WOLF CREEK
NUCLEAR OPERATING CORPORATION

Russell A. Smith
Site Vice President and Chief Nuclear Operating Officer

March 21, 2014

WO 14-0038

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Subject: Docket No. 50-482: Request for Interpretation of Technical Specification 3.7.11, "Control Room Air Conditioning System (CRACS)"

Gentlemen:

Wolf Creek Nuclear Operating Corporation (WCNOC) is requesting Nuclear Regulatory Commission (NRC) concurrence with the following position regarding the intent of Technical Specification (TS) 3.7.11, "Control Room Air Conditioning System (CRACS)," specifically, Surveillance Requirement (SR) 3.7.11.1. This request is based on the guidance in NRC Information Notice 97-80, "Licensee Technical Specification Interpretations," as supported by NRC Inspection Manual, Part 9900: Technical Guidance, Chapter STSINTR, "Licensee Technical Specification Interpretations."

> 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 water flow measurement.

WCNOC considers this position on SR 3.7.11.1 to be consistent with the Wolf Creek Generating Station (WCGS) licensing basis.

On November 1, 2012, control room personnel entered Surveillance Requirement (SR) 3.0.3 for missed SR 3.7.11.1 when the Nuclear Regulatory Commission (NRC) resident inspector determined that the procedures 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 of the specified Frequency (18 month). The application of SR 3.0.3 requires the testing to be performed prior to May 1, 2014 at 1332 hours Central Daylight Time.

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WCNOC, in conjunction with industry experts, developed a new test method to measure the capability to remove the assumed heat load. Based on recent testing of the WCGS CRACS trains, it is unlikely that the test method developed will produce repeatable, valid results for the reason that the CRACS operates with a heat load that is much less than design limiting conditions during normal operation. WCNOC 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 discussions with the NRC Project Manager and the Region IV Reactor Projects Branch B Chief, in lieu of requesting an amendment, WCNOC is requesting a technical specification interpretation.

Your response is requested by April 25, 2014 to allow plant startup from the current mid-cycle outage. The current outage schedule indicates that the plant will be in MODE 5 on May 1, 2014 with MODE 4 projected for May 2, 2014.

This letter contains no commitments. If you have any questions concerning this matter, please contact me at (620) 364-4156, or Mr. Michael J. Westman at (620) 364-4009.

Sincerely,

Russell A. Smith

RAS/rlt

Attachment

cc: M. A. Dapas (NRC), w/a
C. F. Lyon (NRC), w/a
N. F. O'Keefe (NRC), w/a
Senior Resident Inspector (NRC), w/a

REQUEST FOR INTERPRETATION OF TECHNICAL SPECIFICATION 3.7.11, "CONTROL ROOM AIR CONDITIONING SYSTEM (CRACS)"

Wolf Creek Nuclear Operating Corporation (WCNOC) 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 WCNOC Positiion

Conditions that the Requested TS Interpretation is Intended to Resolve

On November 1, 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.

On November 1, 2012, control room personnel entered SR 3.0.3 for a missed surveillance (SR 3.7.11.1). A risk evaluation was performed to delay 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. On November 5, 2012, the inspector questioned the application of SR 3.0.3 to SR 3.7.11.1 indicating that if the surveillance testing (i.e., a performance test measuring the capability of the CRACS trains to remove the assumed heat load) had never been performed then SR 3.0.3 cannot be applied. This position was based on Task Interface Agreement (TIA) 2008-004 (Reference 1), "Evaluation of Application of Technical Specification (TS) 4.0.3, "Surveillance Requirement Applicability," at Pilgram." Subsequently, Operability Evaluation OE GK-12-017-00, Revision 0, "SGK04A/B Control Room Air Conditioning System (CRACS)," was performed utilizing acceptance testing prior to plant operation to determine that SGK04A/B are capable of performing their specified safety function and application of SR 3.0.3 was appropriate.

Subsequently, on February 13, 2013, NRC Integrated Inspection Report 05000482/2012005 issued non-cited violation (NCV) 05000482/2012005-04, "Failure to Perform Sufficient Control Room Air Conditioning Testing to Satisfy Technical Specification Surveillance Requirements." The details of the non-cited violation are provided below.

1. Introduction. The inspectors identified a Green non-cited violation for failure to perform surveillance testing specified in Technical Specification 3.7.11, "Control Room Air Conditioning System." The activities the licensee was crediting to meet the requirement to verify heat removal capability were not adequate.

   Description. While reviewing operating experience, the inspectors were following up on an issue in which Generic Letter 89-13 heat exchanger testing was being substituted for technical specification surveillance requirements. The inspectors reviewed Wolf Creek's technical specifications. 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 noted that the licensee's technical specification surveillance testing database included three test procedures that were credited to meet Surveillance Requirement 3.7.11.1. Procedure, STS GK-001A/B, is an operability test which runs each train of the air conditioning and ventilation system for 4 consecutive hours. Procedure STS PE-016A/B, measures the air flow across the evaporator. Procedure, STS MT-072/073, requires cleaning and inspection of the air conditioning condenser tubes. This third procedure also was also credited to satisfy the Generic Letter 89-13 heat exchanger reliability program requirements for the control room air conditioning units, and was specifically credited as heat removal verification by the licensee's surveillance testing database. Upon review of these procedures, the inspectors identified that none of the procedures measured the capability to remove the assumed heat load as specified in the wording of Surveillance Requirement 3.7.11.1.

   The inspectors brought this concern to the attention of the surveillance coordinator. The surveillance coordinator immediately notified operations management and instructed the shift manager to enter Surveillance Requirement 3.0.3. The licensee determined that there was a reasonable expectation that air conditioning units SGK04A and SGK04B were still fully capable of meeting their specified safety function. Therefore, the air conditioning units were declared operable but non-conforming. The inspectors reviewed the prompt operability determination and risk assessment and determined that such a judgment was appropriate to the circumstances.

   The inspectors reviewed the design and licensing basis history for the control room air conditioning units SGK04A and SGK04B. Wolf Creek's original custom technical specifications in use from 1985-1999, did not include any limiting conditions for operation or surveillance requirements for the control room air conditioning units. The control room air conditioners were added to the technical specifications upon Wolf Creek's conversion to improved standard technical specifications in 1999. The standard Westinghouse improved technical specification wording was adopted. In the technical specification bases, the licensee did acknowledge that they may not subject the control room air conditioning units to heat exchanger performance testing, but were instead performing regular cleaning and inspection in accordance with their Generic Letter 89-13 heat exchanger reliability program. 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 reflects that. However, since this is only one of several variables affecting heat removal capabilities, 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. The failure to perform sufficient testing to satisfy a surveillance requirement required by technical specifications is a performance deficiency. Specifically, the licensee did not measure heat removal capability of the control room air conditioning units within the required periodicity 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 1999 and is not indicative of current licensee performance.

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 (18 month). The application of SR 3.0.3 requires the testing to be performed prior to May 1, 2014 at 1332 hours Central Daylight Time (CDT). The current outage schedule indicates that the plant will be in MODE 5 on May 1, 2014 with MODE 4 projected for May 2, 2014. With both CRACS trains inoperable in MODE 5, Condition D would be entered with Required Actions D.1 and D.2 requiring the suspension of CORE ALTERATIONS and suspension of movement of irradiated fuel assemblies.

WCNOC 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 discussions with the NRC Project Manager and the Region IV Reactor Projects Branch B Chief, in lieu of requesting an amendment, WCNOC is requesting a technical specification interpretation.

Technical Specification Background

TS 3/4.7.6, "Control Room Emergency Ventilation System," existed prior to the improved TSs. The associated TS Bases for TS 3/4.7.6 indicated that the OPERABILITY of the Control Room Emergency Ventilation System 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, WCNOC joined with Pacific Gas and Electric (Diablo Canyon), TU Electric (Comanche Peak), and Union Electric (Callaway Plant) in a joint effort to convert the current 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 WCNOC letter ET 97-0050 (Reference 2), "Technical Specification Conversion Application," on May 15, 1997. Amendment No. 123 (Reference 3) approved the conversion to the improved TS. The improved TSs were implemented on December 19, 1999. Prior to the improved TSs a standalone specification for the Control Room Air Conditioning System (CRACS) did not exist.

Conversion application discussion of change (DOC) 11-01-M indicated that a new specification for control room heat removal is 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 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.

NUREG-1431, Rev. 1, SR 3.7.11.1 states: "Verify each CREATS train has the capability to remove the assumed heat load." CREATS is the abbreviation for Control Room Emergency Air Temperature Control System. WCNOC modified the wording from CREATS to Control Room Air Conditioning System (CRACS) for consistency with plant specific terminology. No changes have been made to SR 3.7.11.1 since issuance of Amendment No. 123.

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."

In the conversion application, WCNOC modified the SR 3.7.11.1 Bases to 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 18 month Frequency is appropriate since significant degradation of the CRACS is slow and is not expected over this time period."

Surveillance Requirement 4.7.6.a. (verifying control room air temperature) was relocated to a licensee controlled document, Technical Requirements Manual, TR 3.7.22, "Area Temperature Monitoring," under DOC 10-07-LG.

During the NRC review of the conversion application, there were no specific requests for additional information from the NRC related to SR 3.7.11.1 and the associated Bases. No changes had been made to the SR 3.7.11.1 Bases since issuance of Amendment No. 123 until February 27, 2014 (Revision 61). Revision 61 to SR 3.7.11.1 Bases was made to indicate that the SR consists of a combination of testing and calculations based on the development of a testing protocol to measure the capability of the CRACS trains to remove the assumed heat load.

Actions Taken in Response to (NCV) 05000482/2012005-04

Upon entering SR 3.0.3 on November 1, 2012, the condition was documented in condition report (CR) 00059406 as a potential violation and an Apparent Cause Evaluation was commenced. The Apparent Cause Evaluation, completed on December 5, 2012, concluded that heat transfer testing of the CRACS trains was not a viable option based on available heat transfer testing methods, and that all the necessary parameters for performance testing or inspection to meet SR 3.7.11.1, as defined in the TS Bases, were not performed or credited. This conclusion was supported by the leading industry heat transfer testing experts. The Apparent Cause Evaluation also identified deficiencies in surveillance procedures that were being credited for meeting the SR at that time, including additional data points that should be taken to ensure the equipment was capable of removing the assumed heat load. These deficiencies have been corrected by actions from CR00059406.

Upon receipt of the February 13, 2013, NRC Integrated Inspection Report 05000482/2012005, which included the Green non-Cited Violation for failure to perform surveillance testing specified in TS 3.7.11, a gap analysis was performed on the existing Apparent Cause Evaluation. Due to the specificity of the wording in the actual violation, WCNOC 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, Zachry Nuclear, Inc., industry experts in heat transfer testing were selected and contracted to review the Apparent Cause Evaluation 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 generally 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. WCNOC, in conjunction with industry experts, believed that this methodology could effectively measure 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 2 below.

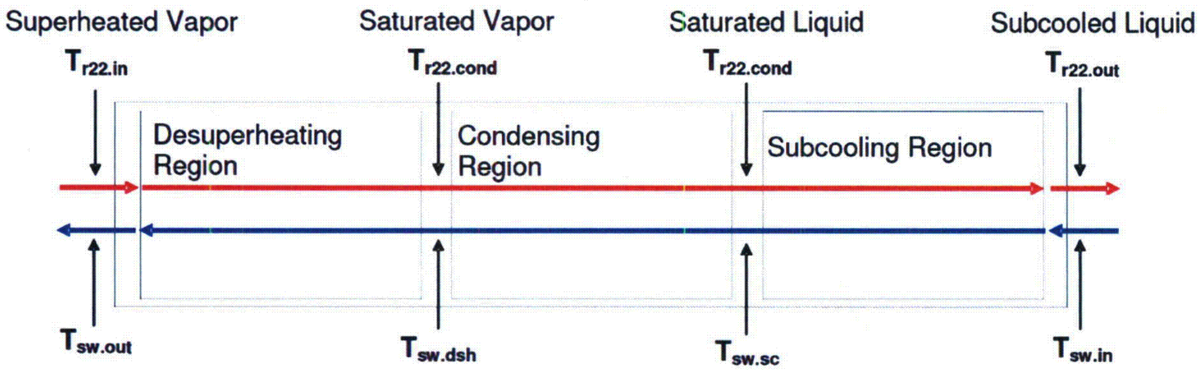

Figure 2

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 saturated vapor 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 Pradtl 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. Engineering decided that a test should be attempted because the wide range of applicable fluid properties and heat transfer coefficients used in the model would provide sufficient flexibility to handle test conditions that were significantly lower load that the design condition. As such, WCNOC pursued the development of a heat transfer test methodology and test procedures.

Using this approach, the 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.

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. The tube-side heat removal and shell-side heat removal values should be equal, large deviation from equality indicates invalid test data collection. Despite reasonable field data, the model analysis was invalid as test-condition refrigerant sub-cooling was much greater than design conditions rendering the overall heat transfer coefficient of the sub-cooling region erroneous due to invalid correlations to the benchmarked design model.

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 testing performed using procedures STS PE-302A/B, 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, 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 response 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 exchanger, 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.

WCNOC letter ET 94-0012 (Reference 6), provided an updated response to Generic Letter 89-13. This letter states, in part:

"It was also determined that ten of the 32 heat exchangers in the program were not well suited to heat transfer verification testing due to their unique design applications. These were the Diesel Generator Heat Exchangers (EKJ03A & B, EKJ04A & B, EKJ06A & B), the Control Room Air Conditioning Units (SGK04A & B), and the Class I/E Air Conditioning Units (SGK05A & B). The Diesel Generator Heat Exchangers carry heat loads which are not easily determined by field instruments due to temperature modulating valves and the Control Room and Class I/E Room Air Conditioning Units are water-to-freon heat exchangers which involve quantifying phase changes, enthalpy changes, and transient flow patterns. For these reasons, mechanical and/or chemical cleaning is performed for corrosion or deposit removal. Also, this group of heat exchangers is visually inspected for erosion, corrosion, biofouling, pitting, and wall thinning. This maintenance program is currently performed once per refueling cycle on these particular components."

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 dependant 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 biofouling and corrosion deposits that create tube blockage. Any fouling that partially blocks tube flow is considered plugged per inspection procedure QCP-20-518 "Visual Examination of Heat Exchangers and Piping Components." This inspection procedure is used for condenser heat exchanger visual inspections to evaluate As-Found conditions; therefore, 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

Updated Safety Analysis Report (USAR) 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 Criteria - 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.

Calculation GK-M-001, Rev. 3, "Cooling and Heating Load Calculation for Control Room HVAC System Capabilities During Normal Plant Operation and Accident Conditions – (SGK04A/B)," calculates the minimum required cooling coil (evaporator) capacity for accident conditions to be 463,087 BTU/hr. The installed compressor and condenser heat exchanger were designed per Design Specification M-622.1A "Replacement Packaged Air Conditioning Units for the Wolf Creek Generating Station ASME Boiler and Pressure Vessel Code Section III Class 3." The manufacturer of the installed equipment used a total cooling coil load design input of 493,700 BTU/hr (M-622.1A-VDS-1.03 Revision W02, "SGK04A/B Cooling Coil and Compressor Data Sheet") to size the equipment. This input is conservatively 30,613 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-622.1A-VDS-1.02 Revision W02, "Condenser Data Sheet SGK04A/B," at design limiting conditions, the condenser is designed to reject 644,561 BTU/hr. This requires, per the data sheet, an ESW flow rate of 85 gpm at the limiting condition of a 95 °F Ultimate Heat Sink temperature. Accounting for test measurement uncertainty and additional uncertainty to account for Emergency Diesel Generator postulated voltage variations, a measured minimum flow rate of 89 gpm is required. This value includes a design tube-side fouling of 0.002 hr-ft^2-F/BTU.

Calculation GK-M-009 Revision 1, "Tube Plugging Criteria for Control Room A/C Unit SGK04A/B Condensers and ESF Switchgear Rooms AC Unit SGK05A/B Condensers" conservatively shows that with 10% of the condenser tubes plugged (5 tubes per pass maximum for a maximum of 15 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 trains heat removal capability.

STS PE-010A/B, "Control Room A/C System Flow Rate Verification [A/B] Train,"

The purpose of surveillance procedures STS PE-010A/B is to verify an adequate airflow capacity through SGK04A/B. This is accomplished by performing a pitot tube velocity transverse at the suction duct immediately upstream of the air conditioning unit, using an air data multimeter or equivalent instrument, to determine the average velocity. Using the obtained airflow velocity and the cross sectional area of the duct, the flow rate is directly calculated as the product of airflow velocity and flow area. The result verifies that the air flow is at or above the design flow rate, including instrument uncertainty.

- For SGK04A, this test was last performed on August 13, 2013 with a flow rate of 21,237 cfm.

- For the SGK04B, this test was last performed July 18, 2013 with a flow rate of 23, 802 cfm.

Both of these values are within the acceptance criteria (≥ 21,012 cfm based on Calcualtion GK-M-001) provided within the surveillance procedures.

STN PE-037A/B, "ESW Train [A/B] Heat Exchanger Flow and DP Trending"

Verification of ESW flow rate and differential pressure trending is performed on a semiannual basis by procedure STN PE-037A/B, "ESW Train [A/B] Heat Exchanger Flow and DP Trending," and are recorded in STS MT-072/073 "SGK04[A/B] Heat Exchanger Inspection," on an 18-month Frequency.

The purpose of STN PE-037A/B is to verify design flow rate and trend heat exchanger differential pressure through all Safety-Related Essential Service Water Heat Exchangers. Within the surveillance procedures, the available flow to the SGK04A/B condensers is verified, after included instrument uncertainty to be above the required design flow rate. Trending of differential pressure drop is performed to provide indication of excessive macrofouling that could prevent the heat exchanger from performing its design function.

- For SGK04A, this test was last performed on January 20, 2014 with an available ESW flow rate of 201 gpm. Differential pressure trending did not indicate excessive macrofouling of the heat exchanger.

- For SGK04B, this test was last performed on January 7, 2014 with an available ESW flow rate of 195 gpm. Differential pressure trending did not indicate excessive macrofouling of the heat exchanger.

The as-found flow rate for the CRACS trains met the minimum flow rate acceptance criteria of 89 gpm.

STS MT-072/073 "SGK04[A/B] Heat Exchanger Inspection"

The purpose of surveillance procedures STS MT-072 and STS MT-073 are to verify that SGK04A/B have the capability to remove the assumed heat load through inspection and cleaning of both the condenser heat exchanger and evaporator heat exchanger coils. The surveillance also includes recording ESW water flow measured per the most recent STN PE-037A/B is greater than design plus instrument uncertainty and that the ESW flow verification was performed within the 18 month duration of the SR. This is accomplished by the repetitive inspection and cleaning of the condenser heat exchangers with verification that the tube fouling acceptance criteria is met and external inspection of the evaporator heat exchanger coils. Based on inspection history and notion that the condenser heat exchangers were recently cleaned, reasonable expectation exists that the condenser heat exchangers are below the plugging acceptance criteria of 5 tubes per pass or a total of 15 tubes required by calculation GK-M-009, Revision 001, "Tube Plugging Criteria for Control Room A/C Unit SGK04A/B Condensers and ESF Switchgear Rooms A/C unit SGK05A/B Condensers."

- For SGK04A, the inspection was last performed on February 18, 2014 (WO 13-376362-001) and the 'As Found' visual inspection revealed no tube blockage and zero tubes plugged. The tubes were then cleaned prior to final assembly (WO 13-376362-000). Evaporator heat exchanger coils were inspected with acceptable results.

- For SGK04B the inspection was last performed on July 17, 2013 (WO 12-358135-001), and the 'As Found' visual inspection revealed no tube blockage and zero tubes plugged. The tubes were then cleaned prior to final assembly (WO 12-358135-000). Evaporator heat exchanger coils were inspected with acceptable results.

These surveillances met the acceptance criteria.

STS GK-002A/B "Control Room A/C Unit Operability Test"

Surveillance procedures STS GK-002A/B "Control Room A/C Unit Operability Test" will satisfy this requirement. The purpose of surveillance procedures STS GK-002A/B is to demonstrate of proper operation of major components in the refrigeration cycle. The acceptance criteria associated with meeting this surveillance procedure is that the major components in the refrigeration cycle of SGK04A/B operate properly for greater than or equal to 4 hours. This surveillance procedure does not begin until the refrigeration compressor starts. The purpose of this condition-monitoring task is to detect the onset of pressure boundary tube degradation and to provide data in support of heat exchanger performance monitoring activities.

- For SGK04A, this surveillance procedure was last performed on February 18, 2014 (total run time of 4 hours and 10 minutes).

- For SGK0B, this surveillance procedure was last performed on October 5, 2013 (total run time of 4 hours and 2 minutes).

Both of these surveillances met the acceptance criteria.

Conclusion

A heat transfer test that performs a measurement of the capability of each CRACS train to remove the assumed heat load is impractical. WCNOC 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 Apparent Cause Evaluation for CR00059406 identified deficiencies in surveillance procedures that were being credited for meeting SR 3.7.11.1, including additional data points that should be taken to ensure the equipment was capable of removing the assumed heat load. These deficiencies have been corrected through revisions to the procedures as discussed above. 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 Pilgram (TIA2008-004)," December 31, 2008. ADAMS Accession No. ML083660174.

2. WCNOC letter ET 97-0050, "Technical Specification Conversion Application," May 15, 1997.

3. Letter from J. N. Donohew, USNRC, to O. L. Maynard, WCNOC, "Conversion to Improved Technical Specification for Wolf Creek Generating Station – Amendment No. 123 to Facility Operating License No. NPF-42 (TAC NO. M98738)," March 31, 1999. ADAMS Accession No. ML022050061.

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. WCNOC letter ET 94-0012, "Updated Response to Generic Letter 89-13," February 18, 1994.

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