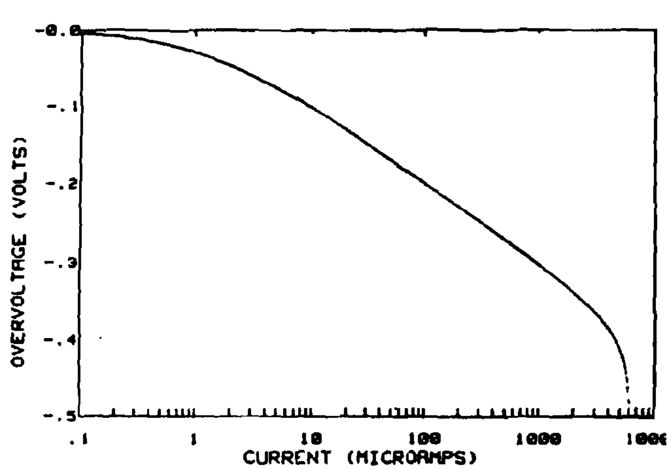

Figure 3. Overvoltage vs log current with concentration polarization.

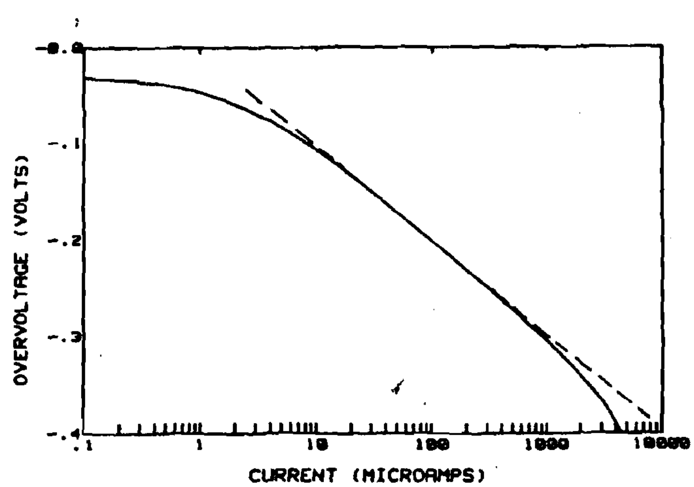

Figure 4. Overvoltage vs log current with concentration polarization and resistance polarization present.

Entergy Nuclear Generation Co. and Entergy Nuclear Operations, Inc.

Pilgrim Nuclear Power Station

Docket No. 50-293-LR

ASLBP No. 06-848-02-LR

AFFIDAVIT OF DR. JAMES A. DAVIS IN RESPONSE TO

PILGRIM WATCH MOTION TO STRIKE TESTIMONY

ATTACHMENT 2

"Corrosion Prevention", page 205 - 210

Mars G. Fontana and Norbert D. Greene

7. Avoid hot spots during heat-transfer operations. Heat exchangers and other heat-transfer devices should be designed to ensure uniform temperature gradients. Uneven temperature distribution leads to local heating and high corrosion rates. Further, hot spots tend to produce stresses which may produce stress corrosion cracking failures.
8. Design to exclude air. Oxygen reduction is one of the most common cathodic reactions during corrosion, and if oxygen is eliminated, corrosion can often be reduced or prevented. In designing chemical plant equipment, particular attention should be paid to agitators, liquid inlets, and other points where air entrainment is a possibility. Exceptions to this rule are active-passive metals and alloys. Titanium and stainless steels are more resistant to acids containing dissolved air or other oxidizers.
9. The most general rule for design is: *avoid heterogeneity.* Dissimilar metals, vapor spaces, uneven heat and stress distributions, and other differences between points in the system lead to corrosion damage. Hence, in design, attempt to make all conditions as uniform as possible throughout the entire system.

CATHODIC AND ANODIC PROTECTION

6-8 Cathodic Protection Cathodic protection was employed before the science of electrochemistry had been developed. Humphrey Davy used cathodic protection on British naval ships in 1824. The principles of cathodic protection may be explained by considering the corrosion of a typical metal M in an acid environment. Electrochemical reactions occurring are the dissolution of the metal and the evolution of hydrogen gas, according to Eqs. (6.3) and (6.4):

$$M \rightarrow M^{+n} + ne \qquad (6.3)$$

$$2H^+ + 2e \rightarrow H_2 \qquad (6.4)$$

Cathodic protection is achieved by supplying electrons to the metal structure to be protected. Examination of Eqs. (6.3) and (6.4) indicates that the addition of electrons to the structure will tend to suppress metal dissolution and increase the rate of hydrogen evolution. If current is considered to flow from (+) to (−), as in conventional electrical theory, then a structure is protected if current enters it from the electrolyte. Conversely, accelerated corrosion occurs if current passes from the metal to the electrolyte. This current convention has been adopted in cathodic protection technology and is used here for consistency.

There are two ways to cathodically protect a structure: (1) by an external power supply or, (2) by appropriate galvanic coupling. Figure 6-1 illustrates cathodic protection by impressed current. Here, an external dc power supply is connected to an underground tank. The negative terminal of the power supply is connected to the tank, and the positive to an inert anode such as graphite or

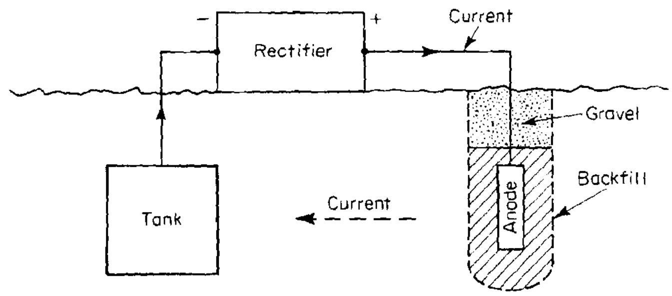

Fig. 6-1. Cathodic protection of an underground tank using impressed currents.

Duriron. The electric leads to the tank and the inert electrode are carefully insulated to prevent current leakage. The anode is usually surrounded by backfill consisting of coke breeze, gypsum, or bentonite, which improves electric contact between the anode and the surrounding soil. As shown in Fig. 6-1, current passes to the metallic structure, and corrosion is suppressed.

Cathodic protection by galvanic coupling to magnesium is shown in Fig. 6-2. As discussed in Chap. 3, magnesium is anodic with respect to steel and corrodes preferentially when galvanically coupled. The anode in this case is called a sacrificial anode since it is consumed during the protection of the steel structure. Cathodic protection using sacrificial anodes can also be used to protect buried pipelines, as shown in Fig. 6-3. The anodes are spaced along the pipe to ensure uniform current distribution.

√ *Protective currents* are usually determined empirically, and some typical values are listed in Table 6-2. Aggressive corrosives such as hot acids require prohibitively high currents, whereas much lower currents are needed to protect steel in less severe environments (concrete). Table 6-2 indicates typical average

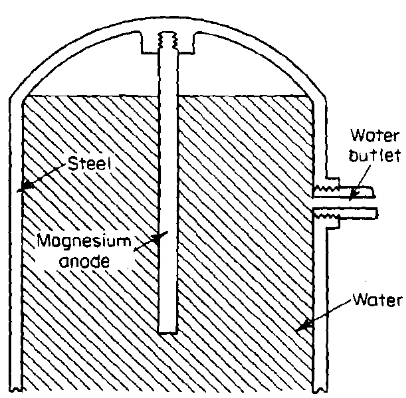

Fig. 6-2. Cathodic protection of a domestic hot-water tank using a sacrificial anode.

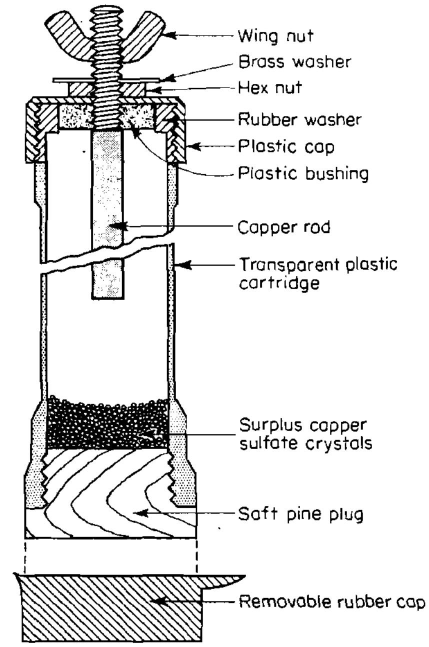

Fig. 6-4. Copper-copper sulfate reference electrode.

size of anodes needed for full protection. On long pipes or large, complex structures, reference-electrode surveying is utilized to determine uniformity of applied currents.

Anode selection for cathodic protection is based on engineering and economic considerations. Table 6-3 compares several types of sacrificial and impressed-current anodes. Of the sacrificial anodes, magnesium is the most widely used. Although its efficiency is low (about 50%), this is more than offset by its very negative potential, which provides high current output.

There is a considerable variety of impressed-current anodes ranging from low-cost scrap steel, which suffers relatively large losses, to the inert platinized titanium which is both efficient and expensive. Steel, graphite, and silicon-iron are the most widely used anode materials, with lead and platinized titanium finding increased applications in marine environments.

Stray-current effects are often encountered in cathodic-protection systems. The term *stray current* refers to extraneous direct currents in the earth. If a metallic

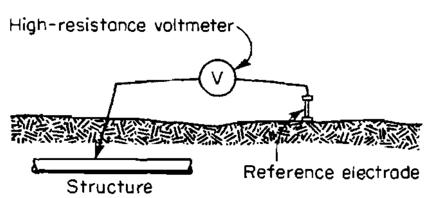

Fig. 6-5. Pipe potential measurements with a reference electrode.

Table 6-3 Comparisons of Sacrificial and Impressed-current Anodes for Cathodic Protection

Sacrificial Anodes

	Magnesium	*Zinc*	*Aluminum-tin*
Theoretical consumption, lb/amp-year	9	23	6.5
Actual consumption, lb/amp-year	18	25	16–20
Potential vs. $Cu/CuSO_4$	−1.7	−1.15	−1.3

Impressed-current Anodes

Material	*Typical applications*	*Typical loss, lb/amp-year*
Scrap steel	Soil, fresh- and seawater	20
Aluminum	Soil, fresh- and seawater	10–12
Graphite	Soil and freshwater	0.25–5.0
High-silicon iron and Si-Cr iron	Soil, fresh- and seawater	0.25–1.0
Lead	Seawater	0.1–0.25
Platinized titanium	Seawater	nil

SOURCE: Modified from J. H. Morgan, "Cathodic Protection" The Macmillan Company, New York, 1960.

object is placed in a strong current field, a potential difference develops across it and accelerated corrosion occurs at points where current leaves the object and enters the soil. Stray-current problems were quite common in previous years due to current leakage from trolley tracks. Pipelines and tanks under tracks were rapidly corroded. However, since this type of transportation is now obsolete, stray currents from this source are no longer a problem. A more common source of stray currents is from cathodic-protection systems. This is especially pronounced in densely populated oil production fields and within industrial complexes containing numerous buried pipelines.

Figure 6-6 illustrates stray currents resulting from a cathodic-protection system. The owner of the buried tank installed cathodic protection. He did not know of the nearby pipeline which failed rapidly due to the stray-current field. If the owner of the pipeline applies cathodic protection, it is possible to prevent stray-current attack of his pipe, but it will produce stray-current attack of the buried tank. It is easy to see how stray-current corrosion tends to escalate.

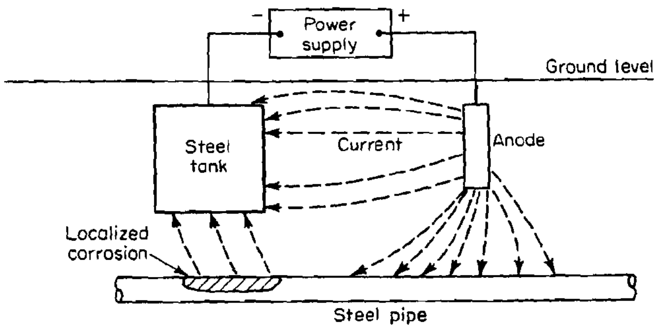

Fig. 6-6. Stray currents resulting from cathodic protection.

As each owner adds or increases protective currents to his structures, he increases the current requirements on other adjacent structures. In one industrial area containing a high density of protected underground structures, protective current requirements rapidly rose to 20 ma/ft^2 in several areas! The solution to this problem is cooperation between operators. For example, the stray-current problem shown in Fig. 6-6 could be prevented by electrically connecting the tank and pipe by a buss connector and rearranging anodes as shown in Fig. 6-7. Here, both pipe and tank are protected without stray-current effects, with the owners sharing the cost of installation and operation.

6-9 Anodic Protection In contrast to cathodic protection, anodic protection is relatively new; it was first suggested by Edeleanu in 1954. This technique was developed using electrode kinetics principles and is somewhat difficult to describe without introducing advanced concepts of electrochemical theory. Simply,

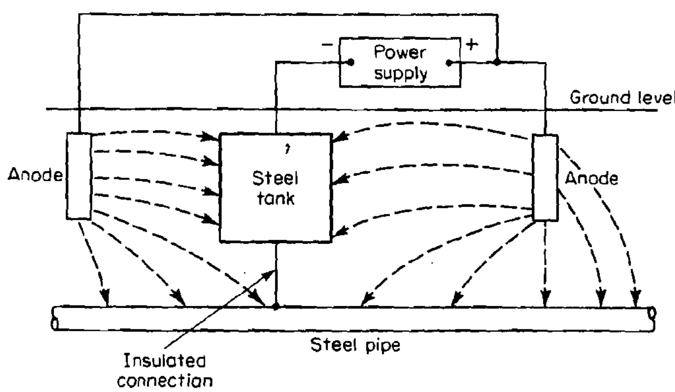

Fig. 6-7. Prevention of stray-current corrosion by proper design.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
Entergy Nuclear Generation Co. and	)	
Entergy Nuclear Operations, Inc.	)	Docket No. 50-293-LR
	)	
(Pilgrim Nuclear Power Station)	)	ASLBP No. 06-848-02-LR
	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of "NRC STAFF RESPONSE IN OPPOSITION TO (1) PILGRIM WATCH MOTION TO STRIKE TESTIMONY and (2) MOTION TO INCLUDE AS PART OF THE RECORD EXHIBITS ATTACHED TO PILGRIM WATCH MOTION TO STRIKE TESTIMONY" in the above-captioned proceeding have been served on the following by electronic mail and by deposit in the U.S. Nuclear Regulatory Commission's internal mail system, or, as indicated by an asterisk (*), by electronic mail and by deposit in the U.S. Mail system this 27th day of May, 2008.

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