EXHIBIT 4

5/32

Watts Bar Unit 1 Ice Condenser System
Westinghouse Assessment of
Broken Ice Basket Sheet Metal Screws

Summary Report
MSE-REE-1371
June 22, 1995

1.0 Issue

TVA Watts Bar personnel identified to Westinghouse that 162 Ice Condenser Ice Basket Sheet Metal Screw Heads were found in an ice melt tank after cleanup from the recent Ice Bed Ice Loading operations at the Watts Bar Unit No. 1 Plant (References 1, 2). It was postulated by TVA that the screw heads had been broken off during the recent ice loading and ice weighing operations, since prior to initiation of this recent ice loading operations the ice condenser area had been cleaned.

2.0 Assessment Program

The intent of the assessment program was to ensure the structural adequacy of the ice condenser system based upon configuration parameters contained in this report..

The results of this assessment are reported herein and are supported by calculations in the Westinghouse ice condenser engineering project file. The scope of the investigation was the following:

- o Perform statistical evaluation establishing probability of screws missing in any single ice basket connection based on random occurrence.

  The evaluation concentrates on the probability of one and two screws missing at any one single ice basket connection, and the probability of two adjacent screws missing at any single ice basket connection.

- o Evaluate the ability of the ice basket coupling connection to resist the design basis loadings with a minimum of 10 sheet metal screws versus the design basis that has 12 sheet metal screws.

- o Consider an ice basket column (or portion of column) becoming a missile, evaluate:

  - whether the basket can impact the top deck structure and cause damage to safety systems outside of the ice condenser compartment

  - the structural integrity of the top deck structure if ice basket impact occurs

- the structural integrity of the intermediate deck given an unrestrained ice basket column impact.

- the potential for bypass flow paths being opened up around the ice condenser making it inoperable.

The results obtained from the investigation in each of these areas are described in the sections that follow. Prior to discussing the results, the hardware design condition is described.

3.0 Hardware Description

There are 186,624 sheet metal (AISI 1022 steel) screws in the 1944 ice condenser ice basket columns. Each basket column is made up of four 12 foot long perforated sheet metal ice baskets coupled together on end with an internal sheet metal coupling ring. There is a double row of 6 equally spaced #10-32 x 0.50 long sheet metal screws in each basket side of the coupling, or 24 sheet metal screws at each basket joint. There is also a double row of 6 sheet metal screws at the very bottom of the basket column attaching the bottom attachment assembly ring to the bottom of the bottom basket, and a double row of 6 sheet metal screws attaching a coupling ring to the very top of the column which acts as a reinforcement for maintenance lifting purposes.

4.0 Statistical Evaluation

During an inspection, personnel at the Watts Bar Unit 1 ice condenser discovered the heads of 162 sheet metal screws believed to be from the coupling connections of the ice basket columns (assumed to be randomly distributed within the ice condenser compartment). There are 1944 ice basket columns in a Westinghouse ice condenser containment system. Each ice basket column contains eight mechanical connections with 12 sheet metal screws in each connection. A statistical evaluation was performed to establish the probability associated with two and three sheet metal screws missing from the same mechanical connection. Based on a random distribution of failed ice basket sheet metal screws throughout the ice bed there is a 1 in 7 million chance (probability equals 1.43×10^{-07}) that 3 sheet metal screws are missing from the same mechanical connection. Consequently, this evaluation will focus on two sheet metal screws missing from the same mechanical connection.

The random distribution of failed ice basket screws is justifiable based on the fact that the entire ice bed was ice loaded and ice weighed under the same procedures and operations prior to the discovery of the 162 broken screw heads.

5.0 Structural Considerations

5.1 Coupling Connection Evaluation

It was found from the statistical evaluation performed that having more than two screws missing at the same mechanical connection is remote, and the probability that two sheet metal screws are missing from the same mechanical connection is very small. Therefore, the purpose of the coupling connection evaluation was to demonstrate the adequacy of the coupling connection with the loss of two sheet metal screws at the same mechanical connection. It is noted that in the statistical study performed the azimuthal location of the missing screws is not restricted.

The maximum design shear load applied to a single sheet metal screw (original configuration 12 screws per connection) was determined to be 278 lbs. The maximum design load occurs at the 12 ft. elevation for the load combination Case I (deadweight (D) plus operating basis earthquake (OBE)). Using the ice condenser design criteria developed in 1974, which is based on the design allowables of the AISC code, a single sheet metal screw connection is rated to 670 lbs (shear load). Actual tests for AISI 1022 (Reference 3) have demonstrated that the ice basket mechanical connection (12 screws) is capable of supporting a load of 14,500 lbs or 1,208 lbs per sheet metal screw. As required by the ice condenser design criteria, the test load is derated for the Case I load combination by the factors 1.1 and 1.87 (equivalent to 1.1 x 1.87 = 2.057). The resulting design shear load based on tests is 587 lbs per sheet metal screw, implying that the original design factor of safety in the connection is 2.11 (i.e., {587/278}).

The shear load imparted on a single sheet metal screw is a function of the horizontal and vertical loads in the ice basket column and its azimuthal location in the basket connection. Horizontal reactions from the lattice frame generate an internal moment in the basket column which is reacted through each mechanical connection by the sheet metal screws in shear. In the evaluation performed, enveloping missing screw configuration cases are considered. To envelope the possible connection configurations the following formula for the maximum shear load, Vmax was defined:

$$V_{max} = \text{Max}\ [(0.326*H+0.167*V),\ (0.329*H+0.125*V)]$$

This formula is based on the original interaction formula for the maximum sheet metal screw load:

$$V_{max} = 0.163*H+0.0833*V$$

The resulting Vmax for the controlling case, Case I, is calculated to be 556 lbs.

The margin against design allowable (i.e., {Vallowable / Vmax}) in the connection with two sheet metal screws missing at the same mechanical connection (10 screws remain from a possible of 12) are at least equal to the following for the different loading cases.

Case I - Dead Load plus Operating Basis Earthquake	1.06
Case II - Dead Load plus Design Basis Accident (DBA)	2.45
Case III - Dead Load plus Design Basis Earthquake (DBE)	1.10
Case IV - Dead Load plus DBA and DBE	1.13

As seen from this evaluation, the connection is within the allowable limits with two missing screws considering DBA and seismic conditions.

6.0 Functionality Concerns

6.1 Ice Basket Missile Evaluation

In the highly unlikely event that the loss of the structural integrity of an ice basket connection occurs, the 48 foot ice basket column or portion thereof could become a missile. Given only a seismic event, the seismic excitation cannot cause uplift since the vertical seismic component is under one g. This is not true for the design basis accident condition where the LOCA load can reach a force of 2543 pounds on a 48 foot ice basket column. The ice basket condition with the most energy to cause damage was found to be a 48 foot column with one-third of the ice melted (basket plus ice weight of 983 pounds). A conservative low minimum ice basket column ice weight of 1100 pounds was used in lieu of the current Watts Bar minimum ice weight of 1212 pounds in anticipation of future ice weight reduction programs. The forcing function applied to the ice basket considering dead weight effect is given in the table below.

Forcing Function Applied to Ice Basket		
Time [sec]	Force [lbs]	Net Force [lbs]
0.0000	0	-983.0
0.0275	0	-983.0
0.0375	43	-940.0
0.0470	375	-608.0
0.0564	1109	126.0
0.0659	1876	893.0
0.0754	2346	1,363.0
0.0833	2505	1,522.0
0.0933	2543	1,560.0
0.1068	2435	1,452.0
0.1241	2054	1,071.0
0.1427	2123	1,140.0
0.2123	1791	808.0
0.2459	2100	1,117.0
0.3133	1792	809.0
0.3913	1472	489.0
0.4692	1329	346.0
0.5472	1174	191.0

Forcing Function Applied to Ice Basket		
Time [sec]	Force [lbs]	Net Force [lbs]
0.6378	1002	19.0
0.7513	947	-36.0
0.8596	835	-148.0
0.9716	765	-218.0
1.0024	733	-250.0

6.2 Ice Basket Vertical Uplift

A time history analysis was performed using the DBA ice basket forcing function as defined in the table given in Section 6.0 to determine how far the 48 foot ice basket column of 983 pound weight will move up in the vertical direction. It was found that the maximum vertical displacement of the ice basket will be less than 13.5 feet and have no potential to become a missile outside of the ice condenser compartment.

6.3 Integrity of Top Deck Structure

Since it was determined that the maximum uplift distance of an ice basket column is less than 13.5 feet, there will be no impact of the top deck structure by the ice basket. Therefore, the structural integrity of the top deck structure will not be impaired.

6.4 Integrity of Intermediate Deck Structure

The bottom of the intermediate deck structure is about four inches from the top of the ice basket columns. Impact of an ice basket with this structure can potentially occur given the loss of the ice basket coupling connection and the occurrence of the DBA. An evaluation of the structural integrity of the intermediate deck was performed. The intermediate deck consists of doors attached to W8x31 beams that have a yield stress of 50 ksi. The doors open 0.1 seconds after the start of the LOCA (DBA). There is a 3.71" clearance between the top of the ice basket and the bottom of the beam. For the ice basket (983 pounds basket column) to reach this height takes about 0.2 seconds; therefore, the doors will have opened. Once the doors are opened, the hinge loads on the beams are small. Approximately thirty percent of the baskets can pass through the space left with the doors open without impacting the deck structure. Therefore, 70% of the ice baskets could potentially impact the structure. The controlling stress in the design calculation is due to bending in the beams. The beams are simply supported, and the worst case would be for the ice basket to strike the beam in the center. Only one ice basket is considered to strike the structure because of the very low probability that more than one basket could uplift and strike the same portion of the intermediate deck structure. Even if more than one basket uplifts and strikes the same intermediate deck member, the probability that the two baskets would impact the beam simultaneously is remote.

Impact loads on the W8x31 were established based on energy conservation formulations. No reduction in load for nonlinear behavior (e.g., yielding, local crushing of the ice basket) was considered. From the time history analysis performed (Section 6.0) at the time of impact it was determined that the ice basket velocity is 60 in/sec. It is noted that this velocity is conservative for the minimum weight basket condition assumed since the effect of friction, potential binding, and frozen in place baskets is not considered. It was found that for a direct impact of the ice basket in the center of the beam the stress is below the bending stress allowable considering dead load plus ice basket impact, plus LOCA. If the ice basket strikes the beam with an eccentricity causing torsion, lower impact loads will result because the impact stiffness is lower. Further, the beam is free to twist because of the simple connection at the ends. Twisting may cause bending moments in the columns that support the beam. These moments will not induce sufficient stress in the columns that will cause the beams to fall. The columns will still be able to perform their design function providing vertical support. The connections at the ends of the beam will not fail causing the beams to fall. Further, since the doors are open prior to the ice basket impact with the beam, the opening of the doors will not be impaired by any local buckling or permanent set in the beams or columns.

In conclusion the intermediate deck will resist postulated impact loads and remain within the allowable stress range.

6.5 Bypass Flow Paths/Blockage

The maximum vertical displacement of an ice basket column is less than 13.5' as discussed above. Therefore, a total ice basket column will not leave the ice bed. Thus, it will not be possible to have a bypass flow condition. Further, if any local structural damage, or blockage, or flow bypass paths occurs from the falling ice baskets after they reach their maximum height, this would be after the peak blowdown pressure and flow rate has occurred and is of no consequence to ice condenser function.

The potential for an ice basket column, or portion of, to cause blockage of flow passageways between ice basket columns was also evaluated and determined to be of minor consequence. Flow blockages of up to 15% have been determined to be acceptable for ice condenser operability. A single ice basket column, inelastically deformed upon impact with the intermediate deck structure, has been assessed at potentially providing 0.05% flow blockage to the entire ice bed. Based on the statistical probability and distribution of baskets with failed sheet metal screws, the fact that the initial peak blowdown forces are over prior to any potential impact with the intermediate deck structure, and the ice baskets have uplifted less than four inches prior to potential impact with the intermediate deck, flow passageway blockage is insignificant. In addition, any prior existing flow passageway blockage from ice and frost formations and accumulations will have been eliminated from the ice bed at the time of initial blowdown forces, thus providing compensation for any postulated flow blockage from damaged baskets.

7.0 Conclusion

In conclusion, based on the evaluations performed, the following reasons are given why the ice condenser may be considered operable for the defined design deviation.

Structural

1. The statistical evaluation concluded that the failure probability of the ice basket coupling due to the missing screws is remote.

Functionality

2. Ice basket ejection from LOCA loads cannot reach the Top Deck Structure which is 15 feet away, and therefore cannot be considered a missile in the containment. The maximum ice basket displacement is 13.5 feet vertically up and out of the ice bed.

3. Since the ice baskets can at most lift up 13.5 feet, the ice bed geometry is not compromised resulting in flow bypass paths.

4. The Intermediate Deck Structure Support Beams and Door Framing can stop the Ice Basket Columns from ejecting out of the Ice Bed and still maintain its integrity (stresses are within design criteria allowable).

5. Ice Basket couplings are justified to perform their function against all design basis accident loads and surveillance loading with a minimum of 10 sheet metal screws in lieu of 12 sheet metal screws.

8.0 References

Full Dev. Rept.

1. FDR No. WATM-10356, Ice Basket Sheet Metal Screws, 6/15/95.

2. TVA PER, Tracking No. WBPER950246, Rev. 0, 4/26/95.

3. Duke Load Test Results of Ice Condenser Couplings, Duke Power Transmittal Letter MMEE-91-313, August 7, 1991.