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OFFICE OF RIVER PROTECTION POSITION ON ADEQUACY OF PERFORMANCE-BASED METHODOLOGY FOR DETERMINING THE NEED FOR THE FIRE PROTECTION OF STRUCTURAL STEEL

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WTP SAFETY REGULATION DIVISION POSITION ON ADEQUACY OF PERFORMANCE-BASED METHODOLOGY FOR DETERMINING THE NEED FOR THE FIRE PROTECTION OF STRUCTURAL STEEL

1.0 Background

Bechtel National, Inc. (BNI) is committed[1,2] to apply the non-structural requirements of the International Building Code (IBC), 2000 Edition to the design and construction of the River Protection Project Waste Treatment and Immobilization Plant (WTP) process buildings. This includes determining the type of construction for each WTP process building based on IBC 2000 Table 503 and Paragraph 503.1.2, where applicable. BNI has tentatively identified the following types of construction: Pretreatment (Type IB), High Level Waste (Type IIB – using paragraph 503.1.2), Low Activity Waste (Type IIB – using paragraph 503.1.2), and the Analytical Laboratory (Type IIB). Per IBC 2000, Table 601, these types of construction set the fire-resistance rating requirements for building elements as follows:

	Type IB	Type IIB
Structural frame (incl. columns, girders, trusses)	2 hours	0 hours
Bearing walls (exterior and interior)	2 hours	0 hours
Floor construction (incl. supporting beams and joists)	2 hours	0 hours
Roof construction (incl. supporting beams and joists)	1 hour	0 hours

In addition to these requirements, BNI must also meet the IBC 2000 fire-resistance requirements for building elements based on occupancy separations, protection of shaft enclosures, protection of exit passageways, etc.

BNI must further meet the requirements for structural steel fireproofing in accordance with the implementing codes and standards identified in the Safety Requirements Document (SRD), Section 4.5, "Fire Protection;" namely, DOE O 420.1A, "Facility Safety," DOE-STD-1066-97, "Fire Protection Design Criteria," and NFPA Standard 801-2003, "Standard for Fire Protection for Facilities Handling Radioactive Materials." The structural steel fireproofing requirements are primarily identified in DOE-STD-1066, Section 9.2, "Fire Barriers." Subsection 9.2.2 states: "Where required by the FHA or SAR, the structural shell surrounding critical areas and their supporting members should remain standing and continue to act as a confinement structure during anticipated fire conditions including failure of any fire suppression system not designed as a safety class item. Fire resistance of this shell should be attained by an integral part of the structure (concrete slab, walls, beams, and columns) and not by composite assembly (membrane fireproofing). In no event should the fire resistance rating be less than 2 hours under conditions of failure of any fire suppression system not designed as a safety class item." The Definitions

[1] BNI letter from R. F. Naventi to R. J. Schepens, BNI, "Transmittal for Approval: Authorization Basis Change Notice 24590-WTP-ABCN-ESH-02-033, Revision 0, 'Applications of IBC 2000 for Determination of Classification of Construction Type for the RPP-WTP Process Facilities and Analytical Laboratory'," CCN-035822, dated October 31, 2002.

[2] ORP letter from R. J. Schepens to J. P. Henschel, BNI, "Partial, Conditional Approval of Authorization Basis Change Notice (ABCN) 24590-WTP-ABCN-ESH-02-033, Revision 0, 'Applications of IBC 2000 for Determination of Classification of Construction Type for the RPP-WTP Process Facilities'," 03-OSR-0145, dated April 4, 2003.

(Section 4) in DOE-STD-1066 define Fire Resistance Rating as “the time that a particular construction will withstand a standard fire exposure in hours as determined by NFPA 251 (ASTM E-119), "Standard Methods of Tests of Fire Endurance of Building Construction and Materials." Fire testing of materials and construction per ASTM E-119 use the standard time-temperature curve (Figure 1 of the standard) for the desired fire test duration. In addition, the DOE-STD-1066, "Definitions," Section 4, defines a Fire Area as a "location bounded by construction having a minimum fire resistance rating of 2 hours with openings protected by appropriately fire-rated doors, windows, fire dampers, or penetration seals." This definition applies independent of Section 9.2.2 requirements.

2.0 Discussion

BNI has identified, and is designing, the WTP process buildings to meet the structural steel fireproofing requirements of IBC, 2000. However, BNI has proposed to use a “performance-based” approach to satisfying the additional structural steel fireproofing requirements from the SRD, Section 4.5 implementing codes and standards; in particular, DOE-STD-1066. The objective of using the approach is to avoid project cost by only protecting fire barrier structural steel that is evaluated to potentially fail during a fire event based on the actual combustibles present in the fire area and their proximity to the steel.

The methodology for the performance-based evaluation of WTP structural steel proposed by BNI has two parts: first, the determination of the fire exposure and second, assessment of the response of the structural steel members. The methodology for assessing fire exposure has three subparts: identifying the limits on fire development [i.e., ventilation limited fires or fuel controlled fires (cable tray and lubricating oil burning characteristics)], applying simplified fire modeling techniques (i.e., using a heat balance method) to postulated fires, and determining local heating effects (plume modeling for cable tray and pool fires). The fire exposure assessment also includes consideration of the transient combustibles that could potentially be in the fire area. This would be done using a “backward approach” wherein the amount of transient combustibles required to exceed the critical temperature of the steel is determined. Then, it would be confirmed that administrative or operational controls were sufficient to preclude this amount of transient combustibles from being present in the area.

The methodology proposed by BNI identifies an 1100ºF cross-sectional average temperature of the steel member as the temperature below which no protection of the steel is required. If the area or localized temperature is greater than 1100ºF, then the temperature of the structural steel is calculated. If the steel temperature is calculated to be below 1100ºF, then no protection is required. If the steel temperature exceeds 1100ºF, then the steel member is protected or measures are taken to reduce the fire exposure to a level such that the member temperature will be less than 1100ºF.

Use of a methodology to establish the need to protect structural steel members from the effects of fires was accepted for use in the commercial nuclear reactor industry by the U.S. Nuclear

Regulatory Commission (NRC) in 1984[3] at one facility. The NRC approval was based, in part, on review of the methodology by their consultant, Brookhaven National Laboratory (BNL).[4] BNL concluded that the fire heat balance model method used there was sound in that instance and conservatively neglected any losses through enclosure openings. The major shortcoming identified by BNL was due to the use, as input, of cable fire heat release rate data that did not include enclosure feedback effects. Further, BNL concluded that the localized heating and transient combustible analysis were also sound but could have been more complete if stratification and wall and corner effects were considered. BNL also concluded that steel failure criteria that included the concept of critical load would have been more complete, but a critical temperature of 1100ºF appeared to be accepted in the open literature at the time. Finally, BNL concluded that the overall methodology was sound, that its application could be made more conservative and complete, but that the results should be appropriate in determining the survivability of structural steel during fire.

3.0 Evaluation

The approach/methodology proposed by BNI to satisfy the additional structural steel fireproofing requirements of DOE-STD-1066-97 was reviewed by ORP, an ORP consultant, and the EM-5 fire protection engineer (FPE). In addition, feedback on the approach was received from a DOE Savannah River Site (SRS) FPE. The review focused on the following three areas:

1. Technical acceptability, degree of conservativeness, and applicability to WTP of the methodology.

    a. BNL found the performance-based approach somewhat incomplete and not as conservative as it could have been. However, BNL concluded that these concerns were outweighed by compensating conservatisms incorporated into the methodology. Important factors not considered in the methodology, according to BNL, included the lack of consideration of enclosure feedback effects with cable fires, ceiling stratification, the effects of fires near enclosure walls and corners, lube oil fire calculations not considering cables or other combustibles being involved, and the effects of transient fires on nearby columns. Conservatisms considered by the methodology that tend to counter these non-conservatisms were, according to BNL, the assumption of no convective or radioactive heat losses through enclosure openings and the doubling of the quantity of oil involved in a lubricating oil fire. Given the number and significance of the non-conservatisms identified by BNL for the methodology, the application of the BNL conclusion that these non-conservatisms were outweighed by compensating conservatisms incorporated into the methodology to the evaluation of the WTP fire protection system design appears subjective and arguable. Of particular

[3] NUREG-0991, Supplement No. 2, Safety Evaluation Report related to the operation of Limerick Generating Station, Units 1 and 2, Docket Nos. 50-352 and 50-353, Philadelphia Electric Company, dated October 1984.
[4] Evaluation of the Analytical Fire Modeling by Philadelphia Electric Company in their February 24, 1984 Rev. 2 Submittal "Structural Steel Survivability Evaluation for Limerick Generating Station Unit 1," Charles J. Ruger and Manomohan Subudhi, Department of Nuclear Energy, Brookhaven National Laboratory, Upton, New York 11973.

concern to ORP in considering the use of the methodology for WTP buildings is whether a more extensive model is required to determine if a flashover with steel temperatures exceeding the critical point would be precluded.

b. BNL concluded that extensive calculations would be required to prove that the non-conservatisms discussed in item a above are cancelled out by other methodology conservatisms (e.g., no credit for heat loss through enclosure openings, doubling of the quantity of oil used as a possible combustible). The credited conservatisms were peculiar to the example of the application of the methodology reviewed by BNL; however, factors not considered in the BNL review could be important if not included in any WTP analysis. For instance, BNL observed that the reviewed example of the application of the methodology assumed only two of four doors to an enclosure open where an additional open door would have resulted in excessive exposure to the unprotected steel. (Under smoky fire fighting conditions, this assumption may not be valid, and is not conservative.) This illustrates the vulnerability of adopting this methodology in lieu of prescriptive architectural safeguards.

c. NRC approval of the use of the methodology for Limerick relied upon pre-inspection of the completed nuclear power plant, including an inventory of combustible materials and ignition sources, administrative control of combustibles and ignition sources, and a trained facility fire brigade. The inventory of combustibles and ignition sources is a controlled document that must be updated for every change in combustibles or ignition sources. Were BNI to apply this methodology to WTP, it would be done without a facility fire brigade and with preliminary and changing design information for the other considerations (e.g., fixed and transient combustible loadings, administrative controls, etc.) relied upon by the NRC in its acceptance of the methodology at Limerick.

d. For the example of the application of the methodology reviewed by BNL, the methodology was applied to each of the 48 plant areas for which it was desired to show that structural steel elements need not be protected from fires. For WTP, BNI is proposing to evaluate a few limiting or bounding configurations and develop justification for application of the results to other areas of the facility where structural steel will not be protected introducing uncertainty into the assumption that limiting and bounding configurations have, in fact, been identified.

e. The methodology places reliance on limiting combustion air or fuel. In the application reviewed by BNL, forced air ventilation systems were assumed not to contribute to the ventilation rate since installed fire dampers were assumed to close. For WTP process buildings, maintaining confinement of the building atmosphere is a primary safety consideration. As a result, WTP process building C5 extract flow-paths do not contain fire dampers to limit airflow in served building areas during fire events. Fire/smoke dampers in an in-bleed between a C3 and C5 area will close due to smoke or high temperature conditions to

preclude potential backflow from the C5 area to the C3 area and to limit smoke egress into the C5 area. While this will limit, to some extent, ventilation airflow into the C5 area, the assumption about limited ventilation during fire events is not valid for the design of the WTP process buildings. During a fire event within a WTP process building, the C5 extract system will continue operating and providing airflow to maintain a negative pressure relative to adjacent C3 areas.

f. The steel calculations discussed in the application of the methodology reviewed by BNL were based on average steel temperatures and did not consider localized hot spots, high strength steel, restraints, end effects, moments, buckling, or heat flow at walls and corners. In addition, an adjustment would have to be made to the temperature limitation used in the methodology for application to WTP, since WTP steel is loaded to 66% of yield strength versus the 60% used in the application of the methodology reviewed by BNL.

g. The methodology relies on average room gas temperatures to determine auto ignition of cable; however, localized ignition occurs much sooner than the average room gas temperature would indicate.

h. The methodology does not appear to account for heat transfer through structural steel elements that could pose a hazard to combustible materials outside of the fire area boundary. Heat transfer sufficient to ignite combustibles in an adjacent fire area occurs at a much lower temperature than structural steel failure. Should this potential exist, the effect would be to increase the size of the fire area and the maximum possible fire loss (MPFL). This could result in the application of additional requirements for redundant fire suppression systems and 3-hour rated boundaries.

i. For WTP applications, the numerous pros and cons of the conservatisms of the methodology identified by BNL would need to be evaluated using SAR evaluation criteria where the fire areas separate important-to-safety or safe state components.

j. The methodology uses a "backward approach" to assess the amount of transient combustibles required to exceed the critical temperature of the steel. For WTP, knowledge of the transient combustible allowance may not occur early enough to avoid potentially significant and costly backfits.

k. DOE SRS fire protection engineering indicated that they were not aware of a single case in which the DOE requirements for the fire protection of structural elements in fire barriers were waived (exemption or equivalency) at SRS. They further noted that the DOE-STD-1066 fire area requirements are a compromise from older DOE standards and superseded Orders. These older standards and Orders included requirements for 4-hour free-standing fire walls; thus, DOE-STD-1066 already reflects a reduction in requirements.

2. Basis for the structural steel fire resistance requirements embodied in DOE-STD-1066-97.

   a. DOE requirements for fire protection are codified in 10CFR830, Section 206 that requires DOE contractors to use the design criteria in DOE O 420.1, Facility Safety, or obtain DOE approval of alternate criteria. DOE O 420.1A, Section 4.2 requires DOE facilities, sites, and activities (including design and construction) to be characterized by a level of fire protection that is sufficient to fulfill the requirements of the best protected class of industrial risks ("Highly Protected Risk" or "Improved Risk") and to be provided protection to achieve "defense-in-depth." BNI has committed in Section 4.5 of the SRD to fulfill these DOE O 420.1A requirements by implementation of the requirements from DOE-STD-1066-97. As discussed in the Background section of this Position Paper, DOE-STD-1066, Section 9.2.2 requires no less than 2-hour rated fire barriers under conditions of failure of any fire suppression system not designed as a safety class item. Criteria for the design of fire barriers in both DOE-STD-1066 and IBC, 2000 are based upon ASTM E-119 test criteria, involving a fire having the characteristics of the standard fire curve. Thus, using the proposed methodology, the steel in fire barriers, for which DOE-STD-1066 criteria would require at least 2 hours of protection, could be unprotected, while other steel is protected in accordance with IBC requirements. This goes against the intent of the DOE criteria for "highly protected risk," "improved risk" and "defense in depth" and results in a facility design that is not characterized by a level of fire protection that is sufficient to fulfill the requirements of the best protected class of industrial risks.

   b. Fire protection criteria in DOE O 420.1 require "multiple layers of protection" and "defense-in-depth". WTP use of the methodology would eliminate protection of steel as one layer of defense.

   c. DOE fire protection criteria require attention to property loss and continued use of the process - NRC's singular concern is safe shutdown; therefore, fire hazards and fire potential during non-operational periods of maintenance and modifications do not have to be considered.

   d. The NRC approval includes the alternate of sprinkler protection of steel; DOE MPFL criteria require an assumption of non-safety class sprinkler failure (i.e., sprinklers are one level of protection, protection of steel supporting a fire area compartment is another).

3. Additional disadvantages of the methodology identified by the review.

   a. The costs for the necessarily detailed design study to justify leaving steel unprotected and administrative controls throughout the operating life of the facility could exceed, by many times, the capital cost associated with protecting the steel.

b. Application of the methodology would replace passive engineered controls with greater administrative controls and operational restrictions imposed and monitored throughout the life of the facilities (i.e., stricter and more complex controls for combustibles, door closure, etc.). Administrative controls used in place of passive engineering controls potentially interfere with operations and maintenance activities.

c. The lack of passive engineering controls may limit the ability to make facility changes that, while providing operational improvements or benefits, increase the combustible loading in the areas relying only on administrative controls.

4.0 Conclusions

BNI is proposing a fire protection design for the WTP facilities that is dependent upon a valid analysis of limited combustible loading and reliable sprinkler operation in the protected areas, with minimum reliance upon static building construction fire resistance characteristics. This is an "all eggs in one basket" approach that is highly dependent upon presumptive analysis for a plant not yet built or operating, administrative controls, and unchanging conditions. Under as-built conditions, the NRC may have, after an on-site inspection, felt confident that the use of the methodology resulted in a nuclear power plant that was fire-safe for operation, but this should not serve as a precedent for deviating from the previously selected and approved DOE fire protection requirements applied to the WTP. DOE criteria provide for an alternate approach where it achieves a comparable level of safety. There may be limited exceptions in the WTP for which it is possible to use a more well-defined and updated location specific version of the methodology. However, the current proposed elimination of the protection of steel supporting fire areas does not appear to provide a comparable level of safety.

Through extensive review of building code requirements and adoption of the IBC, a considerable cost savings in steel protection is now realized without deviating from IBC and DOE fire protection requirements. A further savings would accrue to application of the unlimited area clause (Section 503.1.2) of the IBC. As a matter of IBC interpretation, BNI has made an argument for adopting Section 503.1.2 that ORP is still evaluating. This leaves the improved risk and defense-in-depth concepts of DOE policy embedded in the 2-hour rated fire enclosure requirement. This requirement should not be removed though adoption of a methodology that eliminates protection of the supporting steel and, thus, 2-hour enclosures meeting DOE-STD-1066 requirements based upon NFPA 251 (ASTM E-119) test requirements.

5.0 Position

Based on the concerns enumerated above on the applicability of the methodology to WTP process buildings, the degree of conservatism embodied in the methodology, the objectives (i.e., "highly protected risk," "improved risk," defense-in-depth, protection against significant property loss and/or loss of mission) intentionally built into DOE fire protection requirements that have no corollary in the commercial nuclear (i.e., NRC-regulated) industry, and the

unknown and potentially significant life cycle costs for the administrative controls required in place of passive engineering controls, ORP's position is that the BNI methodology is insufficiently mature to adequately define an alternate fire protection approach to the DOE-STD-1066, Subsection 9.2.2 two-hour rated fire barrier requirement.