March 28, 2005

MEMORANDUM TO: John Hannon, Chief
Plant Systems Branch
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

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SUBJECT: PRELIMINARY PASS/FAIL TEST RESULTS FOR HEMYC 1-HOUR RATED ELECTRICAL RACEWAY FIRE BARRIER SYSTEMS

The purpose of this memorandum is to communicate the preliminary pass/fail test results for the Hemyc 1-hour fire rated, Electrical Raceway Fire Barrier System (ERFBS). The testing was conducted on March 11 and 25, 2005, at Omega Point Laboratories (OPL), San Antonio, Texas.

The principal focus of this testing was basic electrical raceway configurations protected with typical Hemyc 1-hour fire rated ERFBS. The Hemyc ERFBS was manufactured and installed by Promatec using materials and installation techniques common to those configurations installed in the nuclear industry. The conduct of the testing and acceptance criteria were in accordance with NRC guidance as documented in Generic Letter 86-10, Supplement 1, "Fire Endurance Test Acceptance Criteria for Fire Barrier Systems used to Separate Redundant Safe-Shutdown Trains within the Same Fire Area."

Attachment 1 provides the preliminary pass/fail test results for the Hemyc 1-hour fire rated ERFBS. A total of 16 configurations were tested in the two full scale fire endurance test; all configurations failed to meet the NRC acceptance criteria. After our review of the Quality Assurance (QA) documentation and the detailed test data, including material properties testing of Siltemp, we will transmit the final report to you by separate correspondence.

If you have any questions, please contact Mark Salley (x2840) or Roy Woods (x6622) of my staff.

Attachment: As Stated

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Preliminary Pass/Fail Report for Hemyc 1 Hour Fire Rated ERFBS Testing

Purpose of the Testing

The purpose of this testing was to perform confirmatory fire endurance testing on typical Hemyc 1-hour fire rated Electrical Raceway Fire Barrier Systems (ERFBS). The testing was conducted on March 11 and 25, 2005, at Omega Point Laboratories (OPL), San Antonio, Texas. The Hemyc ERFBS was manufactured and installed by Promatec using materials and installation techniques common to those configurations installed in the nuclear industry. The testing protocol and acceptance criteria used for this testing were in accordance with NRC guidance as documented in Generic Letter 86-10, Supplement 1, "Fire Endurance Test Acceptance Criteria for Fire Barrier Systems used to Separate Redundant Safe-Shutdown Trains within the Same Fire Area."

Scope of the Testing

The scope of the testing was to perform confirmatory testing on conduits, cable trays, junction boxes, air drops and supports protected with Hemyc 1-hour fire rated ERFBS. The first test consisted of 1, 2-1/2, and 4-inch conduits empty and with significant cable fill, junction box, and structural steel supports. All Hemyc ERFBS were directly attached to the raceways. The second test consisted of 12 and 36-inch cable trays and cable airdrop configurations with direct attachment and 2-inch air gap Hemyc attachment over space frames, and a junction box with direct attachment. Electrical cable ampacity de-rating and ERFBS seismic position retention testing was beyond the scope of this testing. Based upon the Hemyc materials performance during the fire endurance testing, the scope of the testing was expanded to include material property testing of the Siltemp outer covering.

Preliminary Test Results & Observations

The preliminary test results for the first test are provided in Table 1. The preliminary results of the second test are provided in Table 2. In addition to the tabular results, key observations including the preliminary results of the material property testing are provided in the following discussions.

1. Siltemp Material Properties and Shrinkage:

   Hemyc mats are constructed of 2-inch Kaowool insulation inside an outer covering of Siltemp high temperature fabric. The mats are custom sized for the electrical raceway and machine stitched to produce the factory mats. Hemyc mats, which are installed over spaced frames to provide the 2-inch air gap design, are identical with the exception that 1 ½-inch Kaowool is used instead of the 2-inch material.

The vendor manual references either Siltemp, Refrasil, or Alpha 600 as equivalent materials for the outer covering of the Hemyc ERFBS mats. This testing used the Refrasil brand fabric. The term “Siltemp” is most commonly used in the nuclear industry to describe the outer covering fabric of the Hemyc ERFBS mats. Therefore, the term “Siltemp” will be used generically throughout this report to describe the outer covering fabric of the Hemyc ERFBS. Siltemp is no longer manufactured and cannot be obtained on the open market today. The RES staff obtained a sample of New Old Stock (NOS) Siltemp material from a licensee for material property testing. Sandia National Laboratory (SNL) performed preliminary examinations of the NOS Siltemp material to verify the material used to construct the test assemblies was representative of the material installed in the 1980's in actual NPP installations. SNL’s preliminary testing indicates the material density, thickness, and fabric weave are identical for both Siltemp and Refrasil.

During the fire testing, the outer layer of Siltemp consistently experienced a phenomenon of thermal shrinkage and change of color from tan to white. This shrinkage led to the mats contracting and opening gaps in the ERFBS. SNL has investigated this phenomenon. SNL has performed radiant heating of the NOS Siltemp and Refrasil fabrics. SNL preliminary findings indicate that the color change and shrinkage of both NOS Siltemp and Refrasil materials were uniform and virtually identical. SNL’s testing of small samples indicates a shrinkage on the order of 5%. Further research by SNL has determined that Siltemp and Refrasil are available in both standard and pre-shrunk versions. The versions are readily identifiable in that the standard material is tan in color while the pre-shrunk material is a stark white. Manufacturer data shows linear shrinkage of 8.3 and 6.7 percent for Siltemp and Refrasil, respectively. The NRC staff observed that the outer covering of Hemyc installations in the industry is tan, indicating that the standard Siltemp material was used for the fabrication of the Hemyc mats. This is consistent with the requirements in the Hemyc vendor manual.

2. Joint Failure:

This testing examined the four most common methods of joining the Hemyc material into a complete ERFBS, namely stitched joints, minimum 6-inch collars over a joint, minimum 2-inch overlapping of the mats, and through bolts/fender washers for cable trays and junction boxes using the 2-inch air gap space frames. The Siltemp shrinkage led to the failure of each of the joint systems. In the case of stitched joints, the shrinkage led to the seams being ripped open. This is most graphically illustrated in the first junction box test and where the Hemyc mats were installed over condolets. The second test contained an identical Hemyc junction box installation with the exception of 1/2-inch stainless steel banding added over the completed assembly. The second junction box experienced the same seam failure as was seen in the first test with the exception that the banding held the Hemyc mats in place rather than the mats falling free after the joints failed. Failure of the second junction box was 31 minutes vs. the 15 minutes experienced in the first test. The stitched joints are considered to be the weakest or first joints to fail. The minimum 6-inch collar joints also experienced failures. It appeared that the 6-inch collar would often contract and move with one side of the material. Siltemp shrinkage was common during the testing, usually great enough to expose the raceway. The 2-inch overlapping joints also experienced failures. In these examples, Siltemp shrinkage led to the joints being pulled apart under the 1/2-inch Stainless Steel banding. The through-bolting of the Hemyc mats on the cable tray designs using the 2-inch air gap space frames appeared to provide the most robust resistance to Siltemp shrinkage. However, due to this rigid fixed mounting of the Hemyc mats, the Siltemp experienced tearing of the machine sewn seams and tearing of the fabric.

3. Supports and Intervening Item Protection:

This confirmatory testing was performed to determine the relative performance of typical electrical raceways protected with Hemyc 1-hour fire rated ERFBS. It must be noted that the raceway and the structural supports were specifically not tested together. The reason for this was to ensure that potential thermal shorts from the structural supports would not invalidate the data obtained for the raceways. Given this information and the new insight that the Siltemp fabric shrinks when exposed to fire conditions, the unprotected joint between the support protection and raceway protection would be expected to fail (open). Further, with only the 3-inch protection on supports as required by the vendor manual, thermal shorts could be introduced into the ERFBS in the range of 13 to 32 minutes. These findings would also apply to intervening metallic items that penetrate the completed Hemyc ERFBS as is common in NPP installations.

<u>**Table 1**</u>

Conduit , Supports & Junction Box
HEMYC 1 Hour Fire Rated Test Results

Raceway	Time to $\Delta T_{ave} \geq 250^oF$ (min.)	Time to Single Point $\Delta T > 325^oF$ (min.)	Max. Temp. Bare #8 @ 1 hour[1] (^oF)	Joint Failure/ Structural Failure[2] Yes/No	Pass Hose Stream[3] Yes/No	Final Grade[4] Rating (Minutes)
1" Conduit (1E) (Empty)	46	42	1013	Yes	Yes	42
1" Conduit (1F) 1.02 lb./lin.ft. Cable Fill	44	34	1177	Yes	Yes	34
2 ½ " Conduit (1C) (Empty)	48	41	709	Yes	Yes	41
2 ½ " Conduit (1D) 5.85 lb./lin.ft. Cable Fill	51	38	446	Yes	Yes	38
4" Conduit (1A) (Empty)	49	33	865	Yes	Yes	33
4" Conduit (1B) 14.84 lb./lin.ft. Cable Fill	57	43	199	Yes	Yes	43
Junction Box[5] 18" x 24" x 8"	17	15	NA	Yes	Yes	15
Unistrut Support[6]	NA	22 - 32	NA	NA	Yes	22 - 32
2" Tube Steel Support[6]	NA	13 - 25	NA	NA	Yes	13 - 25

Table 1 (continued)

Conduit , Supports & Junction Box
HEMYC 1 Hour Fire Rated Test Results

Notes:

1. The temperatures recorded on the Bare #8 should be viewed with extreme caution for at least two reasons. First, to insure the integrity of the thermocouple's jacket and insulation during installation, the instrumented Bare # 8 was located in the center of the cable bundle rather than on the outside bottom where it would have scavenged the most heat. The second reason was the joint failure experienced during the testing. This will produce local hot spots on the interior of the raceway that may or may not have been picked-up by the Bare #8.

2. All Hemyc ERFBS experienced some thermal shrinkage of the outer Siltemp covering. This led to joints opening and exposing the conduits to the furnace temperature at varying points during the test. This was not burn-through as Siltemp and Kaowool are non-combustible.

3. By definition, all assemblies would have failed the hose stream testing since the raceway was exposed to joint failure as discussed in Note 2. However, no Hemyc was displaced during the fog nozzle testing and as such, the ERFBS would be expected to pass the hose stream testing provided the joints remained tight.

4. The final rating is based on the first temperature rise criteria point to be exceeded. Note that all raceways failed on the single point criteria ($\Delta T > 325^{o}F$) which further indicates the joint failure.

5. The Junction Box experienced catastrophic failure when the seams of the Hemyc mats opened up & the Hemyc mat fell off the JB. It should be noted that the junction box design had minimal documentation in the Installation Manual as how to install the system on a JB. The design tested relied on stitched seams with no external banding or other attachment.

6. Failure of the structural supports was determined to be when the time to the Single Point temperature rise (ΔT) exceeded $325^{o}F$ at a distance 3-inches into the Hemyc protected structural steel.

Table 2

Cable Tray, Junction Box, & Airdrop
Hemyc 1 Hour Fire Rated Test Results

Raceway	Right Side Tray Rail $\Delta T_{ave} \geq$ 250°F (min.)	Right Side Tray Rail Single Point $\Delta T > 325$°F (min.)	Left Side Tray Rail $\Delta T_{ave} \geq$ 250°F (min.)	Left Side Tray Rail Single Point $\Delta T > 325$°F (min.)	Bare #8 $\Delta T_{ave} \geq$ 250°F (min.)	Bare #8 Single Point $\Delta T > 325$°F (min.)	Burn-Through/ Structural Failure[1] Yes/No	Pass Hose Stream[2] Yes/No	Final Grade[3] Pass/ Fail
12" Cable Tray Empty, (2A) Direct Attachment	36	34	27	18	32	32	Yes	Yes	18
12" Cable Tray Empty, (2B) 2" Air Gap	37	35	38	35	33	34	Yes	Yes	35
36" Cable Tray Empty, (2C) Direct Attachment	41	39	34	33	35	35	Yes	Yes	33
36" Cable Tray Empty, (2D) 2" Air Gap	32	31	33	32	28	27	Yes	Yes	31
Air Drop, (2E) Direct Attachment	NA	NA	NA	NA	35	32	Yes	Yes	32
Air Drop, (2F) 2" Air Gap	NA	NA	NA	NA	32	28	Yes	Yes	28
18” x24” x 8”Junction Box,(2G) Direct Attachment with Bands[4]	31	32	NA	NA	NA	NA	Yes	Yes	31

Table 2 (continued)

Cable Tray, Junction Box, & Airdrop
Hemyc 1 Hour Fire Rated Test Results

Notes:

1. All Hemyc ERFBS experienced some thermal shrinkage of the outer Siltemp covering. This led to joints opening and exposing the conduits to the furnace temperature at varying points during the test. This was not burn-through as Siltemp and Kaowool are non-combustible.

2. By definition, all assemblies would have failed the hose stream testing since the raceway was exposed to joint failure as discussed in Note 1. However, no Hemyc was displaced during the fog nozzle testing and as such, the ERFBS would be expected to pass the hose stream testing provided the joints remained tight.

3. The final rating is based on the first temperature rise criteria point to be exceeded. Note that all raceways with the exception of the junction box failed on the single point criteria ($\Delta T > 325^{o}F$) which further indicates the joint failure.

4, The junction box average temperature is the average across all thermocouples mounted on the outside of the box's surface. The single point temperature is also measured on the external surface of the junction box.