May 26, 1992

Docket Nos. 50-390
and 50-391

Tennessee Valley Authority
ATTN: Dr. Mark O. Medford, Vice President
Nuclear Assurance, Licensing and Fuels
3B Lookout Place
1101 Market Street
Chattanooga, Tennessee 37402-2801

Dear Dr. Medford:

SUBJECT: WATTS BAR NUCLEAR PLANT - IN-OFFICE AUDIT OF CIVIL CALCULATIONS (TAC NOS. R00514, M73097 and M73098)

By letter dated April 1, 1992, TVA responded to some of the open issues in our audit report dated January 31, 1992 (for audit dated September 9-13, 1991). We performed an in-office audit of the calculations submitted with the April 1, 1992 letter and conclude that most of the open issues documented in the referenced audit report are resolved.

The enclosed supplemental audit report provides details. As discussed in the report, there are some issues for which TVA either has not completed verification of design calculations, or needs to provide additional information. These areas will remain open; however, none of them is considered a major staff concern. We will discuss, with your site licensing staff, the submittal needed to address the remaining open issues, and will publish another supplemental audit report when those issues are resolved.

Sincerely,

Original signed by

Peter S. Tam, Senior Project Manager
Project Directorate II-4
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Enclosure:
Supplemental Audit Report

cc w/enclosure:
See Next Page

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

SUPPLEMENTAL AUDIT REPORT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

CIVIL CALCULATION PROGRAM

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2

DOCKET NOS. 50-390 and 50-391

1.0 BACKGROUND

The first staff audit on the Civil Calculation Program was conducted during April 15-19, 1991 and the follow-up audit was conducted during September 9-1 1991 (report dated January 31, 1992). There have been several open items as a consequence of the September 1991 audit. In response to these open items identified in the September 1991 audit, the applicant submitted a written the September 1991 audit, the applicant submitted a written response on September 1991 audit, the applicant submitted a written response on April 1, 1992 (Watts Bar Nuclear Plant Units 1 and 2 "Response to NRC Information Request"). The staff performed an in-office audit of the documents attached to TVA's April 1, 1992, letter.

2.0 OPEN ITEMS

The in-office audit was performed during the month of April, 1992, primarily by A. Unsel and N. Tsai, NRC consultants, under supervision of S. B. Kim of the staff. The sections that follow document the audit findings and conclusions.

2.1 Reinforced Concrete Elements

2.1.1 Open Items From Previous Audit (Sept 9-13, 1991)

2.1.1.1 Item No: AU-1 (Closed)

During the previous audit, the staff reviewed a finite element analysis performed by TVA of the slab panels located at elevation 737.0' of the aux iliary control building between column lines A4, A12, r, and t. The thickness of the slab in this area was 1'-0", and it was heavily loaded due to the location of various heat exchangers. The staff performed a detailed review of the TVA evaluation.

The review of the finite element analysis showed that TVA used different live loads for the same slab areas corresponding to plant operation and outage con ditions. The staff questioned as to how these different live loads would be controlled, especially during plant operation where certain slabs have zero live load associated with them. In response to this staff concern, TVA pro vided design change notice DCN S-16590-A which would revise and document all permissible floor design live loads during plant operation and outage. The revised drawings would then become the control room drawings. This documen tation of tracking the permissible live loads for the selected worst case slabs was acceptable to the staff. Since the worst case slabs represent the total population of slabs, the limitation of live loads on these worst case slabs have to be applied to the total population of slabs. The TVA program to limit live loads on the total population of the slabs was not clear. There fore, this item was left open pending additional information from TVA as to the methodology of determining the permissible live loads on the total population of slabs.

The TVA response dated April 1, 1992, shows that the live load drawing has been revised by DCN S16590 to show the permissible operating and outage floor live loads by area. The permissible floor live loads for the total population of slabs were established through a process of comparing individual slab attributes (span, thickness, reinforcement), existing loads, and loading requirements to those of the worst case slabs. TVA has documented this comparison in calculation WCG-1-1187. The staff finds the TVA response adequate and therefore considers this item closed.

2.1.1.2 Item No: AU-5 (Closed)

During the previous audit, the review of finite element analysis of slab panels as described in section 2.1.1.1 of this report, the staff found that the punching shear around columns was obtained from the finite element analy sis by averaging the reaction forces at the nodes representing the four cor- ners the column. Instead, the staff stated that the punching shear should be the total summation of the column reaction forces. TVA revised calculation WCG-1-923 to recalculate the punching shears around various columns and to show that they were still within the ACI 318-77 code allowables. Although this revised calculation was acceptable to the staff, the staff requested that TVA evaluate the other slab areas analyzed by finite element models to determine whether the staff concern about punching shear calculations around columns is generic or not. Therefore, this item was left open pending TVA evaluation of the other slab areas.

TVA's response dated April 1, 1992, states that a generic review was performed, and only one other case was determined to contain the same staff concern. For this case, TVA has revised calculation WCG-1-923 to use the sum mation of reaction forces for the calculation of the punching shear. Therefore, the staff considers this item to be closed.

2.1.1.3 Item No: AU-10 (Open)

During the previous audit, the review of the finite element analysis results, as described in section 2.1.1.1 of this report, also showed erroneous reaction forces along column line t, which is the north boundary of the finite element model. The large variation of the magnitude and the change of direction of adjacent reaction forces along this edge were not explainable, and therefore, could be the result of an inadequate finite element model representing the actual physical situation. The erroneous reaction forces along this edge might have an effect on the punching shear forces around columns along column line s. There ore, the staff stated that TVA should further evaluate the adequacy of the finite element model to determine whether it represented the actual structure and loading distribution. This evaluation should also be extended to other finite element models used for the evaluation of other slab areas. Therefore, this item was left open pending further TVA evaluation.

TVA's response dated April 1, 1992, does not provide any additional information for this particular slab panel from that which was presented during the previous audit. The cause of the large variation of the magnitude and the change of direction of adjacent reaction forces along column line t still has not been determined. Therefore, this portion of this item will be left open pending further TVA evaluation.

TVA, in its submittal dated April 1, 1992, also stated that it has reviewed the slab calculations completed within the Civil/Seismic program to determine whether the staff concern would extend to other finite element analyses. TVA's review showed that the reactor fill slab calculation used a finite element analysis. TVA determined that the finite element model for this calculation was adequate to represent the actual conditions and loadings. The staff found this portion of the TVA review to be acceptable.

2.1.2 List of Open Items

AU-10: Validity of reaction forces and adequacy of the finite element model at boundary of slab.

2.1.3 List of Documents Reviewed

1. TVA Letter by John H. Garrity to U.S. Nuclear Regulatory Commission, Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Response to NRC Information Request (TACS R00514, M73097, M73098), dated April 1, 1992.

2.2 <u>Embedded Plates</u>

2.2.1 Open Items From Previous Audit (Sept 9-13, 1991)

2.2.1.1 Item No: AU-11a

During the previous audit, the staff reviewed TVA calculation WCG-1-873 Rev. 2, which included the worst case selection of HAAUP embedded plates for evaluation. The staff had a concern relating to the worst case selection methodology. The capacities developed for various types of embedded plates did not consider the location of the attachment to the embedded plate. This is important because the capacity of the embedded plate could be effected depending on the location of the attachment. To resolve this staff concern, TVA committed to evaluate additional cases for each type of embedded plate to account for the effects of attachment location. This methodology was satisfactory to the staff; however, this item was left open pending a revision to calculation WCG-1-873 stating the selection of additional samples to account for attachment location effects.

TVA's response dated April 1, 1992, shows that TVA has committed to revise calculation WCG-1-873 by June 12, 1992. As a result of this commitment by TVA, the staff considers this item to be closed.

2.2.1.2 Item No: AU-11b

During the previous audit, the staff reviewed TVA calculation WCG 1-873 Rev 2, which showed that the capacities of various embedded plates did not account for shear in the stud anchors. The capacities of the embedded plates were based on only tensile forces in the stud anchors. However, the total capacity should have been a combination of tensile and shear forces. To address this staff concern, TVA proposed that additional samples of embedded plates with high shear forces would be evaluated to account for shear effects. This was acceptable to the staff; however, this item was left open pending a revision to calculation WCG-1-873 documenting this additional sampling process.

TVA's response dated April 1, 1992, shows that TVA has committed to revise calculation WCG-1-873 by June 12, 1992. As a result of this commitment by TVA, the staff considers this item to be closed.

2.2.1.3 Item No: AU-12

TVA calculations WCG-1-848 and WCG-1-841 (RIMS Nos. B18 910413 273 and B18 910413 265) used an elliptical formula for calculating the interaction of tension and shear in the stud anchors. However, calculations WCG-1-845 and WCG-1-837 (RIMS Nos. B18 910413 281 and B18 910413 257) used a straight line formula for the same interaction. The staff requested TVA to justify the use of the elliptical formula used in calculations WCG-1-848 and WCG-1-841.

TVA response dated April 1, 1992, states that the elliptical interaction equation for existing attachments is documented in TVA Design Standard DS-C1.7.1 Section 5.3. TVA states that the elliptical interaction equation is described in "Headed Steel Anchor Under Combined Loadings", American Institute of Steel Construction Volume 10, Appendix B. The staff also confirmed the use of elliptical formula for stud anchors from the manufacturer's catalog (TRW NELSON studs). The use of the elliptical formula for existing attachments is acceptable to the staff. This item is therefore closed.

2.2.1.4 Item No: AU-13

In calculation WCG-1-841 (RIMS No. B18 910413 265), TVA should justify why the vertical force (Fy) obtained from the STRUDL computer analysis is lower for SSE than for OBE.

TVA's response to this item dated April 1, 1992, shows that the vertical force used in calculation WCG-1-841 was obtained from calculation WCG-1-769. The STRUDL output in calculation WCG-1-769 shows that the SSE vertical force is greater than the OBE vertical force. However, the governing load combination for this vertical force is dead load plus live load. This response is acceptable to the staff. This item is therefore closed.

2.2.2 List of Open Items

There are no open items relating to the review of embedded plates.

2.2.3 List of Documents Reviewed

1. TVA Letter by John H. Garrity to U.S. Nuclear Regulatory Commission, Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Response to NRC Information Request (TACS R00514, M73097, M73098), dated April 1, 1992.

2. TVA Design Standard DS-C1.7.1, General Anchorage to Concrete, Rev 4, 7/28/87.

3. TRW NELSON Division Catalog, Embedment Properties of Headed Anchors, 1977.

2.5 Geotechnical Issues

2.5.1 Introduction

Previous staff review identified five open items in the geotechnical area that required further assessments by TVA. These open items are:

1. Stability of slopes adjacent to the intake channel;

2. Acceptance criteria for buried piping;

3. Stress induced in buried piping at the cradle;

4. Shear stress analyses for soils within sheetpile walls at the intake pumping station (IPS); and

5. Bearing pressures under Category I structures.

2.5.2 Review Findings

Findings from staff review of the TVA responses submitted to NRC on April 1, 1992, are discussed below.

2.5.2.1 Slope Stability Analysis Along Intake Channel

Previous staff concerns with the slope stability analysis immediately adjacent to the intake channel were the use of assumed soil strength properties for the potentially liquefiable materials there and the very marginal factor of safety resulting from such analysis. The staff also had concern that the effect of vertical earthquake was not included in the analysis. In the previous audit report, the staff requested TVA to reanalyze the stability of the slopes immediately to the intake channel using actual slope configurations and soil strength properties based on either conservative assumptions or laboratory data. In addition, the staff suggested TVA to consider the effect of both horizontal and vertical earthquake components in the analysis.

In response to the staff request of a reanalysis of the slope stability along the intake channel, TVA modified the critical section of the slope to more closely reflect the actual field conditions, and performed a parametric study of the modified critical section by varying the soil strengths of the potentially liquefiable silty-sand layer. The modified critical section was established by taking the following measures:

1. Selection of a section cut along the inside curve of the construction road on the southwest side of the IPS, which lines up reasonably well with the critical section used in the existing analysis;

2. Setting the contact between the clay fill making up the intake channel and the underlying base rock at Elevation 665 because the slope stability is not critical there according to the existing analysis;

3. Setting the contact between the backfill in the underground barrier and the base rock in accordance with as-built cross-sections of the underground barrier;

4. Using as-built granular fill properties for the backfill in the underground barrier in lieu of the clay backfill that was conservatively assumed in the existing analysis;

5. Taking the excavation line of the underground barrier from as-built profiles on the east and west sides of the underground barrier;

6. Setting the depth of the silty-sand layer at the interface with the under ground barrier based on the as-built depth of sand;

7. Inclusion of the basal gravel layer based on interpolation of data from borings, the properties of the basal gravel being based on those used in analysis of the intake channel;

8. Slight lowering of the ground water table to reflect the level given in the design criteria and adjusting the water level upward in the area within the underground barrier to reflect the design level used in the underground barrier calculation;

9. Using actual slope for the intake channel fill considering the curvature of the section rather than the 4H:1V maximum slope used in the existing analysis.

The modified critical section is described in Appendix B of the revised TVA calculation WCG-1-547 as shown in Attachment 2 to the TVA letter dated April 1, 1992, (Ref. 1). It reasonably reflects the as-built field conditions and is acceptable.

In the parametric study, the soil properties used were the same as those in the existing analysis, except for the addition of the basal gravel and the granular backfill for the underground barrier. Since the staff concern was with the strength loss of the silty-sand, the parametric study considered fourteen cases of the properties of the silty-sand expressed in terms of the cohesion, c, and internal friction angle, Ø. The range of variation was 300 psf to 600 psf for c and 5 to 20 degrees for Ø. The upper bound case was characterized with c = 600 psf and Ø = 20 degrees, which were used in the original design analysis. The resulting factor of safety was 1.398 for the modified critical section. One medium case was characterized with c = 300 psf (a 50% reduction from design value) and Ø = 14 degrees (a 30% reduction from design value), which gave a factor of safety equal to 1.160. Compared to the factor of safety of 1.038 that was computed in the existing analysis using the same reduced strength but with the unmodified critical section, this represents a 12% increase in the safety margin. The marginal safety factor of 1.038 from the existing analysis was the source for the previous staff concern. For the lower bound case with c = 300 psf (a 50% reduction) and Ø = 10 degrees (a 50% reduction), the factor of safety for the modified critical section was 1.092. Another lower bound case, with c = 450 psf (a 25% reduction) and Ø = 5 degrees (a 75% reduction), gave a factor of safety equal to 1.061, which was the lowest among the safety factors for all 14 parametric cases. The staff found the range of variation in the soil strength for the silty-sand to be sufficient for the parametric study. According to the analysis results, the use of the modified critical section that more closely reflects the as-built conditions in the field improved the safety margin, and the previous staff concern with the slope stability along the intake channel is considered resolved.

Regarding the staff request to include the effect of vertical earthquake in the slope stability analysis, Attachment 3 to the April 1, 1992 TVA letter (Ref. 1) presents the TVA position, considering only the effect of the horizontal earthquake has been previously accepted by the staff in accordance with the Safety Evaluation Report (NUREG-0847) issued in June, 1982; hence the issue is closed. In addition, TVA cited several references published in 1975 and earlier to substantiate its position that considering only the horizontal earthquake component was the industry practice then. The staff disagrees with the TVA position because it has been the industry practice for quite many years to consider both horizontal and vertical earthquake components in the dynamic slope stability analysis and because the Standard Review Plan, Rev. 2, calls for the use of the state-of-the-art methods for such application. This item remains open.

2.5.2.2 Acceptance Criteria for Buried Piping

The previous staff concern was that it may not be appropriate to apply ASME Code Equation 10A as the stress acceptance criteria to the design of the safety-related buried piping presented in TVA calculation WCG-1-867. In its response, TVA confirmed that the essential raw cooling water (ERCW) and high pressure fire protection (HPFP) piping is classified as ASME piping and therefore must comply with the ASME Code. In addition, TVA confirmed the applicability of ASME Code Equation 10A based on the provisions of Proposed Code Case N-XXX, "Alternate Rules for Analysis of Class 2 and 3 Buried Piping." This resolves the staff concern.

2.5.2.3 Stress Induced in Buried Piping at the Cradle

Previous staff concerns with the stress analysis of the buried piping included:

1. The effects of surface overburden have not been accounted for;

2. The length of unsupported pipe was assumed and no basis was provided;

3. The effect of lift-off of the pipe from the cradle has not been considered;

4. Stress concentration has not been considered.

In its response, TVA submitted an Attachment 4, which contains TVA calculation WCG-1-867, to address the staff concerns (Ref. 3). In addition, TVA added a layer of sand between the pipe and cradle in order to provide for a gradual transition and avoid a concentration of the bending stress induced in the pipe at the exit from the pipe cradle.

TVA calculation WCG-1-867 presents a reanalysis of the buried ERCW and HPFP safety-related piping subjected to soil settlement. The analysis considered two conditions. The first condition considered the portions of buried piping away from building connections. Based on the soil settlement data taken at borings along the buried piping, the maximum differential settlement between boring holes, typically spaced about 100' apart, was determined to be 3.3". The bending stress induced in the buried pipe, scaled by the maximum concentration factor for pipe elbows, was compared to the minimum allowable stress for carbon steel (3*Sc = 45000 psi) per ASME Code Equation 10A. Sufficient margin was resulted. The second condition considered the piping connected to a building via the pipe cradle. The maximum soil settlement based on boring data was taken to be 4.8". Surface overburden was computed. The effective length of unsupported pipe coming off the cradle was then taken to be one half of the span of a pipe that deflected 4.8" at the mid span when fictitiously fixed at both ends and loaded with the overburden. The maximum bending stress in the pipe was then determined based on the differential pipe deflection and associated effective length. The resulting stress was marginally within the allowable stress. This is acceptable in view of the sand layer TVA added between the pipe and cradle which would alleviate the bending stress computed based on the assumption the pipe was fixed at the end of the cradle. Regarding the potential effect of pipe lift-off over the cradle, TVA calculation WCG-1-867 noted that a lift-off of the pipe, if it occurred, would further alleviate the pipe stress because it would allow additional rotation of the pipe at the exit from the cradle.

In summary, the staff concludes that the addition of the sand layer between the pipe and cradle and the reanalysis of the ERCW and HPFP safety-related buried piping are sufficient to resolve the previous staff concerns.

2.5.2.4 Shear Stress in Soils within Sheetpile Walls at the IPS

TVA is in the process of revising calculation CEB820604002 to address previous staff concerns with the frequency dependency of acceleration levels and the shear stress analysis of soils within the sheetpile walls at the IPS. TVA will provide this revised calculation for staff review by June 12, 1992. This item remains open.

2.5.2.5 Rock Bearing Pressures under Category I Structures

TVA evaluated the rock bearing pressures for the reactor building as a worst case due to its high aspect ratio (height to width) and foundation size. The resulting rock bearing pressure was 20.2 ksi, which is within the bearing capacity of 26 ksi specified in TVA Design Criteria WB-DC-20-1 for rock. This evaluation is acceptable.

2.5.3 Conclusions

Based on the review findings discussed previously, the staff concludes that TVA resolved the staff concern with the configuration and soil strength of the critical section used in evaluating the stability of the slopes adjacent to the intake channel. However, the staff disagrees with the TVA position that the requirement to consider the effect of vertical earthquake in the slope stability analysis is not applicable to WBN. The staff concludes that the TVA response resolved the staff concern with the acceptance criteria for buried piping, the stress induced in buried piping at the cradle, and the bearing pressures under rock-supported Category I structures. Because the shear stress analysis for the soils within the sheetpile walls at the IPS will not be available for staff review until June 12, 1992, this item remains open.

2.5.4 Summary of Open Issues

Two issues remain open:

1. Inclusion of vertical earthquake in the slope stability analysis adjacent to the intake channel.

2. Shear stress analyses of soils within the sheetpile walls at the intake pumping station (IPS).

2.5.5 References

1. "Revised Pages of WBN Calc. WCG-1-547, Intake Channel Slope Stability Analysis," Attachment 2 to letter from J. H. Garrity of TVA to NRC, dated April 1, 1992.

2. "Previous Response Provided and Reviewed by the Staff, Intake Channel Slope Analysis," Attachment 3 to letter from J. H. Garrity of TVA to NRC, dated April 1, 1992.

3. "Calculation WCG-1-867, Buried ERCW and HPFP Piping/Settlement Evaluation," Attachment 4 to letter from J. H. Garrity of TVA to NRC, dated April 1, 1992 (B18 910429 253).

2.8 Above-Ground Vertical Steel Tank

2.8.1 Introduction

The refueling water storage tank (RWST) is the only safety-related above-ground vertical steel tank at WBN. Structural integrity of the tank during earthquakes has been found adequate during the calculation audit conducted previously from September 9 to 13, 1991. The only item remaining open was the structural integrity of the tank due to the nozzle loads from the pipes connected to the tank, because TVA calculations were not available for review during that audit.

2.8.2 Review Findings

Three pipes are connected to the tank. A 6"Ø pipe and an 8"Ø pipe are connected to the tank about 4' above the base. The two nozzles are about 14" apart from each other. A 24"Ø pipe is connected to the tank at the bottom, and the nozzle is sufficiently far away on the other two nozzles. Findings for the three pipe nozzles based on the TVA calculations submitted for staff review are separately discussed.

2.8.2.1 Evaluation of Tank Shell at the 6"Ø Pipe Nozzle

Results of TVA evaluation are documented in TVA calculation WCG-ACQ-0275, Rev. 1 (Ref. 1). Because of the proximity between the 6"Ø and 8"Ø nozzles, both nozzles were included in a flat-plate finite element model for the stress analysis using the ANSYS code. The nozzle loads were taken from TVA piping analysis calculation N3-72-01A, Rev. 13, for the 6"Ø nozzle and calculation N3-72-09A, Rev. 0, for the 8"Ø nozzle. The maximum primary membrane stress, Pm, and primary membrane plus bending stress, Pm + Pb, in the shell around the 6"Ø nozzle were within the allowables for both the upset and faulted conditions. The evaluation was based on ASME Code Section III, Subsection NC, 1974 edition through the winter 1976 addenda. During the review, the staff found the 8"Ø nozzles loads used in the analysis are not the updated loads as shown in TVA piping analysis calculation N3-072-09A, Rev. 1. The revised 8"Ø nozzle loads are about the same as or slightly smaller than the un-updated ones with the exception of only one force component, Fy. Because of this, and because of the sufficient margin between calculated stresses and allowables shown in the existing analysis, the staff concludes that the tank shell evaluation around the 6"Ø nozzle is acceptable.

2.8.2.2 Evaluation of Tank Shell at the 8"Ø Pipe Nozzle

The evaluation of the shell at the 8"Ø nozzle, documented in TVA calculation WCG-ACQ-0291, Rev. 0 (Ref. 2), was based on the updated 8"Ø nozzle loads but the effect from the nearby 6"Ø nozzle was excluded. This evaluation used the

Bijlaard method to determine the stresses in a cylindrical shell due to external loads applied on a nozzle. The resulting shell stresses were within the allowables. Because the effect of the nearby 6"Ø nozzle was not included in the evaluation and the significance of this effect is not known, the staff cannot reach a final conclusion pending a further assessment by TVA.

2.8.2.3 Evaluation of Tank Shell at the 24"Ø Pipe Nozzle

TVA calculation N3-03-63A documents the evaluation results. The evaluation was done using a simple but conservative screening approach, by comparing the individual nozzle load components to the corresponding allowable load components. The results show that the tank shell passed this screening evaluation because every nozzle load component was within the corresponding allowable component load. This is acceptable.

2.8.3 Conclusion

The staff accepts the evaluation of the tank shell at the 6"Ø and 24"Ø nozzles due to the nozzle loads. For the 8"Ø nozzle, the staff cannot reach a final conclusion because the interaction effect from the nearby 6"Ø nozzle is not known. TVA should perform an assessment of this effect.

2.8.4 List of Open Items

The effect of the 6"Ø nozzle loads on the 8"Ø nozzle should be addressed.

2.8.5 References

1. TVA Calculation WCG-ACQ-0275, Rev. 1, "RWST 6 and 8 Inch Nozzle Qualification," (B26 910308 152).

2. TVA Calculation WCG-ACQ-0291, Rev. 0, "Refueling Water Storage Tank 8" Nozzle Load Qualification," (B26 900716 155).

3. TVA Calculation N3-63-07A, Rev. 1, "Piping Analysis Calculation No. N3-63-07A," (B18 901127 049).

Principal Contributors: S. B. Kim

Date: May 26, 1992