ENCLOSURE 1

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

SEP 20 1983

MEMORANDUM FOR: Richard H. Vollmer, Director
Division of Engineering

FROM: Darrell G. Eisenhut, Director
Division of Licensing

SUBJECT: EVALUATION OF THE LANDSMAN CONCERNS FOR MIDLAND

Your letter of September 8, 1983 (Enclosure 1) provided a revised schedule for the DE work plan regarding the Landsman concerns. While I find the proposed schedule acceptable I feel compelled to emphasize that we must ensure that no further slippage occurs.

I am also in receipt of a letter from Billie Garde (Enclosure 2) that indicates their understanding that several staff members had "strong feelsings about the approval by the DGB resolution." Please consider this letter in your ongoing review.

Darrell G. Eisenhut, Director
Division of Licensing

Enclosures:
1. Vollmer memo to DGEisenhut
8/8/83
2. B. Garde to DGEisenhut
7/19/83

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

SEP 8 1983

MEMORANDUM FOR: Darrell G. Eisenhut, Director
Division of Licensing, ONRR

FROM: Richard H. Vollmer, Director
Division of Engineering, ONRR

SUBJECT: EVALUATION OF LANDSMAN'S CONCERNS REGARDING DIESEL GENERATOR BUILDING AT MIDLAND

References:
1. Memo, Eisenhut to Keppler, June 27, 1983
2. Memo, Vollmer to Eisenhut, July 21, 1983
3. Memo, Landsman to Warnick, July 19, 1983

Due to schedule conflicts between the Diablo Canyon Review and this effort on Midland which affects the personnel from Brookhaven National Laboratory (BNL), DE must reschedule the completion of the Midland DGB review from September 28 to October 15, 1983. During the month of September, the BNL personnel will partially be committed to Diablo Canyon reviewing ITR's, preparing testimony and taking depositions. If you do not concur with slipping this effort to accommodate the demands of Diablo Canyon, please advise accordingly.

Enclosed is a revised Work Plan for the completion of the DE evaluation of the Landsman's concerns. The ASLB (via OELD) should be advised of the revised schedule for completion.

Richard H. Vollmer, Director
Division of Engineering, ONRR

Enclosure:
As stated

cc: H. Denton
J. Knight
G. Lear
P. Kuo
N. Romney
C. Tan
E. Adensam
D. Hood

CONTACT: N. Romney, SGEB
49-28987

8309210424

ENCLOSURE

Midland NPP Diesel Generator Building Review

Work Plan

August 24 - 25, 1983	Task Force - Site Visit - Completed
September 8, 1983	Task Force meet with: F. Rinaldi J. Kane J. Matra G. Harstead
September 13, 1983 (AM)	Task Force meet with R. Landsman (Ann Arbor, Michigan)
September 12 - 13, 1983	Task Force conduct audit of Midland DGB (Ann Arbor, Michigan)
October 15, 1983	Issue Report of Findings

GOVERNMENT ACCOUNTABILITY PROJECT
Institute for Policy Studies
1901 Que Street, N.W., Washington, D.C. 20009 (202) 234-9382

August 19, 1983

Mr. Darrell G. Eisenhut, Director
Division of Licensing
Office of Nuclear Reactor Regulations
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Eisenhut:

On August 10, 1983 you responded to my Aug. 8, 1983 request for information regarding the review group formed to consider the concerns of Mr. Ross Landsman. On Aug. 11, 1983 during a public meeting on the Construction Completion Plan (CCP) you indicated that a review of the NRR Engineering Division had indicated no support or agreement with Mr. Landsman. Mrs. Barbara Stamiris, the Citizen Intervenor on the soils settlement ("OM") proceedings inquired specifically about Mr. Joe Kane of your office and a consultant, Dr. Sing, of the U.S. Army Corps of Engineers. You indicated that you were not aware of whether or not those individuals had been asked or not. Please inform Mrs. Stamiris and myself of the answer to that question.

More specifically, it is our clear understanding that several members of the Engineering Staff in both the Region and in headquarters had very strong feelings about the approval of the DGB resolution. We expect your technical review to include the past concerns of both Regional and headquarters engineers. Furthermore, since the concerns about this issue and its resolution are of interest to Congress, the local intervenors and GAP we respectfully request that your office issue an Interim report, allow time for review and comment by the public, and hold at least one open meeting prior to the issurance of the final report on this subject.

A final concern we wish to raise with your office deals with the background of the individuals you have nominated to complete the review of Dr. Landsman's concerns. All of the people selected are structural engineers. Dr. Landsman of course, is a geo-technical engineer. Clearly, any review team should contain professional representation from Dr. Landsman's discipline, and suggest that you appoint an independent geo-technical consultant to review the work of your engineers.

Finally, we concur with Mr. Robert Warnicks suggestion contained in his July 21, 1983 memo to you that "all related correspondence and the resulting report(s) and documentation should be placed in the public document room and distribution list."

8309260410

Thank you for your extraordinary promptness to my August 8, 1983 letter, it was a pleasant surprise. I look forward to an equally pleasant substantive report on the DGB from your office.

Sincerely,

Billie Pirner Garde
Citizens Clinic Director

wgw

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

October 11, 1983

Docket Nos: 50-329 OM, OL
and 50-330 OM, OL

MEMORANDUM FOR: The Atomic Safety and Licensing Board for the Midland Plant, Units 1 & 2

FROM: Thomas M. Novak, Assistant Director for Licensing
Division of Licensing

SUBJECT: SUPPLEMENTARY NOTIFICATION REGARDING DR. LANDSMAN'S CONCERNS FOR THE MIDLAND DIESEL GENERATOR BUILDING (BN 83-153)

Board Notifications 83-109 and 83-142 have transmitted the NRC staff's plan to address the concerns of Dr. Ross Landsman of Region III regarding the structural adequacy of the Midland Diesel Generator Building (DGB). These Notifications are deemed to provide information material and relevant to safety issues in the Midland OM/OL proceeding, including testimony by members of the NRC staff and staff consultants during the December 10, 1982, hearing session.

This Board Notification 83-153 further supplements the information regarding Dr. Landsman's concern, and is provided for your information. Enclosure 1 provides a reply by Mr. J. P. Knight to inquiries (Enclosure 1 to Knight's memorandum) by Mr. R. Vollmer as to (1) whether or not any members of Mr. Knight's staff, or consultants thereto, share Dr. Landsman's concerns that the DGB is inadequate to return to service from a safety point of view, and (2) whether or not any of these individuals share Dr. Landsman's specific technical concerns, notwithstanding their judgement that the building is safe for operation.

George W. Knighton
for Thomas M. Novak, Assistant Director
for Licensing
Division of Licensing

Enclosures:
As stated

PDR

8308300767

OCT 17 1983

DISTRIBUTION LIST FOR BOARD NOTIFICATION

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Docket Nos. 50-329/330

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MIDLAND (For BNs)

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Detroit, Michigan 48226

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

SEP 23 1983

MEMORANDUM FOR: Richard H. Vollmer, Director
Division of Engineering

FROM: James P. Knight, Assistant Director
for Components & Structures Engineering
Division of Engineering

SUBJECT: MIDLAND

This is in response to your note of August 15, 1983 asking if any members of my staff, or our consultants, share R. Landsman's concerns that the Midland diesel generator building is inadequate for its intended service and whether they share any of his specific technical concerns.

A task group, including consultants from Brookhaven National Laboratory (BNL), was formed under the supervision of Dr. P. T. Kuo of the NRC staff to conduct a reevaluation of the staff's position with regard to acceptance of the Midland diesel generator building. Upon receiving Dr. Landsman's statement of concerns, dated July 19, 1983, members of the Midland review staff, and consultants named below, were given copies of Dr. Landsman's memo. Their initial reactions were that Dr. Landsman's statement contained no new information and that their previous sentiments, as discussed further below, remained unchanged. On September 8, 1983, the task group consisting of Dr. Kuo, Dr. C. P. Tan and Mr. N. Romney of the NRC staff, with the assistance of Drs. C. A. Miller, C. J. Constantino and A. J. Philippacopoulos of BNL, conducted individual interviews with Mr. J. Kane, NRC staff, Dr. L. Heller, NRC staff, and Mr. H. Singh, Corps of Engineers, and a group interview with Mr. F. Rinaldi of the NRC staff, Mr. J. Matra of the Naval Ordinance Laboratory and Dr. G. Harstead of Harstead Associates. These individuals represent to the best of our knowledge all members of the NRC staff and our consultants who were principally involved in the review activities associated with the Midland diesel generator building. As you know, the task group solicited all information and opinions related to the diesel generator building in addition to comments on Dr. Landsman's statement.

The results of all interviews conducted in this effort are being compiled as a part of the overall task group report which is scheduled to be completed in October, 1983. It is my understanding that the sentiments expressed by these individuals were essentially the same sentiments contained in the staff and consultant testimony before the Atomic Safety & Licensing Board; Mr. Rinaldi, Mr. Matra, Dr. Harstead, Mr. Kane and Mr. Singh were among the staff and consultant witnesses on this matter. Although Dr. Heller, Mr. Kane and Mr. Singh were not satisfied with certain aspects of the analyses performed by the

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applicant, and some of these same aspects were echoed by Dr. Landsman in his July 19, 1983 statement, none of these individuals have made a final assessment as to the acceptability of the diesel generator building for its intended service because they feel that the basis for such a judgement is incomplete.

Consistent with the hearing record, Dr. Harstead, Mr. Matra and Mr. Rinaldi reiterated their judgement that the diesel generator building was structurally acceptable for service, i.e., would remain structurally functional under design loading conditions.

The task group met with representatives of the applicant at the offices of Bechtel Corporation in Ann Arbor, Michigan and went to the site on August 24 & 25, 1983. The task group returned to the Bechtel offices in Ann Arbor on September 12 & 13, 1983 for a further audit of the calculations employed to investigate the predicted performance of the diesel generator building. Both of these meetings were preannounced public meetings; however, there was no attendance by members of the public. Dr. Landsman was also interviewed by the task group on September 13, 1983.

George Lear
for James P. Knight, Assistant Director
for Components & Structures Engineering
Division of Engineering

Enclosure:
R. Vollmer's Note to J. Knight
dated August 15, 1983

cc w/encl:
H. Denton
D. Eisenhut
T. Novak
E. Adensam
G. Lear
D. Hood
L. Heller
P. T. Kuo
F. Rinaldi
J. Kane

Enclosure 1

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

August 15, 1983

NOTE TO: Jim Knight

With respect to the Landsman issue, I would like to know if any of your staff or consultants share Landsman's concerns that the Midland Diesel Generator Building is inadequate to return to service from a safety point of view, i.e., inability to meet design requirements. I would also like an answer to the broader question: do they share any of his specific technical concerns even though their bottom line judgment would be that the building is safe for operation.

I would like to discuss this with you on August 22nd.

R. Vollmer

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Jay Harrison RFW

November 22, 1983

Docket Nos: 50-329 OM, OL
and 50-330 OM, OL

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MEMORANDUM FOR: Darrell G. Eisenhut, Director
Division of Licensing

FROM: Darl S. Hood, Project Manager
Licensing Branch No. 4
Division of Licensing

SUBJECT: RECOMMENDATION FOR SUPPLEMENTAL BOARD NOTIFICATION
REGARDING MIDLAND DIESEL GENERATOR BUILDING

Board Notification 83-165 dated October 26, 1983, transmitted the report of a special task group on the re-evaluation of the structural design and construction adequacy of the Midland Diesel Generator Building (DGB). The re-evaluation had been prompted by the concern of Dr. Landsman in BN 83-109. Also, BN 83-153 dated October 11, 1983, had transmitted a reply to an inquiry by NRR's Director of the Division of Engineering as to whether or not any member of that Division or NRC consultant shared Dr. Landsman's specific technical concerns.

Review of the task group's report by others, and the NRC's internal process of soliciting comments on the Applicant's Proposed Findings of Fact and Conclusions of Law on Remedial Soils Issues, have resulted in recent comments on the DGB which are material and relevant to issues before the Board. The comments further indicate the views of NRR members and consultants regarding Dr. Landsman's concerns as expressed in BN 83-153. Because of the contents of the task group's report, but also, in part, because of these supplemental comments, the NRC staff stated during the Midland OM-OL hearing session of November 19, 1983, it would advise the Board by December 1, 1983, of its position on the need to reopen the record on the special task group's re-review of the DGB. The staff also noted during the November session that if it takes the position that the record need not be re-opened, it will file responsive findings with respect to the DGB on December 9, 1983. As part of this decision process, Messrs. J. Kane and F. Rinaldi were requested to provide comments on the task group's report and to provide their recommendation as to whether of not the hearing should be reopened. Both replied November 18, 1983. I recommend that the Board be notified of these supplemental comments relative to the DGB. These are discussed below.

Jay - The documents you requested are enclosed. DH

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I. Comments of Joseph Kane on Applicant's Findings

The task group's report, in part, discussed the results of an interview with Mr. J. Kane:

> "With regard to the structural analyses using actual settlement data, Mr. Kane observed 70-80% of the cracks to be in areas where the analyses indicated areas of high stress. Mr. Kane has documented his concerns in memos dated August 2, 1983, and are included in Attachments 1 and 2." [page AII-3].

In Attachment 1 of the task group's report, page 2, Mr. Kane noted he personally had serious problems and questions with a report documenting an analysis performed by an NRC consultant, the U.S. Naval Surface Weapons Center (NSWC), and explained why he had not pursued his concerns at that time. He acknowledged that the staff position does not rely on the results or conclusions of the NSWC study.

In Attachment 2 of the task group's report, second paragraph, Mr. Kane questions why total settlements were used in the NSWC study to compute maximum stresses and movements in checking for areas of cracking. Mr. Kane noted the need to clarify this with NSWC and re-examine computed stresses and movements with available crack mapping. He also noted that in several of the walls there does appear to be correlation of cracks with high stress areas and that this should be discussed with NSWC.

Supplemental information regarding the above concerns in BN 83-165 is contained in a memorandum from G. Lear dated October 14, 1983, which transmits to OELD the Geotechnical Engineering review comments on the applicant's proposed findings of fact and conclusions of law regarding technical aspects of the OM-OL proceeding. The comments were prepared by J. Kane. On page 12 (Enclosure 1) Mr. Kane notes the results of his examination of the results of the NSWC report and attaches a table showing the results of his comparison from which he concludes that in the majority of locations, cracks do appear in the identified areas of high stress. Mr. Kane notes the need to resolve this difference with NSWC, and that if his conclusions are correct, "both the applicant's findings and the hearing record need to be corrected in order for the Board to make the proper findings."

I recommend that Enclosure 1 be forwarded to the Midland Board for supplemental information to BN 83-165 and BN 83-153, even though the staff did not rely on the NSWC study nor the applicant's analyses, for its conclusion regarding the adequacy of the DGB. The information is potentially relevant since the concern, if valid, would be contrary to other information on the record, which if relied upon by the Board, could lead to improper findings or cause the issue to be viewed in a different light. Specifically:

The NSWC report (Consumers Power Company Exhibit 30) concluded, in part, that:

> "the analyses show that other areas [other than at the duct bank areas] of the DGB walls still have high stresses and in all probability should also be cracked. <u>But no cracks were observed in these areas</u>." [Statments in brackets and underlining added.]

and that:

> "2. The measured settlement values imposed on the analytical models resulted in very high stresses (over ten times yield) in areas where no cracks now exist. Thus indicating that this settlement value more than likely was not seen by this structure."

Similar statements are made in the hearing by J. Matra of NSWC (Tr. pp. 11094 - 11127) and K. Wiedner (Tr. p. 10815).

II. Comments by U.S. Army Corps of Engineers

Mr. G. Lear's memorandum of November 16, 1983 (Enclosure 2) transmits to LB #4 an October 28, 1983, coverletter from the Corps. of Engineers (COE) with two memoranda containing the comments of H. N. Singh. Mr. Singh's comments further explain why "the Corps is not in a position to certify the adequacy of the structure." Mr. Singh expresses numerous differences with the Applicants proposed findings of fact, and presents significant conclusions of his own. For example, Mr. Singh finds "surcharging has created major structural distress in different parts of the building," ... "The Applicant's decision to cast concrete [to complete construction of the DGB] during the surcharge does not comply with the sound construction practices." ... "There has been considerable warping of the structure during and subsequent to the removal of the surcharge" ... "numerous cracks which have developed due to the settlement have been ignored for the purpose of stress evaluation." ... "The soil spring constant used in the analysis is not appropriate" ... "It is clear from the east wall that all the cracks which are inclined and have developed after the release of the duct banks are shear cracks" ... "Obviously, all of the Applicant's analyses are erroneous. If the structure can not be correctly analyzed, that is not a justification to declare it structurally adequate."

Enclosure 2 is also relevant to the Board because as a composit document, it may cause the Board to view the Corps' position on the DGB in a different light.

III. Comments of J. Kane on Task Group's Report and Recommendations to Reopen Hearing

In Enclosure 3, Mr. J. Kane notes numerous conflicts between hearing testimony and the Task Group's report. Paragraph 4C of Enclosure 3 states that an incorrect conclusion has not yet been brought to the Board's attention. Mr. Kane presents several reasons why the hearing should be reopened on the DGB. Enclosure 3 speaks for itself as to why it is material and relevant to the issues before the Board. Accordingly, the Board should be notified of this document.

IV. Evaluation of F. Rinaldi on need to Reopen Hearing

In Enclosure 4, Mr. Rinaldi, using the same criteria as Mr. Kane in III above, reaches the contrasting view that the hearing record need not be reopened on the DGB. The issue of whether the Task Group's report provides a sufficient basis to reopen the hearing is material and relevant to issues before the Board. Hence, Mr. Rinaldi's views should be forwarded to the Board.

/S/
Darl S. Hood, Project Manager
Licensing Branch No. 4
Division of Licensing

Enclosures:
As stated

cc: See next page

for info

DL:LB #4 DSH	AD:L:DL
DHood/hmc	TNovak
11/21/83	11/ /83

Enclosure 1

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

Hood

OCT 14 1983

MEMORANDUM FOR: William D. Paton, Attorney
Office of the Executive Legal Director

FROM: George Lear, Chief
Structural and Geotechnical Engineering Branch
Division of Engineering

SUBJECT: GEOTECHNICAL ENGINEERING REVIEW COMMENTS ON THE APPLICANT'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW - MIDLAND PLANT

We have enclosed the final phase of geotechnical engineering input on Midland's Finding of Fact in response to OELD request. Comments 1 through 23 were previously provided to you in my memos of September 27, 1983 and September 30, 1983. The enclosed comments cover our review of the Applicant's Findings on the Borated Water Storage Tanks, Diesel Fuel Oil Tanks, Underground Piping, Liquefaction and Dewatering, Slope Stability of Baffle and Perimeter Dikes and the Diesel Generator Building.

The enclosed comments were prepared by Joseph Kane (28153) who may be contacted if you wish to further discuss the comments.

Lyman W. Heller
for George Lear, Chief
Structural and Geotechnical
Engineering Branch
Division of Engineering

cc: w/attachment
R. Vollmer
J. Knight
T. Sullivan
E. Adensam
G. Lear
P. Kuo
L. Heller
D. Hood
N. Wright
M. Wilcove
R. Gonzales
F. Rinaldi
J. Kimball
H. Singh, COE
J. Kane

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actual Finding discussions. Because of the above effects we feel major revisions to the Applicant's Findings are needed in order to adequately reflect the Staff's SER positions and conclusions in the NRC Findings.

Diesel Generator Building

61. (Page 134, Par. 166). In this paragraph the Applicant's Findings cite the results of the Naval Surface Weapon Center (NSWC) study which ultimately concludes that when the measured settlement values are imposed on the analytical models of the DGB, very high stresses result in areas where no cracks now exist. In response to this study conclusion, we have examined the results of the NSWC report. As indicated in the attached tables where we have compared the areas of high stress computed by the NSWC with areas of recorded cracking (visible signs of potential structural distress) our conclusions in this review indicate that in the majority of locations cracks do appear in the identified areas of high stress. Because the NSWC conclusions are so significantly different from our conclusions we feel it is necessary to resolve this difference with the NSWC. If our conclusions are correct we feel both the Applicant's Findings and the hearing record need to be corrected in order for the Board to make the proper Findings.

Comparison of Computed High Stress Areas with Recorded Cracked Areas

WEST CENTER WALL

NSWC Figure	Computed High Stress Areas	Period of Measured Settlement	Observations of J. Kane in Comparison of Cracked Areas with High Stress Area: Fig. 14-2 Mapping December 1978	Figs. 28-2 and 28-3 Mapping Dec 1978; Sept 1979 to Jan 1980	Fig. 49 Mapping July 1981	Conclusions on Comparison
31	On south side (1) below El. 650	3/28/78 to 8/15/78 (presurcharge)	*No cracks shown on 12/78 Map	Crack observed in 9/79 is recorded in this area and is identified as crack due to structural displacement	Same crack observed in 9/79 is again recorded in 7/81.	Cracks do appear in all NSWC identified areas of high stress when incremental settlements for a given time frame are imposed and the latest crack mapping (July 1981) is used.
32	On north side (2) below El 650	3/28/78 to 8/15/78 (presurcharge)	*Crack shown in 12/78 Map	No cracks shown on 9/79 Map	Cracks shown in 7/81 Mapping	*If comparision is limited to available maps closest to dates of measured settlement, then cracks appear in 4 out of the 6 locations (shown by asterisks) of high stresses. The fact that cracks were observed in 12/78, not observed in 9/79 but reappear in same locations in 7/81 could mean the cracks were missed in 9/79.
33	On north side (3) above El 634.	8/78 to 1/79 (presurcharge)	*Cracks shown in 12/78 Map	No cracks shown on 9/79 Map	Cracks shown in 7/81 Mapping and slight extension of 12/78 mapped cracks.	
35	On north side (2) below El 650	8/78 to 1/79 (presurcharge)	*Crack shown in 12/78 Map	No cracks shown on 9/79 Map	Cracks shown in 7/81 Mapping	
37	On north side (3) above El 634	1/79 to 8/79 (Surcharge Period)	Fig 14-2 Mapping not applicable as it predates this period of settlement	*No cracks shown on 9/79 Mapp	Cracks shown in 7/81 mapping and slightly extend 12/78 mapped cracks.	
39	On south side (4) above El 634	1/79 to 8/79 (Surcharge Period)	Fig. 14-2 Mapping not applicable.	*Crack shown in 9/79 map and is identified as structural displacement crack.	Same crack observed in 9/79 is again recorded in 7/81.	

Comparison of Computed High Stress Areas with Recorded Cracked Areas

CENTER WALL

NSWC Figure	Computed High Stress Areas	Period of Measured Settlement	Observations of J. Kane in Comparison of Cracked Areas with High Stress Area: Fig. 14-2 Mapping December 1978	Figs. 28-2 and 28-3 Mapping Dec. 1978; Sept 1979 to Jan 1980	Fig. 49 Mapping July 1981	Conclusions on Co[illegible]
31	On north side ① above El. 634	3/28/78 to 8/15/78 (presurcharge)	Cracks shown in 12/78 Map	Cracks shown and increase from 12/78 to 9/79	Cracks shown in 7/81 Mapping	Cracks do appear in 5 out of the 6 locations where NSWC has computed areas of high stress and on crack maps with dates closest to the periods of measured settlements.
32	On north side ② below El. 650	3/28/78 to 8/15/78 (presurcharge)	Cracks shown in 12/78 Map	Cracks shown and increase from 12/78 to 9/79.	Crack shown in 7/81 Mapping	
33	On north side ① above El. 634	8/78 to 1/79 (presurcharge)	Cracks shown in 12/78 Map	Cracks shown and increase from 12/78 to 9/79.	Cracks shown in 7/81 Mapping	
35	On north side ① above El. 634	8/78 to 1/79 (presurcharge)	Cracks shown in 12/78 Map	Cracks shown and increase from 12/78 to 9/79.	Cracks shown in 7/81 Mapping	
37	On north side ① above El. 634	1/79 to 8/79 (Surcharge Period)	Fig. 14-2 Mapping not applicable as it predates this period of settlements	Cracks shown and increase from 12/78 to 9/79	Cracks shown in 7/81 Mapping	
39	On south side ③ above El. 634	1/79 to 8/79 (Surcharge Period)	Fig. 14-2 Mapping not applicable	No cracks shown on 9/79 Map	No cracks shown on 7/81 Map	

Comparison of Computed High Stress Areas with Recorded Cracked Areas

EAST CENTER WALL

NSWC Figure	Computed High Stress Areas	Period of* Measured Settlement	Observations of J. Kane in Comparision of Cracked Areas with High Stress Areas: Fig. 14-2 Mapping December 1978	Figs. 28-2 and 28-3 Mapping Dec. 1978; Sept. 1979 to Jan 1980	Fig. 49 Mapping July 1981	Conclusions on Compar…
31	On south side below El 663 (not reasonable since wall is built only to El 656 at this time).	→	→	→	→	Location of high stress is unreasonable for this stage of construction. No comparison therefore can be made.
32	On north side ① below El. 650	3/28/78 to 8/15/78 (presurcharge)	*Cracks shown in 12/78	No cracks shown in 9/79 Map	Cracks shown in 7/81 Mapping	Cracks do appear in all NSWC identified areas of high stress when incremental settlements for a given time frame are imposed and the latest crack mapping (July 1981) is used.
33	On north side ② above El. 634	8/78 to 1/79 (presurcharge)	*Cracks shown in 12/78 Map	No cracks shown in 9/79 Map	Cracks shown in 7/81 Mapping	
35	On south side ③ above El. 640	8/78 to 1/79 (presurcharge)	*Cracks appear very close to this location in 12/78 Map	Crack shown in 12/78 Map	Crack shown in 7/81 mapping	*If comparison is limited to available maps closest to dates of measured settlements, then cracks appear in 3 out of the 5 locations (shown by asterisks) of high stresses.
37	On north side ④ above El 640	1/79 to 8/79 (surcharge period)	Fig. 14-2 Mapping not applicable as it predates this period of settlement	*No cracks shown in 9/79 Map	Cracks shown in 7/81 mapping	
39	On south side ⑤ above El. 634	1/79 to 8/79 (Surcharge Period)	Fig. 14-2 Mapping not applicable.	*Crack shown in 12/78 Map but not in 9/79 Map	Crack shown in 7/81 Mapping	

Enclosure 2

Item 11CB

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

NOV 16 1983

MEMORANDUM FOR: Elinor Adensam, Chief
Licensing Branch No. 4
Division of Licensing

FROM: George Lear, Chief
Structural and Geotechnical Engineering Branch
Division of Engineering

SUBJECT: CORPS OF ENGINEERS MEMORANDA ON DIESEL GENERATOR BUILDING - MIDLAND PLANT

We have recently received the attached letter from P. McCallister, Chief, Engineering Division, U.S. Army Corps of Engineers which is dated October 28, 1983 and includes two enclosures that pertain to the Diesel Generator Building at the Midland plant. The enclosures were originated by the Corps reviewer for the Midland project, Mr. Hari N. Singh.

The October 28, 1983 letter and two enclosures are being forwarded to DL for your information and appropriate licensing action.

We plan to address the items identified in the two enclosures to the October 28, 1983 letter, where they are appropriate, in our future input to NRC Findings of Fact for the Diesel Generator Building.

George Lear

George Lear, Chief
Structural and Geotechnical
Engineering Branch
Division of Engineering

Attachments:
As stated

cc: w/o attachments
R. Vollmer
D. Eisenhut
J. Knight

w/attachments
G. Lear
L. Heller
P. Kuo
D. Hood
F. Rinaldi
J. Kane

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50-330

DEPARTMENT OF THE ARMY

DETROIT DISTRICT, CORPS OF ENGINEERS
BOX 1027
DETROIT, MICHIGAN 48231

REPLY TO
ATTENTION OF

Design Branch

SUBJECT: Two Memoranda Concerning the Midland Nuclear Power Plant

Mr. George Lear
U.S. Nuclear Regulatory Commission
Chief, Hydrologic and Geotechnical Engr Br
Division of Engineering
Mail Stop P-214
Washington, D. C. 20555

Dear Mr. Lear:

Attached are two memoranda providing Corps of Engineers comments regarding the recent controversy over the structural adequacy of the Diesel Generator Building (D.G.B.). These memoranda are Midland Nuclear Power Plant, Midland, Michigan dated 28 September 1983 and Applicant's Proposed Finding of Fact and Conclusions of Law on Remedial Soils Issues-Midland Nuclear Power Plant, Midland, Michigan.

Sincerely,

Enclosures

P. McCallister, P. E.
Chief, Engineering Division

check
XA

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NCDTD-G 28 September 1983

SUBJECT: Midland Nuclear Power Plant, Midland, Michigan

TO: File

FROM: H.N. Singh

1. The controversy over the structural adequacy of the Diesel Generator Building (DGB) of the Midland Nuclear Power Plant led the formation of an Independent Review Committee of four experts by the Nuclear Regulatory Commission.

2. Pursuant to an interagency agreement between the U.S. Army Corps of Engineers (the Corps) and the U.S. Nuclear Regulatory Commission (NRC), which became effective in September 1979, we have reviewed the geotechnical aspects of the Midland Nuclear Power Plant, and have concluded that the DGB has not been correctly analysed (H.N. Singh's testimony of 10 December 1982 before the U.S. Atomic Safety Licensing Board, ASLB). Therefore, the Corps is not in a position to certify the adequacy of the structure.

3. The NRC geotechnical experts have also concluded that the effects of the foundation settlement have not been considered in the analyses, therefore, the structural analyses performed by the Consumers Power Company (CPCO) are not appropriate. Dr. R. B. Landsman of the NRC Region III office has testified to this aspect before the Congressman Udall's subcommitte, and before the ASLB. Mr. J. D. Kane, Principal geotechnical Engineer of the NRC also expressed his concern before the ASLB hearing on 10 December 1982.

4. On 8 September 1983, I was called upon by the newly formed Independent Review Committee to apprise the committee of the Corps' concerns regarding the DGB.

5. I informed the Committee that the details of my concerns are provided in my testimony of 10 December 1982 before the ASLB, and in the Corps' report of 7 July 1980, and 16 April 1981. An abstract of the Corps' concerns are:

a. The CPCO has not considered the effect of differential settlement of the DGB in structural analyses.

b. The DGB has numerous cracks on its walls. These cracks have reduced the rigidity of the structure, therefore, the effects of cracking must be considered in structural analysis.

c. CPCO method of computing stresses in the reinforcing bars on the basis of the crack width is not appropriate.

6. A list of concerns resulting from the review of the CPCO's "Proposed Findings of Fact and Conclusions of Law in the Midland Proceeding" is inclosed.

HN Singh.

H. N. Singh, PESE
Lead Reviewer
Midland Nuclear Power Plant

NCDED-G

SUBJECT: Applicant's Proposed Findings of Fact and Conclusions of Law on Remedial Soils Issues - Midland Nuclear Plant, Midland, Michigan

The Corps of Engineers has reviewed the subject report. The following are the comments:

1. Para. 91: The main reason for uneven settlement of the Diesel Generator Building (DGB) is variable soil stiffness resulting from poorly compacted soil. No doubt, the duct banks did contribute to unequal settlement in the beginning, but there has been significant uneven settlement subsequent to their release from the walls in December, 1978.

2. Para. 92: The major cracks in the east wall of the DGB developed subsequent to the release of the duct banks from the building. The number of cracks prior to the release of the duct banks are shown in Attachment #2 of the original testimony of H. N. Singh. This attachment shows only 10 cracks on the east wall, but today there are 16 cracks on the wall.

3. Para. 92: The settlement of the D.G.B. after the release of the duct banks is not uniform as claimed by the Applicant in the last sentence of this paragraph. As shown in Attachment No.-2 (Fig-2) of the testimony of Mr. H. N. Singh, there has been considerable differential settlement after the release of the duct banks.

4. Para. 93: The settlement of the D.G.B. during the surcharge has created many cracks, (Singh's original testimony Q-9). On the east wall, the number of cracks increased from 10 to 16. Therefore, the surcharge did reduced the structural integrity of the D.G.B. The Applicant has not considered the settlement in his structural analyses (Singh testified before ASLD on 10 Dec 1982 to this aspect), and has not been able to demonstrate the adequacy of the D.G.B.

5. Para. 95: Partially saturated soil will not consolidate as saturated clay as claimed by the Applicant in this paragraph. The Corps of Engineers' concern as to this matter was communicated to the Applicant through the Corps' report of 7 July 1980 para. 63(a).

6. Para. 96,97, 98: We do not understand the intent of providing the contents of these three pargraphs. The matter described is well-known. Every soil engineer knows when primary consolidation is completed, and the secondary portion of consolidation continues as a straight line when plotted on logarithimic time scale.

7. Para. 99: Surcharging of a completed or partially completed structure is not a well established and widely accepted technique as claimed by the Applicant in this paragraph. A number of precedents described in Dr. Peck's testimony are nothing but surcharging of foundations; the portions of structures which are

affected by the differential settlement were not completed. The case of the D.G.B. is entirely different, where almost entire structure was completed during the surcharge. Therefore, surcharging has created major structural distress in different parts of the building.

8. Para. 102: The surcharge did not produce adequate stresses in the foundation soils to negate the effect of future loads (dewatering etc.) on the settlement. This has been substantiated by the excessive measured settlement after the plant area was dewatered to elevations less than 595.

9. Para. 103: It is not a sound engineering practice to cast concrete, when the structure is moving (settling). The Applicant's decision to cast concrete during the surcharge does not comply with the sound construction practices.

10. The piezometer readings and the shape of the consolidation curves did not confirm that all the excessive pore pressures were dissipated. The reasons are given in the Corps of Engineers report of 16 April 1981 (Question Nol 40).

11. Para. 106: To limit the accuracy of survey instruments (transit) to 1/8" is too high to be realistic. The normal measuring devices in leveling instruments can read up to 1/1000 of a foot, therefore, it appears that Applicant's settlement measuring method was not appropriate. Further, the error in measurement can be either plus or minus resulting in uncertainty in the measured settlement. In such case, to insure safety of the structure, it is reasonable to use higher values of settlement. The Applicant's method of computing settlement and creating error band of 1/4", and neglecting the differential settlement for computing stresses are not appropriate.

12. Para. 107: It is not known how the observations of the borros anchors would improve the precision of the data obtained. The data from borros anchors are more susceptible to errors than the reading on the markers which were located at the fixed points on the walls of the D.G.B.

13. Para. 112: Although, the pond level was raised to elevation 627.00, there is no evidence that water level below the D.G.B. rose above elevation 622.0 (Corps' report of 16 April 1981, see piezometer 12, 17, 23, 25, 29, 34, 36, 40, and 43).

14. Para. 114: The primary consolidation under the D.G.B. was not completed at all the points (Singh testified before ASLB on 10 Dec 1982 on this aspect) as claimed by the Applicant.

15. Para. 117: The foundation of the D.G.B. did not remain in plane after the removal of the surcharge. There has been considerable warping of the structure during and subsequent to the removal of the surcharge (see Singh's original testimony).

16. Para. 121: The reduction in stresses due to the surcharge removal did not exceed the stresses due to the added loads. For example the dewatering has added so much stress in excess of the surcharge stress that the foundation soils started showing primary consolidation.

17. Para. 125: The settlement due to the dewatering is primary settlement. I don't know when and how Dr. Peck added this settlement to the secondary settlement. It should be the part of the primary settlement. Part of this might be compensated by the additional settlement for continuing the surcharge load which has been included in the total predicted settlement. But definitely it has not been included in the secondary settlement.

18. Para. 130: There is no justification for correcting the measured settlement the way the Applicant has done. Applicant has consistently made unjustified corrections to reduce the differential settlement in the structure. If there are errors in survey, there is possibility that corrections might increase the settlement. But the Applicant's corrections have always reduced the settlement.

19. Para. 131: Dr. Peck's conclusion that piezometer observations are prone to anomalies is correct. But in the case of Midland Plant, a substantial number of piezometers consistently showed that pore pressures under the D.G.B. have not been completely dissipated. Hence taking advantage of anomalies to justify an incorrect result is not appropriate.

20. Para. 132: Dr. Peck's calculations of permeability are based on many questionable assumptions. Therefore, there is no merit in the values of the permeability calculated.

21. Para. 135: Dr. Peck's conclusion in para. 135 is not appropriate. In case of future cracks, a redistribution of stresses will take place, and the soil which was bridged by the structure before cracking will be subjected to more loading, causing additional settlement and more stresses in the structure.

22. Para. 138: I do not know whether Licensing Board has agreed with Peck's and Hendron's conclusions.

23. Para. 147: Dr. Peck's and Hendron's conclusion that the structural integrity of the structure has not been impaired is not correct. Mr. Singh has already shown in his original testimony that number of cracks on the east wall has increased from 10 to 16 after the surcharge. The curvature of the structure has considerably increased after the surcharge. This is a clear indication that stresses in the structure had increased to such a level due to the surcharge that numerous new cracks developed. Further the analysis of the D.G.B. structure due to settlement is incorrect. Differential settlement of the structure has not been considered in the evaluation of the stresses. Also numerous cracks which have developed due to the settlement have been ignored for the purpose of stress evaluation.

24. Para. 150, 151: The soil spring constant used in the analysis is not appropriate. Bechtel did not consider the correct values of spring constant.

25. Para. 154: It is clear from the east wall that all the cracks which are inclined and have developed after the release of the duct banks are shear cracks. These cracks have bent towards south, indicating shear stree due to excessive settlement at the southeast corner.

26. Para. 166. The error band created by the Applicant is not justified. The ASLB has been informed by Mr. Singh and Mr. Kane on 10 December 1982 regarding this fact.

27. Para. 168: Dr. Corley was wrong in making the statement that there is no evidence in the structure of any other hard spot. I do not know what is the basis of his conclusion. There are evidences of large cracks on the east wall which occurred after the release of the duct banks. This clearly establishes that these large shear cracks have occurred following the settlement of the southeast corner. Further, settlement patterns developed after the release of the duct banks clearly indicate that there are many soft spots under the D.G.B. Further, the variation made in the spring constant over a 15' length was not adequate to reflect the softness of the large area under the foundation.

28. Para. 169: No cracks have been considered in the analysis.

29. Para. 170: If the Applicant can not analyse the structure correctly, that does not mean that he will perform incorrect analysis to justify the adequacy of the structure. Obviously, all of the Applicant's analyses are erroneous. If the structure can not be correctly analyzed, that is not a justification to declare it structurally adequate.

Hn Singh.

H. N. SINGH, P.E.S.E.
NCDED-G
Lead Reviewer
Midland Nuclear Plant

Enclosure 3

D. Hood
11/6

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

NOV 18 1983

MEMORANDUM FOR: George Lear, Chief
Structural and Geotechnical Engineering Branch
Division of Engineering

THRU: Lyman W. Heller, Leader
Geotechnical Engineering Section
Structural and Geotechnical Engineering Branch
Division of Engineering

FROM: Joseph Kane, Sr. Geotechnical Engineer
Geotechnical Engineering Section
Structural and Geotechnical Engineering Branch
Division of Engineering

SUBJECT: COMMENTS ON OCTOBER 21, 1983 REPORT BY INDEPENDENT TASK GROUP REVIEW OF THE DGB AT THE MIDLAND PLANT

In response to your verbal request, I have enclosed my review comments on the October 21, 1983 report by the Independent Task Group which was formed to evaluate the concerns expressed by R. B. Landsman of Region III for the Diesel Generator Building.

It is my understanding that my review comments will ultimately be considered in OELD deliberations as to whether it is necessary for NRC to request reopening of the ASLB hearings on the DGB. The general guidelines provided by OELD relative to their decision which I have used in identifying the potential hearing considerations are the following:

1. Does the issue which I have identified in the Independent Task Group report provide new evidence that affects or modifies the hearing record evidence?

2. Are the facts or expert opinions which are expressed in the Independent Task Group Report significant and different from the facts or expert opinions that are now in evidence before the Licensing Board which could affect a conclusion with respect to the structural adequacy of the DGB?

3. Although the information from the Independent Task Group report does not change the Staff conclusion with respect to the DGB - in "fairness to the Board" should the Board have the benefit of reviewing the evidence in the report in order to reach its conclusion?

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On the basis of my review of the Independent Task Group report and my comparison with the guideline provided by OELD, I have provided my comments in Enclosure 1.

Joseph Kane, Senior Geotechnical Engineer
Geotechnical Engineering Section
Structural and Geotechnical
Engineering Branch
Division of Engineering

Enclosure:
As stated

cc: w/enclosure
R. Vollmer
J. Knight
T. Novak
L. Heller
P. Kuo
T. Sullivan
E. Adensam
D. Hood
W. Paton, OELD
M. Wilcove, OELD
F. Rinaldi
H. Singh, COE
J. Kane

Subject: Review Comments on October 21, 1983 Report by Independent Task Group on the DGB
Plant: Midland Plant Units 1 and 2, 50-329/330
Prepared by: Joseph Kane, NRR, DE, SGEB

1. A. Potential Hearing Consideration - There are statements in the Independent Task Group report on the completeness and accuracy of available settlement data and history that are in conflict with the previous testimony of reviewers from the NRC geotechnical engineering staff and the Corps of Engineers. The specific areas of the report are:

   a. Group Report, Pg. 6. "a complete and accurate settlement history does not exist."

   b. Group Report, Pg. 12. "there are no such detailed settlement measurements available, especially for the early stages of construction."

   c. Group Report, Pg. 15. "Given the unavailability of the data necessary to complete the input to the analysis by the staff's consultant, the previously stated staff position is reasonable."

   d. Group Report, Pg. 20. "However, such settlement history for the DGB does not exist."

   e. Group Report, Pg. 21. "Inconsistencies in the documentation of the settlement history needs to be resolved."

   f. Appendix III, Pg. 5. "However, it should be mentioned that the exact settlement history at the various settlement markers at the DGB is open to question." (Reasons for this statement are subsequently given).

   g. Appendix III, Pg. 7. "These analyses, though different in detail, lead to the similar conclusion that the settlement measurements were (and continue to be) in significant error."

   h. Appendix III, Pg. 8. "The first period (where measured settlements are being used to compute stresses) spans from the <u>beginning</u> of construction through August 1978 at which time construction was halted."

   i. Appendix III, Pg. 17. "However, it is recommended that the anomalies in the documentation of the settlement history be resolved" (Last paragraph of App. III, Section 2.2).

   These nine statements are in conflict with SSER No. 2, pg. 2-33 and the testimony of J. Kane and H. Singh during the week of December 6 - 10, 1982.

B. <u>Applicable OELD Guidelines</u> - Guidelines Nos. 1, 2 and 3

C. <u>Basis for Identifying Issue As Potential Hearing Consideration</u> - Because the nine identified statements in the Independent Task Group report raise questions with respect to the completeness and accuracy of the DGB settlement history and because this is in conflict with previous Staff testimony, the hearing record has become unclear and confusing. Also item i. in the above identified statements appropriately recommends that these anomalies be resolved. In my opinion all three of the guidelines identified by OELD would apply when considering the need to reopen the hearings in order to straighten out the hearing record on this issue.

2. A. <u>Potential Hearing Consideration</u>. At this particular time there are questions and significant doubts as to the defensibility of NRC position in concluding there is reasonable assurance that the structural integrity of the DGB will be maintained and its functional requirement fulfilled (See October 21, 1983 memo from P. T. Kuo to J. P. Knight, pg. 1; Group Report, pg. 21, Conclusion no. 5; App. III, pg. 17, Conclusion no. 6). The questions and doubts result from the following items in the Independent Task Group report:

a. The report in several locations identifies the need for the Applicant and the NRC staff to properly document the information and calculations for crack width approach for all DGB walls in order for the stresses that are induced by settlements to be known and evaluated. (See October 21, 1983 memo, pg. 2, item 3; Group Report, pgs. 16 and 21, item 2; App. III, pgs. 11, 16, 17 item 2).

b. Closely related to this issue is the report's acknowledgement that the crack method approach is questionable where relatively few cracks occurred (App. III, pg. 11) and the absence of written justification in the FSAR for using this approach for structures like the DGB (App. III, pg. 16).

c. In addition the report in several locations points out the inadequacies of the present crack monitoring program and the need for improvement (Group Report, pgs. 17 and 21 item 4; App. III, pgs. 13, 16 and 17) and the need to establish action levels (Oct. 21, 1983 memo, pg. 2 item 5; App III, pgs. 16 and 17 item 4).

d. The NRC Staff position on DGB acceptability uses the crack width approach to estimate settlement induced stresses and this position is heavily dependent on the accuracy of available crack maps. In several locations in the Task Group report, the reliability and accuracy of presently available crack maps are questioned and the Group report cites concern that cracking in the DGB has not stabilized and the cracks are growing (See Oct. 21, 1983 memo, pg. 2 item 4; App. III pgs. 6, 7, 13 and 17 item 3). In my opinion it will be necessary to obtain and use more recent and accurate crack maps of the DGB before the recommendation of the Task Group can be followed for establishing crack width levels that will reflect a sufficient stress margin available to resist critical load combinations (October 21, 1983 memo, pg. 2 item 5).

B. Applicable OELD Guidelines. Guideline Nos. 1, 2 and 3.

C. Basis for Identifying Issue As Potential Hearing Consideration. For the NRC staff to have a reasonable and defensible position in judging the adequacy of the DGB there is a need to have a good data basis. The Task Group report, as indicated by the above comments, correctly points out that at this time we do not have that basis. The report provides some specific recommendations that should be followed in order to reach the needed sound engineering basis. Both the Board and the public have already asked what is the NRC Staff response to the report's recommendations and will want to know what significant information is developed in carrying out these recommendations. For these reasons I believe all three of the guidelines provided by OELD apply and would be the basis for reopening the hearing on the DGB.

3. A. Potential Hearing Consideration. The Task Group report in many locations discusses the controversial finite element analysis completed by the Applicant where the measured/predicted displacements were "straight lined" which essentially disregards any effect of differential settlement. (See Group Report, pgs. 7, 20 item 1; App. III, pgs. 9 and 14). In the Dec. 6 through 10, 1982 hearing sessions this issue was extensively discussed and reflected significant differences in professional opinions that has left the hearing record unclear and unresolved. The statements in the Task Group report on this controversial subject are very specific and clear "that this model (the Applicant's) will yield unconservative estimates of stresses." (App. III, pg. 9, 2nd par.) and "We therefore conclude that this approach to compute settlement stresses is inappropriate." (App III, pg. 9) and "The straight line representation of the settlements along the north and south wall for the analysis reported in 2.4.1 is said to be in error. As indicated in that section of this report, it is our opinion that this analysis will result in unconservative predictions of stresses due to settlements. As such, it is considered to be an inappropriate analysis." (App. III, pg. 14, 2nd par.).

B. Applicable OELD Guidelines. Guideline Nos. 1, 2 and 3.

C. Basis for Identifying Issue As Potential Hearing Consideration. In my opinion the presently conflicting evidence before the Board on this issue is significantly impacted by the Task Group's findings. I believe the clear engineering explanation provided in the report's statements on why this analytical approach is not appropriate would be helpful to the Board in assisting them to reach a decision on this issue.

4. A. Potential Hearing Consideration. A previously identified concern expressed by J. Kane (Oct. 24, 1983 memo, G. Lear to W. Paton on the Applicant's Proposed Findings, pg. 12, item 61) with the results of the Naval Surface Weapon Center (NSWC) study is also impacted by the Task Group's report. Although the Task Group in App. III, pg. 10 questions the value of the NSWC conclusions because of the apparent linear assumption of settlement data points made in the study, the report by the Group reflects an influence of the NSWC results by referencing the important conclusion by the NSWC study - that very high stresses are calculated in areas of the DGB where no cracks now exist. (See Group Report, pgs. 8 and 20 item 1; App. III pgs. 14 and 15). This NSWC conclusion is seriously questioned when a comparison is made of the computed areas of high stress with areas of recorded cracking (See enclosure tables to Oct. 24, 1983 memo). When the internal walls of the DGB are evaluated for computed areas of high stress with areas of recorded cracking, it can be shown that cracks appear in 94 percent of the locations where the NSWC study has computed high stresses.

B. Applicable OELD Guidelines - Guidelines Nos. 1, 2 and 3.

C. Basis for Identifying Issue As Potential Hearing Consideration. Both the Task Group report and the present hearing record offer the conclusion by the NSWC study that cracks do not appear in areas of computed high stress, thereby indicating that the settlement values more than likely were not seen by the structure. This NSWC conclusion is incorrect and this issue has not yet been brought to the Board's attention. It is quite likely that the Board would place significant reliance on the NSWC conclusion, if left uncorrected, in reaching its decision with respect to the safety of the DGB. For these reasons I feel it should be brought to the Board's attention.

5. There are less important considerations affected by the information within the Independent Task Group report, that would not require reopening of the DGB hearing, but which would be helpful to the Board if addressed, since they are related to previous testimony. These items are:

   a. Group Report, pgs. 3 and 4. The implication that surcharging the completed DGB structure relieved it of stress.

   b. App. III, pg. 5. The questionable significance of the piezometer data during surcharging.

   c. App. III, pg. 12. The statement that serious structural distress was caused by the very large settlements at the DGB.

   d. App. III pgs. 12 and 13. The need to improve the accuracy of future settlement monitoring at the DGB and to require better methods for monitoring crack growth with reliable strain gages.

Enclosure 4

D. Hood
116

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

NOV 18 1983

MEMORANDUM FOR: George Lear, Chief
Structural and Geotechnical Engineering Branch
Division of Engineering

THRU: Pao-Tsin Kuo, Leader
Structural Engineering Section B
Structural and Geotechnical Engineering Branch
Division of Engineering

FROM: Frank Rinaldi, Structural Engineer
Structural Engineering Section B
Structural and Geotechnical Engineering Branch
Division of Engineering

SUBJECT: EVALUATION OF EVIDENCE ON DIESEL GENERATOR BUILDING - MIDLAND PROJECT FOR DETERMINATION OF NEED TO REOPEN HEARINGS

Pursuant to your request of November 8, 1983, for my evaluation of any new evidence related to the structural adequacy of the Diesel Generator Building (DGB), I have evaluated the report by the NRR Task Group dated October 21, 1983, for the test conditions provided by your management (Enclosure 1) and expanded by the staff attorney (Enclosure 2).

Foremost, I like to state that the NRC staff decision to reopen the hearings on the DGB lies on the NRC legal staff. The NRC legal staff is aware of the official staff position and personal technical positions of staff members and consultants, as stated in written and oral testimony during the ASLB hearing of December, 1982. In addition, the NRC legal staff is aware of the questions raised by the Region III-IE inspector as well as the answers provided by all concerned parties. Indeed the NRR Task Group Report of October 21, 1982, documents the conclusions, discussions, and specific answers to the questions raised by Region III-IE inspector. The NRR Task Group report includes their findings, those of their consultant staff from Brookhaven National Laboratory (BNL), as well as the replies by NRR Structural and Geotechnical staff and their consultants to the questions raised by the Region III-IE inspector. Please note that errata has been pointed out to the Task Group. The need for corrections has been acknowledged by the Task Group and errata pages have been issued.

Recognizing the fact that my recommendations on the subject of reopening the hearing for the DGB are needed for the final decision making, I will identify the important facts stated by the Task Group and state if they constitute, from the structural engineering point of view, new evidence or if they impact on the previous conclusions reached by the structural engineering staff. The major points are the following:

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1. The Task Group used the same facts and evidence used by the review staff in their evaluation of the DGB.

2. The Task Group reached the same bottom line conclusion, "that there is reasonable assurance that the structural integrity of the DGB will be maintained and its functional requirements fulfilled."

3. The Task Group concluded that, "The most reasonable estimate of stress due to settlement is based on the crack width data. However, the calculations that have been done in this area need to be completely documented."

4. The Task Group stated, "That a more accurate and reliable crack monitoring program be established," and that sufficient stress margins for Action Level and specific repairs be established for Alert Level of crack/s width/s. Also, they recommended a general repair program prior to plant operation.

The first two items are self-explanatory and from a structural engineering technical point of view should be the major reasons that no additional hearings are required to establish the structural adequacy of the DGB. The third item asks for the documentation of the calculations used in the determination of the conservative stress values utilizing the crack width data. The approach has been discussed, the results have been documented, and the data used for the calculations has been identified. Therefore the requested documentation will consist of nothing more than presenting the information related to the assumptions made, formula used, input data, calculations, and results. The actual calculations require basic skills and engineering judgment. The resulting stress values can be easily verified with the stress results identified in the written and oral testimony of the applicant and the staff. I do not consider this documentation to be new evidence because the facts do not change. The fourth item recommends a modification to the monitoring program previously proposed by the applicant and accepted by the staff and a general repair program. The Task Group does not provide specific approaches that would fulfill these recommendations. BNL report recommends the extensive use of Whitmore strain gages in place of the three crack monitoring windows currently accepted by the staff, but recommends the same general approaches as the Task Group for requirements on the general repairs and the requirements on the Alert and Action Levels. The Task Group was aware of the BNL recommendation related to the Whitmore strain gages, but did not make such firm recommendation. The above stated facts lead me to the conclusion that the Task Group is leaving the structural review staff and the applicant with the task of resolving these concerns.

I conclude from my review of the Task Group report that the NRC staff needs to start discussions with the applicant concerning the documentation of the rebar stresses as determined from all available crack-width data, the usefulness and effectiveness of the strain gages proposed by BNL, and if more specific actions should be established now, or as results of meetings with the applicant after the alert and/or action levels are reached. The applicant has contracted with Portland Cement Association (PCA) to review and evaluate all field data (cracks and deflections) to evaluate potential and specific problems identified by the monitoring program. The staff was relying on this independent monitoring and evaluation by PCA in the acceptance of the monitoring requirements.

I understand the fact that some people may not fully understand the structural engineering technical aspects of this case and may consider the availability of any new document as solid ground for reopening the hearings on the DGB. However, based on the fact that no new evidence was uncovered in the preparation of the conclusions of the Task Group, that the structural adequacy of the DGB was assured, and that no specific detailed recommendations were made other than generic suggestions which the staff can request the applicant to resolve and then inform the board of the resolutions; I do not recommend, from the structural engineering technical point of view, to reopen the hearing on the structural safety of the DGB.

Frank Rinaldi, Structural Engineer
Structural Engineering Section B
Structural and Geotechnical
Engineering Branch
Division of Engineering

Enclosures:
As stated

cc: R. Vollmer
J. Knight
T. Novak
T. Sullivan
E. Adensam
D. Hood
W. Paton
P. Kuo
L. Heller
J. Kane
G. Harstead
J. Matra
F. Rinaldi

st to apply in deciding whether to recommend that the hearing be reopened.

- Is there new evidence that modifies the evidence of record? For example, does the new evidence affect what was said by the witnesses (any or all) in such a way that something different would have been said if the information had been available before the testimony was given?

- The issue is one of "fairness to the board". If our feeling is that the evidence would not change our conclusions but that the board nevertheless, should have the benefit of reviewing this new evidence to reach its conclusions, then we should recommend for reopening the record.

ENCLOSURE 1

Are the facts or expert opinions in the DGB Task Report that are different from facts or expert opinions now in evidence before the Licensing Board. (The facts and expert opinions referred to are significant facts and expert opinions, i. e. - facts and expert opinions that could effect a conclusion with respect to the structural adequacy of the Diesel Generator Building)

TERA

PRINCIPAL STAFF			
RA		DPRP	
D/RA		DE	
A/RA		DRMSP	
RC		DRMA	
PAO		SCS	
SGA		ML	
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January 4, 1984

Mr. James W. Cook
Vice President
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Mr. J. G. Keppler
Administrator, Region III
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U.S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, IL 60137

Mr. D. G. Eisenhut
Director, Division of Licensing
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: Docket Nos. 50-329 OM, OL and 50-330 OM, OL
Midland Nuclear Plant - Units 1 and 2
Independent Design and Construction Verification (IDCV) Program
Structural Evaluation of the Diesel Generator Building -
Assessment of the Structural Performance Capability as
Potentially Affected by Settlement Induced Cracking

Gentlemen:

Attached is our recently completed engineering evaluation of the structural performance capability of the diesel generator building. This evaluation was undertaken in accordance with the defined scope of the IDCVP as part of our broader assessment of the quality of the design and constructed product of the Midland plant Standby Electric Power system. We are transmitting it to you because of its relevance to ongoing discussions concerning the potential effects of settlement induced cracking on the capability of the DGB to meet intended performance requirements over its service life.

We have concluded that the existing cracks, generally being of small size, are not indicative of a condition that would compromise the capability of the DGB in meeting its intended performance requirements. Furthermore, it is judged that significant future cracking is unanticipated and the DGB is expected to remain serviceable without further remedial action at this point in time. We have

D02
1/1

reviewed Consumers Power Company's commitments to verify continued serviceability and have concluded that these are acceptable; however, we have offered certain recommendations for consideration that are intended to improve available information and reduce operational constraints.

Should you desire further articulation of the bases for our conclusions, we would welcome the opportunity for discussion.

Sincerely,

Howard A. Levin
Project Manager
Midland IDCV Program

Enclosure

cc: L. Gibson, CPC.
R. Erhardt, CPC
J. Mooney, CPC
D. Budzik, CPC
D. Quammy, CPC (site)
R. Whitaker, CPC (site)
R. Burg, Bechtel
J. Taylor, NRC, I&E HQ
T. Ankrum, NRC, I&E HQ
D. Hood, NRC, NRR
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AND CONSTRUCTION VERIFICATION PROGRAM

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Midland Daily News
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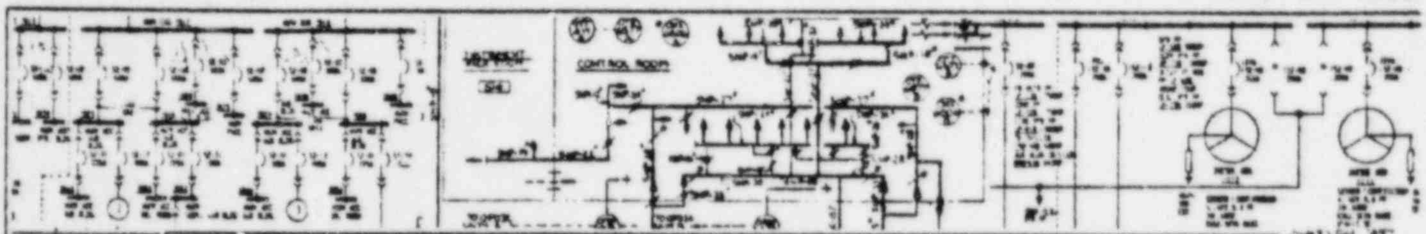
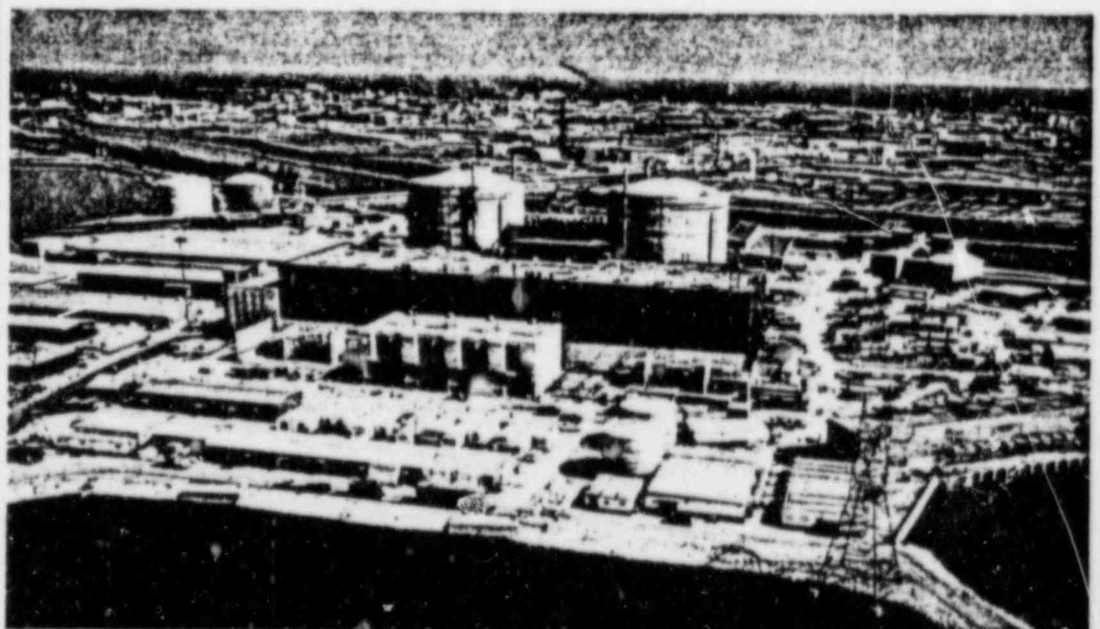
Midland, Michigan 48640

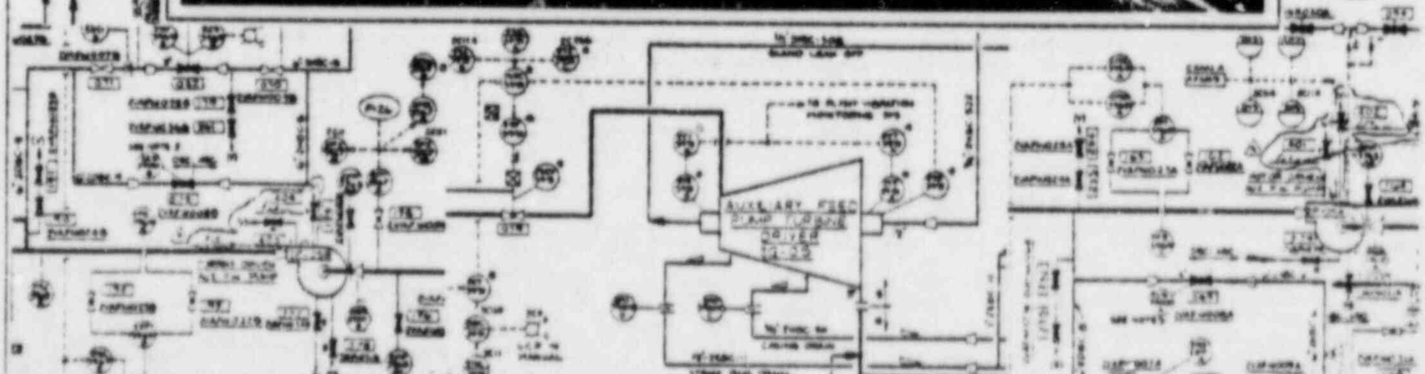
United States Nuclear Regulatory Commission
Docket Numbers 50-329 & 50-330



Midland Independent Design and Construction Verification Program

Structural Evaluation of the Diesel Generator Building





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PDR ADOCK 05000329
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TERA CORPORATIO

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January 4, 1984

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Midland Daily News
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ENGINEERING EVALUATION COVER SHEET

TITLE Structural Evaluation of the Diesel Generator Bldg.

CONT. ID. NO. 3201-001-031

NO. OF SHTS. 42

PROJECT: CONSUMERS POWER COMPANY MIDLAND IDCV

SUPERSEDES ENG. EVAL. NO.

REV. NO.	REVISION	ORIGINATOR	DATE	REVIEWED BY	DATE	APPROVED BY	DATE
0	Original	Clle	12/30/83	G.E.S	12/30/83	[signature]	1/4/84

☐ PRIMARY EVALUATION ☒ SUPPORTING EVALUATION

TOPIC NUMBER III.5-2, III.6-2, III.7-2

TOPIC TITLE Civil/Structural Design Considerations, Foundations, Concrete/Steel Design

METHOD/EXTENT OF REVIEW

1. Review of Midland project generated information including calculations, consultant reports, testimony, etc.
2. Independent calculations and evaluations by IDCVP Review Team.

PURPOSE

Evaluation of settlement induced cracking as it may potentially affect intended performance requirements and serviceability of the diesel generator building.

CONTENTS (SEE SECTION 2., PI-3201-001)

- ☒ ABSTRACT
- ☒ OVERVIEW OF REVIEW PROCESS
- ☒ BASES FOR SAMPLE SELECTION
- ☒ SOURCES OF INFORMATION/REFERENCES
- ☒ BACKGROUND DATA (INPUTS, ASSUMPTIONS, RELATED CALCULATIONS)
- ☒ ACCEPTANCE CRITERIA (CODES, STANDARDS, FSAR, NRC GUIDANCE, REGULATIONS)
- ☒ EVALUATION (DOCUMENTATION OF REVIEW AGAINST CHECK LIST, (ACCEPTANCE CRITERIA)
- ☒ CONCLUSIONS

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STRUCTURAL EVALUATION OF THE DIESEL GENERATOR BUILDING - ASSESSMENT OF THE STRUCTURAL PERFORMANCE CAPABILITY AND SERVICEABILITY AS POTENTIALLY AFFECTED BY SETTLEMENT INDUCED CRACKING

TERA CORPORATION

TABLE OF CONTENTS

1.0 ABSTRACT

An engineering evaluation has been completed to assess the structural performance capability and serviceability of the Midland plant diesel generator building (DGB) as potentially affected by settlement induced cracking. The evaluation was initiated by TERA Corporation as part of the Midland Independent Design and Construction Verification Program (IDCVP). The performance requirements for the DGB were identified and the acceptance criteria for meeting these requirements were reviewed. Information generated by the Midland project as well as independent calculations and evaluations by the IDCVP review team serve as input to the conclusions of the engineering evaluation. It was concluded that the existing cracks, generally being of small size, are not indicative of a condition that would compromise the capability of the DGB in meeting its intended performance requirements.

Furthermore, it was judged that significant future cracking is unanticipated and the DGB is expected to remain serviceable without further remedial action at this time. Consumers Power Company (CPC) commitments to verify continued serviceability were reviewed and found to be acceptable. Certain recommendations have been offered for consideration that are intended to improve available information and reduce operational constraints.

2.0 OVERVIEW OF REVIEW PROCESS

This engineering evaluation was undertaken as part of a broader assessment of the quality of the design and constructed product of the Midland plant Standby Electric Power (SEP) system. The specific scope of review documented herein includes a structural evaluation of the diesel generator building (DGB), the structure which houses four emergency diesel generators which are principal components of the SEP system. The main emphasis of the review is on the civil/structural design considerations for the DGB and how settlement induced cracking may potentially affect the intended performance requirements. Accordingly, this evaluation addresses the following topics within the Midland IDCVP:

- Topic III.5-2 - Civil/Structural Design Considerations
- Topic III.6-2 - Foundations, and
- Topic III.7-2 - Concrete/Steel Design;

therefore, representing partial fulfillment of the structural design review scope pertaining to SEP system. This evaluation has required input from other ongoing topic reviews such as:

- Topic III.1-2 - Seismic Design/Input to Equipment, and
- Topic III.2-2 - Wind and Tornado Design/Missile Protection;

however, these evaluations are documented under separate covers. The DGB construction/installation documentation reviews and the associated physical verification have not been completed and are not documented in this evaluation. Accordingly, should the results of these evaluations affect the conclusions drawn herein, the engineering evaluation will be appropriately revised.

The review concept includes a determination of the DGB performance requirements and important design inputs (i.e. engineering data and assumptions); an evaluation of their accuracy, consistency, and adequacy; and an evaluation of the implementation of these commitments. Current licensing criteria are utilized as a baseline as well as consideration of various other regulatory criteria which evolved during the licensing process. Given the unique circumstances associated with the DGB design and construction processes, the IDCVP assessment used the intent of today's licensing criteria and corresponding margins of safety and reliability.

The review draws upon two principal sources of information; that generated by the Midland project (e.g. Bechtel calculations, consultant reports, testimony, etc.) and by the IDCVP review team (e.g. independent calculations and evaluations, etc.). Pertinent background data and references are documented in Section 3.0. Conclusions are reached through an integrated assessment of these data, discussions with Midland project personnel, as well as engineering judgement.

The following individuals made technical contributions to this engineering evaluation:

Dr. Jorma Arros	-	Structural Reviewer, Midland IDCVP and Senior Structural Engineer, TERA Corporation
Dr. William J. Hall	-	Member Senior Review Team, Midland IDCVP and Professor of Civil Engineering, University of Illinois
Professor Myle J. Holley	-	Consultant, Midland IDCVP, Professor of Civil Engineering Emeritus, Massachusetts Institute of Technology and President, Hansen, Holley and Biggs, Inc.
Mr. Howard Levin	-	Project Manager, Midland IDCVP and Manager, Engineering, TERA Corporation
Dr. Christian Mortgat	-	Lead Technical Reviewer, Standby Electric Power System Structural Review, Midland IDCVP and Principal Structural Engineer, TERA Corporation

The following chronology of external interactions transpired as part of this review.

Date	Activity
August 24, 1983	Review team members observe NRC task force meeting on structural rereview of DGB at Bechtel's Ann Arbor, Michigan offices.
November 17, 1983	Review team members inspect diesel-generator building.
November 18, 1983	Review team members discuss civil/structural design considerations for the DGB and collect information at Bechtel's Ann Arbor, Michigan offices.
December 12-16, 1983	Review team members review DGB finite element and seismic stick models at Bechtel's Ann Arbor, Michigan offices.

3.0 BACKGROUND DATA AND REFERENCES

The following table identifies references and sources of information that were selected for review and served as input to this engineering evaluation. The numbers in the left margin correspond to references made within the body of the engineering evaluation.

ATTACHMENT B, PI-3201-001, REV 2.

REFERENCES/SOURCES OF INFORMATION

TOPIC TITLE Civil/Structural Design Considerations, Foundations, Concrete/Structural Steel TOPIC NO. III.5-2, III.6-2, III.7-2 PAGE 1 OF 3

ENGINEERING EVALUATION Structural Eval. of the Diesel Generator Bldg CONT. ID. NO. 3201-001-031 REV. 0 DATE 12/30/83

	ORIGINATING ORG./ AUTHOR	IDENTIFICATION/ NUMBER	REV.	DATE	TITLE	WHERE/HOW LOCATED	DOCUMENT TYPE
1.	Bechtel	File 0485.16/B13.3 Serial 22423	48	5/83	Final Safety Analysis Report	Ann Arbor	FSAR
2.	NRC	50-329/330	0	10/21 83	Report on the Review of the Diesel Generator Building - Midland	Docket	Report
3.	Bechtel	--	0	8/24/ 83	Midland Units 1 and 2 Diesel Gen. Bldg. Exec. Summary	Ann Arbor, 11/18/83 Meeting	
4.	Wiedner	testimony at pp 10804-11007	0	9/8/ 82	Testimony of Karl Wiedner for the Midland Plant Diesel Gen. Bldg.	Docket	Testimony
5.	CPC	File 0485.16, B3.0.3, Serial 17228	0	6/1/ 82	Technical Report-Structural Stresses Induced by Differential Settlement of the Diesel Generator Bldg.	CPC, Jackson	Report
6.	CPC		3	9/79	Response to NRC regarding Plant Fill	Docket	Report
7.	ACI	ACI 318-77			Building Code Requirements for Reinforced Concrete	Library	Standard
8.	ACI	ACI 349-76			Code Requirements for Nuclear Safety Related Concrete Structures	Library	Standard
9.	TERA	PI-3201-009	3	7/15/ 83	Engineering Program Plan	IDCVP Proj. Files	Project Instruction
10.	Sozen	--	0	2/11/ 82	Eval. of the Effect on Structural Strength of Cracks in the Walls of the Diesel Generator Building	Transcript at 10950	Report
11.	Peck	Testimony at p. 10180	0	12/6/ 82	Testimony of Ralph Peck	Transcript at 10180	Report
12.	Corley, et. al.	--	0	4/19/ 82	Effects of Cracks on Serviceability of Structures at Midland Plant	Transcript at 11204	Report
13.	CPC	FSAR Ch. 16	45	9/82	Tech. Spec. 16.3/4.13 Settlement Monitoring	Ann Arbor	FSAR
14.	CPC	Exhibit 29R	0	--	DGB Areas for Crack Width Monitoring During Operation of the Plant	Ann Arbor, 11/18/83 Meeting	Partial/ Corres.
15.	Bechtel	DQ-52.0(Q)	2	9/9/ 83	Diesel Gen. Bldg. Reanalysis Using Revised Settlement Load Case	Ann Arbor	Calc

TERA CORPORATION

REFERENCES/SOURCES OF INFORMATION

TOPIC TITLE Civil/Structural Design Considerations, Foundations, Concrete/Structural Steel TOPIC NO. III.5-2, III.6-2 III.7-2 PAGE 2 OF 3

ENGINEERING EVALUATION Structural Eval. of the Diesel Generator Bldg. CONT. ID. NO. 3201-001-031 REV 0 DATE 12/30/83

	ORIGINATING ORG./ AUTHOR	IDENTIFICATION/ NUMBER	REV.	DATE	TITLE	WHERE/HOW LOCATED	DOCUMENT TYPE
16.	Bechtel	DQ-52.1(Q)	1	8/27/82	DGB Settlement Analysis - Load Case 1A	Ann Arbor	Calc
17.	Bechtel	DQ-52.2(Q)	0	5/12/82	DGB Settlement Analysis - Load Case 1B	Ann Arbor	Calc
18.	Bechtel	DQ-52.3(Q)	1	9/28/83	DGB Surcharge Condition (2A)	Ann Arbor	Calc
19.	Bechtel	DQ-52.4(Q)	0	6/28/82	DGB Settlement for 40 yr Life (2B)	Ann Arbor	Calc
20.	Bechtel	DQ-52.6(Q)	1	9/7/83	DGB Analysis for Uniform Torsion	Ann Arbor	Calc
21.	Bechtel	DQ-52.7(Q)	1	9/7/83	DGB Anal. Imposing 40 yr displacements	Ann Arbor	Calc
22.	Bechtel	DQ-12(Q)	1	4/15/83	DGB Reanalysis (including cracking of concrete)	Ann Arbor	Calc
23.	Bechtel	DQ-52.0-C7(Q)	0	5/18/82	Optcon ACI-349 - Nonseismic Load Cases 7-18 - Diesel Gen. Bldg. Settlement Analysis (partial)	Ann Arbor	Calc
24.	Bechtel	DQ-52.0-C2(Q)	0	5/4/82	DGB Load Combination (partial)	Ann Arbor	Calc
25.	Bechtel	DQ-52.2-C5(Q)	0	5/12/82	DGB Settlement Analysis - Load Case 1B - Free Body Analysis of Trial #3 (partial)	Ann Arbor	Calc
26.	Bechtel	DQ-52.3-C7(Q)	0	9/28/83	DGB - Settlement Case 2A - Free Body Analysis on Best Fit (Surcharge) (Partial)	Ann Arbor	Calc
27.	Bechtel	DQ-52.4-C4(Q)	0	5/12/82	DGB Analysis - Free Body Analysis of Best Fit 40-Year Case	Ann Arbor	Calc
28.	Bechtel	DQ-23-C4(Q)	0	12/11/81	DGB Roller Support (FSAR Criteria)	Ann Arbor	Calc
29.	Bechtel	S-110	1	11/11/82	Static & Dynamic Spring Constant of DGB for Structural Stress Anal.	Ann Arbor	Calc
30.	Bechtel	S-175	3	2/22/82	Update of Settlement Prediction DGB - After Surcharge Removal	Ann Arbor	Calc
31.	Bechtel	S-238	0	7/15/82	Settlement of DGB Between 9/14/79 and 12/31/2021	Ann Arbor	Calc

ATTACHMENT B, PI-3201-001, REV 2.

REFERENCES/SOURCES OF INFORMATION

TOPIC TITLE Civil/Structural Design Considerations, Foundations, Concrete/Structural Steel TOPIC NO. III.5-2, III.6-2, III.7-2 PAGE 3 OF 3

ENGINEERING EVALUATION Structural Eval. of the Diesel Generator Bldg CONT. ID. NO. 3201-001-031 REV 0 DATE 12/30/83

	ORIGINATING ORG./ AUTHOR	IDENTIFICATION/ NUMBER	REV.	DATE	TITLE	WHERE/HOW LOCATED	DOCUMENT TYPE
32.	Bechtel	SQ-147(Q)	1	5/2/83	Seismic Analysis of DGB and DG Pedestal	Ann Arbor	Calc
33.	Bechtel	DQ-52.11(Q)	0	9/9/83	DGB: Reduction of Settlement Data (Partial)	Ann Arbor	Calc
34.	Bechtel	SK-C-2343-1/24	F	12/5 83	Settlement Data for DGB	Ann Arbor	Drawing
35.	CPC	File 0485.16 Serial 18371	0	8/2/82	Midland Concrete Wall Repair Program	Att. 2 to Testimony of Corley @ p.11206	Letter
36.	NRC	50-329/330	0	9/29/81	Trip Report - Midland DGB Structural Design Audit	Docket	Report
37.	Neville	Lib. of Congress No. 72-12066	1	1975	Properties of Concrete	Library	Text Book
38.	TERA	3201-003-007	0	12/30/83	Structural Analysis of Diesel Generator Building	IDCVP Proj. Files	Calc
39.	Bechtel	DQ-14(Q)	1	8/12/83	Response to NRC Question 26 Re: Diesel Generator Building	Ann Arbor	Calc
40.	Bechtel	DQ-23(Q)	1	10/11/83	DGB Reanalysis (in support of public hearing testimony)	Ann Arbor	Calc

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4.0 ACCEPTANCE CRITERIA

4.1 LOAD COMBINATIONS

The loads and load combinations employed for the original design and analysis were provided in the FSAR subsection 3.8.6.3 (revision 0, dated November 1977). These original design criteria did not contain settlement effects. Four additional loading combinations were established and committed for consideration as a result of Question 15 of the NRC Requests Regarding Plant Fill of September 1979. These loading combinations combined differential settlement with long-term operating loads and either wind or the operating basis earthquake (OBE). As Wiedner (reference 4) and CPC (reference 5) point out these expressions are more stringent than the requirements of ACI 318 (reference 7), but less stringent than ACI 349 (reference 8). In the latter case the loading combinations combine differential settlement with extreme loads such as tornadoes and the safe shutdown earthquake (SSE). Subsequently, in response to Question 26 of the NRC Requests Regarding Plant Fill, a commitment was made to undertake a separate structural reanalysis of the DGB in accordance with ACI-349 as supplemented by NRC Regulatory Guide 1.142 for comparison purpose only.

The following loads were considered in the reanalysis:

(a) dead loads (D)

(b) effects of settlement combined with creep, shrinkage and temperature (T)

(c) live loads (L)

(d) wind loads (W)

(e) tornado loads (W')

(f) OBE loads (E)

(g) SSE loads (E')

(h) thermal effects (T_o)

It is to be noted that thermal effects appear twice by virtue of the manner in which the loading combinations were developed. The load combination established and committed to in response to NRC Requests Regarding Plant Fill, Question 15 are as follows:

a. 1.05 D + 1.28 L + 1.05 T

b. 1.4 D + 1.4 T

c. 1.0 D + 1.0 L + 1.0 W + 1.0 T

d. 1.0 D + 1.0 L + 1.0 E + 1.0 T

A number of load cases appearing in the load combinations for Seismic Category I structures listed in FSAR Subsection 3.8.6.3 do not occur in the diesel generator building and other load combinations can be eliminated from the analysis after comparison with more severe loads or load equations (reference 5). As a result the remaining load combinations to be considered are:

e. 1.4 D + 1.7 L

f. 1.25 (D + L + W) + 1.0 T_o

g. 1.4 (D + L + E) + 1.0 T_o

h. 0.9 D + 1.25 E + 1.0 T_o

i. 1.0 (D + L + E') + 1.0 T_o

j. 1.0 (D + L + W') + 1.0 T_o

4.2 ALLOWABLE MATERIAL LIMITS

In accordance with regulatory requirements, the maximum rebar tensile stress allowed in the diesel generator building rebar should not exceed 0.90 f_y (where f_y equals yield strength) for computation of section capacities. Because the diesel generator building rebar has an f_y value of 60 ksi, the maximum allowable tensile rebar stress due to flexural and axial loads is 54.0 ksi. Accordingly, reinforced concrete section capacities for the diesel generator building were based on this maximum allowable rebar stress value (54 ksi), a design concrete compressive strength of 4000 psi and a maximum allowable concrete compressive strain level of 0.003 in./in.

5.0 BASES FOR SAMPLE SELECTION

The diesel generator building (DGB) was selected for review because it serves an important support function in providing protection against external hazards for the diesel generators which are integral components of the Standby Electric Power (SEP) System. The DGB falls within the sample selection boundaries defined in the Engineering Program Plan (reference 9). Commitments were made in this reference to review civil/structural design considerations for the DGB including foundations and concrete/steel design. Based on programmatic commitments, emphasis is to be placed on structural performance and not detailed soil mechanics aspects which are not within the scope of the Midland Independent Design and Construction Verification Program (IDCVP).

This engineering evaluation addresses the potential effects of settlement induced cracking on the ability of the DGB to meet its intended performance requirements. Accordingly, verification of the Midland project treatment of the settlement/cracking issues which have affected several structures at the Midland site is addressed herein. While a structural review of the auxiliary building is also within the IDCVP scope as part of the Auxiliary Feedwater (AFW) system review, the specific settlement/cracking issue as it may affect the auxiliary building is not being treated directly by the IDCVP. Thus, this evaluation of the DGB represents the IDCVP sample addressing the settlement/cracking issues.

It is estimated that approximately one third of the project's calculations and evaluations addressing the structural design of the DGB were selected for review. Emphasis was placed on the selection of portions of the project's evaluations that address controlling design conditions (e.g. important load combinations producing the highest predicted stresses or strains, as appropriate). Principal project consultant reports were reviewed as well as other docketed information that documents CPC commitments to the NRC (see section 3.0).

6.0 ENGINEERING EVALUATION

6.1 BUILDING PERFORMANCE REQUIREMENTS

The diesel generator building (DGB) is a two story reinforced concrete box type building partitioned into four bays, each bay containing one diesel powered electric generator (see Figure 6-1). The purpose of the diesel generators is to supply standby electrical power to operate the Midland plant during power outages and to provide the necessary power to ensure safe shutdown of the plant in the event of a design basis event. Accordingly, the diesel generators and the DGB are classified as Seismic Category I, and as a result must maintain functionability during external events such as earthquakes and tornadoes.

The DGB provides protection for the diesel generators and associated supply and service lines, instruments and equipment, assuring ready availability of this supplementary power source. This protective function includes not only the normal sheltering of building contents from rain, snow, wind, and ice, but in addition, resistance to the effects of earthquakes and tornadoes including tornado generated missiles. It is these latter effects which are of principal structural interest, and which dictate a more massive type of construction than normally would be employed for shelter from the commonly considered weather extremes.

The DGB was founded on plant fill and constructed between the Fall of 1977 and the Spring of 1979. During that period it was discovered that the building was experiencing an unusual rate of unequal settlement, and duct banks had made contact with the footings which led to building distortion and reinforced concrete cracking. The details of the settlement monitoring, duct structural modifications, and surcharge consolidation program are described in detail in references 3 and 5.

6.2 ACCEPTANCE CRITERIA

In response to applied loadings (dead, live, earthquake-induced, wind, tornado, tornado missiles) and certain secondary effects such as settlement, local internal forces are developed throughout the structure. These local forces consist of in-plane forces, sometimes termed membrane forces, and out-of-plane forces, i.e., transverse shear forces, and bending moments. In design it is customary for the internal forces associated with a particular loading to be multiplied by a specified "load factor" and these load factored sets must be combined for the several specified loadings to obtain what may be called a local internal demand. This demand must not exceed the local "strength", i.e., capacity of the structure. The acceptance criteria consists of the following:

- Statements of the several different load combinations that must be satisfied, and the load factors to be applied to each of the loadings (dead, live, tornado, etc.) within that combination.

- Specific expressions, or procedures, for determining the local strength which must not be exceeded.

It may be noted that certain of the specified load combinations focus on serviceability of the structure. These do not include the infrequent extreme loadings, but incorporate relatively large load factors to assure a modest demand/capacity ratio for (unfactored) loadings experienced in normal operating conditions. For the combinations which include extreme and rare loadings, safety in the sense of protecting personnel and equipment, yet retaining functionability, is the primary consideration rather than serviceability. Thus crack widths, including those widths which may reflect yielding of the tension rebars, are not a consideration provided that they do not imply a reduction in the local strengths. Accordingly, such specified factored load combinations typically incorporate smaller specified load factors. In effect a larger demand/capacity ratio for these unfactored load combinations is acceptable for these rare conditions.

It should be noted that the specified expressions, or procedures, for determining the local internal strength do not typically include any direct limitation on rebar tensile strain, or on crack widths which accompany such strain, although there are indirect limitations for certain conditions. (Note that the limiting condition specified by various ACI codes (references 7 and 8) are related to maximum allowable concrete compressive strains where a value of 0.003 in./in. is specified). This strain reflects the fact that certain components of local strength are not sensitive to rebar strain but only to the tensile yield strength of the rebars. As an example, full development of the local out-of-plane bending strength of a slab, or beam, with a modest rebar ratio may imply tensile rebar strain into the yield range. Indeed this is specifically recognized by codes which specify that, for rebar strains in excess of the elastic strain at yield stress the stress must be assumed to be constant at the yield stress value. This approach often is overlooked because, for the majority of local conditions of interest it is computationally much more convenient to evaluate local sections on the assumption that the steel strains remain within the elastic range, and to compute rebar stresses associated with the particular factored load combination demand rather than to compute the local section strength, per se. In some cases this approach is slightly conservative, but often there is no difference whatever. However, the fact that there are circumstances, where small tensile rebar strains into the yield range occur, yet are acceptable, and do not degrade the required local strength, may be unrecognized because of the focus on elastic behavior inherent in the computation process. Margins of strength, as reflected in codes, are implicitly based on the ductile behavior of structural systems as just noted.

6.2.1 Structural Primary Loadings

The DGB must resist the following principal primary loadings:

- Gravity- induced dead and live loads
- Earthquake- induced loads
- Tornado- induced differential air pressure
- Tornado- borne missiles

Gravity- induced loads produce out-of-plane shear forces and bending moments in the floor and roof systems and in portions of the walls immediately adjacent thereto. These loads also produce in-plane forces in the walls and, of course, bending moments and shear forces in the strip footings.

Earthquake- induced loads produce in-plane forces in the walls which are substantial, and more modest in-plane forces in floor and roof slabs. They also produce out-of-plane shear forces in floor and roof slabs and walls.

Tornadic winds produce in-plane and out-of-plane forces in walls and roofs. Tornado- induced differential air pressures are the principal source of out-of-plane shear forces and bending moments in floor systems and walls, and they also produce in-plane forces.

Tornado- borne missiles produce highly localized out-of-plane loading of the walls. The capacity of the wall to resist such missiles is evaluated independently of all other loadings.

6.2.2 Secondary Loadings

Restrained non-load-induced volume changes (e,g., due to concrete shrinkage and or temperature strains) may produce internal forces. It has long been recognized that these forces rarely have any significant effect on the local strengths, and in most cases they are neglected. The reasons relate directly to the ductility of the tension rebars. If the local strength is mobilized, by an imposed set of local demand forces, it typically will be the same whether or not the forces associated with the non-load induced effects are included. The difference will be that the tensile rebar strain,including some yield strain, will be larger when these secondary forces are included. This yielding has the effect of decreasing, and sometimes completely eliminating, the local forces which were initialy introduced by the non-load effect. It is for this reason that the forces associated with such non-load induced effects often are termed "self-relieving" or secondary.

In the design of most reinforced concrete buildings the local internal forces arising from restrained shrinkage and thermal strains as well as that induced by settlement are not included in the application of the strength criteria. In the design of nuclear safety related concrete structures it is the accepted practice to account for through-the-wall thermal gradients, although shrinkage effects are not typically included. Even accounting for the thermal gradients is a conservative requirement the justification for which is at least debatable. However they were accounted for in the DGB design as required by the acceptance criteria. It may be noted that underlying codes, from which the acceptance criteria were developed, typically called for inclusion of these non-load-induced forces with the load-induced forces only where their structural effects may be significant. In the case of the DGB it may reasonably be debated whether such effects are indeed "significant", as envisioned by the code.

In the initial design of the DGB it would not reasonbly have been assumed that the forces associated with foundation settlement could be significant nor, that they should be included with the load-induced forces in the factored load combinations. Clearly, the building was designed for continuous support on what was intended to be a relatively homogeneous soil medium. Thus the designer could justifiably assume that there would be little if any redistribution of the upward soil reactions on the strip footings due to major point-to-point variations in local stiffness of the supporting medium. When the building was only partly completed it became evident that such stiffness variations did, in fact, exist i.e., a very stiff support at the location of footing contact with ducts, together with poorly consolidated soil (low in stiffness, and non-uniform) elsewhere. These conditions caused an extreme example of non-uniform settlement which did indeed induce internal forces sufficient to cause cracks in the walls of the then partially completed structure.

Upon noting that the settlement had led to interference between the foundation and buried ducts, the unintended footing-to-duct connections were physically disengaged and the unsatisfactory foundation condition was corrected by a surcharge loading procedure. It is to be noted (reference 36) that the surcharge loading procedure began on January 26, 1979, incrementally, and that construction of the DGB continued thereafter. The final surcharge placement took place between March 22, 1979 and April 7, 1979, just as the roof and parapet construction was completed. The subsequently completed DGB structure has been in place, in its completed condition for more than four years with no indications of additional distress in any way comparable to that associated with the footing-to-duct contact and the poorly consolidated soil. It may be argued that the structure now is supported as was intended at the time of design, that the effects of any future differential settlement will not be significant, and that the effects of such cracking as developed in the partially completed structure also are not significant to local internal strengths relied upon to resist the forces associated with applied load combinations. From all this it would naturally follow that the internal forces induced by differential settlements need not necessarily be included with the load-induced forces in the combinations specified by the acceptance criteria. These arguments may be justified but, in fact, there is a licensing commitment to include the settlement-induced forces in the relevant load combinations.

Since the internal forces induced by a specific non-uniform settlement are self-relieving (as was described earlier, for thermally induced forces), why must they be included; i.e., when may their effects be "significant". In some structures the magnitude of possible future settlement may be uncertain, and there may be little or no prospect for monitoring of the settlement or the state of the structure during its service life. Accordingly, inclusion of settlement-induced forces in the design would be appropriate to limit the possible development of structural distress which would be costly to repair, or which in some special cases, like a containment structure, may affect functionability by creation of large liner strains. For other structures these forces might prudently be included to avoid excessive yield strains in the tension rebars (and the associated large crack widths) which might degrade the local internal strength under some set of the local internal forces associated with applied loads, particularly if no monitoring of the structure for such effects could be anticipated.

For the DGB structure the principal structural elements are relatively accessible, and a monitoring program is planned. Nevertheless it is required to demonstrate by application of the relevant acceptance criteria, including the effects of differential settlement, that the local internal strengths are not presently degraded and are unlikely to be degraded by any probable future differential settlements. The acceptance criteria do not include any specification of the method by which the associated internal forces are to be determined. This is an important consideration in any effort to apply the acceptance criteria. There are essentialy three alternatives:

a) One may assume a magnitude and distribution of differential settlement and impose this displacement pattern upon the structure. In contrast to the situation at the design stage the analyst for the DGB has settlement measurements to consider in arriving at the postulated differential settlements to be used.

b) One may postulate one or more perturbations of the distribution of upward soil reactions associated with dead load which may be associated with differential settlement, and determine the local internal forces for each. It will be apparent that this approach produces the forces due to dead loads plus differential settlement. This is not an unreasonable approach, if sufficient attention is given to parametric variations, particularly if the analyst lacks data on differential settlement which he considers sufficiently precise to use directly in method (a).

c) One may postulate the local internal forces directly from the observed condition of an (existing) structure; i.e., the crack widths in the DGB. This is an option clearly not available at the time of design.

The method of imposed differential settlements may lead to unrealistically large internal forces unless the analysis can account for cracking, and time-dependent concrete properties. The cost-benefit of such an analysis may not be justified, particularly if other suitable options (b or c) exist.

The method of analyzing the dead load condition for several postulated distributions of soil reaction is suitable, but it may be difficult to choose sets of distributions which cover the possible differential settlements but which are not unjustifiably extreme.

For the DGB, which has been observed in its completed state for more than four years, inference of the internal local forces from the condition of the existing structure (c) seems to be the most attractive approach. It is the most direct. It is particularly attractive since any significant changes in the condition of the structure will be observable during its service life. Observations related to this approach follow.

6.3 EVALUATION OF BUILDING PERFORMANCE CAPABILITY

The performance capability of the structure is to be assessed in two steps: the first one considering the building in its present state and the other addressing its structural integrity and serviceability over the next 40 years. Inputs to the evaluation are keyed to a number of elements such as: available physical data, analytical studies, understanding of concrete behavior and engineering judgement.

6.3.1 Available Data

The most important data available to estimate the present state of stress in the DGB consists of:

1. Observations of the building as it exists today.
2. The record of the crack monitoring program.
3. The settlement history of the building.

The cracks have been surveyed on several occasions (Reference 3). The maximum crack width recorded during the monitoring program prior to isolation of the duct banks was 28 mils. After the isolation of the duct banks, the cracks decreased in size (testimony Peck and Weidner references 11 and 4 respectively) implying a stress decrease in the higher stressed areas. Presently the largest cracks are of the order of 20 mils. An evaluation of the existing cracks has been performed by two Bechtel consultants, Dr. Mete Sozen (reference 10) of the University of Illinois and Dr. W. Gene Corley (reference 12) of the Portland Cement Association.

The building settlements have been monitored at close intervals during the construction period and thereafter. Figure 6-2 presents the location of the settlement markers indicating where survey measurements are taken. The data spans over a period of 5 years with measurements taken approximately every other week. This large amount of data allows one to follow the settlement history through the stages of construction, duct bank isolation, surcharge period, dewatering, and up through the present. It also provides a means of assessing potential random and systematic errors in the measurements. The Midland project has concluded that significant errors exist in the measurements due to a variety of circumstances. A study of these data is presented in the following section.

6.3.2 Midland Project Evaluations

The Midland project followed two separate approaches to estimate the state of stress in the building:

- study of the cracking history
- study of the settlement history.

The future state of stress due to settlement was estimated based upon predicted settlements.

6.3.2.1 Evaluation of DGB Based on Observed Cracking

In its present condition the DGB has cracks which appear to be settlement-induced or settlement-intensified, generally arising during the early construction phases. Maximum present crack widths are reported to be about 20 mils, and Dr. Sozen (reference 10) has shown that the associated rebar stress as estimated in a region of numerous cracks, adjacent to a duct bank penetration of the center wall, may be judged to be between 20 and 30 ksi. We find his evaluation to be reasonable incorporating techniques that are state of the art, widely accepted and supported by laboratory tests. Dr. Sozen also has argued that the presence of initial cracks does not degrade the capacity of a reinforced concrete element in any of the important structural modes; i.e., direct tension force, direct compression force, in-plane shear force, and out-of-plane bending. Again, we agree with Dr. Sozen that precracks of the width thus far evidenced in the walls of the Midland DGB would not significantly degrade capacities in the several modes developed by the principal loadings, and in their required factored combinations.

Dr. Sozen did not specifically address the possible influence of an initial rebar stress which is associated with a self-relieving internal force, that is, a force caused by foundation settlement. He does not indicate his opinion whether or not the self-relieving internal force implied by the initial rebar stress should be included with the internal forces due to applied loadings or can be neglected because it is self-relieving. It is our understanding that the Bechtel evaluations of the DGB for the effects of dead load plus foundation settlement did not utilize the initial rebar stress magnitude estimated by Dr. Sozen but rather computed it based on the settlement history of the building.

6.3.2.2 Evaluation of DGB Based on Settlement History

The settlement effects were modeled by Bechtel into the structure considering four distinct time periods. Measured or estimated settlement values corresponding to each of the time periods were used:

- Case IA: 3/28/78 to 8/15/78 (Structure partially completed to elevation 656.5') - A long hand calculation was used to determine the stresses due to early settlements. The structure was assumed fully cracked and the stresses in the reinforcing steel were assessed based upon local strains corresponding to an imposed differential settlement (reference 16).

- Case IB: 8/15/78 to 1/5/79 (Structure partially completed to elevation 662.'0.) - The duct banks were seperated from the structure which caused the north wall to settle rapidly. (reference 17)

- Case 2A: 1/5/79 to 8/3/79 (Structure in process of completion.)- Surcharge period. (reference 18)

- Case 2B: Forty year settlement composed of:

  - measured settlements from 8/3/79 to 12/31/81, and

  - predicted secondary consolidation settlement from 12/31/81 to 12/31/2025. (reference 19)

The last three analyses used a finite element model having stiffness corresponding to an uncracked condition. In these analyses the foundation stiffnesses have been varied, in an iterative process, to achieve final settlements approximating a set of target settlements. These target settlements were based upon a linear best fit through the measured settlement data. The analyses have been criticized (reference 2) because the analytically predicted settlements do not match variations in the measured settlements. It is appropriate to ask whether the iterated non-linear foundation stiffnesses are realistic since the target settlements were not the measured settlements but a linear best fit, essentially assuming rigid motion of the North and South walls. The best fit data were utilized in an attempt to deal with scatter in the measured data. Such scatter potentially due to either random or systematic errors was estimated to be of the order of plus or minus 0.125 inches.

In our opinion the described method of accounting for foundation stiffnesses utilizing the linear best fit data may not be satisfactory for correlation with observed cracking in relation to differential settlement. We concur that settlement measurements may not be of sufficient accuracy to permit a precision computation of settlement-induced internal forces. Furthermore, the marker locations are spaced at wider intervals than would be desirable as input to analyses of building strains. Nevertheless, the general level of stress implied by the magnitude of cracking is not in contradiction to that which may be derived from the measured settlement data, realistically accounting for flexibility including consideration of phenomena such as creep (see section

6.3.3 for a more detailed discussion). As discussed in Section 6.2.2, an exact determination of secondary stress levels is of lesser importance given the nature of the loading and the fact that capacity is not adversely affected.

In separate sensitivity studies Bechtel engineers considered among others, the two following cases:

- The zero spring condition analysis (reference 3) which investigated the structure's ability to span any soft soil condition. A zero soil spring value was used at the junction of the south wall and east center wall. Soil values were increased linearly back to their original value within a distance of approximately 15 feet from the zero spring. The stresses in the building underwent moderate increase in the area of the bridging. In our judgement this is a reasonable approach, but one may ask whether the size and locations of such postulated "soft" zones were bounding.

- The imposed 40 year settlement analysis (reference 21) which forced the building to match the predicted settlement values at 10 points along the foundation. This analysis led to very large reaction forces at the points of imposed settlements, and some of these acted downward on the structure, i.e., implying tensions in the soil, which is not possible. Moreover, the analysis indicated very large rebar tensile stresses, where at several points a multiple of the yield strength was indicated. Of course the structure does not display the very wide cracks which would accompany such high stresses. For these reasons Bechtel engineers concluded that the settlement measurements cannot be an accurate representation of the actual settlement nonuniformities.

We have noted that the settlement data may not be an adequate basis for computing settlement effects. However, we believe the described analysis exaggerates the effects of the displacement input data which was questioned by the project. Our reasons are that the analysis assumed uncracked concrete and used the short-term concrete modulus of elasticity. Appropriate reduction of the concrete modulus, to reflect creep under sustained loading, would have lead to reactions and internal forces perhaps 50 percent less than were obtained. Decreases in stiffness associated with concrete cracking could result in additional large reductions. An excellent discussion of the physical and engineering significance of creep is found in chapter 6 of reference 37.

Perhaps more important, rebar stresses appear to have been computed on the assumption that the local internal tensile forces developed in the uncracked concrete are unreduced by cracking, i.e., this unreduced force is imposed on the rebars. In our judgment this is not the best physical representation. The rebar stresses are expected to be more nearly indicated by the local strains in the concrete (uncracked) than by the forces in the concrete (uncracked). Thus, the rebar stresses are better approximated by the product of steel modulus and concrete strain (uncracked); i.e., by the product of modular ratio, n, (Youngs modulus of the steel/Youngs modulus of the concrete) and concrete stress.

$$f_s \cong n\, f_c$$

in contrast we believe that the following expression was used

$$f_s \cong \frac{1}{p} f_c$$

where p is the reinforcement ratio (rebar area/section area). This later expression greatly overestimates rebar stress. To illustrate, for p = 0.0043 and n = 8, the suggested approach gives rebar stress about 1/30 of the Bechtel computed value. While reality is likely in between, and the former expression is approximate, we believe that it is a closer representation of the existing situation.

6.3.3 IDCVP EVALUATIONS

In addition to reviewing the information generated by the project and the studies performed by others, the IDCVP concentrated attention on two major elements in the review process:

- Observations of the building and its present state of cracking, and

- The settlement history of the building.
  - Settlement data
  - Gross stress estimation

6.3.3.1 Building Inspection

A careful inspection of the building was performed together with a review of the crack mapping data. As it exists at present, many cracks of small size are evident in the building but there is no evidence to support that these cracks are indicative of a high state of stress in the building and degraded capacity. Past experience and laboratory tests indicate that concrete elements in a state of distress -particularly stiff shear walls of the type in the DGB - exhibit large deformations and cracks, much greater than present in the DGB. This would probably be accompanied by scabbing and other phenomena which are not apparent in the DGB.

Our conclusion from visual inspection of the building is that its state of stress is low and would not impair its performance and functionability. A body of relevant information developed in industry, university and government programs and structural experience supports this conclusion.

6.3.3.2 Settlement Data

A study of the settlement data recorded between 11/24/78 and 8/28/80 is presented in reference 5. We reproduced and expanded this analysis to include the most recent data (reference 38). The two time periods covered were from

5/12/78 to 9/14/79 (reference 33) and 9/14/79 to 8/23/83 (reference 34). Our goal was two fold: (1) assess the overall deformation of the building with time and (2) estimate the random error present in any one set of measurements. We studied the following data.

1. Cumulative settlement recorded overtime.

2. Incremental settlement between successive readings.

3. A measure of the curvature between any three consecutive markers along the foundation as it varies with time. The curvature d''_i at marker i is defined as:

   $$d''_i = 0.5\,(d_{i-1} + d_{i+1}) - d_i$$

   where d_i is the total settlement.

   The quantity d" equals zero when the three points are on a straight line; it remains constant in time if the three points move as a rigid body.

4. A measure of the deformation of the building with respect to its rigid body motion. The rigid body motion is "removed" by computing the vertical position of all markers with respect to the plane defined by three corner markers. This analysis was done both for each incremental reading and cumulatively.

An upper limit of the random error in any set of readings is given by the maximum difference of incremental settlement between any two markers from one reading time to the next. When the building has not experienced any settlement between two readings, this quantity is the random error; it bounds it otherwise. At the beginning of the record, this quantity is large where the building was undergoing large differential settlements and reading accuracy might have been reduced by marker transfer necessitated by the placement of surcharge. However, this quantity decreases rapidly and after June 1979 is never greater than 0.150". After the removal of the surcharge for the readings starting 9/19/79 which we will refer to as the recent readings, the random error is smaller than 0.125", 95 percent of the time which would give a random error of about ± 1/16 of an inch. This implies that a higher level of confidence can be given to the recent measurements.

Jumps in readings from one period to the next are sometimes large implying that the building would rapidly move up or down by a uniform amount. These jumps are attributed to systematic errors in locating the reference elevation.

Figure 6-3 shows the incremental settlement for 6 time periods between July 1978 and August 1979 for the south wall of the DGB. The first three measurements show large differential deformations and introduction of curvature in the wall. The latter ones show stabilization of differential settlements implying that the wall is still settling but as a rigid unit, introducing little additional in-plane bending. For more recent recordings the stabilizing trend is even more noticeable. Study of the foundation curvature variation and deformation of the building with respect to its rigid body motion point toward the same trend. This is supported by an evaluation discussed in reference 4, where it was noted that the settlements occurring during the time periods represented by lines c and d (reference 4, figure DGB-7), were those that are expected of a rigid body. In figure DGB-7, line c represents settlement during the surcharging period (1/79 - 8/79) and line d represents estimated settlement during the post-surcharge period (9/79 - 12/2025). The point here is that the early cracking occurred when the building was only partially completed. Upon completion, the five sided (four walls and a roof) structure is now responding as a stiffer, essentially rigid body as would be expected.

Hence during its construction stage, the building underwent substantial differential settlement that introduced in-plane curvature in the walls with resulting stress and cracking compounded with normal shrinkage cracking. As the building was completed and the concrete aged, its tended to behave more and more as a rigid unit, the whole foundation (or building) moving as a plane (or a unit). The recent data indicates that for the last four years the building has generally settled as a rigid body introducing relatively little additional distortion in the structure. We expect this behavior to persist in time.

One may speculate on the magnitude of the absolute settlements over the service life; however, these are of lesser structural concern to the building itself, and would only affect clearance to obstructions and connected items.

These latter elements can accommodate some degree of distortion and can be modified in the future if warranted.

6.3.3.3 Gross Stress Estimation

Even though we have noted that settlement data may not provide an acceptable basis for computing settlement effects, it is our opinion that if credit had been taken to account for:

- creep and stress relaxation in young concrete,
- reduced stiffness associated with the geometry of the uncompleted structure
- stiffness reduction due to cracking

the exact recorded settlement could have been imposed on the structure without generating stresses in gross contradiction to that observed via crack patterns in the DGB. This would have qualitative value to an overall understanding of building behavior.

In order to improve our understanding of building behavior and to generally qualify the influence of these effects, we modeled the north and south walls of the building using a simplified finite element model (reference 38). As a first order check of our partial model, we reproduced the 40 year imposed settlement analysis performed by Bechtel on the uncracked structure. We obtained stresses within 25 percent of Bechtel's which is reasonable considering the simplified model we used.

We imposed the recorded settlements on the incomplete wall for Case IA and IB and on the complete wall for Case 2B. For cracked concrete, the stresses were computed as described in Section 6.3.2.2.

The following approximate maximum values of stress were obtained:

LOADING	STEEL (ksi)
CASE 1A	11.3
CASE 1B	3.5
CASE 2A	4.6

This leads to a total stress of 19.4 ksi which is in good agreement with Dr. Sozen's independent analysis (see section 6.3.2.1 and reference 10).

We recognize that the above analysis represents a simplified approximation of the very complicated effects of creep and cracking but it provides a qualitative estimate of the state of stress of the building.

We believe the results of our analyses, properly interpreted are both useful and positive, specifically.

- When modified for the effect of concrete creep and concrete cracking the foundation reactions when combined with reactions due to dead load, would not imply a physically impossible state of tension stress in the soil.
- When the rebar tension stresses are properly determined, that is on the basis of strain in the uncracked concrete rather than on the basis of stress in the uncracked concrete, they are quite modest rather than unrealistically large.

6.3.4 IDCVP Assessment/Interpretation of Results

In our opinion the settlement-induced internal forces implied by the associated rebar stresses, as they presently exist in the Midland DGB will not degrade the capacities to resist the internal forces and moments caused by the factored load combinations and therefore the DGB is expected to meet its intended performance requirements. There is reason to believe as supported by recent observations, that the completed building is settling as a rigid unit based upon the stabilized foundation properties. In this mode, the DGB capacity is not expected to be compromised over time. We believe that the settlement-induced, self-relieving, internal forces implied by the present crack widths and associated rebar stresses could safely be ignored in evaluating the building. However, licensing criteria include certain load combinations in which it is specifically required to include the settlement-induced internal forces. Based upon our knowledge of available margins associated with controlling load combinations, we believe that compliance with these criteria can generally be demonstrated, appropriately accounting for creep, relaxation and other phenomena; however, we do not endorse such an endeavor because of the secondary nature of the settlement induced loads and the fact that capacity is unaffected.

6.4 SERVICEABILITY, FUTURE CAPABILITY, AND MONITORING

The previous sections address the significance of settlement induced cracking on the performance capability of the DGB in its current condition. It is important that the DGB continue to meet specified performance requirements over its service life; hence, this section addresses serviceability of the DGB and any actions that may be necessary to identify and mitigate potential future conditions which could compromise the DGB performance.

6.4.1 Midland Project Evaluations and Commitments

The effects of cracks on the serviceability of Midland plant structures were addressed in reference 12. Three principal issues were evaluated:

- Freezing and thawing resistance,
- Chemical attack, and
- Corrosion of reinforcement

It was concluded in reference 12 that observed cracks are not expected to have a significant influence on the durability of the DGB. Accordingly, remedial measures such as epoxy injection were considered unnecessary to ensure long term performance capability. Nevertheless, CPC committed (reference 35) to repair existing cracks which are 20 mils and larger (up to a point in length where the crack remains 10 mils or larger) by epoxy injection and application of a concrete sealant to accessible surfaces.

A Technical Specification (TS) 16.3/4.13 (reference 13) has been proposed to monitor settlement over the service life of the DGB. The specification requires that the total settlement be measured (to nearest 0.01 foot) at least once every 90 days for the first year of operation. The frequency for subsequent years has been left for future determination. The total allowable settlement corresponding to predictions for the service life (12/31/81 thru 12/31/2025) has been specified at 12 markers. Engineering evaluations are required if total settlement reaches 80% of the allowable values (Alert Limit). Additionally, the inspection frequency is to be increased to once every 60 days if the 80% level has been reached.

If the DGB exceeds total allowable settlements, the plant must initiate actions to be in cold shutdown within 30 hours (Action Limit).

CPC has also committed to conduct a crack width monitoring program (reference 14) which includes individual crack width and cumulative crack width measurements at 3 locations over a 10 foot gage length. This program will be conducted once every year for the first five years of operation and at five year intervals thereafter. The following criteria apply:

	Alert Limit	Action Limit
single crack	50 mils	60 mils
cumulative cracks (over 10' gage length)	150 mils	200 mills

Identical actions as defined in T.S. 16.3/4.13 are required if these limits are reached.

6.4.2 IDCVP Assessment

We concur with the conclusions drawn in reference 12 relative to the influence of existing cracks on the performance capability of the DGB and its continued serviceability. While significant future cracking is unanticipated, it would only be in these circumstances that we would recommend remedial actions such as epoxy or sealant application to insure continued durability. Furthermore, should such procedures continue to be contemplated for purposes of potential increased protection, we urge that applications of any compounds not be made in such a manner as to mask surfaces so that cracks are not visually accessible. Notwithstanding the potential future inconvenience of removing compounds from selected surfaces, there is a potential that these compounds may influence behavior and modify surface expression of cracks, making future engineering evaluations more difficult.

We recommend that consideration be given to modifying T.S. 16.3/4.13. The following points summarize our evaluation and our recommendations.

- Visual inspection - The building should be examined visually twice a year in concert with an evaluation of settlement data to identify any unusual deviations in crack patterns and gross changes in dimensions. This may represent an additional commitment.

- Total allowable settlement - These limits should be based upon structural/mechanical performance requirements considering items such as the physical clearances to obstructions (e.g. duct banks) and permissible deflections for attached items (e.g. incoming fuel lines). Notwithstanding these considerations, absolute settlements and corresponding rigid body motion of the building is of minor concern to building performance capability other than as it might affect clearances to obstructions and connected items. The existing limits may trigger potentially unnecessary evaluations. A 90-day survey interval appears reasonable for the first year of operation. This approach may represent a redefinition of certain total allowable settlement limits.

- Differential settlement

  - Diesel Generator Building

    Forces induced by differential motion within the DGB are of interest, but generally only at a time at which crack width levels approach an order of magnitude greater than has been observed. Capacity is not expected to be degraded for settlement induced cracks with sizes up to this general level. Even at this point, the residual state of secondary stress in the DGB may be low due to factors discussed in Section 6.3; however, one must evaluate shear transfer mechanics across crack boundaries of dimensions of the same order as the fracture surface roughness. It is recommended for consideration that limits for differential motion between points within the DGB (discounting all rigid body components of motion) be specified such that these motions are correlated with potential future crack widths up to an order of magnitude greater than has been observed to date; thus providing functionally defined limits for differential movements. Remedial effort to protect external surfaces may be considered at approximately half these values. The program may include development of an initial set of data which would provide a baseline for potential future reference. Additional survey data would be collected in the future if indicated by the visual inspection program and absolute settlement measurement surveys. If adopted this approach may represent a redefiniton of allowable settlement limits and a restructuring of the proposed tech specs.

  - Diesel Generator Pedestals

    Although, relatively of lesser concern, at such a time as the diesel generators are run for an extended period, potential differential movement of the isolated diesel generator pedestals is of interest as such movement may affect connected lines. Accordingly, we endorse continued monitoring of pedestal settlement and comparison to functionally defined differential movements.

We conclude that the committed crack monitoring program will produce results which are of engineering interest but not necessarily of safety significance. Accordingly, we do not see a need to specify alert and action limits based upon this program. We base this conclusion primarily on the limited number of locations to be monitored and the fact that appropriate locations are difficult to determine a priori, not knowing how the building will behave in the future. One could specify locations based upon predictions of future response, but if the building responds as predicted, this will be of less interest then if it does not, in which case alternate locations would be more desireable. This is related to our recommendation not to mask surfaces through application of new compounds.

In summary, we conclude that the performance characteristics of the DGB are not likely to be compromised over its service life. Various commitments have been made by CPC to verify continued serviceability. While we conclude that several of these commitments may not be totally necessary, we do not view that safety will be compromised by the specified actions. Certain improvements may be made which may produce valuable information and reduce operational constraints.

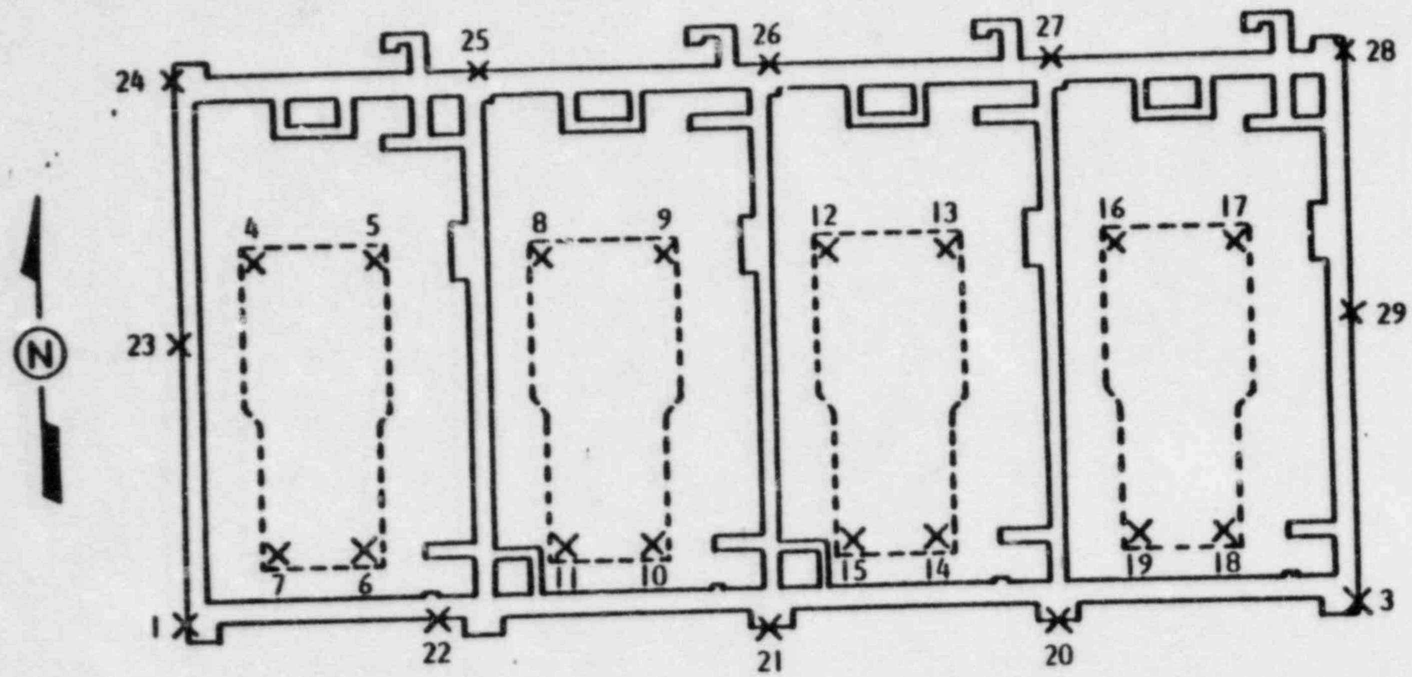

FIGURE 6-2

DIESEL GENERATOR BUILDING
SETTLEMENT MARKER LOCATIONS

TERA CORPORATION

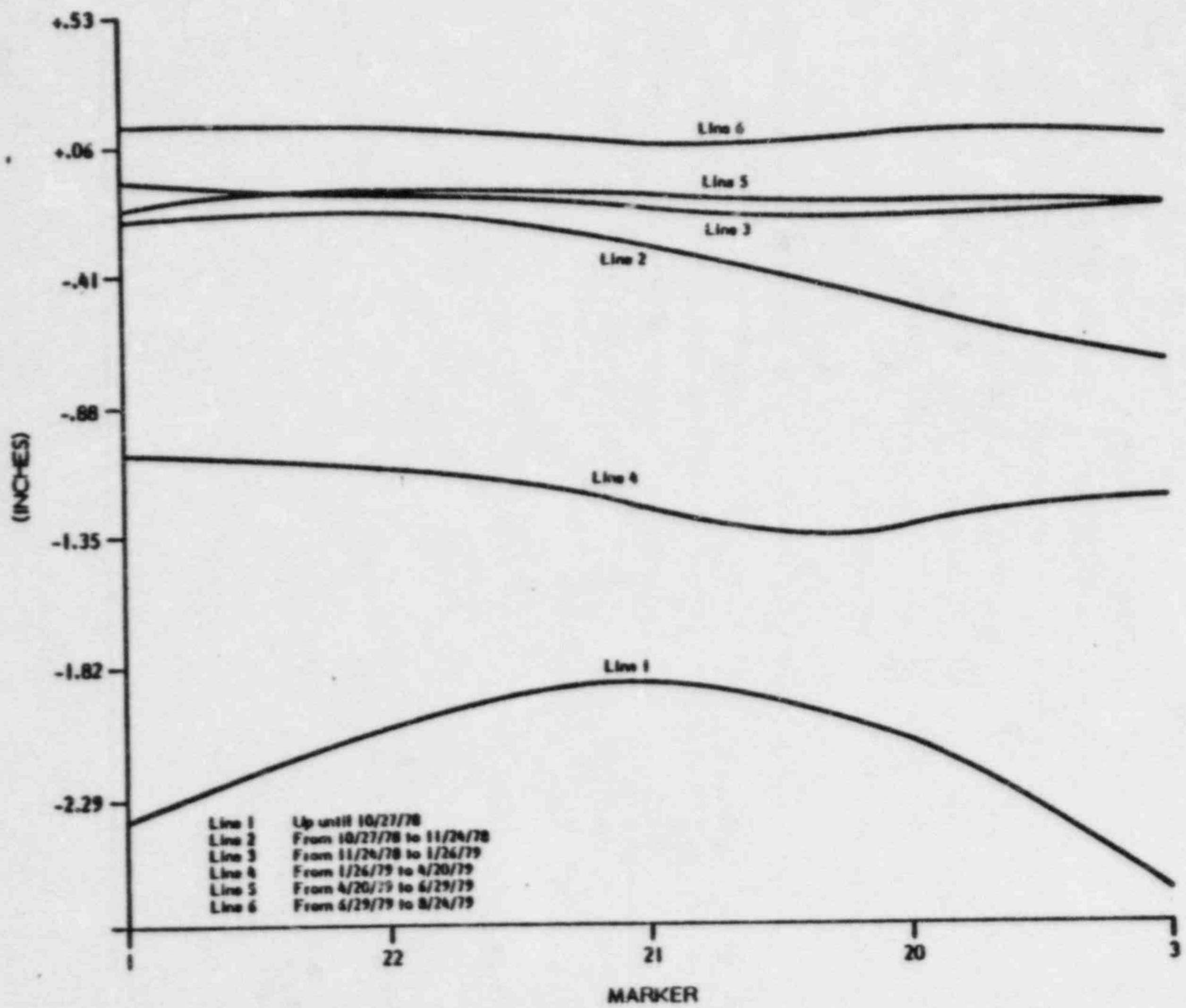

FIGURE 6-3

DIESEL GENERATOR BUILDING
SOUTH WALL
SETTLEMENT INCREMENT

TERA CORPORATION

7.0 CONCLUSIONS

As the diesel generator building exists today it is quite capable of performing its intended design functions. Many cracks of small size are evident in the existing building but there is no evidence to suggest that these cracks — in spite of the various possible mechanisms of origin - generally of small size, would be indicative of a condition that would suggest the DGB is incapable of performing its function. It is our belief that in its present condition this building is fully functional in all respects. Although we believe it is improbable, if excessive localized differential settlement is observed, remedial corrective measures could be undertaken to improve serviceability.

The committed monitoring program clearly will reveal any potential distress. It is suggested that a comprehensive visual inspection of DGB be carried out biannually (twice a year) in concert with the settlement measurement program. In Section 6.4 we have offered certain recommendations for consideration that are intended to improve information collected and reduce operational constraints.

RFW

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

PRINCIPAL STAFF	
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SGA	ML
ENF	File

OCT 21 1983

MEMORANDUM FOR: James P. Knight, Assistant Director for Components and Structures Engineering Division of Engineering

FROM: Pao-Tsin Kuo, Section Leader
Structural Engineering Section B
Structural and Geotechnical Engineering Branch
Division of Engineering, ONRR

SUBJECT: REPORT ON THE REVIEW OF THE DIESEL GENERATOR BUILDING AT MIDLAND

References:

1. Memo from R. F. Wanick, Region III to D. G. Eisenhut NRR/DE, "Evaluation of Dr. Landsman's Concerns Regarding the Diesel Generator Building at Midland," dated July 21, 1983.

2. Memo from R. H. Vollmer, DE to D. G. Eisenhut, DL "Evaluation of Dr. Landsman's Concerns Regarding Diesel Generator Building at Midland," dated July 21, 1983.

Pursuant to Reference 2 above, a task group, consisting of three members of the Structural Engineering staff and a consultant team of Brookhaven National Laboratory, was formed to re-evaluate the structural design and construction adequacy of the Midland Diesel Generator Building (DGB). The group, headed by P. T. Kuo, reviewed the design review documents and the construction reports; physically inspected the building; interviewed concerned individuals, including Dr. Landsman; and prepared a final report on the adequacy of the Midland NPP Diesel Generator Building. The final report on the adequacy of the Midland DGB is enclosed.

The task group's conclusions and recommendations are summarized as follows:

1. The settlement data indicate that the fill under the DGB is well into the secondary consolidation phase so that large additional settlements are not anticipated;

2. It is judged that there is reasonable assurance that the structural integrity of the DGB will be maintained and its functional requirement fulfilled. However, it is difficult to show that the stresses in the DGB can meet the criteria of the FSAR. The stresses due to settlement were either underestimated or overestimated by the Applicant's previous analyses;

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3. The most reasonable estimate of stresses due to settlement is based on the crack width data. However, the calculations that have been done in this area need to be completely documented;

4. There is evidence that the number of cracks in the DGB is continuing to grow. It is essential that a more accurate and reliable crack monitoring program be established; and

5. The monitoring program should specify an upset crack width level that would reflect a sufficient stress margin available to resist critical load combinations. The monitoring program should mandate structural repairs if the Alert Limit (in crack width) were exceeded.

Pao-Tsin Kuo, Section Leader
Structural Engineering Section B
Structural and Geotechnical
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Enclosure:
As stated

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REPORT ON THE REVIEW OF THE

DIESEL GENERATOR BUILDING AT MIDLAND

OCTOBER, 1983

BY

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Mr. Norman D. Romney
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Structural Engineering Section B
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TABLE OF CONTENTS

1. INTRODUCTION

The Diesel Generator Building (DGB) at the Midland Nuclear Power Plant (NPP) is a reinforced concrete structure which has undergone excessive unequal settlement since its construction. The concrete walls of the DGB have been more extensively cracked than usually expected of such a concrete structure. On the basis of review and evaluation of the Applicant's (Consumer Power Co.) various analytical studies, remedial measures taken, and the commitments made and of the staff's own assessments, the original structural engineering staff reviewer came to the conclusion that the DGB was acceptable. However, an NRC regional inspector disagrees with the conclusion as to the acceptability of the DGB and has expressed his concerns in a hearing before a Congressional Government Oversight Committee.

In the wake of this controversy, the Division of Engineering (DE) formed an independent Task Group to re-review the structural adequacy of the DGB. The Task Group consists of three members from the structural engineering staff and a consultant team from Brookhaven National Laboratory. The consultant team provides expertise in both structural and geotechnical engineering. The charter of the group and its composition, the names of the Staff, and its consultants involved are included in Appendix I to this report. The Charter of this Task Group has three elements that are interwoven and do not lend themselves to neat separation. The Task Group was charged:

(1) to re-evaluate the structural design and construction adequacy of the DGB as accepted by the structural engineering staff reviewer

(2) to assess the concerns as indicated by comments from other NRC personnel, and

(3) to make recommendations to resolve any lingering concerns.

It is acknowledged that the Task Group has had outstanding cooperation from the Applicant, the structural engineering staff reviewer and its consultants, the geotechnical engineering staff reviewer and its consultant, and NRC Region III Inspector, in either group's on-site inspection, interviews, or design audit in Applicant's A/E office. It is this cooperation that enables the Task Group to assemble all the necessary information and facts in a short period of time. The chronology of the group's various activities and persons contacted are presented in Appendix II to this report.

An independent report written by Brookhaven National Laboratory is included in Appendix III of this report.

2. DESCRIPTION OF THE DGB AND ITS PROBLEMS

The DGB is a two-story, box-type reinforced-concrete (RC) structure with three cross walls that divide the structure into four cells, each of which contains a diesel generator unit. The building is supported on continuous RC footings 10' - 0" wide and 2' - 6" thick founded at plant elevation 628' and resting on a fill that extends down to approximately elevation 603'. The building has exterior wall thickness of 30", roof slab and interior wall thickness of 18". Plan dimensions of DGB are 155' x 70 with a total internal height of approximately 44'. Each diesel generator rests on a 6'-6" thick, RC pedestal that is not structurally connected to the building foundation. Figure 1 shows the general layout of the DGB.

The DGB as implied by its name is a building which houses the diesel generators and is classified as a seismic Category I structure. As such it is designed against the effects of extreme environmental conditions such as seismic load and tornado wind load. The latter includes a wind pressure, a differential pressure and tornado missile impact. The use of thick exterior walls and roof slab is basically a result of the consideration of the effects of the tornado missile impact load.

When the building was approximately 60% complete, unusual settlement and cracking of concrete walls were observed. The building was settling due to the consolidation of the underlying fill while it was partially supported along the north portion by four electrical duct banks acting as vertical piers resting on natural soil below the fill. A soil boring program to determine the quality of the backfill under the foundation discovered that the fill was uncontrolled and improperly compacted. The fill consisted of both cohesive soil, granular soil and lean concrete. The fill ranged from very soft to very stiff for cohesive soil and from very loose to dense for granular soil. At the time of the soil exploration, the groundwater level was observed to be ranging from elev. 616' to 622' and the cooling pond, located about 275 feet south of the building, had a water level at approximately elev. 622'.

In view of the condition of the DGB as described above, it was apparent that corrective measures must be taken to relieve the DGB from its distress. The remedial actions taken by the Applicant can be summarized as follows:

(A) Separate the DGB from the duct banks - The duct banks entering the DGB were isolated from the building, thus relieving the building from the effects of the rigid supports.

(B) Surcharge the DGB and the surrounding area - The purpose of the surcharge was to accelerate the settlement and consolidate the fill material so that future settlement under the operating loads would be within tolerable limits.

(C) Install a permanent dewatering system - The purpose of the permanent dewatering system is to maintain water level below elev. 610' in the area of DGB, thus minimizing the potential of liquefaction of the loose sands contained in the fill.

The effects of the remedial measures taken can be observed from the amount of settlement which the DGB has gone through as indicated in Figure 2 and also from the crack sizes and crack patterns of the walls as shown in Figure 3. Details of both settlement and cracking issues are discussed in the following sections.

3. SETTLEMENT AND CRACKING ISSUES

As a result of the remedial actions taken by the Applicant, it appears that the settlement of the DGB has mostly stabilized. However the fact still remains that the building has undergone unusual settlement and its walls have experienced extensive cracking. It has given rise to the concern of the DGB's structural capability to fulfill the function of protecting the safety-related equipment located therein as originally designed. In order to alleviate this concern and to assure that the structural integrity is preserved, the Applicant undertook a number of structural re-analyses using the FSAR criteria and the ACI 349 criteria and taking the settlement and cracking into consideration. On the basis of the results of the re-analyses, the Applicant concluded as follows:

(a) The settlements during early stages of construction and during the surcharge did not cause any unusual distress or significant loss of structural strength. As a result of surcharging, future settlement can be conservatively predicted and will not be excessive. The installation of the permanent dewatering system has eliminated any potential for liquefaction of the sand backfill below the DGB during a seismic event.

(b) Cracking of the walls during construction and surcharging has not impaired the ultimate strength of the structure.

(c) The building will be re-evaluated for its structural adequacy when the allowable limit for the cracking width is exceeded under the established monitoring program, thus insuring its safety function.

The structural engineering staff reviewer and its consultants with findings of their own independent assessments in essence concurred with the Applicant's conclusions. However, the geotechnical engineering staff reviewer and its consultant together with the Region III inspector disagreed.

A major point of contention was that the Applicant's analyses linearized the unequal settlements and thus the effect of unequal settlements has not properly been considered. The Region III inspector also contended that, because actual cracking of the concrete walls was not considered in the Applicant's analyses, the rebar stresses as calculated by the Applicant were not representative of the stress for the loading combinations considered.

In what follows the Task Group shall present its major observations of the analyses performed by the Applicant and by the consultants to the structural engineering staff, the issues raised, and its assessment of the Applicant's conclusion on the DGB structural integrity.

4. STRUCTURAL RE-ANALYSES

In the preceding section, it is indicated that the Applicant has made a number of structural re-analyses and used the results of the re-analyses to justify the DGB structural adequacy, and that there have been concerns expressed as to the appropriateness of the re-analyses. The essential elements of the applicant's re-analyses are succinctly summarized.

Settlement Analyses

Settlement of the DGB is time-dependent and load-dependent, but a complete and accurate settlement history does not exist. On the basis of the availability of the measured or estimated settlement values at various stages of construction, four cases of settlement analyses were performed by the Applicant as listed in Table 1, with the corresponding settlement values shown in Figure 2. With the exception of Case 1A which was analyzed by long hand computation and by idealizing the partially completed DGB as a series of individual beams, the other three cases were analyzed by computer through the discretion of the DGB into a number of finite elements as exemplified in Figure 4. Case 1A was accomplished by passing deflection curve through any three measured neighboring settlement points and selecting the one with the largest curvature for moment computation, and eventually, stress determination. This calculation indicated that the measured displacements would result in a maximum rebar stress of 11 ksi. For the other three settlement cases, individual finite-element models were used. For settlement Case 1B, the finite-element model represents the structure as built to el. 662 f 0 in.

For settlement Cases 2A and 2B, the finite-element model represents a fully completed structure. For Cases 1B, 2A, and 2B, springs were typically calculated at each nodal point along the foundation by dividing the structural load represented at the selected point by the measured or predicted settlement at that point. The finite-element analysis of each case then involved several iterations in which the soil springs were varied until the deflected shape of the DGB, as calculated by the model, approximated the "best fit" settlements. The resulting deflections of the DGB from these analyses as shown in Figures 5 and 6 are not in conformance with the measured values and are almost linearly related. The magnitude of stresses would depend on the final cycle of iteration selected and would bear no relationship to the actual stresses resulting from settlement. Other analyses performed by the Applicant consisted of (1) using zero and near zero soil springs to simulate the soft soil condition, and (2) considering the DGB to be simply supported. The purpose of these analyses was to study if the DGB has the capability of bridging voids and soft spots in the soil.

In an attempt to provide more insight into the problem the consultant to the structural engineering staff was requested to make an independent analysis by using the measured settlement values at 12 locations as input. It was found that the DGB should have cracked extensively and yielded to failure. However, the cracking condition as exhibited by the DGB does not bear out the conclusion of the analysis. It was, therefore, concluded by the staff's consultant that the DGB did not experience the settlement as measured and that the analysis did not reflect the actual settlement history of the DGB.

Cracking Analysis

Cracks in reinforced concrete (RC) members may be caused by the conditions of hardening or curing of the concrete (its shrinkage) or by excessive stresses in the materials (induced by too heavy loads, settlement of the footings and/or changes in temperature). Cracks due to excessive stresses appear most frequent in the tension zones and are seldom encountered in the compression zone of concrete members. Cracks in the RC walls of the DGB are caused by a combination of shrinkage, unequal settlement and temperature changes.

Drying shrinkage and thermal contraction cause shallow cracks at surface.As soon as the cracks are formed the tensile strain is relieved. In the case of cracks due to unequal settlement the tensile strain is to be resisted by the reinforcing steel. The purpose of the cracking analysis is to determine the rebar stresses from the measured crack width. First, the Applicant made an analysis of a single through crack in a subsection of the east wall of the DGB by using the Automatic Dynamic Incremental Non-linear Analysis (ADINA) computer program. The purpose of this analysis was to evaluate the ultimate capacity of a concrete section containing a single crack. As such, the results of the analysis are of only limited value in assessing the effects of the cracks. As a further attempt to resolve the concerns on cracking, the Applicant sought the opinion of Professor M. A. Sozen of the University of Illinois. On the basis of the crack patterns and crack-size, Prof. Sozen estimated the stresses in the rebar across the cracks to be in the range of 20 to 30 ksi.

The structural engineering staff reviewer also made his own assessment by combining the rebar stresses estimated from crack widths with stresses resulting from the Applicant's analyses for other operating loads. It showed that the resultant stress was within the acceptance criteria (Tr. 11086).

In order to assure the structural integrity of the DGB, the Applicant has proposed a crack monitoring and evaluation program to be used during the life of the DGB, in addition to an initial repair program. Specific acceptance criteria (i.e. alert limits and action limits) for crack width and crack width increases have been specified by the structural engineering staff reviewer and agreed to by the Applicant.

5. VIEWS ON THE ISSUES RAISED

The four concerns as raised by Region III inspector, Dr. R. B. Landsman, are directly quoted from his memorandum to R. F. Warnick, Director, Chief of Special Cases of NRC Region III, dated July 19, 1983, as follows.

I. Concern:

"My first concern deals with the finite element analysis that Consumers Power Company (CPCo) used to show that the building is structurally sound. Their model of the building assumed a very rigid structure without any cracks. The building has numerous cracks, reducing the rigidity of the structure. The effects of these cracks have not been taken into account in the analysis. CPCo's interpretation of the settlement data as a straight line approximation always stems from their position that the building is too rigid to deform as indicated by actual settlement readings. The settlement of the building occurred over a period of time during different phases of construction. It is this time dependent effect that was also not used in their model. Even CPCo expert Dr. Corely testified at the ASLB hearings that the analysis should have "taken into account cracking and time dependent effects" in order to give correct results. Finally, the staff's official position, as stated by Dr. Schauer, on CPCo's analysis was, "The staff takes no position with regard to that analysis."

Comment:

The first part of this concern is that the cracks have not been considered in the Applicant's analyses. As indicated in previous discussion, cracks in the walls of the DGB are due to a combination of shrinkage, unequal settlement and temperature changes. Ordinary drying shrinkage and temperature change cracks are generally surface cracks. As soon as the cracks are formed, the tensile strain is relieved. Cracks due to differential settlement are generally through cracks across the wall thickness and, therefore,reduce the stiffness of the structural members. Structural engineers involved in reinforced concrete design are well aware of this fact. In order to take cracking of structural members into consideration, structural engineers first assume these members are uncracked and perform the structural analyses to obtain the moments, shears and axial forces required for the design of member sections. In designing the members concrete is then assumed to be cracked and does not take tension. Such a procedure of analysis and design is a standard practice and is, in fact, recommended by the ACI 318-77 code.

The second part of this concern is that the actually measured settlements have not been used in the Applicant's analyses. From the settlement data available it is obvious that settlement was continuing with the progress of construction with the maximum attained after the removal of the duct bank restraints and at the end of surcharging. In the early stages of construction the components such as the continuous strip footings, and wall portions forming the lower part of the DGB were most likely very flexible, and deflected in conformance with the settlement without creating any excessive stresses in the as-built portion of the DGB. There might be cracks in some of the components of this portion of the DGB due to shrinkage and/or displacement of the green concrete as a result of settlement. In order to adequately consider effects of settlement over the period of time during different phases of construction, the analytical models would have to be different for different phases of construction and to be meaningful there should be settlement measurements corresponding to each phase. However, there are no such detailed settlement measurements available, especially for the early stages of construction. The settlement measurements which are available correspond to those in the later stages of DGB construction, that is, when the as-built portions of the DGB are relatively rigid. The Applicant performed three separate finite element analyses for which measured and/or predicted settlement values are available. The measured and/or predicted settlement values are used as data points in linearizing the settlement. The differences between the measured/predicted settlement values and the resulting linearized values have been discounted as survey inaccuracies. This is basically equivalent to assuming that the north and south walls underwent rigid body motions. The computed stresses from this model are due to racking only. The stresses obtained in the process of linearizing the settlements, therefore, do not represent the actual settlement stresses.

The use of survey inaccuracies to discount the differences between the measured/predicted settlements and the linearized values is not convincing in view of the fact that all the settlements have not occurred after the completion of the DGB construction.

The third part of this concern is that the time dependent effect has not been considered in the Applicant's analyses. The Applicant has considered the four stages of construction, therefore the time factor has been taken into consideration but in a very gross manner. As indicated in the preceding comment in order to assess accurately the stresses in the walls of the DGB, detailed information on wall cracks (time-dependent) and on settlement values (also time-dependent) would be required for each step in the construction. There is no detailed information on either the cracks or the settlement values to cover the whole time span of construction. Basically this portion of the concern is inherent in the above two portions of the concern.

The fourth portion of the concern is that the structural engineering staff reviewer has taken no position with respect to the Applicant's analysis. From the preceding comments it is obvious that the adequacy of the Applicant's settlement analysis is questionable and it cannot be relied on to reach any conclusion. The structural engineering staff reviewer took a practical approach by ignoring the analysis, and resorted to the solution through crack analysis.

II. Concern:

"My second concern deals with the acceptance of the diesel generator building in the SSER #2 which was subject to the results of an analysis to be performed by the NRC consultants using the actual settlement values. The consultants testified at the ASLB hearing that this analysis gave unacceptable results and this portion of the SSER should be stricken. They are basing their unacceptable results and comments on their finding of very high stresses obtained in areas where no cracks exist. Therefore, the actual settlement values are not accurate enough (are in error) to be used in an analysis. The consultants, as well as CPCo, ran a linear analysis (structure always in the elastic range) instead of a plastic analysis which would allow a redistribution of loads in the structure. Therefore, supposed areas of high stress, where cracks are not located, may not exist due to redistribution of loads. Finally, the staff's official position, as stated by Mr. Rinaldi, on this analysis as performed by the consultants, was that the actual settlement values could not be relied upon to determine if the diesel generator building meets regulatory requirements."

Comment:

The first portion of concern is that the structural engineering staff reviewer disregarded the results of an analysis done by its consultants on the basis of the actual settlement values. This portion of the concern is in essence the same as the first concern. It is indicated in the comment on the first concern that the settlement was continuing with the progress of construction. When the strip footing concrete was placed, settlement started. Since the footing is a comparatively thin slab, it would likely deform with the settlement without creating excessive stresses. With the build-up of the walls, settlement increases and rigidity also increases. When the intermediate floor slab and the roof slab were completed, the complete structure became a very rigid structure and any settlement should be nearly linear unless there were weak sections across the building. To analyze the completed DGB on the basis of the settlement values which were accumulated during the construction and after its completion would result in exceedingly high stresses which are not representative of the actual values.

The second portion of this concern is that the staff has not used plastic analysis. It is suggested, that in order to conform to the measured settlement values a plastic analysis should be made to allow redistribution of loads in the structure. This observation is valid providing that rebar in the walls and slabs of the DGB have undergone yielding and plastic hinges have formed. It is the judgment of this Task

Group that, without the knowledge of accurate geometry of the DGB at the various phases of settlement, a non-linear model accounting for plastic effects would not be meaningful.

The third portion of this concern is the staff's official position that the results of the analysis by the staff's consultants on the basis of actual settlement measurements cannot be relied upon to determine if the DGB meets regulatory requirements. From the preceding comments, one cannot accurately calculate the stresses in the completed DGB without settlement data from the initial phase of construction. Given the unavailability of the data necessary to complete the input to the analysis by the staff's consultant, the previously stated staff position is reasonable.

III. Concern:

"My third concern deals with the fact that we are not following normal engineering practice in accepting the building by using a crack analysis approacn because there is no practical method available today to analyze a complex structure with cracks in it. The basis of this concern is that there are no formulas available that can estimate stresses in a complex stress field like those which exist in this building. Thus, the evaluation of the structure based on the staff's crack analysis using empirical unproven formulas to determine the rebar stresses is unacceptable."

Comment:

This concern is related to the use of crack analysis to accept the DGB. Contrary to the concern expressed there are computational tools available to relate crack width to rebar stresses, but in effecting the analyses one still has to make some major simplifying assumptions which requires the judgment of the analyst. The results of such analyses in most likelihood will not be exactly the same as what actually exists. In the case of DGB the estimation of rebar stresses from the sizes of cracks is admittedly an approximation. However, it is the judgment of the Task Group that this is the only practical approach available to evaluate the DGB rebar stresses.

In evaluating the rebar stresses estimated from crack widths the following, as a minimum, needs to be considered and documented by the Applicant: whether or not the cracks are through the wall thickness; the sizes and locations of the cracks; whether or not the cracks are growing in width and/or length; whether or not the number of cracks are increasing; and whether the estimated rebar stresses due to settlement are less than the allowable values after accounting for load combinations is made.

IV. Concern:

"My fourth concern deals with the staff accepting the building by relying on a crack monitoring program to evaluate the stresses during the service life of the building. If cracks exceed certain levels, recommendations will be made for maintaining the structural integrity of the building. The basis for my concern deals with the lack of crack size criteria and the lack of formulated corrective action to be taken when the allowed crack sizes are exceeded."

Comment:

This concern questions the staff's acceptance of the DGB on the basis of a crack monitoring program which is not well defined in crack size criteria and in corrective action. The DGB is designed for combinations of dead, live, tornado and earthquake loads, and therefore it is expected to be able to resist these loads and their loading combinations with adequate margins of safety as designed. However, as a result of settlement which was not considered in the original design, the margins of safety have been reduced to some extent and there is some uncertainty as to its capability to resist the design loads. The purpose of monitoring the cracks is to insure that if there is any change in the condition of the structure it will be observed and appropriate actions can be taken, if necessary. The structural engineering staff reviewer has specified and the Applicant has agreed to the crack size criteria and the corrective action to be taken when the allowed sizes are exceeded. The Task Group is of the opinion that, while the approach is reasonable, details of the program should be further examined and improved. It should also be noted that the crack monitoring program should be in complement with a settlement monitoring program, since any assessment based on either of the two monitoring programs alone may be misleading.

6. AN ASSESSMENT OF THE DGB

Before assessing the structural adequacy of the DGB, let us examine general characteristics of structures in their capability to adapt to the settlement of the foundation soil. Structures may be classified as highly flexible, practically flexible, highly rigid and practically rigid on the basis of their deformability with respect to the settlement of the foundation soil.

Highly flexible structures follow the displacement of the foundation soil surface at all points. An example of such a structure is an earth embankment. Non-uniform (differential) settlements do not give rise to any complications in the deformation of such a structure.

Highly rigid structures either have a uniform settlement when subjected to a symmetrical load with symmetrical distribution of the soil compliance, or else tilt without bending. As an example of this are grain elevators, factory chimneys (smoke stacks), blast furnaces, etc. These structures level out the settlements, i.e., they perform in conjunction with the soil bearing material. It is because of re-distribution of the pressure by the structure that differential settlement effect of the supporting material diminishes.

Practically rigid structures, which include most buildings and many engineering structures (multispan trestles and bridges with continuous structural members, reservoirs, storage tanks, etc.), cannot closely follow the foundation soil deformations at all points and, because of differential settlement, are subject to bending. Such structures level out only in part the non-uniform settlements of the foundation soil surface. This results in the development of additional forces in the supporting members of the structures, which are usually disregarded in the course of their designing. Hence the possible development of cracks in such members.

Practically flexible structures largely follow the displacements of the soil surface, i.e., they bend (such as low single-story buildings), but over short sections they are capable of levelling out to a certain extent the differential settlement. This results in the emergence of usually insignificant additional forces in the supporting members. In the event of highly non-uniform settlements these forces can cause the development of cracks and fractures.

On the basis of above classification and because of the box-type construction with heavy reinforced concrete walls and slabs, the completed DGB can be considered as a highly rigid structure. However, in the process of construction, the as-built portions of the DGB at different stages of construction can be considered to vary from highly flexible, practically flexible, practically rigid to highly rigid. It is believed that most of the settlement and settlement cracks appeared at the various stages of construction. However, the cracks have not been carefully studied and mapped at each stage of construction so that a reasonable correlation of the cracks with all the causes can be established. Only the cracks which were mapped in January 1980 have been identified as shrinkage and/or settlement cracks. Most of the cracks which have been identified to be due to unequal settlement are the cracks in the cross-walls, the movement of which was restrained by the duct banks.

The DGB design, as indicated by Applicant's analyses, is controlled by the tornado wind. Under such a load, especially the postulated internal pressure, the full strength of the walls will be mobilized, and there will be a redistribution of the load, if there exist localized high stress areas. This will also be true if the seismic loads are considered. One can make such judgments on the basis of the observation that the DGB is a highly redundant structure. The structural elements are not columns and beams. They are heavy reinforced concrete walls and slabs. With necessary repair work to be done and with adequate monitoring programs, there is reasonable assurance that the structural integrity of the DGB will be maintained and its functional requirement will be fulfilled.

7. CONCLUSIONS AND RECOMMENDATION

Most of our conclusions have been expressed in our comments to the concerns. They may be summarized as follows:

1. Analyses of the DGB either by linearizing the settlements or by applying the settlements as measured render unrealistic results. The stresses due to settlement are either underestimated or overestimated. A realistic analysis would be one which simulates the stage-by-stage construction of the DGB, and uses the actual and more detailed settlement measurements at each stage. However, such settlement history for the DGB does not exist. For this reason, the Task Group believes that a rigorous analysis to compute rebar stresses is unattainable.

2. The estimation of rebar stresses from the crack width is admittedly an approximation. The estimated stresses of 20 to 30 ksi appear to be reasonable. However to be convincing a detailed procedure of crack analysis should be documented and provided.

3. Inconsistences in the documentation of the settlement history needs to be resolved. For example, the Midland Units 1 and 2 Executive Summary dated August, 1983 states that for the July 1978 period, the maximum settlements recorded were 3.5 inches while Figure ES-14 of the same document indicates a maximum of 1.99 inches for the same period.

4. The current monitoring program is inadequate to deduce future distress. Thus, an adequate monitoring program for both settlement and cracks should be developed and implemented to assure that the structural integrity of the DGB should be maintained during the life of the plant.

5. On the basis of the overall evaluation, it is nevertheless felt that the DGB in its current state can fulfill its functional requirement .

6. It is recommended that a repair program be developed and implemented.

TABLE 1

DIESEL GENERATOR BUILDING

SETTLEMENT CASES

CASE	TIME PERIOD	PERIOD	PORTION OF BLDG COMPLETE
1A	3/78 - 8/78	PRE-SURCHARGE	WALLS TO ELEV 654'
1B	8/78 - 1/79	PRE-SURCHARGE	WALLS TO ELEV 662' (BELOW MEZZANINE SLAB)
2A	1/79 - 8/79	SURCHARGE	COMPLETE BUILDING
2B	9/79 - 12/2025	40 YEAR	COMPLETE BUILDING

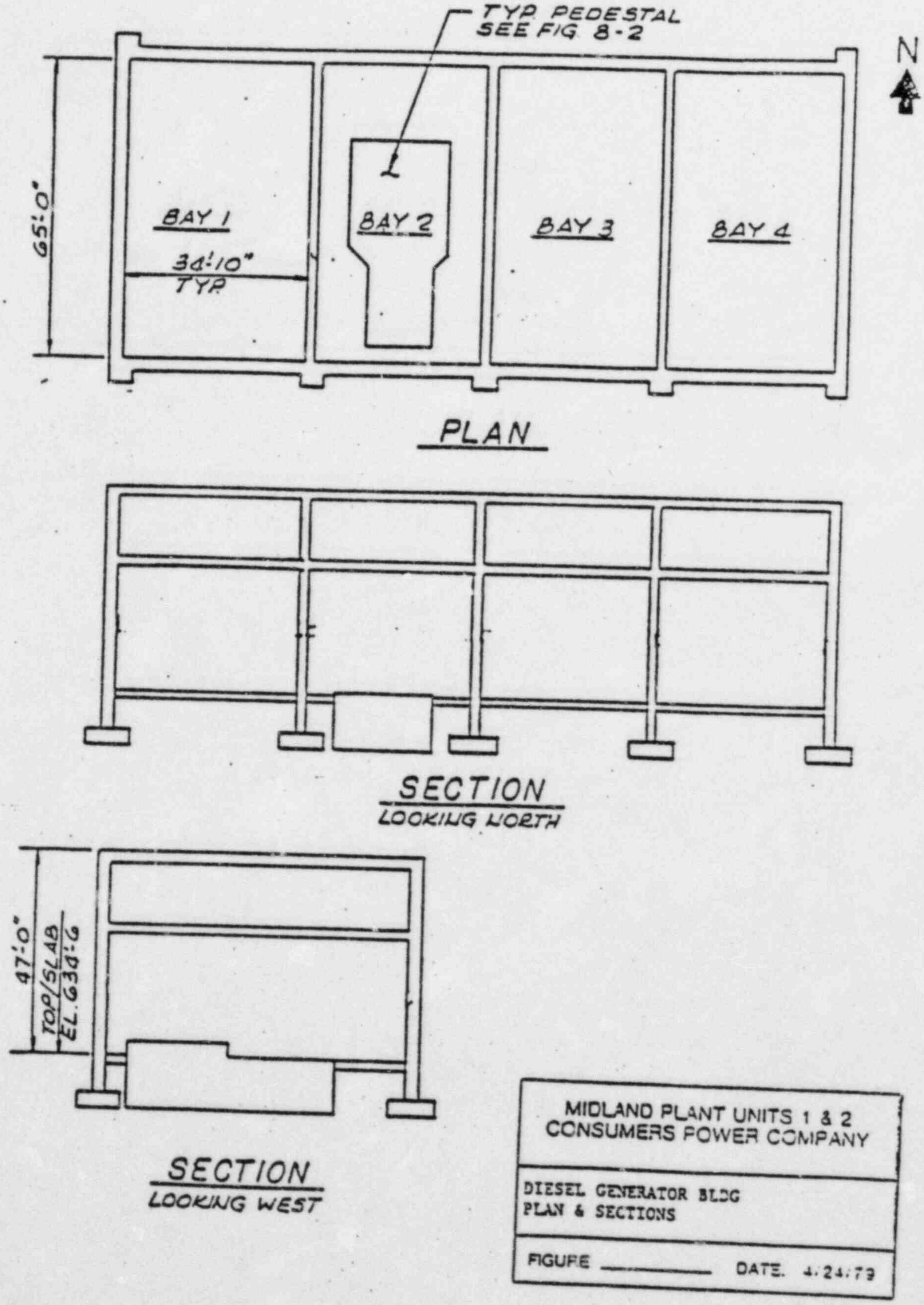
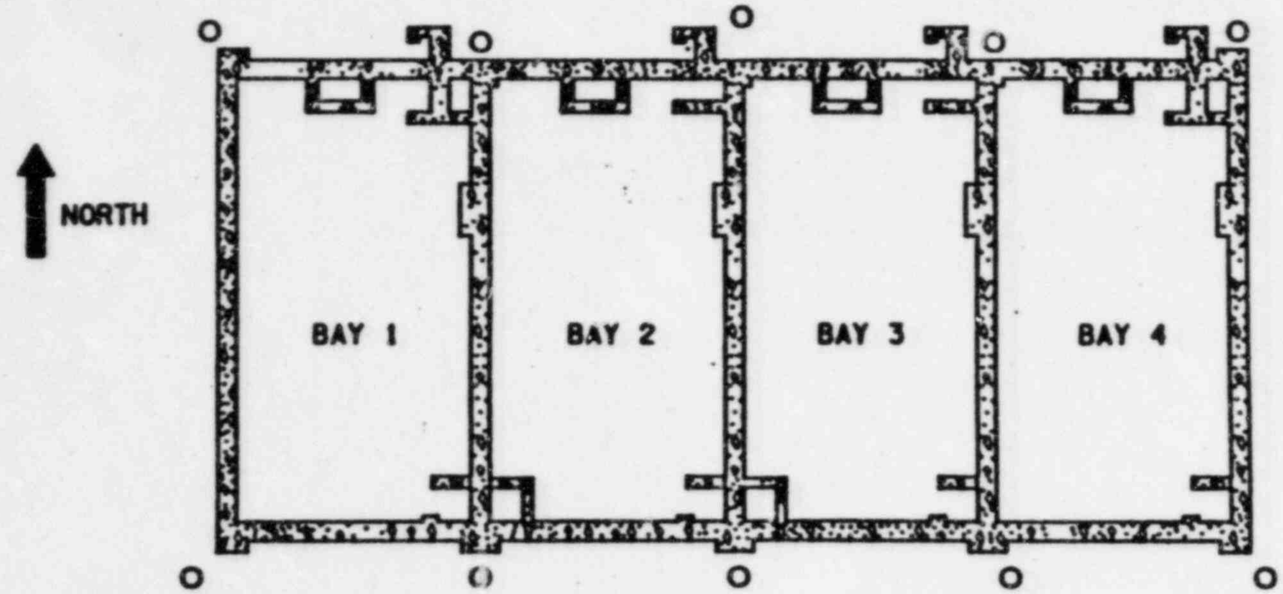

TYP PEDESTAL
SEE FIG 8-2
N
65'-0"
BAY 1
BAY 2
BAY 3
BAY 4
34'-10"
TYP
PLAN
SECTION
LOOKING NORTH
47'-0"
TOP/SLAB
EL. 630'-6
SECTION
LOOKING WEST
MIDLAND PLANT UNITS 1 & 2
CONSUMERS POWER COMPANY
DIESEL GENERATOR BLDG
PLAN & SECTIONS
FIGURE
DATE. 4/24/79

FIGURE 1

LINE A	1.19	1.02	0.90	0.85	0.76
LINE B	0.77	1.09	1.54	1.98	2.41
LINE C	1.50	1.51	1.78	1.86	1.91
LINE D	1.33	1.15	1.19	1.18	1.29
TOTAL	4.79	4.77	5.41	5.87	6.37



LINE A	1.67	1.42	1.28	1.44	1.99
LINE B	1.14	1.12	1.46	1.92	2.21
LINE C	3.00	2.92	3.16	3.37	3.24
LINE D	1.62	1.67	1.69	1.98	1.89
TOTAL	7.43	7.13	7.59	8.71	9.33

LEGEND

O —— DIESEL GENERATOR BUILDING SETTLEMENT MARKER

SETTLEMENT IN INCHES FOR

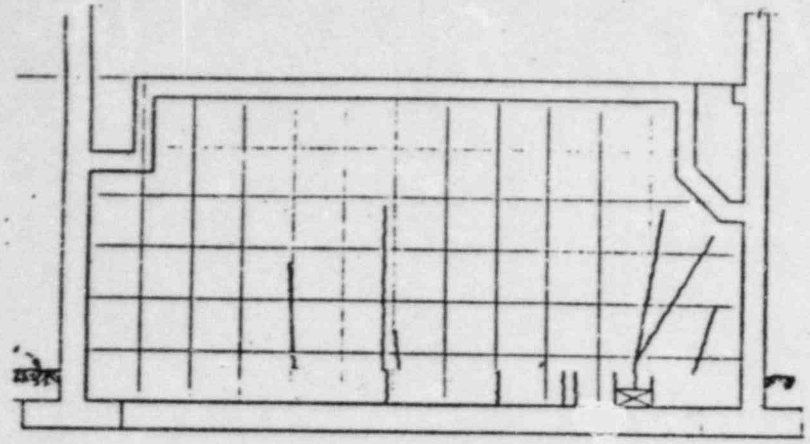
PRE-SURCHARGE PERIOD (3/78-8/78)............LINE A
PRE-SURCHARGE PERIOD (8/78-1/79)............LINE B
SURCHARGE PERIOD (1/79-8/79) ....LINE C
POST SURCHARGE PERIOD (9/79-12/2025)........LINE D
ASSUMING SURCHARGE REMAINS IN PLACE

FIGURE 2

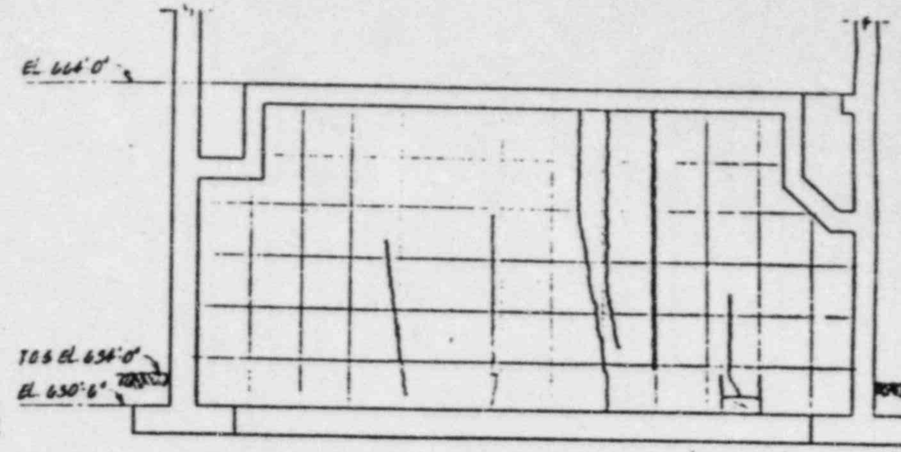
DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY

SUMMARY OF ACTUAL AND ESTIMATED SETTLEMENTS

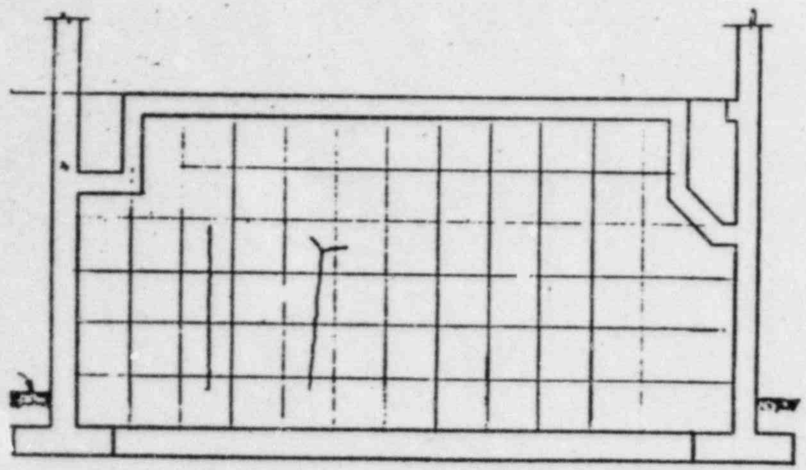
FIGURE ES-14



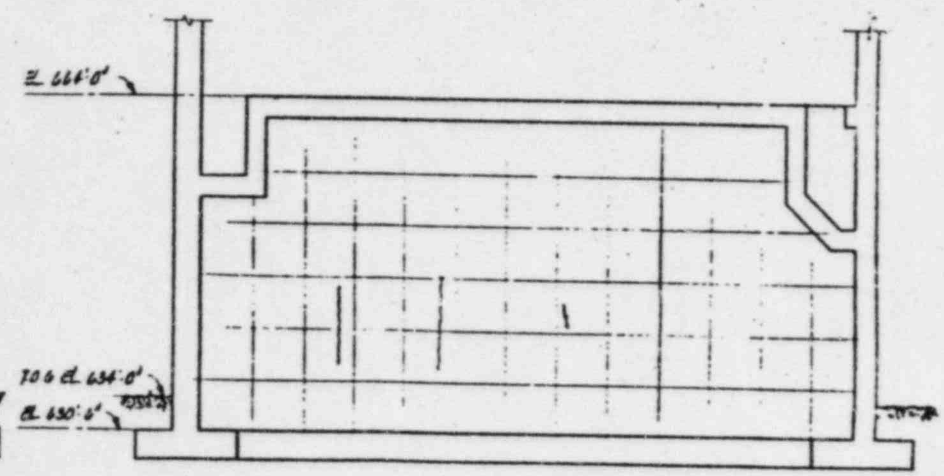
WEST CENTER WALL-EAST SIDE
LOOKING WEST



WEST CENTER WALL-WEST SIDE
LOOKING WEST

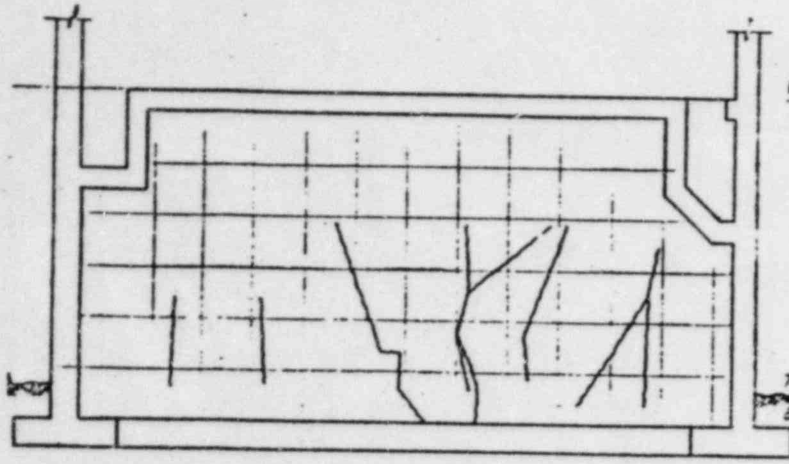


WEST WALL-EAST SIDE
LOOKING WEST

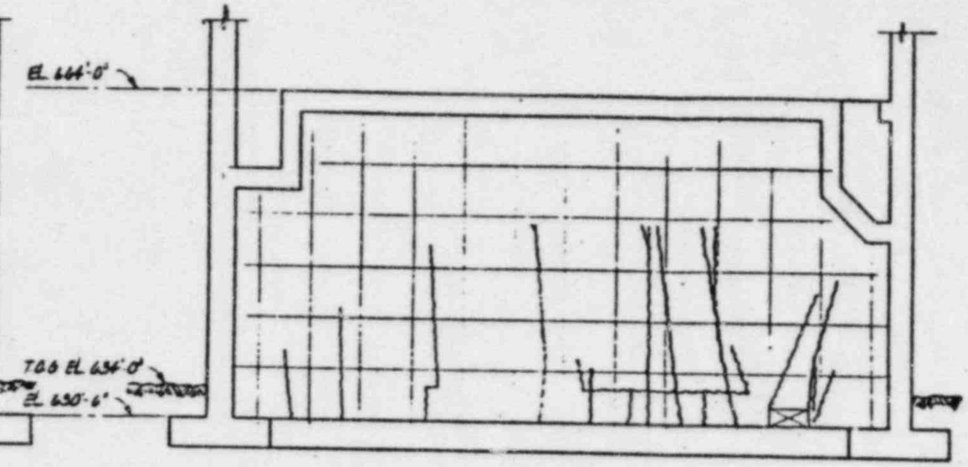


WEST WALL-WEST SIDE
LOOKING WEST

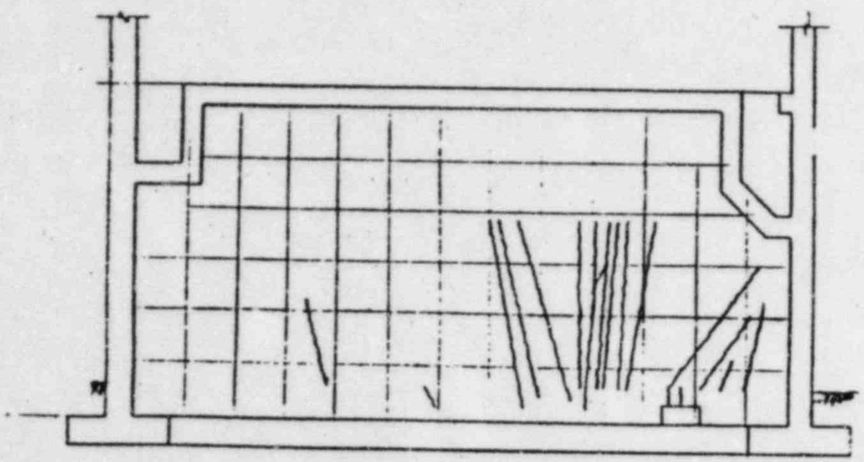
FIGURE 3 - A - 1



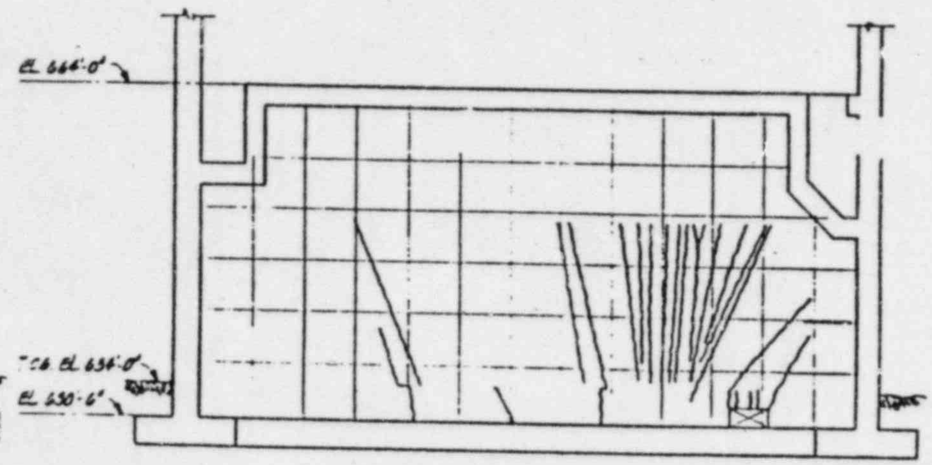
EAST WALL-WEST SIDE
LOOKING WEST



EAST CENTER WALL-EAST SIDE
LOOKING WEST

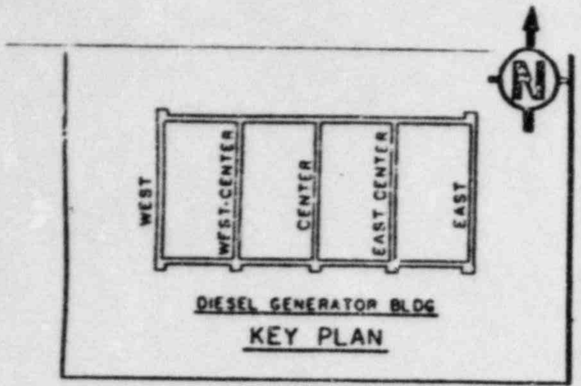


CENTER WALL-EAST SIDE
LOOKING WEST

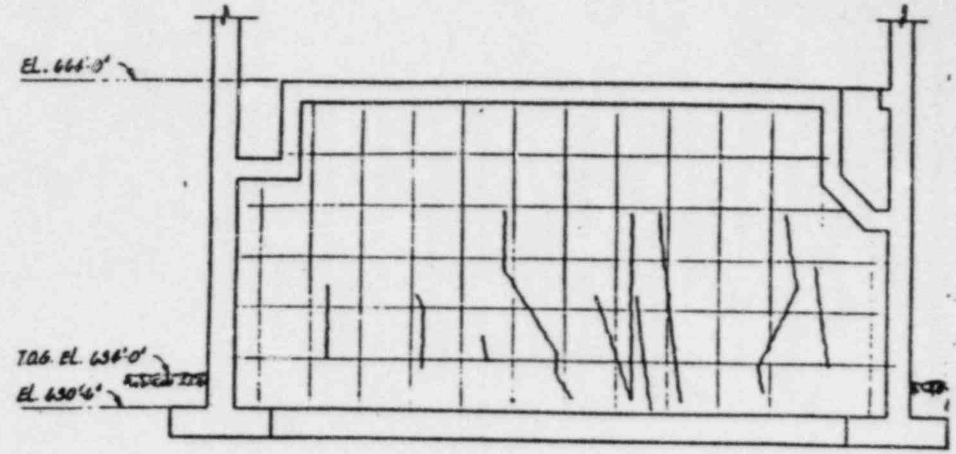


CENTER WALL-WEST SIDE
LOOKING WEST

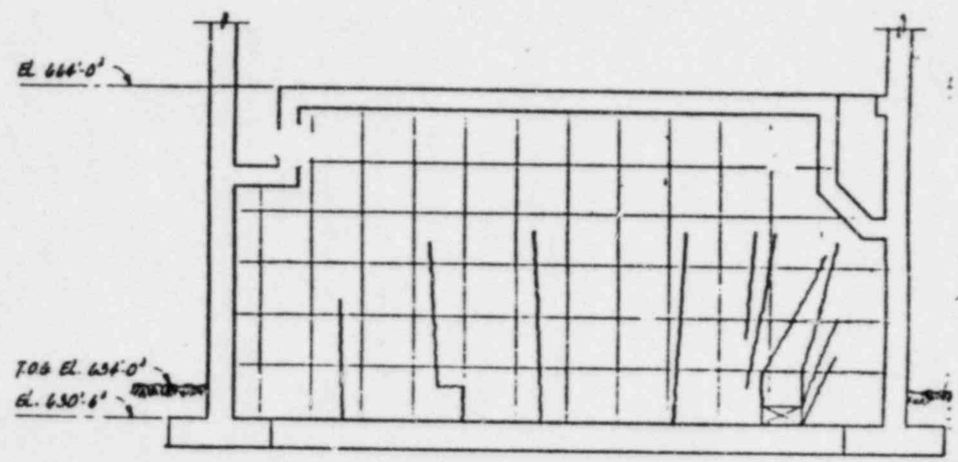
FIGURE 3 A - 2



DIESEL GENERATOR BLDG
KEY PLAN



EAST WALL-EAST SIDE
LOOKING WEST



EAST CENTER WALL-WEST SIDE
LOOKING WEST

NOTES

1. CRACK SHOWN WERE MAPPED PRIOR TO PLACING THE PRELOAD. (12-13-78 TO 12-18-78).
2. NORTH & SOUTH WERE NOT MAPPED SINCE NO SIGNIFICANT CRACKS WERE OBSERVED.
3. IN GENERAL, ALL CRACKS WERE HAIRLINE WITH SOME CRACKS WITH A THICKNESS OF 28 MILS AS OF 2-2-79.

FIGURE 3 A - 3

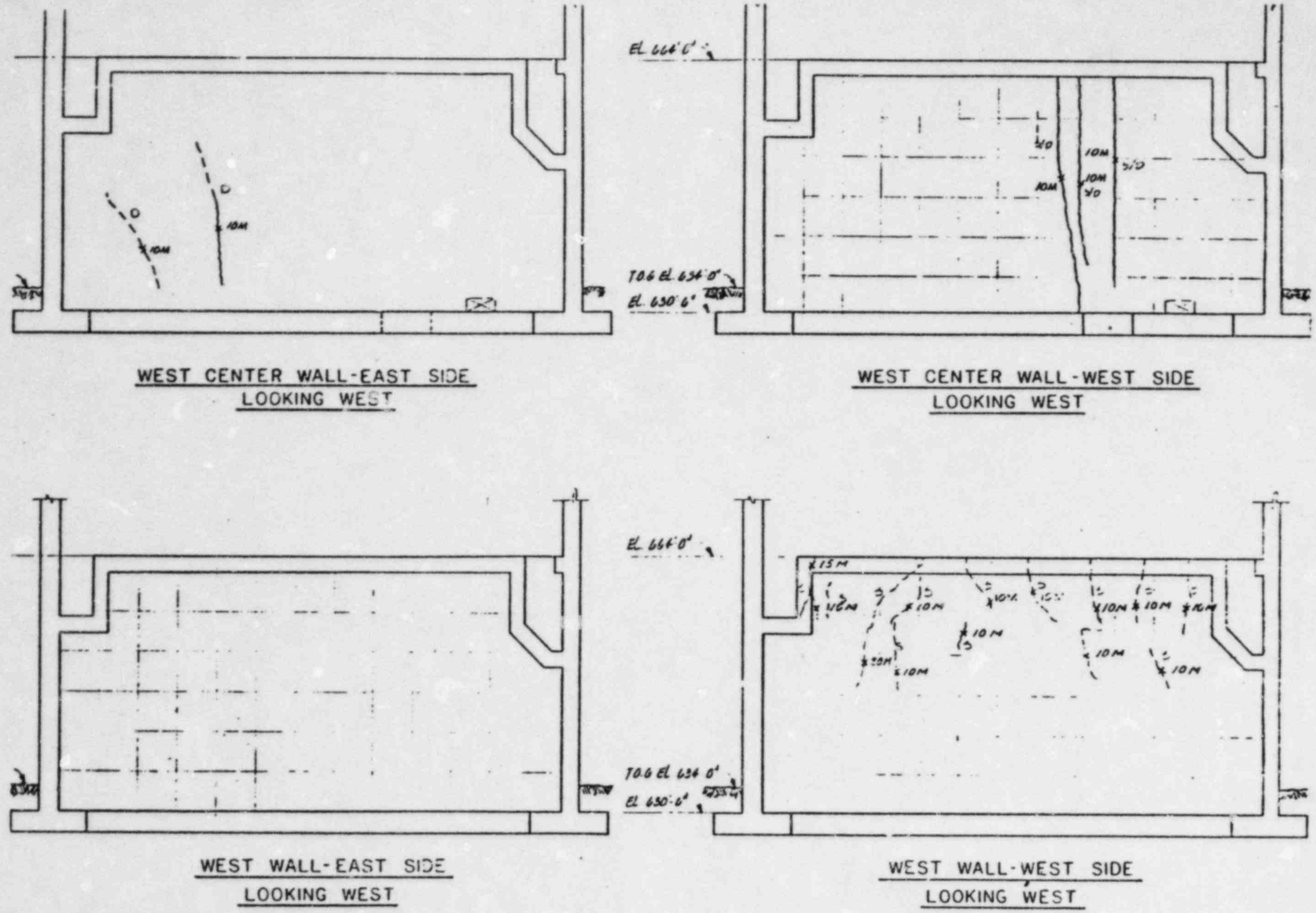
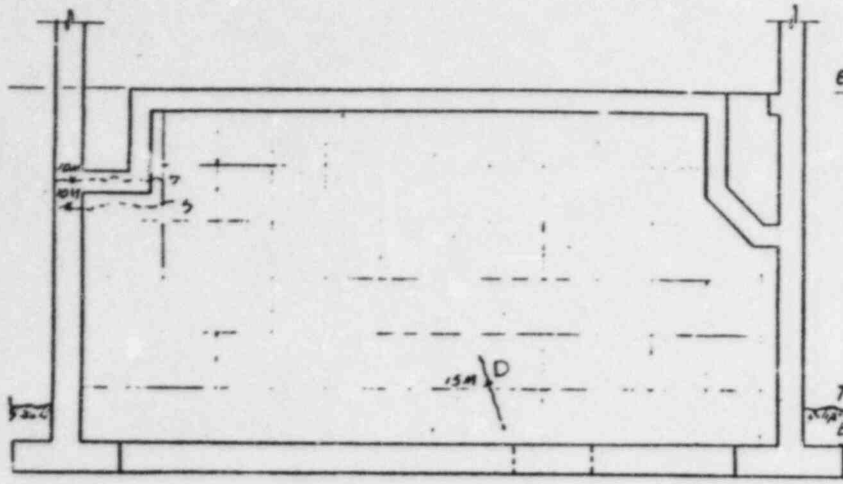
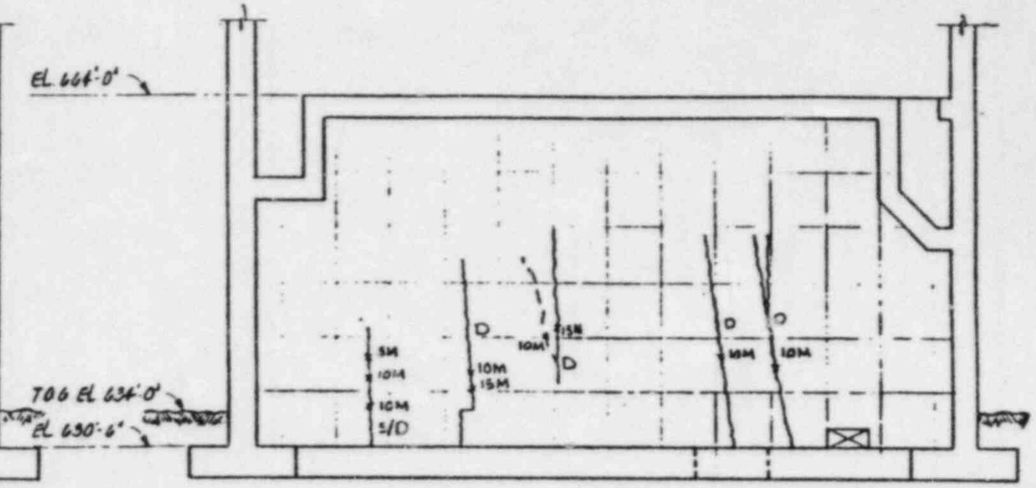

WEST CENTER WALL-EAST SIDE
LOOKING WEST
EL 664'0"
T.O.G EL 634'0"
EL 630'6"
WEST CENTER WALL-WEST SIDE
LOOKING WEST
WEST WALL-EAST SIDE
LOOKING WEST
EL 664'0"
T.O.G EL 634'0"
EL 630'6"
WEST WALL-WEST SIDE
LOOKING WEST

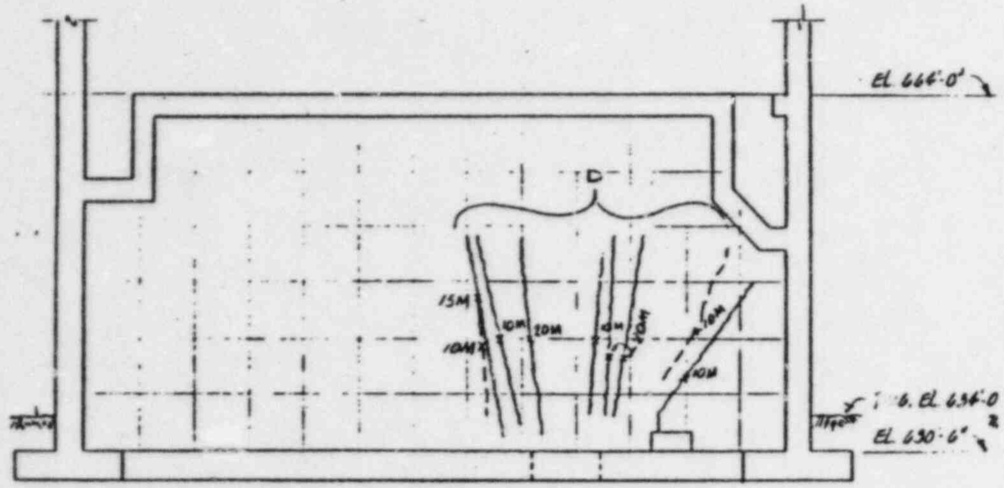
FIGURE 3 B - 1



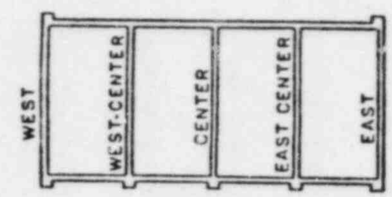
EAST WALL-EAST SIDE
LOOKING WEST



EAST CENTER WALL-EAST SIDE
LOOKING WEST



CENTER WALL-EAST SIDE
LOOKING WEST



DIESEL GENERATOR BLDG
KEY PLAN

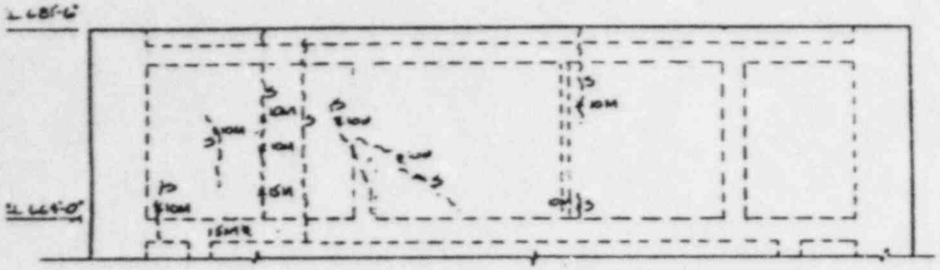
NOTES

1. IN GENERAL ALL CRACKS MAPPED IN DEC 1978 WERE HAIRLINE. SOME CRACKS HAD A THICKNESS OF 28 MILS AS OF 2-2-79.

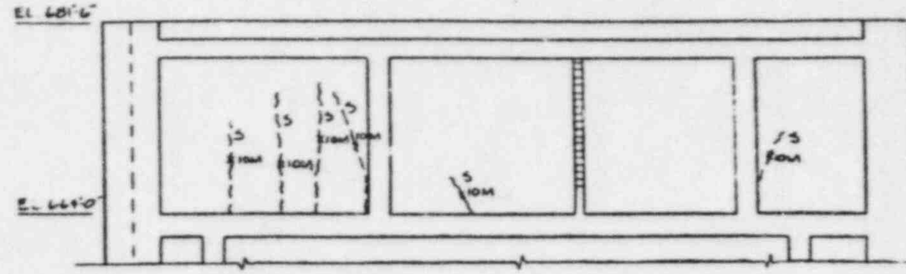
2. FOR CRACK MAPPING OF WALLS FROM EL. 664'-0" TO EL 681'-6" SEE FIG. 28-3

3. CRACKS LESS THAN 10 MILLS IN SIZE ARE NOT SHOWN.

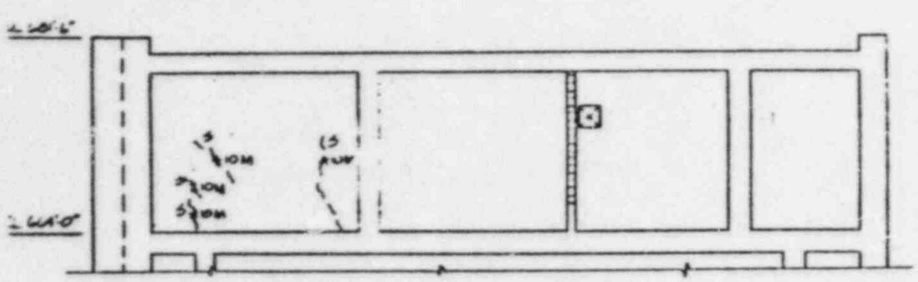
FIGURE 3 B - 2



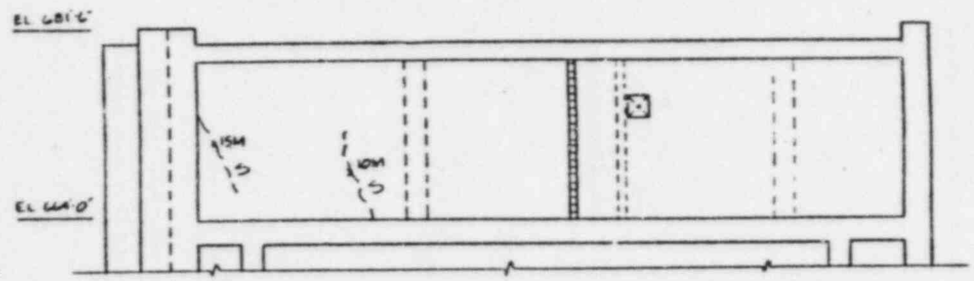
EAST WALL - EAST SIDE
LOOKING WEST



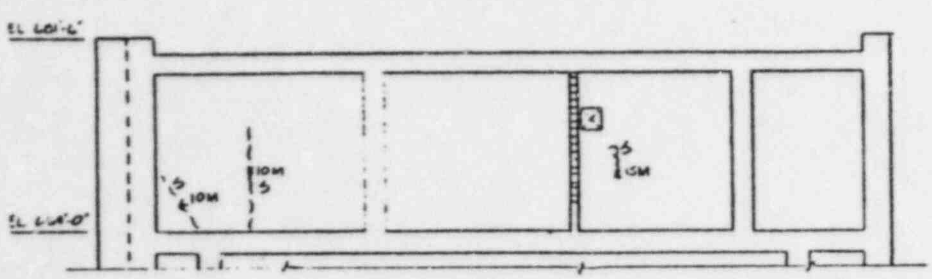
EAST WALL-WEST SIDE
LOOKING WEST



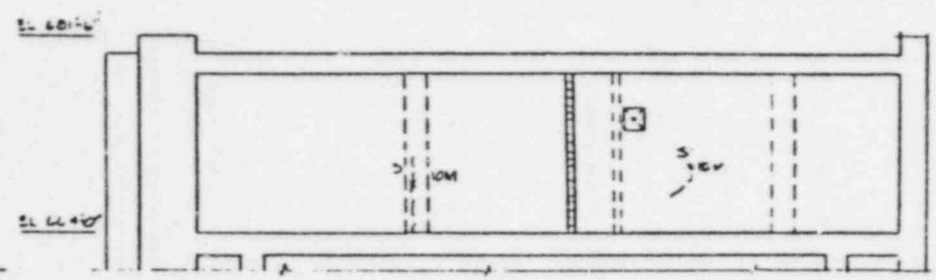
EAST CENTER WALL-WEST SIDE
LOOKING WEST



EAST CENTER WALL-EAST SIDE
LOOKING WEST

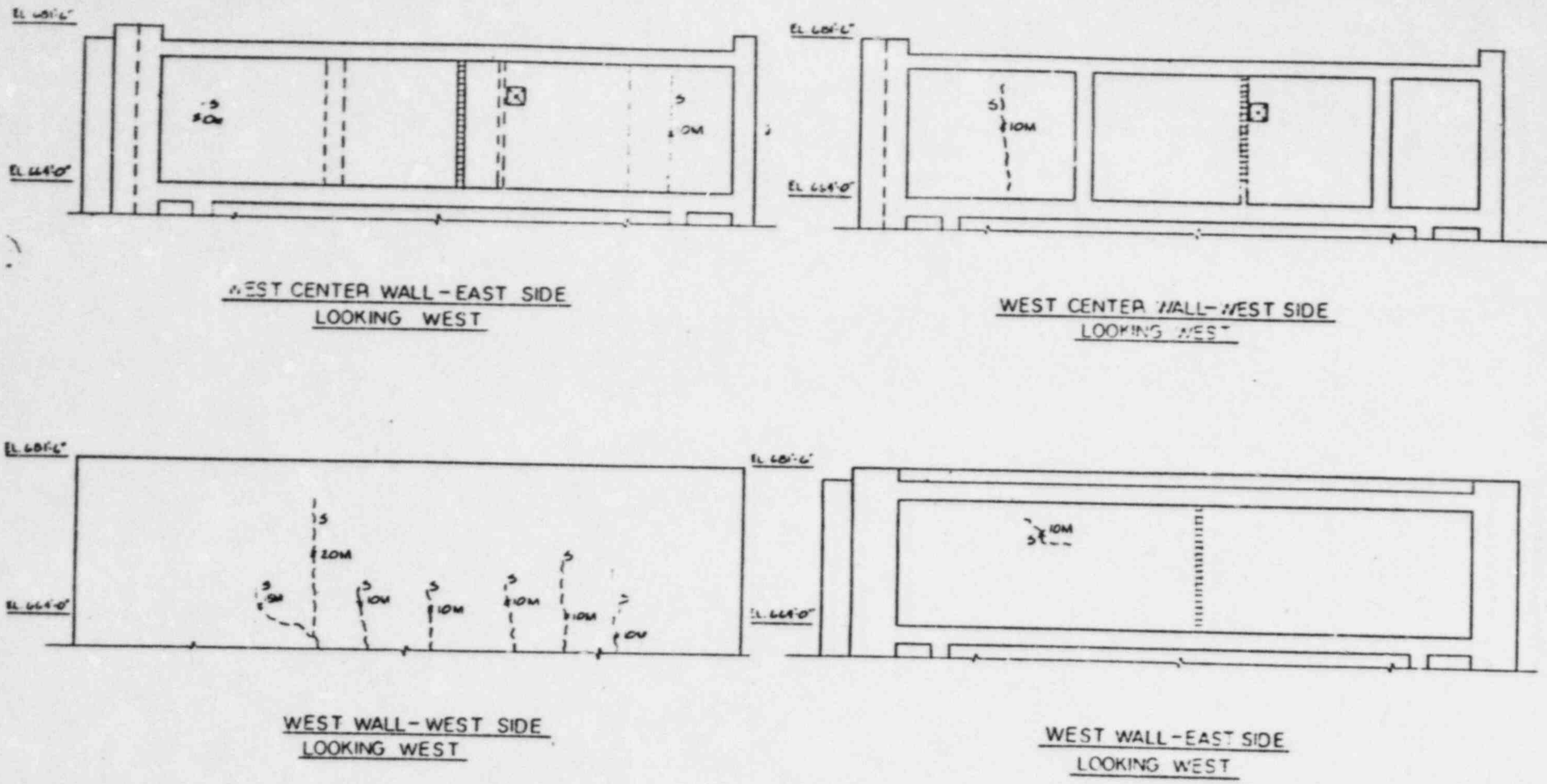


CENTER WALL-WEST SIDE
LOOKING WEST



CENTER WALL-EAST SIDE
LOOKING WEST

FIGURE 3 B - 3



NOTES

1. CRACKS SHOWN WERE MAPPED ON JAN 1980.
2. SEE FIG 28-2 FOR TYPICAL CONSTRUCTION SEQUENCE
3. SEE FIG 28-2 FOR CRACK MAPPING OF WALLS FROM ELEVATION 630'-6" TO 664'-0".
4. SEE FIG 28-2 FOR ADDITIONAL NOTES AND LEGEND

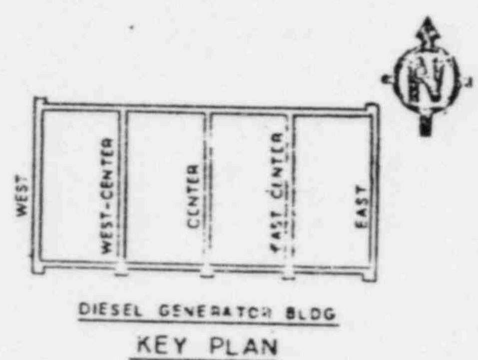


FIGURE 3 3 - 4

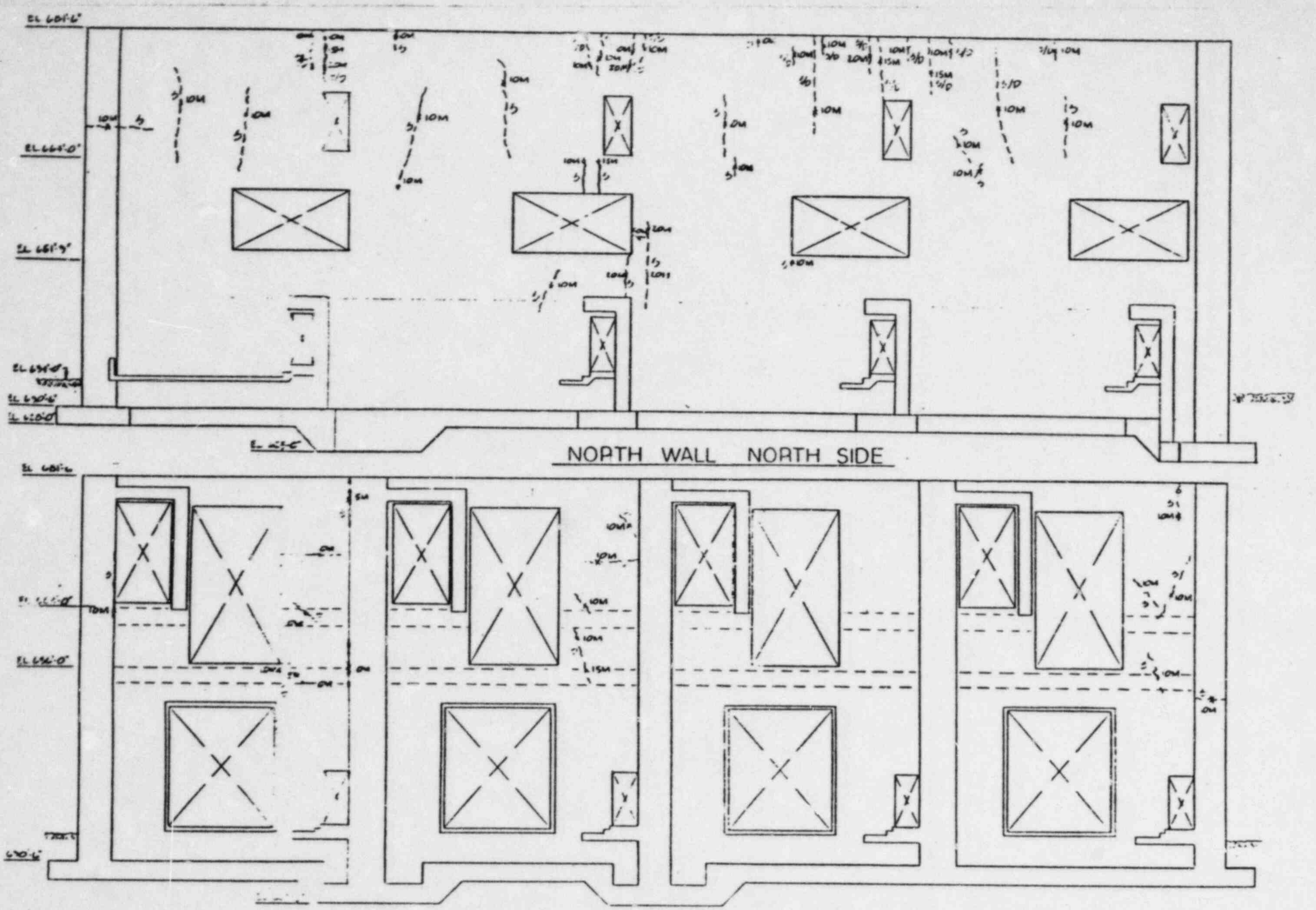


FIGURE 3 B - 5

SOUTH WALL SOUTH SIDE

LOOKING NORTH

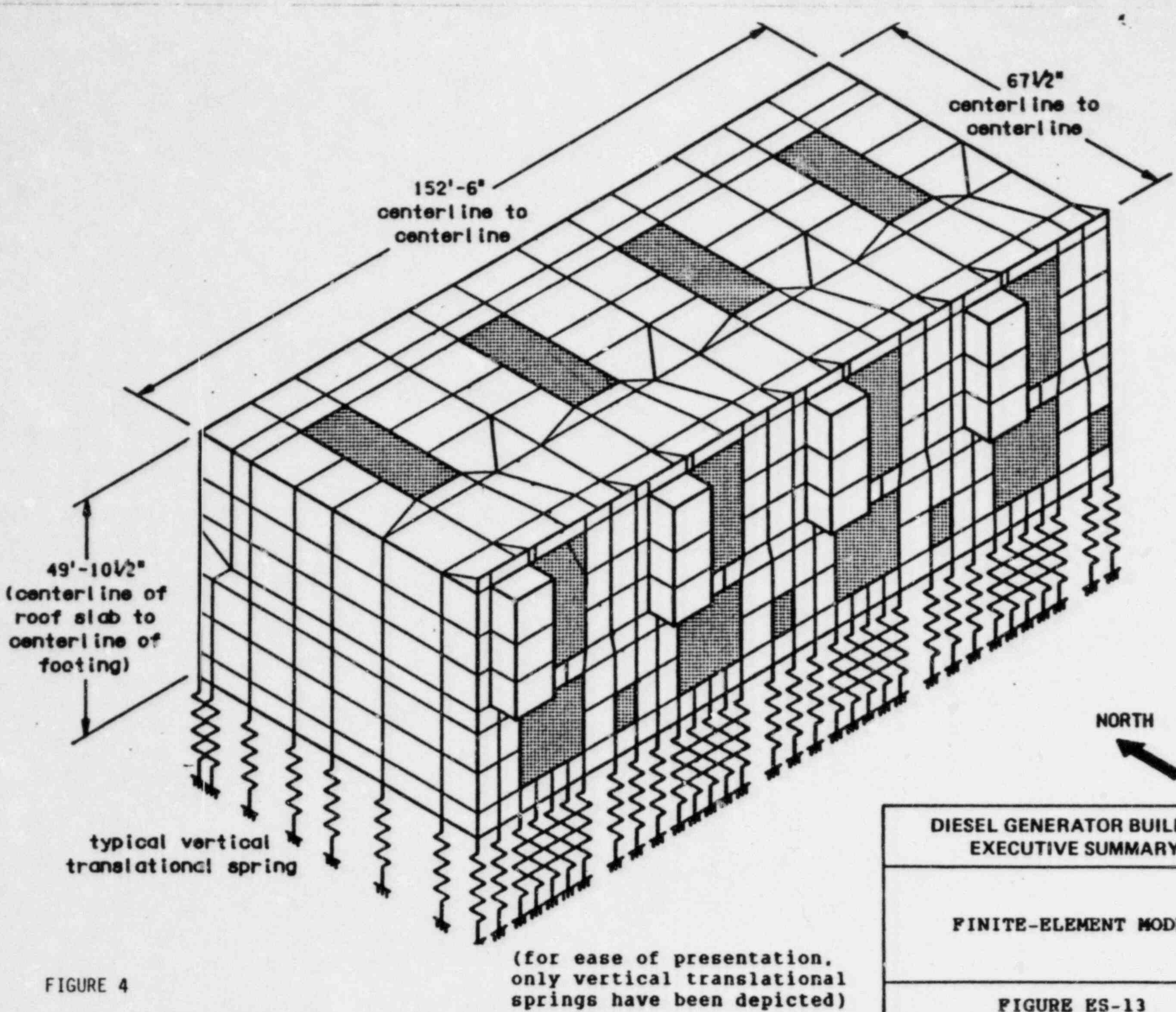


FIGURE 4

DIESEL GENERATOR BUILDING EXECUTIVE SUMMARY
FINITE-ELEMENT MODEL
FIGURE ES-13

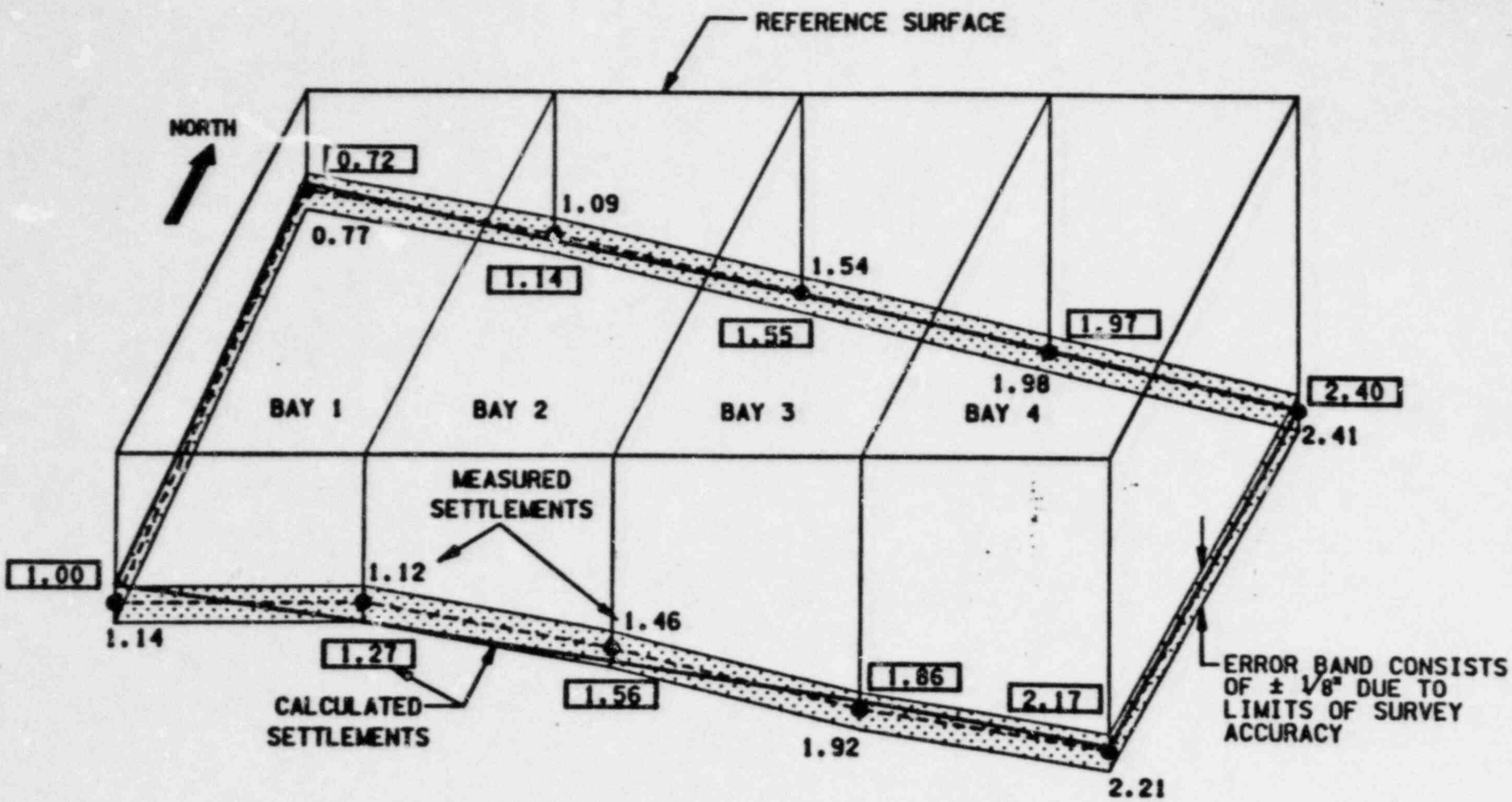
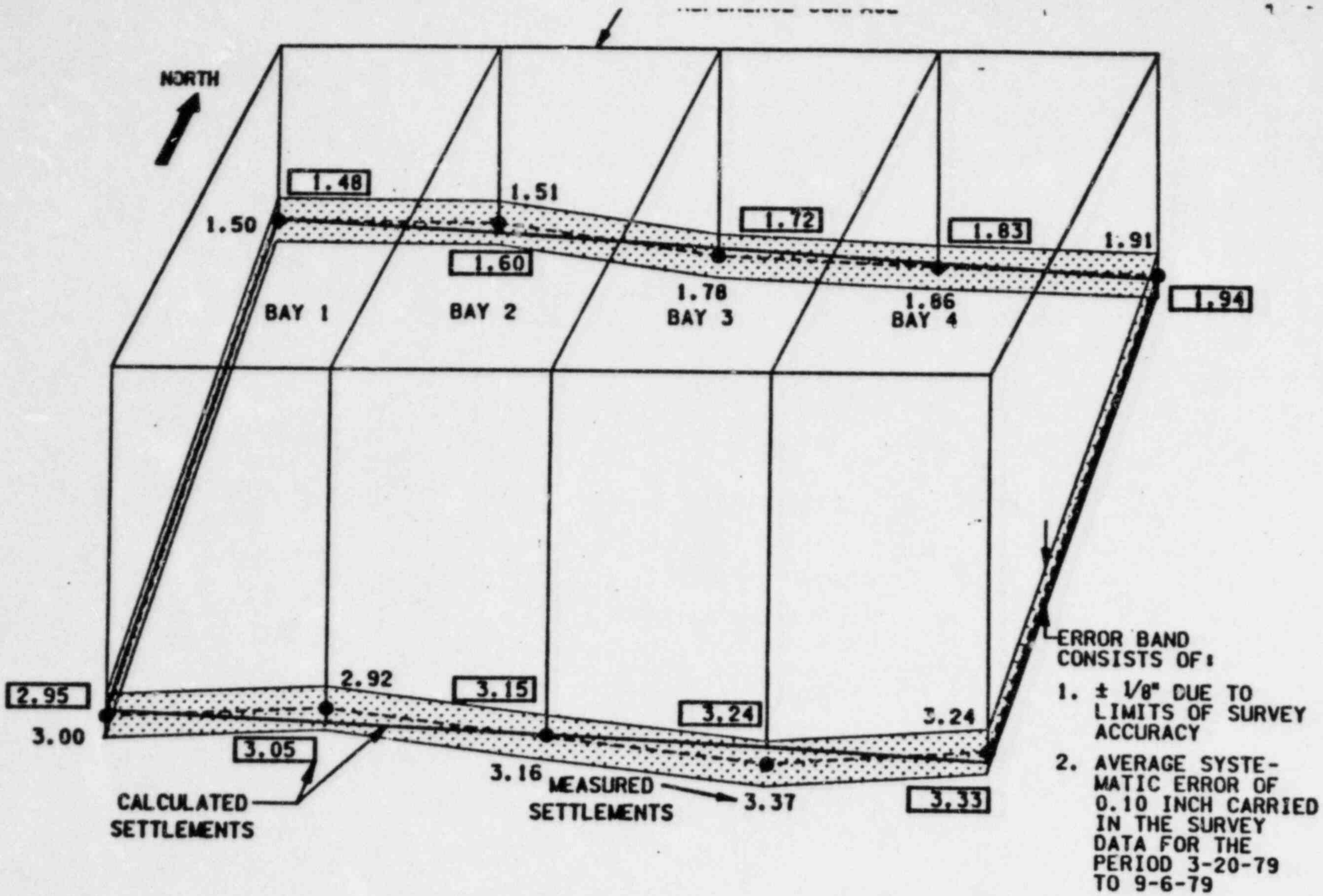


FIGURE 5

DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

COMPARISON OF SETTLEMENT VALUES
PRE-SURCHARGE PERIOD
AUGUST 1978 - JANUARY 1979

FIGURE ES-15

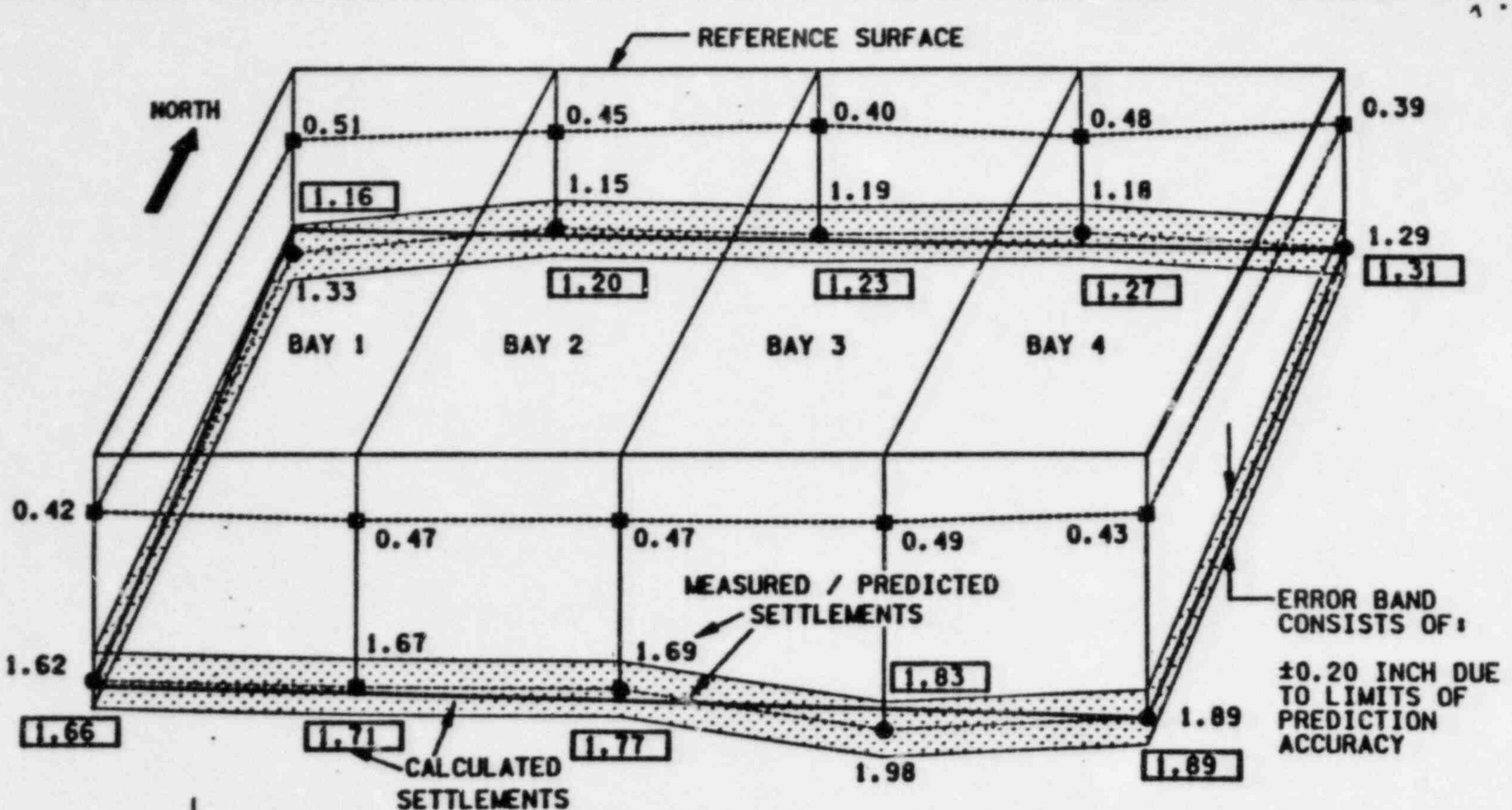


DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

COMPARISON OF SETTLEMENT VALUES
<u>SURCHARGE PERIOD</u>
JANUARY 1979 - AUGUST 1979

FIGURE ES-16

FIGURE 6



ACTUAL MEASURED SETTLEMENT FROM SEPT.14, 1979 TO DEC.31, 1981. THESE INCLUDE EFFECT OF DEWATERING TO APPROXIMATELY EL. 595', AND REPRESENT MOVEMENT OF THE STRUCTURE DUE TO SETTLEMENT OF THE FILL AND NATURAL SOIL BELOW.

ACTUAL MEASURED SETTLEMENTS FROM SEPT.14, 1979 TO DEC.31, 1981 PLUS ESTIMATED SECONDARY COMPRESSION SETTLEMENT FROM DEC.31, 1981 TO DEC.31, 2025 ASSUMING SURCHARGE REMAINS IN PLACE.

FIGURE 7

DIESEL GENERATOR BUILDING
EXECUTIVE SUMMARY

COMPARISON OF SETTLEMENT VALUES
POST-SURCHARGE PERIOD
SEPTEMBER 1979 - DECEMBER 2025

FIGURE ES-17

APPENDIX I

COMPOSITION OF TASK GROUP

NRC Staff: Task Group Leader	Dr. Pao-Tsin Kuo, Section Leader Structural Engineering Section B Structural and Geotechnical Engineering Branch
	Dr. Chen P.Tan, Structural Engineer Structural Engineering Section B Structural and Geotechnical Engineering Branch
	Mr. Norman D. Romney, Structural Engineer Structural Engineering Section B Structural and Geotechnical Engineering Branch
NRC Consultants:	Dr. A. J. Philippacopoulos, Associate Scientist Structural Analysis Division Brookhaven National Laboratory (BNL)
	Dr. Charles A. Miller, Senior Consultant Structural Analysis Division Brookhaven National Laboratory
	Dr. Carl J. Costantino, Senior Consultant Structural Analysis Division Brookhaven National Laboratory

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

AUG 8 1983

MEMORANDUM FOR: C. P. Tan
Norman Romney
Structural Engineering Section B
Structural and Geotechnical Engineering Branch, DE

THRU: George Lear, Chief
Structural and Geotechnical Engineering Branch, DE GL 8/5/83

FROM: P. T. Kuo, Structural Engineering Section B Leader
Structural and Geotechnical Engineering Branch, DE

SUBJECT: EVALUATION OF LANDSMAN'S CONCERNS REGARDING DIESEL GENERATOR BUILDING AT MIDLAND

Reference: Memorandum from R. H. Vollmer to D. G. Eisenhut, dated July 21, 1983

Per the enclosed memo from R. H. Vollmer to D. Eisenhut, a task group to re-evaluate the structural design and construction adequacy of the Midland Diesel Generator Building has been formed and I have been designated as the leader of the group. You are assigned as members of this group. The mission of the group is described in the enclosure.

P. T. Kuo
Structural Engineering Section B Leader
Structural and Geotechnical
Engineering Branch, DE

Enclosure: As stated

cc: w/o enclosure
R. H. Vollmer
J. P. Knight
G. Lear

8308150336

ENCLOSURE

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

JUL 21 1983

MEMORANDUM FOR: Darrell G. Eisenhut, Director
Division of Licensing

FROM: Richard H. Vollmer, Director
Division of Engineering

SUBJECT: EVALUATION OF LANDSMAN'S CONCERNS REGARDING DIESEL GENERATOR BUILDING AT MIDLAND

Responding to your memorandum. subject as above dated June 27, 1983, J. Knight, Assistant Director for Components & Structures Engineering, has formed a task group to re-evaluate the structural design and construction adequacy of the Midland Diesel Generator Building. The group, headed by Dr. P. T. Kuo, will review the design review documents and the construction reports; physically inspect the building; search out and interview concerned individuals, including Mr. Landsman; and prepare a final report on the adequacy of the Midland NPP Diesel Generator Building. The particulars of the groups' composition and charter are developed in more detail in the attached document. Note that we intend to use a consultant in a capacity to critique our findings on Mr. Landsman's concerns. The consultant's views will be provided in our report.

Richard H. Vollmer, Director
Division of Engineering

cc: H. Denton
J. Knight
J. Keppler
T. Novak
E. Adensam
G. Lear
P. Kuo
F. Rinaldi
D. Hood

IMPLEMENTATION CONCEPT

REVIEW OF THE MIDLAND NPP

DIESEL GENERATOR BUILDING

1. MISSION

A review will be conducted as to the structural adequacy of the Midland NPP diesel generator building. All information available from NRC regional inspectors in this matter will be obtained and the impact of that information will be fully considered in the review.

2. BACKGROUND

The NRC structural engineering staff (headquarters) has reviewed the Midland NPP diesel generator building's engineering design and construction and has indicated that the building is structurally adequate to resist its design loads. However, during hearings before a NRC Congressional Oversite Committee, the structural adequacy of the Midland NPP diesel generator building was questioned by an NRC employee, Mr. Ross Landsman, a Region III site inspector for the Midland project. It is considered prudent that a review be undertaken by a technical group to assure that Mr. Landsman's concerns are fully heard and carefully evaluated so that the adequacy of the diesel generator building may be further assured.

3. ORGANIZATION

The review group is composed of four technical members -

a group leader, two team members from the structural review staff and a structural consultant. The consultant will be asked to provide his critique of Landsman's concerns and our findings directly into the final report.

4. SUPPORT

The NRC structural review staff will provide the background technical studies, reports, and other review materials that formed the basis for their review and technical conclusions. The NRC project staff for the Midland NPP will provide general administrative arrangements to facilitate the review. Region III will provide a complete listing of Mr. Landsman's concerns.

5. SCOPE OF EFFORT

The efforts of the review group may include but will not be limited to 1) review of all pertinent technical materials, 2) on-site inspection of the diesel generator building, 3) on-site interviews with all inspection personnel that have information to contribute and 4) preparation of a technical report summarizing their activities, considerations and findings. The report will include, as a separate attachment, the opinion of the consultant group member.

6. TIMING

Review activities should be completed NLT 30 working days after receipt of a written statement of Mr. Landsman's concerns and the final report will be due to the Director, DE NLT 15 working days after completion of the review.

7. DESIRED PRODUCT

The desired final report of the review is a report that discusses each of Mr Landsman's concerns, as well as any other concerns that might be offered during the review, and provide a basis for acceptance or rejection of each concern. A technical review of the adequacy of the diesel generator building should then be presented that is reflective of the groups' final recommendations in this matter in light of new information furnished by Mr. Landsman and others.

APPENDIX II

SUMMARY OF MEETINGS

August Meeting with Applicant and Site Visit

On August 24, 1983 members of the Task Group met with Bechtel and Consumers Power Co. staff in the Bechtel, Ann Arbor, Michigan offices. At this meeting, presentations were made by the applicant and their consultants to provide background on the history of the DGB construction original design philosophy and the analyses done to demonstrate the adequacy of the structure following settlement.

On the evening of August 24 and during the morning of August 25, 1983 the members of the Task Group visited the Midland site to observe the DGB. The Task Group members observed the cracks in the DGB and held discussions with construction personnel to determine the sequence of concrete placement during construction of the DGB. At the site crack maps of the DGB were provided by the Applicant.

Task Group Interviews With Original Reviewers

On September 8, 1983 the Task Group met individually with the original NRC staff reviewers responsible for the Geotechnical and Structural Engineering evaluation of the Midland DGB. The persons interviewed were: Dr. Harry Singh of the U.S. Army Corps of Engineers, Chicago (geotechnical engineering consultant); Mr. Joseph Kane of the Geotechnical Engineering Section, SGEB; Dr. Lyman Heller, Geotechnical Engineering Section Leader, SGEB; Mr. Frank Rinaldi, Structural Engineering Section B, SGEB, Mr. John Matra, Naval Surface Weapons Center, (structural engineering consultant); and Dr. Gunnar Harstead, Harstead Associates (structural engineering consultant. The purpose of the interviews was to gain an understanding and/or clarification of the concerns each reviewer had regarding the Midland DGB.

Dr. Harry Singh was retained by the Geotechnical Engineering Section after discovery of the soils problems existing at the Midland site. Dr. Singh was concerned that the structural analysis of the DGB did not take into account the settlement data as measured. Dr. Singh was concerned with the appropriateness of using crack widths to evaluate rebar stress due to settlement; although he did recommend that the cracks should be monitored as a measure of the DGB's structural adequacy. Generally, Dr. Singh expressed his opinion that the cracks in the DGB were much more extensive than one sees in normal concrete work. Dr. Singh is of the opinion that the DGB is in secondary settlement and that future long term settlement would be about 1-1/4 inches over 30-40 years.

The primary concern of Mr. Joseph Kane involved the Applicant's assumption of a straight line, rigid body motion in the structural evaluation of the effects of settlement on the DGB. Mr. Kane was of the opinion that the settlement values measured by the applicant are appropriate to use in the structural analysis because the building did settle as the soil conditions would have indicated (i.e., nonuniform). Furthermore, Mr. Kane was not concerned about the accuracy of the settlement data because they are the best data available from the Applicant and were more appropriate to use than to assume straight line settlement. With regard to the structural analyses using actual settlement data, Mr. Kane observed 70-80% of the cracks to be in areas where the analyses indicated areas of high stress. Mr. Kane has documented his concerns in memos dated August 2, 1983 and are included in Attachments 1 and 2.

Dr. Lyman Heller met with the Task Group to express his concurrence with the concerns expressed by Mr. Kane. Dr. Heller also offered an explanation as to why cracks were observed in areas where the analyses of the DGB indicated low stresses. The explanation offered was that the settlement of the concrete forms (i.e., yielding) during the pour created discontinuities in the finished concrete which served as preferred paths for the development of cracks.

Dr. Gunnar Harstead, Mr. John Matra and Mr. Frank Rinaldi were interviewed together. Mr. Rinaldi, Mr. Matra and Dr. Harstead maintained that use of the measured settlements would be inappropriate given the accuracy between survey measurements of + or - 1/8". Such inaccuracies in the survey data would result in unrealistic concrete stresses. Mr. Matra discussed the finite element models he prepared and executed for various stages of construction using the settlement measurements as inputs.

He indicated that there was not sufficient settlement data points to make a reasonable stress analysis. To obtain the required input, Mr. Matra stated that he linearly interpolated between the measured settlement data points. As expected there was extremely high stress in areas where no cracks in concrete were observed. Both Dr. Harstead and Mr. Matra mentioned that stresses depended on higher order derivatives. These higher order derivatives cannot be determined accurately from the five measured data points. Mr. Rinaldi indicated the most appropriate method of estimating rebar stresses due to settlement was to estimate stresses from crack widths. This method produced rebar stresses of about 5 ksi which when added to the stresses from the controlling load cases was less than the 54 ksi allowable. Mr. Rinaldi described the crack monitoring program the Applicant agreed to (0.05 /10' as alert limit and 0.06" or 0.020"/10' as action limit). Finally, Mr. Rinaldi and Mr. Matra indicated that the controlling load case for the DGB was tornado depressurization which assumed the DGB to be unvented which is conservative considering the building is vented. Mr. Rinaldi documented his response to Landsman's concerns in a memo in Attachment 3.

Task Group Audit of Design Calculation

The Task Group visited the Bechtel, Ann Arbor, Michigan offices on September 12 and 13, 1983. The purpose of the visit was to conduct an audit of the structural design calculations of the Midland DGB.

On Monday, September 12, 1983 the NRC Task Group reviewed the following DGB calculations:

- concrete/rebar stresses using settlement data by Karl Wiedner;
- straight line (rigid body) settlement by Karl Wiedner;
- concrete/rebar stresses assuming the DGB is supported at four points;
- stress totals from all load combinations;
- finite element modal for DGB.

On Tuesday, September 13, 1983, the NRC Task Group discussed with Dr. Mete Sozen the calculations he did on rebar stresses estimated from concrete crack widths. Dr. Sozen had made calculations estimating rebar stresses from crack widths for the center cross wall only. A call was made to Mr. Rinaldi in Bethesda to verify how he made his calculations on the other walls. Mr. Rinaldi indicated he did the same type of analysis using Dr. Sozen's approach for other walls. However, Mr. Rinaldi did not document the details of his analysis.

Landsman Interview

The Task Group interviewed Dr. Landsman on September 13, 1983 for about 3 hours. Dr. Landsman discussed each of his concerns at length. During the interview, potential resolution of the problem of the DGB cracks was discussed. DR. Landsman agreed that stresses determined from analysis of crack widths would be acceptable, provided that:

(1) these calculations were sufficiently documented; and
(2) an acceptable crack monitoring program was specified and implemented.

A copy of Dr. Landsman's memo of July 19, 1983 documenting his concerns on the Midland Diesel Generator Building is included as Appendix IV.

APPENDIX III

Review of Diesel Generator Building at Midland Plant

by

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Table of Contents

1.0 INTRODUCTION

This report describes a study undertaken by Brookhaven National Laboratory (BNL) to evaluate the extent to which settlement cracks observed in the Diesel Generator Building (DGB) at the Midland Nuclear Power Plant impact on the ability of the building to satisfy design requirements. Dr. R.B Landsman, of Region III, has raised questions regarding this safety issue (Ref. 1). The specific objective of this study is to assess the significance of his comments and to prepare a written response.

This objective was achieved by reviewing the existing pertinent work (published reports, testimony and analytical studies), and by interviewing key personnel so that a correct interpretation of the work performed could be made. Additional calculations were specifically omitted from the scope of this study. All of the conclusions drawn in this report are based on an assessment of calculations and studies performed by others.

The study described herein was carried out during the period of August through September 1983. On August 4, a meeting was held at NRC to discuss the problem and to obtain some of the pertinent literature. Some of this literature was carried back to BNL while other documents were mailed to NRC during the following week. Appendix A contains a listing of all reports used during the program. On August 24, a meeting was held at Bechtel Corporation offices in Ann Arbor, Michigan. Presentations were made by Bechtel and Consumers Power staff summarizing the work performed by project personnel to demonstrate the adequacy of the DGB. Their consultant's (Dr. M. Sozen of the University of Illinois and Dr. G. Corley of Construction Technology Laboratories) also discussed their work. An inspection of the DGB was held on the evening of August 24 and during the morning of August 25. At this inspection, the cracks were observed although no new detailed crack maps were made. Discussions were held with construction personnel to determine the sequence of concrete placement.

Further interviews were held at NRC on September 8. Individual interviews were held with Dr. Harry Singh (soils consultant for NRC from the Army Corps of Engineers), Joseph Kane (NRC staff), and Lyman Heller (NRC staff).

A combined interview was also conducted with Frank Rinaldi (NRC staff), John Matra (structural consultant for NRC from Naval Special Weapons Center), and Dr. Gunnar Haarstead (structural consultant for NRC). The purpose of these interviews was to explore the role each played in the design and analysis of the DGB and to learn of their concerns regarding the adequacy of the DGB.

An audit of the DGB calculations by the task group was held at Bechtel's Ann Arbor offices on September 12 and 13. Dr. Sozen was present on September 13. The following items were reviewed in detail during this audit: numerical models used by Bechtel to calculate stresses in the DGB due to settlement; the magnitude of stresses due to the various load cases; the method of determining stresses from crack data; the accuracy of the survey methods used to monitor settlments; and the concrete pour data. A meeting was held with Dr. Landsman of Region III on September 13, at which time his specific concerns raised in Ref. 1 were discussed.

This report is organized as follows. An evaluation of the literature is presented in Section 2 of the report. Section 3 contains BNL's assessment of the adequacy of the DGB, while specific responses to Dr. Landsman's concerns are given in Section 4. Conclusions are listed in Section 5.

2.0 EVALUATION OF PERTINENT WORK

The material on the DGB which was reviewed during the course of this study is divided into six categories; namely, historical description of the structure and its settelment behavior; developed crack patterns; structural analyses to evaluate settelment stresses; treatment of other loads and stresses; and survey data. The material in each category is described and evaluated in this section of the report.

2.1 History of Structure

The DGB is a reinforced concrete shear wall building consisting of five cross walls connecting a north and south wall. The interior walls are 18" thick while the exterior walls are 30" thick. The structure is 155' by 70' in plan and is 51' high with an intermediate floor slab located 35' above the foundation. Wall footings are located under each of the walls, the footings being 10' wide and 30" deep. The building is founded on about 30' of various fills overlying the natural glacial till.

The fill was placed from 1975 through 1977 with construction of the DGB begun in October 1977. Concrete was placed in 6 lifts as follows:

October	1977	-	to Elev. 630.5 (foundation)
December	1977	-	to Elev. 635.0
March	1978	-	to Elev. 654.0
August	1978	-	to Elev. 662.0
December	1978	-	to Elev. 664.0
February	1979	-	to Elev. 678.3

Within each lift the pours were generally made from east to west. Construction joints occur in the middle of the cross walls and at the west end of each bay for the north and south walls.

Large settlements and cracks in the concrete were noticed while the lift going to Elev. 662 was being poured. Construction was halted while the problem was being studied. It was concluded that the large settlement was due to poor compaction of the fill material. This settlement caused the structure to "hang up" on the duct banks which penetrate the footings on the cross walls. The duct banks were cut loose from the DGB foundation in November 1978 and construction of the building restarted. In January 1979, 20' of sand surcharge was placed on the site to consolidate the fill. This remained in place until August 1979. In September 1980, a permanent dewatering system was installed to maintain the water table below Elev. 610.

2.2 Settlement History

The DGB is founded on approximately 30' of fill material, underlain by a very stiff glacial till about 190 feet thick. A dense sand layer about 140' thick lies below the till, which is in turn underlain by bedrock. The majority of the fill was placed at the site between 1975 and 1977, with actual foundation construction completed by January 1978. During July 1978, settlements of the order of 3.5 inches (Ref. 7) were noted which were greater than the original 40 year predicted settlements. Apparently consolidation of the fill was taking place as structural dead loads were applied. In addition, the four electrical duct banks under the structural crosswalls were acting as hard points to the foundation since they were in turn being supported by the stiff natural soils below the fill. This caused rotation of the building about the duct banks.

Construction was halted during August 1978, a soil boring program undertaken to determine the problem with the fill and Drs. R.B. Peck and A.J. Hendron retained to advise on the remedial action. The exploratory program consisted of 32 borings (with no undisturbed sampling) and 14 Dutch cone penetrometers. These confirmed that the fill had been improperly placed (in an extremely variable density state) and consisted of varying amounts of cohesive as well as granular backfill. Lean concrete was also encountered in the backfill. The thickness of silty clay backfill was found to be greater under the south-east side of the building leading to the generally larger settlements on this side.

A surcharge program was implemented to attempt to consolidate the fill more uniformly. In addition, the duct banks were cut loose from the foundation in November 1978 to eliminate the foundation hard points. Surcharging began in January 1979 and remained in place until August 1979, when it was determined that primary consolidation had been completed. Instrumentation (primarily settlement plates and Borros anchors) placed in the fill was used to arrive at this conclusion. It should be noted that the consolidation test results, obtained from undisturbed samples taken after completion of the surcharge program, did not confirm this conclusion. Data was sufficiently scattered to indicate that the fill may not be uniformly consolidated. Unfortunately, the boring program conducted after the surcharge program was completed, did not include cone penetrometer soundings for comparison with the readings taken before the surcharge was applied.

At the completion of the surcharge program, it was decided that since loose sands still existed in the fill, a permanent dewatering system would be installed to preclude the potential for soil liquefaction during a seismic event. This dewatering caused additional settlements to be developed at the site, but apparently these were related to deep seated consolidation of the natural soils under the fill, and would be more uniform than the settlements caused by the fill consolidation.

It is questionable whether the piezometer data was of any significance in analyzing the excess pore pressure condition developed in the fill during the consolidation process. The readings indicate generally very low pore pressures, about 1/20 the magnitude of the applied surcharge pressures. It is not clear in fact whether the fill was ever fully saturated at the time of the surcharge program.

Peak settlements anticipated at the end of 2025 (actual settlements to date plus secondary settlements from now till then) are specified in Ref. 7 to vary from 4.79 inches (under the NW corner) to 9.33 inches (under the SE corner). However, it should be mentioned that the exact settlement history at the various settlement markers at the DGB is open to question. For example, it is mentioned in Ref. 7 that the maximum settlements in August 1978 were about 3.5 inches. Yet the data used in the stress analyses for the presurcharge period (Figures ES-14 of Ref. 7) indicates peak settlements of only 1.99 inches. It was stated at one of the Bechtel presentations that prior to cutting the duct banks loose from the footing, footings along the North wall actually lifted off from the soil, with the DGB rotating about the duct banks. There is no indication of this behavior in any of the settlement data used in the computations. Ref. 8 lists the settlement increment from 8/79 to 12/2025 to be 2.36 inches under the SE corner of the building. For the same period Ref. 7 lists this data as 1.89 inches. Thus some inconsistencies appear to exist in the various documents.

2.3 Crack Patterns

After it was determined that settlement was a problem, Bechtel initiated a program to monitor cracks in the structure. In general cracks were visually observed and an optical comparator used to determine crack width. Crack widths greater than 10 mils were of specific interest as this corresponds to reinforcing stresses of about 10 ksi. Crack maps were prepared based on surveys conducted during December 1978, September 1979, February 1980 and July 1981. Dr. Corely observed the cracking in January 1982 (Ref. 6) and confirmed that the general pattern of cracks agreed with the July 1981 Bechtel crack maps. He prepared a detailed crack map for the center interior wall. A comparison of this center wall map (Fig. 4.21 of Ref. 6) with that prepared by Bechtel in July 1981 (Fig. 4.17) indicates that more cracking had occurred although the widths of the cracks appear to be about the same.

Cracks were observed during the BNL inspection of the plant on August 25, 1983 and some photographs taken. In general the pattern of cracks appears to be similar to the previously mapped cracks. However cracks, which had not been shown on any of the Bechtel cracks maps, were noted in both the north and south walls. These additional cracks are in the lower level (up to Elev. 664) and run at 45 degree angles to the horizontal up to the cross walls.

The first crack maps prepared from the December 1978 survey indicate vertical cracks in the cross walls which begin near the bottom of the wall and run up to Elev. 664 (this was the top of the concrete pour at the time the settlement problem was first noticed). The pattern of cracking is more severe in the east side of the building. This crack pattern is compatible with the model that assumes the cracks result from flexural stresses caused by the building "hanging up on the duct banks". No crack maps were prepared for the north or south walls.

Th second set of crack maps were prepared from the September 1979 survey. In general, many of the cracks which occurred in the east wall prior to placing the surcharge do not appear on these maps. The east center and center walls show the same type of crack patterns as shown on the first crack maps except for the appearance of additional cracks. These maps also show cracks in the upper level of the building. These cracks occur near the south side of the building in the cross walls. The cracks tend to be vertical with some inclination of the cracks near the south wall. Some cracks are indicated in these maps for the south wall. Primary cracking occurs in the east side of the wall and are concentrated in the upper portion of the wall. The north wall is shown to be more severely cracked than the south wall and contains mostly vertical cracks in the upper part of the wall. The cracks appear to be centered about the three interior walls.

The third set of crack maps were prepared from the July 1981 survey. These maps indicate the same type of cracking as before although the cross wall now contain more cracking near the north side of the building than was evident before. The west wall contains many more cracks than were shown previously. These cracks run from the Elev. 664 level down to the base of the structure.

It appears that many of the cracks which have occurred may be attributed to the building resting on the duct banks. Other cracks have occurred, however, which were most likely caused by differential settlement of the wall footings. Comparison of successive crack observations generally indicates that more cracks are occurring, but that the maximum size of the cracks is still about 20 mils.

2.4 Structural Analyses

The various analyses which have been used to evaluate stresses in the DGB are discussed in this section. The first analysis described is the method used by Bechtel to estimate stresses due to settlement for use in its load combination study. This analysis makes use of the straight line approximations to the profiles of the settlements of the north and south walls. The second and third analyses described are the Bechtel and Matra studies, which attempt to use the actual measured settlements to estimate settlement stresses. These analyses, though different in detail, lead to the similar conclusion that the settlement measurements were (and continue to be) in significant error. The fourth analysis describes a cruder model which attempts to approximate an upper bound to settlement stresses by looking at

Because their surveying was not accurate enough. OK for soils settlement but not OK for crack analysis the crack measurements. The first three analyses are based on detailed finite element models, while the fourth is based on crack patterns and crack widths.

2.4.1 Bechtel's Computation of Settlement Stresses (Ref. 2)

Since the building settlements occurred when the structure was in various stages of construction, the settlement stresses were evaluated for four different time periods. The first period spans from the beginning of construction through August 1978 at which time construction was halted. The second time period extends from August 1978 to January 1979 during which the duct banks were cut loose from the structure and construction resumed. The third time period extends from January 1979 to August 1979 during which time the surcharge was placed. The last time period extends to the year 2025 and includes measured settlements from August 1979 to December 1981 as well as the predicted settlements over the forty year life of the structure.

The actual measured settlements were used to calculate stresses for the first period. Stresses were calculated in each of the walls by determining the arc of a circle which fit any three adjacent measured displacements. The radius of the arc was then used to find the resulting bending moment in the wall, and the moment used to calculate stress. The maximum stress in each of the walls was assumed to exist over the entire wall. The stress in the south wall was 11.3 ksi; the east wall 6.6 ksi; and all other walls 2 ksi.

The increments in stress which occurred during each of the other three time periods were evaluated using a finite element model of the DGB. This model was constructed and run on the Bechtel version of SAP (BSAP). The building was defined with 853 nodal points. Plate elements were used to model the walls, and beam elements used for the footings. Eighty-four (84) boundary elements were used to model the vertical soil stiffness (equivalent to the coefficient of subgrade reaction). An iterative process was then used to determine the stiffness of these boundary elements. A best fit straight line was first fit through the measured settlements for the north wall and another straight line fit to the data for the south wall. It was shown that the measured displacements departure from the best fit straight lines is within the tolerance of the survey data. Dead load reactions were next estimated at each of the 84 boundary elements. The stiffness of any soil element was then determined as the ratio of the dead load reaction to the displacement of the best fit straight line. The BSAP program was run and the reaction found at each of these boundary elements. A new stiffness was then calculated as the ratio of the reaction to the displacement of the best fit straight line. This process was continued for several iterations.

It is our opinion that this model will yield unconservative estimates of stresses. If the iteration process were successfully completed, the deformation of the north and south walls will be straight lines. The only stresses that would be computed would then occur due to racking of the structure caused by the difference in the north and south wall straight lnes. It should be clear that if a best fit plane could be passed through all the settlement points under both the north and south walls, no stresses would be computed anywhere in the building. The stresses computed by this approach are a function of which iterative cycle is used to define to soil spring parameters, and bears no resemblance to the actual soil conditions at the site. There is no reason to expect that the soil stiffness should vary from point to point as shown by the analyses. We therefore conclude that this approach to compute settlement stresses is inappropriate.

2.4.2 Bechtel's Analysis Using Measured Settlements (Ref. 3)

This analysis was performed using the same finite element model described above. This time however, the known survey displacement data was input to the program at the ten (10) wall intersection points. The settlements used were the displacement increments measured for the fourth time period described above. At the remaining 74 boundary element points, the structure was allowed to deform as required to maintain equilibrium (forces equal zero). It was found that computed stresses were very high in those elements adjacent to the wall intersection, but fall off rapidly away from these points. This indicates that the analysis overly penalizes the structure by imposing large concentrated forces at the wall intersections. In fact, at some points, the soil is required to pull the structure downward to match these known displacements.

A modified analysis was performed by Bechtel at the suggestion of the task group. Rather than input only the ten known displacements, a smoothed curve was generated which matched the known settlement data, but eliminated the sharp profile changes developed in the analysis described above. A best fit polynomial was passed through both the north and south wall settlements, and displacements computed at all boundary element points of the finite element model. Comparative plots of wall profiles indicate that this approach would still yield high stresses.

2.4.3 Matra's Analysis Using Measured Settlements (Ref. 4)

The analysis performed by Matra is similar in intent to that described above. Differences between the two are as follows. First, this finite element analysis was performed for all four time periods described in Section 2.4.1. Three separate finite element models were used to define the DGB at various stages of construction. For each problem analyzed, the known settlement data at the wall intersection points was input to the models. The report does not specifically state what input was used at the remaining boundary element points between the wall intersection. However, at the interview, Matra stated that a linear displacement profile was assumed between these points. The stress results of the analyses are similar to those described above for the Bechtel study, with similar conclusions reached. In fact, it can be anticipated that the Matra stress calculations would be even higher than the corresponding Bechtel results due to the linear assumption between data points. If in fact this was done, the conclusions reached in that report would be of little value since such high bending stresses would be generated at these discontinuities.

2.4.4 Estimation of Stresses from Crack Data (Ref. 5)

Sozen considered the problem of predicting reinforcement stresses from a knowledge of the crack patterns. He observed that the usual problem is to predict crack width based upon a given reinforcement stress. When these methods are applied to the DGB center wall, a 20 ksi steel stress is consistent with a crack width of 20 mils. He also adds the crack widths for a series of cracks in the center wall and equates this to the total elongation in the reinforcement. Using an estimated gage length over which this elongation occurred he obtains an estimated stress of 24 ksi, and indicates a probable range of 20-30 ksi considering the uncertainties of the method. (This was presented by Sozen at the August 24 meeting). It is likely that these stress values would be reduced with time. A major cause of cracking was the hard points provided by the duct banks. When these were cut free, one would expect the stresses induced by the uneven support to be relieved. Creep in the concrete would also tend to relieve the settlement-induced stresses.

Rinaldi (pg. 11086 of the testimony) reported at the interview of September 8, that he calculated stresses using Sozen's method in each of the 5 cross walls, as well as the north and south walls. He then added these stresses to the maximum stress reported in each of the walls by Bechtel. The resultant maximum reinforcement stress was found to be less than 54 ksi (the allowable limit). It was noted that the Bechtel stresses already included settlement stresses (to an unknown degree however) from the analyses described in 2.4.1. The crack-based estimates of settlement stresses were added to the maximum of the Bechtel stresses without regard to where they occurred. While this is a conservative approach, there is no documentation of the computations. It should be noted that there would be some question in the application of this method on those walls where relatively few cracks occurred.

2.5 Stress Totals

The finite element model described in 2.4.1 was used to calculate wall forces from all loadings except for the seismic loading. A lumped mass model was used to determine forces resulting from the seismic loading. These forces were then combined according to the load combinations required in ACI 318 and ACI 349. Critical elements were then identified in each of the walls and Bechtel's program OPTCON used to evaluate reinforcement stresses. OPTCON determines the reinforcement stress resulting from out-of-plane bending moment plus in-plane shear loading. The shear capacity of the concrete is deducted from the total shear load with the difference assumed to be carried by the reinforcement. The following are peak reinforcement stresses reported by Bechtel for the critical load cases: north wall - 22 ksi; south wall - 34 ksi; west wall - 29 ksi; east wall - 23 ksi; and interior walls - 20 ksi. The allowable steel streess is 54 ksi.

2.6 Survey Data

Bechtel reports that the accuracy of the survey data describing the DGB settlements is 1/8" until the surcharge was removed and 1/16" since that time. Standard survey techniques and equipment were used.

3.0 ASSESSMENT OF THE DIESEL GENERATOR BUILDING

The DGB has undergone very large settlements which have undoubtedly caused serious structural distress. This distress is manifested in the cracks which have occurred in the building. The purpose of this section of the report is to give an opinion as to (1) whether the building is structurally sound and (2) whether the building still meets the criteria as stated in the FSAR.

An important issue is whether the major part of the settlement has occurred. The settlement data indicate that settlements are well into the secondary consolidation phase so that large additional settlements would not be anticipated. This leads to confidence that predictions of the adequacy of the structure based on settlements which have taken place to date should hold for the life of the structure. Certainly, settlements should be monitored and the problem reconsidered should more than the anticpated additional settlements occur. Relative settlements of points on the structure of .005" are significant. The accuracy of the settlement measurements should be refined to reflect this requirement.

While significant cracking has occurred in the structure, it would appear that there is little evidence to indicate that the structure is unsound. The structure is very massive and is not subjected to large loadings. Even the tornado and seismic loadings do not introduce large stresses and usually these stresses occur at locations that are not critical locations for the settlement stresses.

It is difficult to show that the stresses in the DGB meet the criteria of the FSAR. Bechtel's straight line analysis (see 2.4.1) is based on the claim that the settlement survey data is not sufficiently accurate to calculate structural stresses. The adjustment they make to account for this inaccuracy gives results that are likely unconservative. If conservative assumptions are made then the calculated stresses are too large to satisfy the criteria and not consistent with the crack patterns observed in the structure (see 2.4.2). It is doubtful whether any analysis could now be developed which would provide more realistic estimates of settlement stresses with the required degree of confidence.

The most likely source for obtaining reasonable estimates of settlement stresses are the crack studies (see 2.4.4). However, these studies must be documented much more completely than has been done to date. It is imperative that significantly better methods be used to monitor crack growth than is currently being considered. Whitemore strain gages should be used extensively. Plugs are attached to the concrete on a 2" gage. An instrument is then used to measure the distance between the plugs. Accuracies of .0001" is routine. Such gages would give a good picture of the overall behavior of the cracks. It should be noted that the repair of cracks would not interfere with the use of these instruments. No special "windows" need to be maintained during the crack repair program. This program of crack monitoring is also important because there is some indication that cracks in the DGB have not stabilized and that the number of cracks may in fact be increasing.

4.0 RESPONSE TO CONCERNS OF R.B. LANDSMAN

The Region III inspector has raised four concerns (Ref. 1) regarding the adequacy of the DGB. Each of these is addressed in the following.

Concern 1: FINITE ELEMENT ANALYSIS

The first concern deals with the Bechtel finite element models (see 2.4.1 and 2.4.2) of the DGB used to evaluate stresses due to settlement. There are four objections made to the models.

Concern is raised with regard to the use of uncracked section properties while the concrete is known to be cracked. All concrete structures are cracked and it is standard practice (specifically permitted in the ACI code) to determine forces in concrete structures based on gross section properties (i.e., neglect the cracks in the concrete and the reinforcement). If cracked section properties were used then the stresses calculated by Bechtel (2.4.1) would have been smaller. Therefore neglecting cracks in this analysis is a conservative approximation. On the other hand, the analysis reported in 2.4.2 was used to show that the measured settlements result in stresses which are so high that much more severe cracking would be expected than was observed. It was then argued that the measured values must be in error. If cracked sections were assumed for this analysis the calculated stresses would have been smaller, but probably still not consistent with the observed crack patterns.

The straight line representation of the settlements along the north and south wall for the analysis reported in 2.4.1 is said to be in error. As indicated in that section of this report, it is our opinion that this analysis will result in unconservative predictions of stresses due to settlements. As such, it is considered to be an inappropriate analysis.

The third part of this concern raises questions regarding the time effects of the settlements. Bechtel does calculate stresses for different phases of the settlement. The structure was changing during the significant settlement period. Construction was still in progress during the largest settlements. Therefore the structural geometry changed as did the concrete properties (while maturing). The Bechtel models did not account for these changes. This would have been conservative for the calculation of stresses, but would result in lower stresses in the analyses performed using the measured settlements as input.

The fourth objection deals with the claim that the NRC staff did not approve of the Bechtel analysis. It appears that this is the case and the intention of the staff was to use settlement stress data based on an analysis of the cracks rather than the finite element analyses.

Concern 2: RELIABILITY OF MEASURED SETTLEMENT VALUES

The analyses reported in 2.4.2 and 2.4.3 were used to show that stresses computed from structural models subjected to the measured settlements are very high and would indicate cracking in the structure where no cracks are observed. The objection is raised that a linear model was used and that a non-linear model accounting for plastic effects would result in a redistribution of stresses and the same conclusion may not apply. This observation is true, but by itself would not change the conclusions drawn from these analyses.

As stated above, however, there are other factors which when coupled with this objection may result in a different conclusion. The other important factors are: the assumed shape of the settlement between the measured points; and the differing geometry of the DGB when the various phases of settlement occurred.

Concern 3: STRESSES DETERMINED FROM CRACK SIZES

If the finite element analyses are not reliable then one alternative approach is to find settlement stresses from a study of the crack sizes. The objection raised is that this approach is not consistent with normal engineering practice and that there are no equations available to evaluate stresses from crack data when the stress fields are as complex as occur in the DGB. It is true that this would not be standard practice, but "non-standard" analyses may be used provided they are sufficiently documented and shown to give results that are conservative.

An approach that could predict approximate settlement stresses in the DGB could probably be used to demonstrate its adequacy. This is true for two reasons. First, stresses in the structure due to other loadings are rather low and there is a large reserve for settlement stresses. Second, if large settlement stresses and local yielding of the reinforcement occurs, the resulting deformations of the structure will reduce the settlement induced loadings.

The documentation of the crack analyses used to determine stresses is not sufficient. There is no calculation on record which calculates stresses in all of the walls using this method. There is also no written justification showing that the method may be used for structures like the DGB.

Concern 4: CRACK MONITORING

This concern deals with the lack of a good crack monitoring system and specification of action to be taken if the cracks exceed certain limits. As stated in Section 3.0, it is our opinion that the planned crack monitoring system is not adequate. More reliable gages (e.g., Whitemore Strain Gages) should be placed in areas where cracking is now evident. These gages can be used even after crack repairs are made.

Two limits are now defined in the current crack monitoring program. If the crack width reaches .05" (Action Limit) a meeting will be held to evaluate what steps to take when the cracks reach the next limit. The next upset limit is set at .06" (Alert Limit). It is our opinion that the form of this plan is adequate, but that the specific threshold numbers must be based on a resolution of the current settlement stresses. A safety margin must be left for the other potential loading events, such as tornado or seismic loads, with the remaining allowable stress allocated to future potential settelments.

Once this limit was reached the only solution would be to make a structural repair. The exact form of this repair would depend on the location and extent of the crack which exceeded the limit. The planned response could not specify the nature of the repair, but could indicate that an exceedance of the Alert Limit would result in a structural repair rather than performing additional analyses.

5.0 CONCLUSIONS

Based on the review of the studies performed to demonstrate the adequacy of the DGB, the following conclusions are drawn:

1. The settlement data indicates that primary consolidation of the fill is completed. However, it is recommended that the anomolies in the documentation of the settlement history be resolved. (See last paragraph of Section 2.2).

2. It is unlikely that a satisfactory stress analysis can be performed based on the measured settlement data. It is recommended that settlement stresses be estimated from the crack width data. The existing work that has been done in this area must be completely documented.

3. It appears that the number of cracks in the DGB are continuing to increase. It is essential that a better crack monitoring program be established as outlined in Section 3.0.

4. The upset crack width levels specified in the crack monitoring program should be chosen so that a sufficient stress margin is available to resist the critical load combinations.

5. If the Alert Limit (in crack width) were exceeded, specific structural repairs should be mandated.

6. While significant cracking has occurred in the DGB, it is our opinion that the structure will continue to fulfill its functional requirement. This conclusion is based on the fact that stresses induced in the structure by all other extreme loadings are small.

REFERENCES

1. Memorandum for R.F. Warnick through J.J. Harrison from R.B. Landsman, Subject Diesel Generator Building Concerns at Midland, dated July 19, 1983.

2. Bechtel Calculation No. DQ-52.0 (Q), Rev. 2.

3. Bechtel Calculation No. DQ-52.7 (Q) - Finite Element Calculation of Settlement Stresses Using Actual Displacements.

4. Structural Reanalysis of Diesel Generator Building Utilizing Actual Measured Deflections as Load Input, by John Matra, Naval Surface Weapons Center.

5. Evaluation of the Effect on Structural Strength of Cracks in the Walls of the Diesel Generator Building Midland Plant Units 1 and 2, by Mete Sosen, February 11, 1982.

6. Effects of Cracks on Serviceability of Structures at Midland Plant, by W.G. Corely, A.E. Fiorato, and D.C. Stark, April 19, 1982.

7. Executive Summary, Diesel Generator Building, Midland Plants Units 1 and 2, August 1983.

8. Letter from CPCo to NRR dated October 21, 1981; Enclosure 1, Tech. Report, Structural Stresses Induced by Differential Settlement of the DGB.

APPENDIX A: SOURCE MATERIAL FOR STUDY

Site Specific Response Spectra	Midland Plant Units 1 & 2 Addendum to Part 1 Response Spectra--Orginal Ground Surface Jan 81 Weston Geophysical Corp
Site Specific Response Spectra	Midland Plant Units 1 & 2 Part II Response Spectra Applicable for the top of fill material at the plant site April 81 Weston Geophysical Corp
Site Specific Response Spectra	Midland Plant Units 1 & 2 Part III Seismic Hazard Analysis Feb 81 Weston Geophysical Corp
Soil Boring and Testing Program	Midland Plant Units 1 & 2 Test Results Foundation Soils Auxiliary Building Woodward-Clyde Consultants Aug 81 Docket No-. 50-329,50-330

Test Results Perimeter and Baffle Dike Areas Soil Boring and Testing Program
Volume II Supporting Data July 81
Docket Nos. 50-329,50-330

Test Results Perimeter and Baffle Dike Areas Soil Boring and Testing Program
Volume I
Woodward-Clyde Consultants July 81
Docket Nos. 50-329,50,330

Estimates of Maximum Past Consolidation Pressure of Cohesive Fill Materials
Diesel Generator Building
July 81 Woodward-Clyde Consultants
Docket Nos. 50-329,50-330

USA/NRC Before The Atomic Safety and Licensing Board 12/7/82
testimony of; Frank Rinaldi
John Matra
Gunnar Harstead
with respect to the Structural Adequacy of The Diesel Generator Building at Midland

Official Transcript Proceedings Before NRC Atomic Safety and Licensing Board
DKT/CASE No. 50-329,50-330 OL & OM
12/10/82 pages 11008 through 11228

Evaluation Report for Concrete Cracks in the Diesel Generator Building
Consumers Power Company 2/16/82

Evaluation of the Effect on Structural Strength of Cracks in the Walls of the Diesel Generator Building   Mete A. Sozen 2/11/82

Relationship of Observed Concrete Crack Widths and Spacing to Reinforcement Residual Stresses   Consumers Power Company 6/14/82

Observed Cracks in Walls of Midland Plant Structures   6/14/82
Corley and Fiorato
Portland Cement Association

Safety Evaluation Report related to the operation of Midland Plant
Docket Nos. 50-329 and 50-330
Consumers Power Company
USNRC 5/82

Effects of Cracks on Serviceability of Concrete Structures and Repair of Cracks
Consumers Power Company 4/30/82

Effects of Cracks on Serviceability of Structures at Midland Plant
Corley, Fiorato, Stark
Portland Cement Association

Summary of Sept. 8, 1981 Meeting on Seismic Input Parameters   Midland Plant
USNRC 12/3/81

USA/NRC Before the Atomic Safety and Licensing Board   50-329,50-330
testimony of Jeffrey K. Kimball   9/29/81

NRC Atomic Safety and Licensing Board 50-329 OM,OL 50-330 OM,OL
witnesses; Johnson
Burke
Corley
Sozen
Gould

NRC Before the Atomic Safety and Licensing Board   (no date)
NRC staff testimony of Joseph Kane
on Stamiris Contention 4.B
Docket Nos. 50-329 OM,OL 50-330 OM,OL

Safety Evaluation Report related to the operation of Midland Plant   October 82
Docket Nos. 50-329 50-330
USNRC NUREG-0793 Supplement No. 2

Safety Evaluation Report related to the operation of Midland Plant   June 82
Docket Nos. 50-329 50-330
USNRC NUREG-0793 Supplement No. 1

NRC Atomic Safety and Licensing Board   9/29/81
Applicant's Brief on Compatibility of Site Specific Response Spectra Approach with 10 CRF part 100 Appendix A

Safety Evaluation Report related to the operation of Midland Plant   May 82
Docket Nos. 50-329 50-330
NUREG-0793

Response to the NRC Staff request for Settlement Related Analyses for the Diesel Generator Building   6/1/82
Consumers

Technical Report   Structural Stresses Induced by Differential Settlement of the Diesel Generator Building
Consumers Power Company

Test Results of Soil Boring and Testing Program for Diesel Generator Building
Docket Nos. 50-329 50-330   7/31/81
Consumers Power Company

Final Results of Soil Boring and Testing Program for Perimeter and Baffle Dike Areas   7/27/81
Docket Nos. 50-329 50-330
Consumers Power Company

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Kane
Singh
Rinaldi

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Kane   Matra
Hood
Singh

CSE Input to the Midland SER Supplement   Aug. 82
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50-330 OM-OL

Testimony of Dr. Paul F. Hadala with Respect to the Study of Amplication of Earthquake Induced Ground Motions and the Stability of the Cooling Pond Dike Slopes Under Earthquake Loading 9/29/81

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Witnesses; Boos
Hendron
Hanson

Testimony of Ralph B. Peck before the Atomic Safety and Licensing Board, in the the matter of Consumers Power Company (Midland Plant, Units 1 and 2), Docket Nos. 50-329 OM, 50-330 OM, 50-329 OL, 50-330 OL, notarized Nov. 3, 1982.

Letter from CPCo to H.R. Denton dated June 14, 1982 with Enclosure "Response to the NRC Staff Request for Additional Information Required for Completion of Staff Review of Soils Remedial Workd dated June 14, 1982.

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"Structural Reanalysis of Diesel Generator Building Utilizing Actual Measured Deflections as Input", by John Matra.

Letter from CPCo to H.R. Denton dated October 21, 1981 with Enclosures:
"Structural Stresses Induced by Differential Settlement of DGB",
"Subgrade Modulus & Spring Constant Values for DGB Structural Analysis",
"Bearing Capacity Evaluation of DGB Foundation"
"Logterm Monitoring of Settlement for DGB",
"Relative Density and Shakedown Settelment of Sand under DGB",
"Estimates fo Relative Density of granular Fill Materials, DGB",
"Review and Control of Facility Chagnes to DGB",
"DGB Bearing Pressaure due to Equipment and Commodities",

Report form Woodward-Clyde to CPCo dated June 10, 1981, "Preliminary Test Results, Soil Boring & Testing Program, Perimeter and Baffle Dike Areas",

"Seismic Margin Review, Midland Energy Center Project": Volumne 1, Methodology and Criteria, dated February 1983, Volume V, Diesel Generator Building, dated July 1983, prepared for CPCo by Structural Mechanics Associates.

Applicant's Propsed Findings of Facts and Conclusions of Law on Remedial Soils Issue

Docket Nos. 50-329-OM
50-330-OM
50-329-OL
50-330-OL

Testimony of Karl Weidner for the Midland Plant Diesel Generator Building September 8, 1982

Docket Nos. 50-329-OL
50-330-OL
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50-330-OM

Find Report on the ADINA Concrete Cracking Analysis for the Diesel Generator Building by Gygna Energy Services, September 16, 1981

APPENDIX IV ENCLOSURE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION III
799 ROOSEVELT ROAD
GLEN ELLYN, ILLINOIS 60137

JUL 1 8 1983

MEMORANDUM FOR: R. F. Warnick, Director, Office of Special Cases

THRU: J. J. Harrison, Chief, Section 2, Midland

FROM: R. B. Landsman, Reactor Inspector

SUBJECT: DIESEL GENERATOR BUILDING CONCERNS AT MIDLAND

At the recent hearing before Congressman Udall's subcommittee, I expressed my concern regarding the structural adequacy of the diesel generator building because of numerous structural cracks that have occurred throughout the building over the years. I also expressed the same concern during the recent ASLB hearings. Mr. Eisenhut has requested me to document the basis of my concerns about the building so an independent review group can analyze them.

My first concern deals with the finite element analysis that Consumers Power Company (CPCo) used to show that the building is structurally sound. Their model of the building assumed a very rigid structure without any cracks. The building has numerous cracks, reducing the rigidity of the structure. The effects of these cracks have not been taken into account in the analysis. CPCo's interpretation of the settlement data as a straight line approximation always stems from their position that the building is too rigid to deform as indicated by actual settlement readings. The settlement of the building occurred over a period of time during different phases of construction. It is this time dependent effect that was also not used in their model. Even CPCo expert Dr. Corely testified at the ASLB hearings that the analysis should have "taken into account cracking and time dependent effects" in order to give correct results. Finally, the staff's official position, as stated by Dr. Schauer, on CPCo's analysis was, "The staff takes no position with regard to that analysis."

My second concern deals with the acceptance of the diesel generator building in the SSER #2 which was subject to the results of an analysis to be performed by the NRC consultants using the actual settlement values. The consultants testified at the ASLB hearing that this analysis gave unacceptable results and this portion of the SSER should be stricken. They are basing their unacceptable results and comments on their finding of

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very high stresses obtained in areas where no cracks exist. Therefore, the actual settlement values are not accurate enough (are in error) to be used in an analysis. The consultants, as well as CPCo, ran a linear analysis (structure always in the elastic range) instead of a plastic analysis which would allow a redistribution of loads in the structure. Therefore, supposed areas of high stress, where cracks are not located, may not exist due to redistribution of loads. Finally, the staff's official position, as stated by Mr. Rinaldi, on this analysis as performed by the consultants, was that the actual settlement values could not be relied upon to determine if the diesel generator building meets regulatory requirements.

My third concern deals with the fact that we are not following normal engineering practice in accepting the building by using a crack analysis approach because there is no practical method available today to analyze a complex structure with cracks in it. The basis of this concern is that there are no formulas available that can estimate stresses in a complex stress field like those which exist in this building. Thus, the evaluation of the structure based on the staff's crack analysis using empirical unproven formulas to determine the rebar stresses is unacceptable.

My fourth concern deals with the staff accepting the building by relying on a crack monitoring program to evaluate the stresses during the service life of the building. If cracks exceed certain levels, recommendations will be made for maintaining the structural integrity of the building. The basis for my concern deals with the lack of crack size criteria and the lack of formulated corrective action to be taken when the allowed crack sizes are exceeded.

These concerns which I have just enumerated are also shared by members of Mr. Vollmer's engineering staff, as well as their consultant. These concerns were documented in the ASLB hearing transcripts of December 10, 1982, prior to my ever expressing my concerns before the ASLB hearing or Congressman Udall's subcommittee.

In summary, since it is impossible to analyze this severely cracked structure to the total staff's approval, I recommend some remedial structural fixes be undertaken to ensure the structural integrity of the building to provide an adequate margin of safety.

Ross B. Landsman

Ross B. Landsman
Reactor Inspector

cc: DMB/Document Control Desk (RIDS)