Ameren
MISSOURI

Callaway Plant

March 26, 2014

ULNRC-06104

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

10 CFR 50.36(c)(3)

Ladies and Gentlemen:

DOCKET NUMBER 50-483
CALLAWAY PLANT UNIT 1
UNION ELECTRIC CO.
FACILITY OPERATING LICENSE NPF-30
REQUEST FOR INTERPRETATION OF TECHNICAL SPECIFICATION SURVEILLANCE REQUIREMENT 3.7.11.1, "VERIFY EACH CRACS TRAIN HAS THE CAPABILITY TO REMOVE THE ASSUMED HEAT LOAD"

Pursuant to the guidance of Nuclear Regulatory Commission (NRC) Information Notice (IN) 97-80, "Licensee Technical Specification Interpretations," as supported by NRC Inspection Manual, Part 9900: Technical Guidance, Chapter STSINTR, "Licensee Technical Specification Interpretations," Union Electric Company (Ameren Missouri) hereby requests NRC concurrence with the following position regarding the intent of the Technical Specification (TS) Surveillance Requirement (SR) 3.7.11.1, "Verify each CRACS train has the capability to remove the assumed heat load."

> SR 3.7.11.1 requires verification that each Control Room Air Conditioning System (CRACS) train has the capability to remove the assumed heat load. At Callaway Plant, this Surveillance Requirement is satisfied by verifying the heat removal capability of the condenser heat exchanger (either through performance testing or inspection), ensuring the proper operation of major components in the refrigeration cycle and verification of unit air flow capacity.

Ameren Missouri considers this position on SR 3.7.11.1 to be consistent with the Callaway Plant licensing basis. Justification for this position is provided in the Attachment.

On November 7, 2012, control room personnel entered Surveillance Requirement (SR) 3.0.3 for missed surveillance (SR 3.7.11.1) when the Nuclear Regulatory Commission (NRC) resident inspector determined that the procedures for testing and inspection of the CRACS trains were not adequate to meet the requirements of SR 3.7.11.1. In accordance with SR 3.0.3, the requirement to declare the Limiting Condition for Operation (LCO) not met has been delayed for a period not to exceed the limit

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PO Box 620 Fulton, MO 65251 AmerenMissouri.com
STARS Alliance

designate as original. Fred Lyon 4/16/14
Callaway PM

of the specified Frequency (18 month). The application of SR 3.0.3 requires the testing to be performed prior to May 7, 2014 at 1600 hours Central Daylight Time.

In conjunction with Wolf Creek Nuclear Operating Company (WCNOC), other industry peers and industry experts, Ameren Missouri pursued development of a test method that had a high probability of measuring the capability of each CRACS train to remove the assumed heat load. Based on recent testing of the Wolf Creek Generating Station (WCGS) CRACS trains, it is unlikely that the test method developed will produce repeatable, valid results for the reason that, during normal operation, the CRACS operates with a heat load that is much less than design limiting conditions. Ameren Missouri has determined that a heat transfer test that performs an actual measurement of each CRACS train's capability to remove the assumed heat load under design conditions is impractical.

Based on discussions with the NRC Project Manager and the Region IV Reactor Projects Branch B Chief, in lieu of requesting an amendment, Ameren Missouri is requesting a Technical Specification interpretation with regard to the testing and/or inspection required to satisfy SR 3.7.11. Ameren Missouri respectfully requests your response by April 30, 2014.

This letter does not contain new commitments.

If there are any questions, please contact J. P. Kovar at 314-225-1478.

Sincerely,

L. H. Graessle
Senior Director, Operations Support

JPK/

Attachment

cc: Mr. Marc L. Dapas
Regional Administrator
U. S. Nuclear Regulatory Commission
Region IV
1600 East Lamar Boulevard
Arlington, TX 76011-4511

Senior Resident Inspector
Callaway Resident Office
U.S. Nuclear Regulatory Commission
8201 NRC Road
Steedman, MO 65077

Mr. Fred Lyon
Project Manager, Callaway Plant
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Mail Stop O-8B1
Washington, DC 20555-2738

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**Request for Interpretation of Technical Specification 3.7.11,
"Control Room Air Conditioning System (CRACS)"**

Union Electric (Ameren Missouri) Position

SR 3.7.11.1 states: "Verify each CRACS train has the capability to remove the assumed heat load." The intent of the SR is met by verifying the heat removal capability of the condenser heat exchanger (either through performance testing or inspection), ensuring the proper operation of major components in the refrigeration cycle, verification of unit air flow capacity, and Essential Service Water (ESW) flow measurement.

Basis for Ameren Missouri Position

Conditions that the Requested TS Interpretation is Intended to Resolve

On November 7, 2012, the Nuclear Regulatory Commission (NRC) Resident Inspector determined that the procedures for testing and inspection of the CRACS trains (SGK04A/B) were not adequate to meet the requirements of SR 3.7.11.1. The inspector indicated that the wording in TS SR 3.7.11.1 requires procedures that measure a CRACS train capability to remove the assumed heat load.

The TS Bases for SR 3.7.11.1 stated, in part:

> "This SR consists of verifying the heat removal capability of the condenser heat exchanger (either through performance testing or inspection), ensuring the proper operation of major components in the refrigeration cycle and verification of unit air flow capacity."

The inspector indicated that the inspection and cleaning of the SGK04A/B heat exchangers in conjunction with verifying proper refrigeration system operation and proper air handling flow was not a performance test that verifies the capability to remove the assumed heat load.

In response to the Inspector's position, on November 7, 2012, control room personnel entered SR 3.0.3 for a missed surveillance (SR 3.7.11.1). Based on Task Interface Agreement (TIA) 2008-004 (Reference 1), "Evaluation of Application of Technical Specification (TS) 4.0.3, 'Surveillance Requirement Applicability,' at Pilgrim," and consistent with the industry position presented in TSTF-529 (Reference 10), "Clarify Use and Application Rules," acceptance testing prior to plant operation provided reasonable assurance that SGK04A/B are capable of performing their specified safety function, and application of SR 3.0.3 was therefore appropriate. A risk evaluation was performed regarding delaying performance of the SR for greater than 24 hours. The risk evaluation determined that the risk in delaying the performance of the surveillance was not significant and that the surveillance should be performed at the first reasonable opportunity.

Subsequently, on February 13, 2013, NRC Integrated Inspection Report 05000483/2012005 issued non-cited violation (NCV) 05000483/2012005-01, "Failure to Perform Technical Specification Surveillance Requirements on the Control Room Air Conditioning System." The details of the non-cited violation are provided below.

Introduction

The inspectors identified a Green non-cited violation of Technical Specification 3.7.11, "Control Room Air Conditioning System (CRACS)," for failure to perform the surveillance requirements specified for the control room air conditioning system. The activities the licensee was crediting to meet the requirement to verify heat removal capability were not adequate to satisfy the requirement.

Description

The inspectors identified an issue where the licensee failed to perform heat removal capability testing as specified in Surveillance Requirement 3.7.11.1. Surveillance Requirement 3.7.11.1 requires, "Verify each Control Room Air Conditioning System train has the capability to remove the assumed heat load," once every 18 months. The inspectors determined the proper testing had only been performed once, in 1979. The inspectors discussed this concern with operations and engineering personnel, who provided the four station test procedures that were being credited to meet Surveillance Requirement 3.7.11.1. Procedure ESP-GK-0004A/B, "Condenser Inspection for SGK04A/B," was an inspection to check for blocked and plugged heat exchanger tubes inside control room air conditioning units SGK04A and SGK04B. Procedure ESP-EF-0002A/B, "Essential Service Water Train A/B Flow Verification," tests for adequate flow through the essential service water system, which cools the control room air conditioners. Procedure ETP-ZZ-03001, "GL 89-13 Heat Exchanger Inspection," directs the cleaning and inspection of heat exchanger tubes. This procedure was intended to satisfy the Generic Letter 89-13 heat exchanger reliability program requirements and was specifically credited as heat removal verification by the licensee's surveillance testing database. Procedure MSE-GK-0004A/B, "Refrigeration Cycle and Air Flow for SGK04A/B," was an operability test for SGK04A and SGK04B compressors, control circuits, evaporator coils, and fans. Upon review of these procedures, the inspectors found no measurement of heat removal capability specified in the wording of Surveillance Requirement 3.7.11.1. The inspectors brought this concern to the attention of the shift manager and operations management. On November 7, 2012, Callaway entered Surveillance Requirement 3.0.3 for missing this requirement on each train, and performed the required risk assessment. The licensee must verify that each control room air conditioning system train has the capability to remove the assumed heat load no later than May 7, 2014.

The inspectors reviewed the design and licensing basis history for air conditioning units SGK04A and SGK04B. Callaway's original technical specifications did not specify any heat removal verification surveillance requirements for the control room air conditioning units. The heat removal capability was initially tested in 1979. In response to Generic Letter 89-13, the licensee committed to clean and inspect the condensers for SGK04A and SGK04B in order to ensure that fouling remained within design basis assumptions. The control room air conditioners were added to the technical specifications upon Callaway's conversion to improved standard technical specifications in 2000, when the standard Westinghouse pressurized water reactor improved technical specification wording was adopted. In the technical specification bases, the licensee stated that heat removal capability would be verified by either heat exchanger performance testing or regular cleaning and inspection. The inspectors acknowledge that verifying the absence of heat exchanger fouling does provide added assurance that it is functioning properly, and the justification in the prompt operability determination reflected that. However, since this is only one of several variables affecting heat removal capability, the inspectors concluded that although it was specified in the basis, this action alone would not satisfy the surveillance requirement because it did not measure heat removal capability.

Analysis
Failure to perform sufficient testing to satisfy a technical specifications surveillance requirement is a performance deficiency. Specifically, the licensee did not measure heat removal capability to verify that the control room air conditioning units have the capability to remove the assumed heat load since the surveillance requirement was added to technical specifications in 2000. The performance deficiency was more than minor because it impacted the structures, systems, and components and barrier performance attribute of the control room and auxiliary building, and the Barrier Integrity Cornerstone objective to provide reasonable assurance the radiological barrier remains functional. Specifically, surveillance instructions did not meet licensing basis requirement to verify heat removal capability. Using Inspection Manual Chapter 0609 Appendix A, Exhibit 3, "Barrier Integrity Screening Questions," the inspectors determined that the finding screened as Green because it did not represent an actual degradation of the barrier function of the control room to protect the operators inside from smoke or a toxic atmosphere. The inspectors did not assign a cross-cutting aspect because the performance deficiency occurred in 2000 and is not a reflection of current licensee performance.

Enforcement
Callaway Technical Specification Surveillance Requirement 3.7.11.1 requires the licensee verify that each control room air conditioning system train has the capability to remove the assumed heat load once every 18 months. Contrary to the above, from April 1, 2000, through November 7, 2012, Callaway failed to verify that each control room air conditioning system train has the capability to remove the assumed heat load. This violation is being treated as a non-cited violation, consistent with Section 2.3.2 of the Enforcement Policy, because it was of very low safety significance and was entered into the licensee's corrective action program as Callaway Action Request 201207859: NCV 05000483/2012005-01, "Failure to Perform Technical Specification Surveillance Requirements on the Control Room Air Conditioning System."

In accordance with SR 3.0.3, the requirement to declare the Limiting Condition for Operation (LCO) not met has been delayed for a period not to exceed the limit of the specified Frequency (i.e., 18 months per the Surveillance Frequency Control Program). The application of SR 3.0.3 requires the

CRACS testing to be performed prior to May 7, 2014 at 1600 hours Central Daylight Time (CDT). If satisfactory results cannot be obtained from such testing, inoperability of both CRACS trains would result. With both CRACS trains thus becoming inoperable in MODE 1, TS 3.7.11 Condition E would be entered with Required Action E.1 requiring immediate entry into LCO 3.0.3, resulting in a required initiation of shutdown within 1 hour, shutdown to MODE 3 within 7 hours, to MODE 4 within 13 hours, and to MODE 5 within 37 hours.

Ameren Missouri has determined that a heat transfer test that performs an actual measurement of the CRACS trains capability to remove the assumed heat load under design conditions is impractical. Based on verbal and email discussions (Reference 9) with the NRC Project Manager and the Region IV Reactor Projects Branch B Chief, Ameren Missouri is requesting a technical specification interpretation in lieu of requesting an amendment.

Technical Specification Background

TS 3/4.7.6, "Control Room Emergency Ventilation System," existed prior to the improved TSs. Prior to the improved TSs a stand-alone specification for the Control Room Air Conditioning System (CRACS) subsystem of the Control Room Emergency Ventilation System (CREVS) did not exist. The associated TS Bases for TS 3/4.7.6 indicated that the OPERABILITY of the CREVS ensures that (1) the ambient air temperature does not exceed the allowable temperature for continuous-duty rating for the equipment and instrumentation cooled by this system, and (2) the control room will remain habitable for operations personnel during and following all credible accident conditions. Surveillance Requirement 4.7.6.a. required verifying that the control room air temperature is less than or equal to 84 °F at least once per 12 hours.

In October 1995, Ameren Missouri joined with Pacific Gas and Electric (Diablo Canyon), TU Electric (Comanche Peak), and Wolf Creek Nuclear Operating Company (Wolf Creek) in a joint effort to convert each plant's TS to the improved TSs. The conversion to the improved TSs was based on NUREG-1431, Revision 1, "Standard Technical Specifications Westinghouse Plants." This joint effort resulted in the submittal of a significant license amendment application, Ameren Missouri letter ULNRC-03578 (Reference 2), "Technical Specification Conversion Application," on May 15, 1997. Amendment No. 133 (Reference 3) approved the conversion to the improved TS on May 28, 1999 and the improved TSs were implemented on April 1, 2000.

Conversion application discussion of change (DOC) 11-01-M indicated that a new specification for control room heat removal was to be added per NUREG-1431. Conversion application DOC 11-02-LS-28 indicated that while ITS 3.7.11 was considered to be a new Specification, the Control Room A/C units were previously considered to be part of TS 3/4.7.6. DOC 11-02-LS-28 justified changing the Completion Time for one inoperable CRACS train from 7 days to 30 days. (A separate TS (3.7.10) was established for the Control Room Emergency Ventilation System (CREVS) under the ITS for Callaway.)

NUREG-1431, Rev. 1, SR 3.7.11.1 states: "Verify each CREATCS train has the capability to remove the assumed heat load." CREATS is the abbreviation for Control Room Emergency Air Temperature

Control System. Ameren Missouri modified the wording from CREATCS to Control Room Air Conditioning System (CRACS) for consistency with plant specific terminology.

Per Amendment No. 202 (Reference 8), issued July 28, 2011, Ameren Missouri changed the original 18 month frequency for SR 3.7.11.1 to instead be in accordance with the Surveillance Frequency Control Program.

The NUREG-1431, Rev. 1, SR 3.7.11.1 Bases states:

> This SR verifies that the heat removal capability of the system is sufficient to remove the heat load assumed in the [safety analyses] in the control room. This SR consists of a combination of testing and calculations. The [18] month Frequency is appropriate since significant degradation of the CREATCS is slow and is not expected over this time period.

To implement Amendment No. 133, and to subsequently implement Amendment No. 202, Ameren Missouri modified the SR 3.7.11.1 Bases to presently state:

> This SR verifies that the heat removal capability of the CRACS air conditioning units is adequate to remove the heat load assumed in the control room during design basis accidents. This SR consists of verifying the heat removal capability of the condenser heat exchanger (either through performance testing or inspection), ensuring the proper operation of major components in the refrigeration cycle and verification of unit air flow capacity. The Surveillance Frequency is based on operating experience, equipment reliability, and plant risk and is controlled under the Surveillance Frequency Control Program.

Original Surveillance Requirement 4.7.6.a. (for verifying control room air temperature) was relocated to a licensee controlled Technical Requirement found in Final Safety Analysis Report (FSAR) 16.7.4.1.1, "Area Temperature Monitoring – Surveillance Requirements," in accordance with DOC 10-07-LG.

During the NRC reviews of the conversion application and the subsequent license amendment request to implement the Surveillance Frequency Control Program, there were no specific requests for additional information from the NRC related to SR 3.7.11.1 or the associated Bases. No changes have been made to SR 3.7.11.1 or its Bases since implementation of Amendments No. 133 and 202.

Actions Taken in Response to NCV 05000483/2012005-01

Upon entering SR 3.0.3 on November 7, 2012, the condition was documented in Callaway Action Request (CAR) 201207859 as a potential violation. NRC Integrated Inspection Report 05000483/2012005, issued February 13, 2013, included a Green non-Cited Violation (NCV) for failure to perform surveillance testing specified in TS 3.7.11. Due to the specificity of the wording in the actual violation, Ameren Missouri and WCNOC, which had received a Green NCV for the same issue, determined that in parallel with preparing a possible license amendment request to change the SR 3.7.11.1 wording, an independent technical expert would be utilized to determine options for measuring the heat removal capability of the CRACS trains. As a result, industry experts in heat transfer testing (i.e., Zachry Nuclear, Inc.) , were selected and contracted to review the issue and determine if an acceptable method to verify the heat removal capability could be developed.

After extensive review of the system data and CRACS equipment design information, a new method of testing the CRACS, specifically the capability of the condenser heat exchanger to reject the assumed heat load to the Ultimate Heat Sink was devised. The condenser heat exchanger is the subject of testing heat removal capability as it is the only component in the system that is subject to undiscernible degradation at normal on-line operating conditions. This is due to the condenser heat exchanger being cooled by service water which is therefore subject to changes in performance over time due to fouling accumulation inside the tubes. Performance changes in other components, such as the compressor and evaporator are more immediately detectable during normal operation, as well as through other testing performed for meeting SR 3.7.11.1. Further, the heat load from the refrigerant cycle, including the control room heat load must be rejected via the condenser heat exchanger to the Ultimate Heat Sink for proper operation of the CRACS.

Some heat transfer testing is performed in the nuclear industry on air-to-water (safety related room coolers, chilled water coils, containment coolers) and water-to-water heat exchangers (component cooling water heat exchangers, essential chilled water systems), but not on direct-expansion coil air conditioning units, primarily due to the difficulty in accurately modeling phase changes throughout the refrigerant cycle and dependence on cycle operation at test conditions far removed from design. Thus, heat transfer testing by the specific methodology devised had previously not been performed. Ameren Missouri and Wolf Creek Nuclear Operating Company (WCNOC), in conjunction with industry experts, believed that this methodology had a high probability of measuring the capability to remove the assumed heat load. As such, the pursuit of a license amendment request to change the SR 3.7.11.1 wording was abandoned.

The unique complexities of modeling the condenser heat exchanger are realized when specifying the control volumes associated with the condenser, visually represented in Figure 1 below.

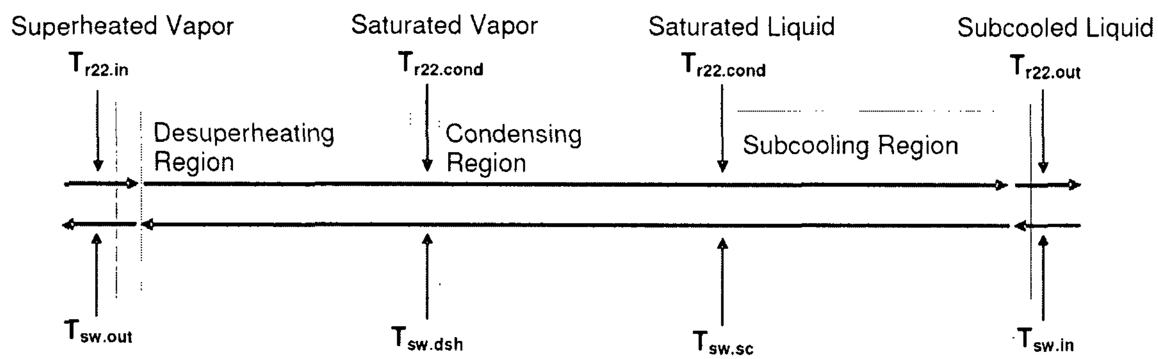

Figure 1

To derive a valid heat transfer testing model and benchmark that model to design conditions, all the refrigerant state properties must be calculated for each heat transfer region as well as service water temperatures at each region. These values at the design loading condition are not defined in design documents and are calculated based on design heat loads and the effect of the design heat loads on the cycle. Development of a test method is consequentially complex.

To show the extent of these complexities, consider common heat transfer test methodology of a water-to-water shell and tube heat exchanger of similar construction to the SGK04A/B condensers. Inlet temperatures, outlet temperatures and mass flow rates are determined by test equipment over a steady state operational period to calculate test condition heat removal rates of both the shell-side and tube-side fluids. The governing equations are equivalent:

$$Q = \dot{m}_{shell}\,\bar{c_p}\Delta T_{shell} = \dot{m}_{tube}\,\bar{c_p}\Delta T_{tube}$$

Where:
- subscript "shell" refers to the shell-side fluid
- subscript "tube" refers to the tube-side fluid
- Q = heat transfer rate (BTU/hr)
- m = mass flow rate (lb/hr)
- C_p = specific heat at the average temperature difference of the respective fluid (BTU/lb-F)
- ΔT = temperature difference between the inlet and outlet of the specific fluid (F)

These two equations are also equivalent to the Log Mean Temperature Difference Method Heat Transfer Equation:

$$Q = \dot{m}_{shell}\,\bar{c_p}\Delta T_{shell} = \dot{m}_{tube}\,\bar{c_p}\Delta T_{tube} = UA_{eff}F\Delta T_{lmtd}$$

Where:
- U = overall heat transfer coefficient (BTU/hr-ft^2-F)
- A_{eff} = total effective heat transfer surface area (ft^2)
- F = correction factor (unitless) (heat exchanger parameter dependent on construction)
- ΔT_{lmtd} = log mean temperature difference (F) (a logarithmic temperature difference relation used to determine the temperature driving force for heat transfer in flow systems)

Specifically the overall heat transfer coefficient is defined as the reciprocal of the sum of all physical resistances to heat transfer through the tube wall:

$$U_x = \left[\frac{1}{h_{i,x}} \cdot A_r + R_f + R_w + R_{fin} + \frac{1}{h_{off,x} \cdot h_{o,x}}\right]^{-1}$$

Where:
- subscript "x" refers to the respective overall heat transfer process control volume
- A_r = area ratio between the outside and inside of the tube construction (unitless)
- R_f = overall thermal resistance due to fouling (fouling factor) (hr-ft^2-F/BTU)

R_w = thermal resistance through the tube wall (dependent on tube thermal conductivity) (hr-ft^2-F/BTU)
R_{fin} = thermal resistance of tube fins (dependent on fin material and construction (hr-ft^2-F/BTU)
h_i = inside film heat transfer coefficient (hr-ft^2-F/BTU)
h_o = outside film heat transfer coefficient (hr-ft^2-F/BTU)
h_{off} = outside film correction factor (unitless)

At the test condition, the equations are equated and solved for fouling factor. This represents the actual test condition fouling. Without displaying the remaining mathematical operations for conciseness, the test fouling factor – the only variable that will vary with time due to accumulation of fouling in the tubes – is then used to extrapolate to a design condition. The result is three equations with three unknowns that are simultaneously solved to determine the projected heat removal rate at design conditions.

To test a refrigeration cycle condenser, however, a new test method had to be developed. As can be visually ascertained from Figure 1, the SGK04A/B condenser heat exchanger analysis consists of three different heat transfer zones (de-superheating, condensing and sub-cooling) that must be evaluated to determine a test condition fouling which must, by some means, be compared in a meaningful way to what the projected heat exchanger performance would be at design conditions. The governing equations for a heat transfer test of the SGK04A/B condensers are:

$$Q = \dot{m}_{tube}\,\bar{c_p}\Delta T_{tube} = \dot{m}_{R22}\left[\left(h_{R22.sh} - h_{R22.g}\right) + \left(h_{R22.fg}\right) + \left(h_{R22.f} - h_{R22.sc}\right)\right]$$
$$= U_{dsh}A_{dsh}F\Delta T_{lmtd.dsh} + U_c A_c F\Delta T_{lmtd.c} + U_{sc}A_{sc}F\Delta T_{lmtd.sc}$$

Where:
The subscript R22 refers to shell-side refrigerant states
The subscript sh refers to superheated refrigerant
The subscript g refers to the saturation point at the test pressure
The subscript f refers to the saturated liquid point at the test pressure
The subscript dsh refers to the de-superheating region of the control volume
The subscript c refers to the condensing region of the control volume
The subscript sc refers to the sub-cooling region of the control volume
h = enthalpy of the referenced state (Btu/lb)

Due to the physical reality of the governing equation, each region consists of separate overall heat transfer coefficients, effective heat removal areas, inside and outside film coefficients and outside film coefficient correction factors. Further, the model must calculate the inlet and outlet temperatures for each region separately. Due to the higher complexity from a 'normal' heat transfer test, fouling cannot be solved for in the normal fashion, but rather must be iterated until the resulting calculated areas for each region, when added, are equivalent to the known total effective heat transfer area to determine its real value.

What this means is that the only way to benchmark the model to a design condition is to benchmark the inner and outer film coefficients and the outside film coefficient correction factor to what they would be given limiting condition heat loading, water flow and inlet water temperature. The fluid properties change these values, and there are correlations for these values that are valid over certain ranges of Reynolds and Prandtl numbers (dimensionless values that characterize fluid flow characteristics that are dependent on fluid properties). Simply stated, rather than obtaining a fouling and extrapolating to design, the only way to compare the test heat removal rate to design is to obtain test data at a condition that meets the limitations imposed on the model that is benchmarked to the design condition.

The end requirement of this test is that the refrigeration cycle conditions the condenser heat exchanger experiences at test condition must be similar to conditions experienced at design conditions. Because of the wide range of applicable fluid properties that may be used in correlations to determine the heat transfer film coefficient that is used in the benchmarked model, WCNOC Programs Engineering determined that a successful test was probable. As such, WCNOC and Ameren Missouri pursued the development of a heat transfer test methodology and test procedures.

Using this approach, a heat transfer test model was developed by Zachry and WCNOC Programs Engineering. The model and test methodology, Zachry Engineering Evaluation 13-E08, "Wolf Creek SGK04A/B Condenser Model Development and Parametric Analysis," was completed on December 3, 2013, and was reviewed and accepted by Engineering on January 13, 2014. Surveillance test procedures STS PE-302A/B "CRACS Heat Removal Capability Test [A/B] Train," were subsequently developed and released on February 17, 2014.

At Wolf Creek, SGK04A was tested using procedure STS PE-302A on February 27, 2014. Field test data appeared acceptable as the resulting heat balance error was satisfactory and a reasonable period of steady state data was obtained. Heat balance error is a qualitative comparison of test condition tube-side heat removal and shell-side heat removal rates. Since the tube-side heat removal and shell-side heat removal values should be equal, a large deviation from equality indicates invalid test data collection. Despite reasonable field data, the model analysis was invalid as test-condition refrigerant sub-cooling proved to be much less than design conditions, thus rendering the overall heat transfer coefficient of the sub-cooling region erroneous due to invalid correlations to the benchmarked design model.

Also at Wolf Creek, SGK04B was tested using procedure STS PE-302B on March 6, 2014. Again, field test data appeared reasonable as heat balance error was satisfactory and a period of steady state data was obtained. However, the model analysis for this test was also invalid due to low tube-side velocities invalidating the tube-side heat transfer film coefficient correlation of the sub-cooling region of the condenser heat exchanger.

Based on the results of testing performed at Wolf Creek using procedures STS PE-302A/B, Ameren Missouri believes it is unlikely that the test method developed specifically to address measuring heat removal capability of the CRACS trains (SR 3.7.11.1) will produce repeatable and valid results, for the reason that the CRACS operates with a heat load that is much less than design limiting conditions during normal modes of operation.

Technical Evaluation of Heat Transfer Testing Suitability

SR 3.7.11.1 requires verifying each CRACS train (SGK04A/B) has the capability to remove the assumed heat load. The condenser heat exchangers on SGK04A/B employ Essential Service Water (ESW) to remove heat from the refrigeration cycle. The ability of the system to reject the design heat load is directly dependent on the capacity of the condenser heat exchangers to reject the design coil load combined with compressor work input. Therefore, the heat rejected from the refrigeration cycle of the respective equipment is exchanged with the Ultimate Heat Sink. This places the condenser units of each air conditioner under the scope of NRC Generic Letter 89-13 (Reference 4), "Service Water System Problems Affecting Safety-Related Equipment (Generic Letter 89-13)." Generic Letter 89-13 was issued due to operating experience and studies that led the NRC to question the compliance of the service water systems in nuclear power plants that were required to meet the minimum requirements of 10 CFR 50 Appendix A, General Design Criteria (GDC) 44, "Cooling water," GDC 45, "Inspection of cooling water system," GDC 46, "Testing of cooling water system," and quality assurance requirements.

Generic Letter 89-13 requested plants perform five recommended actions or provide assurance that alternative programs satisfy the heat removal requirements of the service water system. Specifically, recommended Action II of GL 89-13 requested, in part, that plants

> "Conduct a test program to verify the heat transfer capability of all safety-related heat exchangers cooled by service water."
>
> "A program acceptable to the NRC for heat exchanger testing is described in "Program for Testing Heat Transfer Capability" (Enclosure 2). It should be noted that Enclosure 2 is provided as guidance for an acceptable program. An equally effective program to ensure satisfaction of the heat removal requirements of the service water system would also be acceptable."
>
> "An example of an alternative action that would be acceptable to the NRC is frequent regular maintenance of a heat exchanger in lieu of testing for degraded performance of the heat exchanger."

Subsequently, the NRC issued Generic Letter 89-13, Supplement 1 (Reference 5) that provided questions and answers from four workshops conducted on the generic letter. Enclosure 1, Section III, "Action II – Heat Transfer Testing," Subsection A, "Testing Method," Questions 4, 5, and 6 relate to acceptable testing methods. Applicable questions and the NRC responses are provided below.

4. Page 5, paragraph 3. What is meant by "The relevant temperatures should be verified to be within the design limits?" Does this imply testing should be conducted with the design-basis heat load? Is it acceptable to conduct testing for all heat exchangers at off normal conditions,

provided accurate and relevant data can be acquired, and analytical methods used to determine the heat transfer capacity at design conditions? (Portland General Electric)

Answer

Enclosure 2 of the generic letter discusses in detail verifying various parameters to be within design limits. Testing with design-basis heat loads is recommended ideally. If testing can be done under design conditions, it should be done under those conditions. Realizing this may not be practicable in nonaccident circumstances, the next best step is to conduct tests under off-design conditions and analytically correct the results to the design conditions. Such a procedure is acceptable if it is necessary but not if testing under design conditions is practicable.

5. For heat exchangers that cannot be tested at the design heat removal rate, what is the NRC-recommended method to extrapolate the test data to design conditions? Does the NRC have any additional recommendations for extrapolating test data taken at very low loads (less than 10% design load) to design conditions? (Southern California Edison)

   Answer

   The staff does not have a recommended method of extrapolation. However, the EPRI service water system working group has been developing such guidance as have some licensees such as Duke Power. These may be places to start when developing appropriate testing programs.

6. Recommended Action II requires that "the relevant temperatures should be verified to be within design limits." Also, Enclosure 2, Item II.A states, "Perform functional testing with the heat exchanger operating, if practical, at its design heat removal rate to verify its capabilities. Temperature and flow compensation should be made in the calculations to adjust the results to the design conditions."

   It is not practical to test the heat exchangers at design heat removal rates. Also, we are unable to find a method which has the requisite level of precision to adjust the test results to design conditions.

   Please discuss an acceptable method to adjust the test results to the design conditions. Also provide the scientific bases, or a reference, for the proposed method.

   Also, the heat removal test cannot be performed on the containment spray heat exchangers because there is no heat source. The only test that can be performed is a pressure drop test. Is this acceptable? If not, what is recommended? (Indiana and Michigan Power)

Answer

As mentioned previously, the NRC does not have a recommended test method. See the answer to the previous question. With regard to the testing of containment spray heat exchangers, as of all safety-related heat exchangers, a pressure drop test alone is not sufficient to satisfy the indicated heat transfer capability concerns. If it is not practicable to test a heat exchanger, then the licensee or applicant may propose a program of periodic inspection, maintenance, and cleaning as an alternative. We are aware, however, of one licensee who was able to test the containment spray heat exchanger by heating the refueling water storage tank water approximately 10°F and then performing temperature monitoring tests as well as pressure drop tests.

Ameren Missouri letter ULNRC-05425 (Reference 6), provided an updated response to Generic Letter 89-13 regarding heat exchanger performance monitoring in a new Commitment 50122. Commitment 50122 states in part:

SGK04A/B, SGK05A/B The primary monitoring method for the A/C heat exchangers will be cleaning and inspection of the heat exchanger tubes per EDP-ZZ- 01112. The frequency of the clean and inspect action will not exceed 5 years and will be determined based on past inspection results. Flushing of the heat exchangers will be performed by guidance from EDP-ZZ-01112. Essential Service Water flow verification will be performed by Essential Service Water flow verification under ESP-EF-0002A/B.

The responsibility for performing Essential Service Water flow verification has recently been transferred from Engineering to Operations; accordingly, surveillance procedures ESP-EF-0002A/B, "Essential Service Water Train [A/B] Flow Verification," have been redesignated as OSP-EF-0002A/B. This administrative change will be reflected in a revision to Commitment 50122 that is being tracked as an action under CAR 201307636.

A review of Electric Power Research Institute (EPRI) TR-107397, 1998 Final Report, "Service Water Heat Exchanger Testing Guidelines," indicates that the design of SGK04A/B makes heat transfer performance testing of these units impractical. Section 1.2 outlines unique challenges that face implementation of service water heat exchanger test programs. Other components in the nuclear industry that are commonly tested such as safety related pumps are routinely operated at or near conditions that are at or near the conditions at which performance is to be evaluated. Since test parameters are measured at or near limiting conditions, the sensitivity of test results to measurement uncertainty is well controlled. When this is the case, simple correction curves or basic analysis can be used to correct the measured performance to that of accident conditions. Unlike these components, the SGK04A/B condenser heat exchangers operate at conditions that are much less than design basis accident conditions. The loads on the refrigeration cycle are significantly lower than worst-case loading conditions, and the service water temperature does not approach the limit of the Ultimate Heat Sink design basis temperature. Given existing test conditions, the data would have to be extrapolated to determine heat load removal capabilities.

SGK04A/B utilize direct-expansion refrigerant coils to cool the air as opposed to a chilled water system used in some plants that do have test procedures for CRACS. To achieve testing similar to what has been done by other utilities on chilled water systems, air-side data points would have to be collected including inlet and outlet temperature and humidity. This data is achievable, but will have very high individual parameter uncertainty due to high bias measurement uncertainty, which significantly increases the overall test uncertainty. This occurs because the flow distribution across air coils is never completely uniform, creating large temperature gradients across the coil face. In addition, compressor work would have to be determined and subtracted from the condenser heat load to properly credit total system heat removal. If the design condition could be accurately modeled, the uncertainty involved with each value would produce significant error upon extrapolation to design conditions.

The SGK04A/B condenser heat exchangers are dependent on the efficiency of the refrigeration cycle, which is directly dependent on the cycle's ability to reject heat through the condenser, which is dependent on the service water flow and temperature. Subjecting the unit to limiting conditions would testing provide an accurate measurement of the heat load removal capabilities of the entire system. However, duplicating design conditions is not practical.

Chapter 2, "Test Methods," of EPRI TR-107397 provides additional insight on the appropriate testing or monitoring methods. The topical report examines the test and monitoring methods that are deemed acceptable per the 1994 ASME "Standards and Guides for Operation and Maintenance of Nuclear Power Plants," Part 21, "Inservice Performance Testing of Heat Exchangers in Light-Water Reactor Power Plants." These test and monitoring methods include: Function Test, Heat Transfer Test, Temperature Effectiveness Test, Temperature Difference Monitoring method, Pressure Loss Monitoring method and Visual Inspection Monitoring method.

Applying the EPRI TR-107397 guidance to SGK04A/B, a Functional Test is not possible because the limiting conditions cannot be achieved for test conditions. A Heat Transfer Test has been found not to be accurate because when data is extrapolated to design conditions instrument uncertainty becomes large, accident flow/temperature conditions are not achievable and phase changes that occur throughout the cycle require extensive modeling that is based on assumptions that may be inaccurate during test conditions. A Temperature Effectiveness Test is not applicable because mass flow rates must closely approximate limiting condition, which is not possible given the load variance of the refrigeration cycle. The Temperature Difference Monitoring method is not applicable because it cannot be used for situations involving phase change such as condensation, which is present across both the shell and tube side of the evaporator.

Thus, per EPRI TR-107397, the only monitoring methods applicable to SGK04A/B are the Pressure Loss Monitoring method and the Visual Inspection Monitoring method. The Pressure Loss Monitoring method requires a test condition flow rate near the specified value. This is achievable when the units are secured and the condenser modulating valve is fully open as the condition provides the maximum available flow to the unit, i.e. the flow that would be available given a design heat loading demand at limiting conditions. Flow and pressure drop across the condenser provides a metric to monitor cleanliness of the heat exchanger. High in-service macrofouling will cause a significant increase in differential pressure across the condenser heat exchanger, normalized to design flow, the pressure drop is a trendable indication of macrofouling that does not require opening the heat exchanger.

Visual Inspection Monitoring performed on the condenser heat exchanger will reveal dominant thermal performance degradation mechanisms such as sediment, biofouling and corrosion deposits that create tube blockage. Per inspection procedure ETP-ZZ-03001, "GL89-13 Heat Exchanger Inspection" (as referenced in EDP-ZZ-01112, "Heat Exchanger Predictive Performance Manual"), sediment and corrosion product deposits identified during the inspection are measured and foreign material blockage is noted and documented. These As-Found results are trended and evaluated for impact. This inspection procedure is used for condenser heat exchanger visual inspections to evaluate As-Found conditions, ensuring that As-Found conditions that violate the acceptance criterion for tube blockage are evaluated.

Verification of Heat Removal Capability

Heat Loading Assumed in Design Bases Accident Conditions

FSAR Section 9.4.1.1 specifies that the CRACS provides the control room with a conditioned atmosphere during all modes of plant operation, including post-accident operation (General Design Criterion 19). The CRACS operates in a continuous recirculation mode to maintain the control room temperature. The amount of cooling provided by the self-contained refrigeration system is self-regulating and therefore automatically compensates for changes in the control room heat load, including latent load due to presence of moisture.

Using an assumption that minimum required cooling coil (evaporator) capacity for accident conditions was 432,851 BTU/hr, calculation ARC-433, Rev. 0, "Control Room Temperature Analysis," determined the Control Room temperature would be maintained below 84 °F, as specified in the Bases for TS 3.7.11, during the most limiting normal or post-accident conditions (i.e., Control Room Ventilation Isolation Signal (CRVIS) received without Station Blackout (SBO)). The installed compressor and condenser heat exchanger were designed per Design Specification M-622.1 Revision 008 "Packaged Air Conditioning Units." The manufacturer of the installed equipment used a total cooling coil load design input of 493,700 BTU/hr to size the equipment. This input is conservatively 60,849 Btu/hr greater than the minimum required.

The condenser heat exchanger is manufactured to reject the assumed accident cooling coil load of 493,700 BTU/hr plus compressor work input at design limiting conditions. Per M-622.1, at design limiting conditions, the condenser is designed to reject 662,864 BTU/hr. This requires, per the data sheet, an ESW flow rate of 140 gpm at the limiting condition of a 95 °F Ultimate Heat Sink temperature. This value includes a design tube-side fouling of 0.002 hr-ft^2-F/BTU.

Calculation GK-17 Revision 000, "Ctrl Rm Air Cond Unit Plugged Tubes, Min Flow and Fouling Limits," conservatively shows that with 40% of the condenser tubes plugged (i.e., 16 tubes maximum for passes #1 and #3, and 12 tubes maximum for pass #2, for a total maximum of 44 tubes), the SGK04A/B condensers are capable of removing the required heat from the refrigerant to maintain the overall total cooling capacity for the SGK04A/B units, based on available margin.

Surveillance Testing

The following describes the surveillance testing that satisfies the SR 3.7.11.1 requirements that verify each CRACS train's heat removal capability.

<u>Procedures MSE-GK-0004A/B, "Refrigeration Cycle and Air Flow for SGK04[A/B]"</u>

The purpose of surveillance procedures MSE-GK-0004A/B is to verify an adequate airflow capacity through SGK04A/B and proper operation of the compressors. Verification of the required air flow is performed by Surveillances PM0907177 and PM0907178, for SGK04A and SGK04B, respectively. The acceptance criteria for air flow through each fan unit are 16200 to 19800 CFM.

Verification that compressors are performing their design function is also accomplished through Surveillances PM0907177 and PM0907178, for SGK04A and SGK04B, respectively. These surveillances measure a variety of operational parameters of the cooling unit. Compressor inlet and outlet pressure and temperatures are measured and an acceptable range for discharge pressure is also specified (200 to 290 psig), which verifies that the control circuit components are functioning as designed. Additionally, expansion valve outlet temperatures, oil pressure and liquid line temperature are measured. The evaporator coils are verified functional by demonstrating that all 4 solenoid valves are energized when the thermostat is turned down to 55 degrees F. Verification of these critical refrigeration cycle parameters correlates directly with the capability of the SGK04A/B units to perform as designed and thus ensure the capability to remove the assumed heat load.

Each of these Surveillances is scheduled on an 18-month frequency in accordance with the Surveillance Frequency Control Program, as specified in TS SR 3.7.11.1. Results of the most recent performances of these Surveillances are as follows:

Component	Surveillance	Job	Complete	Result
SGK04A	PM0907177	12511892	08/06/2013	SAT
SGK04B	PM0907178	12505303	08/25/2013	SAT

<u>Procedures OSP-EF-0002A/B, "Essential Service Water Train [A/B] Flow Verification"</u>

Verification of ESW flow is performed per Surveillances PM0817388 and PM0818541 for 'A' and 'B' ESW trains, respectively. The acceptance criteria utilized in the surveillance procedures is derived from Calculation EF-45, which considers pump degradation, UHS level changes, instrument uncertainties, Auxiliary Feedwater Pump Demand and corrosion product build up in ESW piping. The acceptance criteria for minimum ESW flow rate to SGK04A and SGK04B are 159 gpm and 167 gpm, respectively.

Each of these Surveillances is scheduled on an 18-month frequency (i.e., during every refueling outage) in accordance with the Surveillance Frequency Control Program, as specified in TS SR 3.6.6.7. Results of the most recent performances of these Surveillances are as follows:

Component	Surveillance	Job	Complete	Result
SGK04A	PM0817388	11514820	05/03/2013	SAT
SGK04B	PM0818541	11514535	04/25/2013	SAT

Procedures ESP-GK-0004A/B, "Condenser Inspection for SGK04[A/B]"

Visual inspection of SGK04A and SGK04B is performed per Surveillances PM0907175 and PM0907176, respectively. Each of these procedures directs the inspector to use ETP-ZZ-03001, for which the purpose is defined: "This procedure is a guideline for inspecting heat exchangers governed by the requirements of NRC Generic Letter 89-13, 'Service Water Problems Affecting Safety-Related Equipment'." The intent of NRC GL 89-13 is to verify the heat removal capability of service water (ESW) cooled heat exchangers.

Visual inspection of heat exchangers in accordance with ETP-ZZ-03001 provides a qualitative assessment of heat exchanger condition and mandates that it meets Visual Inspection Acceptance Criteria, which are established by a qualified inspector to effectively verify its capability to meet all design safety functions. The visual inspection addresses issues capable of affecting heat transfer capability such as: bypass flow; macro-fouling or tube plugging within acceptable limits (Calculation GK-17 Addenda 1); micro-fouling below design limitations; and corrosion which could affect the structural integrity of the heat exchanger. Verification that tube blockage remains below the maximum accepted values established per Calculation GK-17 is performed during visual inspection.

Routine flushing of SGK04A and SGK04B is performed per Preventive Maintenance (PM) Task IDs PM0823229 and PM0823230, respectively, at 12 week intervals. Performance of these PMs requires operation (opening) of ESW Control Valves, GKV0765 and GKV0766, to allow full water flow through the condensing heat exchanger. This provides a dual purpose not only to remove sedimentation from the heat exchanger but also allows verification of proper operation of the ESW control valves.

The visual inspection Surveillances are scheduled on an 18-month frequency in accordance with the Surveillance Frequency Control Program, as specified in TS SR 3.7.11.1, while the flushing PMs are scheduled on a 12-week frequency as noted above. Results of the most recent performances of these Surveillances and flushing PMs are as follows:

Component	Surveillance / PM	Job	Complete	Result
SGK04A	PM0907175	12512745	01/27/2014	SAT (by Job 12512139.580)
	PM0823229	13513896	01/29/2014	SAT (by Job 12512139.500 & .580)
SGK04B	PM0907176	12505512	08/27/2013	SAT (by Job 12505285.580)
	PM0823230	13514436	03/12/2014	SAT

Conclusion

A heat transfer test that performs a measurement of the capability of each CRACS train to remove the assumed heat load is impractical. Ameren Missouri considers SR 3.7.11.1 as being met by verifying the heat removal capability of the heat exchanger through periodic inspection monitoring, maintenance, and cleaning in conjunction with verification of the proper operation of major components in the refrigeration cycle, verification of unit air flow capacity, and verification of water flow measurement. The testing being performed provides reasonable assurance that the CRACS trains have the capability to remove the assumed heat load and therefore perform their specified safety function.

References

1. TIA 2008-004, “Task Interface Agreement (TIA) - Evaluation of Application of Technical Specification (TS) 4.0.3, 'Surveillance Requirement Applicability,' at Pilgrim (TIA2008-004),” December 31, 2008. [ADAMS Accession No. ML083660174].

2. Ameren Missouri letter ULNRC-03578, “Technical Specification Conversion Application,” May 15, 1997.

3. Callaway Unit 1 License Amendment No. 133, "Conversion to Improved Technical Specifications for Callaway Plant, Unit 1," May 28, 1999 [ADAMS Accession No. ML021640446].

4. NRC Generic Letter 89-13, “Service Water System Problems Affecting Safety-Related Equipment (Generic Letter 89-13),” July 18, 1989.

5. NRC Generic Letter 89-13, Supplement 1, “Service Water System Problems Affecting Safety-Related Equipment (Generic Letter 89-13, Supplement 1),” April 4, 1990.

6. ULNRC-05425, “Cycle 15 Commitment Change Summary Report,” July 16, 2007 [ADAMS Accession No. ML072060371].

7. EPRI TR-107397, “Service Water Heat Exchanger Testing Guidelines,” March 1998.

8. Callaway Unit 1 License Amendment No. 202, "Adoption of TSTF-425, Revision 3, 'Relocate Surveillance Frequencies to Licensee Control -RITSTF Initiative 58' (TAC No. ME4506)," July 29, 2011 [ADAMS Accession No. ML111661877].

9. Email from Fred Lyon, NRR to Steve G. Wideman, WCNOC, et al. "RE: SR 3.7.11.1 License Amendment Request – Options," March 19, 2014.

10. TSTF-529, Revision 2, "Clarify Use and Application Rules," included as attachment to Technical Specifications Task Force letter to NRC TSTF-14-02 "Transmittal of TSTF-529, Revision 2, 'Clarify Use and Application Rules'," January 19, 2014 [ADAMS Accession No. ML14014A330]