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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE ON THE QUALIFICATION PROGRAM FOR
SAFETY RELATED EQUIPMENT

- - -

Nuclear Regulatory Commission
Room 1167
1717 H Street, N.W.
Washington, D.C.

Tuesday, January 15, 1986

The subcommittee convened, pursuant to notice, at 8:30 a.m., C. Wylie, Chairman of the Subcommittee, presiding.

<u>ACRS Members Present:</u>

C. WYLIE, Chairman
J. EBERSOLE
G. REED
D. WARD
C. SIESS

<u>ACRS Consultant Present:</u>

W. LIPINSKI

<u>ACRS Cognizant Engineers Present:</u>

R. SAVIO
A. CAPPUCCI

<u>NRC STAFF AND PRESENTERS PRESENT:</u>

T. Y. CHANG
J. THOMAS
A. ROBY
P. YANEV
S. EDGAR
B. BOSNAK
N. ANDERSON

PUBLIC NOTICE BY THE

UNITED STATES NUCLEAR REGULATORY COMMISSIONERS'

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

WEDNESDAY, JANUARY 15, 1986

The contents of this stenographic transcript of the proceedings of the United States Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards (ACRS), as reported herein, is an uncorrected record of the discussions recorded at the meeting held on the above date.

No member of the ACRS Staff and no participant at this meeting accepts any responsibility for errors or inaccuracies of statement or data contained in this transcript.

N. SMITH
B. SCHMIDT
P. Y. CHEN

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P R O C E E D I N G S

MR. WYLIE: The meeting will come to order. This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on the Qualification Program for Safety-related Equipment.

I am Charlie Wylie, subcommittee chairman. Glenn Reed, to my left, is the ACRS member in attendance. And Dr. Siess is joining us in a little bit. Jesse Ebersole and Dave Ward will be joining us later this morning, also subcommittee members, ACRS members.

Also in attendance is ACRS consultant Walter Lipinski. And Richard Savio and Tony Cappucci are the Staff Cognizant Engineers with us this morning.

The purpose of this meeting is to discuss resolution and implementation of USI A-46. SQUG evaluation of the March 1985 Chilean earthquake and the preliminary evaluation of the recent Mexican earthquake will also be discussed.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on Thursday, December 19, 1985. We received no written comments from members of the public, and we have received no requests for time to make oral statements from members of the public.

We've got a full agenda today, so I will ask the

presenters to be brief and to try to stay on schedule.

I believe a schedule has been passed out, and we will have presentations from the staff on the proposed resolution and comments on the staff's proposed resolution from the Seismic Qualification Utilities Group, the Atomic Industrial Forum, and a report on the implementation of the SQUG program.

And we will discuss comments, following Mr. Thomas' presentation, by the subcommittee as to what will be presented to the main committee at its February meeting. There has been two hours allotted at that meeting for presentations on this subject.

Following that, we will have a closed meeting on the equipment qualification research budget.

I will ask whether there are any comments that Mr. Reed would like to make?

MR. REED: I notice in Item 5 you have a discussion on the Chilean earthquake. It seems to me in August we got a pretty thorough rundown on that with respect to the eight areas. Are we going to repeat that, or what is the plan?

MR. WYLIE: As I understand it, today's presentation is to be directed more equipment-specific as pertains to the various classes of equipment rather than general damage. Perhaps Mr. Thomas might want to comment

about that, or Mr. Yanev.

MR. THOMAS: We can really present that any way you would like us to. I think what you just said is our intent, is to try to give you a little more information on the specific equipment. I would kind of like to start out with an overall summary of both earthquakes and their impact, and then try to get some specific information on the next category of equipment that you haven't seen before; then after that, a little more equipment-specific on Chile.

MR. REED: Well, all I am saying is I had a very thorough briefing before on Chile, and I just don't think we should concentrate on that.

MR. THOMAS: Well, we're mainly interested in pertinent and new information rather than old.

Dr. Siess, do you have any comments?

MR. SIESS: Not knowing what went before, I will save them.

MR. WYLIE: What about Walter Lipinski?

(No response.)

MR. WYLIE: All right. Well, suppose we proceed then, and I will call on the first speaker. We have Mr. Chang.

MR. CHANG: My name is T.Y. Chang. I am the Task Manager of A-46. Today I would like to present our

proposed resolution of public comments on A-46.

Here is a brief rundown of what has transpired. We talked to CRGR back in July last year, and they reviewed the package. And they recommended to have the package issued for public comment. And the package was issued for public comment in September, and comments were due in the middle of November.

The proposed resolution of comments now is complete. I have to remind you that the NRC management has not yet reviewed the comments.

The originators of public comments, we got comments from eight utilities. Some of them belong to the SQUG. Two industry groups, the SQUG and the Nuclear Utility Group on Equipment Qualification. One national lab, the Sandia. And also we received comments from EPRI and the AIS.

I have grouped the comments according to the issues in different categories. The numbers appearing after each title is the number of comments we received on the issue.

The most comments received are the top several ones. The application of backfit rule, justification for A-46 review, we got ten comments on those. Implementation Schedule, 12. Relay review guidelines, ten. Scope of review, ten, and so forth.

I am going to go into each one now. This is the rest of the categories.

The first one is on the backfit issue. The first comment is, "The new backfit rule should be applied to the resolution of A-46." And then the second one is, "Regulatory analysis does not properly quantify cost benefit." And also, they believe, "The earthquake experience shows that the equipment is inherently rugged; therefore, no need to do review."

Our response to the first comment is that we quote from the backfit rule. It requires the "systematic and documented analysis for backfit that the NRC seeks to impose on the utilities." We believe when they say analysis, quantitative analysis is one of the alternatives, we believe the quantitative PRA analysis for evaluating the risk reduction from seismically qualifying equipment has very high uncertainty and it's highly dependent on the assumptions.

So we don't think that a quantitative analysis is very too meaningful here.

MR. SIESS: Excuse me. Is that statement intended to apply exclusively to seismic?

MR. CHANG: Yes. Just for the seismic qualification of equipment.

MR. SIESS: Because quantitative PRA analyses are

being used in many other areas of the regulatory process?

MR. CHANG: Yes. Agreed. The reason is that the seismic qualification procedure itself does not really change the risk. Only if you actually physically modify the equipment, then there will be some change. So the qualification process itself will not really change the fragility of the equipment.

MR. SIESS: It will change the uncertainty, though, which seems to be driving a lot of people on risk analysis.

MR. ANDERSON: Well, I think that this statement is even more specific than that, because what we're considering is that this numbers that can be estimated from this type of an exercise on equipment is highly dependent upon the assumptions that you make.

MR. SIESS: About what?

MR. ANDERSON: Like, well, if we would assume that a piece of equipment has not been qualified or has not been verified to be seismically adequate, that it's going to fail given an SSE, then it would drive -- you'd develop an extremely high core melt probability. On the other hand, if we would assume that it's going to survive, then we would see no safety benefit at all.

And we don't know how to make that assumption, and we think it's so dependent upon the assumptions that

you make, that we can't develop the meaningful information in this instance. We're not saying that PRAs should not be used and aren't any good.

MR. SIESS: But it seems to me that exactly the thing you're saying you can't do is being done in other PRAs.

MR. ANDERSON: I understand that. And we're very carefully looking at the uncertainties.

MR. SIESS: What I am hearing is that this element of the stuff doesn't want to use PRA if there's -- there might be very good reasons, but there are other people on the staff that are using PRA to make decisions where the same reasons would apply.

Is there any policy in the same level in the staff, or is this, you know -- you fellows are skeptical and somebody else --

MR. BOSNAK: I think in this particular area we feel that you either assume that you're going to have complete failure of the equipment, you know, or you go all the way over to the other side and you make some assumptions about where the equipment is going to be able to function and where it isn't.

So we believe in PRAs, but we also believe that there are a lot of assumptions that you have to make, and if you aren't sure, you aren't positive about the

assumptions, then you have to proceed with caution.

I don't know if that answers your question.

MR. SIESS: Well, I mean, that's a great statement. I would like to see it inscribed in stone. I guess my concern is that the questions you've raised I think apply in other areas of PRA --

MR. BOSNAK: Well, they do. They do.

MR. SIESS: -- and the staff in other areas seem to be putting considerable weight on PRAs.

MR. ANDERSON: Well, the only policy -- excuse me, I didn't mean to interrupt you.

MR. SIESS: I think you're taking a not unreasonable approach.

MR. ANDERSON: But with regard to your question about the policy, my understanding is that the policies that the NRC applies in using PRAs is that they not be used in an absolute sense, that they are used to determine the relative risks between systems and functions only, and that the PRA methodology is not mature enough to gain a lot of confidence in the absolute numbers that they're cranking in.

MR. SIESS: But you see, one thing that drives this whole thing is PRAs. This is not unrelated to seismic margins, which is being driven by the fact that PRAs have been made to show seismic as, quote, a major contributor to

risk, partly because of the assumptions that have been made.

Now, we use PRA to start this thing, but we won't use PRA to end it.

MR. CHEN: May I add something? Dr. Siess, to answer your question, the PRA you are talking about, I think it is more plant-specific, and therefore, it's more meaningful. But in here, you are trying to address it generically, using PRA for A-46. I think we already had one of the programs in the Brookhaven look at the seismic risk. We found out -- and that is plant-specific -- it's very hard to draw a conclusive conclusion.

MR. SIESS: I think that's a very legitimate statement. So you're trying to settle some of it as highly plant-specific on a generic basis, and that is another kind of an issue. I think that we need to consider. In fact, I think that was something that was addressed by the comments.

But this, many aspects of the resolution of A-46 are plant-specific. And yet it is, quote, a generic item.

MR. ANDERSON: It is generic, but its application has to be very plant-specific.

MR. SIESS: It's a generic issue, but it can't be applied --

MR. CHANG: There was a PRA study done by

Brookhaven National Lab for our A-46, and the conclusion is that they study is really very plant-specific and depends on the system and also plants. It's very hard to generalize the conclusion from there for the A-46 issue.

I might add also that the fragility data is very limited on equipment, so there is a lot of assumptions that have to be made on the fragility. That is another source of uncertainty.

MR. SIESS: Yes, but the whole object of the SQUG was to eliminate some of those uncertainties on fragility, or at least to raise the threshold.

The design basis would say anything greater than the SSE, everything fails. And this is the way Chapter 15 analyses are made, and SQUG essentially says, with certain exceptions, it's two or three times the SSE before you want to consider everything fails.

The two big uncertainties in seismic PRAs are the hazard -- you've done nothing to change that, obviously -- and the fragilities. But this whole thing has been addressed to raising the threshold of uncertainty on fragilities. It seems to me that's what the effort is.

MR. CHANG: Well, if this constraint is not all the way to the fragility level, all we are interested in then is to look at seismic adequacy at the level of earthquake we're talking about, SSE level. Fragility

certainly goes much higher beyond that, and that's not really in the realm of A-46 study.

MR. SIESS: Well, strictly in A-46 you're looking at seismic adequacy at the SSE level.

MR. CHANG: SSE level only.

MR. SIESS: And I guess when you get down to the design-basis events, PRA is not much application anyway.

MR. ANDERSON: That's correct. In addition to that, the study that we did was not done to the level of detail that would show individual components. It shows major components and systems, and there was an attempt made to order the various systems and major components in the order of this significance.

MR. SIESS: All right. Now, you said "plant-specific."

MR. ANDERSON: Yes.

MR. SIESS: When you say "plant-specific," what comes to mind now are the SEP plants, and the seismic capability, with qualification, was an issue in the SEP plants.

MR. ANDERSON: Correct.

MR. SIESS: And in some cases, that was addressed on a PRA-type basis. There were limited PRAs, evaluations of significance.

MR. ANDERSON: I wasn't aware of that. They

did? Oh, just one. Okay.

MR. CHANG: Big Rock.

MR. ANDERSON: Oh, the Big Rock. Yes.

MR. SIESS: Well, Big Rock, you know, every plant was looked at.

MR. ANDERSON: Yes.

MR. SIESS: The decision as to what to be done in terms of seismic upgrading, seismic qualification, sometimes was governed by PRA. Big Rock was an outstanding example. We don't know where it ends up yet, but the last I heard on Big Rock is they would start with the things that were most important and fix them until they spent a million dollars and quit. That's all they could afford to spend.

MR. WYLIE: Okay. Let's proceed.

MR. ANDERSON: Yes, sir.

MR. REED: I am trying to see the broad aspect here. I guess from the comments that the backfit rule should be applied, you agree that it should be applied?

MR. CHANG: Yes. We agree upon that.

MR. REED: That's not clear in your response.

The second thing is that we get into this argument about qualitative versus quantitative, and I am wondering how qualitative is qualitative. Apparently, you're not going to use PRA, so how much is there to

qualitative?

Does qualitative take into consideration, for instance, that a plant, say, is located in a zone zero damage area? Will it take that into consideration in trying to decide where there shall be backfit or not?

MR. CHANG: Every plant in the state will have to consider seismic design according to the local geology and so on.

MR. REED: So qualitative is more than one sentence, you're saying; it's not just an evaluative sentence, it's a number of facts that pertain?

MR. ANDERSON: It's qualitative in the sense that we looked at all the previous studies that had been done and previous walkdowns, and considered the SEP program and some of the alleged deficiencies that were found there.

We also had the benefit of some other work that was done by Sandia with regard to USI A-45, where they went into, I think, six or seven -- maybe nine plants -- and looked for plant-specific fragilities. And although all the inspections had been done previously, they're still finding some problems with anchorages, problems with -- well, in one case, I think it was the battery rack, they still found what we would term outliers in the A-46 program. They found one very heavy valve operator with a corklip eccentric length on a two-inch pipe.

So we concluded from this -- and this is on a qualitative basis -- that although a lot of these studies have previously been done, we have evidence that there are still some potential deficiencies in the plants. So this was one factor in looking at the issue.

MR. SIESS: On the backfit question, let me get something clear. 50.109 refers to all backfits, whether they're generic or plant-specific. Am I right?

MR. WYLIE: That's correct.

MR. SIESS: Now, in terms of the actual operation, if it's generic, CRGR is the body that makes the initial ruling on the backfit. Am I right?

MR. ANDERSON: Well, no, they make --

MR. SIESS: If it's plant-specific, it goes through a different process?

MR. ANDERSON: The CRGR makes recommendations.

MR. SIESS: Okay. But if they're the review body --

MR. ANDERSON: Yes, that's correct.

MR. SIESS: -- on a plant-specific, it's essentially the applicant has to make a complaint, the licensee?

MR. ANDERSON: Well, they're given the option of making a complaint, but I think it requires the staff to justify any backfit decision they make on plant-specific

issues.

MR. SIESS: But in this case, since this is generic, you're depending on CRGR to at least do the review for backfitting?

MR. ANDERSON: That's correct.

MR. SIESS: And yet you say the application now is plant-specific?

MR. ANDERSON: That's correct. What that means, Dr. Siess, is that following the A-46 plant-specific implementation, if we get one, that if a deficiency in a plant is found, say, and we get agreement that it is a deficiency, then the four -- that particular deficiency could be fixed. There would have to be a cost-benefit analysis done on that particular one.

MR. SIESS: Plant-specific?

MR. ANDERSON: That's right. On a plant-specific basis. That's currently our interpretation of what the backfit rule tells us we have to do.

MR. SIESS: And in such a cost-benefit analysis you would have to evaluate risk reduction as a benefit?

MR. ANDERSON: We would have to estimate the safety benefit, whether it's done with a PRA or we can do it again on some basis, which may be qualitative in nature, make an estimate.

MR. SIESS: Thank you.

MR. CHANG: On the third point, we agree that equipment is inherently rugged. However, we believe the following three things have to be looked at: The first is equipment anchorage. The second is functional capability of essential relays. Essential relays are those relays that have to function without chatter during the strong-motion earthquake period. And number three, they have to look at the outliers of equipment.

MR. SIESS: Does outliers include systems interactions, non-Category 1 versus Category 1?

MR. CHANG: System interaction will be looked at in USI A-17. Outliers --

MR. WYLIE: No.

(Simultaneous conversation.)

MR. CHANG: We believe that we have agreement with those three.

MR. WYLIE: Are you or SQUG or someone going to discuss further the limitations placed on the functional capability relays as far as classifying it as being something important or not important, and so forth?

MR. ANDERSON: I don't know whether SQUG will address that today.

MR. THOMAS: I plan to discuss that in our part.

MR. CHANG: The next issue is on the implementation schedule. The first comment is, "The

schedule should be negotiated on an individual utility basis, considering living schedule for plant modification."

"Proposed completion schedule 'no later than 28 months from date of issuance' sho[illegible] be changed.

"Schedules should permit implementation and modifications during plant outages.

"Walkthrough inspections should not be required until EPRI/Research test data collection and SQUG efforts to address the remaining classes of equipment is complete."

The last one is, "Generic group is given 90 days to respond to requirement why individual utilities are given only 45 days."

On the first one, we agree that for all the utilities, including members of SQUG, they should negotiate on an individual basis with the NRC on the implementation schedule. The text will be modified to reflect that.

On the 28 months issue, we agree that 28 months is the general guideline, but that actual implementation schedule will be negotiated with each individual utility.

Now we think that both members of SQUG and other individual utilities will be given 60 days to respond. So the requirement is uniform now on that.

MR. SIESS: To respond to what? The generic letter?

MR. CHANG: Respond to the generic letter to tell

us about the implementation schedule.

MR. SIESS: And that's the one in which they could claim a backfit?

MR. ANDERSON: No. That's the point at which they could negotiate with us what the schedule for the review would be.

MR. SIESS: Schedule for the review or the implementation?

MR. ANDERSON: Well, the implementation review, I think.

MR. SIESS: Okay.

MR. ANDERSON: We've been using them interchangeably. That's what we mean.

MR. SIESS: All right.

MR. CHANG: The next issue, relay review guidelines. We got ten comments on that.

In summary, we can summarize them in four. The first is, "Relay chatter in certain cases is inconsequential." So there is really no requirement to look at every relay.

"Credit should be given for operator action to restore systems and equipment after earthquake."

"Equipment functionality should be restricted to relays only."

And the last one is, "Requirement for review of

electrical relays should be revised in view of SQUG work on relay review procedure."

On number 1 and 4, we agree with the comments. The requirement for relay review, already revised to incorporate what's being done by the SQUG.

On number 2, we agree in principle that utilities can take credit for operator action to restore systems, provided if procedures are in place to determine what to do in case this kind of thing happens.

MR. SIESS: Those procedures include knowing that something has happened? In other words, if relay chatter has caused the lockout --

MR. CHANG: Right?

MR. SIESS: -- that there is some way they'd know that?

MR. CHANG: They have to know the logic of the relay and the sequence of resetting the relays and things like that. So there should be no guessing work.

MR. ANDERSON: It should be a diagnostic procedure as well as --

MR. SIESS: If there's a lockout, there should be some way of knowing there's a lockout, or testing for it?

MR. CHANG: First of all, they have to know there's a lockout, and they have to be able to pinpoint where is the relay that is being locked out.

MR. SIESS: It's in the procedures.

MR. ANDERSON: Right.

MR. CHANG: And also, the second requirement is provided there is sufficient time to do so. And, yes, we agree that the only function of functionality constraint on equipment is relay, that really there is no other components or equipment that we have functionality concern.

MR. LIPINSKI: I would like to offer a comment. There are some relays that are normally open, if they were to be shaken and go to the makeup state, they might seal in, and there may not be an indication that they have been shaken and sealed in. And unless you look at your circuits, you don't know if your circuit has such a feature in it or not.

How do you propose to determine whether such conditions exist unless you look at all of the circuits in a plant?

MR. CHANG: The present proposal, presently SQUG is looking into those areas. Their proposal is that the reveal of relay should start from the function of systems. The relays associated with the equipment, which functioning is required for shutdown should be looked at, and then they are required to look at the circuitry for the systems that are required to be looked at and try to identify the relays in the circuitry that would be called upon to function

during the 30 seconds. Those would be the essential relays.

MR. LIPINSKI: That's right.

MR. CHANG: So they are going to look from a systems point of view to pinpoint the relays that should be functioning.

MR. LIPINSKI: Okay. But this has to be done on a plant-specific basis unless you can verify that certain plants --

MR. CHANG: That's correct. They have to look at this from --

MR. LIPINSKI: -- are identical circuit-wise.

MR. CHANG: -- the plant-specific basis. Each utility has to do that.

MR. LIPINSKI: Okay.

MR. WYLIE: Do you classify pressure switches and things such as that as relays?

MR. ANDERSON: There are certain type of pressure balance relays, protective-type relays, that are included.

MR. WYLIE: I'm not talking about protective relays. I'm talking about things like pressure switches. Say, for example -- of course, I don't know if through your analysis you found that this is not a problem or is a problem -- but pressure switches sometimes are sensitive to vibration.

MR. CHANG: Well, as I understand, it's not included as part of the relays.

MR. ANDERSON: No, it's not part of the relays.

MR. WYLIE: Oh, I know it's not part of that. I was just wondering whether you threw that in the classification as being a concern. You say that's the only thing you're concerned about in functionality is relays.

MR. ANDERSON: I don't think I can answer that right now. I'm not sure that we have any pressure devices that we're concerned about. If they show up and they're not on our equipment list, they'd be classified as outliers.

I know that in looking at all of the experience data, the only devices that we had seen any trouble with at all is mercury-type switches, and it's what you'd expect. But I don't know how extensively the pressure-type switches are used in plants that are in the database. That's what we'll have to --

MR. WYLIE: Mr. Thomas has a comment.

MR. ANDERSON: Do you have one, Jim?

MR. THOMAS: I would just like to add a little bit. Reiterating what Newt just said, we have not seen any evidence in any of the experience data that those types of switches have caused any problems.

As a matter of fact, it's even further, we have

not seen any evidence that any type of relay other than a protective fault detection relay has caused any problems.

We have not seen any seen any evidence of any systems operating when they should not or not operating or stopping operation if they're in operation during the earthquake, unless it's something that is a protective action, the results of a protective relay even being moved by the event. Or in a couple of cases, we're not quite sure, but if there was any chatter, it was in the protective relay.

That goes also in regards to other protective-type functions such as vibration monitors. We've seen some turbines trip because of a vibration monitor sensing vibrations, which was actually being generated by the seismic event.

We have not seen any evidence of functionality problems, with the exception of protective relays. And on that basis, we still have the opinion that the functionality should definitely be limited to relays. And again our program, as it currently is being set up, is broader than the scope of what we had seen problems in.

We are still trying to narrow the scope in the relay area, and we're looking at more relays than just protective relays. But as far as our experience data and any kind of indication of systems problems, it has been

totally limited to protective relay items.

MR. LIPINSKI: I would like a clarification. When you say you have not seen, are you talking about during seismic events or during a circuit analysis where you're looking possibly for the relay changes state?

MR. THOMAS: The actual earthquakes that we've investigated in our extensive interviews with operators as to what type of problems they had during and after the event. And we have not found any attributable particularly -- we made a very strong effort in Mexico and Chile to interview the operators on those type problems, and the only problem that we're able to trace ended up at a protective relay.

They could not give us any evidence of other type relays causing any problems, whether they chattered or not, you can't prove it, but there was no system malfunctions that they could attribute to it.

MR. LIPINSKI: Okay. But the circuits that you saw in Mexico and Chile are not the same circuits that you see in nuclear plants. That's where the difference is.

MR. THOMAS: They're not exactly the same, but the control systems for such things as emergency diesel generators, the control systems for the turbines, they're very similar in the way relays are used.

The nuclear plants are, I think, armed to go to

the fail-safe mode in relay chatter in protection systems. The protection systems in the process are definitely different. When we've looked at that in the systems analysis about everything we look at is that you would get a quicker trip, which is what we'd really want if you're going to have a trip. The chatter will generate trips in the protective system.

We can't find anything in the protection systems that we can see any chatter would cause a problem. Those circuits are different. But the other type process control systems are very similar.

MR. WYLIE: Of course, you'll agree that if a pressure switch or a thermostat or something of that nature operated, it'd turn the piece of equipment on or start a system or something, in which case the operator probably wouldn't recognize it or make note of it anyhow.

MR. THOMAS: Yes, that's correct. And we think that the most critical area to look at in regard to relay chatter -- and again I say it's the broader scope than where we've seen the problems -- is to make sure that we wouldn't have some type of system or valve operate that would cause us some type of mini LOCA and that we didn't get a break or anything.

But for example, if you were to get a valve that would depressurize the system, you didn't want that valve

to operate. So those were the critical systems that we think we need to look at.

MR. LIPINSKI: Okay. Thank you.

MR. CHANG: The next feature is, "The scope of review. The scope of A-46 review should reflect the minor significance of any remaining A-46 issues in view of the seismic experience and test experience data."

The response to that is, "Yes." The scope has already been narrowed down to the three areas I mentioned earlier, the equipment anchorage review, the functional capability of relays review, and we have to look at the categories of outliers of equipment.

"Assumption that SSE does not cause LOCAs should be extended to include high-energy line break and steam-line break accidents."

Yes, we agree with this. This is based on the seismic experience data, and also that IE Bulletin 79-02, -07 and 79-14 had reviewed the safety-related piping again. So that's being reviewed already.

And from the evidence of the seismic experience, piping is not liable to fail because of seismic inertia. It may fail due to corrosion of piping or due to the so-called "differential anchor movement effect." But the differential anchor movement effect has been reviewed in the IE bulletin 02 and 70-14 review.

So we believe that LOCA and HELB and SLBA should not be included.

The next comment is, "Accident mitigation system piping is not included in the scope because of extensive piping system design margins. It should be stated that such piping margins exist in all systems, including the reactor coolant system."

Yes, we agree. The reason is the same as on comment number 2.

"Typical equipment list in the regulatory analysis should state, 'This list is based on SQUG polls of member utilities and is expected to include all of the types of safe shutdown equipment in nuclear power plants; therefore, plant-specific lists are expected to be shorter than what's presented in that list.'"

Yes, we agree with that.

"Not all PORVs should be considered as equipment unique to nuclear power plants."

Yes, we agree.

"Electrical penetration assemblies and neutron detectors should not be included in scope of A-46, since they are passive."

Yes, I talked with Newt, and we agree on that. However, seismic adequacy can be verified for both by experience data or test data. So we don't have any

objection if a utility wants to include this in the scope.

"Anchorage review of tanks and heat exchangers have not been justified."

Well, we think that tank and heat exchanger anchorage is important to shutdown function. And experience data also shows that anchorage is important.

We are not going to look at the structural integrity of tanks and heat exchangers in A-46. That's going to be covered by USI A-40. All we are looking at is the anchorage part of that.

MR. SIESS: What is A-40?

MR. ANDERSON: Seismic design criteria.

MR. BOSNAK: Short-term.

MR. CHANG: Another comment on the scope is, "It is not justified to document seismic adequacy of the equipment beyond the original eight classes, since seismic experience demonstrates that the equipment is inherently rugged."

Well, we think that caveats and exclusions, as well as appropriate bounding spectra, those things have to be looked at, even for the equipment other than the eight classes.

Walkthrough inspection scope. The first one is about the sampling that should be allowed as one of the approaches to inspect the anchorage. And only if sampling

shows anomalies, then maybe a bigger scope of review should be required.

The second one is, "Credit should be given for previous walkthroughs or available engineering documents on anchorage."

"Equipment anchorage already addressed by IE Bulletins and IE Information Notice 80-21." So that comment is that there is no need of anchorage review.

Our response to the comment is that, on the first one, the sampling approach is currently being considered by SSRAP, and when their recommendation is out, then certainly we will consider that.

MR. SIESS: What would be the basis for sampling? Who designed it? What type of equipment it was? Who built it?

MR. ANDERSON: Well, it would really be an audit of the design process and --

MR. CHANG: On plant-specific basis.

MR. ANDERSON: There is some evidence in past walkthroughs that if you can sample the anchorages and determine that their design system and maintenance and installation have worked, that is generally uniform throughout the plant.

MR. CHANG: On giving credit to previous walkthroughs, we disagree with that. There is still

evidence that problems exist in the anchorage area after all those reviews.

Also, previous walkthroughs don't necessarily address all the concerns in the anchorage guidelines and the walkthrough procedure that's going to be issued later. It's still in the development.

MR. WYLIE: Let me ask you about that. You say there's evidence. You found things that were changed, actually found things that were changed or not put in the way they were designed? Is that what you're saying?

MR. CHANG: Yes. I think Newt can answer that. On A-45 --

MR. ANDERSON: Yes. Although there have been quite a few previous efforts to look at anchorages and to look at equipment, I think one of these -- I don't know which one -- addressed only electrical equipment anchorages. They haven't been broad in scope as looking at, like, all hot shutdown equipment.

And further, on some of the mini reviews that we've had, and the one that I'm citing, is the exercise to go look at plant-specific fragilities for the purpose of doing a seismic PRA for A-45 ESI. We found a number of alleged deficiencies in anchorage systems and in the mounting of equipment down among the plant with a battery rack that was screwed to a masonry wall and a couple of

items like that.

So it leads us to believe that the scope of the previous reviews have not been broad enough to pick up these deficiencies.

MR. WYLIE: Okay.

MR. SIESS: Is there any relation then between the sampling approach and what's been done previously?

MR. ANDERSON: Well, that appears to be a little contradictory. But even in the comments made by the Sandia Laboratory people and their consultants who did these walkthroughs for A-45 was that if they found deficiencies or alleged deficiencies of this type in a plant, that generally they would find more and that the plants where they didn't find them, it was usually uniformly good.

So it gives us some indication that it's more a matter of whether or not there are design and installation and maintenance system works or not. And I think we believe this is generally true.

MR. CHANG: And on the IE Bulletins and the IE Information Notice, we disagree with that comment because IE Information Notice 80-21 was for anchorage of Class 1-E electrical equipment only, it doesn't cover all the equipment. And IE Bulletin 79-02 and -14 were for piping only.

So those reviews don't really cover all the

equipment anchorages.

MR. SIESS: But you had a review of previously covered electrical equipment anchorages. Do you still have to do that again?

MR. CHANG: That is Information Notice. It's just for information only. It's not a requirement, really.

MR. SIESS: But suppose they did something and documented it in response to that Information Notice.

MR. BOSNAK: I think if you found a plant that had documentation and also that Region and I&E were in agreement that something was done, then that would be taken into account and we wouldn't have to go through and do that all over again.

MR. CHANG: Yes, I think that that's --

MR. SIESS: But it certainly affects the sampling.

MR. BOSNAK: It certainly could.

MR. ANDERSON: Well, if there was evidence that people had taken this Information Notice seriously and had looked hard at anchorages of electrical equipment and feel very comfortable about it.

However, the anchorage of electrical cabinets is one of the principal areas of concern that was identified for this development of plant-specific fragilities, and these were plants who have received that Information

Notices.

MR. SIESS: Okay.

MR. CHANG: Also, I think if the review was documented, then the documents probably should be checked against the anchorage guidelines. That's going to come out. But certainly a portion of that should be able to taken credit for.

On the justification for continued operation requirements, the comments are that, first, "The requirement for JCO is not warranted. Reporting requirements exist in 10 CFR 50.72 and .73."

Instead of a JCO, utilities propose to commit to resolve deficiency by a certain date, or JCO kept in licensee's file instead of submitting to NRC, or deficiencies reported by using 10 CFR 50.72 and .73.

Another comment is that most deficiencies will not present a serious safety concern and, therefore, should not require a JCO. This is to shine some light about the scope of the JCO.

The response is that we are going to clarify the word "deficiency" better in the text, but we think JCO should be required for proven deficiencies if not corrected within 30 days.

MR. WYLIE: You say you're going to clarify. How are you going to clarify?

MR. ANDERSON: Excuse me. Let me answer that.

MR. WYLIE: Okay. Go ahead. Yes.

MR. ANDERSON: We think that the concern that people have stated with regard to JCOs hinges on our definition of what a deficiency is for which a JCO would be required. We've had some debate previously, but I think this point still is not clear.

The implementation review as it is certainly conceived to be is going to be a screening process, to a large extent, because there are a lot of equipment that we do have good seismic experience data and we can immediately remove from consideration.

After that initial process and the screening, there is going to be some equipment that we didn't -- that we weren't able to screen out from consideration. Now, those things, we're not calling deficiencies, because they didn't pass that first screen. And I think there has been some confusion about that point.

There will be some outliers, and what we're calling outliers is equipment that's currently outside the range of experience data that we have for things that are unique to nuclear plants and we don't have test data for or things that have a particularly odd-ball configuration, you know. We don't know how many of those there are.

But we are not going to call those deficiencies

if they don't fall through that first screen. They have the opportunity to evaluate those.

If, upon evaluation of these items that don't pass the screen, they make a finding that this is indeed a deficiency and you've got a good likelihood that in event of an SSE that is going to fail, then we think at that time that the utility should be obligated to tell us whether, if they don't fix it within -- they either fix it within about 30 days or provide us with some kind of a story on why they can continue to operate with it not being fixed.

So it limits the number of components that they can potentially have a JCO filed on to only those that, after further analysis and review, they make a finding that it definitely is not adequate.

MR. SIESS: Well, what do you do with a JCO? You review it?

MR. ANDERSON: Yes.

MR. SIESS: You respond to it?

MR. ANDERSON: Yes, we would respond to it.

MR. SIESS: And if you disagree with it --

MR. ANDERSON: Well, then we would --

MR. SIESS: -- do you shut them down or do you tell them to come back with a better justification?

MR. ANDERSON: Well, we would probably have a lot of discussions with them over the subject, and if we

-- we think that if the utilities make that determination themselves, that if they find a condition in the plant that is a concern, that they would do something about it. We want them to tell us, and we will have a dialogue with them with regard to whether or not it's of sufficient safety significance that they should take some action. It may be some administrative procedures, it may -- I don't know what that action might be.

MR. SIESS: Does the requirement for a JCO then impose a greater discipline on the utility? Do you feel it makes them make a better review?

MR. BOSNAK: I think it does make them make a better review. We had several situations with equipment qualification deadlines that came up in the recent past that they had to submit JCOs, and if the staff didn't agree with the JCOs, there was an iterative process until we finally agreed that there was justification for continued operation.

So it forced the utility to focus on the situation and either correct it or not receive staff approval to continue to operate.

MR. ANDERSON: Or take some other measures which would maybe offset this alleged deficiency.

MR. CHANG: On cost estimate, well, generally, the utilities believe that the costs may be low by a factor

of two due to low labor estimates.

And SEP experience indicates that equipment review is two to three times higher than cost of the equipment review, two to three times higher than A-46 estimates.

Well, for A-46 approach, there will be "extensive analysis and guidelines developed up front." So that should reduce the labor cost as compared to each plant doing their own individual review without that.

MR. SIESS: Does "up front" mean within the 60 days or within the 28 months?

MR. ANDERSON: That's prior to --

MR. CHANG: Prior to the issuance of the final resolution.

MR. ANDERSON: Let me clarify that. The utility group, SQUG and their consultants are in the process now of developing the detailed implementation procedures for use by the individual utilities. They will conduct trial walkdowns and fine-tune the procedures and hold workshops for the utilities.

So that we think it would be a much more efficient process than if we just tell them to go do it and they start from scratch.

MR. SIESS: But again, have they got 60 days to do that or 28 months?

MR. ANDERSON: They have 60 days to reply to the generic letter and tell us what their schedule for doing it is.

MR. SIESS: Okay.

MR. CHANG: On the SEP experience, we disagree. SEP plants are typically older, and we believe the equipment and anchorage in later plants have better seismic capability.

"A-46 approach is for analysis before review," as mentioned in (1). "Guidelines and procedures will minimize review time and costs."

MR. SIESS: Let me understand that on the SEP. They're citing the SEP as indicating how long it takes to review. And does it take less time to find out things are okay than to find out that they're not? I don't quite get your argument. If things are better, it's going to take less time to find out that they're better?

MR. ANDERSON: Well, it looks like we could probably argue on either side of that argument, and maybe we're, you know, just making words here to try to justify what we've done. I think that, in essence, you know, our cost estimate is about the best we could do, and I think we'd be very fortunate if we could get within a factor of two.

I think the point being made here is that the

older SEP plants, before the SEP review, you might say, you think they'd spend more time finding and arguing and debating deficiencies than they would in the newer plants, is the point we're attempting to make.

These costs numbers are always soft. It's very difficult to predict what that cost is going to be.

MR. SIESS: Well, yours are always lower than the industry's or the industry's are always higher than yours. I think that's an accepted fact.

(Laughter.)

MR. ANDERSON: Well, we should take an average, maybe.

(Laughter.)

MR. SIESS: I thought that the factor of two was probably one of the lowest I've seen recently.

MR. CHANG: Guidelines for replacing equipment. The comment is that A-46 criteria are acceptable to seismically qualified replacement equipment regardless of reason of replacement.

So they're saying that the A-46 criteria shouldn't be restricted to only equipment replaced as a result of A-46.

Well, we think that's a reasonable comment, and we agree. The regulatory analysis will be revised accordingly.

Safe shutdown requirement. A-46 should permit timely operator actions to demonstrate the achievement and maintenance of hot shutdown. As we said earlier, operator actions, they can take credit for that, provided procedures are available and very sufficient time to do so.

"The assumption of a nonseismically-related single random component failure should be eliminated. Single train of safe shutdown equipment would provide assurance plant can be shut down safely because of low earthquake probability and the inherent ruggedness of the equipment."

We disagree on that. We still maintain that if a single component is required for hot shutdown and if it can fail because of random failure or because of seismic reasons, then there should be an other alternative to not using that piece of probability to bring the plant down to hot shutdown function.

MR. SIESS: Are there cases in a plant where single failure, single random failure could prevent you from going to hot shutdown and not violate the single-failure criteria?

MR. ANDERSON: Well, for safety systems or running electrical systems we're required to meet the single-failure criteria separation.

But for the types of shutdown systems, these

rules don't always apply to them. And what we're saying is that for this particular requirement, what we'd like to assure ourselves is that if going to hot shutdown requires the function of a single active component -- and we're not talking about tanks or pipes, but an active component, piece of equipment -- that we think that the utility should show that they have some alternate method of getting there which doesn't depend on the function of this piece of equipment.

It's kind of a modified single-failure thing. We're not saying you have to have redundant components, but another alternative for bringing it to shutdown which doesn't depend on that component.

We think that most of the plants have more than two alternatives. They have a lot of ways of using various system lineups, various valves and pumps.

MR. SIESS: That's in 45, as I recall.

MR. ANDERSON: Yes. That's right.

We don't think that's particularly restrictive on the utility, but we don't want to get into a position where we're only concerned with a single train where it depends upon a single vulnerable component.

MR. CHANG: The next comment is that, "The regulatory analysis appears to refer to a passive, not active, component in (2) above."

But our intention is to include only active components in this context. The text will be clarified.

The last comment on this issue is, "One of the four functions required to be performed for hot shutdown in conjunction with the SSE is 'to provide AC and DC current emergency power.' This is not needed, since the need for AC and/or DC emergency power to meet the other three functions is the plant-specific consideration."

We agree, and the sentence will be revised to read that, "provide AC and/or DC emergency power as needed on a plant-specific basis."

MR. SIESS: I'm sorry, I don't remember what the four functions were. Could you state them briefly?

MR. CHANG: The four functions. The first is the plant should be able to achieve hot shutdown and maintain it. The second one is that the control or instrumentation, the control room should be able to monitor.

MR. SIESS: Yes. You have to have sufficient monitors available to the operator to be able to monitor that.

MR. CHANG: Information to the operator to monitor it.

MR. SIESS: As you say, with the hot shutdown and stay there, doesn't that imply you have to have --

MR. ANDERSON: Well, yes, sir, that's the subset

of that. We've broken it out into a little more detail than may be necessary.

MR. SIESS: Okay.

MR. CHANG: Equipment seismic demand and the seismic capacity. Comment, "When will generic bounding spectra for equipment other than eight classes be available? If not available, can type A bounding spectra be used?"

The appropriate generic bounding spectra for equipment other than eight classes will be available, we believe, in the early part of 1987 for use in implementation program on the equipment other than eight classes.

I think something is missing there. If they are not -- oh, okay. Since we believe that they will be available, so there is no answer to question number 2.

Comment, "For verification of anchorage, can floor spectra be used to obtain the equipment spectra acceleration?"

Yes. You can always use the floor spectra to estimate the spectra acceleration to estimate anchorage capacity.

"Utilities should not have to adopt the generic floor response spectra if they can show that their own spectra are less."

Yes.

Number 4, "SQUG is considering extending SSRAP bounding spectra to equipment higher than 40 feet above grade by the use of appropriate amplification factors. This approach should be permitted for equipment higher than 40 feet above grade with SSRAP/NRC apprcval."

Our response on that is that NRC will look at SQUG's proposal and SSRAP recommendation. It is now premature to include in the text.

"The degree of fragility of component support should not have to be analyzed, since effort to determine any possible amplification of response spectra won't provide meaningful information, since the component they support are qualified by seismic experience."

Yes, we agree there is no need to analyze the rigidity or frequency of each component support. During walkthrough inspections, obvious weak spots will be identified.

The statement that --

MR. SIESS: In the response, it refers to the frequency and the other part to the weakness. Weakness is simply a structural question, but if the frequency was such as to cause unusual amplification, that really isn't related to weakness. You can't tell that by looking at it. I don't really understand.

MR. ANDERSON: That's poor choice of words, I think.

MR. SIESS: Yes.

MR. ANDERSON: I think that weakness and rigidity are certainly related. We just stated it improperly.

MR. SIESS: I don't know how you tell by looking at it what the frequency is. You might tell by looking at it that it's clearly greater than 33 Hz or something.

MR. ANDERSON: Well, that's true, isn't it?

MR. SIESS: Yes.

MR. ANDERSON: I mean, we're not -- I don't think that you could tell --

(Simultaneous conversation.)

MR. CHANG: The second sentence is very related to the first one. The thing is that we don't believe it's a simple matter to estimate the frequency, so very likely what they have to do is to pick the peak acceleration from the spectra instead of trying to figure out which spectra acceleration should be used according to what frequency.

We don't think it's a simple matter, really, to estimate accurately that the frequency of a piece of equipment.

MR. SIESS: And of course, that was in the experience base.

MR. ANDERSON: Right.

MR. CHANG: Right.

MR. ANDERSON: We didn't really handle the answer to that that well. I think we didn't state it that well.

MR. CHANG: "The statement that (for other than eight classes, 'these generic bounding spectra will not exceed the type A bounding spectra' should be justified."

We are saying that we expect the bounding spectra for the other than eight classes will be coming, and they shouldn't exceed type A bounding spectra unless it can be proven by test data or other justification.

Since type A is the highest bounding spectra used for the eight classes of equipment in the pilot program, so based on the seismic database information, we believe type A is the highest limit you can use unless you can prove by other means that you can raise this.

MR. ANDERSON: There is some consideration about raising those spectra levels based on the information gained in Chile and also the test data that's being collected by EPRI/SQUG.

MR. CHANG: So, based on the new information, the bounding structure probably can be modified.

Makeup of the walkthrough inspection team. They believe that there is no need to have an operations supervisor or SRO on the team. "He will be useful in generating lists of required equipment," but not to go

around and actually do the walkthrough.

"Team members should not be restricted to degreed engineers as long as they have relevant knowledge and experience.

"All members of the inspection team should not be required for all parts of the walkthrough."

Yes, we agree on the first one. However, operations supervisor or SRO should be available for consultation before and during walkthrough process, but he need not be physically there during the walkthrough.

On the number 2 comment, yes, there is no attempt to restrict team members to degreed engineers. The emphasis is on the relevant experience.

On number 3 we agree. Not all members should be there to look at all the equipment during the walkthrough. However, appropriate technical expertise should be included for each review area.

On expansion of seismic experience database, the comment is, "SQUG has increased the database from eight classes to 21 now. 21 classes now sufficient to cover everything."

Yes, we believe, as it stands, the 21 classes should cover everything except the outliers.

MR. SIESS: I am not familiar with SQUG document that goes from eight to 21. Could you give me a reference

to it sometime?

MR. CHANG: In the pilot program, they looked at only eight classes. I think we mentioned those eight classes before. Now they are trying to expand the database to cover more that just the eight classes.

MR. ANDERSON: Has that report been issued? Has the 21-class report been issued yet?

MR. CHANG: It has not really been issued formally.

MR. SIESS: Your statement is in the past tense.

MR. CHANG: Right.

MR. SIESS: I thought it had been issued.

MR. CHANG: "The caveats in NUREG-1030 most likely will be relaxed due to investigation of Chilean earthquake."

Yes, we agree.

MR. SIESS: Which caveats would that be? The 40-foot?

MR. CHANG: No, I think the biggest impact will be on the data on the motor-operated valves.

MR. ANDERSON: No, there was some restriction with regard to pipe sizes and eccentric links and --

MR. CHANG: No, they gathered more information on that from the Chilean earthquake.

Number 3, "NUREG-1030 implies that scope of equipment covered by experience database is limited to original eight classes. This should be clarified."

Yes. Text will be changed to reflect that.

The next issue is on the role of SQUG in generic implementation. The first comment is, "SQUG should not be in the position to enforce the requirement of A-46 position. Rather, it should be in a position to provide implementation criteria and assistance."

Yes, we agree.

The next comment, "SQUG should not assume responsibility for implementation on individual plants," and, "suggest SQUG develop generic implementation procedures and submit to NRC a generic schedule for its development of implementation procedures and for training seminars for participating utilities."

So SQUG will provide those information to NRC instead of submitting the schedules for the whole group for implementation.

Each individual utility, SQUG member or not -- I think something is missing -- should negotiate with NRC on the implementation schedule. SQUG will not submit generic implementation schedule to NRC.

MR. SIESS: I have a list that says there are 72 plants --

MR. CHANG: Yes.

MR. SIESS: -- that would be covered. How many of those are represented by SQUG?

MR. CHANG: Based on the current roster, we believe there are only seven plants that falls out of SQUG membership.

MR. SIESS: Fine. Thank you.

MR. CHANG: Yes, we agree that each utility should negotiate implementation schedule with NRC and the generic group is not required to submit a generic implementation schedule to NRC.

A continuation of that. "SQUG should not certify completion of walkthrough inspection by individual utilities. SQUG should provide results of audit performed and SSRAP should not endorse SQUG audits but report results of reviews and audits performed by them.

Yes, that's acceptable to NRC so long as SQUG and SSRAP report on their reviews and audits.

Accessibility of SQUG results to non-SQUG members. The comments are that generic implementation procedures now being developed by SQUG will likely not be available to non-member utilities.

Yes, we will revise the text in regulatory analysis to reflect this. However, NRC and the Research-sponsored work is publicly available.

Plant-specific SERs, "Will the NRC prepare plant-specific SERs to close out A-46?"

The answer is, yes, we will be doing that.

Applicability of A-46 to new plants and new equipment. Comment, "Suggest NRC say that A-46 methodology is an acceptable method of complying with current licensing requirements on equipment seismic qualifications."

Well, actually, I understand that 344 1975 -- well, it's for issue. It's not '75. In the new proposed issue of IEEE 344, a section is going to be included on the use of seismic experience data for seismic qualification of electrical equipment.

NRC may accept through endorsement of the standard for future plants. But for A-46, since A-46 only addresses operating plants, A-46 doesn't really address the changes to current requirements.

MR. ANDERSON: I might note that ASME is also interested in possibly incorporating the use of the experience data.

MR. CHANG: Applicability of A-46 to specific plants. The first one is, "Plants located in a relatively aseismic area such as Florida shall be excluded from consideration in the resolution of any seismic risk issue."

We disagree on that. Seismic design basis is not part of A-46, is not evaluated by A-46.

The second one, "McGuire Nuclear Station should not be required to perform an A-46 review, since it was evaluated to current licensing requirements -- that is, IEEE 344-1975 version, as endorsed by Regulatory Guide 1.100 -- and found to be in compliance."

Well, our reply to that is, if evidence is presented, than McGuire will be removed.

MR. SIESS: I noticed in that list that I mentioned previously that all of the SEP plants in the list, is that double jeopardy?

MR. ANDERSON: No -- well, I think we've also stated -- well, not today here, but in our regulatory analysis -- credit begins in the SEP reviews. There may be -- there is quite a bit of overlap.

MR. CHANG: Well, SEP looked at the structural integrity parts. However, I think in the SERs it's

mentioned that the functionality review will be postponed until April 6.

MR. SIESS: Okay.

MR. CHEN: I said that the functionality problem will be reviewed.

MR. ANDERSON: That's correct.

MR. CHANG: That concludes my presentation. Are there any other questions?

MR. WYLIE: Let me ask questions. Backing up a little bit, on your response to the accessibility of SQUG results to non-SQUG members, your comment was SQUG members suggest that results of SQUG and EPRI studies should not be accessible to all utilities.

I understand the SQUG results being available to them. But the comment about EPRI, is that -- at least in my understanding, EPRI data is available to EPRI --

MR. ANDERSON: To members --

MR. WYLIE: Well, to anybody that requests them.

MR. ANDERSON: Well, we were really trying to avoid that issue. We recognize that SQUG has developed a lot of information that they've paid for.

MR. WYLIE: Oh, yes, I agree.

MR. ANDERSON: Whether or not EPRI wants to withhold what they consider to be their data from the public I think is pretty much up to EPRI.

MR. WYLIE: Yes.

MR. ANDERSON: We're not going to get into that one. The only statement that we can make is that the NRC data and developed with government money and government funds has to be available to everybody.

MR. WYLIE: Sure. Sure. Okay.

Let's see, the other one -- oh, under the response to the applicability of experience data to qualification for new plant equipment, you refer to the IEEE Standard 344-75 and the modification adding the useof experience data in seismic qualification. You say NRC may accept your endorsement of the standard. Is it your intent to do that?

MR. ANDERSON: That's -- well, I think --

MR. BOSNAK: I think we have to wait to really see the standard and make sure that it's --

MR. WYLIE: Well, you've got a feel for it, I mean.

MR. ANDERSON: Well, we've had the draft standard. If I had to guess, I would say yes. But I don't know.

MR. WYLIE: Okay.

MR. ANDERSON: But what we're trying to indicate here, that's the most likely route that it would be put into our current position through the standard.

MR. WYLIE: Oh, okay. I see. All right.

Any other comments?

MR. SIESS: I would just like to say that's probably one of the best presentations on response to the public comments I have heard in a long time.

MR. WYLIE: Very good.

MR. SIESS: Very good job.

MR. WYLIE: Okay.

(Brief recess.)

MR. WYLIE: May we get started again?

Okay. I guess Jim Thomas, of the SQUG group, is the next presenter.

(Pause.)

MR. THOMAS: Okay. Again, I am Jim Thomas, the Duke Power Company and represnting the Seismic Qualification Utility Group.

I will try to review briefly the comments that SQUG did prepare in regard to the proposed resolution of USI A-46. I think most of them have been pretty well covered by the presentation we just had. But I would like to emphasize maybe two or three where our major concern is.

Our first overall comment is that we do think that, from an overall standpoint, the proposed program is a practical and effective approach to address any issues that may need to be addressed in seismic qualific-tion of

equipment in the older operating plants.

Now, our second comment, which was discussed in detail in regard to the need to justify any effort in accordance with the backfit rule, I think that our general position at SQUG could be summarized in that we feel that all the work that we've done and the work with the NRC has enabled us to focus on the areas that have some potential of providing some risk reduction if further work is required at individual sites.

However, we do feel that that risk reduction does need to be analyzed from a value-impact standpoint to show that we do get a commensurate risk reduction for the amount that would have to be spent to do this implementation.

MR. WYLIE: Is there any disagreement aside from this point?

(No response.)

MR. WYLIE: Are we all in agreement then?

MR. ANDERSON: I think we are in basic agreement with that. We had discussed our regulatory analysis and that we had not quantified it. I think that the SQUG would like us to provide a much more rigorous basic benefit analysis. We don't think it's practical, though we still think that, as Jim stated, that SQUG believes that there is some potential for safety benefit there.

MR. SIESS: Does SQUG think that if the staff did

a PRA-type analysis, that this whole thing would go away?

MR. THOMAS: I think that it has a strong probability of being substantially reduced from the SQUG that is currently stated. It is our opinion that our overall program has definitely shown that the issue is not near as significant as a safety issue as it was once perceived, and that also from an overall standpoint, what we've learned in these actual earthquakes would provide a substantial challenge to some of the assumptions that are made in the PRAs.

We are not seeing failures in earthquakes that are much higher than that what we are designing for. We're seeing a number of cases to where the anchorage issue created some problems, but it's a few number, it's not significant. We have not seen any kind of really what you'd call generic problems in systems operation or anything like that.

MR. SIESS: But, now, the thing is narrowed down now to anchorages; to relay chatter, which is still not well defined as to what relays; and to outliers. In the first place, no PRA they're ever going to do is going to find the outliers. By definition, they're the ones I think that are usually out of the PRA.

So unless a PRA would put the whole thing to rest, all you've got to do is look at relay chatter and

look at anchorages.

MR. THOMAS: I think that we concur that --

MR. SIESS: And the way you've got to do it gets burdensome because you have to do it in a regulatory world.

MR. THOMAS: Yes. I think we would concur that, again, kind of reemphasize what I said before, is that we focused on the sensitive areas, which you said. It's our general opinion that the area that would have the most potential for providing a risk reduction would be a review of anchorage. In our opinion, below that, and second, would be the outliers; and third, the relay issue.

However, based on our overall experience, we don't feel that we're going to find many cases of having anchorage problems, and we don't think we're going to find many cases of what's called an outlier.

So the amount that you would have to spend to determine that and any resulting modifications you make is, the point that we're trying to make, that the risk reduction that we may achieve may well not be commensurate with the amount of money we have to spend to do that.

MR. SIESS: I think I see your point, if I spread this over 72 plants and all of them have to do it. But if two plants find some otuliers or some anchorage problems, the risk reduction for those plants might be significant.

But it does become plant-specific.

MR. THOMAS: I would have to concur with that.

MR. SIESS: And I just don't know how to get that factored into a resolution of a generic issue.

MR. THOMAS: I think one of the things, too, is that a lot of these plants have been required to take a look at anchorage by one requirement or another over the years and that there is a lot of plants that can show a lot of work has been done to assure anchorage is correct. I think we should be allowed to take credit for that. And if we have evidence of previous anchorage reviews, then it should not be required as part of the A-46.

MR. SIESS: Plant by plant.

MR. THOMAS: Plant by plant.

MR. SIESS: Well, I think the staff said they would be willing to look at that. I think, overall, if I look at the overall risk and the overall cost, overall risk reduction and the overall cost, it probably wouldn't cost a cost-benefit analysis. There are 72 plants that each spend several hundred thousand dollars. I would not be at all surprised if a couple of plants don't find some things that would be significant reductions in risk.

MR. THOMAS: There is another possibility that we are still discussing in our overall program that you might

possibly want to implement a spot check, and if you found problems at a particular plant, then you do the full-blown walkdown, if you don't, by an appropriate audit of typical type features of equipment -- for example, there's hundreds of valves and motor operators
-- you may want to look at sample, and if that particular plant which has a standard anchorage practice finds zero problems in, say, ten out of a few hundred, maybe that plant would not have to go any further on the anchorage aspect.

MR. SIESS: That's a pretty small sample but --

MR. THOMAS: Well, let's just use it as an example of possible ways that we might still get this into a more cost-effective type implementation.

MR. SIESS: But that would be plant by plant, really. Now, the staff has said that any deficiencies they found in an individual plant would be treated as a plant-specific backfit, and they'd try to do a cost-benefit on that. But what you're trying to get at is some sort of an overall cost-benefit that would reduce the burden of finding those deficiencies.

MR. THOMAS: Yes. In regard to what we've learned from an overall standpoint, a broad view is that the risk reduction that could be achieved is somewhat questionable from a big, overall viewpoint because we just

can't find serious problems in plants around the world that haven't even been designed in any manner to earthquakes, and they've seen earthquakes much stronger than most of the plants that are in the scope of A-46.

MR. SIESS: So what you're looking for is some relaxation in the implementation of the reviews to narrow it down somewhat?

MR. THOMAS: I think it can be justified.

MR. WYLIE: Have you got a proposal?

MR. THOMAS: I think we're still working on such a thing with SQUG. That's kind of one of our other comments -- I might as well cover it now -- is that the current proposed resolution essentially had to more or less take a snapshot of the SQUG program as it was when this was written.

But the SQUG program is continuing to gain more knowledge and put things together, and I think we've got concurrence from the staff that these things that we do learn can be incorporated.

It didn't specifically address this issue, which is that if there might be some more appropriate way of still further reducing the impact or the cost expenditures required to make such an assessment at an individual plant, that we may have some relaxation from what's in the program.

I would like to hope that we could continue to work toward that, and if we did see that some smaller scope of these walkdowns would be appropriate and we could get concurrence, that it ought to be an acceptable type sampling approach, that we should be able to do that.

MR. SIESS: Have you got any feeling that the very high level of cooperation between the staff and SQUG is not likely to continue?

MR. THOMAS: No. Not only, I guess, a day-to-day work basis, I guess past experience of when something is finalized and issued as a mandate, I've seen a lot of things escalate to something that was not really intended by the people who put it out.

I think we saw that in some of the environmental qualification things, that it turned into a real bear, so to speak, that was beyond the scope of the people originally thought it would be.

MR. SIESS: Like fire protection.

MR. THOMAS: That's another example.

MR. ANDERSON: I would like to comment on that statement. With regard to the implementation of A-46, assuming that we get that far, and I think we probably will, we have got concurrence from NRC management that the same team of people who have been working with SQUG in developing the resolution will be following through and

working with them on the implementation.

Dr. Chang, who is the USI A-46 task manager, is also responsible for the implementation clear through the issuance of the SERs. So we don't see that there's going to be any controversy with regard to having other people taking the issue and deciding how to implement it.

MR. SIESS: Is Dr. Chang in NRR?

MR. ANDERSON: Right here today --

MR. SIESS: Is he in NRR?

MR. ANDERSON: Yes, sir.

MR. EBERSOLE: Let me ask a question. When you talk about anchorage, you're not talking about the struts or supports or whatever it is to which the anchorage or which the anchorage is holding. You're talking about the anchorage per se?

MR. THOMAS: Of the equipment that's in the --

MR. EBERSOLE: To the concrete wall or whatever. And I find it some problem to imagine that a walkthrough can tell you that an anchorage is what it should be. I don't know whether you've got two grids holding it or none at all or whatever.

What's the significance of a walkthrough in something you can't see with your eyeballs?

MR. THOMAS: We have a pretty extensive program being sponsored by EPRI to come up with a generic program

that would enable us to do just that. By the size of number of types of anchors, you can pretty well assess the depth. If you've got some oddballs, I think, there's actually available a little electronic device that just by being placed on top of the anchor that's in the --

MR. EBERSOLE: Okay.

MR. THOMAS: You can determine the depth.

MR. EBERSOLE: I didn't realize there --

MR. THOMAS: Thre's a lot of things that we're still working to simplify this walkdown, and we think that we're going to have a pretty simplified approach resulting, and we're still working toward that. We're trying to get it back to kind of a practical approach and get rid of some of the analytical type things that anchorage are designed to. As far as the walkdown, you just want to verify that you did anchor as it should have been and you should be able to inspect it in some manner.

There will be some, again, outliers in that that might give us a problem.

MR. EBERSOLE: Yes. Have you prepared a kind of a description of what you can and cannot see in a walkthrough? For instance, can you look at a strut or set of supports that's holding a cable tray up and say that's enough?

MR. THOMAS: Based on experience data to date,

yes, because particularly -- you'll probably see some of these slides this afternoon on Mexico -- is that we still can't find any cable tray problems, and we have seen some of the worst type supports of cable trays, and in Mexico, some of the most severely overloaded cable trays that were on the brink of structural failure due to loading, but then saw the .35 g quake and it produced no further damage to the cable tray.

MR. EBERSOLE: So you say there's enough margin in the design you can eyeball it into --

MR. THOMAS: Yes. Cable tray especially.

MR. EBERSOLE: I often wish I had a rule of thumb for something that says what I can see and don't need to analyze.

MR. THOMAS: Yes. Well, we're trying to incorporate what we have seen in experience and take advantage of knowing what such type designs have withstood an actual earthquake and incorporate that into our walkdown.

MR. WYLIE: Please continue.

MR. THOMAS: Okay. I guess to summarize that comment is that we do think that some further work may be justified on the value impact analysis as to really what should be required, if any, in certain areas.

I am just going to give you some examples of the

detailed comments, because you've seen the detailed comments.

I think our general overall discussion of specific comments have kind of resolved one issue, is that we shouldn't limit ourselves to the snapshot as currently described in the proposed resolution, that we should be able to update it as we learn more from SQUG.

Just a quick discussion, and I will cover it a little more in the next presentation that I give on the SQUG program. But I would just like to reemphasize that in regard to our relay study and the issue on relays, I think when we started our overall SQUG program, we kind of immediately set relays aside, saying that it's kind of an issue all of its own. And we have made a lot of efforts to attack that issue recently, during 1985 especially, with Chile and Mexico.

And we think that the overall knowledge that we gained has reduced our concern for relays, in particular, commensuarate with our overall reduction of concern for seismic adequacy of the things that were totally in the scope of SQUG to begin with.

We've got a real good, warm feeling from the numerous systems and operator interviews in the Chile earthquake that the catastrophic type system function failures that we were afraid might would occur just don't

seem to be happening. And we're currently trying to document why that is so.

We've done a lot of documentation in generating judgments for the additional classes of equipment as to why these animals don't have problems. And we're still doing that on relays. And I think one of the things that once you see there's no problems and you start trying to think about why there isn't a problem, that the circuits that have these relays that have a potential to chatter, see a lot of chatter just in the operation of the relays themselves. Every relay bounces, and you have to design your circuits to where it's immune to contact bounce or it wouldn't operate correctly to start with.

A lot of the relays that we used have been developed over many years of experience to where it can't tolerate someone bumping into the cabinet, tripping your system.

So the relays themselves, even though you probably can't trace back to a specific seismic design, have a lot of inherent ruggedness that seismic forces don't seem to be overcoming their design for these other reasons.

Also, the circuits themselves have been designed over a number of years to where they're somewhat immune to this minute chatter effect.

Now, you can find cases where you have problems,

and we're trying to look at what would be the best method to really narrow in on those areas. But we do think that the relay issue is a lot less of a concern than we ourselves thought two or three years ago.

MR. LIPINSKI: May I ask a question?

MR. THOMAS:

MR. LIPINSKI: In high relay chatter, will that cause the MSIVs to close in a BWR?

MR. THOMAS: It's plant-specific, I think, and it may or may not.

MR. LIPINSKI: Okay. And relay chatter, will it delay the scram on a BWR?

MR. THOMAS: My thought is that it will not.

MR. LIPINSKI: It will not?

MR. THOMAS: The results of our circuit study so far on that issue -- maybe Bill might could add to that -- is that what we can determine from our systems analysis in relay chatter is that it would not.

MR. LIPINSKI: Okay. I would have to see your analysis, because if the relay is chattering, interrupting energy to the solenoid valves, it depends on the rate of chatter as to whether the solenoid valve is going to change state. And if you have that combination of events where you can get the MSIVs to close, delay scram, on the BWR, depending on how long that seismic event takes place, you

may not want tc be there.

MR. THOMAS: Well, we agree that those type things are priority to make sure that we wouldn't have problems. We're looking at it. And our studies are really showing that these circuits are a heck of a lot more immune to such chatter causing an adverse effect than we thought.

MR. LIPINSKI: Okay. But you're drawing your conclusions based on looking at fossil-fired plants that have different requirements where the time scales are not as important as they are in nuclear plants; namely, MSIV closure and a failure to scram.

MR. THOMAS: The experience data, yes. The systems analysis we're doing in trying to look at the effects of the chatter in a specific circuit are for nuclear power plants.

MR. SCHMIDT: I might just add that we do have a presentation in Jim Thomas' next discussion, and the staff will describe in more detail our approach to the relay review. And it does address not only inadvertent actuation but will you make sure you do get actuations when the circuits call for it. So we'll cover that, I think, in the next presentation.

MR. THOMAS: This program is working very closely with the staff on making sure that they concur that the type work we're doing is appropriate. And we're really

just getting started on it, and we've got a good bit of work ahead of us, but we're certainly making a lot of progress. We just hope we can continue to get the interaction with the staff to conclude that portion of the program.

If there are no other questions, I think that all of the detailed comments that SQUG has submitted were discussed, and I think most of them were appropriately resolved. I think about the only two that we do have a little bit of concern is further work may be required in those areas of value impact assessment and a little more leeway to work out this relay issue.

MR. WYLIE: Are there any questions for Mr. Thomas?

(No response.)

MR. WYLIE: There are no other questions. Thank you.

MR. EBERSOLE: Let me just ask one.

MR. WYLIE: Yes.

MR. EBERSOLE: Do you do a general survey to find apparatus that has g forces as an integral part of their operational scheme, like governors on diesels, you know, some hammer relays use gravity as a means to clear. At least, they used to. Do you look at these potential candidates for trouble, where gravity itself is one of the

driving forces to function?

MR. THOMAS: I have not seen any problem resulting from such type equipment.

MR. EBERSOLE: I don't even know that they still exist. They used to. I think the Woodward governance, in fact, have a gravity force.

MR. THOMAS: Now, you're talking about, I think, kind of indirect effects.

MR. EBERSOLE: Yes.

MR. THOMAS: And I think that one standout indirect effect is what we found on fault pressure relays for transformers is that they're functioning correctly but you don't really want them to trip. The reason they're functioning is because they're being fooled.

MR. EBERSOLE: Yes.

MR. THOMAS: They're seeing a change in the pressure due to the sloshing in the transformer, and we've been very careful to try to -- in all of our surveys that we've done in SQUG and our interviews -- is to try to dig into as much of that as we can. And the particular ones you're talking about, we haven't seen the evidence.

MR. EBERSOLE: What about the level devices, based on liquid levels?

MR. WYLIE: Tank levels.

MR. EBERSOLE: In which there are waves.

MR. THOMAS: Obviously, if you get some sloshing, then you could fool your sensors in that regard also. That would have to be incorporated into a systems type assessment as to whether the level of sloshing you would see would give you any problems.

My personal opinion is it is truly a sloshing, and if it's going up higher than it should, then that's not the right direction to be safe, it's also going to go down and cause you to trip a little quicker, because it's kind of an instantaneous type thing going on in a matter of 15-20 seconds. And there is definitely margin in our safety systems to tolerate this 10- or 15-second type train that might be occurring during the event.

MR. EBERSOLE: I notice in the fourth bullet here on examples of detailed comments, you made a statement that plans for evaluation of seismic operability of "essential relays" is under development. Well, there are lots of nonessential relays that could cause havoc.

MR. THOMAS: You're using the word "essential" in a different way than we are. We're talking about anything that could cause havoc in reaching a safe shutdown --

MR. EBERSOLE: Okay.

MR. THOMAS: -- is what we're calling "essential."

MR. EBERSOLE: Right. But, you know --

MR. THOMAS: It's not Class 1-E. It's not --

MR. EBERSOLE: You'll have to be explicit about it, though, or you'll find yourself just loking at the critical ones.

MR. THOMAS: That's the reason we used the word "essential." That was kind of no longer --

MR. EBERSOLE: Yes.

MR. THOMAS: -- typically associated with Class 1-E or safety. What we're trying to say is that we can limit the scope significantly -- well, I think the program itself, from a systems standpoint, is limited to scope a lot. We can further limit that by determining in those systems which relays truly could give you a problem with the chatter and --

MR. EBERSOLE: Which may not be essential relays in the usual context.

MR. THOMAS: True. But in our context, it's that final group that we would call essential.

MR. EBERSOLE: Right. I think that's the larger group.

MR. THOMAS: Well, we did, too. We thought it would be. But the more we worked, the smaller it gets.

MR. EBERSOLE: Good.

MR. WYLIE: Jim, are you going to address the implementation program afterwards?

MR. THOMAS: I do it either way you like. I can do it now or afterwards.

MR. WYLIE: It'd be just as well to go ahead and address that and then Mr. Roby can cover AIF afterward.

MR. THOMAS: Okay.

(Pause.)

MR. THOMAS: Okay. Again, I would like to kind of reiterate a comment that what you're seeing now is another snapshot in time of where our current program is. It's an ongoing program that we're continually learning additional facts and findings in resolving the overall issues.

The major changes that have been incorporated into the program since the regulatory analysis and NUREG has been written is that we are getting closer to publishing and getting an SSRAP review of the traditional data that was collected in Chile and Mexico.

We feel that that will be definitely a relaxation of some of some of the caveats in regard to spectrums for some of the equipment. But that gets back to kind of specific things inside the SSRAP report. We will be working with those the first quarter of this year, and hopefully we will get most of that resolved fairly soon.

There were some questions earlier about the report on the 21 classes or the 23 classes. We're still

finalizing that, and we are following the recommendations of the staff to expand from eight to the overall total number of classes of equipment that would be required to achieve a hot shutdown, this generic list, and are compiling "caveats and exclusions" based on not only the experience data and not limited to the experience data, but based on judgment and other type inputs such as the test data from EPRI.

The EPRI support programs themselves are progressing very well and very close to having some published results. That's the anchorage guidelines to assist us in walkdowns. And a summary of -- you might have heard the terminology -- GERs, the generic equipment response spectra based on analyzing various tests that's been done over the years in triyng to kind of create something equivalent to our experience data.

One of the, I guess, major ongoing programs that's really kind of just getting kicked off is the relay study that we were discussing. We hope that we will be able to evaluate that program the latter part of this year to really determine how effective we can be in assessing essential relays, so to speak. And that is being coordinated closely with the staff and their team.

We plan to again have a trial plant walkdown for the overall generic implementation and are continuing to

work with the staff and SSRAP to get current with our approach.

We feel that the program will extend into '87. We don't really think we'll be able to finalize the overall plant or implementation procedures until '87. And we do plan to train the SQUG members, utility members, part of the plant-specific reviews and set up a program for some type of selected verification of the walkdowns. All of this, of course, will be following whatever is finalized as the required implementation plan.

Just quickly I would like to discuss a little bit more about this. Again it's what I described as a major activity of SQUG is the relay functionality review. We feel that the program will be very successful. It is taking a lot of time.

But the major aspects of the program is to identify the plant functions which must be available, which we have made a lot of progress on, and try to determine kind of a distinction of whether it could be affected by the short-term effets, the motions or if there is nothing that can happen and you only have to worry about after the strong motion is ended.

We are doing a systems type analysis to identify which systems would see a problem if you saw some type of relay chatter. And as we said, we feel that the major

systems that we've got to look at are anything that could cause some type of depressurization. Along with that, we don't want to get any overpressurization of low-pressure systems that could potentially cause a problem there.

MR. EBERSOLE: You mean secondary depressurization, too, don't you?

MR. THOMAS: Yes.

MR. EBERSOLE: What about the defeat of interlock systems, like inadvertent transfer to dry suction of RHR, which will then get the bumps?

MR. THOMAS: All of that is things we have to look at.

MR. EBERSOLE: So it's a systems.

MR. LIPINSKI: Two of the most important ones that are not on your list are overpressurization on the BWR and delay of scram.

MR. THOMAS: Well, I think one of the reasons they're not there, and probably because we haven't made available the documentation of the results of our rviews is, again we feel that what we've done so far about delay of scram is that it's not going to happen.

Now, our study will have to document that. These are the ones we think that could happen that we're still looking at and we're not as far along.

MR. LIPINSKI: Okay.

MR. THOMAS: Then, again, I think we're looking in the program because we've had some very good feedback from the experience data again that once the strong motion is over, that operators have and don't seem to have any problem of assessing their systems and achieving the appropriate resets.

I think a good example of that was at the oil refinery in Chile where they had an emergency diesel that was called on for an automatic start. During the strong motion, a protective relay -- a fault current relay, I believe it was -- tripped that start and prevented it from achieving the full startup.

We're not sure in that case whether it was chatter or whether the relay was fooled. Maybe some vibration out there, it may have seen some kind of current spike or something. But anyway, it did prevent that diesel from starting automatically. But the operator was able to immediately assess where the problem was and immediately reset that specific relay out of many that was on his control console and immediately was able toget the diesel manually restartd.

So again, we're getting a lot of good, warm feelings about the capabilities of operators after earthquake. We'll be considering that in the overall analysis to try to determine where we may need to take

credit fcr such a thing and whether it is something that you could be able to take credit for.

MR. EBERSOLE: Could you comment on what you're going to do about the common initiation simultaneously of all fire protection equipment?

MR. THOMAS: I don't think that will happen.

MR. EBERSOLE: Well, that equipment has not been seismically designed.

MR. THOMAS: Well, those type systems exist in these facilities that we looked at, and the earthquakes did not initiate them.

MR. EBERSOLE: That had an intrinsic resistance?

MR. THOMAS: Just about everything we looked at seems to have an intrinsic resistance to seismic forces, the forces that are not high enough to generate generic what you'd call -- I would call that a catastrophic problem.

MR. EBERSOLE: Any of those plants have mercroid switches in them?

MR. THOMAS: They shouldn't.

(Laughter.)

MR. THOMAS: I guess that is one given, in that we would concede that if there's mercroid switches there, there shouldn't be.

MR. LIPINSKI: Does your analysis look at turbine

trips during the course of an earthquake?

MR. THOMAS: We will be looking at the effects of the turbine trip on the primary system when we start analyzing relays. They would have to function to get to the safe shutdown. That is probable, in that the turbine protective systems such as vibration sensors probably will trip.

MR. LIPINSKI: Will respond to the earthquake at the turbine?

MR. THOMAS: Although we've had a lot of cases on the lower-level earthquakes, but still exceed our design basis for some of these nuclear plants that they don't trip and, in fact, ride right through it and continue to supply power to the system, both in California and in Chile.

So it appears to be requiring a substantially higher level of motion or forces up around .35-.40. I think Peter has a chart that shows the success of these units that were operating during the earthquakes as to at what point they seem to start tripping. And I think it's somewhere around .2, somewhere in that neighborhood?

MR. YANEV: Yes. Close.

MR. SCHMIDT: Neal Schmidt from Commonwealth Edison. The chart generally shows that around .35 to .40 is where the tripping starts to begin in earnest. But there are a number of cases where the tripping has occurred

at .1 g. At Long Beach it was even a little bit less than that.

So we cannot generalize and say that the trip will not occur, but we can say that in general, it appears the trip, you know, where the plants start to trip is somewhere in the neighborhood of .35 to .40.

MR. THOMAS: Part of the substantial -- one of the things that I thought was rather humorous when we were discussing with some of the operators in Chile the operation of their plant, he was telling us about how his turbine tripped.

And we were asking, "Well, why does that happen?" And he was saying, "Well, that always happens. Every earthquake we have, it always trips because the vibration sensor is too sensitive. But we haven't been able to convince them to change it out to one that's not so sensitive."

So it's a lot of cases where you do get the trips, it can be attributed to not the earthquake itself but maybe your sensors being too sensitive.

MR. EBERSOLE: A couple of years ago we were asking Diablo Canyon, since that's a challenge to the overheat safety devices, is it influenced by the vibration effects. Do you follow me?

MR. THOMAS: Yes, I follow you.

MR. EBERSOLE: Again, it's a Woodward Grovesnor design. It has gravity inputs. The conclusion was that it did not at that time. It might be worth a second look.

MR. THOMAS: Did you make a note of that, Bill?

MR. SCHMIDT: Yes.

MR. THOMAS: Good.

MR. WYLIE: You mentioned the sudden-pressure relays. Were there instances where they did operate during the earthquake?

MR. THOMAS: Yes. The fault pressure relays in many cases -- as a matter of fact, it's kind of a dilemma to some of the Chilean engineers. You need the protection, but they don't think that the earthquake should cause them to trip in all the cases, and it's kind of a dilemma as to what you do.

They've eventually kind of adopted a policy in Chile that what they actually do is they really segregate -- I mean, they shut down the power system for Chile after a strong earthquake and then slowly bring it back up.

MR. SIESS: It prevents fires.

MR. THOMAS: Yes. It's more of a public safety type thing that they're responding to. What usually hpapens is the plant is usually tripped by these fault pressure relays or by some actual fault caused by something out on the system that collapsed that really, you know,

small distribution station or something that's causing some type of short where it isn't very well designed.

MR. WYLIE: But they did cause some trips just from the --

MR. WYLIE: Yes.

MR. WYLIE: -- seismic forces?

MR. THOMAS: Yes.

MR. WYLIE: Okay.

MR. THOMAS: And just concluding our kind of summary, the final thing that we would get to is screening the relay functions and then evaluate what's left, the essential relays, on a plant-specific basis. And we're still incorporating what we're learning from EPRI, their work on relays as far as the GERs type approach and incorporating what we learned there.

MR. SCHMIDT: I might note in that regard that EPRI test data is confirming what a lot of relay manufacturers and told us, and that is that there are many, many auxiliary and general-purpose relay types out there in plants which, in fact, don't chatter and which have thresholds for chatter that are in the 1 g zero-period acceleration and up, which we don't expect to have any problem with for the majority of our plants. And in those cases, those will be screened out of consideration early in the process.

We think it will just be protective relays, the delicate type relays that will be of concern, and only those where they're in circuits which we also have called essential.

MR. THOMAS: I would like to add to that that our assessment is that these types of relays we've seen problems with are rarely used in the system that are essential.

MR. EBERSOLE: I guess I didn't understand the 1 g zero-period.

MR. SCHMIDT: What I was indicating is that early in the game we talked to manufacturers of relays, like General Electric and others, who told us that, yes, relays have chattered on tests but, in general, at very g levels, g levels that were set by people who wanted to qualify relays for use in plants all over the world, Japan and so forth, and that, in effect, they tested them to levels far beyond anything we actually need for SSE levels.

But what we're finding in looking at actual test data that's being gathered by EPRI is that for many, many classes of general-purpose and auxiliary relays, the level at which they start seeing chatter on shaketable tests, typically on the order of 1 g peak acceleration --

MR. EBERSOLE: Oh.

MR. SCHMIDT: -- and above. There are exceptions

to that.

MR. SIESS: That's 1 g on the relay?

MR. SCHMIDT: No. 1 g zero period. And typically 2 g is --

MR. SIESS: And what does zero-period mean for a relay?

MR. EBERSOLE: I don't understand.

MR. SIESS: Zero period is a term that applies to a spectra.

MR. THOMAS: That's right. And the zero period is the peak acceleration at the relay.

MR. SIESS: What is the peak acceleration at the relay?

MR. SCHMIDT: The peak ground motion, the peak motion at the device, typically we're finding to be 1 g, and in the spectral peak about 2 g. That's the kind of level at which we're seeing on such chatter in most general-purpose type relays.

MR. LIPINSKI: There's something wrong with that. The relay is a spring massed system that has a resonance at a specific frequency.

VOICES: Right.

MR. SCHMIDT: And all we're saying is that the spring forces that hold the relay shut are not being overcome at levels below the 1 g to 2 g for most relays.

MR. SIESS: And that's 1 g and 2 g at what frequencies?

MR. SCHMIDT: 2 g is about the spectral peak of a response spectra, and 1 g is about the zero period level.

MR. SIESS: Where does the relay frequency fall in relation to that spectra?

MR. SCHMIDT: Well, I guess what I am saying is I don't care where it's hit, the peak is 2 g. That's for deenergized relays.

We're also finding data that would indicate that energized relays have a higher resistance to chatter because the holding forces are higher.

We're not there yet. We expect to have this data in the next several months. But that's what it's indicating.

MR. EBERSOLE: There was a topic brought up some time ago that says, not relays but, say, pressure monitors, et cetera, parameter monitors of various sorts -- pressure, level, whatever -- may be tested in some cases when the parameter being measured is not applied to it near the trip set point. And the fact that if you're near to a pressure limit or level limit or some other kind of limit, affects whether it works inadvertently or not.

Do you follow me?

MR. THOMAS: I hear what you're saying, yes.

MR. EBERSOLE: It may be borderline to tripping anyway.

MR. THOMAS: Right.

MR. EBERSOLE: And then it will go ahead and do it when it shouldn't. And that's a traditional requirement on the tests.

MR. THOMAS: (Nodding affirmatively.)

MR. SIESS: I guess what's bothering me is that 1 g doesn't seem to be awfully high for a piece of equipment that's mounted in a building in a cabinet --

MR. THOMAS: It is.

MR. SIESS: -- where the amplification from the ground motion through the building and through the cabinet --

MR. THOMAS: Analytically, you're correct. This is one other thing that isn't specifically listed but is one thing that SQUG has considered quite a bit and feels that a lot of further work is deserved, is that what we're seeing in the actual earthquakes is that this amplification is not what you would predict. It's lower.

MR. SIESS: The damn thing is high?

MR. THOMAS: We're seeing that these floor responses and the effects that are resulting are a lot less than you would predict would happen with the analytical techniques.

MR. WARD: How is that determined?

MR. THOMAS: Well, there are two ways we looked at it. I guess there are some sites that actually have the instrumentation at ground level at the top. Most of it is just looking at direct effects: what happened; a water cooler, one of the types with the bottle sitting there, if it saw the motion that you'd predict, there's no way it could not have tipped over. A lot of indirect effects that we observed.

MR. SIESS: You can get the same conclusion just from looking at the analysis and the assumptions in it. They're all conservative.

MR. THOMAS: And we feel that there is a significant amount of conservatism, just due to the fact that we have designed using these analytical techniques that appeared to be being confirmed that they are a lot more conservative than we thought.

MR. SIESS: Unlike the test spectra, the qualification on a shaketable, get up into the multiple gs.

MR. THOMAS: That's true.

MR. SIESS: 5, 10, thereabouts.

MR. THOMAS: Right. Right.

MR. WARD: I still didn't quite follow the discussion about the zero period and so forth. Let's see, does the resonant frequency of a typical relay tend to be

in the range of concern, and if you have, you know, the spectra that could be caused by an earthquake, does that extend up to high enough frequencies where it would encompass what might be a resonant frequency of relays?

MR. THOMAS: Bill, correct me if I'm wrong, but my basic experience in that area is that the relays don't have this resonance you're talking about in what we're looking at to where it causes a generic type problem. You may have some type of specific relay that may have such a problem, but it would have to be kind of an oddball to be used in the type system we're talking about.

Overall, you've got to also consider that these tests that you see evidence of chatter, you're monitoring this relay with some very sophisticated electronics that detect minute chatter, very small duration open and closing. And in actual circuits, in most cases it's totally transparent what device that that relay is controlling in no way possible could ever respond to that. It just never ceases.

That's one of the reasons that we're seeing that we're determining so many things aren't really essential relays. The only thing that really gets into this problem is the modern electronic sensing circuits that can detect such things as micro-second bounce. And in most of those cases that I know about it's been filtered out to where the

systems just totally ignore such things anyway.

MR. EBERSOLE: That's if it's driving electromagnetic devices?

MR. THOMAS: If it's driving electromagnetic devices, most of them can't respond.

MR. EBERSOLE: Yes.

MR. THOMAS: And if it's driving an electronic circuit that could respond, the electronic circuit has been told not to respond. We're finding that, as a general case.

MR. EBERSOLE: You mean they synthetically put delays in --

MR. THOMAS: Yes.

MR. EBERSOLE: -- electronic circuits?

MR. THOMAS: Correct.

MR. EBERSOLE: To try to keep the electronic --

MR. THOMAS: Particularly in protection system type devices.

MR. EBERSOLE: Is that a requirement or just a happening?

MR. THOMAS: Good design practice. Good design practice that was considered.

MR. LIPINSKI: There's something wrong with your tests if you're not looking at it properly. If you have a normally open relay and you start exciting this on a

shaketable, the resonant arm is going to start moving up and down. You want to know when it finally makes contact to give you a closed contact. And that will be very momentary.

But if I continue to excite that thing with higher g forces, I will get nonlinear where it will make, stay closed, return, stay closed, and return. I can get a duty cycle then. And I can plot the duty cycle as a function of g force at a particular frequency showing where the thing may stay closed and never return on open.

And if I had such a relay driving a valve, depending upon how many chatters, I can get incremental motion for that valve.

MR. THOMAS: All of that can be postulated. The experience that we've seen is that it just doesn't happen that way in the real world in the circuits that are out there in the plants. And our analyses are trying to determine if it could happen on a specific basis.

You're right that you need to look at that, but again we're getting a good, warm feeling that these postulated occurrences don't really happen.

MR. SIESS: Have you looked at what's the natural frequency of that thing that Walt's talking about?

MR. THOMAS: Well, it's relay-specific.

MR. SIESS: But what order of magnitude? It

conceivably could be so far out of the range of the --

MR. THOMAS: In most cases, you're right, it is. In most cases, it is way out there.

MR. SIESS: Is it very high?

MR. THOMAS: In most of the types of relays that I am familiar with that we particularly use at Duke, it's extremely high.

MR. SIESS: So essentially the relay is seeing the equivalent of a static g force rather than a dynamic because the frequency so far out of the range of the exciting frequency.

MR. THOMAS: In my experience, most cases of the type relay that we use in the circuits that we're talking about.

MR. LIPINSKI: In terms of your experience data and the phenomena that we're talking about, had you specificially looked to see if there was incremental valve motion because of chatter, or would everything have been over with and that ttype of data would not be present when you went to make your observations?

MR. THOMAS: Unfortunately, in most cases, you're right, it cannot be specificall determined. Fortunately, the after effects are easily determined from operator gloves and what they had to do to keep the plant in operation or to get it back in operation. And we were not

given any indication from any of the operators that such things that they knew that anything occurred. If it did, it did not cause any type of a problem.

We were pretty confident they were giving us a pretty good story because of the example of the emergency power system that didn't start correctly. They were able to tell us what action they had to take that they knew was a direct result of the earthquake to get it back into an operable condition.

So we spent a lot of time quizzing the operators as to what happened that you didn't want to happen that you had to take action to correct it? It just wasn't there.

MR. LIPINSKI: Would there have been a specific question in the team review asking them whether they saw a valve moving?

MR. THOMAS: Yes, there are specific questions. It doesn't say "valve moving," but it covers that type of condition. We can show this afternoon, if you like, that list of questions.

I think in a previous presentation I made the statement that that list that we spent a lot of time on turned out to be not as beneficial as we thought it may be, it's because we couldn't get past the first question as to what problems did you have, and they'd come back with none.

MR. EBERSOLE: Let me ask you about the set of

systems we call failure-free. Years ago we looked at that system and found out it wasn't failure-free, it was more prone to failure than most other systems because it was driven by a rotating machine or something like that. Most of the time they were.

The only thing about it, it was free of switching transients. It kept a steady 60-cycle wave, and then you bgan to look at the susceptibility to breaking the 60-cycle wave with the items that were connected to it. And it turned out there wasn't any of them that were very susceptible except the clocks and computers, which says the wrong circuits were hung on those "failure-free" but really failure-prone buses. So we got rid of them -- that is, those loads.

What do you find when you look at the failure-free loads which presumably are hung on a bus that can't tolerate a 60-cycle wave break? It's a special set. I'm going to suspect you're going to find a lot of circuitry hung on those that ought not to be there anyway, which can stand switching transients and thus would have an alternate supply.

Do you follow me?

MR. THOMAS: Yes, I follow you, and I think you're correct, that we have learned a lot of lessons and tried to respond to that knowledge at the beginning. This

is part of our systems review, and it definitely affects whether a system can be affected by relay chatter and the end result of seeing some kind of momentary hour.

MR. EBERSOLE: So why do you hang it on a failure-free bus if it doesn't need it and to hang it on there is an inference you can't stand a relay --

MR. THOMAS: Yes. I think that's beyond the scope of SQUG, but it's definitely -- I think a lot of that is being corrected as designs are modified and things like that.

MR. SCHMIDT: I would like to just kind of clarify one thing. In the development of the screening procedures for determining essential relays, apart from the experience data that Jim Thomas has referred to, we are going about a systematic evaluation of what are the consequences of relay chatter in systems which need to cross them and also systems where inadvertent function might be a problem. And anywhere where the consequences of those actuations turned out to be important, we will classify those essential.

That will mean that those relays will either have to be qualified types or they'll have to be types for which we have data which shows they will operate properly during the earthquake.

MR. EBERSOLE: Or you can modify the system

design to where it can tolerate the chatter.

MR. SCHMIDT: We do intend to address these postulated events, like reactor isolations, turbine trips, and the like.

MR. THOMAS: I will have to admit it's not an easy task. It's probably one of the most in-depth type studies that the SQUG has been working on is this particular issue on systems analysis, which we're still trying to find ways to make it as generic as possible and to simplify it. But it is not easy.

MR. LIPINSKI: One of the things that concerns me is, looking at your test data, you're drawing conclusions and saying that this relay is not of concern, therefore I will not classify it as essential, and then go on with the job.

That step is very important as to how you take a look at a relay and determine whether it's qualified or not before you proceed and say I don't have to do anything about it in my particular system.

MR. THOMAS: You're right, and we're not really there yet. We have not said yet to that, based on experience data, this relay is okay.

We're more likely in that particular instance, to say that, based on the GERs generated by EPRI, this relay is okay, because I think we're more likely to be able to

stand behind that data.

But generically -- and that's what our statements are -- generically, the experience data has shown that it is not the major issue we thought it was. We're trying to be specific to document why.

MR. SCHMIDT: I would say that when we do reach our conclusions regarding the test data and the system, they will be reviewed by SSRAP as well as the special panel of NRC relay experts which they have put together for thi purpose.

MR. THOMAS: I think that I could volunteer that this is one program that we would like to pursue further with you when we have more data available and the results from the program, if I could give you another presentation the latter part of this year, depending on if our program proceeds as we hope it will.

MR. SMITH: I have one more bullet that we should have put up but we didn't. That is, SQUG has been doing all the post-earthquake investigations, like, we went to Chile, we've gone to -- starting with the Mexico quake, EPRI is picking up that and will continue to go after earthquakes in the future. They're setting up a program, a post-earthquake investigation program.

So once SQUG goes out of business, there will be a collection of data just to feed this data back to the

industry so we have a much better understanding over a long period of time of how our systems react, how the equipment and structures react.

In addition, EPRI is beginning to fund additional programs and is using post-earthquake investigation data. They're doing some piping investigations. They are also beginning to do some structural investigations.

So I think over the next few years we'll have a much better understanding of how earthquakes really affect our structures.

MR. THOMAS: Yes. I would just amplify on that, as long as SQUG is still in business, we're going definitely to support this EPRI effort and will probably in all cases participate in any kind of survey and after SQUG I think we're working with EPRI to where there will be designated utility representatives that will support that effort also such that we can continue this systems type operability survey in addition to just the structural and the equipment damage type surveys. So we can send a systems engineer out to talk with the operators so we can continue to add to our knowledge about what really happens in an earthquake.

MR. WYLIE: Have you got any feel for when -- or maybe it's now, I don't know -- but when EPRI will pick up the lead for investigating these?

MR. THOMAS: They already have.

MR. WYLIE: They have?

MR. THOMAS: Yes.

MR. WYLIE: Okay.

MR. EBERSOLE: Let me ask you this. These earthquakes that you're talking about and we've rarely experienced, what's the ratio of mechanical severity of these to what we are using for safe shutdown? Are they worse?

MR. THOMAS: Yes -- I'm not sure I understand what you're saying.

MR. EBERSOLE: Are you saying there they're quite a bit worse than the ones we're using as models for design?

MR. THOMAS: Yes. The severity of the earthquake, like, in Chile, the g levels that are actually occurring are much higher than the design basis for the plants.

MR. EBERSOLE: All right. Now, let's go to Chile.

MR. SIESS: Is that true for West Coast plants?

MR. THOMAS: It's close there. It's not --

MR. SIESS: It's close there.

MR. THOMAS: -- substantial margin. It gets closer, but it does somewhat envelope those cases, too, where you get the worst case in Chile and the worst case in

Mexico envelopes a lot of the California sites, too.

MR. SIESS: Yes.

MR. THOMAS: It just doesn't give you that tremendous margin we're seeing compared to East Coast.

MR. EBERSOLE: Well, now, if I were to go to Chile -- and I hope I have more than one earthquake to use as the basis of experience -- and apply the methods that we used to forecast earthquakes in Chile, what would I come up with as a theoretical earthquake, the ones that happened or ones less severe or ones more severe?

MR. THOMAS: Well, they told us that this one, which we thought was tremendous, that they didn't think it was this decade's big one.

MR. SIESS: Yes, but they don't design the same way we do. I suspect if NRC were setting a safe SSE for a plant in Chile, it would come out roughly in the neighborhood of Diablo Canyon. It depends on where it would be in relation to --

MR. THOMAS: The interesting thing about Chile -- it's a good point and I'm glad you brought it up -- is that it is a very seismically active area --

MR. SIESS: Yes.

MR. THOMAS: -- and a lot of these plants that we were looking at, this was not their first earthquake.

MR. SIESS: Yes.

MR. THOMAS: And the experience that we were getting from operators wasn't one earthquake but is in some cases as many as three. And we were able to compare two units sitting side by side, one that saw the recent earthquake and the other one that saw the one before that, too, and in some cases actually make a comparison of some of the design changes they made on the newer plant where they should or should not.

Snubbers is a good issue that they thought they should not have put in.

MR. EBERSOLE: They don't have any reactors in Chile.

MR. THOMAS: Research only. We were not able to gain access. We got general feedback that they didn't have any serious problems. I guess they did say we had access. They called once they knew we were on the plane on the way back. Then they said, "If you had stayed an extra couple of hours, you could have gotten in."

(Laughter.)

MR. THOMAS: We tried.

Any other questions on the overall SQUG program?

(No response.)

MR. THOMAS: And I guess the offer, if you would like to invite us back, we would be willing to further

discuss the relay work the latter part of this year.

MR. WYLIE: Okay. Thank you, Jim.

Next, I believe, is Mr. Roby, representing the Atomic Industrial Forum.

MR. ROBY: Good morning. My name is Arnold Roby, and I am the chairman of the AIF Subcommittee on Equipment Qualification.

I would like today to present to you the AIF position for what essentially is the resolution of USI A-46. And this is a subject that the AIF has had a working group active on, I guess since 1980; certainly, since that time. It's had periods of intense activity, and of course, it's had periods of kind of wait-and-see-what's happening.

But that group has essentially done two things documentationwise. It has produced a position paper, an AIF position paper, regarding seismic qualification in operating nuclear power plants. And that position paper was submitted to the NRC in November of 1983. I'm not sure how many of you would have seen that, but certainly it still is in existence today as their latest position.

We also provided in November of 1985, of course, as again you heard this morning, we provided as specific comments on the regulatory analysis for the proposed resolution of unresolved safety issue A-46. Many of those, of course, this morning we heard the staff detail how they

would propose to deal with the comments.

I think today what I would like to do for you is to develop further the basis for the AIF conclusion that pair-plant equipment can confidently be expected to survive acceleration levels far in excess of the SSE requirements regardless of whether or not the equipment was specifically qualified for seismic service.

That really gets to the heart of this issue. It affects essentially the equipment which may not specifically, by today's standards, have been qualified for seismic service.

I have several overheads, and I think the first one stresses some of the points that I would like to make. And that is that historically for nuclear power plants --

MR. SIESS: Do we have copies of those to be passed out?

MR. ROBY: I didn't get them until very late this morning. But I can certainly get copies.

MR. WYLIE: Well, then could you move the lectern so that you're not standing in front of it?

MR. ROBY: Yes. Maybe I should do it from -- or move me so I am not standing in front of it. Here we go. How's that?

MR. WYLIE: Thank you.

MR. ROBY: Historically, I think all of us can be

assured that nuclear power plant designs have included conservative engineering practices to assure compensation for uncertainties in seismic loadings.

Examples of these practices are the ones that I have indicated on the board. And they range from the margins that are available between the allowable stresses on the components and the ultimate stress of engineering materials which are used, the conservatism which has been used in the methods, which combine the loads, seismic loads specifically, which are applied to plant equipment, the seismic structural capability of nonstructural elements where these are not normally considered in the design calculations.

I guess a lot of what Jim has said this morning tended to indicate that.

We have a cooler that we would have expected to fall over if we did an analysis on where we located it and at that particular g level. It doesn't do that. A good question is, "Why doesn't it do that?" And inherently, it's because of some of the nonstructural elements, which are not included and we wouldn't include it in our design, are inherently there. Things tend to work to our benefit in seismic.

MR. WARD: I still don't understand what you mean by the third item.

MR. ROBY: The third item.

MR. WARD: Coul'd you give us an example?

MR. ROBY: Well, many times that we would do an analysis of a device which is located in a panel position, we will take credit for those elements which we can quite definitely see are going to give it the seismic resistance.

Inherently, we can also see that there are other elements there which we can expect to act in that same mode, but because we can't predict the way in which they will act with the certainty of other structural elements, we don't include in the design, not in the design calculation which addresses seismic capability.

There are usually more things in those designs than we take credit for in our design analysis.

MR. WARD: Yes.

MR. ROBY: I think generally, everything we've seen from the evaluations would lead us to conclude that that's a fair statement to make.

I think, also, we have to recognize -- and I'm not sure how much we all recognize this -- that we have provided equipment throughout the course of the nuclear power program which has been designed and manufactured in full compliance with national codes and standards.

And it's interesting to understand that when we

do this, we're acting for the requirements of the standard which usually has been developed over a period of years to include and be responsive to those problems that have occurred with equipment.

The standard will start out being, well, it's just a good idea in the minds of many people who are accredited experts on the subject as to what should be included.

Over the years, as information is fed back to committees and subcommittees which are standards-writing committees, those problems which are associated with the equipment in its practical use, those things which we have become knowledgeable about as the course of time proceeds inherently become a part of the standard-writing activity.

They're included in the updates, in the revisions, in those things that cause standards-writing not to be an ongoing subject. And certainly, in many of the equipment -- oh, regardless, I will probably say all of the equipment -- which we use in the power plants, the standards that we have built our nuclear plants to have been a result of that development.

And were seismic ever to have been a known problem to the extent that the users of the equipment wanted to ensure that seismic concerns were addressed in

the equipment they were purchasing or procuring, the ability to get that in the standards has always been there.

The fact that if you look at the national standards and say there isn't very much in that, which talks about seismic capability, is very likely to be there because seismic problems have not arisen in the application of equipment manufactured in accordance with those standards.

So you shouldn't read into the absence of rigid requirements that that's an omission that should be taken care of. It's very likely something that is not proven itself to be worthwhile of including in a standard.

MR. EBERSOLE: Well, let me ask you, in the design of an electrical apparatus like a circuit breaker or a contactor or a relay or whatever, I don't know of any standard that sets requirements on the frame, the structural rigidity, the mechanical aspects of the electrical device. There is on the electrical function.

MR. ROBY: Yes.

MR. EBERSOLE: And I don't know of any common impact standards, like you're supposed to be able to drop it ten feet off a truck. I expect they may be put in as a practical need, but I don't know of any written requirements. Are there any?

MR. ROBY: There are requirements which talk

about the ability to withstand vibration. There are requirements which, as you say, are really not specific as would direct the design. What we're really interested in is writing performance standards.

MR. EBERSOLE: Right.

MR. ROBY: And really, we don't go along in detail that in order to meet that requirement you must design it with a frame this size or that size or whatever it is. The standards that we would all want to use and should be using are performance standards.

The requirement on the vendor, on the manufacturer, is to identify compliance with those requirements.

MR. EBERSOLE: In the performance standard.

MR. ROBY: In the performance standard, yes.

MR. EBERSOLE: But that's electrical performance standard.

MR. ROBY: But it has mechanical characteristics associated with it. For instance, we would not require -- we would require the equipment not to be subject to inadvertent operation on an impact loading of some description.

MR. EBERSOLE: Well, I don't know. You hear time and time again that a janitor trips a whole unit off line.

MR. ROBY: Absolutely right. In fact, those are

usually being the problems with which we've been concerned, more than the seismic ability which has been imparted to the equipment by some kind of an earthquake motion.

That also, I think, establishes a point that we heard this morning that usually those types of shocks are very high frequency if you relate them in terms of the frequency components that they have, which are probably very likely to be very far removed from the types of frequency response that we're seeing from the seismic effect.

In fact, the resonance surges which are done on equipment such as relays usually generate a spectra of concerns which is way out of range, frequencywise, from those which we require because of the way in which we mount in the seismic response. We test the relays. Nevertheless, the relays are tested to demonstrate the ability to withstand the frequency range which is imparted by the seismic event.

And the standards in those instances do talk about contact closures, contact closure 101 shall not be more than one millisecond. And that's what the relay is tested to demonstrate.

We've got knowledge. Of course, the designer can then take credit for that length of time of closure or opening and can design his subsequent auxiliary relays and

the remainder of the circuitry in order to accommodate that kind of contact closure if that kind of contact closure is worth concern to him.

I think that these practices, the ones that I have indicated here -- and there are others -- really provide more than a reasonable assurance that the p.'ants have been constructed in a manner where the inherent seismic margin may be greater than has been generally assumed, where it'svery likely to assess a 1968 plant as having no seismic margin and we require the nth degree of documentation to support its adequacy. I think there is a margin which is usually greater than we've assumed.

Importantly, I think that the design criteria, although we can recognize that the design criteria and the methods for seismic qualification have really undergone significant change over the life of the nuclear power program, we cannot establish today any substantive indication that industry practices need to be reassessed to more than just a modest degree, even for the earliest operating plants that we have, in order to address the seismic issues.

My second point really establishes this on an experience base wherein we can today I think take credit for an expanding database of information which evaluates the seismic performance of equipment installed in both

conventionals and nuclear power plants, and that that database clearly indicates that the equipment has performed realistically and in an exemplary manner under site touring and after strong earthquake situations.

If we accept that concerns regarding equipment anchorge and relay contact chatter can be addressed -- and I will touch on those two issues in a few minutes -- I think historical and current data demonstrates that the seismic capability of equipment in operating nuclear power plants is not the significant safety issue.

To further support these conclusions, as the second bullet indicates, important data from fragility testing programs is the observation that plant equipment can be expected to survive accleration levels which are far in excess of the building responses in which the equipment may be installed.

Equipment and supports which fail in a structural mode and which are designed to resist seismic loading typically have capacities of several times the SSE specified in plant dsigns.

Historical experience data has demonstrated that equipment which has not been vigorously seismically tested has performed very well, almost without failure, during severe earthquake events.

NUREG/CR-116.65 concluded that two fossil units experiencing an earthquake of a Richter magnitude of 6.6 were safely shut down with no malfunction, no known malfunction, of electrical or control and instrumentation equipment during or after the earthquake.

Today, I think you will be hearing, and have heard in some ways, great detail of the results of the extensive testing program to gather and develop a seismic experience base, database.

The AIF supports as particularly valuable the SQUG contribution to that database. We're not surprised at

its findings, and really they only supplement the conclusion which was in our 1983 position paper that upgrading the seismic qualification of equipment in operating plants is not justified either in terms of risk reduction or safety significance.

MR. WARD: Did your '83 paper point out that the two concerns of equipment anchorage and relay chatter?

MR. ROBY: Yes, it did. Yes. It touched on those. At that time, those position papers, remember, are prepared essentially on the AIF on value judgments. They're prepared by panels of people who can -- who have had long experience in the particular subject that they're addressing, and the value judgment at that time was that relays could be a concern to us. And also, equipment anchorage was seen at that time as a concern, and it touches on both those issues, although only in either single- or two-paragraph fashion.

Since that time, of course, on the subject of equipment anchorage, the staff has, in fact, taken some action.

Proper equipment anchorage has long been an industry concern which, in many respects -- and certainly in some plants more than others -- but in many respects, it has been addressed somewhat fully through the IE Bulletin 79-02 and the IE Notice 80-21.

We would expect that the licensees be given full credit for the work that they have done on the verification activities that they have already accomplished.

Many plants went beyond the requirements, by the way, that we heard talked about this morning. One of the very earliest requirements that we saw was that nonsafety equipment not be moved, not be able to be moved or slide or overturned, because of its potential impact on safety equipment.

So many of us did not limit our reviews to what was just safety equipment at that time, however you defined safety equipment. We looked at all the non-1-E equipment which had the potential to possibly impact safeguards equipment. And in that respect, many of the things that we did were done to non-1-E equipment in order to safeguard it.

We have to recognize also that inadequate anchorage has got a whole scope of activities associated with it by which it could remedy situations. These range from very simple things -- torque on bolts -- to the very complex situations -- additional supports.

And the costs associated with the more complex of these modifications can be extremely high. And we believe that licensees should be allowed, through the regulatory program, to take full credit and to be given the full

flexibility to recognize and establish the implementation program in the light of all the alternatives.

Certainly rigid activities, rigid directions in these efforts, don't help us.

MR. EBERSOLE: May I ask a question? I think it was Zion wh^re the plant that went through an analysis, and they discovered that dependent type pumps with long vertical shafts where the pump is in a bowl 6C feet below the motor or something like that --

MR. ROBY: With a long driveshaft.

MR. EBERSOLE: -- those were notably vulnerable to earthquake effects. And I wondered, on a generic basis, are those pumps cared for now by proper bracing at the bottom?

MR. ROBY: The Zion-specific now, rather than the question of vertical pumps --

MR. EBERSOLE: Yes.

MR. ROBY: -- as opposed to horizontal.

MR. EBERSOLE: Yes. Right.

MR. ROBY: I am unable to say whether Zion or not has taken care of that. I am sure that if they --

MR. EBERSOLE: Well, tney did, whatever plant it was. I'm not certain it was Zion. But they certainly -- you know, they put in swing braces.

MR. ROBY: Yes. Yes.

MR. EBERSOLE: And can the staff say, did they do that generically all over?

MR. ANDERSON: There had been some concern about deep-draft pumps, but the one I remember is, I think, was in Beaver Valley. But I think the ones that we have looked at have been corrected in some manner. But I don't know that there are -- don't know personally of any other instances where we've taken specific actions on them. I know some other plants do have the deep-draft pumps.

MR. EBERSOLE: Well, these happen to pull up essential water for cooling.

MR. ANDERSON: Yes.

MR. SCHMIDT: We also know of cases in SEP where there were deep-draft pumps that were evaluated and found to be acceptable the way they were.

MR. ROBY: Yes. I think basically, a lot of the problem that you might be finding with the anchorage is because it hasn't been done in accordance with what would have been or should have been, or perhaps even was, the manufacturer's instructions.

Usually, we look to the vendor of the equipment to define the adequate anchorage that we should supply, the anchorage that shall be supplied. If we believe that we have a specific case which would cause them to go, want to go beyond that which the work that he would normally do,

then we would request him to do that.

The second issue that we have is relay chatter. And I don't know that I am going to be able to do any more for you this morning than has already been done on that.

Certainly, I think the things that I have identified as bullets on the overhead substantiate the fact that relay chatter, relay contact chatter during a seismic event is a recogized issue. We don't believe -- and I didn't hear anything that suggested that we could this morning -- we don't believe it's possible to identify generic problems. And by and large, that's because the ways the application, the way in which the relays are applied vary so much from plant to plant that it would not be easy -- it would not even be true -- to identify one particular relay and say that this is a generic problem for the whole of industry.

There are so many ways in which it is applied to the system of which it is an integral part to the way in which it is mounted to the way in which it is used in that particular system. But really, you have to do unique system analysis in order to even get a good feel on whether or not the relay is a potential source of a problem.

We do believe, though, that only a very small subset -- and usually these are the fault detection relays themselves -- are likely to be, of the total number of

electro-mechanical relays, are likely to be vulnerable.

Inherently, one hears that the problem is associated with the electro-mechcanical relays that are used in plant systems. That covers a multitude of different types of relays, far too many for the subset which we believe are the particular problem that we would want to address.

The fault detection relays can clearly be seen to be in a category where we might suspect them to be affected, because essentially their contacts float, they have no restraint applied to them, they're exceedingly light, of course, and they have to be very sensitive in order to detect the very situation that they're applied for.

So, inherently, one would suspect that there is a small subset that we should get to grips with and we should really become aware of what their attributes are and their negative characteristics insofar as we're concerned.

Those would have to be addressed on a plant-specific basis. I think we could very well expect to establish the type of relay that may be vulnerable. Whether it is or not, it would still have to be a plant-specific analysis.

Again, the licensee should be allowed to produce a relay -- I guess one might call it -- a "relay assurance

program" -- which will allow the licensee full flexibility to address his particular units. And again, even in that respect, there is a lot of information available on relays to the designer from which he could carry out, develop an analysis which would ascribe whether or not he could expect his equipment, his system to be affected.

There are certain, of course, systems that we might have to characteristically say we shouldn't include in addressing these. And many of these are associated with the relays which are used in the transmission and distribution system and all of those systems which are used to provide offsite power.

Historically, many of their relays have been, of necessity, subject to a requirement for high sensitivity during full conditions. I think we have to get around to recognizing that the relays of concern that we have are those that protect the auxiliary buses within the plant and the power supplies, the onsite power supplies to those auxiliary buses.

The things like the generator, onsite generator differential relays, the bus protection differential relays -- all of these are in this very highly sensitive category. They do exist, and those are the ones that we should really get to grips with under the relay assessment program.

The AIF, as we heard this morning also in the staff presentation, would consider that any requirement to backfit a facility for seismic requirements should meet with the requirements of the backfitting rule. It should be determined on the basis that there has to be, there is shown to be, a substantial increase in the overall protection to the public health and safety.

All of the direct and indirect costs associated with implementation should be justified in respect of the increase to the protection that's afforded.

We cannot conclude that any study today has quantified the risk improvement in terms of cost benefit. Statements which do exist which conclude that the NRC inspection program, the regulatory analysis program, would result in significant safety improvement really absent the evaluation to support that conclusion.

Walkdown anchorage reviews, as a typical example, walkdown anchorage reviews which have been completed to date for structural adequacy and structural adequacy evaluations for SEP plants, we know them to have required expenditures of in excess of $500,000 in some instances.

Our perspective is today as it was, I guess, in 1980, when we first began to consider seriously the subject, is that the industry has always played more than just modest attention to seismic design. High inherent

seismic resistance is present in the overwhelming majority of equipment used in both nuclear or nonnuclear facilities, where that equipment has been designed and installed in accordance with proven industry standards.

Equipment which seismically performed well in nonnuclear facilities is designed to the same industry standards as similar equipment in nuclear plants. And the only difference is in the degree of documentation available for nuclear plants.

All of us who, where our day-to-day activities are concerned with either nuclear or fossil plants, are well aware that all of th controls and instrumentation schemes, protection schemes in nuclear plants are exactly the same from a designer's perspective as in the nuclear plants.

The only thing we have going for us in the nuclear plants is the degree of redundancy that's available to us over and above QA. The degree of redundancy, the control system for an auxiliary feedwater system for a fossil plant is exactly the same as for a nuclear plant, even to the items of equipment that we use to assure that auxiliary feedwater source of supply.

I think what I have hoped to do is to present you with the information that there can be more than reasonable assurance that the seismic adequacy of equipment in nuclear

plants is acceptable and that upgrading that equipment has not been shown to be justified on a cost-benefit assessment, and we should not certainly impose the present-day criteria on the older operating plants.

I would attempt to answer any questions you may have.

MR. WYLIE: Thank you, Mr. Roby.

I have a question. Let me see if I understand AIF's position. I believe the AIF position was stated in a letter of November 22 by Mr. J.W. Williams, Chairman, Committee on Power Plant Design, Construction, and Engineering.

MR. ROBY: Yes.

MR. WYLIE: And I assume that that is still the AIF's position?

MR. ROBY: Yes. We wrote that then I guess just a short while ago, Tony, and it is still --

MR. WYLIE: Yes. So I guess that the AIF is in disagreement with the staff regarding the requirement for walkthrough on the basis that the credit is not being allowed for original engineering and work already performed in the seismic area.

MR. ROBY: Yes. And to the extent that we heard the staff talk about that this morning, I think that still is my perspective. They are reluctant to allow that credit

to be given to the licensees.

MR. WYLIE: And the reason, as I understand -- and the staff may want to comment on this -- is that the staffs's taking that position is that they don't believe that the original analysis and walkthrough and engineering work done was adequate. I mean, I think that's what I think I heard them say.

MR. BOSNAK: Well, I think we also said, for instance, 79-02, that was a piping issue, and there are other items that are important. So I think also we said we are willing to give credit where there is documentation and there is agreement on what was done. And if it had been covered before, that's fine.

Those things that weren't covered, with particular emphasis on the equipment anchorages and getting into the relay chatter issue, those are the things that we want to cover in the walkdown, the walkthrough, particularly the equipment anchorages.

MR. WYLIE: Yes, I understand. I mean, the walkdown, you can address the anchorage and relay chatter is a separate issue.

MR. BOSNAK: A separate issue.

MR. WYLIE: But that basically, you're saying that the documentation of work previously done in the seismic area is acceptable if --

MR. BOSNAK: If it's been done properly.

MR. WYLIE: If it's done properly.

MR. BOSNAK: We don't like to repeat things that have been done and done correctly. But if it hasn't been done, hasn't been done correctly, those are the issues we want to concentrate on. So I don't think we're too far apart.

MR. WYLIE: I wouldn't think so.

MR. ANDERSON: May I comment on that?

MR. WYLIE: Sure.

MR. ANDERSON: I think that following our first encounter with CRGR, we had not taken credit or reviewed in enough detail work that had been done previously through the 79-02, 79-14, various notices and I&E bulletins that have been sent out.

Following that meeting, we did go back and review in some detail all of the work that had been done. Our conclusion was that although there had been work done in a number of areas, that none of these bulletins covered the area in total that we're looking at. As a matter of fact, all of them in total didn't cover, we felt, the area in that detail. There were still open areas that hadn't been covered by all of these I&E bulletins.

And in addition, with regard to several other reviews, as we pointed out this morning, we had gone in to

look specifically at anchorages for the purpose of developing plant-specific fragilities for PRA analysis, and we had found that there are still anchorage deficiencies in the plants.

So that we don't feel as comfortable as the AIF does that all of the past experiences have covered the area well enough that we're concerned with.

So I guess I would also like to comment that I don't think that -- I am speaking mostly for myself, but I think most of the people on the staff agree with me -- that we don't have the same confidence in the design process per se that the AIF has stated. We think that most of the problems that we know about that have arisen have either been in installation, fabrication errors, modifications put in the plant later. And we know that these things are all covered by procedure, and we look at them. But they do slip through, and we have evidence that they have.

One particular item that I thought of as Mr. Roby was talking about the design process and his confidence in it, there was an inventory of valve operators. And, you know, I think they're very nice. But a utility doesn't buy a valve and a stem and an operator all together, they buy the parts separately and put them together themselves. So I don't think that I can say that since Limitorque (phonetic) does such a good job of design

that I am not concerned about their installations in the plant.

You know, I think there are other instances of that same thing. But before I sit down -- I don't want to take potshots at the AIF position because I think that the staff in general agrees with it, and I think we have backed off a long way from where we started a couple of years ago with regard to our concerns. I think we have reduced our concerns just to the few items that we think have some potential for safety benefit and recognize that we were unable to provide a quantitative risk assessment. I think we tried to explain to you why.

But I think that the staff continues to maintain that the limited scope of the review that we have in our focus now we think is justified and we think will provide safety benefits.

Unless we hear more detailed information with regard to complete coverage of these previous reviews that they have addressed our concerns, I think we are going to probably stand on the same position we are.

But we still maintain that we will give any individual utility credit for reviews done in specific areas, provided that they have adequate documentation and that they can provide that to us and show us that they have indeed verified the adequacy in these areas.

MR. WYLIE: Will that be a part of your resolution, that it's documented?

MR. ANDERSON: Yes, sir.

MR. ROBY: I'm not sure myself whether your concern is the design or design assurance.

MR. ANDERSON: My concern is what is there in the plant today --

MR. ROBY: That's design --

MR. ANDERSON: -- that's going to --

MR. ROBY: That's design assurance. Not design.

MR. ANDERSON: Okay.

MR. ROBY: Thank you.

MR. REED: I am a little concerned. I heard the word over here twice, "adequate documentation," and again you repeated "adequate documentation." I think documentation may not exist for many very rugged pieces of equipment that would stand all kinds of seismic challenges.

What are you saying? Are you saying that for this equipment, that by experience data they'd say is fine and dandy just by the normal ruggedness that's built into power plant equipment, anyway, that you're going to want documentation, where I am sure it doesn't exist?

MR. BOSNAK: No. I used that in a different sense. I used the "documentation" on things that have been previously done. We're talking about the 79-02 and the 79-

14 bulletins, how they were answered. And if they were done adequately and properly documented, that's the sense that I used the "documentation," not for the documentation of rugged piece of equipment.

That way we hope to get from the experience factor. I think that's a separate issue.

MR. ANDERSON: Well, I have a little bit different slant on that in addition to what Bob said, is that we're not concerned about documentation of massive equipment where we have experience data -- well, not only massive equipment -- rugged equipment where we have experience data and have some comfortableness that it's not going to fail.

For instance, we're not concerned about electric motors, we're not concerned about horizontal pumps. There are a number of items that we think that you're not going to be able to shake those things in any manner that you're going to cause to lose function.

No, the only thing we're concerned about, I think as we stated, are to look for certain outliers which are nontypical configurations that may be particularly susceptible to seismic damage or a limited scope and may end up being a screening process for looking at anchorages for equipment within our scope and a screening type relay review procedure which is under development by SQUG.

Now, outside of those areas, we're not questioning either the anchorage or the functionality of the equipment in seismic ruggedness.

MR. WYLIE: So basically, staff does not believe that there are deficiencies in the work done under 79-02 and 14.

MR. ANDERSON: To my knowledge, we have no knowledge that there are deficiencies in the work that was done under those.

MR. CHANG: That was piping.

MR. ANDERSON: Yes.

As T.Y. points out, they are for piping. And our major point is that they were fairly limited in scope.

MR. WYLIE: Yes. Okay.

Mr. Thomas?

MR. THOMAS: I would just like to make one comment about what I think we as utilities feel is adequate documentation in regard to anchorage. An example, if the drawing exists that shows an adequate anchorage, it shouldn't be necessary to walk down that equipment into scope of A-46, because it's not a qualification issue. That is a QA issue.

MR. ROBY: Absolutely.

MR. THOMAS: If we have a drawing that was used in the construction of a plant that shows that adequate

anchorage exists for that equipment, then it shouldn't be necessary to go walk it down. If there's confidence in the drawing being correct, then everything gets out of the scope of A-46, which is qualification, not QA.

MR. WYLIE: What you're saying is if the design is correct and there's documentation in the form of a drawing issued --

MR. ANDERSON: Then that would be acceptable to us.

MR. WYLIE: -- then that would be acceptable documentation.

MR. ROBY: Design assurance, which is what Jim is talking about, goes to many more pieces of equipment than we would cover in the seismic concerns. Design assurance is an issue which every plant has to address to convince or to satisfy the NRC that his program is adequate for him to be able to say that what was installed is in accordancen with the design.

And that thread runs throughout all of the equipment that we have under the regulatory process in a nuclear power plant. There's no need to do more on that issue for seismic than there is for other issues.

Every time we do a plant modification to a control system, add a terminal block, design assurance has to be included in that program in order that we can satisfy

that, yes, it was installed as the designer required it to be. It's part of a bigger program, bigger issue.

MR. WYLIE: Now, are you including both safety-grade equipment and nonsafety-grade?

MR. ROBY: Where nonsafety-grade equipment can fail in a manner which would impact safety-grade equipment, yes. We either had to demonstrate that it will not do that if it did fail, or we have to qualify it as 1-E equipment. Those are the options that are available to us.

MR. LIPINSKI: On the older plants, would quality assurance apply like --

MR. ROBY: No, no.

MR. WARD: Well -- wait just a minute. Wait. But how do you tell that from a drawing, for example?

MR. ROBY: With the assurance program that the plant has in place, or a licensee would have in place, realistically, in order to verify that what was installed was in accordance with the design.

Now, in the older plants, over the years that issue has been visited and revisited many times. It's visited every time we go for a modification. And it's an ongoing program that we're always -- which is current between the licensee and I&E at this present time.

MR. LIPINSKI: But on an older plant, you have never been required to do a total QA against a design.

It's only if you do a mod that current QA applies.

MR. ROBY: Well, on an older plant we can -- even now on an older plant we can be required to demonstrate that what is installed in the design is in accordance with what's on the drawings. And we would, as Jim says, we would take credit for that according to the degree by which our QA program assured that. If we couldn't do that, we'd have to go and do a walkdown.

If right now we don't believe that we could assure that that pump which was installed in 1968 was installed in accordance with the design, when you asked us to demonstrate that, then a walkdown may be necessary. But we would be given the option, we would be allowed the opportunity to address why we can say that that design is in accordance -- the installation is in accordance with the design.

MR. LIPINSKI: If we take your oldest plant, take the electrical cubicles, and you look at your design drawings for those cubicles, I don't think the QA ever was in place to guarantee that those cubicles were done in accordance with the design. It might have been a question of economics on the plant owner to see that indeed the contractor was doing his job. But in terms of today's QA paperwork and all the levels of checks that go in, it didn't apply in those days.

MR. ROBY: You may well be right. However, what I am saying is that it's not necessary to mandate that simply because the plant is an SEP plant, you must walk down all the plant equipment to assure that it is in accordance with the plant design.

Many utilities may say, "Five years ago we carried out the walkdown to do this, not as part of the SEP program, not as part of any regulatory bulletin. Why shouldn't we be allowed to put that forward as supportive evidence that we have assured the design?"

MR. LIPINSKI: Okay. That, I think everybody is in agreement with. But if you've never done it, that's another issue.

MR. ROBY: Yes. I understand. And your concern could arise. I think to arbitrarily make the decision that it will always be the case and therefore plant walkdowns are required at this time to deal with that issue is not supported.

MR. WYLIE: Yes?

MR. SCHMIDT: The way the SQUG approach is going to work, the issue of whether or not the drawings are accurate, it's a plant-specific issue. And if the utilities feel they can have absolute confidence in their drawings and that they can do all their reviews from their drawings without going out in the plant, that's up to them.

The SQUG group is going to do a field review of that equipment. That field review -- and take the drawings out in the field with them, and if they're not right, we'll know about it.

So this discussion we're having I think is sort of moot because it's really a function of how the utility wants to do their work. And if I were the utility, I would at least check my drawings and do some field work. If I thought my drawings were really good, I might stop there. On the other hand, if I thought I needed a lot of additional work, I would do it.

The senior seismic review and advisory panel is going to take some of the plants that the SQUG people have done their independent technical reviews on and will make sure that, in fact, we've done an adeuate job. So there's a multilayer approach to assure that the anchorage is, inf act, adequate.

Whether the utilities start with just drawings or they start with walkdowns, the net result is there will be walkdowns somewhere, at least on a partial set of equipment, that will provide the confidence to everybody that things are appropriate.

MR. WYLIE: Are there any further questions of Mr. Roby?

(No response.)

MR. WYLIE: Thank you, Mr. Roby.

I have been requested by the staff to take up Item 6 before we adjourn for lunch, because they have commitments this afternoon. And this has to do with the subcommittee comments regarding the schedule for the presentation at the February full committee meeting.

Before we do that, I would like to ask a question of the staff regarding where we are in schedule for final resolution of this issue.

Now, in the presentation this morning the staff said that the resolution to the comments that they covered in their presentation this morning still had review within the Commission, as I understood it, to be done, and then there will be some disposition of the proposed items of resolution on all the comments.

Could you tell us what the schedule is for resolution of those comments and the final resolution of this issue, the issues covered?

MR. ANDERSON: We have a proposed resolution of all the comments, as we told you. And T.Y. has about completed incorporating all the ones that -- the results of these comments into the regulatory analysis in the package that we will submit.

Our next step will then be to send this to

Mr. Denton and his staff for review, and I would think that we would be able to do that by the end of this month. We're a little bit behind schedule now, so I am kind of projecting that. By the end of January we think we can get that package to Mr. Denton and give him a couple of weeks for his staff to review it and meet with him, and we'd send it to CRGR the middle of February.

And we're thinking March or April, providing we get a favorable recommendation from the CRGR to proceed, that we would issue the generic letter.

MR. WYLIE: So you say March or April?

MR. ANDERSON: Yes. In that time frame. You know, these things always take much longer than I think they will.

(Laughter.)

MR. ANDERSON: Well, T.Y. reminds me that we were thinking it maybe as late as June or July. He's more realistic than I am.

MR. SIESS: When did you start it?

MR. ANDERSON: When did we start?

MR. SIESS: A-46.

MR. ANDERSON: A-46 was designated as a USI in December 1980.

MR. WYLIE: Do you contemplate any major changes once Mr. Denton and his staff have reviewed this?

MR. ANDERSON: I don't believe so, because I think that we've narrowed our concern down to a few items which I think we have some justification for, and we believe that the industry -- the SQUG group, I should say -- is in essential agreement that there are some potential concerns in the areas we're looking at.

I certainly don't anticipate that we're going to have that much difficulty in proceeding with the issue from here on.

MR. SIESS: When we met in August, did we have the draft for the full committee?

MR. ANDERSON: Well, if you had it then, it probably wouldn't be in its current form.

MR. SIESS: Yes. It wasn't referenced in the letter.

MR. ANDERSON: The current form is the one that was issued for public comment on November 15. And I am sure that the ACRS has received copies of that.

MR. SIESS: This one?

MR. ANDERSON: Yes. The blue one.

MR. SIESS: This didn't go out until November?

MR. CHANG: Issued in September.

MR. ANDERSON: Oh, yeah. Okay. Issued in September for comment.

MR. SIESS: Okay.

MR. WYLIE: All right. Thank you.

I will ask the subcommittee now, bearing in mind what we heard this morning and the discussions we heard, and the schedule, should we make a presentation to the full committee in February?

MR. REED: Well, I don't think that anything is urgent enough or pressing enough or disagreed-upon enough to warrant taking anything to the full committee except maybe the chairman or the subcommittee's update, rather than bring other people in.

As I see it, the comments are mostly agreed upon, the general comments, except about two. And there seems to be at this time still continuing progress between the staff and SQUG on resolving the backfitting and walkdown issue.

That's not a hardline-drawn issue yet, is it?

MR. ANDERSON: That's correct.

MR. REED: And the relay chatter one is still one of investigation. So there doesn't seem to be any hard spots that would warrant full committee attention.

MR. SIESS: But the --

MR. WYLIE: Beg your pardon?

MR. SIESS: In our letter of August 13 we state that we intend to review and comment on the final proposed resolution following a public comment phase. We made a promise. I think we have to comment on it. It's the

resolution of a USI. It is now after the public comment phase. The resolution will be whatever they document in the final draft 1030. Right? And the final draft of the generic letter.

MR. ANDERSON: Yes.

MR. SIESS: So I think that once we have those things final, we have to write a letter on it, and that means we have to have the staff in -- I think we have to have the staff in.

MR. WYLIE: Do we write the letter before or after they issue their generic letter?

MR. SIESS: Well, we should write the letter after we have seen what they propose to issue.

MR. WARD: Before the generic letter, but it seems like there are going to be some changes between now and then.

MR. WYLIE: Yes. Right now, it looks like --

MR. SIESS: Because I think we have to have documentation in order to write a letter.

MR. WYLIE: It looks like it's going to be sometime after our February meeting before it's finalized.

MR. SIESS: Yes. But what I'm saying is, we promised a letter. We usually have the staff in if we're going to write a letter on something this important, and I don't see that we can really have them in until they've got

a final position --

MR. WYLIE: Yes.

MR. SIESS: -- which would mean either the draft final report and generic letter or the one that's ready to go out. I mean, we should see if the -- that has to go to the Commission finally, doesn't it?

MR. ANDERSON: The final issuance, we'll send a Commission paper notifying them that we're issuing a Federal Register notice and the other documentation. But once the CRGR gives us a favorable recommendation, we will go ahead and prepare the final issuance package.

MR. SIESS: I think when we get the package, you know, that's the appropriate time. We want to do it far enough in advance to give the Commission some advice before they act on it.

MR. ANDERSON: That would probably be appropriate then to review about the time or immediately following the CRGR recommendation because it generally takes us some time to put the package together for issuance for publication and --

MR. WYLIE: But that is estimated now for March or April, right?

MR. ANDERSON: Well, I will average the time with T.Y. I will go back to June if he'll come up from July.

(Laughter.)

MR. WYLIE: We would be bringing it to the full committee then, until, say, June.

MR. BOSNAK: Yes, or in that time frame somewhere.

MR. SIESS: It ought to be as soon as they think they're final so that they can get our advice before they are final.

MR. WYLIE: Yes.

MR. ANDERSON: Okay.

MR. SIESS: Certainly, if the Commission can get our advice about the same time they get the SECY or before it.

MR. WARD: May I ask maybe, where does this screening procedure for determining what relays to worry about, where does this fit into this resolution?

MR. WYLIE: That's part of the SQUG program.

MR. WARD: Yes.

MR. WYLIE: Plant-specific.

MR. WARD: But is the resolution package that the staff is going to prepare crediting some activity there?

MR. ANDERSON: Yes.

MR. WARD: And how do you credit it if you don't know what it is yet?

MR. ANDERSON: Well, we don't know what it is. We feel comfortable with it because, first of all, we are

actively participating in that development, and as well as we're getting commments and review by our SSRAP review panel.

We have, I think as you heard today -- or maybe it was before you came in -- that we have --

MR. WARD: Let's see, you call it your SSRAP review panel?

MR. ANDERSON: No, no, no, no. I said "our." They're joint panels funded by the industry, jointly selected by the NRC and the SQUG group.

MR. WARD: Okay. So you did say "our."

MR. ANDERSON: They're an independent panel.

MR. WARD: All right.

MR. ANDERSON: Yes. And we funded one of the members.

MR. WARD: Okay.

MR. ANDERSON: He works for a national lab, and it's the only way we could get money to him.

But at any rate, we had explained earlier, and it may have been before you came in, that we have made arrangements for the same team to follow this thing through the implementation phase an dthat we now have a staff relay review team specifically assigned to this project, and they're already working with the SQUG group in developing the relay review procedures.

So for that reason, we have some confidence that we can go ahead before we have a final review procedure that we would approve.

As a matter of fact, we've gone further with the development of implementation on this USI generic issue than we normally do. We normally say this is the effect of the resolution, this is what you have to do, and then somebody else goes off and decides how to do it.

MR. LIPINSKI: Let me ask a question. We heard that you're analyzing some typical relays, or actually not analyzing them, but measuring their characteristics, and then you were gong to try to qualify them, saying that based on the g forces experienced din the plant, these particular relays are acceptable.

Now, when will that work be finished?

MR. ANDERSON: That work is -- I think you're referring to this as the development of generic equipment ruggedness spectra test data --

MR. LIPINSKI: Right.

MR. ANDERSON: And that work is scheduled to be done near the end of calendar '86 -- is that correct? Or early '87? Yes, December of '86. That work is supposed to be finished.

MR. LIPINSKI: So how does that help the individual plant owners then in terms of their response

schedule to your generic letter?

MR. ANDERSON: Well, the response schedule says that within the time they receive that generic letter, which is sometime this summer, that they have 60 days from that date to respond to us, giving us their proposed schedule for implementing.

At that time, if there are uncertainties with regard to the completion of the relay review procedure or the anchorage guidelines or any part of the implementation procedure, then we will, of course, debate that point with individual utilities or the SQUG group.

The staff is willing to be very flexible with regard to what this implementation schedule should be.

MR. LIPINSKI: Then if your work isn't finished till December '86, don't you have to check everybody to respond on their schedule following December '86, based on your work?

MR. ANDERSON: Well, we're asking them to respond. If their response says that is conditional upon a completion of this guideline within -- by December '86, I think we would accept that. We are interested in going ahead and proceeding with this rather than waiting.

It's been our experience that if we hold up our resolution on issues of this nature until all the work is completed or every last part is in place, we're back down

the road a couple of years. We would really like to avoid that.

MR. WARD: Charlie, I don't know if you want to work in an opportunity for the subcommittee to hear about what the industry is going to do with this relay screening thing as part of the review in the spring.

MR. SIESS: It would be advantageous to invite them back.

MR. WARD: Well, yes. Mr. Thomas offered that. But maybe that could be part of whatever additional meeting you could have.

MR. SIESS: That makes us smarter.

MR. WARD: Yes.

MR. SIESS: But otherwise, we hope we get all of this by the time they come in next time.

(Laughter.)

MR. WYLIE: Okay. Well, we will plan to do that then. And then we'll have to follow the pogress and plan to bring it to the full committee then sometime in May or June when they're ready. Okay.

MR. EBERSOLE: In that connection, Charlie, let me ask something about the framework of the submission of what they're going to do about the relays. I would hope that they would sort of put this together in two categories that I would like to call -- we have to see that certain

functions must take place under these potential transient conditions, and I suspect we're going to face transient conditions.

And in seeing that these functions take place, we're granted the privilege of requiring a single random active failure in the support equipment that gives us these functions, you know. That's the standard practice. Not just a single train, effective equipment.

And then category B, or the other side, is we must see that these events and consequences do not happen which will influence the ones which have to happen in an undue way.

These are just two big packages as I can visualize them, and we need to see both sets. I guess that's plant-specific.

MR. SIESS: Plant-specific?

MR. EBERSOLE: Well, I don't know how you're going to --

MR. SIESS: 72 plants?

MR. SCHMIDT: We are addressing this to the extent that we can generically. And we do intend to look at both of the areas you mentioned, inadvertent actuations, which can get you in trouble, as well as actuations which you have to have for some safety function.

We have also further broken those down into

actions which must occur during the short period of strong motion, and those which must occur but can occur sometime later, that time being in the order of the time it would take an operator, for example, to restore a circuit they might have locked out.

So both those packages are being looked at, and it is our intent to try out this approach on a PWR and a BWR on trial basis to see to what extent we can make the generic work --

MR. EBERSOLE: All right. Well, a PWR and a BWR in any plant only about maybe half of the critical functions are in the vendor scope. The rest is a combination of AE and the owner-utilities logic and notions about how to do things. So if you line up vendor by vendor, you don't get there. And out in the AE and architect-engineer scope, things have very, very little critical functions and designs of support systems.

MR. SCHMIDT: Well, the screening approach whereby we start with functions, we expect to be very similar; and that is, if we decide reactor trip is something that you definitely want to occur during the period of strong motion, then that will be all of your language you need to assure that will be essential.

So, normally, with decay heat removal, reactor isolation and the like, the actual verification of whether

that will happen under assumed relay chatter will end up being a plant-specific.

MR. EBERSOLE: I would suspect that plant trip is about one-tenth percent of the problem. The rest of it is the prolongation of the heat removal function. By far, the bulk of the problem will be in guaranteeing the continuity of heat removal.

MR. SCHMIDT: That's the problem. Our initial look is the reactor trip, it won't matter what happens, but that you'll get into trip if the circuits are deenergized, which is the way they're designed to function. And the shaking them will probably make that happen even sooner, but not prevent it.

MR. ROBY: If that were to be the case, and I think it clearly is, then you will worry about survivability and not operability, which I think every time we have really looked in depth at the problems associated with relays and the untoward operation of relays, always in the end lead substantially to survivability and not operability.

MR. SCHMIDT: That's right.

MR. ROBY: And defined in that way, you again limit the relays that you have to look at to an even smaller subset.

MR. EBERSOLE: That's right.

MR. SCHMIDT: We are finding very few functions that you have to count on occurring within the few seconds of strong motion.

MR. SIESS: Yes.

MR. WYLIE: Okay. Any other comments?

(No response.)

MR. WYLIE: Well, this afternoon, after lunch, we will have a presentation by the SQUG group, Mr. Peter Yanev, regarding the SQUG investigation of the Chilean and Mexican earthquakes, and then that will be followed by a closed session on review of the research program.

Okay, we will adjourn until 1:30.

(Whereupon, at 12:30 p.m., the subcommittee was recessed for lunch, to resume at 1:30 p.m., this same day.)

AFTERNOON SESSION

(1:35 p.m.)

MR. WYLIE: Let's get the meeting started again.

Mr. Peter Yanev from EQE will make the presentation on the earthquakes in Chile and Mexico.

MR. YANEV: I am going to split the presentation with Steve Eder also from EQE. The way we are planning to make the presentation is first I will give a brief comparison of the two earthquakes and kind of give you the overall view on how they looked in front of each other.

By the way, all the viewgraphs you have a copy of. Because the time got cut back, we have cut out a number of the viewgraphs, but in the handout that you do have, the big one, that contains all the information you are going to hear today and more.

Then after the introductory remarks, Steve will cover in some detail the Mexico earthquake and then I will go to the Chile earthquake afterwards.

What I have tried to do is concentrate a little bit more on equipment details this time. I am putting back some of the slides, and I don't recall if you saw all of these, but you have seen some of them, just to put things back in perspective as to what the building damage and other piping effects might have been. But the intent here is to primarily cover equipment. So I will stress that.

(Slide.)

I am not going to follow the exact order of viewgraphs there.

For a summary, I wanted to kind of leave three primary statements.

First is the investigated earthquakes are major events with high accelerations and very long durations, and I will show you examples.

The inventory of facilities affected contributed very substantially to the SQUG data base in both cases.

The conclusion that equipment is rugged, reached by SQUG and the NRC prior to the earthquakes, was reinforced very strongly.

No equipment was found to malfunction with the exception of protective relays. And, as we have known for a number of years, certain tanks are quite vulnerable to strong earthquake motion, and I will show a few examples of that.

And, finally, the one thing that really jumps out in terms of overall design to make a broad, sweeping statement is that the equivalent static coefficient design for seismic loads, and we have taken "most" out of the title, for seismic loads of most components and structures of nuclear plants is adequate. That really jumps out of the data that I will show you.

(Slide.)

A very brief comparison of the two earthquakes. They both occurred in two of the world's most seismically active areas. If you recall, the dots in here, the darkened areas are the epicenters of about 42,000 earthquakes that occurred between '61 and '70. So along the Circum Pacific Belt we have the Mexico epicenter approximately in this area, an area of intense activity in general. And along the Nazca plate and its intersection with the South American plate we have the Chile epicenter right there.

The two earthquakes were of a magnitude, for Chile it is 7.8 and Mexico it is 8.1. So they are comparable very, very large earthquakes. Comparisons have been made in terms of earthquakes in California, and this is about as powerful an earthquake as you would get in California in terms of effects. A larger magnitude in California will strongly shake an area over a larger area. But in terms of intensity or strength of shaking of a specific site, that is probably about it.

Aftershocks, Chile had a 7.2, a large one, and Mexico had 7.5. In terms of energy released, since you have about a factor of 30 to 1 in a change of magnitude, there is really a small amount of additional energy, but in terms of earthquakes, they are very large earthquakes

themselves.

Affected area, and by affected we mean damage, about 20,000 square miles in each case. In Chile it spread in an area of 100 by 200 miles pretty evenly over the area with some very high intensive spots of course.

In Mexico we have a very different situation. The epicentral area was affected, as you will see, but the concentration of actual dollar loss and certainly almost all the life lost was in Mexico City itself about 250 miles away from the source of the event.

The population in both cases was large, 6 million in Chile and 10 million in Mexico, so comparable. Now that is very interesting of course. The deaths in Chile, 180. In Mexico the official toll is pushing 10,000. The unofficially official toll will be probably more like 20,000.

Homeless, comparable numbers, a quarter million or so in Chile and about 400,000 in Mexico.

Dwellings destroyed, actually Chile had more. This is primarily 45,000 versus 34,000 in Mexico. The reason for that is in Chile the strong motion was over the larger area.

Collapsed highrises. Now here we see a clear indication of the differences in design between Chile and Mexico, which I think are very important, a thing that has

been missed in the media certainly. We have two highrises collapse and both of them are partial collapses in Chile and at least 300 collapses in Mexico. I will contribute much of that to the design practices, almost all of it to the design practices in the two countries.

The reason I am saying the practices is because in Chile they aren't going to do that. They don't have flexible buildings like that. If they had had the same type of response spectrum in Chile, I suspect there would have been additional damage to highrises. We do not have that of course.

Direct damage, Chile is about $1.8 billion, and these are very approximate numbers and I think these numbers can be off by a factor of two, and in Mexico about $3.6 billion, double. A lot of that again, Mexico City itself.

(Slide.)

Now these earthquakes are part of four that we have investigated in various degrees of detail since the completion of the pilot program you saw about three years ago or so.

They are interesting in that now we have had opportunities to examine the performance of structures, et cetera, and especially equipment in what we would consider reasonably small earthquake magnitude in the low 6's, and

then a very strong but localized moderate magnitude quake in Coalinga at 6.7, and then this last year two very great earthquakes of a magnitude of about 8 with very large aftershocks, et cetera.

So I think it has been very valuable from that viewpoint. We have had a good cross-section of the various earthquakes and all of them have been in industrial areas or we have had a good example.

(Slide.)

A brief summary of the ground motions for both events. Above all, they were very long and strong. Specifically the Chile earthquake reported very high accelerations, and here is a quick summary of the two.

In terms of records obtained, both earthquakes were well instrumented. Chile picked up 31 strong motion records and Mexico picked up 18 strong motion records.

Peak horizontal acceleration in Chile, and this is the peak of the two components, the highest we have is 68 percent and in Mexico we get 28 percent G in the epicentral area. These are equivalent distances, by the way, from the source, the epicenters.

The peak vertical accelerations, in Chile we get 86 and in Mexico we get 15, an interesting difference. The highest average horizontal acceleration in SQUG, we have usually used the average acceleration, which is take the

two horizontal peaks and get the average of that for a record.

So for one record here we have 67 percent G. In Mexico the average is 24 percent, and that is off from this 28, and you will see some of there records in a minute.

Duration. In Chile at least one record has a 42-second duration of motion in excess of .1G. This is back in the duration of .1G or more, and we have 42 seconds. In Mexico we have about 40 seconds. So they are comparable in that way.

MR. SIESS: The Mexico records you said were near the epicenter or in the city?

MR. YANEV: These are near the epicenter. This record is near the epicenter.

MR. SIESS: These are more typical records?

MR. YANEV: They are. They are very typical for great magnitude quakes. They are atypical in that we were very surprised at long the accelerations are and I cannot explain that.

MR. WARD: Well, the .28 is a maximum that was recorded?

MR. YANEV: Correct.

MR. WARD: But are there estimates that there are greater accelerations somewhere in locations that weren't instrumented?

MR. YANEV: My opinion of that would be that yes, there would be higher accelerations, but none were recorded because of where the records were brought.

MR. SIESS: But even in Mexico City they didn't get much higher.

MR. YANEV: Mexico City, they highest ground motion was 18 percent ground.

MR. EDER: A lot of these records were on rock. This record of 28 percent is the only record that was on soil.

MR. SIESS: Well, these have quite different periods from the stuff we saw on Mexico City.

MR. YANEV: We will show that in a few minutes.

MR. SIESS: This is the typical ---

MR. YANEV: If you wanted to congratulate the NRC on one thing, this is on the Reg. Guide 160 spectrum. These are pretty much a definition of Reg. Guide 160, as you will see in a minute. They are very full spectra and very broad banded.

We tried to give you an approximate idea of what, if there was a reg. guide spectra, they would look like, and the strongest record from Chile where we have some equipment completely envelopes a .4G reg. guide. If you allow a few peaks to go over, it is about a .5G. And the same with Mexico City, the strong record completely

envelopes 17 percent. It actually is about a 20 percent reg. guide spectrum full.

(Slide.)

Now first with Mexico, and I will show a few viewgraphs before Steve starts with his slides.

In this particular case EPRI had the opportunity to send under their new program a team to Mexico, and they sponsored the team. So much of the kudos for that go to them and EQE funded also a significant portion of the trip and EPRI has contributed also funding for this.

The reconnaissance team left the day after the earthquake, which was September 19th, and it was led by Sam Swan and Steve with EQE, Brad Burdick representing the NRC. He is from Lawrence Livermore National Lab, Bob Cassewara from EPRI and Dennis, Ostrom, he is in the audience, from Southern Cal. Edison, and he is on the steering committee and he also went to Chile.

We had two other teams go to Mexico on conventional business in Mexico City. So we sent several other engineers to look at it, but that was not equipment related. It did give us a much better picture of what happened in Mexico City.

And we felt while one of the teams was there that it would be a good idea to go back to the epicentral area and get some more data. So Steve and Dave McCormick, who

was in Chile, went, and this November 6 to 11, and spent some additional time there. So a lot of the information is relatively new and was collected after the Mexicans had some time to put themselves together.

(Slide.)

Now the earthquake occurred approximately here on the Coast of Mexico. Mexico City is over here and the main aftershock was in this area. So now we will cover this area in quite a bit of detail for you and cover also Mexico City.

(Slide.)

Here is a summary, and I will show the actual traces of the records. We have the six strongest records shown with the two horizontal peak accelerations, the vertical and the average of the horizontal.

The strongest on soil is Zacatula record, 28 percent GP, and 19 in the other direction for an average of 24 and a concurrent 15 percent in the vertical.

Then the other three records, these three, if you notice about 14 percent, between 12 and 14 percent with a little bit under 10 percent G vertical. They are all on rock in the epicentral area. So there is a difference. This is rock and this is soil.

(Slide.)

In Mexico City we have, and this is not exactly

rock. This is the university, or we are calling it the university rock. I am not familiar with all of the details of it yet, but it is pretty competent material.

In as recent article Professor Rosenbluth also indicates that there were records down to 1 percent G in the vicinity of Mexico City.

So, anyway, here we have on the competent material three percent and four percent with the two vertical in the middle of the lake bed where some of the worst destruction occurred. That is kicked up to 17 percent in one component and 10 in the other for an average of about 14.

MR. SIESS: And that probably is about what you would expect at 400 kilometers away from the ---

MR. YANEV: That is right. The 1 to 5 is probably a good range.

(Slide.)

This is there again for future reference. Fortunately, we have records right where the industrial facilities are. The records are the open dots here, here, here and here. The Zacatula record is the high one. The record records are this, this and this. The power plants we will be talking about are El Infiernillo and the La Villita power plant, these two, and then there are a number of square miles of large industrial facilities Lazaro Cardenas area where the .28G record is. So it is a good

record for that area and it is on typical ground conditions which is reasonably recent.

There are a number of records further down towards Acapulco and they drop off pretty quickly. There are no surprises there of any sort. And of course in Mexico City, we have the Valle de Mexico power plant there that saw pretty much ground motion and there were no adverse effects.

(Slide.)

Here is the strongest record. It is a bit condensed so you lose the sense of the power of the record. This is the .28 peak Zacatula record. This is 60 seconds. So, as you can see here, there is about 50 seconds of strong duration and the bracket duration is about 40 seconds.

If you look at it there appear to be two earthquakes, two large events right back to back, which probably is the case. There has been some discussion in the community about that, and they are comparable.

(Pause.)

This is reversed I guess this must be the 19 percent and this is the 15 vertical. So there is a typo in there. This is the vertical and you can see a little more high frequency stuff, and this is the other horizontal.

The spectra. Here is Reg. Guide 160 at a quarter

G compared to the Zacatula record. This is the average of the two now. So we are coming down to about .24 peak horizontal as against a very full record. To completely envelope 17 and 20, it would come in kind of like this with a couple of little dips across it. So it is really like a .2G reg. guide spectrum, a very full spectrum.

(Slide.)

This is one of the rock records, and in your handout you will see another one. This might as well be a 15 percent G reg. guide spectrum record. It is incredible.

Now if you remember, the reg. guide spectrum is based on a large number of records both on a variety of soft-ground conditions and rock. So what this is saying is in the epicentral area you have a very broad spectrum.

(Slide.)

We visited a total of 10 sites in the affected area, including a couple of power plants, a large substation, a large steel mill, and by large we are talking on the order of 10 square miles of structures and grounds with piping and cable trays et cetera, very, very large. And also the fertilizer plant and the concrete plant. In that vicinity are also a number of significant and large industrial facilities such as bottling plants and so on. We have not had a look at those.

In the plants themselves, there are three power

plants, at La Villita four hydro units, at El Infiernillo five hydro units and at the Sicartsa Steel Mill two thermal units, and Steve will show you that.

(Slide.)

In terms of design criteria, we have given you a conservative summary of the typical minimum lateral coefficients that are required by the code of the Mexico utility. This is not for Mexico. This is the utility. It is a very sophisticated code and it is a rather sizeable document.

As you can see, basically the structures are designed between 10 and 15 percent G using static coefficient that is comparable to what we do in California, and the performance is comparable here. We do see quite a bit of damage and a lot of it has to do with concrete structures and a lot has to do with ground failures affecting the structures.

(Slide.)

Before we show Mexico, the last slide is the lake bed record, and this is what caused the incredible amount of destruction in Mexico City.

As you can see, this is plotted again on the frequency scale for equipment purposes, but we have this extremely sharp spike that at five percent one of the components, and this is the average, but one of the

components goes to a G going in one direction. Some of these highrises that were designed in Mexico for probably a couple of percent or less, for wind loads basically, saw a G. So there is little wonder that so many of them came down.

(Slide.)

Now one thing we would like to do, and I am not sure how well it will work, so we may cut it off, what we thought is we would like to put some of the conclusions that we have that are in the report for each of the areas and then talk with slides about the effects there.

So this is sort of the bottom line. Mexico City illustrates the need for building designs to consider local soil conditions. It also illustrates the critical importance of detailing for reinforced concrete framed structures.

Steve.

MR. EDER: Okay. We will go through this list on a short summary.

Mexico City, as Peter said, it is about 250 miles from the epicenter. Over 400 building collapsed that were severely damaged. Most of the damaged buildings, and I will show a slide of this later, they experienced a double resonance situation, the ground motion distance from the epicenter received a long period motion, and the lake bed

has a natural frequency of about two seconds. It has been measured in the past. There was one residence building sitting on it with the same frequency range experienced in other residences.

Collapsed buildings damaged some power distribution lines. That is mainly what caused the disconnection of some of the main power plants we looked at. There were about 5,000 breaks in the city water system. They were asbestos cement water pipes and they did not have a lot of play tie-up pipes because they were all damaged from previous earthquakes in '57 and '78. There were no major industrial facilities in the affected area of Mexico City.

(Slide.)

Here is the map Peter showed before. On here in looking at Mexico City, which is 250 miles away from the epicenter.

(Slide.)

This is the double residence phenomena that I spoke of. Along the coast we have a typical earthquake with good high frequency and broad band content. As we attenuate away from the epicenter we get into the long period waves.

Here is a record at the university where they measured four percent gravity. This spectrum here also had

a two period frequency content which shows that that is essentially what Mexico City got.

The ancient lake bad, the in-fill material in the lake bed has been measured to have a natural period of about two seconds. And then the building sitting on that, that amplified the motion to 18 percent gravity. The building sitting on that with the spectra that Peter showed before had spectral accelerations of about 1G.

MR. SILSS: What they got on rock was two seconds then?

MR. EDER: It was two seconds on rock, not quite as narrow, but it peaked at two seconds. So that is what was coming into the city.

(Slide.)

This is a figure from Rosenbluth's article. He shows the boundary of the old lake bed area. The white dots indicate the collapsed building and the black ones indicate the severely damaged buildings.

MR. YANEV: The highrises.

MR. EDER: These buildings were generally between 8 and 15 stories tall, and as damaged progressed in these buildings, a lot of them were a little bit higher frequency and they shifted over.

This here is a circle that was damaged in the 1957 earthquake. It was very similar and it had an epicenter

off the coast of Acapulco. They had similar measurements in Acapulco and in Mexico City 250 miles away, the same phenomenon.

In '78 they had a smaller earthquake that was about a 7.5, and it was in the same general area where this epicenter was. And this had damage in this area of Mexico City, not as severe because they didn't quite have the same accelerations, but the same phenomena.

(Slide.)

This is a time history recording on the lake bed in Mexico City. All of them are almost exactly two seconds. It is like a sign wave that came into that city. That is why we get the sharp spectral peak.

(Slide.)

This really shows the whole thing that happened in Mexico City. Here we have a highrise building that saw that high spectral acceleration.

Here we have an older unreinforced bring structure that essentially never saw the earthquake. It was arriving in a two-second wave about 30 centimeters peak to peak and no resonance in the building. It was like a rock in the mud.

(Slide.)

This is the collapsed Regis Hotel. This got a lot of publicity. Many people died here.

What we are going to do now is we are going to walk down the street about half a block.

(Slide.)

This is the Palace of Fine Arts, unreinforced, mostly marble. It never saw the earthquake. There wasn't a cracked window in the structure.

MR. YANEV: This is intensity 6.

MR. WARD: I am sorry, would you say that again.

MR. YANEV: Intensity 6 is where you have that going off.

MR. EDER: That should be just coming off at very low acceleration levels at the right frequency.

MR. SIESS: If they haven't fallen off by now, that is an old building.

(Laughter.)

MR. EDER: Right, quite an old one. It is not well reinforced either.

MR. WARD: Were there highrises that stood and weren't damaged?

MR. EDER: Yes. There were some more modern highrises constructed since the recent building ---

MR. WARD: And the explanation is they didn't have this resonant frequency that was in this range?

MR. EDER: Right.

MR. SIESS: Some of them weren't in the lake bed area either.

MR. EDER: Well now, see, in the lake bed area, most of the buildings that were in that storage range were older buildings because that is where the buildings started. That is where Mexico City started, and then it has grown out so that the newer buildings are more away from the -- they are away from the in-fill area. So you really didn't have a test of the most modern structures.

MR. EBERSOLE: Now the ground acceleration on that old masonry building, was it similar to the ones you are describing?

MR. EDER: Yes.

MR. SIESS: Except its frequency was such that it just didn't see it.

MR. EDER: It is a stiff structure and it was a low frequency earthquake. So it just rolled slowly back and forth.

(Slide.)

Here is another example of the shorter, stiffer building undamaged next to a severely damaged building. This was a prison. This shows some of the problem they had with the concrete reinforcing details. This is a column of the building and you can see the slabs are just pulled away and you can see the minimal ties between the columns and the slabs.

MR. YANEV: What is interesting here is if you

want to estimate the period of a building, which is one over frequency quickly, take a building like this, two stories, and use .1 seconds per floor. So it is a .2 second building or 5/3rds. So it is a stiff structure. Whereas here you have, let's say, and I forget this, let's say a 10-store building. So it is one second. So it is into the peak.

(Slide.)

MR. EDER: Here is another example of an old building. This is a 19th Century church, not a broken window, nothing.

(Slide.)

Here we have anotner example of old buildings across the street that didn't see the earthquake. Here I believe this was a 13-story building that completely collapsed into the street. This shows some of the construction details that was another one of the problems. They use unreinforced masonry in-fill panels. These things take a lot of the force through the earthquake, and when they crack your whole frequency shifts and you leave the vulnerable bare concrete frame.

(Slide.)

Here is a building that is very near to collapsing. You can see how the panels have fallen out leaving the bare frame here. In a couple more seconds it

probably would have gone.

(Slide.)

A typical failure mode. When the panels drop out, the columns have to take the forces immediately after the panels are gone and they can't take it. This is four stories there that collapsed.

MR. SIESS: You can speculate that in a 10-second earthquake that a lot of them would have stood up.

MR. YANEV: That is what happened in '78 exactly.

(Slide.)

MR. EDER: This is the front of the building. This is king of nice because it illustrates that you jump under your desk when the ground starts shaking. Here the desk is holding up the floor and the same here.

(Slide.)

Here is another building ---

MR. WARD: The 40 seconds came all the way from the epicenter?

MR. EDER: Right, and they recorded for the same duration, about a minute, in Mexico City. And there were other reports that the length that it was resonating on and off was for about three minutes after that.

MR. YANEV: If you are in a building that is moving pretty well, you probably felt like it was a three-minute earthquake because even if the earthquake itself and

the significant motion ended after about a minute, you have probably a couple of minutes of resonant motion until it dies down to imperceptible.

MR. SIESS: There were reports of people that got out of the buildings before the earthquake was over.

MR. EDER: True. This is a building that probably would not have been damaged then if this hadn't been pounding it. You can see that it is collapsed at the top here and the first floor is gone.

(Slide.)

Here is one example of some of the poor construction practice as you can see. These are three identical buildings and these had no apparent damage at all. This one in the middle completely collapsed.

(Slide.)

MR. WARD: So much for just checking the drawings.

(Laughter.)

MR. EDER: Here is I believe it is a 10-story shear-wall building. This is the shear wall that was vertical. It was sitting up on top of the rest of the wall here and cracked and overturned into the street.

(Slide.)

This is a building in a completely evacuated apartment district. There were about 20,000 people here that had to relocate. This building had partially

collapsed on the 1st floor and it is also tilting that way. We don't know how these flower pots managed to stay up there.

MR. SIESS: Was that Plata Lopo?

MR. EDER: Plata Lopo, right.

(Slide.)

This is one power substation we observed in the Del Tores district near to that prison I showed you with the columns protruding. It had some brick failure up on top.

(Slide.)

I took a quick look inside and I saw some really old equipment. I don't know if it was damaged or not. It is about the 1900's vintage.

MR. SIESS: It is an aging study.

(Laughter.)

(Slide.)

MR. EDER: This is what I first saw when I first got into Mexico City, and you just look and look and you don't see a damaged building. Less than one percent of the buildings in Mexico City had serious problems and less than two percent were even affected by the earthquake.

MR. YANEV: Now this shows some highrise undamaged buildings, some probably due to good design and mainly because of location.

MR. EDER: The damaged area was right here. We are kind of looking right at it. This is the boundary of the lake bed. So we are away from it.

MR. YANEV: I am sorry we didn't put there the Latino Americana Tower. Newmark was involved in the design of that. That is the tallest building in Mexico City. It is about 30-some stories high. It is a steel frame building and it lost one pane of glass.

MR. SIESS: That is what it lost in the last one in '57 I think.

MR. YANEV: It is probably the same one.

(Laughter.)

(Slide.)

MR. EDER: This is equipment that I found on the top of that building that I went up to take the photograph of. Unanchored, and it should have moved, but it didn't.

(Slide.)

This is the HVAC equipment on the roof. This is all unanchored. It is just sitting on the roof. It didn't slide and it didn't move. It was out past the earthquake on the other side.

(Slide.)

This is the Mexico power plant that serves that serves most of Mexico -- well, not most of Mexico, but a lot of the lower portion of Mexico City.

I spoke to operators at the plant and they said, what earthquake. They had about two percent gravity and no effects and no system problems. They had some shutdowns.

(Slide.)

Here is the control room. They had some shutdowns because of buildings falling on their distribution lines.

(Slide.)

This is the power distribution system for CFE, the national utility. These are two epicenters, the main shock and the aftershock. We are going to look at La Villata power plant here and El Infiernillo hydro plant here. The industrial area is in here.

The town of Lazaro Cardenas has been culled out as MMI-IX, and then we go down here to Ixtapa which is probably the same modified Mercalian intensity, but nobody has reported it yet.

(Slide.)

This is Lazaro Cardenas here. Unreinforced masonry panel is falling out of the building. I observed damage similar to this in about one out of every four structures in this town.

(Slide.)

The severe damage observed at the port in Lazaro Cardenas. The port facility and adjacent industry included large steel buildings several hundred feet long. A lot of

that area we had not had time to investigate.

(Slide.)

This is some of the damage that I will show you in the town of Lazaro Cardenas. This is all in that high intensity area.

MR. YANEV: Again, according to the University of Mexico here, we are looking at an intensity of 9. One out of every four buildings is severely damaged. Most of the new buildings are seismically designed buildings. So the intensity was rather high. The accelerations of .28G seem low for the amount of damage. Of course, the record is very long.

MR. SIESS: What was the period?

MR. YANEV: For the earthquake?

MR. YANEV: That is the broad-banded spectrum and this is the full spectrum.

MR. SIESS: Two-second stuff only after it went 400 kilometers?

MR. YANEV: Right, only in Mexico City.

MR. SIESS: Something filtered it out?

MR. YANEV: These spectra showed nothing in two seconds, no peak at all.

(Slide.)

MR. EDER: This is another building, a nine-story hotel building in Lazaro Cardenas. You can see there are

shear cracks in every one of these panels between the windows. I have a close-up. Every one of them was gone.

(Slide.)

Here is a wing of a two-story school building. There is not a whole lot left holding it up but just the rebar. It is holding up half of that structure.

(Slide.)

This is the bridge going to the Lazaro Cardenas Industrial Port. This bridge was closed and every one of these piers had spalled and the abutting walls had settled about two feet.

(Slide.)

MR. SIESS: Those are circular piers. Do they have any spiral reinforcement in them?

MR. EDER: I have no idea.

This is the approach way. This is pretty wide crack. It was about two foot wide and two foot deep. It may have been from just a settlement problem along the river.

(Slide.)

This is going into the industrial port area. This is a large silo assembly. This is a four-story building on top. I should have photographed it from the other side. There is a partial collapse right along this level and you can see some in here. That was a story level.

(Slide.)

This is the port. There is some minor separation of the walls and it damaged some of the railways for the crane.

(Slide.)

This is an example of some of these large steel buildings that I was talking about. These are several hundred yards long. There were many of these, a bottle facility, a grain handling facility. We didn't get a chanced to see any of these.

(Slide.)

This is Ixtapa. Ixtapa includes about 12 modern highrise hotel buildings. Every one of them was damaged and two of them remained open when we were there, mainly in the 5 to 15 story range.

(Slide.)

This is the most severely damaged one. It is typical, the panels cracked. These buildings were mainly closed because of the architectural damage on the inside.

(Slide.)

This is the Holiday Day Inn where we stayed. There was some structural damage, shear cracks through the column, but mainly not structural architectural damage.

(Slide.)

Here are some damaged beach umbrellas down by the

coast.

(Slide.)

This is the El Infiernillo Dam.

(Slide.)

Here we have the plant experienced low-level long-duration ground motion and perform well. Everything we saw reinforces all previous findings that the equipment performed well. There was minimal damage. Some superficial damage at the crest of the dam.

The water sloshing up through a vent line. That may have been the cause of a shutdown. We are not quite sure of that. We have received different reports from the operators, depending on who we talked to, but they believe that water came up through a vent line or the generators and flushed under the generator and caused a ground fault.

(Slide.)

Here is the dam. It is about 500 feet tall and a thousand feet long. It is a large one. The power house is under this rock here. It is all tunneled in.

(Slide.)

MR. SIESS: Is that earth fill or rock fill?

MR. EDER: Earth.

This is the access where we go into the power station, going in this door here. And these are some of the cable trays that were lining the access tunnel. Very

heavily loaded and no seismic effects were observed.

Mexico quickly became our cable tray earthquake because we saw so many good examples of cable trays. I think that will be our focus for follow-up work.

(Slide.)

We had some problems like this, cable trays that had fallen under dead load that had gone through the earthquake. This had been like this years before the earthquake according to the operators. It is not earthquake damage.

MR. YANEV: I think it is important to look at some of the details here since this is part of the SQUG work. What we have here is one type of cantilever quite common in nuclear power plants, just a simple cantilever with a trailing on it. So all the connections that you see here, the clips that tie the cables, they are very, very standard if they are there to start with.

MR. SIESS: How is that anchored to the wall?

MR. EDER: With a book-shelf hanger.

MR. SIESS: With a steel plate?

MR. EDER: No, these are just simple anchor bolts here just like you put book shelves up in your home and then they hook in.

MR. YANEV: It is a sort of channel with bolts holding it to the wall.

MR. THOMAS: Peter, I think you said it was quite common in nuclear power plants. I don't think you meant that.

(Laughter.)

MR. YANEV: I mean that this type of a cantilever configuration, wide-type support and so on, that would definitely be unusual, but the type of support.

MR. SIESS: The ones in the nuclear plants are about ten times that.

(Slide.)

MR. EDER: This is the operating floor. We had a lot of unit substations along the wall here and a lot of electrical equipment in all these plants. The control room is over here.

MR. SIESS: Is this underground?

MR. EDER: This is into that hillside. It is a tunnel structure, a reinforced concrete tunnel structure.

MR. SIESS: I was wondering what they had on the acceleration?

MR. EDER: There was a record here that it measured 15 percent G, but after the earthquake, the day after the earthquake they went to pick it up and open up the box and they got a pile of ashes. It was hit by lightening I believe. They are swearing up and down the walls about that one.

MR. SIESS: It was an act of God.

(Laughter.)

(Slide.)

MR. EDER: This is a control room where we talked to the operators here. They said that they had trouble standing up during the earthquake, but the plant operated right through it and disconnected with distribution line problems.

(Slide.)

MR. SIESS: Did you have any chairs on casters there?

(Laughter.)

All of our plants do.

MR. EDER: I don't know. I wasn't looking.

This is the cable spreading room down below the control room. These are just loaded to the hilt with cables and no observed problem.

That isn't seismic bracing. I believe it is just stability bracing. You can see it hasn't buckled.

MR. YANEV: The important thing we were looking for here, and in some of the ones I will show later in Chile, is we are trying to get kind of a bound on what the data base has in terms of weak structures. I have never seen this in a nuclear plant and this would be an extreme situation.

So again the idea is to find in this case very weak structures. We are not feeling obliged to envelope it with stronger structures. We are trying to get as much data of weaker structures than we normally see.

MR. SIESS: Well, you had one picture that couldn't even made the dead load, and that is weak.

MR. YANEV: And you will see a few more of them.

(Slide.)

This is the La Villita plant. It is about 25 miles from the epicenter. The plant again experienced low-level long-duration ground motion, no new findings. Some nice cable trays were found here.

(Slide.)

This is a dam about 100 feet high. Well, a little bit more, about 200 feet high and about 1,000 feet long. The switchyard up here with storage tanks and no problem. A large power station structure.

(Slide.)

Superficial damage at the crest of the dame. Some of these little roadway barricades had overturned and there was a little settlement of the road.

(Slide.)

This is the switchyard. The use vibration mounts under their ceramic components and none of them had cracked.

MR. SIESS: Go back and say that again. I missed that.

MR. EDER: They have little rubber vibration pads between the concrete pole here and the ceramic poles.

(Slide.)

Here is the control panel. These are some of the relays that tripped due to some problems they had in the switchyard at the steel mill, and we will go there.

MR. YANEV: This is very new equipment, as you can see.

MR. EDER: This is a 1970's plant.

Battery racks. The batteries aren't strapped together and no spacers between. The batteries walked about an eighth of an inch. They didn't topple. Those are little rubber friction pads to keep them from sliding.

MR. SIESS: There was no lateral restraint on those battery racks either, was there?

MR. EDER: No.

(Slide.)

Here is the power station structure, a large building, about 60-feet tall. At the mezzanine level we have a switchgear area, a cable spreading area and a control room. We can look at those now.

(Slide.)

This is in the switchgear area. We thought we had

found some earthquake damage, but it wasn't. The operators said that they had added this brace about three years ago because they had been adding so many cables that they were sagging. They added more cables and it sagged more, and this is buckling from dead load. It is not seismic damage.

(Slide.)

I don't think they could have gotten any more cables into this tray.

(Laughter.)

Again, no damage in any of the supports. That is probably the worst anchorage configuration you could have, but no seismic damage.

(Slide.)

Some of the damage we saw here was in the control room. They had a water bottle overturned and they had some dislodged ceiling panels. That was the extent of the damage.

MR. YANEV: If we take the record alone, we are looking here at about a .2 type reg. guide spectrum at this site.

MR. SIESS: How were those cabinets anchored?

MR. EDER: There was a ---

MR. SIESS: Were they anchored at all in the floor?

MR. EDER: Yes. There was an open steel channel

and they were bolted through to that. They weren't typical anchor bolts.

MR. YANEV: Speed up a little, Steve.

(Slide.)

MR. EDER: The emergency diesel generator didn't go on and wasn't needed.

(Slide.)

A batter rack. This was extremely flexible. It didn't take much to get it moving at all and there was some spilled battery acid.

(Slide.)

Here is the Sicartsa Steel Mill. I will skip the overhead. It goes from here to here. This is a huge facility, about 10 square miles. We are about six miles away now looking at it.

(Slide.)

Here is a dam. This is where the record was that measured 28 percent. This is all river sediment type of soil. So it is all typical of what was obtained here.

(Slide.)

Here is a steel mill. This is Lazaro Cardenas, the town I showed before. You can look at the steel mill. We are going to look at a substation that was here. The fertilizer plant here, the industrial port I showed was here and the cement plant here.

(Slide.)

This is the steel mill. There are many, many of these buildings, huge, four or five hundred yards long.

(Slide.)

MR. SIESS: How would those compare to a turbine building?

MR. EDER: Larger. Not quite as tall, but longer and wider and the same type of structure.

MR. YANEV: I would say that for the typical -- and let's look at a newer plant like Limerick -- that steel structure would be a much heavier steel structure than anything here pound for pound for the size.

MR. EDER: In this switchyard this transformer jumped its rails and shifted about six inches and leaked an oil cooling radiator and they had some ceramic components break. This is what triggered the shutdown at La Villita.

(Slide.)

These are typical of the cable tray runs. We measured some of these guys to about two kilometers in length. There is a lot of unanchored piping just sitting in cradles on these racks and the cable trays in just a simple bracket attachment.

MR. YANEV: This is amusing in that normally when we have in the past collected data on cable trays we would walk them off and estimate the distance. This is the first

time where we drove for two kilometers in the car and recorded the distance.

(Laughter.)

(Slide.)

This we thought was a damaged steel building, but we talked to another operator and he said somebody hit it about two years ago with a fork lift and put a hole in its side.

(Slide.)

This is about all the real cable tray damage they had. This side of the road here slumped about, oh, three feet in places into this channel. This was vertical. So you can see the settlement.

(Slide.)

Buckled braces from the thing turning, but no operability loss according to the plant people we talked to.

MR. SIESS: What are we looking at, building supports or something else?

MR. EDER: These are overhead pipe-hung galleries.

MR. YANEV: We have a lurching of the ground. So you have a slope failure into the water channel and then the structure went with it. So presumably it is a very shallow footing. There was quite a bit of that type of damage.

(Slide.)

MR. EDER: This is in the same general area where the slumping was. This is leaning a little bit. I don't think this pipe was damaged.

(Laughter.)

We are going to look at this support, this pipe support right here. This is the base of that furnace.

(Slide.)

Here is that support I told you about. The pipe was holding up the support during the earthquake.

(Laughter.)

(Slide.)

Here is another damaged cable tray. This conveyor system settled about two feet and just crushed it. But they were still operating, and here is why I assume the cables were functional.

(Slide.)

This is the power station building, a 22 megawatt thermal plant.

(Slide.)

This is the boiler structure. The boiler had some problems here, a base-supported boiler.

(Slide.)

This is the control room of the steel mill power plant, very modern, 1975 and 1976 construction with some

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(Slide.)

This is the control room of the steel mill power plant, very modern, 1975 and 1976 construction with some

solid state components. No problem with the control systems.

(Slide.)

This is the generator.

(Slide.)

These are some large turbine-driven air compressors that they have for the blast furnace.

(Slide.)

This is the boiler, and the boiler is base supported. It shifted about two feet toward this tubing here. It is just instrument tubing and these have been replaced since.

(Slide.)

Here are some pipes that have shifted around and banged up the insulation. It didn't damage the pipe.

(Slide.)

Here is a pipe support that had been bent and the pipe was evidently okay.

(Slide.)

This is the administration building at the steel mill. This was severely damaged and this building was evacuated. This is the only significantly damaged building that we observed there.

(Slide.)

This is an entrance way that extended out about to

here. They have it all cleaned away, but it collapsed.

(Slide.)

This is the inside of the building. All the ceiling panels had fallen and lights had fallen and everything was lost off of these bookshelves.

MR. YANEV: It would be interesting here to take a look at the HVAC system and how it performed under this damage to the building.

(Slide.)

This is a new unit at the steel mill. It is about 95 percent complete. This is further off to the right. Here they had another one of these overhead galleries that had cable trays installed. The cables weren't in the trays yet and trays weren't bolted to the rack, and they were tossed about during the earthquake, just thrown all over.

(Slide.)

These are the overturned transformers in the new unit there.

(Slide.)

This one fell onto a cable tray.

(Slide.)

This is the Lazaro Cardenas Substation, a new substation about 99 percent complete. It is scheduled to begin operation I believe next month.

MR. LIPINSKI: Those overturned transformers,

hadn't they bolted them down yet or didn't they intend to?

MR. EDER: I don't have a picture of the anchorage. They were on rails and there were "C" clamps on the rails to keep them from rolling off the end of the rails, but nothing to prevent overturning.

MR. SIESS: I am surprised at that.

MR. EDER: They are on regular railroad tracks.

MR. WYLIE: I know, but are they on wheels?

MR. EDER: They are on wheels and they have "C" clamps on the tracks so they can't roll off.

MR. YANEV: They went the other way in this case.

MR. WARD: They went sideways.

MR. YANEV: They went sideways anyway in this case.

MR. SIESS: That is surprising to me. That is earthquake country.

MR. YANEV: Yes. By the criteria they should have had an anchorage, but they did not.

MR. SIESS: I mean they have got design criteria, but they just haven't applied it.

MR. YANEV: Yes, they have not applied it.

MR. LIPINSKI: Did they have an American architect/engineer do this for them?

MR. EDER: I believe not. This is all their own in-house thing.

(Slide.)

This is the Lazaro Cardenas substation, brand new with some brand new equipment sitting in here.

(Slide.)

This is the transformer that slid a couple of inches. You can see that it bent this conduit here. The operators piled rocks up against it so it wouldn't go any more and slide off.

(Laughter.)

(Slide.)

They didn't have cable trays. They just had the cables lying on these brackets. They aren't tied down to the brackets and none of them jumped off.

(Slide.)

This is the control room. This is all brand new General Electric equipment and no problems with it all.

(Slide.)

MR. SIESS: Were those holes in the ceiling there?

MR. EDER: That is from construction.

This is the Copsa Cement Plant. They had some buckled railroad tracks there, probably ground failure.

MR. YANEV: This is important to some of the comments I will make later in terms of intensity. You have severely buckled rails here with ground failure.

MR. EDER: There was some new equipment in here,

and maybe we could call it interaction hazardous. It fell on the control building which collapsed.

(Slide.)

This is the Fertimix Fertilizer Plant. This is another large modern facility.

(Slide.)

This is one of about half a dozen sand boils that we observed. These were big. This is about four foot across. It spewed the sand for about a 40-foot radius it, a huge sand boil.

MR. YANEV: This is interesting in terms of some of the data from the Charleston earthquake and how we might get some comparisons. I will make a few comments on that later.

(Slide.)

MR. WARD: Are you going to tell us what a sand boil is?

MR. YANEV: What we have is we have a sandy material. So it is a very compactible material, not dense at all, and here we have a high watertable. During the earthquake as we shake the sand, the sand grains start compacting and they start dropping down. The water has to go some place, and the water starts coming up and you get a quicksand basically. In fact, this becomes like a sprinkler almost, a fountain.

MR. SIESS: It is a result of liquefaction.

MR. YANEV: In fact, you are getting a liquifying of the whole sand strata called liquefaction. And they will go as many as 10 or 15 feet up in the air like a fountain, and what is left is the hole. Normally now, and this is a few days after the earthquake, but normally you would have like a volcano here where the sand has deposited on that squirting. It is a ground failure.

(Slide.)

MR. EDER: This is some damage from the sonami, that is the recurring wave about three hours after the earthquake. The tide went out and three hours later came in, and depending on who you talked to, it was like 10 feet high. It displaced these fence poles and destroyed this railroad track here and shifted it in about 15 feet. It moved this break wall here about 10 foot.

(Slide.)

This is a steel frame building in a very high shaking area. We looked at buckled steel columns, and about every other one of them was buckled like this on the ground floor of this building.

(Slide.)

Some of the cable trays, and this is that column, some of the cable trays are failing under dead load. These are wide cable trays. They are about three and a half feet

wide and not very typical, but no problems through the earthquake.

(Slide.)

This will show you some of the seismic design practice. They have a well anchored storage tank and no problems with it.

MR. SIESS: No buckling?

MR. EDER: No buckling. I didn't see any damaged tanks there.

(Slide.)

Here is one of the concrete frame buildings that was damaged. The roof panels feel down in it.

(Slide.)

This is another one of these overhead racks. This one is on concrete pillars. This is a steel bridge that slid about six inches in this direction.

(Slide.)

You can look at the cable tray here. From the bridge sliding like this on this concrete cantilevered beam, it buckled this tray a little.

(Slide.)

This is the cable spreading building at the fertilizer plant. It runs the control systems for the whole plant.

(Slide.)

They had more cable trays here than I have seen in any nuclear plant. Their cable spreading building was just full of trays.

MR. YANEV: What was the maximum number, 12 or 15?

MR. EDER: They had 19 tiers.

MR. YANEV: Up to 19 tiers, a different configuration.

(Slide.)

This is some more of looking into the building. This building was heavily damaged. Here we have minor spalling of the column. The column for that large conveyor belt yielded a little.

(Slide.)

And this is the picture that Peter loves me to show. A heavily damaged building. It takes a lot to crack that undamaged switch gear inside, and the multiple tier cable trays on the side are undamaged.

I think I will turn it over to Peter now.

MR. YANEV: What was interesting for the intensities here is Mexico is saying 9 in terms of the MMI. Nine 10 and 11 are the highest you get. Eleven was the worst in San Fernando. What is very interesting here is we have major rail buckle.

If you looked at the modified Mercalian intensity scale, that is intensity 10 or 11. And what is very

interesting is a lot of the intensity maps for Charleston are based on rail damage. So we have a tremendous inconsistency in the way we are looking at some of these data, which some of these earthquakes are pointing out.

I am going to make a strong comment on that, that the way we have used the intensities is inconsistent with what we are saying here.

MR. SIESS: It depends on the soil.

MR. YANEV: Right. And here we have comparable soils and we are calling intensities up to 9, and it probably would have been called 8, that in fact if you follow MMI by the book you get 11, especially when you get sonomi in it. So these are interesting inconsistencies that are not the subject of this talk really.

(Slide.)

Now what I would like to do is kind of give you a quick summary of Chile.

As you know, we sent two teams there. The first one is a reconnaissance team that got there a couple of days after the earthquake led by Paul Smith who was previously heading up the SSMIP program at Livermore, and a member of the SSRAP from Henry Degenkolgb's office in San Francisco, Loring Wyllie, who was present for part of that investigation.

And the second investigative team, in which I was

involved, Dennis Ostrom here and Jim Thomas in the back and a few others. We had for an EPRI project on piping Mary Silver to get some rather detailed data on piping. I am not covering that here. And also Anshel Schiff, a Professor at the University of Purdue, and now he is at Stanford as of a few days ago. He is with the SSRAP. He was on the entire investigation with us.

(Slide.)

This is the intensity map for Chile. The area is again 100 by 200 miles. This is provided by the University of Chile. This is very important again in terms of intensities. These are very conservatively biased. The highest you see is intensity eight here.

We have uniformly rather heavy destruction. That could be easily interpreted as up to intensity 9 or 10, depending on how it is looked at.

So the impression that I have from this map is that the earthquake in general has reasonably low intensity, 7 and 8 maximum in some spots. In fact, that is extremely conservative compared to what we currently do here for significant earthquakes and especially when nuclear power plants are involved.

(Slide.)

Now the record, we just received an update on a few of these records. So some of these numbers we will

change. These are the initial numbers we got from the University. I have listed 16 of the 31 records in order of the average horizontal acceleration.

Starting off with the Melipilla record, which I will discuss further at 67 percent average, that was accompanied by 34. This is going to be reduced a little bit and this is going to be kicked up to about 55 percent vertical.

So in fact in this case we have if you want to call it about a .6G in all directions at the same time concurrent. That is the strongest record as far as I know ever recorded that way with a very long duration. The Gasley records from the Soviet Union have some comparable accelerations.

And then we go down. There is one at 64, one at about 58, and this is a substation out of our data base. Unfortunately, they didn't let us take pictures. So I am not showing you any.

(Slide.)

I am not going to talk about the station. So I will mention it here. Right there we had a diesel which kicked in right during the earthquake and stayed on. Also, we have one at this site that kicked in and stayed on, and I will show that one.

Anyway, there are a number of records, as you can

see, with tremendous accelerations by usual standards.

(Slide.)

A plot of some of these versus the locations of our data sites. The triangles, the arrows are where the sites are located to give you an idea. We were pretty well located with some of the stronger records are.

As I indicated, here is San Pedro at .6G approximately in each direction.

Here is the strong record at Llolleo at about two-thirds GP where we have several facilities and so on. I won't go over the details. If you have time to look at it, it is all in the handout.

(Slide.)

This is an interesting comparison we just got last week from the University of Chile in which we have several records compared to each other.

This is the strong record at Llolleo and these are the two horizontal components. This is a peak at 43 percent and this is a peak at 67 percent. The duration here, this is 60 seconds here.

This is the Vina Del Mar where some of the highrises were that I showed before, and I will show a couple of shots quickly, with a peak of 23 and 35 on that record. This is on soft soil.

(Slide.)

This is Valparaiso on a rock site. Now what is interesting there again on the rock site is there is much lower accelerations, as we see also in Mexico, significantly lower. In fact, the perceived duration on that rock record is much shorter also consistent with what we had in Mexico.

And down here another Valparaiso record. This is probably a softer material. And down here we have some of the vertical components.

(Slide.)

I want to show just one other record quickly, and you have some more there. This shows 50 seconds of one of the stronger records. This is horizontal, vertical, horizontal, and these are half G spikes in this area. This is the record where we measured 42 seconds above .1G, pretty much steady state above it.

(Slide.)

Okay. Now how does that compare in terms of all the spectra we have had? I have to apologize. This is a bit confusing until you study it. This is Reg. Guide 160 at the quarter G. So that is your basic east of the Rockies enveloping spectrum.

These are the various other records we have had at the Sylmar Converter Station, Valley Plant, El Centro Steam Plant and Pleasant. The top record is the Llolleo record.

So there it is right there across. It basically envelopes all our data base to date. So we have an extension of the data base, and what is very fortunate of course is we have extensive duration here, major duration.

(Slide.)

This is the record by itself again. This is the average of the two components, the 67 and the 43, or whatever. It completely envelopes in the frequency range of interest, a slide here and a slide here of .4G. A .5G reg. guide would come -- that will be a few dips here and there will be a dip in here. It is effectively a half a G reg. guide. And again it is interesting the shape of it. It is obviously very rich in spectral content.

(Slide.)

We visited 40 sites in Chile and we had a lot more time to study them, especially on the return visit, a number of power plants. The six power plants have 13 units, and I am going to concentrate more on that today with a little bit of concentration on the refinery.

I am skipping pretty much the water treatment plants today and some of the other commercial facilities we have. There are good summaries for you in the handout.

The two short papers, by the way, I am giving you just for general information on the earthquakes. The one thing we neglected is we forgot to put the acknowledgment

and there should be some kudos there SQUG and EPRI in the small handout.

Now for the Chile earthquake, we are coming up with about a 500-page report, a very detailed report in the near future which will be available to the NRC soon.

On Mexico we have written the report and it went out this week to EPRI. That should be released in the near future also. That is a smaller report. It is more of a reconnaissance nature of course.

(Slide.)

Now we have put quite a bit of data for you on the design criteria in Chile. For industrial facilities, I have the power plant and the distribution criteria for some of the equipment, and that is only anchorage when you read it. The only criteria for equipment is anchorage there.

For buildings or industrial facilities the typical practice, and we are talking about a high seismic region in the area we are in, 15 percent for buildings, 20 percent for tanks and all sorts of numbers, very very comparable for what we do in California. As I have indicated to you before, they do a very good design in Chile. What damage you have is usually due to a construction oversight and in some cases it is design oversight, but in general excellent performance.

(Slide.)

I would say for the power plants, they are very comparable to what we have in California. That is why we haven't really had any surprises.

For the industrial facilities, I would say that the practice is better than California in that the equipment typically was much better anchored than a comparable California facility.

MR. SIESS: Did anchorage apply to those cable tray supports?

MR. YANEV: No. As far as I know, there is not a single system that is seismically designed anywhere.

MR. EDER: You can try and back calculate what the design criteria would have been for seismic, and you get between five and ten percent G for cable trays.

MR. SIESS: But you would probably get that if you didn't have any design ---

MR. YANEV: Right. That is exactly what it is.

(Slide.)

I put a little bit of data there, and I don't have time to dwell on it, on the power system performance. We were able to obtain very detailed data on power system performance, how the plants were put back on line, et cetera, and some of that data is in there. Maybe some othei time I will have more time for that.

(Slide.)

One thing that we did on the return trip, and again no need to read any of this, you have it, we did ask a series of detailed questions of the various plant operators to determine in-plant systems behavior, and Jim Thomas and Dennis Ostrom had a lot of involvement in that one.

Jim, would you like to say anything on that?

MR. THOMAS: Nothing other than what I think we covered this morning. We did make very effort we could to try to determine any type of system malfunction damage, and whenever there was any particular malfunction, that we tried to answer every single question we could think of about it to truly ascertain the actual state during the strong motion and afterwards. As we said this morning, we couldn't find it.

(Slide.)

I have summarized one thing that was of interest here, and that is the only summary I will present now with the slide. We did attempt to find every diesel we could get our hands on, and we found 14 sets. None were damaged. One tripped due to the chatter of a protective relay according to the operator.

The operator, I will show the -- no, I cannot show it because we were not allowed to take a picture. The operator, and this was like the third time the same thing

had happened in the previous earthquakes. So the operator knew what to do and he ran over and switched it a couple of minutes after the earthquake.

The first report we got was during the earthquake. So it could have been during the earthquake to a few minutes afterwards, and it kicked the system back in.

MR. SIESS: Some of our plants have diesels that are sitting on a separate foundation from the rest of the building.

MR. YANEV: Yes.

MR. SIESS: Did you find any like that down there, or were these all on the slab?

MR. YANEV: These were all on the same slab. There were a variety of support configurations, and you will see some of those. Some of them were base isolated. So they have a comparable situation perhaps. I don't recall seeing -- none of them are big enough to be on their slab.

(Slide.)

I wanted to summarize that. I have here the number of sets and type of performance. Several were manual starts. They were tried afterwards and they were all fine, but they were not needed. Or I should say they were manual starts, but they were not started during the earthquake. Six were auto start and all started. Five

operated right through and continued to operate as long as they were necessary. One tripped due to a fault current relay and was naturally manually restarted later, as I indicated. And one of these was not needed after the earthquake at all.

(Slide.)

Now what I would like to do is go through some of the sites. I am going to go by distance from the epicenter, and I will start with the closest. Laguna Verde, this is a small, very old power plant. It is a two-unit. One is a 22 megawatt and the other is a 32 megawatt built in '32 and '49. So we have a pretty well aged plant. It is on solid rock. This is approximately 20 miles from the epicenter. The estimated PGA here based on the surrounding records is between .2 and .3G. You have that data.

(Slide.)

We have moderate to heavy damage in the adjacent small town.

(Slide.)

The turbine building was probably designed for about 15 percent G. This is a steel structure. Some equipment anchorages were added after previous earthquakes. The plant had no significant damage. It is a

"P" curve due to its age, and it is in the chart showing plants coming,on line. It was started without really having had it checked sometime after the earthquake and it kicked right in.

(Slide.)

This is to show you some of the equipment. This is well aged equipment, the 30's and 40's vintage. They had no problems with any of this. It is all anchored. Here is a typical cable tray configuration. This happens to be with angles, and in this case we have a small weld here. There are various configurations of this sort.

(Slide.)

This is the typical performance of pipe. This is the old asbestos insulation. A lot of it is smashed from the impacting and moving around. It is good damping. No damage to piping significant.

(Slide.)

This is important. Here is what was lacking in Mexico. This was probably added many, many years ago in another earthquake. This site was probably subjected to six or seven earthquakes of comparable intensities. So it is not the first time. So they knew what they were doing. Now you can remove these very quickly and slide the thing off. What Mexico had effectively was this little thing here to keep it from sliding. It was a little different in

detail, but the same idea.

MR. WARD: So there must have been damage in earlier earthquakes.

MR. YANEV: Yes. I am certain that some of these have flipped over before for them to go ahead and do that. Either that or they are just being cautious at this site from other experience. This is what we tried to get our conventional utilities in California to go back and do to their old equipment. It costs money so it is not easy to do necessarily.

(Slide.)

Overall the plant performed well, especially given its proximity to the epicenter. The motion was not all that strong apparently.

(Slide.)

The next slide, I will just give you an idea of what happened in the worst area, and here we have a hospital that is of a lot of interest to us.

(Slide.)

This is the Port of San Antonio and the town of San Antonio. There was severe damage throughout the San Antonio area. The recorded accelerations here were 67 horizontal and 86 vertical. That is one of the very strong records, the OEA records that you saw.

The typical performance of the older buildings in

town -- Bolt made the statement this is the worst damage he had ever seen to give you an idea of what the intensity was. This is called eight on the map. It is not an eight intensity. This is not the worse I have seen. Manago was significantly worse, but I think the quality of the buildings was much worse, and some of the buildings I have seen in Turkey were a hundred percent down and there was stone and the same arid area Asiatic construction.

(Slide.)

Inside the port, as you saw before, liquefaction and failure of the mold here with the ground falling into the ocean and the cranes tipping, not from inertial forces, but from the ground failure. The same cranes on non-damaged facilities were up.

(Slide.)

Here is Jim standing in front of what would be in the Charleston review, this has been called intensity 10. Here it is called intensity 8 of severe damage to rails. This is caused always, not by rail moving due to inertial forces, but now failing, which is not recognized by the MMI, and therefore the MMI is wrong. This can occur at a very low acceleration level in fact.

The MMI is being very badly misused, and I think the reason for that is we do not have a good enough correlation between the structural people, the soil people

and the seismologists. The seismologists usually determine density. There should be some very significant input by the structurals and by the civils because they understand the behavior of these structures and what causes the problems. It is not acceleration.

Now this is important in that this hospital was well designed. The record is about two-thirds G. This is about a .2G design. In effect what we have is a .2G equivalent static coefficient design. So we have a criteria exceedence here by a large factor, three, four, five, whatever, on that order, and plus it is a dynamic earthquake of course.

I wish I had time to tell you the structural behavior. The important thing here that I will talk about is the system behavior inside some of the severe damage to the columns. Most of this is falling actually of plaster. The concrete has not spoiled that much.

(Slide.)

A close-up. You can see the partitions. The building went through large deflections. Now you have a report of the damage. This is Vicuna Hospital.

(Slide.)

There was serious structural damage, as I said, and very high accelerations. Now this is on the edge of a hill. So it is entirely possible that it saw a lot more

than the two-thirds G record. We are calling it for practical purposes here in excess of .6G, but I don't know what it is.

(Slide.)

The key finding here had to do with the equipment. We found one pipe where it had disconnected as a drain line. There is no positive connection here. There were a number of other pipes, welded pipes. There was no damage to the welded pipes anywhere. Now this building has gone through very large excursions back and forth.

(Slide.)

Here is the diesel. The diesel is kind of elevated and it is an English manufacture. The system kicked in during the earthquake and stayed on during the earthquake and was used to support quite a few systems for quite a few days after the earthquake. The operator of the plant was at home during the event. He ran to the plant, to here, and the equipment was running.

(Slide.)

This is the control panel for the diesel, a small one. We have a a lot of data on these.

(Slide.)

This is the inside. It is a modern piece of equipment.

(Slide.)

Jim, please feel free to add comments on some of this as they come up.

MR. THOMAS: The relays inside that main control panel are typical commercial grade general purpose logic relays that are not as high a quality as what a nuclear power plant used for the logic type controls. Some of them may be identical. I couldn't get too much information on it, but the point is that that type of logic system, relay logic to the control room, is essentially the same as what we use. It is a smaller scale and not quite as much logic involved, but the type of equipment used for all practical purposes is identical.

(Slide.)

A quick visit back to Renca because I want to get to the big industrial facilities up above it. I showed one of the records here, effectively a .2/.25G reg. guide spectrum record.

Now there is a tremendous variety of ground motion here and, unfortunately, the only motion we have inside of buildings, the basements of buildings. So we don't really have the pure free field records. I suspect there was significantly great acceleration in some cases.

(Slide.)

This is part of the town. There is quite a bit of unreinforced masonry damaged throughout the town and a lot

of small building collapses. The poor performance of two buildings I discussed before, and I will just show a couple of slides to be consistent.

(Slide.)

This one damaged in a previous earthquake. A well-designed structure with continuous shear walls inside and they got severely damaged probably along pre-existing damage lines.

MR. SIESS: Is that a shear wall?

MR. YANEV: This is a massive shear wall running the entire height of the structure and this crack, if you want to call it that, that runs the entire height of the structure.

(Slide.)

MR. SIESS: Is that all the reinforcement that is in it?

MR. YANEV: Well, this is pretty heavy shear wall reinforcing. It is a lattice inside, pretty heavy reinforcing.

There are some interesting structural lessons here for highrises in this earthquake, a tremendous amount. There is going to be a lot of study by the U.S. community in conjunction with the Chileans. NSF is making quite a bit of money available for them.

(Slide.)

Inside, to give you an idea of the intensity of the earthquake, pretty much everything is in shambles.

(Slide.)

And right next door to some c̄ these older structures are the newer ones. No significant damage to any of these. You cannot see through this building, but the construction is identical to this one and this one. The shear wall is inside, massive shear walls and well built buildings. Wonderful design.

MR. EBERSOLE: The last picture reminds you of what can happen to the stored emergency procedures and the book cases and the chairs and other things in the control room apart from the structural damage.

MR. YANEV: Well, I suppose I will agree with you if they are up on the 20th floor of a highrise, yes.

(Laughter.)

(Slide.)

Books fall off of shelves under not very strong ground motion.

Con Con, we have a large industrial facility here. This is the refinery.

(Slide.)

It has a two-unit auxiliary power plant for the refinery. It is a U.S. design between 1950 to 1975. It is a huge facility. The estimated PGA based on the

surrounding records is between 22 and 24 G. It is 35 miles from the epicenter itself. Again keep in mind that epicenter doesn't mean a whole lot because the area of faulting is very large.

(Slide.)

This is a deep soil site with reasonably poor clay. The seismic design criteria, you have some of that data. It is probably considered for all structures, and they seem to be all reasonably well designed. The equipment is reasonably well anchored, all of it. I think they missed here some.

Effectively here there was some severe earthquake damage at the facility with some structural damage to concrete frame buildings indicating high intensities.

We could not take as many photographs as I would have liked to. I will show you just a few.

(Slide.)

First, we have about a 10 percent failure of large storage tanks. These are unanchored large storage tanks. This is consistent with previous earthquakes. There are and can be very weak structures.

If you calculate back against the API code for the design, you will see these are typically designed for like between 5 and 15 percent G static equivalent load.

MR. SIESS: Are these concrete tanks?

MR. YANEV: These are steel tanks. Some are floating top and some are fixed top.

MR. SIESS: How did the spherical tanks do?

MR. YANEV: The spherical tanks were not damaged. There was some settlement of some of the foundations. They are pretty well braced. They were seismically designed. I am unaware of the level at which they were designed. That table that I gave you probably covers it. We put it somewhere between 15 and 20 percent G static equivalent.

MR. SIESS: Were they damaged to the point of losing their content?

MR. YANEV: Which?

MR. SIESS: The steel tanks?

MR. YANEV: The circular?

MR. SIESS: No, the others.

MR. YANEV: The other ones. As I said, 10 of them went out totally and lost all content. You can see the spilled oil here.

MR. SIESS: Okay. Thank you.

MR. YANEV: They were lucky the whole place did not go up in flames.

MR. SIESS: The tank itself actually ruptured?

MR. YANEV: Yes, and I will show some photographs.

(Slide.)

These are gasoline tanks. There were several

failures here, and I will show one of them. There is a tear in the tank. Now these are typically pretty corroded tanks, and a lot of the problems were due to corrosion weakening the plate and the thing giving out. Corrosion does not explain the buckle. That is probably rocking of the tank and hitting of the base.

(Slide.)

Here are some of the other tanks, and you can see splashing of oil. There were very fast evacuations. They had a quick rupture of the base and the top would implode because it cannot take the pressure, the vacuum inside.

(Slide.)

Here is a top implosion. This is not damage due to sloshing or anything like that. These were all pretty full tanks.

(Slide.)

Here is an example of settlement. A number of them went down due to settlement in conjunction with the buckling. So you do that and you get a tear across here. You can see the displacement right across here. There were a number of these failures, tank, piping and everything went. Again, you get this when you have a rigid connection. If you have a very flexible connection, nothing happens.

MR. LIPINSKI: Did the bolts shear off that

flange?

MR. YANEV: I cannot guarantee that this picture was given to me by the Chileans.

MR. LIPINSKI: It looks more like it was never connected in the first place.

MR. YANEV: It was under some pressure, but it is possible. I would assume that it was a shear failure.

(Slide.)

There were a number of these horizontal pressure bottles, quite a few of them, large ones. These are comparable to some functions in nuclear plants. In this case they were designed with plants here. No damage.

(Slide.)

It is interesting, the piping performance, a lot of it was reasonably flexible. Now coming typically you had a gap where the piping had been hitting back and forth against the ground and made itself a little area. No damage to that particularly when you have the flexible configurations, reasonably flexible.

(Slide.)

I wish I could show you hundreds and hundreds of pieces of equipment that I saw. They did not let us take pictures of that. I just have a few. We did ask a lot of questions and we have a summary of the damage. There was no equipment damaged. A few items are mentioned in the

notes that you have.

(Slide.)

Typical piping. There is miles and miles of piping, and they had no major line breaks of any sort. I think they had a few small bore pipes probably due to support point movement.

(Slide.)

Here are just miles of this stuff. You can see it is bracketed so it doesn't slide off its saddle and then it is laterally restrained in some cases and not in others.

(Slide.)

There were three pipe failures. These are cast iron or cast steel. We were not able to ascertain that. They were all in one area where this piping was very stiff and the building settled a little bit. So what caused it we are not sure, but I think it was relative movement plus the formation of the structures themselves. The structure was damaged. These pictures were given to us by the Chileans.

You can see there was a repair weld here done before. So the new break occurred right next to it. Also, this is a point of very high stress. There was some corrosion present also.

(Slide.)

Here is the same area, another break that we got.

That was the structural deformation. This is a very short support and you can see the bolts right here. This ripped the support out. Again, a cast pipe. So we got three of those failures. They are well explained and there is nothing new there.

(Slide.)

We were able to get on the reconnaissance when we surprised them a few pictures of some of the equipment. This is typical U.S. manufactured. This is a Joy compressor. No damage to any of this. They had literally hundreds of these pumps of various sizes, quite large, all over the plant. There was no damage to any of that equipment reported.

(Slide.)

Typical anchorage situations. I would say this is very light anchorage. In fact, you can see it here.

(Slide.)

Some of the four to six KV switchgear. What is interesting is you can see this has slipped a number of inches here up to about six inches.

Typically what we found in Chile is they do not anchor the 4 KV switchgear. They let it slide as long as of course you have overhead cable. So it is really not necessary for an industrial facility to anchor this sort of wide equipment so long as you provide for some flexibility

on top or on the bottom.

MR. EBERSOLE: What happens to the porcelain supports for the bus bars, anything?

MR. YANEV: Well, there is no reported damage to any of them so far. So presumably they are fine. I would say with a lot of certainty they are fine because in some cases we have several earthquakes and if there was a crack that had not been detected it might have opened in the following earthquake.

I am not showing you one exception of course where we had one porcelain base. I showed that to you last time.

MR. EBERSCLE: What about the lightening arresters? They are long, skinny, thin things.

MR. YANEV: Right. Lighting arresters, those are lost often.

MR. EBERSOLE: They are lost.

MR. YANEV: Yes.

MR. EBERSOLE: But they lose in an open circuit mode, don't they, or do they?

MR. YANEV: Jim, lightening arresters on transformers, are they lost in an open ---

MR. THOMAS: They are just lost as an open circuit.

MR. EBERSOLE: So they don't create any faults to ground.

MR. THOMAS: That is where your protection relays are acting in tripping things off. If you see some problems out in the switchyards, the fault protection relays are doing their job. So you do see some. It depends on the failure specific case. You do have some breakage that doesn't cause a problem and you do have some that will result in some trips.

MR. ROBY: But you would have to add that the majority of those would be associated with the high voltage trips which are not of course -- which are kind of outside the scope of the equipment in the KV lines.

(Slide.)

I would like to summarize Con Con. I have three or four key findings here.

The emergency diesel here started automatically about three seconds after the earthquake. That is the one where a fault current relay tripped it off and the operator turned it back on. So we have one loss of an emergency system here.

The onsite steam turbines provided the control rooms with power through the earthquake. So that cycle of the plant continued working right through.

With the exception of the emergency diesel generator, there were no malfunctions, false indications, system resets or abnormal occurrences of any form in the

plant control systems in the whole plant.

Steel piping, cable trays, equipment, horizontal and spherical tanks and typical refinery structures performed well.

You have seen the lesson from the vertical tanks. That is an old one.

(Slide.)

This next slide is one of our most important ones, and that is Las Ventanas, the copper refinery. This is a very large industrial facility. To give you an idea, this is about 100 feet high building right here. The stack is 550 meters, about 500 feet high.

This includes a 5.3 megawatt auxiliary power plant. It is German and Chilean design and began operation in 1966. Portions are quite new. It is a deep soil site adjacent to the Las Ventanas power plant. The estimated PGA is based on the in-structure record, which was 18 percent. Our estimate of the ground motion is on the order of 20 to 35 percent G. We will have spectra on all this later on.

This is about 45 miles from the epicenter. There is moderate damage in nearby small towns and extensive damage within 20 miles of the plant. The accelerations recorded get to be a lot larger inland from this coastal site. They go up to .6G recorded inland from it. So

further away from the epicenter.

Seismic design criteria, basically heavy equipment anchorage is probably designed for about .3G to be consistent with what we saw and the criteria that they typically have. Structures are probably designed for 15 percent G against static, soil static equivalent.

(Slide.)

A lot of buildings, large steel buildings, you asked before the question how do they compare to turbine buildings. I would say they are comparable.

(Slide.)

The key findings here are several. They have a suspended brick ceiling inside the main refractory oven. All of that fell in and cost them about $10 million worth of problems because it fell into the molten copper and they had to blast it apart. That is the third earthquake in a row that that has happened.

The emergency diesel here started up with the loss of offsite power and went on operating. So that is one of our sites. The motor operated valves, we found a lot of them on small diameter lines. This was kind of lacking in the previous data base and SSRAP put some very severe and we feel now totally unnecessary restrictions based on this data, especially in considering the location of some of the valves being very high on corroded in the structures

without seismic design of piping.

And again piping cable trays did well. There were no malfunctions or false indication or system resets of normal occurrences. We have a pretty detailed discussion of that. One thing we did find is they had -- it is an extremely dirty place, just the nature of the business as such -- a lot of loose material hanging around. And during the earthquake a number of objects dislodged and fell, and there were three or four breaks in tubing. This would be control tubing. It did not lead to any problems. That goes to say that you just don't leave these objects laying around.

MR. SIESS: These were loose objects?

MR. YANEV: I think in some cases it was like tiles from the ceiling. We have hundred foot buildings and who knows what the material is like.

MR. SIESS: It wasn't a crane or something like that?

MR. YANEV: No, no. They described it as just loose objects left around, and when we walked around you could see a lot You could see tools everywhere. I suspect there was probably like ceiling tiles for pieces of asbestos, corrugated asbestos, roofing coming down from these buildings because there had to be some damage to the roofs at those elevations. But they thought it was totally

trivial. So they didn't bother to record it. So we could not get more details than we have.

(Slide.)

With that, some slides quickly. We will look at some portion of that facility. The area that collapsed partially is in here. There was a lot of piping like this and no damage to piping.

(Slide.)

Here is some of the piping inside, and you can see the quality of it. It is a very dirty environment and you can see some of the cable trays that go way up, high structures. Some of the cable trays are right in here. No seismic design to any of this except for the building.

(Slide.)

Here are some of the valves at elevations between 60 and 100 feet above grade and you can see the heavy corrosion here. These are limitorques. You can see the rather large operators. They go down to about a one-and-a-half inch line without any significant breaks. Very flexible structures.

(Slide.)

That is one of the better outliers we have found. Here are the operators. The shaft goes through the floor.

(Slide.)

It is here. It turns and goes up, and it went up

50 feet or so that I could see, something like that. No damage. In fact, there is a seismic separation joint somewhere in here between the buildings. That is interesting because that is really an outlier and some of these will be found in nuclear plants.

(Slide.)

Cable trays. I am shooting. Again, very dirty and very dark into the structures. Here you can see the various configurations. They seem to be on channels or angles. Here are some brackets off of the walls. These are good sized brackets. So this is decent design. No seismic design. You can see the heavy loading of cable here. Cables are just hanging on. Again, they had no problems. We asked a lot of questions about this. I wouldn't be surprised from swinging and so on that something is dented a little bit, but it didn't lead to any problems. So it is trivial.

(Slide.)

The power plant itself, and I am skipping the structures, it is about three-story building. You have to walk up to look into it. So we are here at the operating floor level, the control room itself. This is German equipment. There were no problems here.

(Slide.)

Here is some of the switchgear. I believe this is

6 KV switchgear. It is the size of a 4 KV. The German equipment typically has pretty stiff panels unlike the English one I will show you later that failed or was damaged. So in this case no effects whatsoever.

We could not ascertain whether or not this was anchored. We couldn't see it. It had not moved.

(Slide.)

Some of the suspensions for the piping. This is about as flexible piping as I have ever seen here, and some of it is quite stiff because it is short. There are quite a few valves attached to this piping.

(Slide.)

Here is some of the MOV's we saw. They go down to pretty small lines. Her we were looking more for the damage. We concentrated in this earthquake on what damage there was and tried to see how it could be explained and what caused it. So we did not take good inventories, but there are massive inventories of equipment, and in this case MOV's. These are German manufactured. They look very comparable to the limitorques.

(Slide.)

This was the diesel at the plant that operated properly. This was on what appeared to be rather weak springs. I suspect if this had been similar quake at a half a G that would have been sheared off. So this was not

consistent with most of their design in my opinion.

(Slide.)

One of the structures inside. This is a very large steel structure with many bridge cranes. There were many bridge cranes throughout the plant. They had no problem with any of them. We did find a couple of other sites where a couple of wheels of cranes were damaged. You can easily damage in a very flexible steel structure a crane by the building virtually breathing in and out and pulling up the wheels because typically a crane is not designed for that, but that would take a flexible structure.

(Slide.)

Here is what they did as a retrofit. That must have been from the last earthquake or whatever. But they went ahead and put brackets around this small transformer and in this case it stayed in place. You can see the care they are taking to protect certain things.

(Slide.)

Our most interesting site, Las Ventanas. I might as well put that viewgraph up. U.S. and Chilean design. The buildings themselves are U.S. Most of it is U.S. Two units, 120 megawatt for Unit 1 and 210 for Unit 2. This is a '64 operation and this is '77 operation engineered over a compacted fill over a deep soil. The removed, and I forget

the exact number, but between 20 and 40 feet of surface material because it was too soft to provide a better foundation.

This is the plant that was instrumented. The instruments are at the base of the Unit 2. Boiler support structure, 18 percent G peak. Sustained motion. On the basis of that we figure that the estimated field PGA and the other records around it is between .2 and .35. In effect we believe that in this case soil structure interaction significantly reduced the peak. Forty-five miles from the epicenter. Moderate damage to nearby small towns and extensive damage in the vicinity. As you go inland again you get up to 60 percent G.

The seismic design equipment anchorage, 50 percent G is the intended. Now it is not always done that way. Sometimes it is more and sometimes it is less, but that is the goal. Some components anchorage, 1 G especially for the substation equipment. That is the criteria.

MR. SIESS: It is U.S. design?

MR. YANEV: Yes. Well, everything I saw was U.S. design or U.S. equipment and the structure was U.S. design.

(Slide.)

We neglected to put down the designer, Ebasco and CTE ---

MR. LIPINSKI: Those are all statics?

MR. YANEV: Everything is static. There is no dynamic anything.

Piping, there was a little bit of piping protected to .2 G static, and a .2 static, this is not that you apply a .2 to the whole pipe and displace it. That is, you take the pipe, take .2 of the pipe and then design a bracket around the pipe for the .2 static load. That is what it means. For the snubbers you put a .2 load there. So the pipe itself is not designed.

The structures, 15 to 27 percent equivalent static loads.

MR. SIESS: Now, let's see, you said typical Chilean practice was about 3/10ths G for anchorage?

MR. YANEV: It is between .3 and .5. This is the power plant.

MR. SIESS: How much more does it cost to design equipment anchorages for one that is .5 say.

MR. YANEV: For one, it may begin to get into some inconsistencies. It would look too big and would not be necessary. But the cost probably would not be different. You are talking instead of a half-inch bolt of a three-quarter inch bolt. When we fix something for commercial plants in California, you throw in what you know are reasonably conservative bolts without having to calculate

forces. So they usually come out probably more than half a G.

(Slide.)

Here is where the records were taken. As I promised, until the Chileans publish it, I cannot give you the full record. I gave you a little one last time. But from zero to 23 seconds, this is the ground at 18 percent, and this kicks up to 81 percent on top of the boiler support structure. You can see it is very cyclical here. This is the soft soil and you can see the structure now. It is a reasonably soft structure.

MR. SIESS: Why are they so difficult to get records out of? Is this government or proprietary ---

MR. YANEV: No. It is partly the government and partly the university, and I think they are interested in treating the records themselves first, and they are certainly interested in obtaining funding for doing some of the work which they don't have.

MR. SIESS: I think one of the notable things about the Mexican earthquake was the rapidity with which the records were made available.

MR. YANEV: And I personally think they did themselves a big favor in that respect. They will attract much more funding certainly in research from the U.S. by having that data up front. I have certainly tried to get

that idea across in Chile. We have been reasonably successful, but not as success as I would have liked to be. I would have a lot more data for you otherwise now.

(Slide.)

So this is the record as it continues on and on. This is 26 to 50 seconds with the upper three components of the top of the boiler support structure.

(Slide.)

The key findings for the plant supported very well what we hope to see there.

(Slide.)

The records are in this unit and you can see some of the very large tanks. In this earthquake there were no structural tank failures. There was little damage.

Now what is interesting is there is quite a bit of electrical equipment up and down these structures. I did not take enough pictures as I found out later.

(Slide.)

The most important damage at the plant which shut it down for a while was a tear at the bellows of a line that went about 1500 feet along this pier. It was just too long so that the longitudinal displacements along the line were large, quite large and the bellows could not accommodate that displacement and tore it. That is at least a second and probably a third time that has occurred,

the previous being in the '65 earthquake and '71 earthquake. Both of these earthquakes were equally large approximately and they were in the same area.

In 1980 there was an earthquake, and we just got some new data on that. They recorded .27 G at the plant in both directions, and that earthquake had the duration of a San Fernando quake. So in effect we have not four earthquakes with reasonably strong shaking at the plant, at Unit 1 and two at Unit 2.

MR. SIESS: Did the last one break the bellows, too?

MR. YANEV: The '80 apparently did not because we did not hear about that. So maybe it was the duration in that case or the frequency content or whatever.

(Slide.)

Here is the bellows in the previous earthquake with a tear. You can see in this case the deflections were a little bigger because the tear is bigger I guess and bellows has been replaced. That kept the plant offline for about a day and a half. That is the only thing that really it offline.

(Slide.)

This is the previous quake and one of the tanks had buckled. No, this is an anchored tank. It did not tear, but it buckled. So their criteria for this was to

tear out the bottom portion here and stiffen it. We can get all these details if necessary. This is the kind of a stiffener they used. They stiffened the bottom and anchored it. It is a different tank, but I am using it as an illustration. That tank this time performed fine. I believe it was covered. So we couldn't photograph it.

MR. SIESS: Why won't it buckle just because of the stiffeners next time?

MR. YANEV: It could. As you get away from that corner the probability is lower, but yes, if it is strong enough it will buckle. It is a highly non-linear behavior, that corner. You have the rocking and you have the impact and you have the stress concentration.

(Slide.)

Sorry, let me go back to the previous one.

(Slide.)

This tank settled in the previous earthquake. It tore a bunch of lines. It did the same thing in this earthquake and you can see the damage. Again, settled. It is obvious the foundation was inadequate.

(Slide.)

I thought I would throw in a couple of pipes. If you are interested for me to continue talking after the next presentation, I have included quite a bit of additional material on piping and one other power plant

that is as big as this one. That would be another half an hour of data if you want to see it. I am not putting it here.

There was a lot of piping. This is main steamlines and you can see the diesel snubbed, but not that heavily, and there was the typical effect where you would have a penetration and that would provide a lot of damping and smashing of the insulation that was replacement. That is what it looked like after the earthquake. This is all trivial damage. It provides very high damping.

(Slide.)

Seismic stops. You can see the lines slamming back and forth. No damage to any line. It provides great damping here. This happens to be a stiff one.

(Slide.)

One tank failed ---

MR. REED: When you take a picture like that one showing pipe insulation damage, maybe that happened as a result of operation. I have seen many pipes like that just from water hammer and other operations and trips and so on.

MR. YANEV: That gives us a lot of heartburn when we are trying to determine the deflections. You can usually tell when it is an earthquake and you are right there after the earthquake and it is very fresh. But if you get there pretty much later, it begins to be

difficult. In some cases we have been at El Centro and we have really played with those because we have been there during a lot condition and during a cold condition. So we could measure. There we have quite a bit of certainty where we are.

MR. SIESS: Peter, there is something in the background there that looks like a snubber. Is it?

MR. YANEV: Yes, it is. These are some of the snubbers. I was asked this morning to cut down on piping. So if you want to go back to it, after 5 o'clock.

(Slide.)

The legs before the earthquake, it was on these legs only. They buckled and these were added after the earthquake. Of interest here was the tank fell over and the piping kept it and the conduit kept it. There was this pipe that goes into the tank. It was wrapped around this conduit. It bent the hell out of the pipe and ripped out the support. The conduit kept it there. It is obvious the two to one type ratio here was adequate to hold it and it was pretty stiff and it connected -- I don't remember, here. You can see that the ductility of this pipe is more than 102. The pipe did not lose integrity. It could have, but this one didn't. A very large deformation.

(Slide.)

Another pipe nearby. A hard impact again on the

structure of the pipe damaged the structure. So as maybe an interaction we should make sure the equipment doesn't wipe out the structure. That was a hard hit.

MR. SIESS: Is that an "H" beam or an angle?

MR. YANEV: It is an angle. It is probably a cut "H" beam.

(Slide.)

We do have some equipment damage, and this was a very flexible line, two valves. It had to travel about a foot to impact several times right there. The same thing happened at El Centro if you recall. So it broke the yoke, the cast iron yoke across here. It happened definitely at one and it probably happened to the second one. We never quite got the story straight. So I am assuming two failed.

In this case that line was taught before the quake. From here to here was pretty tight and it ripped it right off. So that is part of a walk-down and you make sure this is flexible.

MR. SIESS: It hit the railing you say?

MR. YANEV: The pipe swung back and forth and the valve here hit the railing about 12 inches away several times and it broke. So it is an impact failure. It is inertial failure.

MR. SIESS: The railing didn't look that strong. That is why I asked.

MR. YANEV: It is bent a little in this area. In another case we had a pipe hit a railing and just popped it right out. So we had two valves damaged.

(Slide.)

You can see the new weld right here. This is the same valve.

(Slide.)

We had quite a good sample here. This about doubled our previous collected MOV data. We took the effort here of half an extra day to collect the data on the MOV's. They go up, and I can never remember. What is the largest limitorque? Is it size 6?

MR. EDER: I don't know.

MR. YANEV: If it is 6, we found a size 5 here, the second largest down to about the smallest range. There were 50-some valves of this sort. This is Unit 2 in this case, and you can see the very flexible configurations all over through the plant and no damage to any of this equipment. So I hope with this we will significantly relax the current SSRAP criteria.

MR. LIPINSKI: Those were installed at that angle?

MR. YANEV: Yes. You see that in nuclear plants today. That is a very standard 45-degree angle configuration. At Crystal River I recall seeing exactly -- and they might be the same color just like that. We have

photographs for comparison.

(Slide.)

Here is a haven for interaction lovers. You can get all the interaction you want, and most of it obviously helps you a lot. You have to watch out a few places where it doesn't help you. It hurts you. There are valves throughout and you can see the little blue spots with the orange motors. There is lots of opportunity to break and it just doesn't happen that often. In a few cases it does happen. So that is what you are looking for, but it is very rare. In terms of piping and so on, no adverse effects known anywhere here.

(Slide.)

Here are some of the larger valves. This is an aux steam line I believe or main. I don't recall now. We have the data. This is this type of a configuration, and that is about a size 2 or 3.

(Slide.)

This is the biggest one we found, like a size 5 and you can go up to a size 6. This is the feed water. A big one. So this is about like that.

MR. SIESS: Just supported off the pipe?

MR. YANEV: Yes, and right there you have a good support for it, and you should because of the mass. So in this case you use a snubber.

MR. SIESS: Did the snubber work?

MR. YANEV: There is no indication that they did not, but I can't tell you.

MR. SIESS: Mechanical or hydraulic?

MR. YANEV: Hydraulic. The indication of whether they worked is a little hard to determine.

MR. SIESS: Hydraulic ones don't hang up. They fail the other way.

MR. YANEV: What they did have is for the boiler, which I am missing here. I am not showing you the boiler. The boiler stops and is designed to fail and at about .3 to .4 G they expect it to go. They all went. They were all damaged. They had some snubbers and they broke the snubbers, but they were expected to go at those G levels. They were designed to go at those G levels.

(Slide.)

Now some of the other equipment. I am going to be unable to show you, but I have to tell you that on these structures, and here you can see some of the electrical control panels. They go all the way up this 160 feet high structure. They go from the top floor all the way down and you have the vertical control system inside here behind the elevator. So on every floor you would have a series of these panels. They will be both electrically and hydraulically controlled, pneumatics. I just have,

unfortunately, one picture with me. No malfunction and no damage to any of that equipment.

MR. SIESS: Peter, would the amplification of that altitude for that type of frame structure be comparable to the amplification in an aux building, which is a shear wall structure?

MR. YANEV: A 150 feet is a higher building than typically nuclear especially for where the equipment is. I would say in this case we have got four to one. So that will be -- my opinion now, and I am not basing it on ---

MR. SIESS: Four to one amplification?

MR. YANEV: Here. Now my opinion, and not based on analysis, but on reality plus too much analysis, I would say that would be an upper envelope of that.

(Slide.)

MR. WYLIE: Peter, we have got another meeting in about five minutes.

MR. YANEV: Fine.

Here is the equipment cable trays. Jim is scratching his head in looking at the exposed cable trays. That is about an elevation of 130 feet above. These are exposed cable trays. I know one plant right now where Stone and Webster is having trouble with its ties in trying to show they are okay. There is plenty of data to show they are fine.

(Slide.)

Inside a typical configuration, and we have a variety of conditions in these facilities, tack welded there or bolt through, very flexible, no damage to the control panel. We found a little bit of damage to the control panel frame in this corner. It could have been before the earthquake and it could have been due to the earthquake, whatever. It was trivial. The equipment itself was fine. It functioned properly.

(Slide.)

U.S. equipment. This was actually isolation mounted and there are little isolation mounts underneath.

(Slide.)

One panel was badly anchored, very shallow anchorage. This is drilled in anchor bolts. The thing leaned about 10 to 15 degrees. That could have come over and fallen. So this was poor anchorage in that case.

(Slide.)

Here are the bolts, and we can see how short they are in the embedment. It was just a small portion of that. I gather that is two inches. So that is about a three inch total.

(Slide.)

Another cabinet.

(Slide.)

Some of the solid state equipment inside. GE modern equipment for the burner control system I believe.

(Slide.)

Some computers inside, anchored equipment, no damage.

(Slide.)

A typical rack down below and a lot of heavy equipment here for this size rack, a lot of stuff.

(Slide.)

This was a gold mine of relays, and Jim's eyes lit up when we opened this one. Just hundreds of relays inside and no malfunctions and no damage.

(Slide.)

We were looking here at the cut-outs. SSRAP put some pretty severe restrictions based on just conservative, and we find in most of these cabinets we are going to have significantly larger cut-outs than we have imposed. So we hope to relax that to a reasonable degree.

(Slide.)

This is Jim's favorite piece of equipment. Do you want to say a word, or have you already done it?

MR. THOMAS: This is a system identical to the type we use on larger plants.

(Slide.)

MR. YANEV: A very flexible MCC. I was able to

move that one back and forth quite a bit, several inches on top. I would say a couple of inches at least on top, very flexible.

(Slide.)

There were many larger ones. These are the 7700 G series. No damage to any of this.

(Slide.)

This was a gold mine for 4 KV vintage of switchgear. There were several manufacturers. This was one of them. It looks like GE. No damage. Some of these may not have been anchored again and probably slid a little bit.

(Slide.)

That is where that building failed, and I wanted to show you one thing. We have a growth building failing especially when it is upside down.

(Slide.)

And my favorite pipe in the whole place. The building moved probably about two feet and tore out all of the pipe supports.

(Slide.)

That is my favorite pipe by far.

(Slide.)

There is a pipe support torn out, torn out, torn out. The pipe didn't leak.

(Slide.)

This is a penetration through the wall.

(Laughter.)

So I don't know what is holding it up. Something just be. That was a four-inch line.

(Slide.)

Now someone, and I think maybe it was Jesse, I don't remember who asked me once upon a time had I ever seen filaments break in lights. We found at this site, and this is a two-thirds G site, we found in some old German equipment, some lights like this, and I think the bulb is about so big, but I didn't look at them, they lost a few filaments. That is all we could find. I thought it was unimportant and we weren't interested in it much. So we left it. But we did find some light bulbs that busted. I also did find that in one place in Coalinga a fluorescent light actually fell out of its socket.

MR. EBERSOLE: Well, we were told a long time ago that the lighting fixtures were seismically competent in the control rooms, but when we asked the question did the tubes stay in, they answer is we don't know.

MR. YANEV: I know of at least one has fallen out. So the probability is probably on our side.

(Slide.)

Rapel was the one plant that is important. A big

be -- my opinion now, and I am not basing it on ---

MR. SIESS: Four to one amplification?

MR. YANEV: Right.

(Slide.)

Here is Dennis Ostrom in the audience next to the instrument. .31 G at this site. This is one of these anomalous sites where you are in rock in a tunnel. I think the accelerations at this site were more like .4 to .7 G, but the record gives you .3 inside. If we have some more time, I will explain my thoughts on that.

(Slide.)

Typical equipment here. These are MCC's and no damage.

(Slide.)

There was a lot of equipment like this with associated cable tray switchgear, et cetera, a lot of electrical equipment of the kinds we are interested in, MCC's, small ones in this case and no damage.

(Slide.)

The control board again and no damage and no malfunction. One thing that did happen here, and this is an isolated one, one thing that did happen is they popped a few of the covers. Three or four of these popped out on these, I don't know, I will call them brackets. They just popped out. We might look into that a little bit and make

them a little stiffer.

(Slide.)

Examples of valves and equipment in the back. The diesel was fine

(Slide.)

Batteries, there was a little bit of damage, no failure to one of the bars. I will show that later.

MP. WARD: Are those supported there? That looks fairly elaborate.

MR. YANEV: This is rebar. This is wood and they built some of a home-made job, but pretty good. The batteries are bound well. They had poor spaces. They had these very small spaces and they were shaken up and they fell in. And in several cases the batteries in fact like there would be one missing. So you would have a gap. So the batteries did move around a little bit, and in two cases they damped the bars, the bus bars. They didn't bread them and they didn't damage the batteries. There was no interruption of service.

(Slide.)

There was quite a bit of concentration of energy in this building. The ground motion here was much stronger than anywhere else I think in Chile, which we had a record of. There were a lot of ground failures like this on the site and a lot of broken ceramics in the substation.

(Slide.)

Inverters and chargers, no problems here.

(Slide.)

There were quite a few of them. I think about a dozen total.

(Slide.)

This is where we got the failure of the railroad -- not failure to the cabinet of the railroad switchgear. This is a 13.8 KV switchgear. It bent and impacted this MCC. This was not damaged.

(Slide.)

Here is the gear as it is today with the doors in place. The impact occurred here. It is bent over about an inch.

(Slide.)

This is in the down condition before removal. Here it is in the up condition as it was during the earthquake. It is really an oddball compared to our equipment. There are no walls in the front or in the back or in the middle. Typically ours have the door and then a wall and then another wall all the way up like a shear wall. In this case you see right through it.

(Slide.)

Now the switchgear is on and you are looking in the cabinet through the back of it and you see there is

nothing on the bottom. And there is the one brace and that buckled and the whole thing kind of leaned over and it was damaged. Apparently was not damaged to malfunction.

(Slide.)

There is the back where it is busted, the impact on the MCC. So we did find a serious outlier and you don't want to allow this particular condition. Now this is for a very high G site.

(Slide.)

And here is where we got the couple of relays that we have discussed already, the GE. It was in here. This is electro-mechanical pipe protective relay, a large one. There was damage.

(Slide.)

Here is the English equivalent, and I don't recall the exact numbers. We have those where the spring -- in one case the spring popped out. It is one of these like a clock spring on a pivot like a top in there. In one case it popped out and in the other one apparently it deflected enough to contact and short and burn.

(Slide.)

There was a little spilled ink on this strip chart recorder. So we got that as a damaged item.

(Slide.)

And here is one of these batteries. When we got

back the second time they had straightened that out and no damage to the battery itself.

MR. EBERSOLE: There were no cracked casings?

MR. YANEV: If there was, nobody had seen it and it had not affected anything. So I assume no.

MR. EBERSOLE: Sometimes the casings crack just standing there.

(Slide.)

You can see here the space in there which should not really be allowed.

MR. EBERSOLE: What would happen if a casing cracked in the electrolyte went out of it? Would there be a fire?

MR. THOMAS: You would just have the acid on the floor.

MR. YANEV: In fact, in Managua all the batteries fell off of the rack and broke the glass case and I just about stepped in it, and I recall the concrete was kind of etched.

MR. EBERSOLE: That meant they lost the DC functions.

MR. YANEV: They lost a lot. In that case what they lost is the fuel oil pump to the bearings. They wiped out the turbine bearings. So there I did see the spill batteries. They were broken from falling down.

MR. WYLIE: Let me ask the subcommittee. We are going to have to stop here.

MR. YANEV: I have more of the same. That is all.

MR. WYLIE: We have the research program. Would you like to continue after 5 o'clock?

MR. EBERSOLE: I am supposed to split my time downstairs.

MR. WARD: I have a flight.

MR. YANEV: Basically you are going to see more of the same, more equipment.

MR. WYLIE: Well, we thank you for your presentation, and we will call a five-minute break while we close the meeting for the next portion of the meeting with the research group.

(Whereupon, at 3:40 p.m., the subcommittee meeting concluded.)

* * * * * *

CERTIFICATE OF OFFICIAL REPORTER

This is to certify that the attached proceedings before the UNITED STATES NUCLEAR REGULATORY COMMISSION in the matter of:

NAME OF PROCEEDING: ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

QUALIFICATION PROGRAM FOR SAFETY-RELATED EQUIPMENT

DOCKET NO.:

PLACE: WASHINGTON, D. C.

DATE: WEDNESDAY, JANUARY 15, 1986

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission.

(sigt) Mary Simons / sg

(TYPED)

MARY SIMONS

Official Reporter

ACE-FEDERAL REPORTERS, INC.

Reporter's Affiliation

PROPOSED RESOLUTION OF PUBLIC COMMENTS
ON USI A-46

- PROPOSED RESOLUTION PACKAGE REVIEWED BY CRGR ON JULY 8, 1985.
- ISSUED FOR PUBLIC COMMENT ON 9/13/85.
- PUBLIC COMMENTS DUE 11/15/85.
- PROPOSED RESOLUTION OF COMMENTS COMPLETE.
- NRC MANAGEMENT HAS NOT YET REVIEWED COMMENTS.

ORIGINATORS OF PUBLIC COMMENTS

- 8 UTILITIES: 7 SQUG MEMBERS

- 2 INDUSTRY GROUPS:
  - SQUG
  - NUCLEAR UTILITY GROUP ON EQUIPMENT QUALIFICATION

- 1 NATIONAL LABORATORY: - SANDIA

- EPRI

- AIF

CATEGORIZATION OF COMMENTS

- APPLICABILITY OF BACKFIT RULE
- JUSTIFICATION FOR A-46 REVIEW } (10 COMMENTS)
- IMPLEMENTATION SCHEDULE (12)
- RELAY REVIEW GUIDELINES (10)
- SCOPE OF REVIEW (10)
- SCOPE OF WALK-THROUGH INSPECTION (8)
- REQUIREMENT FOR JUSTIFICATION FOR CONTINUED OPERATION (5)
- COST ESTIMATE (5)
- GUIDELINES FOR REPLACEMENT EQUIPMENT (4)
- SAFE SHUTDOWN REQUIREMENT (4)
- EQUIPMENT SEISMIC DEMAND AND SEISMIC CAPACITY (6)
- MAKE-UP OF WALK-THROUGH INSPECTION TEAM (4)
- EXPANSION OF SEISMIC EXPERIENCE DATA BASE (3)

- ROLE OF SQUG IN GENERIC IMPLEMENTATION (3)
- ACCESSIBILITY OF SQUG RESULTS TO NON-SQUG MEMBERS (2)
- PLANT SPECIFIC SERS (2)
- APPLICABILITY OF A-46 TO NEW PLANTS/NEW EQUIPMENT (1)
- APPLICABILITY OF A-46 TO SPECIFIC PLANTS (2)

APPLICABILITY OF BACKFIT RULE AND JUSTIFICATION FOR A-46 REVIEW (10)

° COMMENTS:

(1) THE NEW BACKFIT RULE SHOULD BE APPLIED TO THE RESOLUTION OF A-46.

(2) REGULATORY ANALYSIS DOES NOT PROPERLY QUANTIFY COST BENEFIT.

(3) EARTHQUAKE EXPERIENCE SHOWS THAT EQUIPMENT IS INHERENTLY RUGGED THEREFORE NO NEED TO DO REVIEW.

° RESPONSE:

(1), (2) - THE BACKFIT RULE REQUIRES: "SYSTEMATIC AND DOCUMENTED ANALYSIS....FOR BACKFITS WHICH IT (NRC) SEEKS TO IMPOSE". ANALYSIS CAN BE QUALITATIVE.

- QUANTITATIVE PRA ANALYSIS TO EVALUATE RISK REDUCTION FROM SEISMICALLY QUALIFYING EQUIPMENT HAS HIGH UNCERTAINTY. HIGHLY DEPENDENT ON ASSUMPTIONS.

(3) - ACKNOWLEDGE EQUIPMENT IS INHERENTLY RUGGED, STILL HAVE AREAS OF CONCERN:

(A) EQUIPMENT ANCHORAGE
(B) FUNCTIONAL CAPABILITY OF ESSENTIAL RELAYS
(C) OUTLIERS

WE BELIEVE SQUG IN AGREEMENT.

IMPLEMENTATION SCHEDULE (12)

- COMMENTS:

  (1) IMPLEMENTATION SCHEDULE SHOULD BE NEGOTIATED ON INDIVIDUAL UTILITY BASIS, CONSIDERING LIVING SCHEDULE FOR PLANT MODIFICATION.

  (2) PROPOSED COMPLETION SCHEDULE "NO LATER THAN 28 MONTHS" FROM DATE OF ISSUANCE SHOULD BE CHANGED.

  (3) SCHEDULES SHOULD PERMIT IMPLEMENTATION AND MODIFICATIONS DURING PLANNED OUTAGES.

  (4) WALK-THROUGH INSPECTION SHOULD NOT BE REQUIRED UNTIL EPRI/RES TEST DATA AND SQUG EFFORTS TO ADDRESS REMAINING CLASSES OF EQUIPMENT IS COMPLETE.

  (5) GENERIC GROUP GIVEN 90 DAYS TO RESPOND TO REQUIREMENT, INDIVIDUAL UTILITIES GIVEN 45 DAYS.

- RESPONSE:

  (1) AGREE. WILL MODIFY TEXT.

  (2), (3), (4) 28 MONTHS IS A GENERAL GUIDELINE. TEXT WILL BE CLARIFIED. ACTUAL IMPLEMENTATION SCHEDULE WILL BE NEGOTIATED WITH INDIVIDUAL UTILITIES.

  (5) SQUG AND INDIVIDUAL UTILITIES GIVEN 60 DAYS TO RESPOND.

RELAY REVIEW GUIDELINES (10)

° COMMENTS:

(1) RELAY CHATTER IN CERTAIN CASES IS INCONSEQUENTIAL.

(2) CREDIT SHOULD BE GIVEN FOR OPERATOR ACTION TO RESTORE SYSTEMS AND EQUIPMENT AFTER EARTHQUAKE.

(3) EQUIPMENT FUNCTIONALITY SHOULD BE RESTRICTED TO "RELAYS" ONLY.

(4) REQUIREMENT FOR REVIEW OF ELECTRICAL RELAYS SHOULD BE REVISED, IN VIEW OF SQUG WORK ON RELAY REVIEW PROCEDURE.

° RESPONSE:

(1, (4) AGREE WITH COMMENT. THE REQUIREMENT FOR RELAY REVIEW WILL BE REVISED.

(2) WE AGREE IF PROCEDURES ARE AVAILABLE AND THERE IS SUFFICIENT TIME.

(3) AGREE.

SCOPE OF REVIEW (10)

(1) C: THE SCOPE OF A-46 REVIEW SHOULD REFLECT THE MINOR SIGNIFICANCE OF ANY REMAINING A-46 ISSUES IN VIEW OF THE SEISMIC EXPERIENCE AND TEST EXPERIENCE DATA.

R: SCOPE ALREADY NARROWED DOWN TO:
- EQUIPMENT ANCHORAGES
- FUNCTIONAL CAPABILITY OF RELAYS
- CAVEATS AND OUTLIERS

(2) C: ASSUMPTION THAT SSE DOES NOT CAUSE LOCA SHOULD BE EXTENDED TO INCLUDE HELB AND SLBA.

R: AGREE. THIS IS BASED ON:
- SEISMIC EXPERIENCE DATA.
- IE BULLETIN 79-02, 79-07, 79-14 REVIEW OF SAFETY RELATED PIPING.

(3) C: ACCIDENT MITIGATION SYSTEM PIPING IS NOT INCLUDED IN THE SCOPE BECAUSE OF EXTENSIVE PIPING SYSTEM DESIGN MARGINS. IT SHOULD BE STATED THAT SUCH PIPING MARGINS EXIST IN ALL SYSTEMS INCLUDING THE RC SYSTEM.

R: AGREE. SAME REASON AS IN (3).

(4) C: TYPICAL EQUIPMENT LIST IN REGULATORY ANALYSIS SHOULD STATE "THIS LIST IS BASED ON SQUG POLLS OF MEMBER UTILITIES AND IS EXPECTED TO INCLUDE ALL OF THE TYPES OF SAFE SHUTDOWN EQUIPMENT IN NUCLEAR POWER PLANTS; PLANT-SPECIFIC LISTS ARE EXPECTED TO BE SHORTER."

R: AGREE.

(5) C: NOT ALL PORV'S SHOULD BE CONSIDERED AS EQUIPMENT UNIQUE TO NUCLEAR PLANTS.

R: AGREE.

(6) C: ELECTRICAL PENETRATION ASSEMBLIES AND NEUTRON DETECTORS SHOULD NOT BE INCLUDED IN SCOPE OF A-46 SINCE THEY ARE PASSIVE.

R: AGREE. HOWEVER SEISMIC ADEQUACY CAN BE VERIFIED FOR BOTH BY EXPERIENCE DATA OR TEST DATA. NRC HAS NO OBJECTION TO THEIR INCLUSION.

(7) C: ANCHORAGE REVIEW OF TANKS AND HEAT EXCHANGERS HAS NOT BEEN JUSTIFIED.

R: TANK AND HEAT EXCHANGER ANCHORAGE IMPORTANT TO SHUTDOWN. EXPERIENCE DATA SHOWS ANCHORAGE IMPORTANT.

(8) C: IT IS NOT JUSTIFIED TO DOCUMENT SEISMIC ADEQUACY OF EQUIPMENT BEYOND THE ORIGINAL EIGHT CLASSES SINCE SEISMIC EXPERIENCE DEMONSTRATES THAT EQUIPMENT IS INHERENTLY RUGGED.

R: CAVEATS AND EXCLUSIONS, AS WELL AS APPROPRIATE BOUNDING SPECTRA HAVE TO BE IDENTIFIED FOR ALL EQUIPMENT CLASSES.

SCOPE OF WALK-THROUGH INSPECTION (8)

° COMMENTS:

(1) STATISTICAL SAMPLING SHOULD BE USED FOR ANCHORAGE INSPECTION. FULL REVIEW NEEDED ONLY IF SAMPLING SHOWS ANOMALIES.

(2) CREDIT SHOULD BE GIVEN FOR PREVIOUS WALK-THROUGHS OR AVAILABLE ENGINEERING DOCUMENTS ON ANCHORAGE.

(3) EQUIPMENT ANCHORAGE ALREADY ADDRESSED BY IE BULLETINS 79-02, 79-14 AND IE INFORMATION NOTICE 80-21.

° RESPONSE:

(1) ISSUE WILL BE CONSIDERED AFTER SSRAP RECOMMENDATION.

(2) DISAGREE. THERE IS EVIDENCE PROBLEMS STILL EXIST.
- PREVIOUS WALK-THROUGH DON'T ADDRESS ALL CONCERNS IN THE ANCHORAGE GUIDELINES/WALK-THROUGH PROCEDURE UNDER DEVELOPMENT.

- ENGINEERING DOCUMENTS MAY NOT REFLECT AS BUILT CONDITION. DEFECTS IN INSTALLATION CAN ONLY BE DETECTED BY A WALK-THROUGH INSPECTION.

(3) DISAGREE.
- IE INFORMATION NOTICE 80-21 WAS FOR ANCHORAGE OF CLASS 1E ELECTRICAL EQUIPMENT ONLY.

- IE BULLETINS 79-02, 79-14 WERE FOR PIPING ONLY.

REQUIREMENT TO SUBMIT JUSTIFICATION FOR CONTINUED OPERATION (JCO) (5)

- COMMENTS:

  (1) THE REQUIREMENT FOR JCO NOT WARRANTED.
  - REPORTING REQUIREMENTS EXIST IN 10 CFR 50.72/10 CFR 50.73.

  (2) INSTEAD OF JCO:
  - UTILITIES COMMIT TO RESOLVE DEFICIENCY BY A CERTAIN DATE.
  - JCO KEPT IN LICENSEE'S FILE INSTEAD OF SUBMITTING TO NRC.
  - DEFICIENCIES REPORTED. BY USING 10 CFR 50.72 OR 10 CFR 50.73.

  (3) MOST DEFICIENCIES WILL NOT PRESENT A SERIOUS SAFETY CONCERN AND THEREFORE SHOULD NOT REQUIRE JCO'S.

- RESPONSE:
  - DEFINITION OF DEFICIENCY CLARIFIED.
  - JCO WILL BE REQUIRED FOR PROVEN DEFICIENCIES IF NOT CORRECTED WITHIN 30 DAYS.

COST ESTIMATE (5)

° COMMENTS:

(1) COSTS MAY BE LOW BY FACTOR OF 2 DUE TO LOW LABOR ESTIMATE.

(2) SEP EXPERIENCE INDICATES THAT EQUIPMENT REVIEW 2 TO 3 TIMES HIGHER THAN A-46 ESTIMATES.

° RESPONSE:

(1) EXTENSIVE ANALYSIS AND GUIDELINE DEVELOPED "UP FRONT" WHICH SHOULD REDUCE LABOR COST.

(2) DISAGREE.
- SEP PLANTS ARE TYPICALLY OLDER. EQUIPMENT AND ANCHORAGE IN LATER PLANTS HAVE BETTER SEISMIC CAPABILITY.

- A-46 APPROACH IS FOR ANALYSIS BEFORE REVIEW. GUIDELINES AND PROCEDURES WILL MINIMIZE REVIEW TIME AND COST.

GUIDELINES FOR REPLACEMENT EQUIPMENT (4)

- COMMENTS:

  SUGGEST THAT A-46 CRITERIA ARE ACCEPTABLE TO SEISMICALLY QUALIFY REPLACEMENT EQUIPMENT REGARDLESS OF REASON OF REPLACEMENT.

- RESPONSE:

  AGREE. REGULATORY ANALYSIS WILL BE REVISED.

SAFE SHUTDOWN REQUIREMENT (4)

(1) C: A-46 SHOULD PERMIT TIMELY OPERATOR ACTIONS TO DEMONSTRATE THE ACHIEVEMENT AND MAINTENANCE OF HOT SHUTDOWN.

R: WE AGREE IF PROCEDURES ARE AVAILABLE AND THERE IS SUFFICIENT TIME.

(2) C: THE ASSUMPTION OF A NON-SEISMICALLY RELATED SINGLE RANDOM COMPONENT FAILURE SHOULD BE ELIMINATED. SINGLE TRAIN OF SAFE SHUTDOWN EQUIPMENT WOULD PROVIDE ASSURANCE PLANT CAN BE SHUTDOWN SAFELY, BECAUSE OF LOW EARTHQUAKE PROBABILITY AND INHERENT RUGGEDNESS OF EQUIPMENT.

R: DISAGREE.

(3) C: REGULATORY ANALYSIS APPEARS TO REFER TO PASSIVE NOT ACTIVE COMPONENTS IN (2) ABOVE.

R: INTENTION IS TO INCLUDE ONLY ACTIVE COMPONENTS IN THIS STATEMENT. TEXT WILL BE CORRECTED.

(4) C: ONE OF THE 4 FUNCTIONS REQUIRED TO BE PERFORMED FOR HOT SHUTDOWN IN CONJUNCTION WITH A SSE IS "TO PROVIDE AC AND DC CURRENT EMERGENCY POWER". THIS IS NOT NEEDED, SINCE THE NEED FOR AC AND/OR DC EMERGENCY POWER TO MEET THE OTHER THREE FUNCTIONS IS A PLANT-SPECIFIC CONSIDERATION.

R: THIS SENTENCE WILL BE REVISED TO READ "PROVIDE AC AND/OR DC EMERGENCY POWER AS NEEDED ON A PLANT-SPECIFIC BASIS".

EQUIPMENT SEISMIC DEMAND AND SEISMIC CAPACITY (6)

(1) C: WHEN WILL GENERIC BOUNDING SPECTRA FOR EQUIPMENT OTHER THAN 8 CLASSES BE AVAILABLE?

IF NOT AVAILABLE, CAN TYPE A BOUNDING SPECTRA BE USED?

R: APPROPRIATE GENERIC BOUNDING SPECTRA FOR EQUIPMENT OTHER THAN 8 CLASSES WILL BE AVAILABLE EARLY PART OF 1987 FOR USE IN IMPLEMENTATION PROGRAM.

(2) C: FOR VERIFICATION OF ANCHORAGE, CAN FLOOR SPECTRA BE USED TO OBTAIN THE EQUIPMENT SPECTRAL ACCELERATION?

R: YES.

(3) C: UTILITIES SHOULD NOT HAVE TO ADOPT THE "GENERIC FLOOR RESPONSE SPECTRA" IF THEY CAN SHOW THAT THEIR OWN SPECTRA ARE LESS.

R: AGREE.

(4) C: SQUG IS CONSIDERING EXTENDING SSRAP BOUNDING SPECTRA TO EQUIPMENT HIGHER THAN 40 FEET ABOVE GRADE BY THE USE OF APPROPRIATE AMPLIFICATION FACTORS. THIS APPROACH SHOULD BE PERMITTED FOR EQUIPMENT HIGHER THAN 40 FEET ABOVE GRADE WITH SSRAP/NRC APPROVAL.

R: NRC WILL LOOK AT SQUG PROPOSAL AND WITH SSRAP RECOMMENDATION. IT IS PREMATURE TO INCLUDE THIS IN TEXT.

(5) C: THE DEGREE OF RIGIDITY OF COMPONENT SUPPORT SHOULD NOT HAVE TO BE ANALYZED, SINCE EFFORT TO DETERMINE ANY POSSIBLE AMPLIFICATION OF RESPONSE SPECTRA WON'T PROVIDE MEANINGFUL INFORMATION SINCE COMPONENT THEY SUPPORT ARE QUALIFIED BY SEISMIC EXPERIENCE.

R: AGREE. THERE IS NO NEED TO ANALYZE THE RIGIDITY (FREQUENCY) OF EACH COMPONENT SUPPORT, DURING WALK-THROUGH INSPECTION OBVIOUSLY WEAK SUPPORTS WILL BE IDENTIFIED.

(6) C: THE STATEMENT THAT (FOR EQUIPMENT OTHER THAN 8 CLASSES) "THESE GENERIC BOUNDING SPECTRA WILL NOT EXCEED THE TYPE A BOUNDING SPECTRA" SHOULD BE JUSTIFIED.

R: IF ONLY SEISMIC EXPERIENCE DATA IS USED. TYPE A BOUNDING SPECTRA ARE THE UPPER LIMIT. LIMIT MAY BE RAISED BY TEST DATA.

MAKE-UP OF WALK-THROUGH INSPECTION TEAM (4)

° COMMENTS:

(1) NO NEED TO HAVE AN OPERATIONS SUPERVISOR/SRO ON THE TEAM. HE WILL BE USEFUL IN GENERATING LIST OF REQUIRED EQUIPMENT.

(2) TEAM MEMBERS SHOULD NOT BE RESTRICTED TO DEGREED ENGINEERS AS LONG AS THEY HAVE RELEVANT KNOWLEDGE AND EXPERIENCE.

(3) ALL MEMBERS OF INSPECTION TEAM SHOULD NOT BE REQUIRED FOR ALL PARTS OF THE WALK-THROUGH.

° RESPONSE:

(1) AGREE. HOWEVER THEY SHOULD BE AVAILABLE FOR CONSULTATION BEFORE AND DURING WALK-THROUGH PROCESS.

(2) THERE IS NO ATTEMPT TO RESTRICT TEAM MEMBERS TO DEGREED ENGINEERS. THE EMPHASIS IS ON "RELEVANT EXPERIENCE."

(3) AGREE. HOWEVER APPROPRIATE TECHNICAL EXPERTISE SHOULD BE INCLUDED FOR EACH REVIEW AREA.

EXPANSION OF SEISMIC EXPERIENCE DATA BASE (3)

- COMMENTS:

  (1) SQUG HAS INCREASED THE DATABASE FROM 8 CLASSES TO 21. ARE 21 CLASSES NOW SUFFICIENT TO COVER EVERYTHING?

  (2) THE CAVEATS IN NUREG-1030 MOST LIKELY WILL BE RELAXED DUE TO INVESTIGATION OF CHILEAN EARTHQUAKE.

  (3) NUREG-1030 IMPLIES THAT SCOPE OF EQUIPMENT COVERED BY EXPERIENCE DATA BASE IS LIMITED TO ORIGINAL 8 CLASSES. THIS SHOULD BE CLARIFIED.

- RESPONSE:

  (1) YES. EXCEPT POSSIBLY FOR OUTLIERS.

  (2) AGREE. A STATEMENT OF THAT EFFECT WILL BE ADDED IN THE TEXT.

  (3) AGREE. TEXT WILL BE CHANGED TO REFLECT THIS.

ROLE OF SQUG IN GENERIC IMPLEMENTATION (3)

(1) C: SQUG SHOULD NOT BE IN THE POSITION TO ENFORCE THE REQUIREMENT OF A-46 POSITION, RATHER, IT SHOULD BE IN A POSITION TO PROVIDE IMPLEMENTATION CRITERIA AND ASSISTANCE.

R: AGREE.

(2) C:

- SQUG SHOULD NOT ASSUME RESPONSIBILITY FOR IMPLEMENTATION ON INDIVIDUAL PLANTS.
- SUGGEST SQUG DEVELOP GENERIC IMPLEMENTATION PROCEDURES AND SUBMIT TO NRC A GENERIC SCHEDULE FOR DEVELOPMENT OF IMPLEMENTATION PROCEDURES AND FOR TRAINING SEMINARS FOR PARTICIPATING UTILITIES.
- EACH INDIVIDUAL UTILITY (SQUG MEMBER OR NOT) WITH NRC. SQUG WILL NOT SUBMIT GENERIC IMPLEMENTATION SCHEDULE TO NRC.

R: AGREE. EACH UTILITY SHOULD NEGOTIATE IMPLEMENTATION SCHEDULE WITH NRC.

(3) C: - SQUG SHOULD NOT <u>CERTIFY</u> COMPLETION OF WALK-THROUGH INSPECTION BY INDIVIDUAL UTILITIES.

- SQUG SHOULD PROVIDE RESULTS OF AUDITS PERFORMED.

- SSRAP SHOULD NOT ENDORSE SQUG AUDITS BUT REPORT RESULTS OF REVIEWS AND AUDITS PERFORMED BY THEM.

R: ACCEPTABLE. AS LONG AS SQUG AND SSRAP REPORT ON THEIR REVIEWS AND AUDITS.

ACCESSIBILITY OF SQUG RESULTS TO NON-SQUG MEMBERS (2)

- COMMENTS:

  (1) A SQUG MEMBER SUGGEST THAT RESULTS OF SQUG AND EPRI STUDY SHOULD NOT BE ACCESSIBLE TO ALL UTILITIES. THEY SHOULD ONLY BE AVAILABLE TO SQUG MEMBERS.

  (2) SQUG COMMENTED THAT GENERIC IMPLEMENTATION PROCEDURES WILL LIKELY NOT BE AVAILABLE TO NON-MEMBER UTILITIES.

- RESPONSE:

  (1), (2) WILL REVISE TEXT IN REGULATORY ANALYSIS TO REFLECT THIS. NRC/RES SPONSORED WORK IS PUBLICLY AVAILABLE.

PLANT SPECIFIC SER'S (2)

- COMMENTS:

  WILL THE NRC PREPARE PLANT-SPECIFIC SER'S TO CLOSEOUT A-46?

- RESPONSE:

  YES.

APPLICABILITY OF A-46 TO NEW PLANTS/NEW EQUIPMENT (1)

- COMMENTS:

  SUGGEST NRC STATE THAT A-46 METHODOLOGY IS AN ACCEPTABLE METHOD OF COMPLYING WITH CURRENT LICENSING REQUIREMENT ON EQUIPMENT SEISMIC QUALIFICATION.

- RESPONSE:

  IN PROPOSED CHANGE TO IEEE STANDARD 344/75, A SECTION IS ADDED ON USE OF SEISMIC EXPERIENCE DATA FOR SEISMIC QUALIFICATION OF ELECTRICAL EQUIPMENT. NRC MAY ACCEPT THROUGH ENDORSEMENT OF THE STANDARD. A-46 DOES NOT ADDRESS CHANGES TO CURRENT REQUIREMENTS.

APPLICABILITY OF A-46 TO SPECIFIC PLANTS (2)

° COMMENTS:

(1) PLANTS LOCATED IN A RELATIVELY ASEISMIC AREA SUCH AS FLORIDA SHOULD BE EXCLUDED FROM CONSIDERATION IN THE RESOLUTION OF ANY SEISMIC RISK ISSUE.

(2) McGUIRE NUCLEAR STATION SHOULD NOT BE REQUIRED TO PERFORM AN A-46 REVIEW SINCE IT WAS EVALUATED TO CURRENT LICENSING REQUIREMENTS (IEEE 344-1975/REG. GUIDE 1.100) AND FOUND TO BE IN COMPLIANCE.

° RESPONSE:

(1) DISAGREE. SEISMIC DESIGN BASES NOT EVALUATED BY A-46.

(2) IF EVIDENCE IS PRESENTED, McGUIRE WILL BE REMOVED.

STATUS OF SQUG IMPLEMENTATION PROGRAM

- o ORIGINAL SQUG DATA BASE HAS BEEN EXPANDED SIGNIFICANTLY TO INCLUDE ADDITIONAL CLASSES OF EQUIPMENT AND RECENT SIGNIFICANT EARTHQUAKES:
  - CALIFORNIA (COALINGA, MORGAN HILL) EARTHQUAKES
  - CHILEAN EARTHQUAKE OF 1985
  - MEXICAN EARTHQUAKE OF 1985

  PREVIOUS SQUG/SSRAP/NRC CONCLUSIONS HAVE NOT BEEN MATERIALLY CHANGED.

- o SPECIFIC SEISMIC RUGGEDNESS LEVELS, BOUNDS OF THE EXPERIENCE DATA BASE AND RESTRICTIONS ARE BEING DOCUMENTED FOR EACH CLASS OF SAFE SHUTDOWN EQUIPMENT.

- o EPRI SUPPORT PROGRAMS NEARING SUCCESSFUL CONCLUSION:
  - EQUIPMENT ANCHORAGE GUIDELINES
  - SUMMARY OF AVAILABLE SEISMIC TEST DATA BY EQUIPMENT CLASS

- A METHODOLOGY FOR (1) IDENTIFYING "ESSENTIAL" RELAYS AND (2) EVALUATING THE CONSEQUENCE OF RELAY CHATTER IS BEING DEVELOPED BY SQUG/EPRI AND WILL BE TRIED OUT ON BWR AND PWR PILOT PLANTS IN 1986.

  (NRC HAS FORMED A RELAY EVALUATION TEAM WHICH IS WORKING WITH SQUG.)

- PRELIMINARY GENERIC IMPLEMENTATION PROCEDURES FOR PLANT-SPECIFIC REVIEWS WILL BE PREPARED AND TRIAL USE ON AT LEAST ONE PLANT IS PLANNED.

- REVIEW OF KEY ELEMENTS OF IMPLEMENTATION PLAN BY SSRAP AND NRC.

- POST-1986 PLANS INCLUDE:

  - FINALIZATION OF GENERIC IMPLEMENTATION PROCEDURES

  - TRAINING SEMINARS FOR UTILITY/CONTRACTOR/NRC TEAMS IN THE USE OF GENERIC PROCEDURES

  - PLANT-SPECIFIC REVIEWS

  - SELECTED VERIFICATION BY SQUG

  - OVERVIEW BY SSRAP AND NRC

RELAY FUNCTIONALITY REVIEW

METHODOLOGY INCLUDES THE FOLLOWING KEY ELEMENTS:

- o IDENTIFICATION OF PLANT FUNCTIONS WHICH MUST BE AVAILABLE
  - DURING SHORT PERIOD OF STRONG MOTION
  - IMMEDIATELY AFTER STRONG MOTION
- o IDENTIFICATION OF SYSTEMS WHOSE SPURIOUS ACTUATION MUST BE AVOIDED, E.G.:
  - REACTOR DEPRESSURIZATION (LOCA TYPE EVENTS)
  - OVERPRESSURE OF LOW PRESSURE SYSTEMS
  - UNAVAILABILITY OF SYSTEMS NEEDED AFTER STRONG SHAKING (E.G. DECAY HEAT REMOVAL, EMERGENCY AC POWER, ETC.)

  NOTE: OPERATOR ACTION TO RESET BREAKERS, RESTORE SYSTEMS WILL BE CONSIDERED ACCEPTABLE IF ADEQUATE TIME, AWARENESS AND ACCESS ARE AVAILABLE

- SCREENING OF RELAY FUNCTION TO DETERMINE IF RELAY CHATTER IS UNACCEPTABLE
- EVALUATION OF "ESSENTIAL" CIRCUITS/RELAYS BASED ON:
  - AVAILABLE SEISMIC QUALIFICATION DATA SUMMARIES (EPRI)
  - SPECIFIC RELAY VULNERABILITIES FROM EXPERIENCE DATA (E.G., CHILE)

EARTHQUAKE EXPERIENCE DATA

- EQUIPMENT IN GENERATING PLANTS HAVE DEMONSTRATED EXCELLENT PERFORMANCE.
- FRAGILITY TESTING PROGRAMS ESTABLISH OPERABILITY AT HIGH ACCELERATION LEVELS.

EQUIPMENT ANCHORAGE

- ALREADY ADDRESSED FOR MANY PLANTS.
- PLANT MAINTENANCE AND INSPECTION PROGRAMS CAN VERIFY.
- ONLY NECESSARY TO PREVENT EQUIPMENT OVERTURNING OR SLIDING.

R E L A Y   C O N T A C T   C H A T T E R

- NOT POSSIBLE TO IDENTIFY GENERIC PROBLEMS.
- ONLY A SMALL SUBSET OF RELAYS ARE VULNERABLE.
- CODES AND STANDARDS ALREADY ADDRESS.

CONSERVATIVE ENGINEERING PRACTICES

- MARGINS BETWEEN ALLOWABLE STRESS AND STRENGTH OF MATERIALS USED.
- LOADS COMBINED IN CONSERVATIVE MANNER.
- NON STRUCTURAL ELEMENTS NOT INCLUDED IN DESIGN CALCULATIONS.
- EQUIPMENT DESIGNED AND MANUFACTURED IN COMPLIANCE WITH NATIONAL CODES AND STANDARDS.

SQUG COMMENTS ON NRC PROPOSED RESOLUTION OF USI A46

- THE NRC's PROPOSED RESOLUTION IS A PRACTICAL AND RESPONSIBLE APPROACH BASED ON ACTUAL EARTHQUAKE EXPERIENCE DATA GATHERED AND EVALUATED BY SQUG IN COOPERATION WITH THE NRC STAFF AND A SENIOR REVIEW PANEL. SQUG THEREFORE IS IN GENERAL AGREEMENT WITH THE PROPOSED APPROACH FOR ASSESSING SEISMIC RUGGEDNESS OF EQUIPMENT IN OPERATING NUCLEAR PLANTS.

- SQUG RECOGNIZES AND CONCURS IN THE GENERAL INDUSTRY COMMENT THAT THE NEED FOR THIS EFFORT SHOULD BE JUSTIFIED IN ACCORDANCE WITH THE NRC's BACK FIT RULES.

- SQUG HAS PROVIDED NUMEROUS RECOMMENDATIONS FOR CLARIFICATIONS AND DETAILED REVISIONS IN THE NRC PROPOSED RESOLUTION OF USI A46 IN SQUG LETTER OF 11/12/85.

EXAMPLES OF DETAILED COMMENTS

- o SQUG WILL MAKE USE OF AVAILABLE EARTHQUAKE EXPERIENCE DATA TO EXPAND THE ORIGINAL 8 CLASSES OF EQUIPMENT STUDIED IN THE PILOT PROGRAM TO COVER AS MANY CLASSES OF STANDARD POWER PLANT EQUIPMENT AS POSSIBLE. MOST CLASSES OF NUCLEAR PLANT SAFE SHUTDOWN EQUIPMENT ARE REPRESENTED.

- o THE RESOLUTION PLAN SHOULD PROVIDE FOR REVISION AND UPDATING TO INCORPORATE RESULTS OF ON-GOING WORK BY SQUG TO (1) EXPAND THE DATA BASE, (2) FURTHER EVALUATE BUILDING RESPONSE TO EARTHQUAKE GROUND MOTION AND (3) DEVELOP AND PLANT-CHECK THE GENERIC WALK-THROUGH PROCEDURE FOR RESOLUTION OF USI A46.

- o THE IMPLEMENTATION SCHEDULE SHOULD BE TIED TO PLANT-SPECIFIC INTEGRATED SCHEDULES.

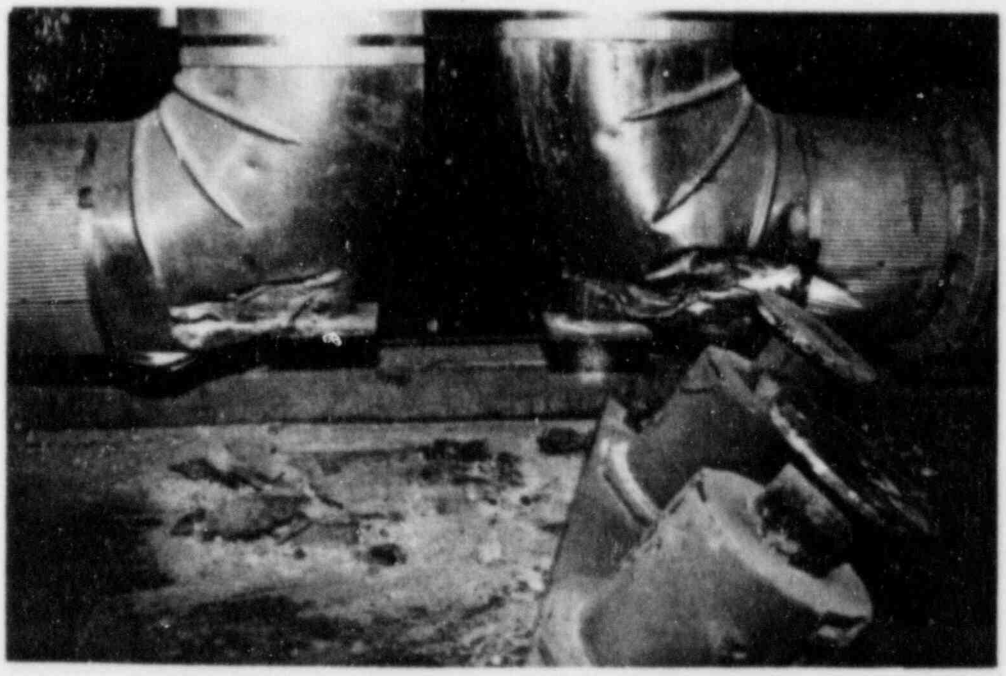
- o THE PLAN FOR EVALUATION OF SEISMIC OPERABILITY OF ESSENTIAL RELAYS IS UNDER DEVELOPMENT BY SQUG AND WILL FOLLOW A SOMEWHAT DIFFERENT APPROACH THAN DESCRIBED IN NUREG-1030.

- o THE GENERIC UTILITY GROUP (SQUG) WILL DEVELOP GENERIC IMPLEMENTATION PROCEDURES FOR PLANT-SPECIFIC REVIEWS BY INDIVIDUAL UTILITY MEMBERS AND WILL PERFORM SELECTED VERIFICATION; IT WILL NOT ASSUME RESPONSIBILITY FOR IMPLEMENTATION OF PLANT-SPECIFIC REVIEWS/WALK-DOWNS.

- THE NRC PLAN SHOULD CLEARLY INDICATE THAT JCO's WILL NOT BE REQUIRED FOR ALL "DEFICIENCIES" IDENTIFIED AS PART OF PLANT-SPECIFIC EVALUATIONS SINCE AVAILABLE EXPERIENCE DATA SHOW THAT POWER PLANT EQUIPMENT HAS INHERENT RUGGEDNESS. IN FACT, THE EARTHQUAKE EXPERIENCE DATA GATHERED BY SQUG DO NOT DEMONSTRATE THE NEED FOR EXTENSIVE REVIEWS OF THE SEISMIC ADEQUACY OF EQUIPMENT.

- THE PROPOSED REQUIREMENT - FUTURE REPLACEMENT OF EQUIPMENT/PARTS SHOULD BE VERIFIED FOR SEISMIC ADEQUACY USING THE A-46 OR CURRENT CRITERIA - SHOULD BE CLARIFIED TO INDICATE IT APPLIES TO ALL FUTURE REPLACEMENTS AND ADDITIONS.

SUMMARY OF THE EFFECTS OF THE CHILE AND MEXICO EARTHQUAKES OF 1985



Damage to Feedwater Pipe Supports
Pipe was not damaged
Las Ventanas Power Plant
Chile Earthquake, March 1985
Magnitude 7.8

Presentation to:

Advisory Committee on Reactor Safeguards
Subcommittee on Qualification Program
for Safety Related Equipment
Washington, D.C.
January 15, 1986

by
Seismic Qualification Utilities Group (SQUG)
Peter I. Yanev and Stephen J. Eder, EQE Incorporated
James E. Thomas, Duke Power Company

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SUMMARY

- The investigated earthquakes are major events with high accelerations and very long durations. The inventory of facilities affected contributes substantially to the SQUG data base

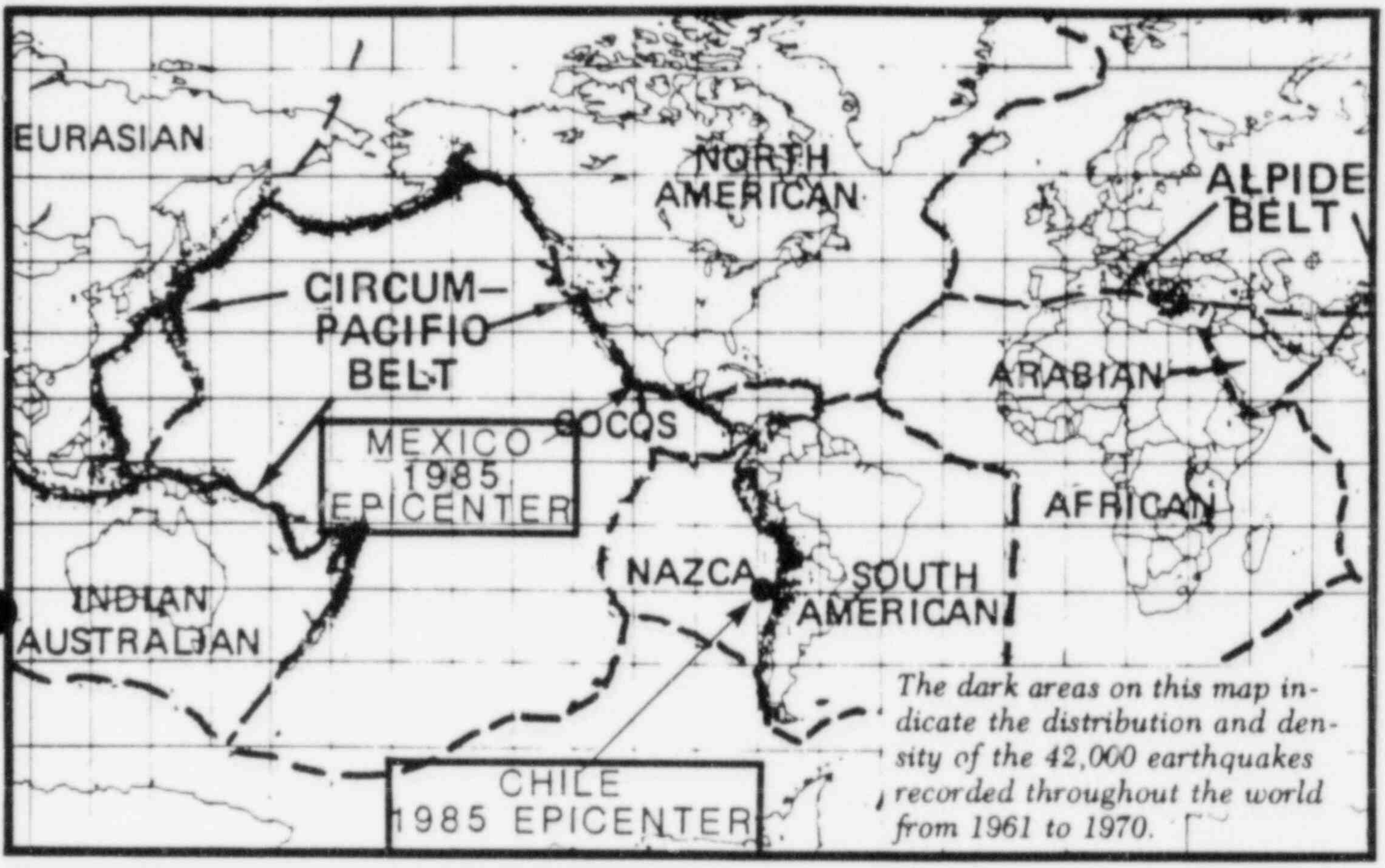
- The conclusion that equipment is rugged, reached by SQUG and the NRC prior to the earthquakes, was reinforced

  - No equipment malfunctioned with the exception of protective relays

  - Certain tanks are vulnerable

- Equivalent static coeffecient design for ~~most~~ seismic loads of most components and structures of nuclear plants is adequate

BOTH THE CHILE AND MEXICO EARTHQUAKES OCCURRED IN TWO OF THE WORLD'S MOST SEISMICALLY ACTIVE AREAS. THE LESSONS FROM THE TWO EVENTS ARE NUMEROUS AND CONTRASTING.



The dark areas on this map indicate the distribution and density of the 42,000 earthquakes recorded throughout the world from 1961 to 1970.

	CHILE	MEXICO
MAIN MAGNITUDE	7.8	8.1
LARGEST AFTERSHOCK	7.2	7.5
AFFECTED AREA (SQ. MILES)	20,000	20,000
AFFECTED POPULATION (MILLIONS)	6	10
DEATHS	180	10,000
HOMELESS	250,000	400,000
DWELLINGS DESTROYED	45,000	34,000
COLLAPSED HIGHRISES	2	300
DIRECT DAMAGE (U.S. $BILLIONS)	1.8	3.6

SUMMARY FROM ROBERT V. WHITMAN, PRESIDENT OF THE EARTHQUAKE ENGINEERING RESEARCH INSTITUTE, AND PROFESSOR AT M.I.T.

Both earthquakes caused extremely strong ground motions in heavily populated and developed areas, in which there were a large number of strong motion instruments - which functioned well and produced very valuable records. Both occurred in countries with a strong tradition of earthquake engineering, with numerous excellent engineers, many of whom were educated in the United States, and with many modern buildings, industrial facilities and lifeline systems engineered to standards similar to those followed in our country. Both were disasters of large magnitude, which severely taxed disaster response organizations. Thus, when these earthquakes occurred it was immediately clear that detailed investigations should be made to learn from the events. It was equally clear that any such investigations should be made in close cooperation with our Chilean and Mexican colleagues, avoiding any suggestion that we were trying to preempt "their earthquake."

Earthquake Engineering Research Institute Newsletter
January 1986, Volume 20, Number 1

SQUG HAS NOW INVESTIGATED FOUR DESTRUCTIVE EARTHQUAKES AFTER THE COMPLETION OF THE PILOT PROGRAM. A TOTAL OF 10 EARTHQUAKES HAVE BEEN INVESTIGATED.

- COALINGA, 1983, M = 6.7
  - MODERATE MAGNITUDE
  - HIGH ACCELERATIONS OVER LIMITED AREA
  - SEVERE DAMAGE
  - MANY FACILITIES
  - STRONG AFTERSHOCKS, UP TO M = 6.0
- MORGAN HILL, 1984, M = 6.2
  - SMALL MAGNITUDE
  - HIGH ACCELERATIONS
  - LIMITED DAMAGE
  - LIMITED FACILITIES
  - SMALL AFTERSHOCKS
- CHILE, 1985, M = 7.8
  - LARGE TO GREAT MAGNITUDE
  - HIGH ACCELERATIONS OVER A LARGE AREA WITH LONG DURATION
  - MANY FACILITIES AND POWER PLANTS
  - STRONG AFTERSHOCKS, UP TO M = 7.2, WITH HIGH ACCELERATIONS
- MEXICO, 1985, M = 8.1
  - GREAT MAGNITUDE
  - MODERATE ACCELERATIONS WITH LONG DURATION
  - AFFECTED MEXICO CITY AT 250 MILES AWAY
  - SEVERAL LARGE FACILITIES
  - STRONG AFTERSHOCK WITH M = 7.5

THE GROUND MOTIONS FOR BOTH EVENTS WERE VERY LONG AND STRONG. THE CHILE EARTHQUAKE RECORDED VERY HIGH ACCELERATIONS.

GROUND MOTION COMPARISONS

	CHILE	MEXICO
RECORDS OBTAINED	31	18
PEAK HORIZONTAL ACCELERATION (g's)	0.68	0.28
PEAK VERTICAL ACCELERATION (g's)	0.86	0.15
HIGHEST AVERAGE HORIZ. ACCEL. (g's)	0.67	0.24
DURATION (0.10g OR GREATER; SEC.)	42	40
ENVELOPE NRC RG1.60 SPECTRA PGA (g's)	0.40	0.17

CHILE EARTHQUAKES

MARCH 3, 1985 M = 7.8

APRIL 8, 1985 M = 7.2

SQUG SENT TWO TEAMS TO INVESTIGATE THE MARCH 3, CHILE EARTHQUAKE. WE WERE ASSISTED AND GUIDED BY PROFESSORS FROM THE UNIVERSITY OF CHILE, SANTIAGO.

RECONNAISSANCE TEAM (MARCH 7-14, 1985)

PAUL D. SMITH - EQE

DAVID L. McCORMICK - EQE

RENE W. LUFT - SG&H

LORING A. WYLLIE, JR. - H.J. DEGENKOLB/SSRAP; PART-TIME

INVESTIGATIVE TEAM (MAY 16-24, 1985)

PETER I. YANEV - EQE

DENNIS K. OSTROM - SCE/SQUG

JAMES E. THOMAS - DUKE/SQUG (EE, SYSTEMS)

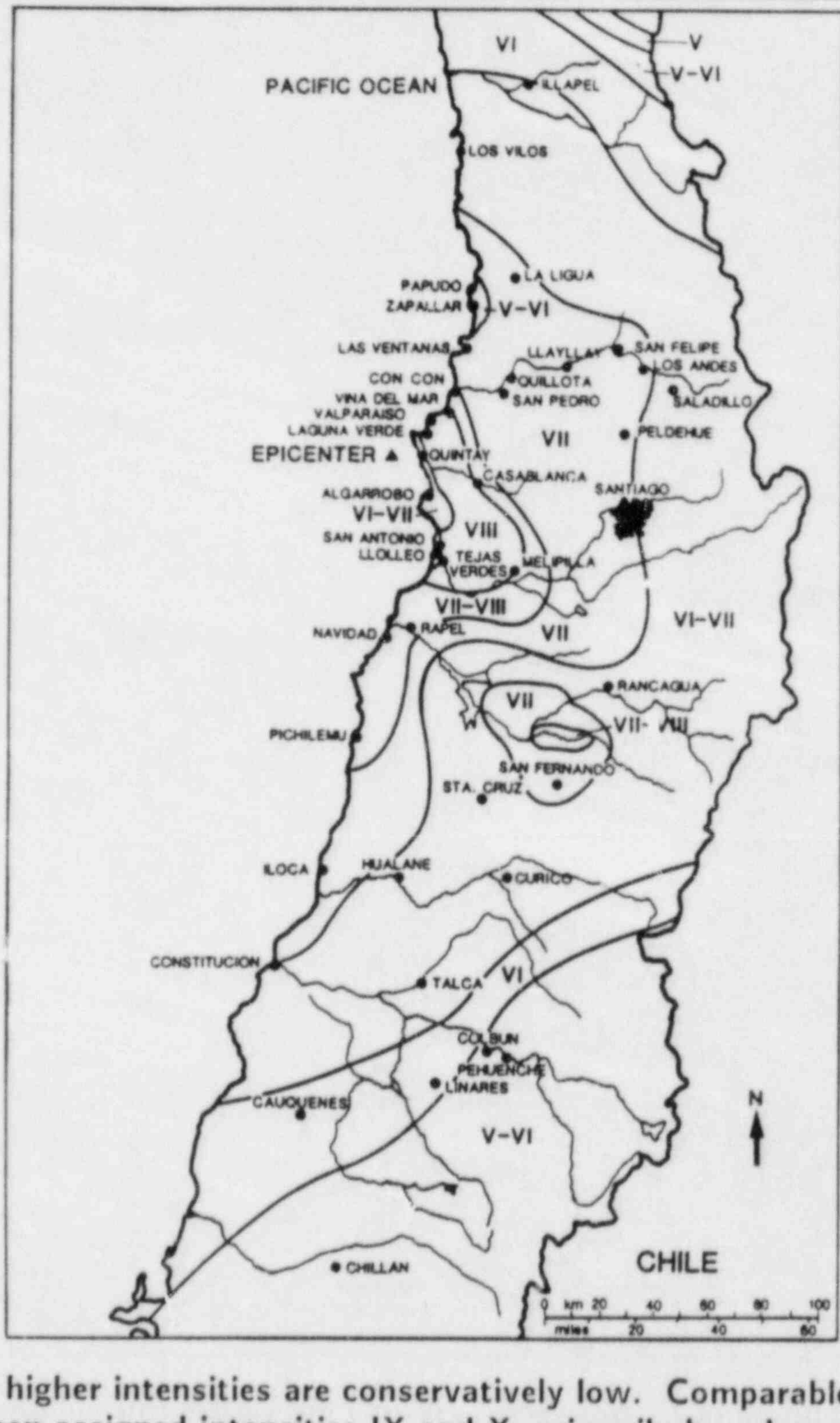
DAVID L. McCORMICK - EQE

STEPHEN HOM - EQE

MARY M. SILVER - EQE/EPRI (PIPING)

ANSHEL J. SCHIFF - PURDUE UNIV./SSRAP

UNIVERSITY OF CHILE; PRELIMINARY ISOSEISMAL MAP. THE AFFECTED REGION (ABOUT 100 MILES BY 200 MILES) IS THE MOST DENSELY POPULATED AREA IN CHILE.



Note: The higher intensities are conservatively low. Comparable damage in the U.S. has been assigned intensities IX and X, primarily based on soils failures.

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EQE

THE HIGHER INTENSITIES FROM THE UNIVERSITY OF CHILE ARE LOW COMPARED TO RECENT ASSIGNMENTS FROM COMPARABLE DAMAGE IN THE U.S.A. AND MEXICO.

Intensities VII through XI of the Modified Mercalli Scale (from Algermissen, 1983)

VIII

VIII+ to IX- R.F.

Fright general — alarm approaches panic.
Disturbed persons driving motor cars.
Trees shaken strongly — branches, trunks, broken off, especially palm trees.
Ejected sand and mud in small amounts.
Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters.
Damage slight in structures (brick) built especially to withstand earthquakes.
Considerable in ordinary substantial buildings, partial collapse: racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling.
Fall of walls.
Cracked, broke, solid stone walls seriously.
Wet ground to some extent, also ground on steep slopes.
Twisting, fall, of chimneys, columns, monuments, also factory stacks, towers.
Moved conspicuously, overturned, very heavy furniture.

IX

IX+ R.F.

Panic general.
Cracked ground conspicuously.
Damage considerable in (masonry) structures built especially to withstand earthquakes:
threw out of plumb some wood-frame houses built especially to withstand earthquakes;
great in substantial (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundations, racked frames;
serious to reservoirs; underground pipes sometimes broken.

X

X R.F.

Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks.
Landslides considerable from river banks and steep coasts.
Shifted sand and mud horizontally on beaches and flat land.
Changed level of water in wells.
Threw water on banks of canals, lakes, rivers, etc.
Damage serious to dams, dikes, embankments.
Severe to well-built wooden structures and bridges, some destroyed.
Developed dangerous cracks in excellent brick walls.
Destroyed most masonry and frame structures, also their foundations.
Bent railroad rails slightly.
Tore apart, or crushed endwise, pipe lines buried in earth.
Open cracks and broad wavy folds in cement pavements and asphalt road surfaces.

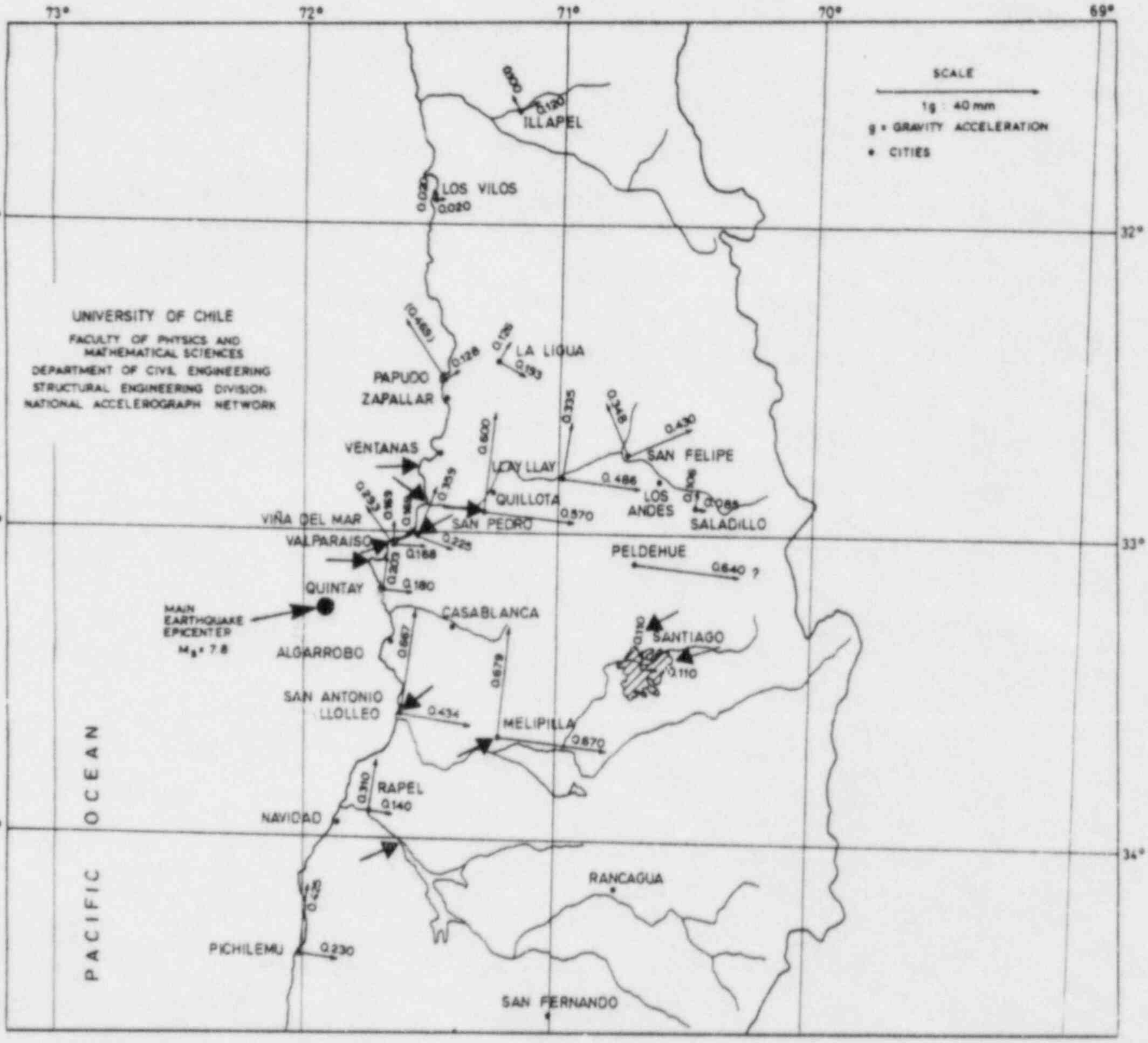
XI

Disturbances in ground many and widespread, varying with ground material.
Broad fissures, earth slumps, and land slips in soft, wet ground.
Ejected water in large amount charged with sand and mud.
Caused sea-waves ("tidal" waves) of significant magnitude.
Damage severe to wood-frame structures, especially near shock centers.
Great to dams, dikes, embankments, often for long distances.
Few, if any (masonry), structures remained standing.

SUMMARY OF STRONGER PEAK ACCELERATION RECORDS (g)

LOCATION	H	H	V	AVE H
1. MELIPILLA	0.67	0.68	0.34	0.67
2. PELDEHUE	0.64	--	--	0.64
3. SAN PEDRO (S.S.)	0.60	0.57	0.38	0.58
4. LLOLLEO	0.43	0.67	0.86	0.55
5. LLAYLLAY	0.34	0.49	--	0.41
6. SAN FELIPE	0.35	0.43	0.21	0.39
7. PICHILEMU	0.43	0.23	0.14	0.33
8. PAPUDO	0.13	0.47	0.11	0.30
9. VINA DEL MAR	0.23	0.36	0.20	0.30
10. ZAPALLAR	0.28	0.26	0.18	0.27
11. RAPEL P.P.	0.31	0.14	0.11	0.23
12. VALPARAISO (1)	0.16	0.29	--	0.22
13. QUINTAY	0.20	0.18	0.13	0.19
14. LAS VENTANAS P.P.	0.18	0.18	0.14	0.18
15. VALPARAISO (2)	0.17	0.19	0.12	0.18
16. SANTIAGO	0.11	0.11	0.07	0.11

THE INVESTIGATED SITES ARE LOCATED AT OR NEAR THE STRONG MOTION RECORDS. THE TWO HORIZONTAL COMPONENTS (IN g's) ARE SHOWN.

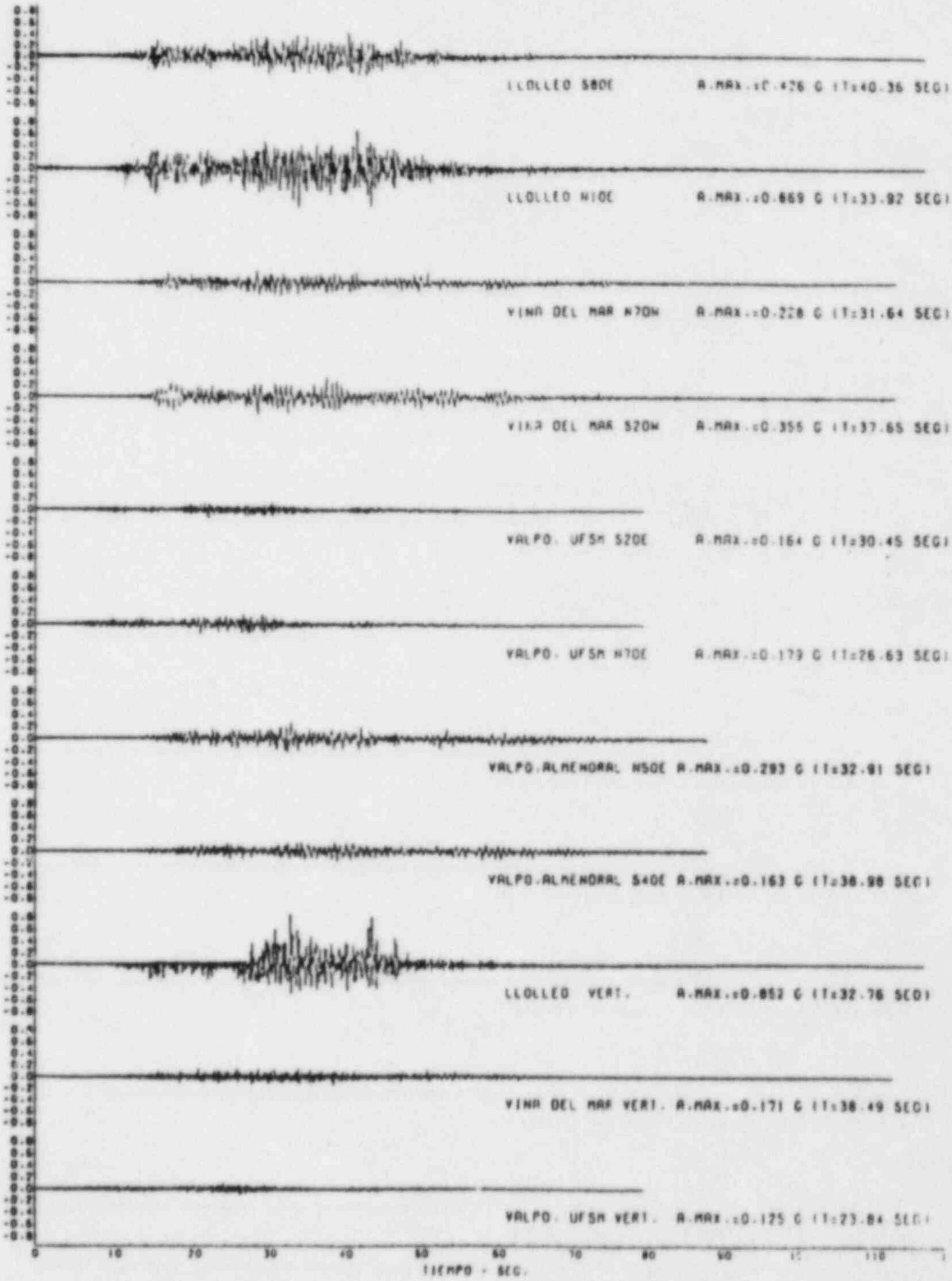


THIRTY-ONE STRONG MOTION RECORDS WERE MADE THROUGHOUT THE AFFECTED AREA. INVESTIGATED SITES ARE SHOWN WITH AN ARROW.

324/acrs1

EQE

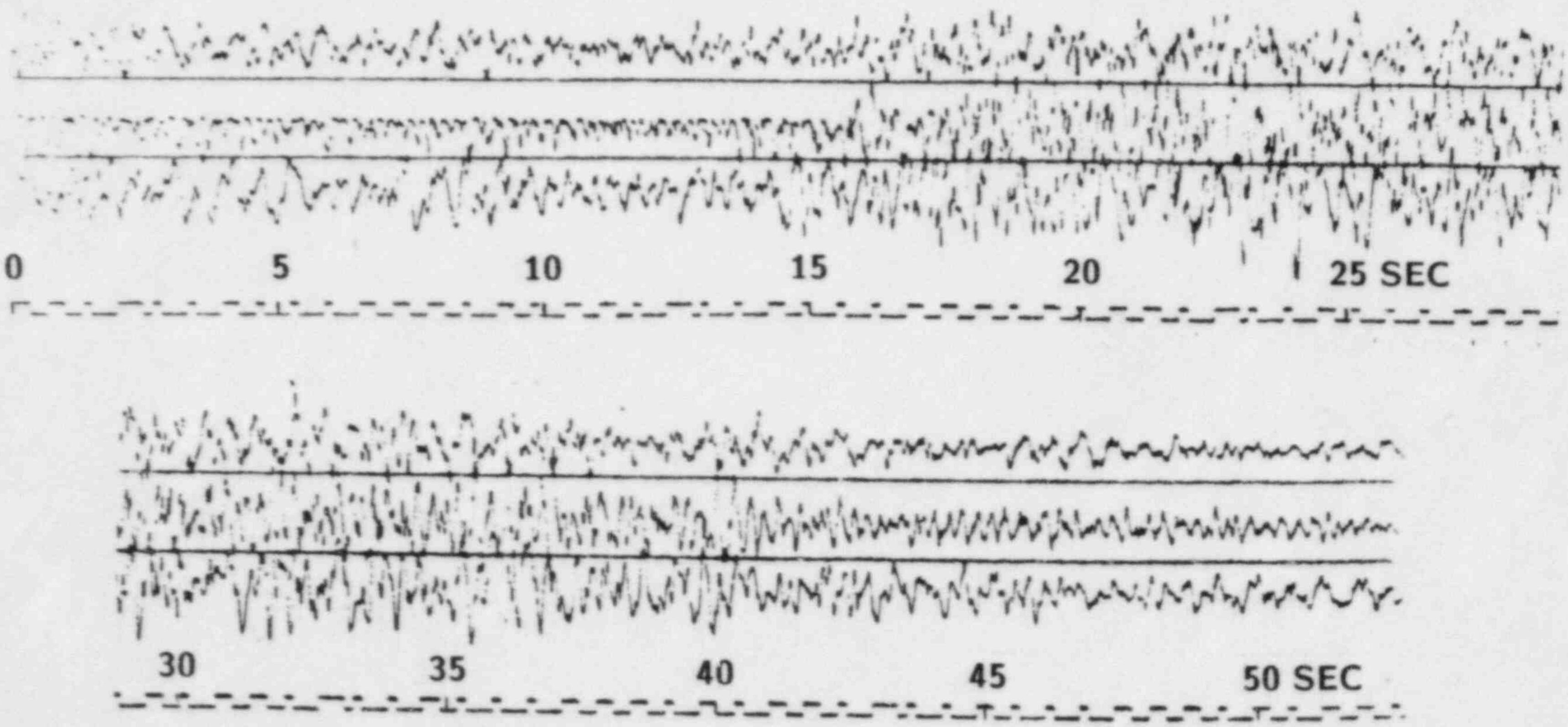
THE CHILE EARTHQUAKE WAS WELL INSTRUMENTED. IT PROVIDES US WITH AN ARRAY OF STRONG MOTION RECORDS WITH LONG DURATIONS



324/acramex

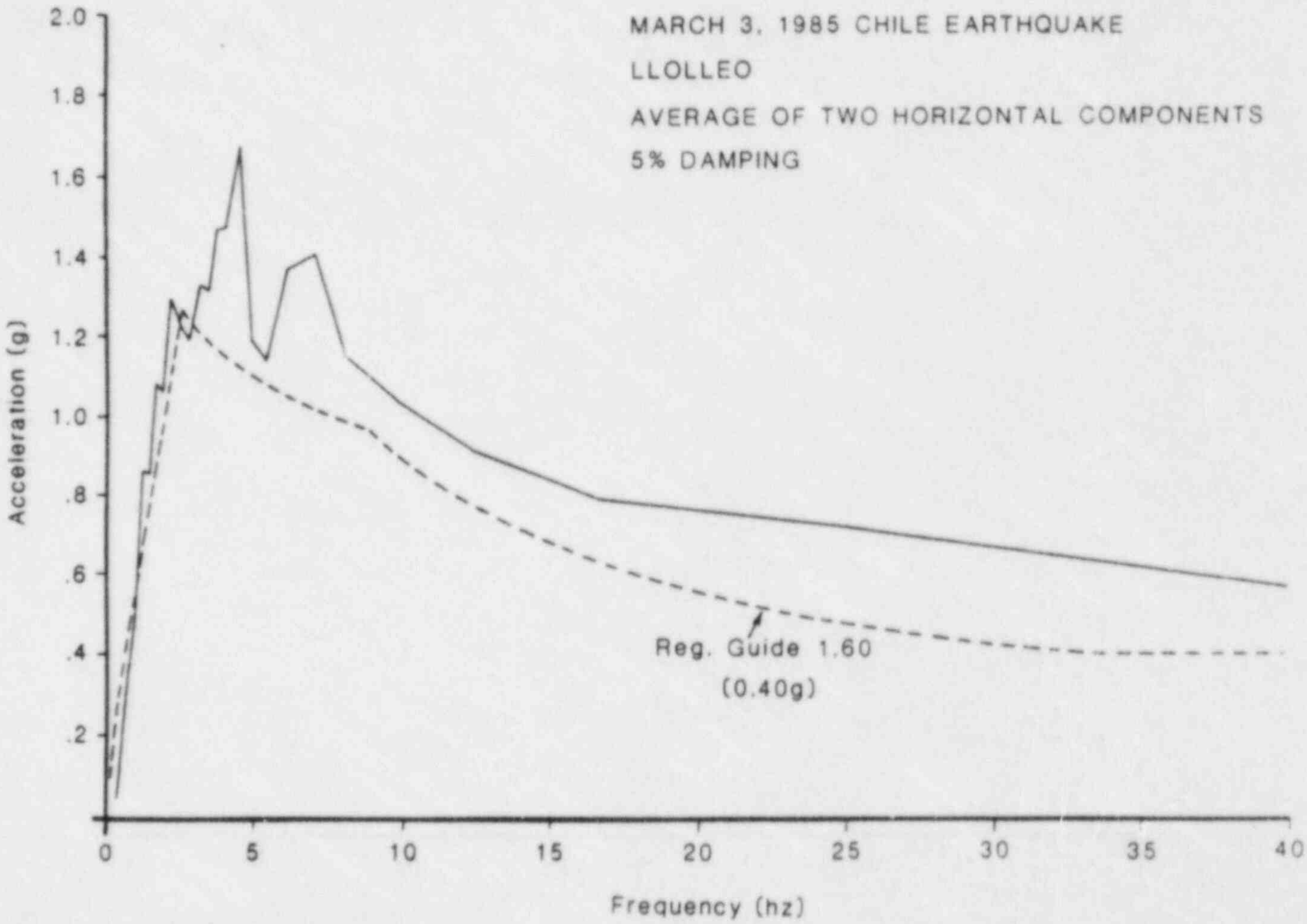
EQE

ONE OF THE STRONGEST RECORDS WAS OBTAINED AT LLOLLEO WITH PEAK ACCELERATIONS OF 0.43g AND 0.67g (HORIZ), AND 0.86g (VERT).



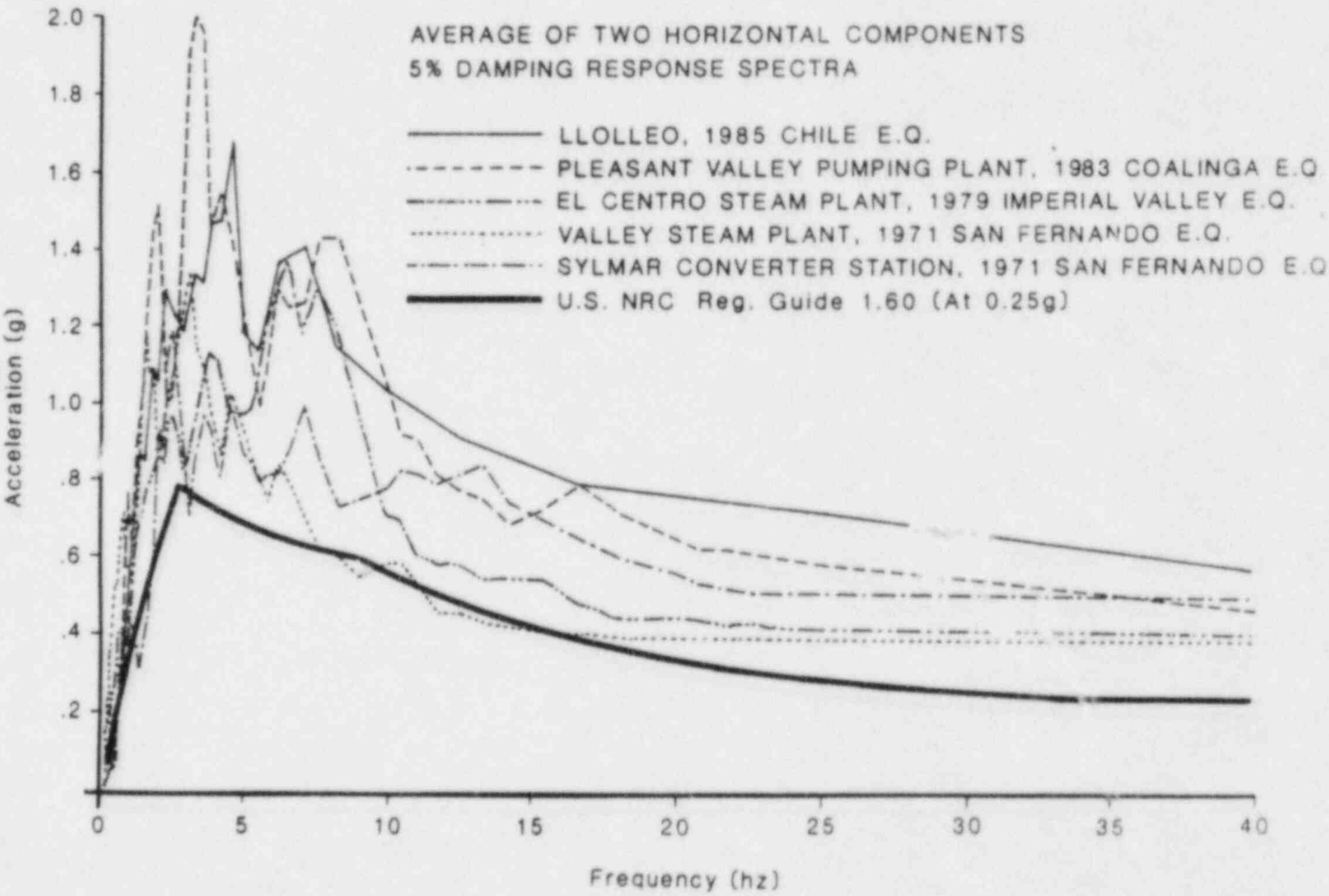
EQE

THE LLOLLEO RESPONSE SPECTRUM ENVELOPS THE NRC REGULATORY GUIDE 1.60 SPECTRUM FOR 0.40g AT NEARLY ALL FREQUENCIES



EQE

THE LLOLLEO RECORD AVERAGE HORIZONTAL RESPONSE SPECTRUM SUBSTANTIALLY ENVELOPS ALL PREVIOUS SQUG DATA BASE RESPONSE SPECTRA IN THE HIGH FREQUENCY RANGE



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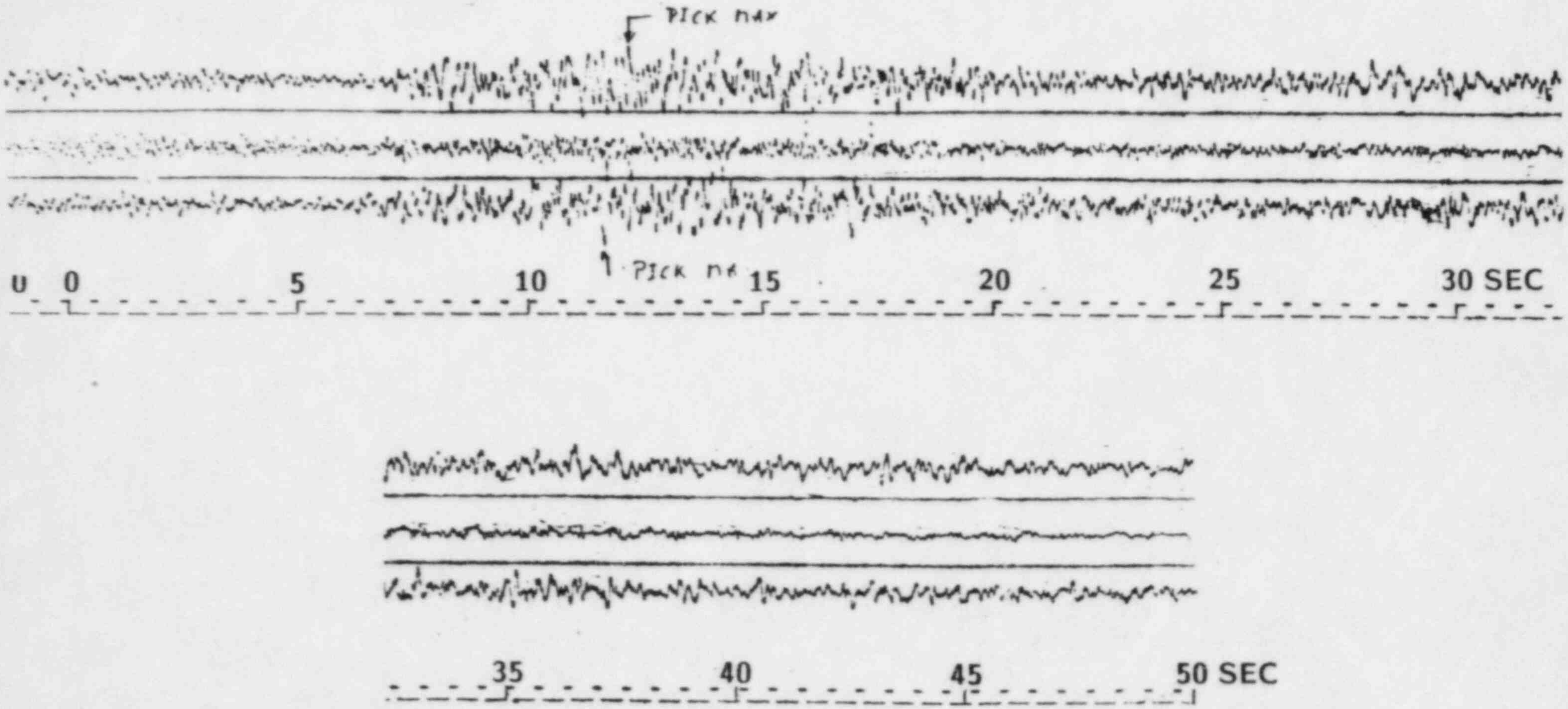
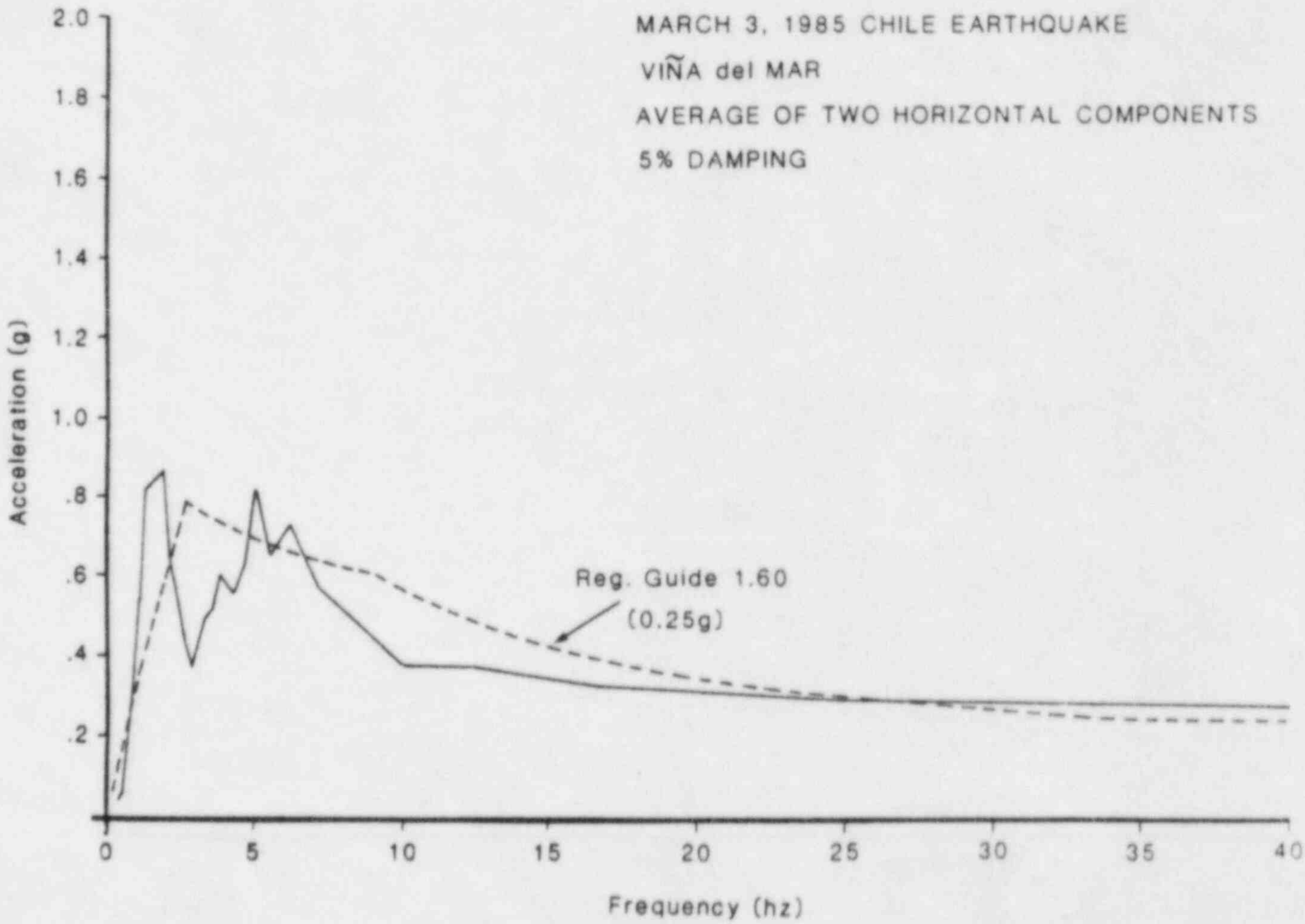
THE STRONG MOTION OF THE SAN FELIPE RECORD

(H = 0.35 AND 0.43; V = 0.21)



EQE

THE VINA DEL MAR RESPONSE SPECTRUM ENVELOPS THE NRC REGULATORY GUIDE 1.60 SPECTRUM FOR ~~0.25g~~ 0.20g AT NEARLY ALL FREQUENCIES



WE VISITED 40 SITES THROUGHOUT THE STRICKEN AREA, INCLUDING:

- 6 POWER PLANTS
- 3 SUBSTATIONS
- 2 VERY LARGE REFINERIES
- 1 CHEMICAL PLANT
- 2 WATER TREATMENT PLANTS
- 5 COMMERCIAL FACILITIES

THE 6 POWER PLANTS HAVE 13 UNITS:

LAS VENTANAS	2 UNITS
LAGUNA VERDE	2 UNITS
RAPEL (HYDRO)	5 UNITS
LAS VENTANAS COPPER	1 UNIT
CON CON REFINERY	1 UNIT
RENCA	2 UNITS

TYPICAL INDUSTRIAL FACILITIES IN CHILE ARE ANALYZED AND DESIGNED FOR THE FOLLOWING STATIC LATERAL COEFFICIENTS

ITEM	HIGH SEISMIC REGION (g)	LOW SEISMIC REGION (g)
Buildings	0.15	0.10 - 0.12
Storage tanks, silos, and bunkers	0.20	0.15
Stacks and processing equipment	0.20	0.15
Heavy equipment anchorages	0.30	0.20
Walls out of plane	0.20	0.15
Parapets and cantilevers	1.00	0.70

THE SEISMIC DESIGN CRITERIA OF CHILECTRA COVERS THE ANCHORAGE DESIGN OF ELECTRICAL AND MECHANICAL EQUIPMENT AND COMPONENTS

- Aim is to assure continuous normal operation without damage during and after earthquakes
- Seismic effects on equipment shall be simulated by equivalent static loads applied simultaneously in horizontal and vertical directions, equivalent to:

  0.50g Horizontal, 0.25g Vertical
- All component parts of the equipment shall be verified similarly for:

  0.10g Horizontal, 0.5g Vertical
- Other dynamic of analysis and experimental methods are allowed

THE SEISMIC DESIGN CRITERIA OF ENDESA WAS WRITTEN IN 1972 AND COVERS HIGH VOLTAGE EQUIPMENT AND SWITCHGEAR

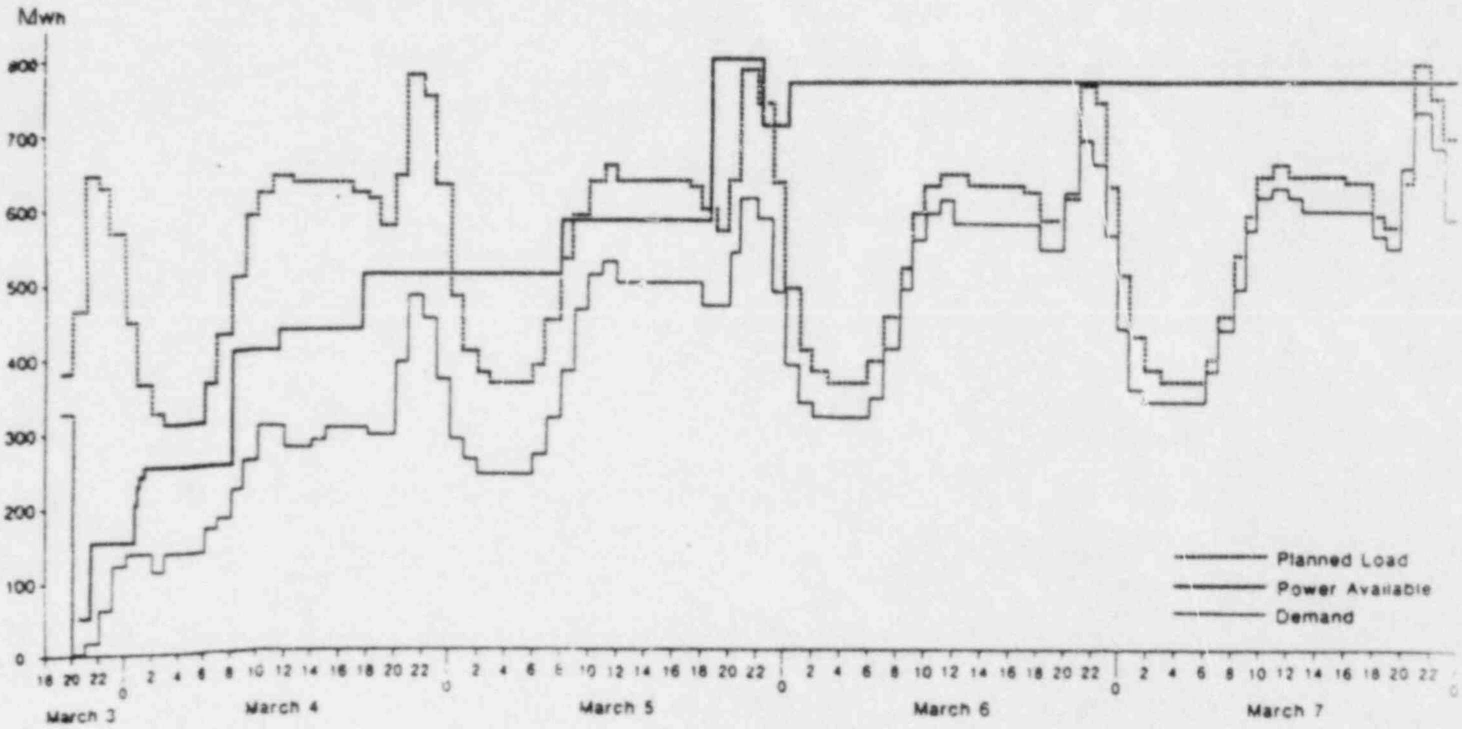
- All equipment shall be designed to withstand, without any damage or service interruption, earthquakes characterized by horizontal
  - accelerations of 0.50g
  - velocities of 60 cm/sec
  - displacements of 46 cm

  and by vertical accelerations of 0.20g

- No provisions are given for other equipment/installations

- ENDESA engineers believe they have:
  - Substantial earthquake experience not requiring other specific provisions
  - Standard commercial grade products supplied for the power industry have functioned with no generic problems

THE POWER SYSTEM WAS RESTORED RAPIDLY. OVERALL, DAMAGE TO THE ENTIRE SYSTEM WAS VERY MODERATE.



System recovery chart for CHILECTRA Generacion. A chronological list of power available is provided in the following table. The power available always exceeded the power demand, although the demand was restricted because of damage to the transmission systems. By March 7, four days after the earthquake, the demand had returned to nearly normal.

CHRONOLOGICAL LIST OF AVAILABLE POWER AND POWER PLANTS

March 3	7:47 p.m.	400 MW	Earthquake, distribution system disconnects
	8 - 9 p.m.	50 MW	Contribution of power from ENDESA
	9 - 10 p.m.	150 MW	Additional contribution of power from ENDESA
	10 - 12 a.m.	150 MW	---
March 4	12 -1 a.m.	240 MW	Unit 2 Renca starts Unit 2 Queltehues starts Unit 1 Queltehues starts Volcan starts
	1 - 2 a.m.	250 MW	Unit 3 Queltehues starts
	2 - 8 a.m.	250 MW	
	8 - 11 a.m.	400 MW	Additional contribution of power from ENDESA
	11 - 6 p.m.	430 MW	Unit 2 Laguna Verde starts
	6 - 7 p.m.	500 MW	Additional contribution of power from ENDESA
	7 - 12 a.m.	500 MW	-
March 5	12 - 8 a.m.	500 MW	-
	8 - 9 a.m.	570 MW	Additional contribution of power from ENDESA
	9 - 6 p.m.	570 MW	-
	6 - 7 p.m.	780 MW	Unit 2 Las Ventanas starts
	7 - 10 p.m.	780 MW	-

A SERIES OF DETAILED QUESTIONS WERE ASKED OF PLANT OPERATORS TO DETERMINE IN-PLANT SYSTEMS BEHAVIOR

Questions related to plant functions:

1. What was the plant status prior to the earthquake?

2. Does the plant have any special earthquake procedures? What are they? Are copies available?

3. During strong motion in the event did automatic action of the plant systems take place? What where these automatic actions? If auto-action did not take place, should it have? In the absence of auto-action (based on alarms, etc.) did the operator take action? What action did he take? What alarms were initiated? Any misleading information? Did the plant respond properly (auto or manual)?

4. After the strong motion was over, what was the plant status? Were any auto-actions which were needed taking place? Were systems resetting to normal? Was the operator required to take manual action? If so, what action did he take and did the plant respond as it was supposed to?

   - Was off-site power lost?
   - Was auxiliary power lost?
   - Was diesel power available?
   - Was d.c. power available and was load shedding required?
   - Did power distribution (internal) respond to loss of power or to relay chatter?

5. In determining failures or damage to equipment: were there any misoperations or malfunctions of equipment of a mechanical nature? (Were there breaker trips which were not electrical in nature?) Were there misoperations or malfunctions of equipment due to relay chatter?

   - What type of equipment? Type of relay?
   - Any damage due to induced improper system alignments?
   - Any events recorders or computer printouts available?
   - Any problems with momentary contacts on switches? Maintained contacts?
   - Any mercury switches? Problems?
   - Any system change of state not attributable to relay chatter?
   - Were any printed circuit cards broken or other such failures? Were there problems with cable or cable terminations?

6. Were there structural failures which affected systems function? Large pipes? Small pipes? Pipe supports? Instrument tubing, instrument air lines?

7. Were there reduced or increased flows in cooling systems? Other degraded functions?

8. Any damage to control boards? CRT's?

9. What worked that wasn't expected to work?
   What failed that was expected to work?

10. What people-related problems were experienced? Access to tools, procedures, damage control equipment, communications, etc.

Questions related to plant functions (continued):

11. What secondary events occurred? Fires? Spills?

12. Any problems with equipment in operation? Cranes? Portable equipment? Maintenance in progress?

13. Is there seismic monitoring equipment at the site?

14. For problems encountered at power plants, were they considered a "systems" problem or an "operation" problem?

    - Steam cycle?
    - Condensate?
    - Feedwater?
    - Power?

Questions related to switchyard functions:

1. Have there been any design changes to prevent vibrations from triggering fault pressure relays when there has been no system damage that would require action?

2. Are there any special switching arrangements developed for earthquake response? Any line isolation provisions?

3. Are there any special provisions for starting if off-site power is lost due to the earthquake (black start)?

4. Were any problems encountered in synchronizing the plant with the transmission system after the earthquake?

5. Were there any degradations in the relaying communications system? What type system - microwave or carrier? Any special procedures related to degraded communications?

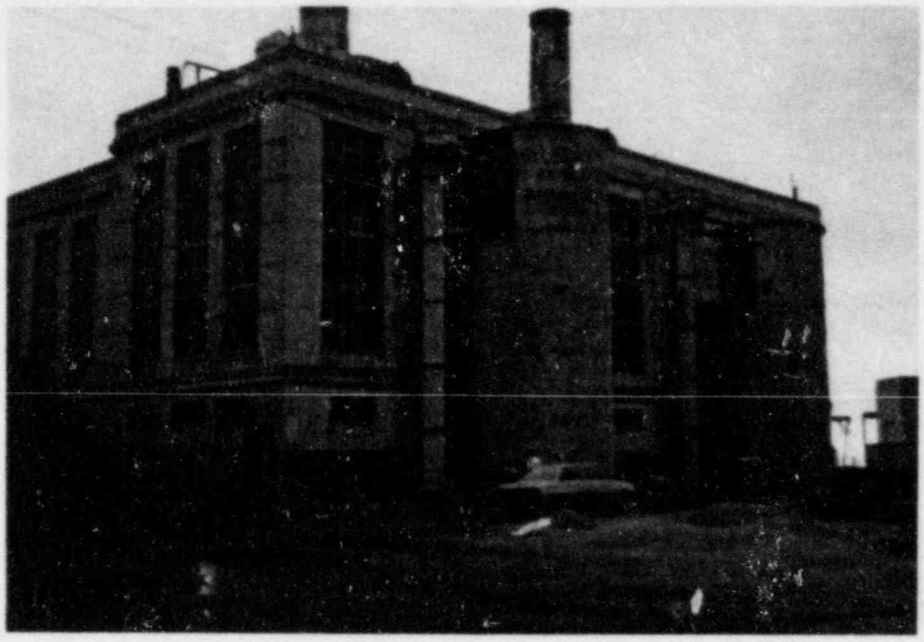
6. Does dispatch system exist? Did it create any problems?

THE PERFORMANCE OF 14 DIESEL GENERATOR SETS WAS INVESTIGATED. NONE WERE DAMAGED; ONE TRIPPED DUE TO RELAY CHATTER.

No. of Sets	Type and Performance
7	Manual start; no malfunctions upon start
6	Auto start; all started; 5 operated through earthquake and afterwards; one tripped due to fault current relay and was manually restarted a few minutes later by resetting the relay.
1	Not needed after earthquake

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: LAGUNA VERDE POWER PLANT



FACILITY

- 2 unit thermoelectric power station, used as a peaker
- Unit 1 capacity 22 mW, Unit 2 capacity 32 mW
- Began operation in 1932 (Unit 1) and 1949 (Unit 2)
- Founded on rock

GROUND MOTION

- Estimated PGA 0.20 to 0.30g
- 20 miles from epicenter
- Moderate to heavy damage in adjacent small town of Laguna Verde. Extensive damage 10 mile to the north in Valparaiso.

SEISMIC DESIGN CRITERIA

- Turbine building probably designed for 0.15g
- Some equipment anchorages added after past earthquakes

LAGUNA VERDE POWER PLANT, cont.

The plant performed remarkably well given its proximity to the epicenter and age. The performance of the equipment, installations, and control systems reinforces previous SQUG findings.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

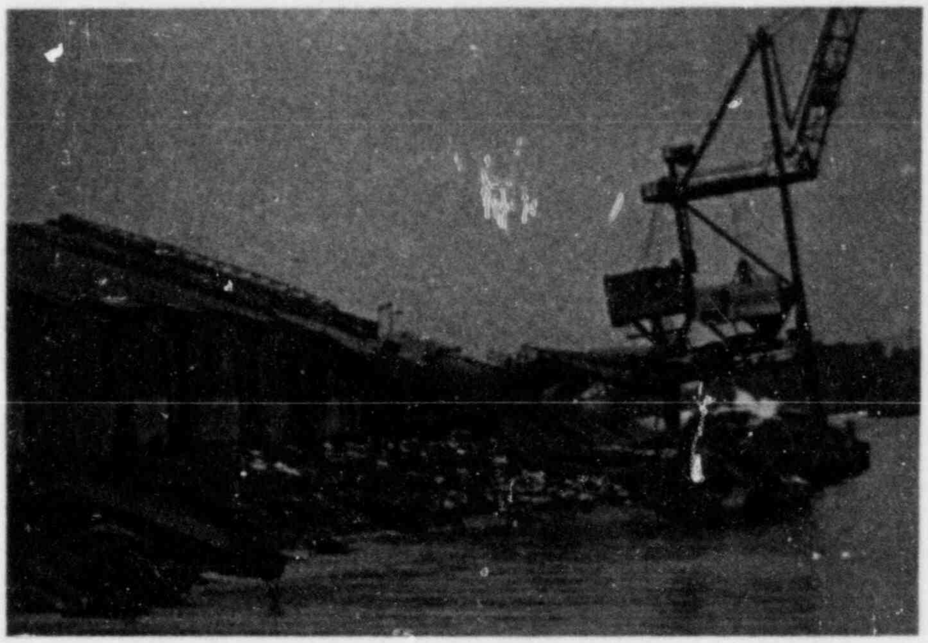
- One condenser pipe leaked the day after the earthquake, partially or totally due to corrosion from sea water that frequently leaks into the system
- A main steam-vapor pipe came off its roller support; pipe integrity was not lost
- Asbestos insulation fell off pipes due to impact with other pipes or structural members; no pipes were damaged
- Some boiler bricks were cracked but operation was not affected
- Minor cracks were observed in a stucco filler wall

KEY FINDINGS

- The plant performed very well. Plants further from the epicenter sustained more damage.
- Unrestrained batteries did not fall from their rack indicating moderate motion. The batteries were on rubber friction pads, and inter-connected with rigid bus bars.
- Piping and cable trays, electrical and mechanical equipment, and typical industrial steel buildings performed well.
- There were no malfunctions, false indications, system resets, or abnormal occurrences of any form in the plant control systems.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Sites: SAN ANTONIO PORT AND TANK FARMS



FACILITIES

- The San Antonio Port area includes a major wharf and container handling facility. There are two tank farms in the area.
- Portions of the port facility are over 50 years old.
- Soil and sand fill sites

GROUND MOTION

- Recorded average PGA 0.55g nearby
- 30 miles from epicenter
- There was severe damage throughout the San Antonio area and in the nearby town of Llolleo. Liquefaction, ground lurching, and settlement caused severe damage to the port.

SEISMIC DESIGN CRITERIA

- All storage tanks in the tank farms were unanchored

SAN ANTONIO PORT AND TANK FARMS, cont.

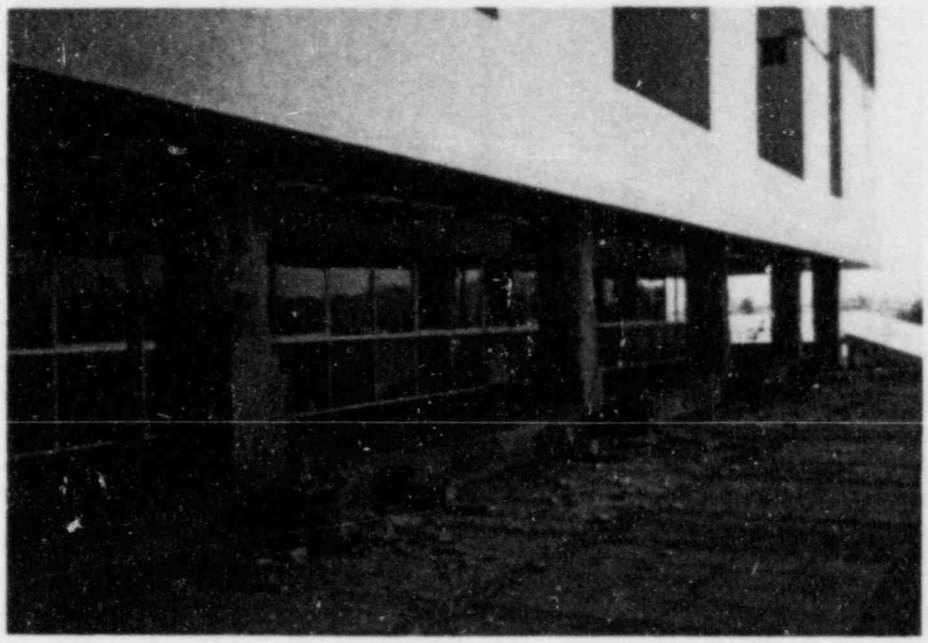
There was severe damage throughout the San Antonio area. Recorded accelerations, 2 miles away, were 0.67g horizontal and 0.86g vertical.

MOST IMPORTANT EARTHQUAKE DAMAGE AND KEY FINDINGS

- The wharf wall, the two buildings, and the cranes located on the outer mole of the port sustained severe damage due to soil and wharf failures.
- Pavement was severely cracked and railroad tracks were badly deformed. Ground settlement to 6 feet was observed.
- Unanchored steel tanks slid on their concrete foundations.
- Walkways connecting adjacent tanks were damaged by differential displacement and deformations of the attached tanks.
- An unanchored tank on legs overturned.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Sites: CLAUDIO VICUNA HOSPITAL



FACILITY

- Modern hospital serving all of San Antonio
- Chilean design, constructed in 1972 to 1982
- On a hill

GROUND MOTION

- Recorded average PGA 0.55g nearby
- 30 miles from epicenter
- There was severe damage in San Antonio, San Antonio port, and the nearby town of Llolleo

SEISMIC DESIGN CRITERIA

- The facility was designed to Chilean code

There was severe damage at the hospital facility; nearby recorded accelerations were in excess of 0.60g. The performance of equipment and control systems reinforces previous SQUG findings.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

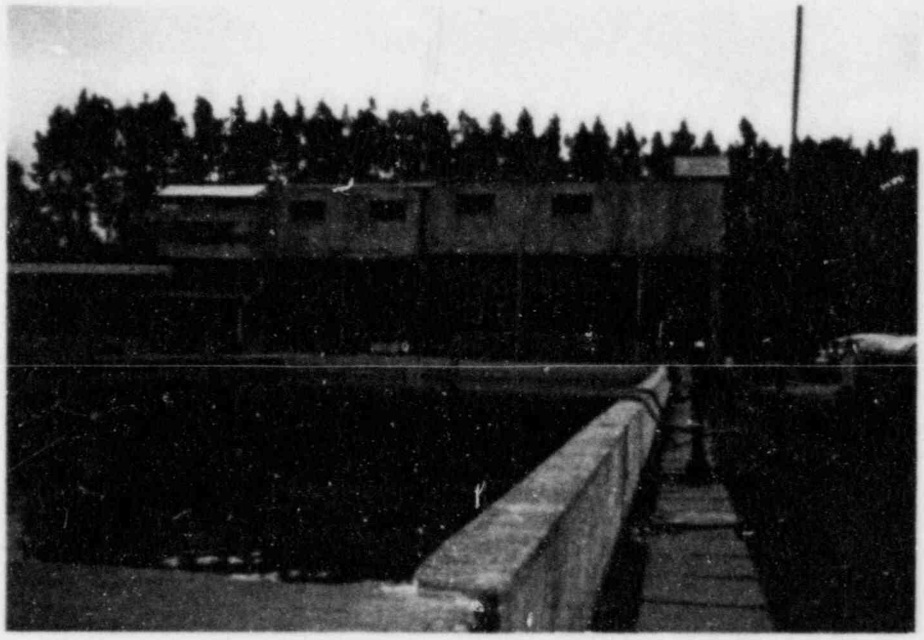
- The hospital experienced extensive structural and architectural damage. The structure experienced an earthquake that was much stronger than its design earthquake. The structural damage, in part, is due to a stiffness discontinuity.
- Three unanchored skid-supported boilers slid as much as 4" during the earthquake. The boilers were not damaged.
- A 4" pipe connected to an unanchored water storage tank failed.

KEY FINDINGS

- The emergency diesel generator started automatically and supplied power to the hospital and adjacent church and school for one week.
- There was no damage to the hospital's HVAC and control systems.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Sites: SAN JUAN DE LLOLLEO PUMPING STATION



FACILITY

- Main water pumping station serving San Antonio area
- Chilean design, constructed in 1953
- Soil site, poorly consolidated

GROUND MOTION

- Recorded average horizontal PGA 0.55g nearby
- 35 miles from epicenter
- Houses in the vicinity were old adobe and masonry structures, moderately to heavily damaged

SEISMIC DESIGN CRITERIA

- The facility was probably not designed to specific criteria

There was heavy damage at the facility due to high accelerations and severe ground settlement.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

- 6 to 8" ground settlement caused severe damage to concrete buildings and filtration structures at the station. The settlement also damaged a bridge crane anchorage (the crane remained operable), piping (causing flooding), and cables.
- A ceramic base of an old circuit breaker in the main control panel switchgear cracked due to pounding from relative movement and settlement.
- Pipes between two buildings which experienced settlement were lifted off their concrete saddle supports.
- Two of six deep well pumps and their casings were damaged from ground displacement and settlement. The motors for the pumps burned due to short circuits.

KEY FINDINGS

- Equipment and piping not damaged directly by the gross settlement of buildings performed well.
- One old circuit breaker sustained broken porcelain base from impact. The flexible panel on which it was mounted was located at the interface of two buildings where relative settlement of several inches occurred.
- The settlement of buildings tore cable and caused short circuits. When the cables were repaired, relays, switches, and contactors functioned properly.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Sites: ADDITIONAL PLACES OF INTEREST

SITES AND GROUND MOTION

- PORT OF VALPARAISO: Major port facility, about 15 miles from the epicenter. Estimated PGA at the port facility is 0.20 to 0.40g.
- EL FARO BUILDING: Modern 8-story apartment building in town of Renca, 30 miles from the epicenter. Estimated PGA is 0.25 to 0.40g. The building is on the edge of a cliff.
- CANAL BEAGLE CONDOMINIUM BUILDINGS: Modern housing complex consisting of many 3- to 5-story buildings, 25 miles from the epicenter. Estimated PGA is much stronger than the 0.20 to 0.40g recorded in the vicinity. The structures were designed to Chilean code.
- GOLD COAST CONDOMINIUM BUILDINGS: About 300 modern 5- to 23- story luxury condominiums along Pacific coast in Viña del Mar, 25 miles from the epicenter. Estimated PGA is 0.20 to 0.40g.

Modern buildings performed well in spite of the long duration strong ground motion. Earthquake damage in the vicinity of the epicenter can be generally attributed to ground failure and/or poor construction or design practice.

MOST IMPORTANT EARTHQUAKE DAMAGE AND KEY FINDINGS

- PORT OF VALPARAISO: Subsidence and horizontal lurching of the soil caused severe damage to the port and its structures. Harbor cranes were disabled by the excessive residual ground displacement. Wharf walls were severely damaged.
- EL FARO BUILDING: The modern 8-story apartment building was severely damaged and was demolished. Heavy damage to first floor walls left the building irreparable.
- CANAL BEAGLE CONDOMINIUM BUILDINGS: Most of the structures (reinforced concrete frame structures with masonry infill walls) were severely damaged, and had to be evacuated. There were many ground failures in the immediate vicinity. The damage is attributed to intense focusing.
- GOLD COAST CONDOMINIUM BUILDINGS: Most of these modern buildings performed well. Two 15-story buildings were severely damaged. Both buildings had irregular layouts that attributed substantially to the damage. Also, both buildings had been damaged in the 1971 earthquake and only cosmetically repaired.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: OXIQUIM CHEMICAL PLANT

FACILITY

- Large chemical manufacturing plant
- Chilean design, ranging from over 30 years old to new
- Rock and soil site

GROUND MOTION

- Estimated PGA 0.20 to 0.40g; higher on the hill slope
- 25 miles from epicenter
- Adjacent to the heavily damaged Canal Beagle apartment buildings; 2 miles from heavily damaged high-rise concrete structures

SEISMIC DESIGN CRITERIA

- Newer portions built to Chilean code
- Most equipment appeared well anchored
- Not considered for piping

OXIQUIM CHEMICAL PLANT, cont.

The chemical plant was in an area of high intensities and several unanchored vertical tanks were damaged. Data collected on the performance of equipment and control systems reinforce previous SQUG findings.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

- Ten large unanchored vertical storage tanks were damaged and some lost their contents
- A chemical fire broke out in a lab when reagents fell from shelves and mixed
- A steam pipe leaked at a flanged connection due to excessive flexibility of the pipe and large deformations experienced
- A connection weld between a stiff 1" line and a flexible 8" line cracked due to excessive movement
- Due to poor welds and corrosion, piping throughout the plant required minor repair
- Braces buckled on a steel frame supporting elevated tank
- Several precast concrete fence sections toppled
- Concrete frame buildings suffered moderate damage including cracking, pounding, and broken windows

KEY FINDINGS

- There were only a few pipe failures in the extensive runs of various ages and support configurations. All failures were associated with corrosion, poor welds, or anchor point movement.
- The plant control systems operated correctly and shutdown the plant upon loss of power.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: CON CON PETROLEUM REFINERY

FACILITY

- Large oil, gasoline, and gas production facility
- Includes 2 unit auxiliary power plant, 5 mW
- U.S. design, 1952 - 1975
- Deep soil site, poor clay

GROUND MOTION

- Estimated PGA 0.20 - 0.40g
- 35 miles from epicenter
- Heavily damaged nearby residential structures

SEISMIC DESIGN CRITERIA

- Probably considered for all structures
- Most equipment appeared well anchored
- No seismic design of piping, conduit, cable trays, etc.

There was some severe earthquake damage at the facility, particularly to large vertical tanks. Equipment performance strengthens the SQUG data base.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

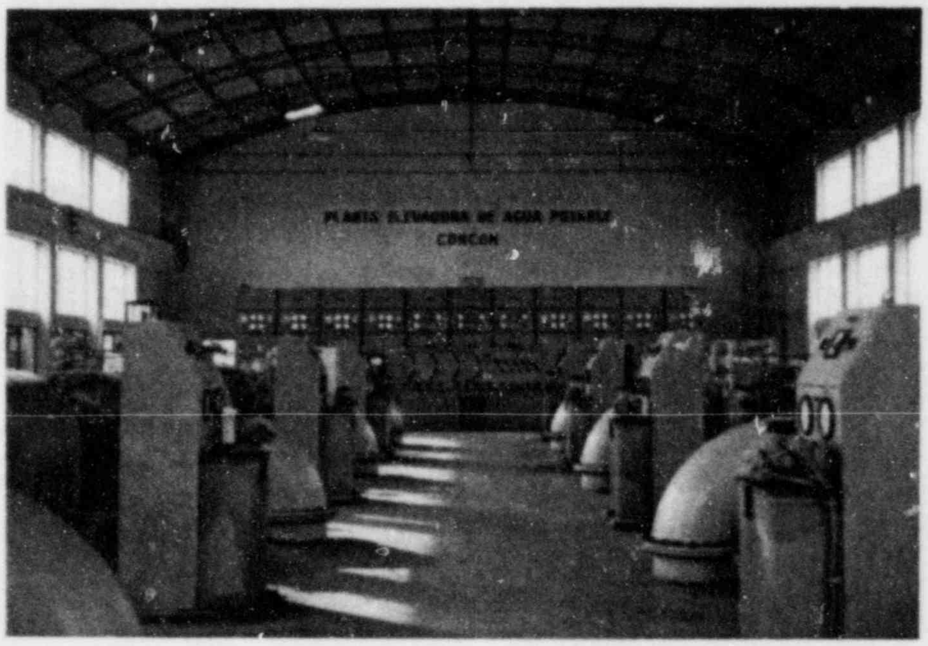
- Cracked cast iron control valves (due to building failure)
- Cracked cast iron piping (due to corrosion, previous repair, or anchor point movement)
- Damaged control panel bracing (wall connections for very large room sized walk-in cabinets); panel and instruments undamaged
- 12 of 120 vertical unanchored cylindrical steel tanks failed and lost their contents
- Damage to concrete frame structures indicating high ground motion intensities

KEY FINDINGS

- The emergency diesel generator started automatically about 3 seconds after the earthquake began. Fault current relay (large electro-mechanical) tripped it off. According to operator, chatter may have caused the trip. It was then manually restarted and operated properly.
- The on-site steam turbines provided the control rooms with power through the earthquake.
- With the exception of the emergency diesel generator, there were no malfunctions, false indications, system resets, or abnormal occurrences of any form in the plant control systems.
- Steel piping, cable trays, equipment, horizontal and spherical tanks, and typical refinery structures performed well.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Sites: CON CON WATER PUMPING STATION



FACILITY

- Main water pumping station for Vina del Mar and Valparaiso
- Originally built in 1910, newer portions in 1963
- Soil site

GROUND MOTION

- Estimated PGA 0.20 to 0.40g
- 35 miles from epicenter
- Masonry and adobe buildings in Con Con (about 2 miles away) were moderately to heavily damaged

SEISMIC DESIGN CRITERIA

- Newer portions probably built to Chilean code

The facility contains mechanical equipment of interest. Data collected on equipment and control systems reinforce previous SQUG findings.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

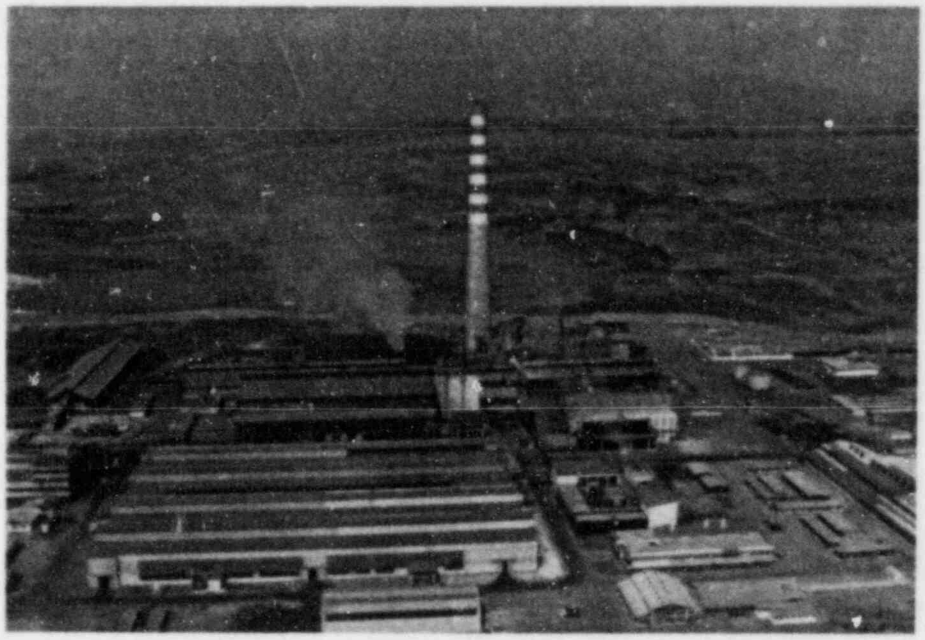
- Weld-repaired cracks in an 8" underground steel pipe re-opened. The damage did not affect plant operation.
- An unanchored spare transformer slid about 8-1/2".
- Two new unanchored chlorine injectors slid and one "malfunctioned". Control cables at the base provided the only resistance to overturning.
- The concrete fence around the plant toppled.

KEY FINDINGS

- Pumps and other equipment, including switchgear and motor-operated valves, were not damaged.
- The manual start emergency diesel generator system was started after a brief inspection and operated properly.
- No problems were experienced with control system equipment.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: LAS VENTANAS COPPER REFINERY AND FOUNDRY



FACILITY

- Very large industrial facility with many structures
- Includes 5.3 mW auxiliary power plant
- German and Chilean design; began operation in 1966
- Deep soil site, adjacent to Las Ventanas power plant

GROUND MOTION

- Estimated PGA 0.20 to 0.35g
- 45 miles from epicenter
- Moderate damage in nearby small town; extensive damage 20 miles to south in large towns

SEISMIC DESIGN CRITERIA

- Heavy equipment anchorage probably designed for 0.30g
- Structures probably designed for 0.15g

LAS VENTANAS COPPER REFINERY AND FOUNDRY, cont.

The plant suffered little damage; brick lined ovens suffered severe damage amounting to more than $2,500,000. The equipment and systems performed well at the large facility and its power plant and add significant information to the SQUG data base.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

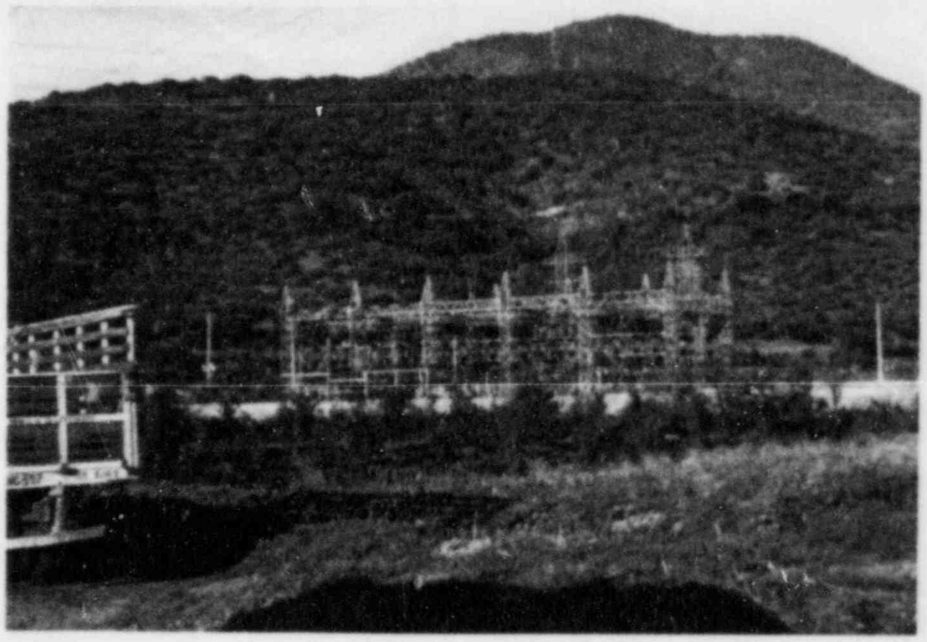
- The brick lining of the large refractory oven collapsed causing most of the financial losses
- A brick furnace used in ingot production was damaged
- A small line supplying oil to a transformer from an elevated tank failed (due to differential displacement)
- Over one-third of the electrolytic cells in the electrolytic refinery were damaged (cracked lead lining) by fallen cathodes (simply supported)
- A mercury manometer pressure gauge line was damaged by falling asbestos roof panels
- A few instrumentation lines were damaged (falling debris)
- A centrifugal blower suffered a minor misalignment between the motor and the fan
- Pounding damage occurred between two portions of the building housing the power plant

KEY FINDINGS

- The suspended brick ceiling of the main refractory oven has failed catastrophically in 3 consecutive earthquakes (1965, 1971 and 1985) causing large losses.
- The emergency diesel generator started up with loss of offsite power and operated properly.
- Motor-operated valves on smaller diameter lines, located 60 to 100 feet above grade, were not damaged.
- Piping and cable trays, electrical and mechanical equipment, and typical steel industrial buildings performed well.
- There were no malfunctions, false indications, system resets, or abnormal occurrences of any form in the plant control systems.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: SAN ISIDRO SUBSTATION



FACILITY

- 220 kV switching station
- Chilean design, completed in 1983
- Possibly shallow soil site

GROUND MOTION

- Recorded average PGA 0.58g
- 45 miles from epicenter
- There was moderate damage at adjacent small towns

SEISMIC DESIGN CRITERIA

- High voltage equipment anchorage designed for 0.50g
- Shear wall building well designed

An accelerometer at the site recorded PGAs of 0.60g and 0.57g horizontally and 0.38g vertically. The performance of the electrical equipment and control and emergency diesel systems strongly reinforces previous SQUG findings.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

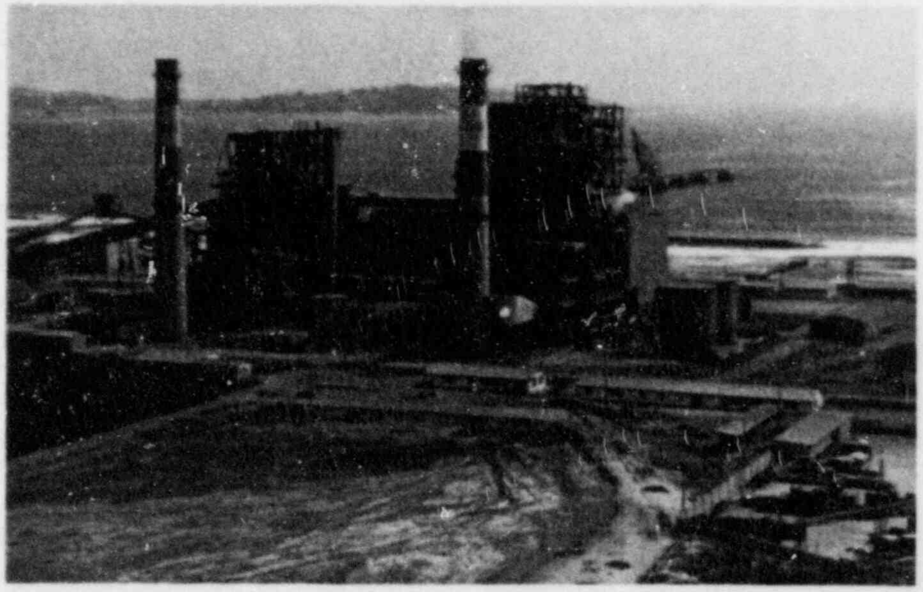
- Control and communications panels on second floor pulled anchor bolts and shifted; the panels continued to operate properly during and after the earthquake
- Batteries shifted and rotated in their frames due to slipped out spacers; the batteries operated through the earthquake and were not damaged
- Minor problems with a 110 kV regulator experienced
- Bolted connections for frames supporting elevated oil drums on two large transformers failed, causing partial collapse of one and an oil leak from an attached small line
- Ceramic components cracked causing failure of air blast circuit breakers and a disconnector switch
- Wall and frame construction joints of the control building suffered minor cracking
- Legs of a transmission tower shifted due to ground settlement of about 6 inches
- Several sections of concrete wall fencing toppled

KEY FINDINGS

- Electrical control cabinets on the second floor of the control building continued to operate properly despite pulled or loosened anchorage and minor shifting.
- The emergency diesel generator started automatically during the earthquake and operated for 8 hours (until offsite power was regained) with no problems.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: LAS VENTANAS POWER PLANT



FACILITY

- Thermoelectric power station, U.S. and Chilean design
- 2 units, at 120 mW (Unit 1) and 210 mW (Unit 2)
- Began operation in 1964 (Unit 1) and 1977 (Unit 2)
- Engineered compacted fill over deep soil

GROUND MOTION

- Estimated free-field PGA 0.20g to 0.35 g;0.18g recorded at base slab
- 45 miles from epicenter
- Moderate damage in nearby small town; extensive damage 20 miles to south in large towns
- Third major earthquake for Unit 1 (1965, 1971)

SEISMIC DESIGN CRITERIA (all static coefficients)

- Equipment: Anchorage 0.50 g; Components anchorage 1.0g
- Some pressure piping 0.20g (static); snubbers; seismic stops
- Structures 0.15 to 0.27g

LAS VENTANAS POWER PLANT, cont.

Peak recorded acceleration at top of boiler structure was 0.81g. There was damage to seismic stops (as expected) and snubbers for the boiler and piping. Damage from previous earthquakes was repeated. All findings reinforce previous SQUG observations and greatly strengthen the data base.

EARTHQUAKE DAMAGE AT FACILITY

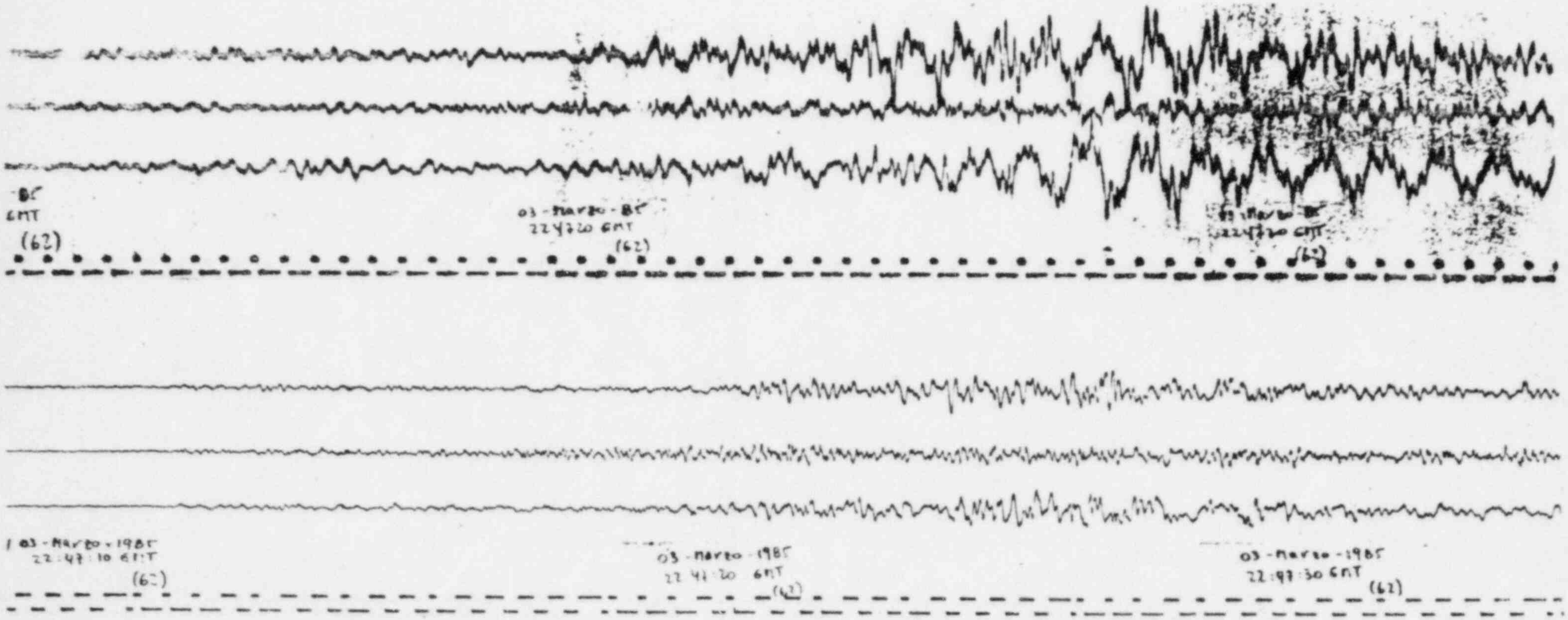
- All lateral restraints for the rod suspended boilers were damaged; they are designed to fail and to absorb energy in order to protect boilers
- Supports for hydraulic snubbers on main steam line were damaged
- Lightly damaged boiler support and silo support steel structures
- Cast iron yokes of one and possibly two air-operated valves cracked due to impact with handrail 12" away
- Piping experienced large displacements, supports and insulation damaged (no loss of pipe integrity)
- Anchorage failed on smaller control room cabinets
- Main control panel sustained minor structural damage; components undamaged and remained functional
- Torn bellows on large bore circulating water pipe due to longitudinal motion of 1500' pier
- Pipes damaged and legs of an elevated tank failed due to unanchored tank movement
- Pipes damaged due to unanchored large water tank settlement

KEY FINDINGS

- Several supports for hydraulic snubbers on a main steam line were damaged.
- All seismic stops for the boilers were damaged (as expected). Several boiler snubbers were broken or damaged.
- A large vertical storage tank repaired and strengthened after being damaged in the 1971 earthquake performed well.
- The boiler and turbine structures strengthened after being badly damaged in the 1965 earthquake performed well.
- Piping and cable trays, electrical and mechanical equipment, vertical tanks, electrical systems, and typical power plant structures performed well.
- There were no malfunctions, false indications, system resets, or abnormal occurrences of any form in the plant control systems.

LAS VENTANAS POWER PLANT (UNIT 2); 0.18g ON BASE SLAB AMPLIFIED TO 0.81g IN BOILER STRUCTURE. FIGURE SHOWS PARTIAL BASE SLAB AND TOP OF BOILER STRUCTURE RECORDS

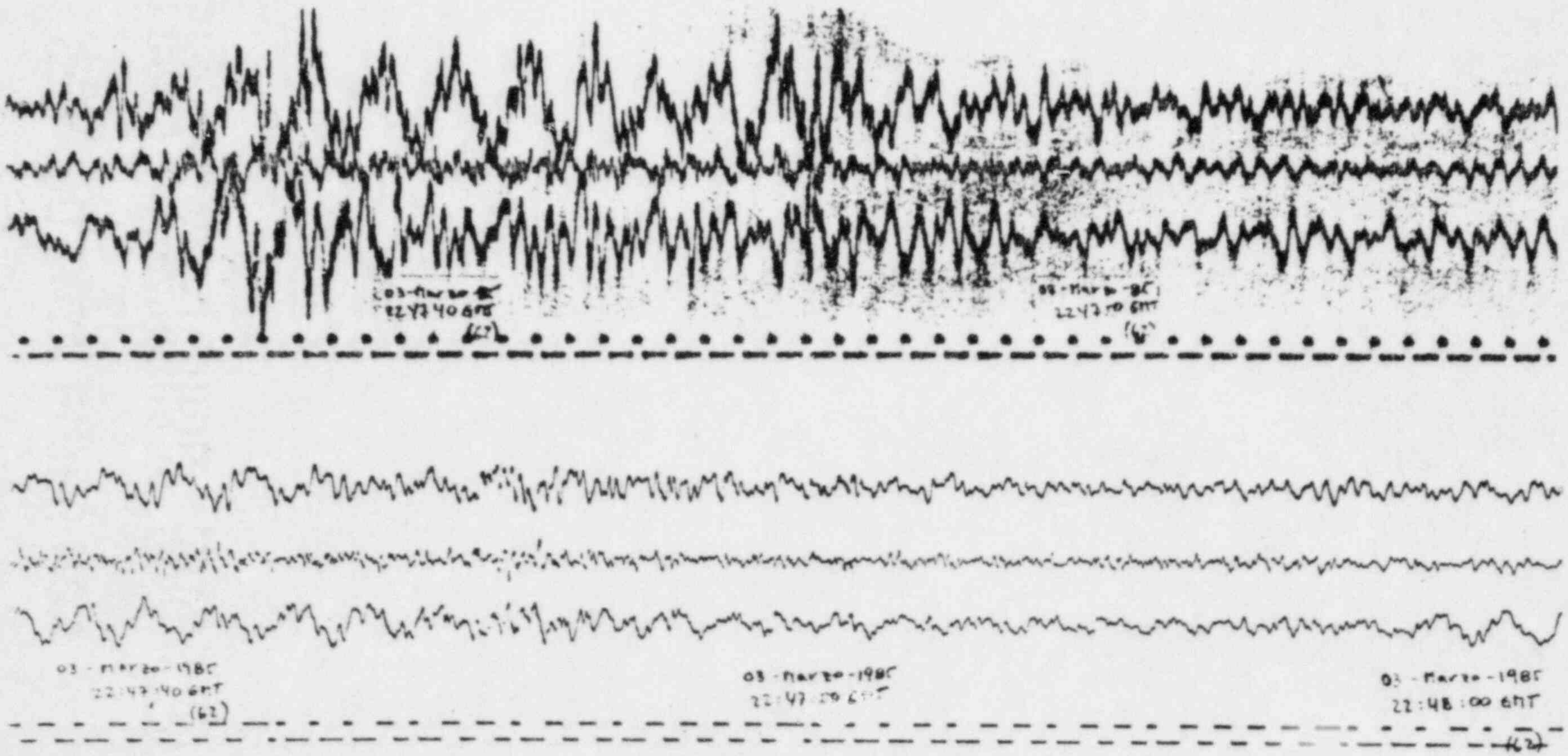
0 TO 23 SEC.



EQE

LAS VENTANAS POWER PLANT (UNIT 2); 0.18g ON BASE SLAB AMPLIFIED TO 0.81g IN BOILER STRUCTURE. FIGURE SHOWS PARTIAL BASE SLAB AND TOP OF BOILER STRUCTURE RECORDS

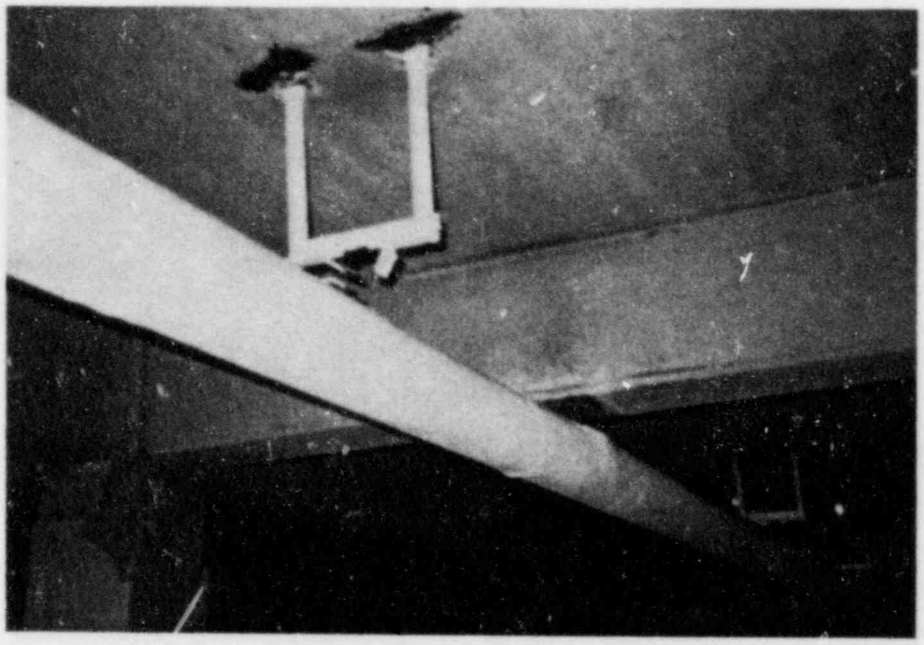
26 SEC TO 50 SEC.



EQE

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: BATA SHOE FACTORY



FACILITY

- Large tannery and shoe factory
- Chilean design, completed about 1960
- Site is located in a valley on clay

GROUND MOTION

- Recorded average PGA nearby 0.67g
- 55 miles from epicenter
- Most of the masonry buildings in the nearby town of Melipilla were damaged. 60 to 90% of the homes were uninhabitable

SEISMIC DESIGN CRITERIA

- Structures probably built to Chilean code
- Not considered for piping or equipment anchorage; many items unanchored

BATA SHOE FACTORY, cont.

The facility experienced high accelerations and was in an area of high intensities.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

- Concrete frame buildings experienced moderate to severe damage.
- A 4" steam line lost all hanger supports and experienced considerable pounding; the pipe was undamaged.
- Several small bore pipes leaked at connections to smaller lines and at elbows due to excessive movement and anchor point motion.
- Various large machinery slid about 2".
- Following the earthquake, a large vertical petroleum tank leaked; attributed to corrosion.
- A 2" underground water line broke.
- The filaments of a few indicator lights on control panels broke; the panels operated properly.

KEY FINDINGS

- A welded steam line suspended from the ceiling of a severely damaged building did not fail despite the failure of all of its supports.
- Control panels operated properly although they were shaken severely enough to have damaged indicator lights.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: RAPEL HYDROELECTRIC POWER PLANT

FACILITY

- 5 units at 75 mW each
- Began operation in 1968 thru 1970
- Designed by Chilean utility, 1960
- Rock site; substation on rock and partial fill

GROUND MOTION

- Estimated PGA 0.40 to 0.70g; 0.23g average PGA recorded in tunnel on rock
- 60 miles from epicenter
- Numerous large landslides and rockfalls in vicinity (plant area is mostly uninhabited)

SEISMIC DESIGN CRITERIA

- 1960 "State-of-the-art" criteria used for dam
- High voltage equipment anchorage probably designed for 0.50g. Good anchorage practices observed

RAPEL HYDROELECTRIC POWER PLANT, cont.

The dam sustained direct earthquake damage amounting to over $20,000,000. Most of the damage is in the concrete structures. Findings point out to SQUG that a focus on relays is important; unusually constructed equipment can sustain damage.

EARTHQUAKE DAMAGE AT FACILITY

- The concrete arch dam and spillway gates experienced structural damage
- Ceramic components broke causing failure of disconnect switches and air-blast circuit breaker
- Transformer components (lightning arrestors and pressure relief mechanisms) failed
- Transmission tower damaged by settlement
- Braces and cabinets buckled on open-framed (unusual, British made) 13.8 kV switchgear. The equipment does not meet the criteria approved by SSRAP
- Damaged protective relays (large electro-mechanical; U.S. and British)
- Buckled bus bar between batteries (no spacers or small spacers between batteries and rack); damage did not interrupt service
- Turbines had eccentricity problems caused by differential displacement of building sections
- Shear walls of the concrete frame control building suffered diagonal shear cracking

KEY FINDINGS

- Protective relays in the substation control building were damaged.
- Switchgear cabinets (of unusual construction) in the substation control building were damaged.
- The emergency diesel generator operated properly after the earthquake.
- There were no control system malfunctions or false alarms during or after the earthquake. The plant is used as a peaker and was not in operation during the earthquake.
- Unusual topographic condition (top of a hill) can cause focusing of ground motion.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Sites: SANTIAGO AND VICINITY

FACILITIES

- A substation, a hospital, the airport, and the general Santiago area were investigated.
- Site soil conditions vary from rock to deep soil

GROUND MOTION

- Recorded PGAs range from 0.11g in Santiago to 0.65g in Peldehue, 20 miles away
- Estimated PGA for most of Santiago is 0.10 to 0.40g
- Santiago is inland, about 80 miles from the epicenter

SEISMIC DESIGN CRITERIA

- Santiago includes older structures with no seismic design as well as many modern structures designed to the modern and stringent Chilean code

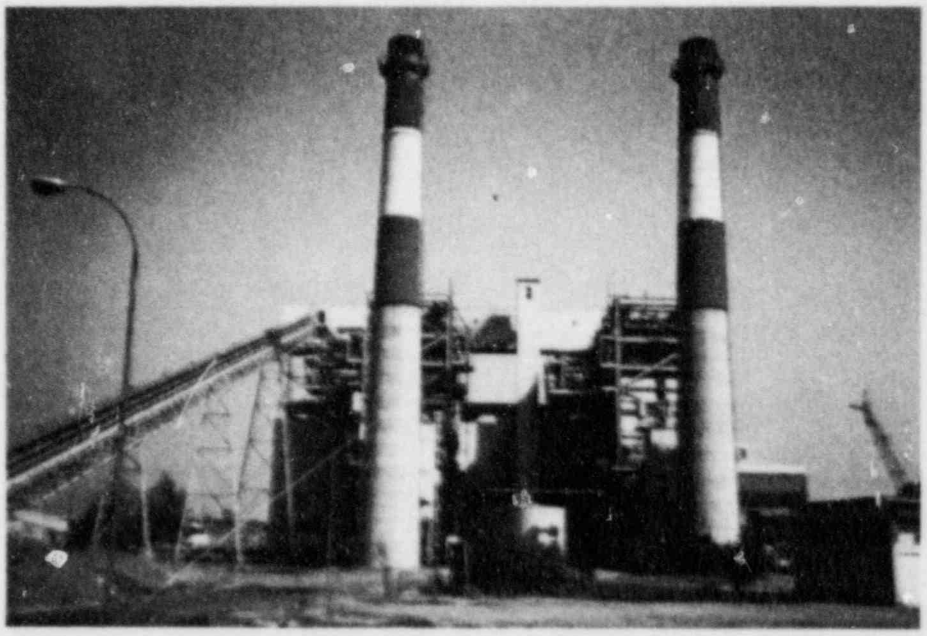
Santiago, over 80 miles from the epicenter, saw PGAs of 0.10 to 0.40g. All findings at the investigated facilities in the city reinforce previous SQUG findings.

MOST IMPORTANT EARTHQUAKE DAMAGE AND KEY FINDINGS

- SAN CRISTOBAL SUBSTATION: Two of four capacitor banks failed when their supporting pedestal ceramic insulators broke. Lightning arrestors were damaged. Anchor bolts failed on communications gear. Several protective relays actuated during the earthquake; the exact cause of the trips are not known.
- CLINICA LAS CONDES: Two patient elevators failed from movement and misalignment of unanchored motors in the elevator machine room. The two emergency diesel generators started automatically upon loss of power and operated properly. Other electrical and mechanical equipment, and piping and cable trays worked properly and were undamaged.
- Well designed buildings throughout the city performed well. Only one partial collapse of a modern structure was reported. Many old masonry structures suffered heavy damage.

M 7.5 Chile Earthquake of March 3, 1985

Data Base Site: RENCA POWER PLANT



FACILITY

- Thermoelectric power station
- 2 units at 50 mW each; used as peakers
- U.S. Design (EBASCO), completed in 1962
- Soil site on northwest outskirts of Santiago

GROUND MOTION

- Estimated PGA 0.25 - 0.40g
- 75 miles from epicenter
- Extensive and severe damage to most masonry residential structures and a hospital in the densely populated area around the plant

SEISMIC DESIGN CRITERIA

- Structures probably designed for 0.15g lateral (static)
- Most equipment well anchored; some anchorages were overlooked
- Some piping runs include seismic stops

RENCA POWER PLANT, cont.

There was some heavy earthquake damage at and around the facility. Equipment, electrical systems, piping, and typical power plant systems and structures performed well, reinforcing previous SQUG findings.

MOST IMPORTANT EARTHQUAKE DAMAGE AT FACILITY

- Damaged seismic stops on boiler; the stops are designed to be damaged and absorb energy; easy to replace
- Damaged anchorage on several pedestal supported large switchyard transformers (may be cumulative damage from previous events)
- Damaged anchorage on horizontal tanks on upper levels of the open air boiler support structure; corrosion present
- Two unanchored motor control center assemblies slid; equipment undamaged
- Derailed and damaged bridge crane wheel
- Failed rod hanger pipe connection; pipe undamaged (this item may or may not be earthquake-related)
- Severely damaged small concrete frame building

KEY FINDINGS

- Several lateral restraints for the suspended boilers were damaged, as expected.
- There were no control system malfunctions or false alarms during the earthquake or following startup after the earthquake. The plant was not in operation during the earthquake.
- Piping, cable trays, electrical and mechanical equipment, and typical power plant structures performed well.

MEXICO EARTHQUAKES

SEPTEMBER 19, 1985 M = 8.1

SEPTEMBER 20, 1985 M = 7.5

EPRI/EQE SENT A TEAM TO INVESTIGATE THE SEPTEMBER 19, MEXICO EARTHQUAKE. WE WERE ASSISTED BY MEMBERS OF THE MEXICAN NATIONAL UTILITY, CFE.

RECONNAISSANCE TEAM (SEPTEMBER 20 - 23, 1985)

SAM W. SWAN - EQE

STEPHEN J. EDER - EQE

BRAD BURDICK - LLNL/NRC

ROBERT KASSAWARA - EPRI

DENNIS OSTROM - SCE/SQUG

RECONNAISSANCE TEAM (NOVEMBER 6 - 11, 1985)

EQE SENT A SECOND TEAM TO COLLECT ADDITIONAL DATA; RESOLVE DISCREPANCIES

STEPHEN J. EDER - EQE

DAVID L. McCORMICK - EQE

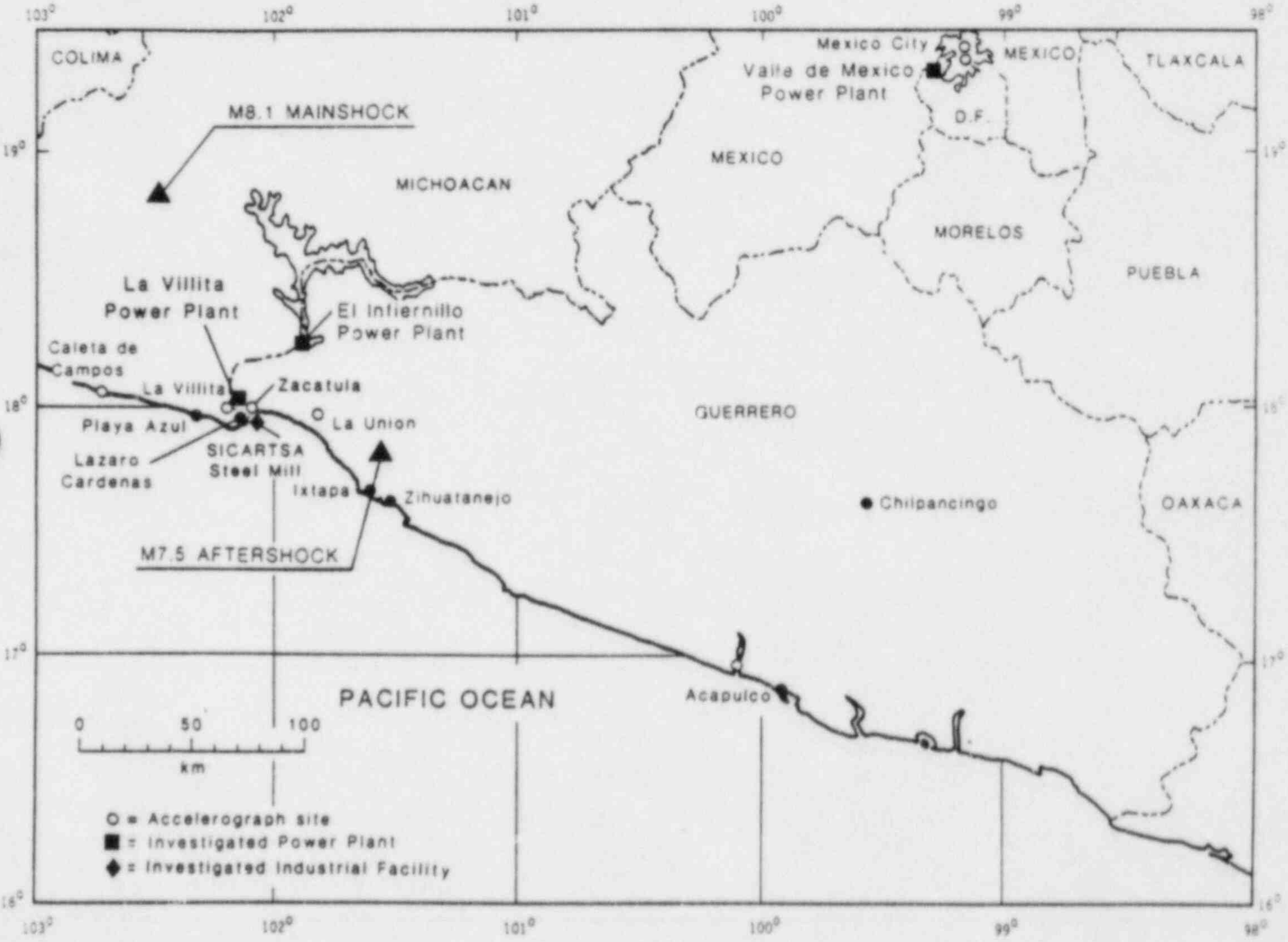
MAP OF MEXICO SHOWING THE LOCATION OF THE SEPTEMBER 19, 1985 M8.1 EARTHQUAKE AND THE M7.5 AFTERSHOCK THAT OCCURRED ON THE FOLLOWING DAY

EQE

SUMMARY OF PEAK ACCELERATION RECORDS (g)

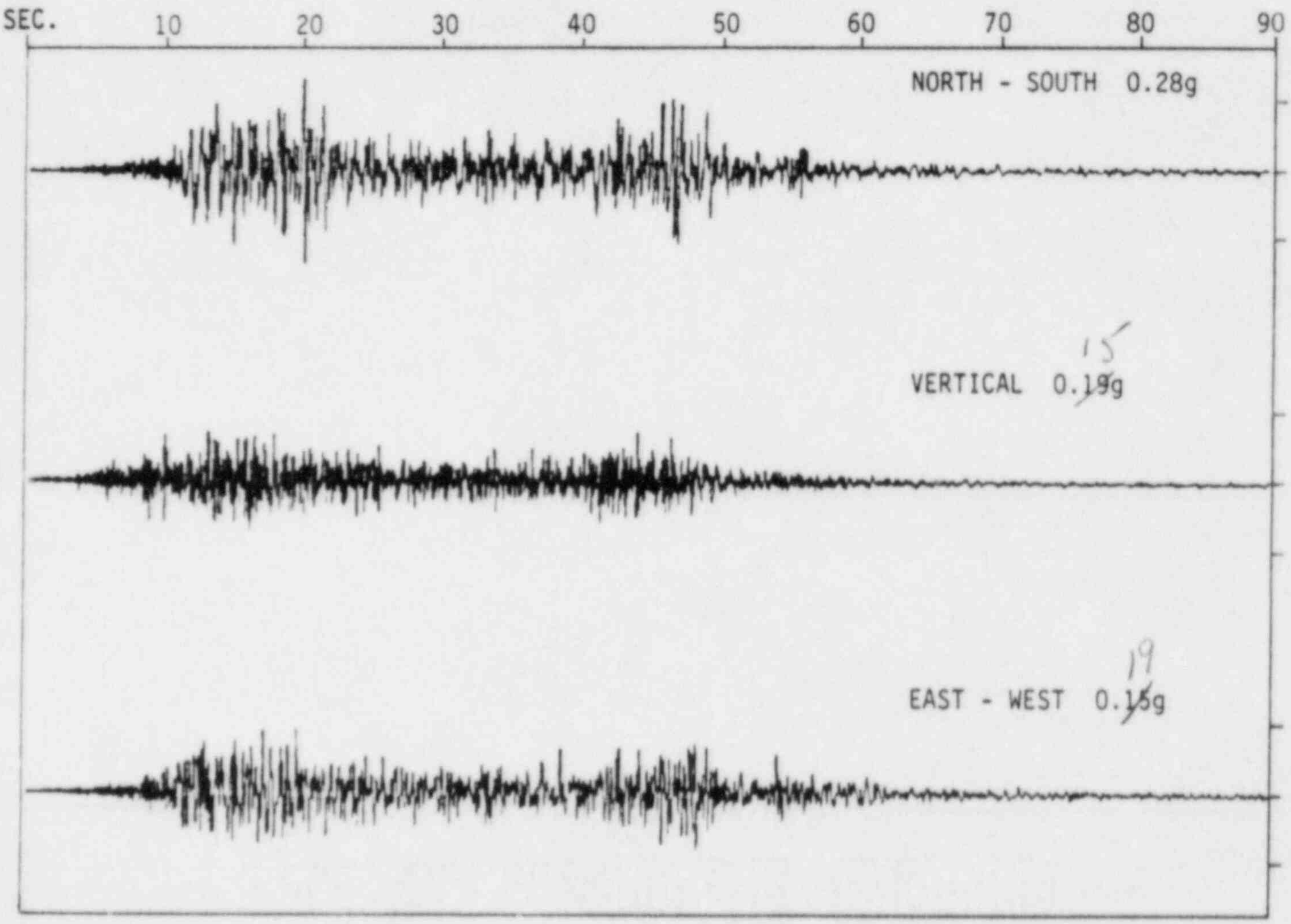
LOCATION	H	H	V	AVE H
1. CALETA DE CAMPOS	0.14	0.14	0.09	0.14
2. LA VILLITA P.P.	0.13	0.14	0.06	0.14
3. LA UNION	0.14	0.12	0.09	0.13
4. ZACATULA	0.28	0.19	0.15	0.24
5. MEXICO CITY, LAKE BED	0.17	0.10	0.04	0.14
6. MEXICO CITY, ROCK	0.03	0.04	0.02	0.04

INDUSTRIAL FACILITIES AND POWER PLANTS IN THE AFFECTED AREAS. FOUR NEARBY GROUND MOTION RECORDS ARE AVAILABLE FOR THE SITES OF INTEREST

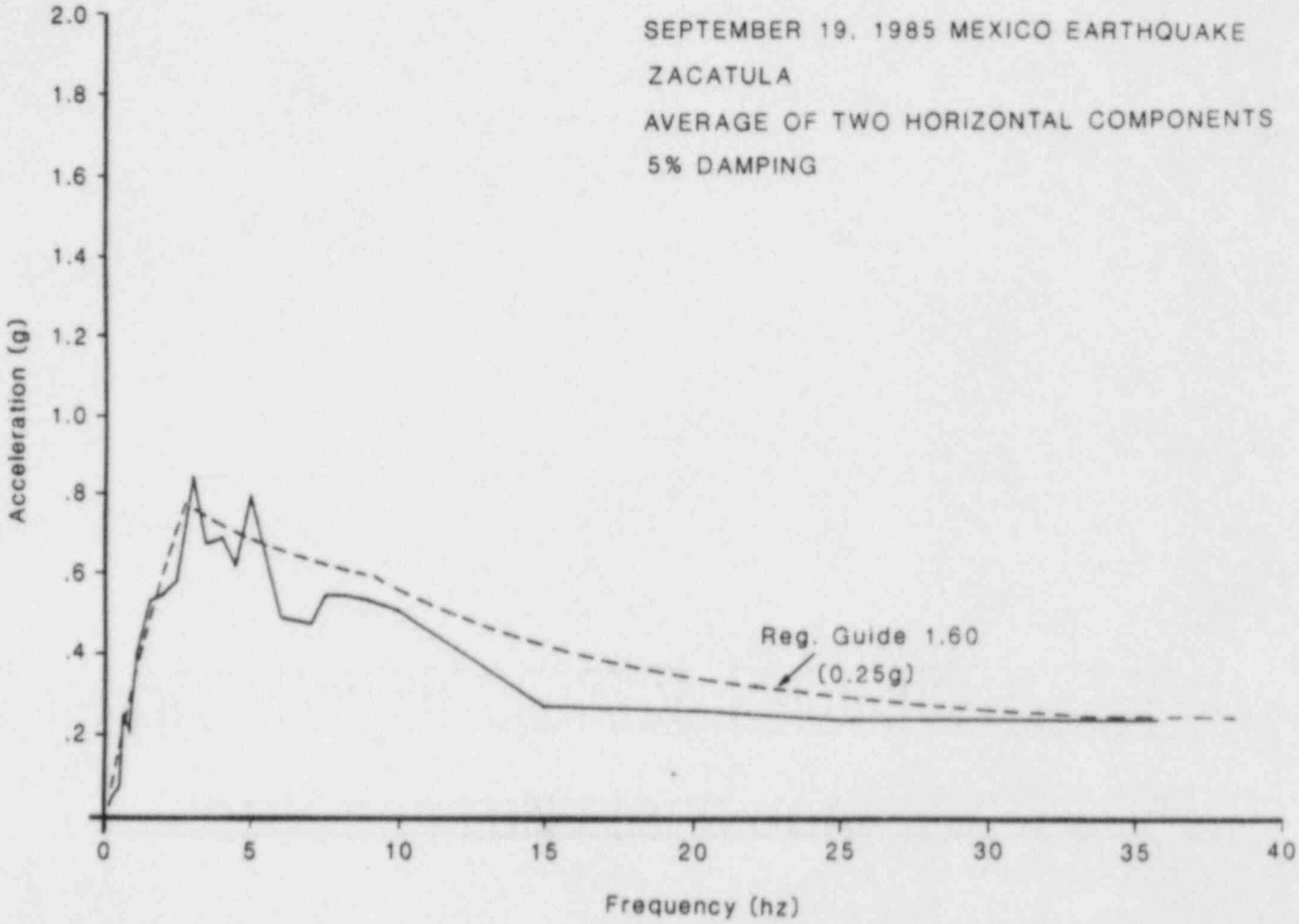


EQE

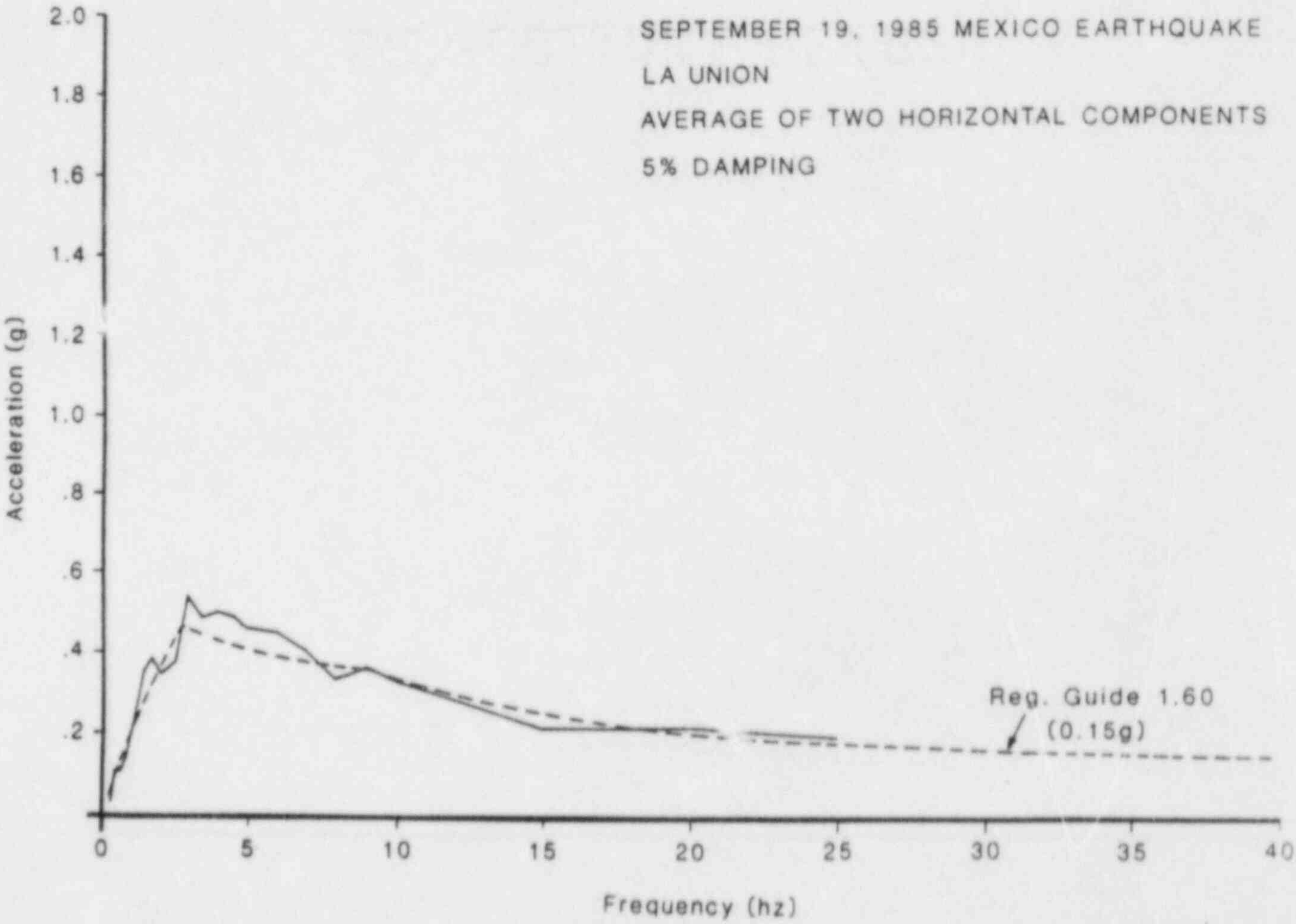
LONG DURATION STRONG MOTION RECORD TAKEN NEAR LAZARO CARDENAS (ZACATULA RECORD)



THE ZACATULA RECORD RESPONSE SPECTRUM IS REPRESENTATIVE OF ALL THE LAZARO CARDENAS INDUSTRIAL FACILITIES.



THE EPICENTRAL REGION ROCK STATION RECORD RESPONSE SPECTRUM IS BROAD-BASED, CLOSELY RESEMBLING THE NRC REGULATORY GUIDE 1.60 RESPONSE SPECTRUM



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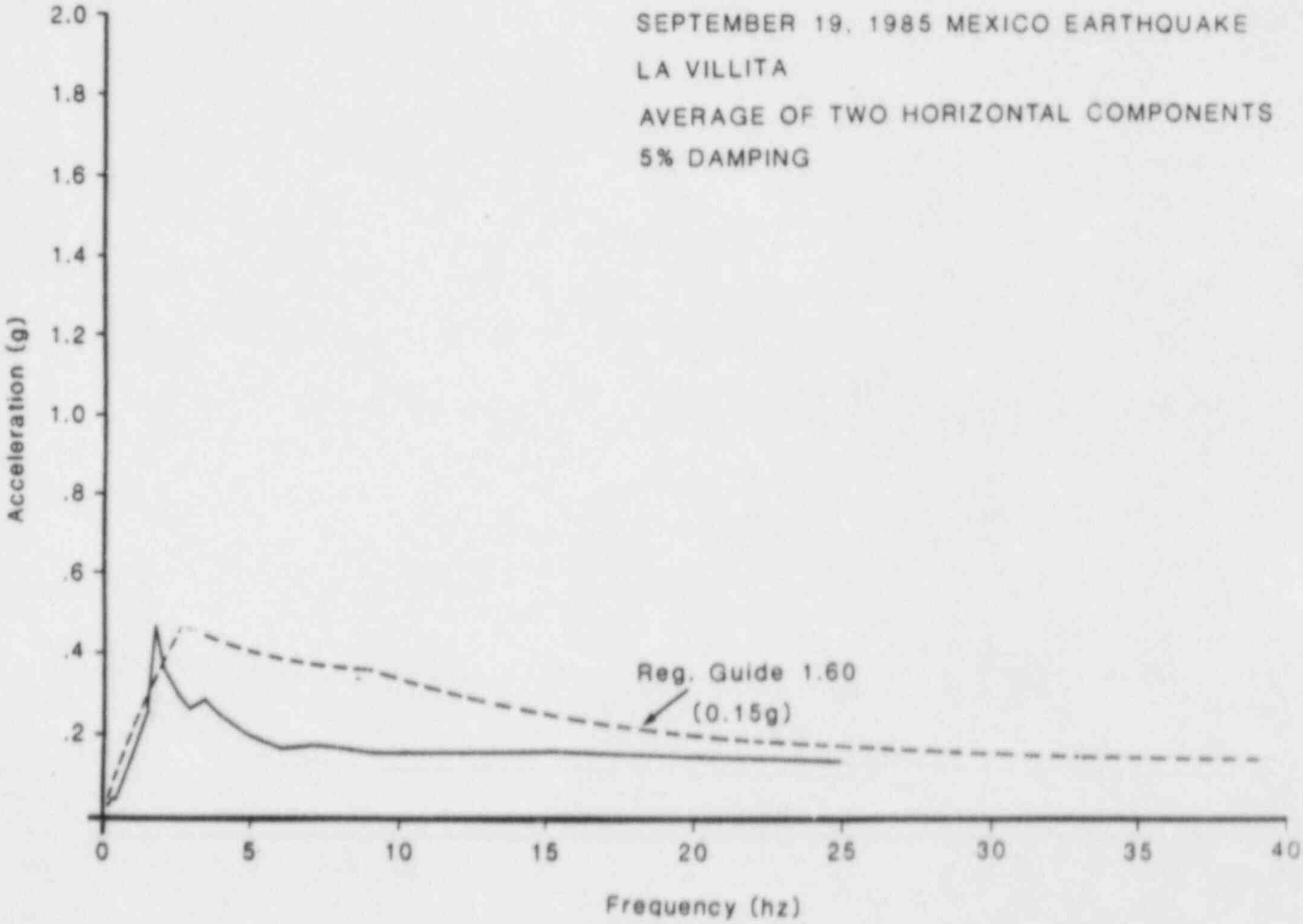
COMPARISON OF THE LA VILLITA RESPONSE SPECTRUM WITH OTHER EPICENTRAL REGION ROCK RECORDS PROBABLY INDICATES THE EFFECTS OF DAM-FOUNDATION INTERACTION AT THE BASE OF THE MASSIVE DAM STRUCTURE.



EQE

WE VISITED 10 SITES IN THE AFFECTED AREA, INCLUDING:

2 POWER PLANTS
1 SUBSTATION
1 VERY LARGE STEEL MILL
1 FERTILIZER PLANT
1 CONCRETE PLANT

THE 2 POWER PLANTS AND THE STEEL MILL HAVE 11 UNITS:

LA VILLITA	4 UNITS
EL INFIERNILLO	5 UNITS
SICARTSA	2 UNITS

TYPICAL POWER PLANTS IN MEXICO ARE ANALYZED AND DESIGNED FOR THE FOLLOWING MINIMUM LATERAL COEFFICIENTS

ITEM	HIGH SEISMIC REGION (g)	LOW SEISMIC REGION (g)
SYMMETRICAL BUILDINGS	.10 - .12	.04 - .06
NON-SYMMETRICAL BUILDINGS	.15 - .24	.04 - .06
CANTILEVERS	.20 - .30	.04 - .06
TANKS	.15 - .24	.04 - .06
EQUIPMENT ANCHORAGE	.15 - .24	.04 - .06
STACKS & TOWERS	.17 - .40	.06 - .10

VALUES ARE ADJUSTED FOR SOIL RESONANCE EFFECTS

M 8.1 Mexico Earthquake of September 19, 1985

Data Base Site: EL INFIERNILLO HYDROELECTRIC POWER PLANT

FACILITY

- 4 units at 160 mW each and 2 units at 180 mW each
- Mexican design, constructed in 1960s
- Rock site, power station built into tunnel

GROUND MOTION

- Estimated PGA 0.15g
- 40 miles from epicenter
- Uninhabited area, some rock slides observed (possibly due to seasonal rains)

SEISMIC DESIGN CRITERIA

- Seismic loading considered in design
- Most equipment well anchored

The plant experienced low level, long duration ground motion and performed well. All findings reinforce previous SQUG findings.

MOST IMPORTANT EARTHQUAKE EFFECTS AT FACILITY

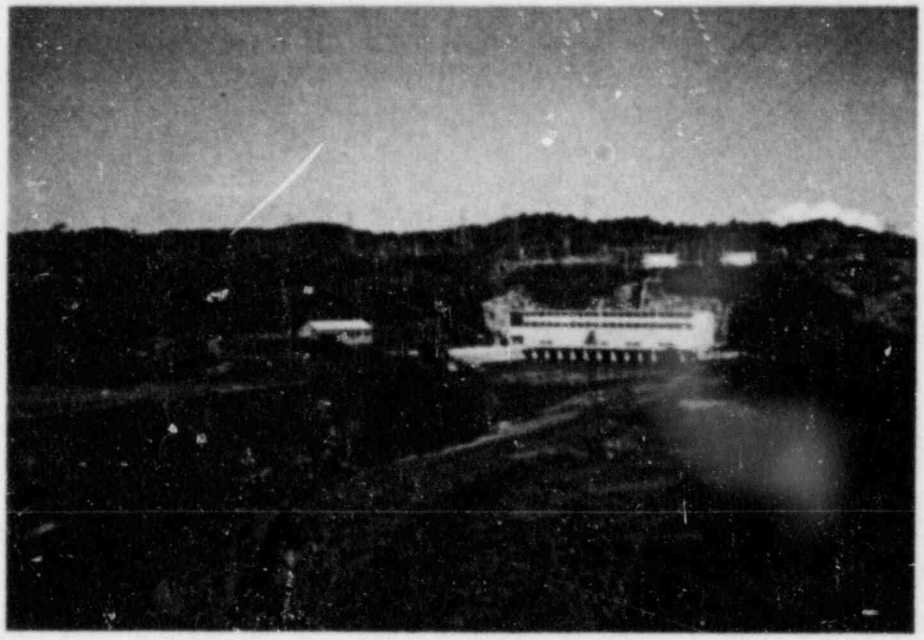
- Superficial damage at crest of dam
- Water sloshed up through an air vent line and onto the generator
- An oil filled high voltage transformer suffered an oil leak
- Spurious vibration caused a ground fault relay to trip

KEY FINDINGS

- Three units that were operating during the earthquake were disconnected from the grid by protective relays; all units were reconnected after a brief inspection.
- Cable trays with dead-load to the point of buckling were not damaged by the earthquake.
- With the exception of the ground fault relay, there were no malfunctions, false indications, system resets, or abnormal occurrences of any form in the plant control systems.
- Electrical and mechanical equipment performed well.

M 8.1 Mexico Earthquake of September 19, 1985

Data Base Site: LA VILLITA HYDROELECTRIC POWER PLANT



FACILITY

- 4 units at 76 mW each
- Mexican design, constructed in 1973
- Rock site

GROUND MOTION

- Recorded PGA 0.14g at base of dam
- 25 miles from epicenter
- 8 miles from Lazaro Cardenas where MMI = IX

SEISMIC DESIGN CRITERIA

- Structures, storage tanks, equipment anchorage, and piping designed to modern CFE code

LA VILLITA HYDROELECTRIC POWER PLANT, cont.

The plant experienced low level, long duration ground motion and performed well. All findings reinforce previous SQUG findings.

MOST IMPORTANT EARTHQUAKE EFFECTS AT FACILITY

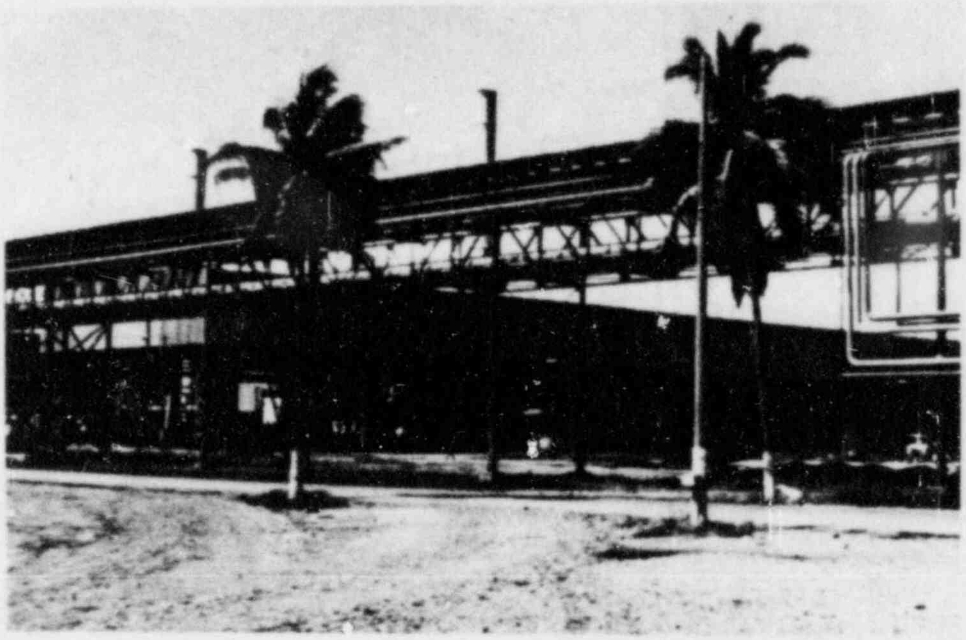
- Superficial damage at crest of dam
- Minor shifting of batteries not secured to their anchored battery racks
- Leaked acid from batteries on very flexible rack
- Shifted ceiling panels in power station control room
- Overturned water cooler bottle in power station control room
- Buholtz relay actuated by sloshing of oil in substation switchyard

KEY FINDINGS

- Two units that were operating during the earthquake were disconnected from the grid by protective relays; both units were reconnected after a brief inspection.
- Cable trays with dead-load to the point of buckling were not damaged by the earthquake.
- With the exception of the Buholtz relay, there were no malfunctions, false indications, system resets, or abnormal occurrences of any form in the plant control systems.
- Piping, cable trays, equipment, vertical tanks, and typical power plant structures performed well.

M 8.1 Mexico Earthquake of September 19, 1985

Data Base Site: SICARTSA STEEL MILL



FACILITY

- Very large modern steel mill, covers about 10 sq. mi.
- Includes 2 unit auxiliary power plant, 22 mW
- Mexican design, built in mid 1970s; a new unit is under construction
- Soil site

GROUND MOTION

- Nearby recorded average PGA 0.24g on similar soil
- 25 miles from epicenter
- Adjacent to town of Lazaro Cardenas where MMI = IX

SEISMIC DESIGN CRITERIA

- Seismic loading probably considered in design
- Most equipment well anchored

SICARTSA STEEL MILL, cont.

There was heavy damage at the plant and in the adjacent town of Lazaro Cardenas. The plant covers about a ten square mile area and includes modern equipment, installations, control systems, and structures.

MOST IMPORTANT EARTHQUAKE EFFECTS AT FACILITY

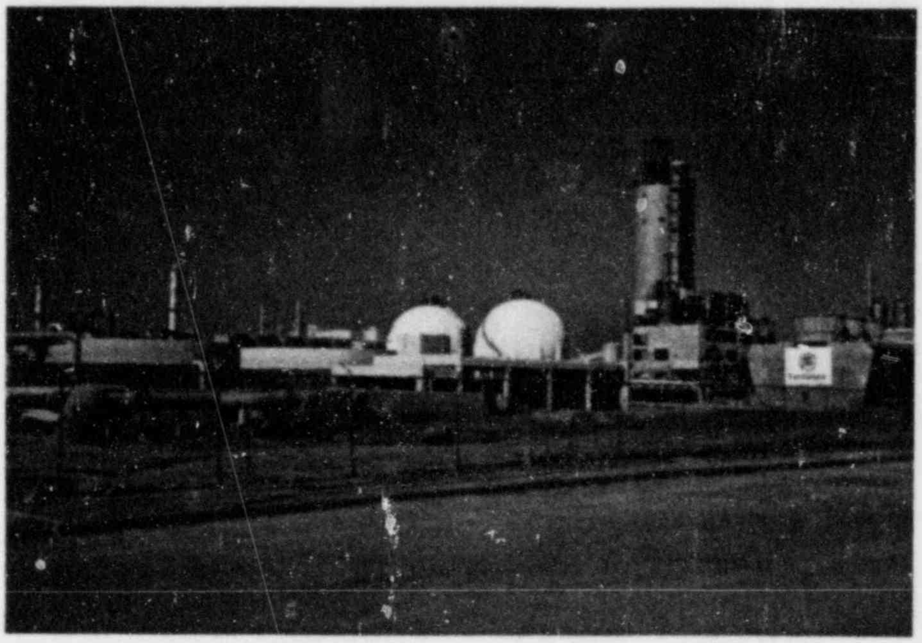
- A concrete frame administration building was severely damaged
- A base supported boiler broke its anchorage and shifted several inches, failing attached small bore piping and instrument tubing
- The steel frame power station building was moderately damaged
- Major ground slumping alongside a channel caused heavy damage to many adjacent structures
- Ceramic components failed in a substation switchyard
- Two large unanchored high voltage transformers overturned
- A switchyard transformer jumped its rails and suffered an oil leak
- An underground cast iron water pipe cracked

KEY FINDINGS

- The centrifugal impeller of a forced draft fan for a boiler became unbalanced following the earthquake.
- One unit was operating at the time of the earthquake and properly shut down by protective relay actuation.
- Miles of piping and cable trays on overhead steel frames (some steel frames were damaged) were undamaged.

M 8.1 Mexico Earthquake of September 19, 1985

Data Base Site: FERTIMEX FERTILIZER PLANT



FACILITY

- Large modern facility, about 90 % completed
- Under construction for about 4 years
- Soil site, poor clay

GROUND MOTION

- Nearby recorded average PGA 0.24g on similar soil
- 25 miles from epicenter
- Adjacent to SICARTSA Steel mill; adjacent to town of Lazaro Cardenas where MMI = IX

SEISMIC DESIGN CRITERIA

- Seismic loading probably considered in design
- Most equipment well anchored

FERTIMEX FERTILIZER PLANT, cont.

This new plant contains much modern equipment, installations and structures. It was in an area of high intensity motion and sustained considerable damage.

MOST IMPORTANT EARTHQUAKE EFFECTS AT FACILITY

- Concrete frame buildings were heavily damaged
- A steel frame building suffered buckled braces and buckled column flanges
- Liquefaction and several large sand boils were observed
- The tsunami undermined two large transmission towers and displaced fence poles and a railroad track several feet
- An overhead cable tray/piping frame bridge shifted, damaging a cable tray due to anchor point movement
- Ground slumping alongside a channel damaged adjacent structures

KEY FINDINGS

- Heavily loaded, multiple tier cable trays in a damaged cable spreading building were undamaged.
- The large sand boils suggest high MMIs.
- During the brief investigation performed, many modern items of equipment were observed.

M 8.1 Mexico Earthquake of September 19, 1985
Data Base Site: COPSA CEMENT PLANT

FACILITY

- Modern cement production facility
- Soil site

GROUND MOTION

- Nearby recorded average PGA 0.24g on similar soil
- 25 miles from epicenter
- Adjacent to SICARTSA steel mill and Lazaro Cardenas where MMI = IX

SEISMIC DESIGN CRITERIA

- Seismic loading probably considered in design
- Most equipment well anchored

COPSA CEMENT PLANT, cont.

This new plant contains modern equipment, installations and structures. It was in an area of high intensity motion and sustained considerable damage.

MOST IMPORTANT EARTHQUAKE EFFECTS AT FACILITY

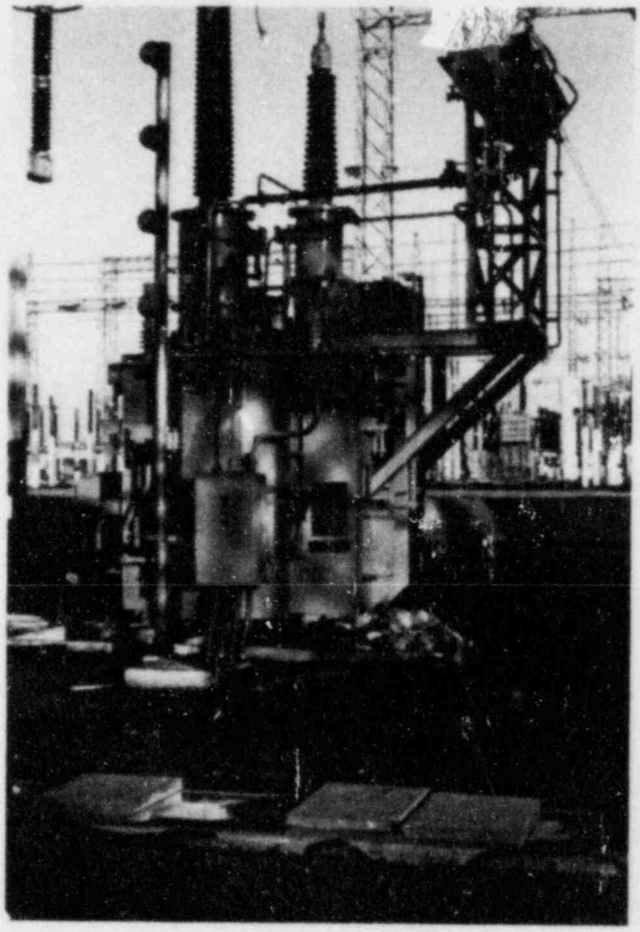
- A steel silo full of cement suffered total collapse. The silo collapsed onto an attached 4-story control building and caused its collapse
- Railroad tracks at the facility were buckled

KEY FINDINGS

- The plant contains modern equipment and installations.

M 8.1 Mexico Earthquake of September 19, 1985

Data Base Site: LAZARO CARDENAS SUBSTATION



FACILITY

- New main 400 kV switching station for La Villita and El Infiernillo power plant
- Will be substation for new 1000 mW thermoelectric power plant under construction

GROUND MOTION

- Recorded PGA 0.24g
- 25 miles from epicenter

SEISMIC DESIGN CRITERIA

- Designed to Modern CFE Code

LAZARO CARDENAS SUBSTATION, cont.

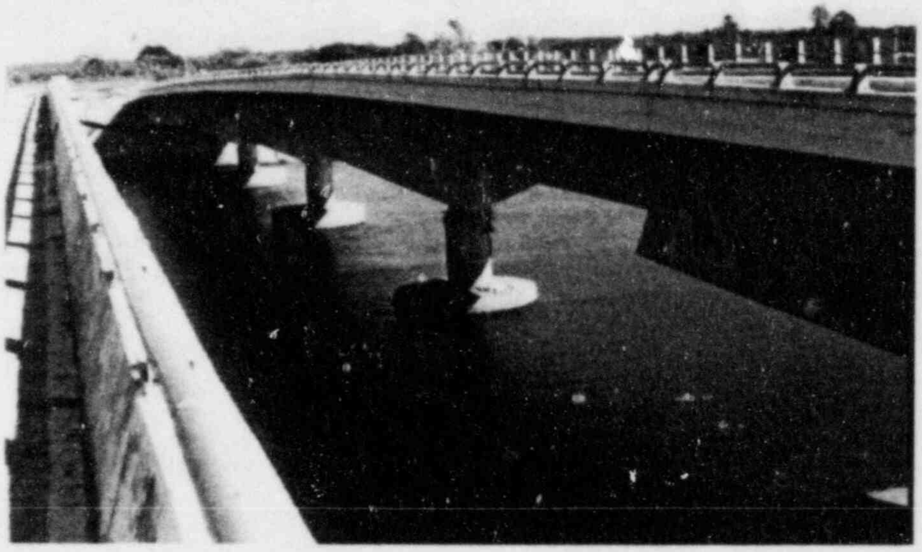
The recently completed substation experienced ground motion similar to an NRC Regulatory Guide 1.60 spectrum scaled to 0.25g, with no severe damage.

MOST IMPORTANT EARTHQUAKE EFFECTS AND KEY FINDINGS

- Three ceramic insulator poles for disconnector structures failed
- A large high voltage transformer slid about one inch, bending attached conduit
- There was no damage to any of the well anchored, modern electrical cabinets
- There was no damage to the emergency diesel generator
- There was no damage to cables. Cables are not installed in cable trays; cables are hung directly on support brackets

M 8.1 Mexico Earthquake of September 19, 1985

Data Base Site: LAZARO CARDENAS INDUSTRIAL PORT



FACILITIES

- Major port facility and container handling facility
- Includes large silo complex
- Nearby is a large Coca-Cola bottling facility
- Constructed on river basin sediments

GROUND MOTION

- Recorded average PGA 0.24g
- 25 miles from epicenter
- MMI = IX in Lazaro Cardenas
- Significant observed damage at port facility

SEISMIC DESIGN CRITERIA

- Seismic loading probably considered in design

LAZARO CARDENAS INDUSTRIAL PORT, cont.

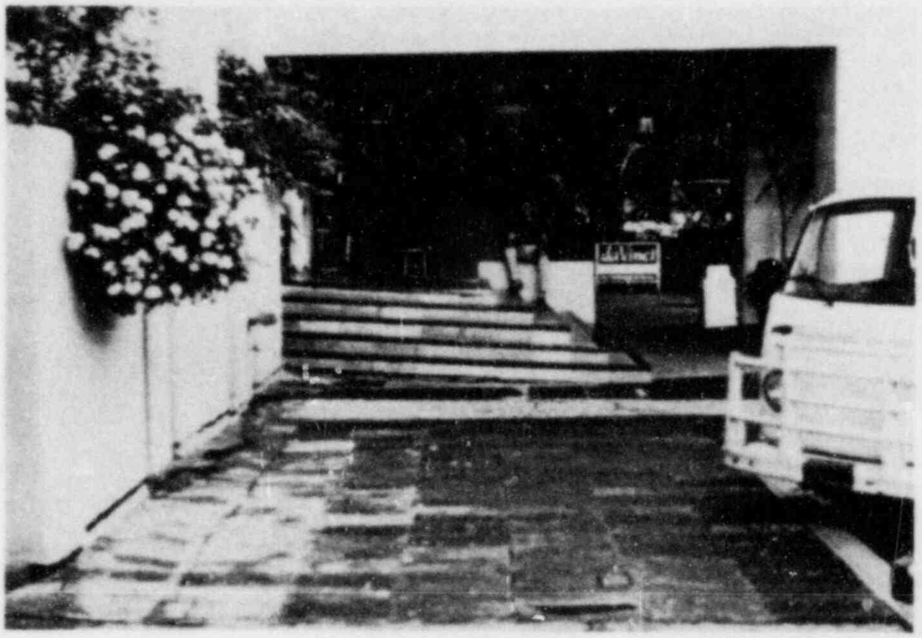
There was severe damage observed at the port and in Lazaro Cardenas. The port facility and adjacent industry include large steel buildings, several hundred feet long.

MOST IMPORTANT EARTHQUAKE DAMAGE AND KEY FINDINGS

- Partially collapsed four-story building atop a large concrete silo structure
- Severely damage highway bridge
- Overturned steel silo
- Damaged dock and cranes at port facility
- Partially collapsed large sign on steel frame in front of bottling facility
- Collapsed and severely damaged buildings (one in four) in town of Lazaro Cardenas
- Damaged hospital in Lazaro Cardenas

M 8.1 Mexico Earthquake of September 19, 1985

Data Base Site: IXTAPA RESORT TOWN



FACILITIES

- Includes about 12 modern 5- to 15-story hotel buildings
- Most structures constructed on deep pile foundations

GROUND MOTION

- About 5 miles from epicenter of aftershock
- About 75 miles from epicenter of main event
- It was reported that the aftershock caused the majority of the damage

SEISMIC DESIGN CRITERIA

- Most buildings constructed in the 1970s
- Some damaged in previous earthquake; only cosmetically repaired

IXTAPA RESORT TOWN, cont.

All of the 12 modern high-rise structures were significantly damaged; only two remained open. Most of the damage was caused by the aftershock.

MOST IMPORTANT EARTHQUAKE EFFECTS AND KEY FINDINGS

- Every one of the reinforced concrete frame structures was significantly damaged
- Some structural damage but mostly heavy architectural damage: only two hotels remained open
- The hotels that remained open had extremely limited service; service was limited to lower floors
- Ground settlement of two to five inches observed around structures
- Most heavily damaged structures had been similarly damaged in previous earthquake (1978/79)
- Many simple one-story dwellings of timber and adobe, with thatched or clay tile roof, were undamaged

M 8.1 Mexico Earthquake of September 19, 1985

Data Base Site: DOWNTOWN MEXICO CITY

FACILITIES

- Many hospitals and an old substation were in the severely affected area
- All damaged buildings were constructed on the filled Texcoco Lake

GROUND MOTION

- Mexico City was hit with a 0.5Hz frequency wave, at PGA = 0.01 to 0.04g
- Amplified by resonance with infilled lake to 0.17g PGA, and spectral peaks of 1.0g for 0.5Hz at 5% damping.

SEISMIC CRITERIA

- Buildings range from over 200 years old to modern
- Latest (1976) Building Code requirement (static) is 0.12g

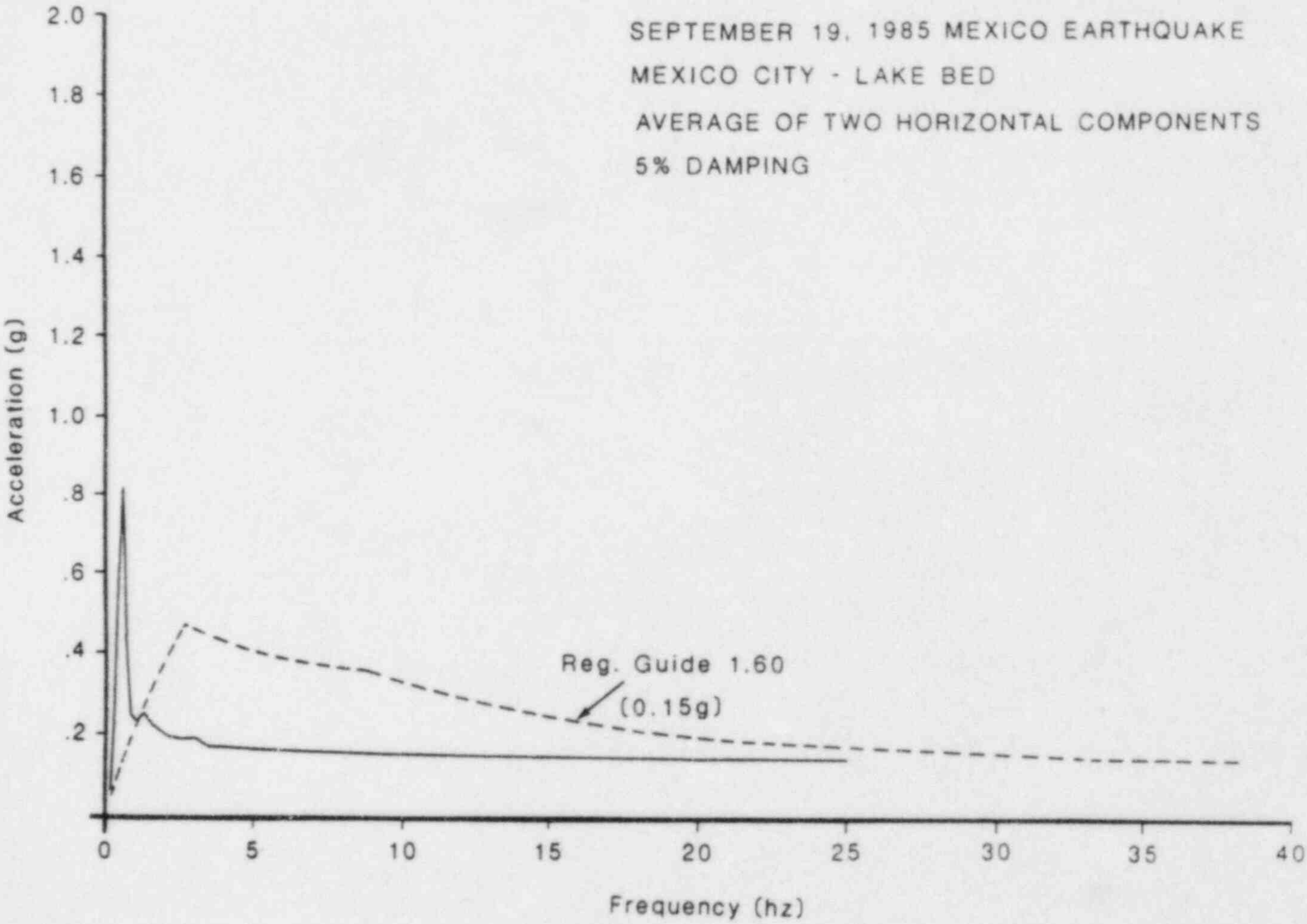
MEXICO CITY, cont.

The disaster in Mexico City illustrates the need for building design to consider local soil conditions. It also illustrates the critical importance of detailing for reinforced concrete frame structures.

MOST IMPORTANT EARTHQUAKE DAMAGE AND KEY FINDINGS:

- Mexico City is 250 miles from the epicenter
- Over 400 buildings collapsed or were seriously damaged
- Most damaged buildings experienced a double resonance situation of soil with motion and building with soil at very low frequencies (less than 0.8Hz)
- Collapsed buildings damaged power distribution lines
- There were over 5000 breaks in the city's asbestos-cement water pipes
- There were no major industrial facilities or power plants in the affected area

THE MEXICO CITY LAKE BED RESPONSE SPECTRA CLEARLY ILLUSTRATES THE 0.5Hz RESONANCE EFFECTS. THE GROUND MOTION CLOSELY RESEMBLED A 0.5Hz SINE WAVE



SUMMARY

- The investigated earthquakes are major events with high accelerations and very long durations. The inventory of facilities affected contributes substantially to the SQUG data base

- The conclusion that equipment is rugged, reached by SQUG and the NRC prior to the earthquakes, was reinforced
  - No equipment malfunctioned with the exception of protective relays
  - Certain tanks are vulnerable

- Equivalent static coeffecient design for ~~most~~ seismic loads of most components and structures of nuclear plants is adequate

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SUMMARY OF THE MARCH 3, 1985 CHILE EARTHQUAKE

EQE INCORPORATED / 121 SECOND STREET / SAN FRANCISCO, CA 94105 / (415) 495-5500 TELEX 296166

SUMMARY OF THE MARCH 3, 1985
CHILE EARTHQUAKE

August 1985

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EQE Incorporated is a San Francisco based firm specializing in earthquake engineering and emergency preparedness planning for business and industry.

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I. INTRODUCTION

On Sunday, March 3, 1985, at approximately 7:45 p.m., local time, a destructive earthquake with a Richter magnitude of 7.8 (M7.8) struck 20 miles offshore of central Chile. The earthquake affected approximately 20,000 square miles of the mainland. This area has a population of over 6 million people and includes the capital city of Santiago. Over the next 18 days, more than 2,000 aftershocks, many of which caused further damage, were recorded. On April 9, an M7.2 aftershock struck the same region. It was predicted that aftershocks will continue for more than four years. Preliminary estimates of the effects of the initial earthquake and its aftershocks listed the number of dead at 180, serious injuries at over 2,500, and dwellings destroyed at 45,000. The total economic loss is estimated at $1.8 billion.

In 1965 and 1971, two earthquakes of similar size struck the same region. Since 1906, 12 earthquakes of M7.5 or greater have occurred in Chile. Over this time period, California has experienced only two earthquakes of comparable magnitude, including the great San Francisco earthquake of 1906 (M8.3). Two recent destructive earthquakes in California occurred in 1983 at Coalinga (M6.5) and in 1984 at Morgan Hill (M6.2). The record clearly indicates that seismic activity is both more frequent and more intense in Chile than it is in California.

After an earthquake, the media tends to report the most severe damage to the general public. The conclusion that total devastation occurred throughout the affected area is usually and erroneously drawn. In the recent Chile earthquake, even the hardest hit areas, such as San Antonio (Figure 1), did not suffer total damage. Few modern structures collapsed totally, although many instances of severe damage were observed. A major portion the damage involved older structures that were not earthquake resistant. The good performance of a majority of the modern buildings indicates that well designed and constructed structures can perform successfully in a major earthquake.

On March 7, three EQE engineers traveled to Chile to survey the effects of the earthquake on the people, the structures, and the country as a whole. A second team of four engineers returned to Chile in May 1985 to collect more detailed data. During the two trips, over 30 sites were visited and over 5000 photographs taken. This report is a brief summary of our observations.

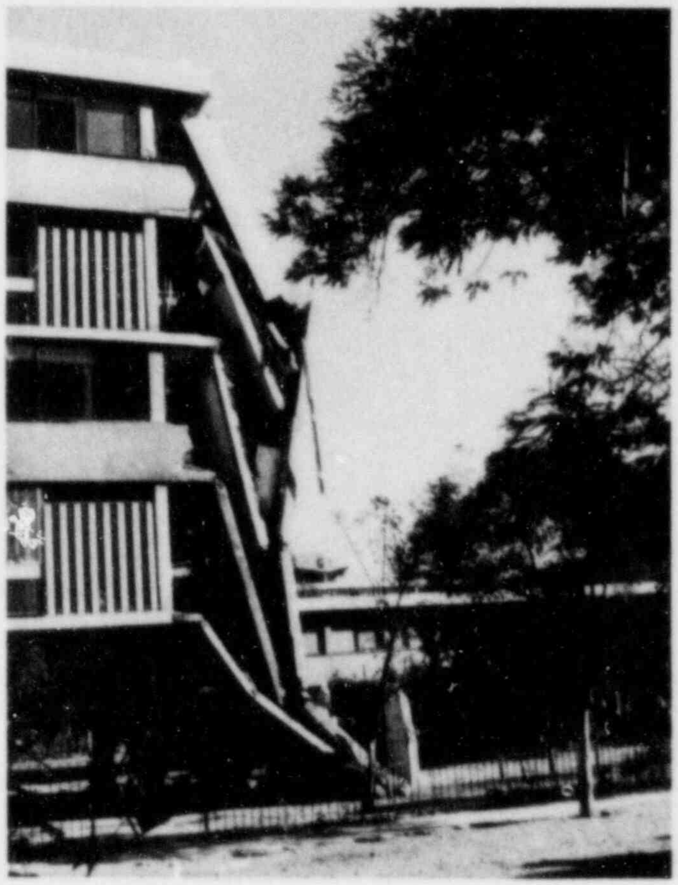
II. COMMERCIAL AND RESIDENTIAL BUILDINGS

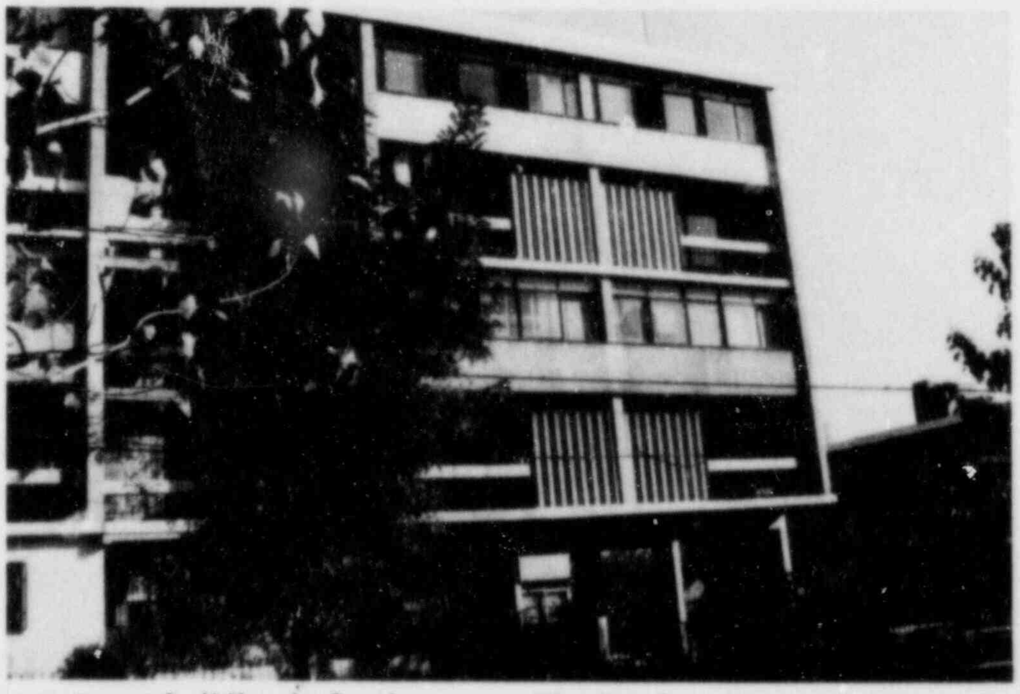
Much modern construction in Chile adheres to the same principles of good engineering followed in California. As a result, the overall performance of the newer Chilean structures was favorable, and only a few are known to have collapsed. Many others, however, sustained serious structural damage and represent large economic losses.

The extent and severity of damage to modern structures was unexpected. Investigations attributed failures to poor construction practices, deficient seismic detailing, poor conceptual designs, and inadequate engineering inspections during construction. Poorly prepared concrete joints were the most common construction error observed. Existing concrete surfaces were often smooth and littered when new concrete was poured over them. As a result, the new concrete did not bond properly with the old; the weak joints led to failures. Proper inspection by qualified engineers during construction could have eliminated such problems.

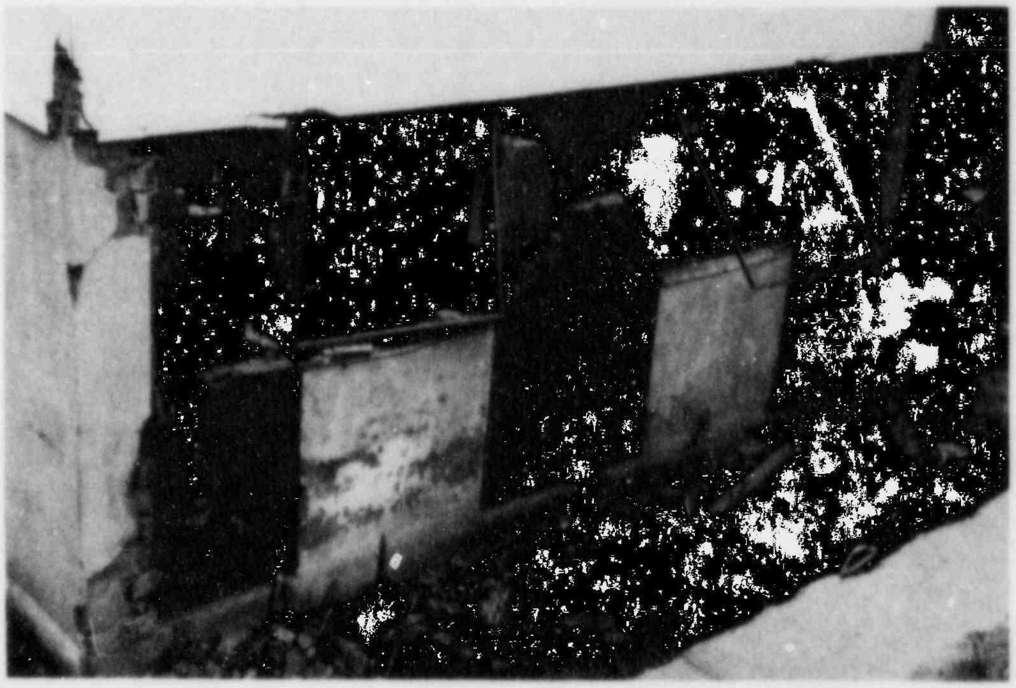
Much of the worst damage was suffered by structures which had been only superficially repaired following the 1965 and 1971 earthquakes. For example, cracks in walls had only been covered by plaster and paint or some other architectural finish. Following the recent earthquake, repair to some of these structures became impossible or impractical, forcing demolition.

Most residential structures which collapsed were built of adobe or unreinforced masonry. The structural elements in such buildings cannot be tied together, and it was expected that general failure would occur during a large earthquake. There were only a few significantly damaged wood-framed houses. Fortunately the earthquake struck on the evening of the last Sunday of summer. The downtown areas were empty and many families were in parks instead of their homes. Also, the main earthquake was preceded by a sizable foreshock. This lasted about ten seconds, giving many people the time to evacuate their homes before the very strong shaking started.

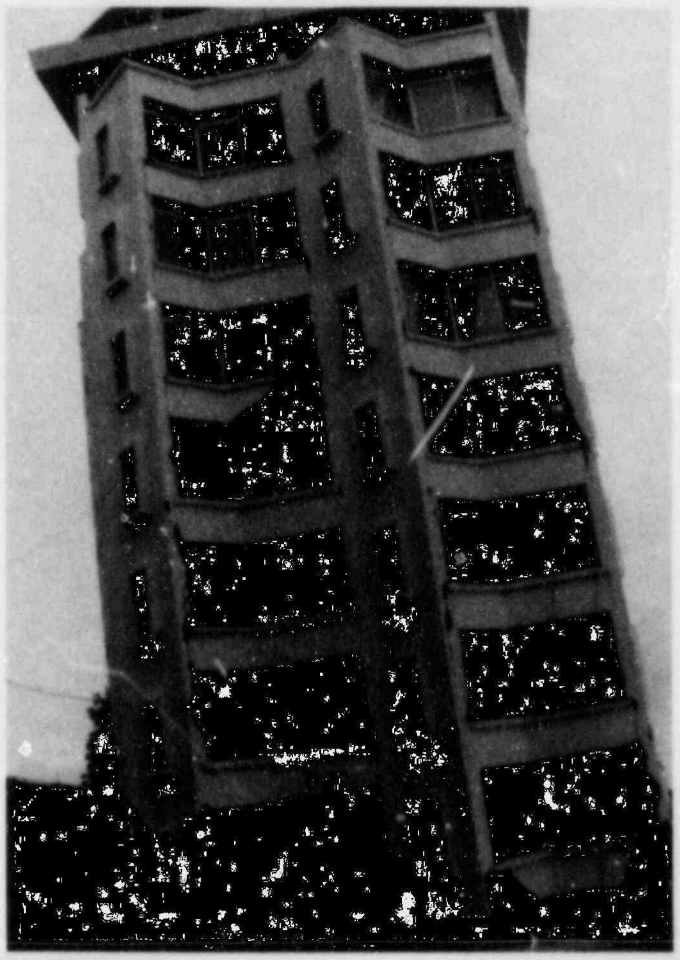




One apartment building in Santiago, over 70 miles from the earthquake epicenter, experienced a partial collapse. The continuous concrete shear walls of the upper stories of these two similar buildings are not continued down to the ground. This created a weak or soft story at ground level which caused the partial collapse of one of the walls.



Many low-rise apartment buildings with reinforced concrete shear walls and frames with masonry infill were severely damaged. The four-story and five-story Canal Beagle apartments in the coastal town of Viña del Mar were damaged and abandoned by approximately 500 families. The buildings follow a standard design utilized throughout Chile. The severity of the damage was unexpected. The apartments are located on the steep slopes of two ridges, and the angles and heights of these sites amplified the ground motions. At the base of one ridge, two buildings identical to the badly damaged buildings suffered little damage.



The El Faro apartment building, located north of the coastal city of Viña del Mar, was badly damaged when the ground floor collapsed. The building was condemned and demolished a few days after the earthquake. A poor conceptual design and construction problems contributed to the collapse. Soil failures were noted in the surrounding area. The same area was heavily damaged in previous earthquakes. Note several lightly damaged or undamaged buildings in the lower photograph.

The "Gold Coast" of the resort city of Viña del Mar has many modern high rise buildings of reinforced concrete, which were generally designed to requirements similar to California building codes. For large magnitude earthquakes, building codes are mainly written to prevent injury, not structural damage. In general, the buildings in Vina del Mar performed well. The Hanga Roa apartment building (above) sustained significant damage. This is partly attributable to its irregular geometry which resulted in additional stress during the earthquake. A large chimney of reinforced concrete on top of the structure was not adequately anchored to the roof and fell 15 stories to the ground. It damaged a beam at the top of the building (see photograph) and the building entryway before embedding itself in the ground.

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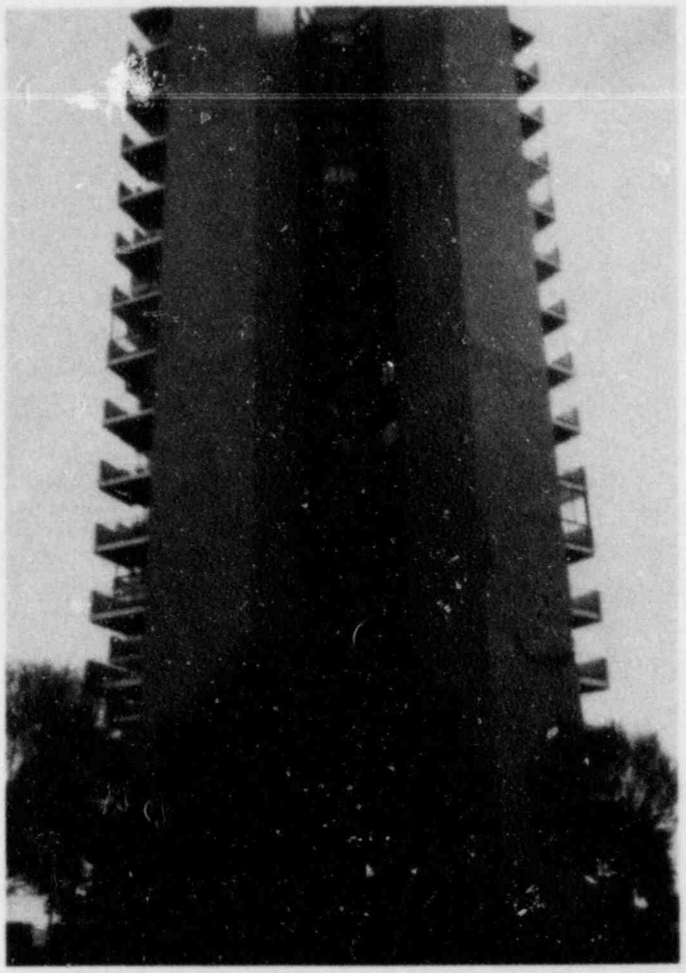
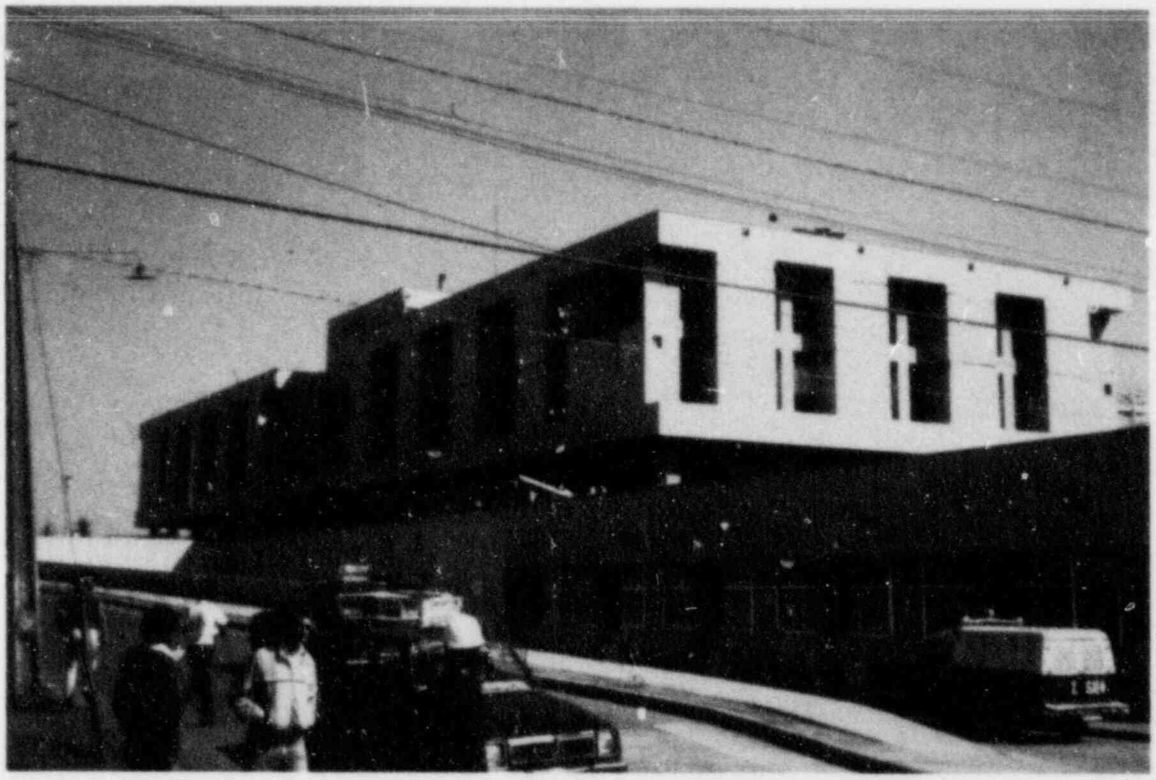
One concrete shear wall in the Hanga Roa apartment building sustained a crack approximately 1 foot wide that extends the full height of the building. The tenants inside were subjected to violent motions and the contents of their apartments were thrown onto the floor. Some of the doors jammed shut and power in the building was lost. The building was evacuated as of June 1985.



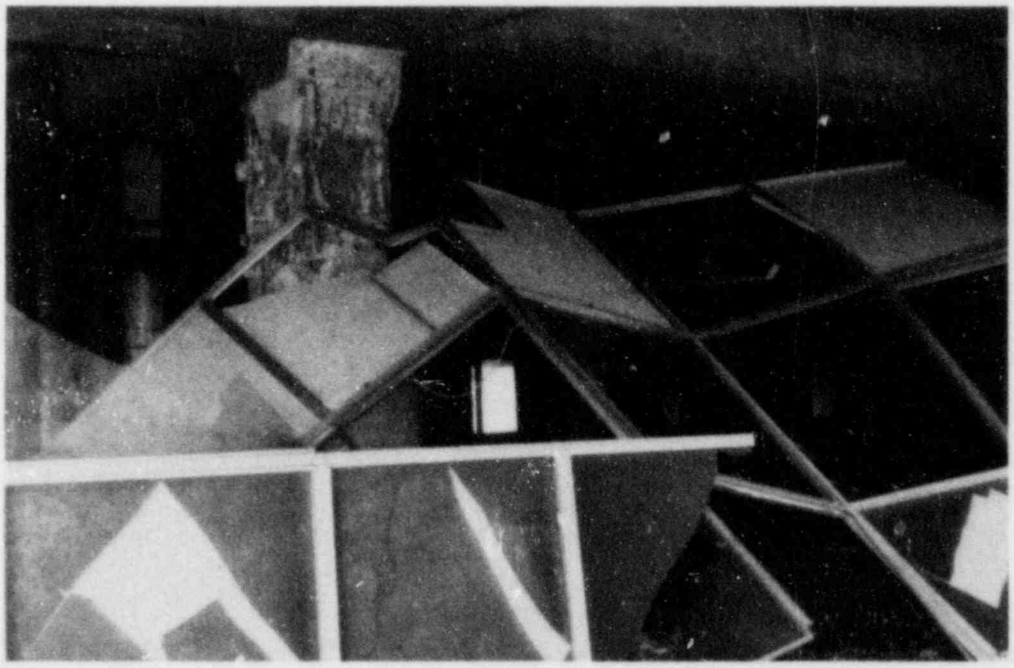
The 15-story Acapulco apartment building, adjacent to the Hanga Roa, was also severely damaged. The shear wall on the east side of the building cracked, exposing buckled reinforcing steel. Damaged interior walls revealed damage from previous earthquakes that had not been properly repaired. This building was evacuated after the earthquake, but will be repaired.

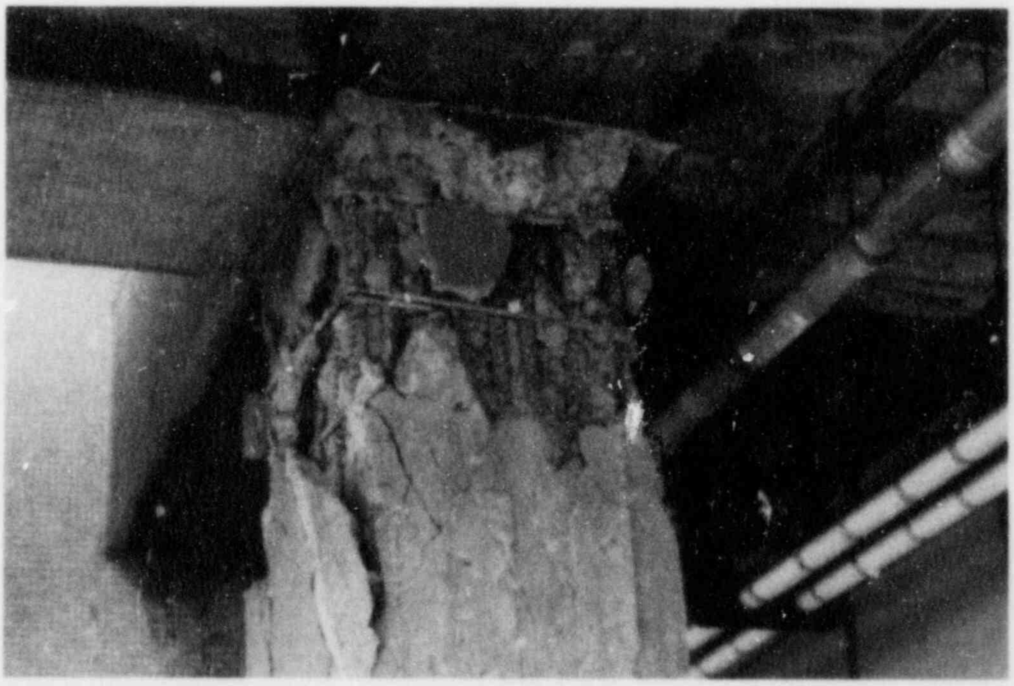
The buildings on the landfill area of Valparaiso were particularly hard hit. These high-rise apartment buildings were damaged, but not abandoned. The concrete spandrel beams were extensively cracked and many of the windows were broken. Pounding between one of the buildings and a walkway connecting it to an adjacent building caused significant damage.

This six-story building in Valparaiso was also located in the landfill area near the port. Several concrete columns at the lower level were badly damaged. Due to a sloping terrain, these columns were shorter and, thus, stiffer than others at the same level. The shorter columns absorbed more lateral earthquake load than the more flexible taller columns and failed.

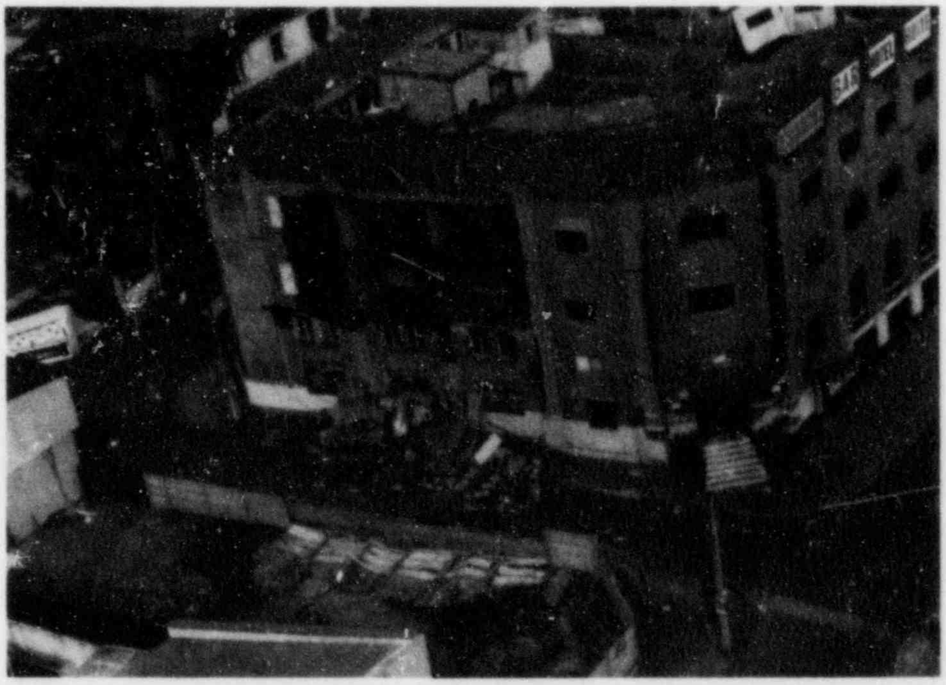


The Claudio Vicuna Hospital in San Antonio is located on a hill overlooking the port. It is a four-story concrete frame building with masonry infill panels between the frames. The panels are isolated from the concrete frames by seismic joints filled with styrofoam. This procedure is intended to minimize damage during an earthquake. However, the builders did not provide minimal connections between the infill and the frames to prevent the infill from falling. In one case a panel from the top floor fell to the ground



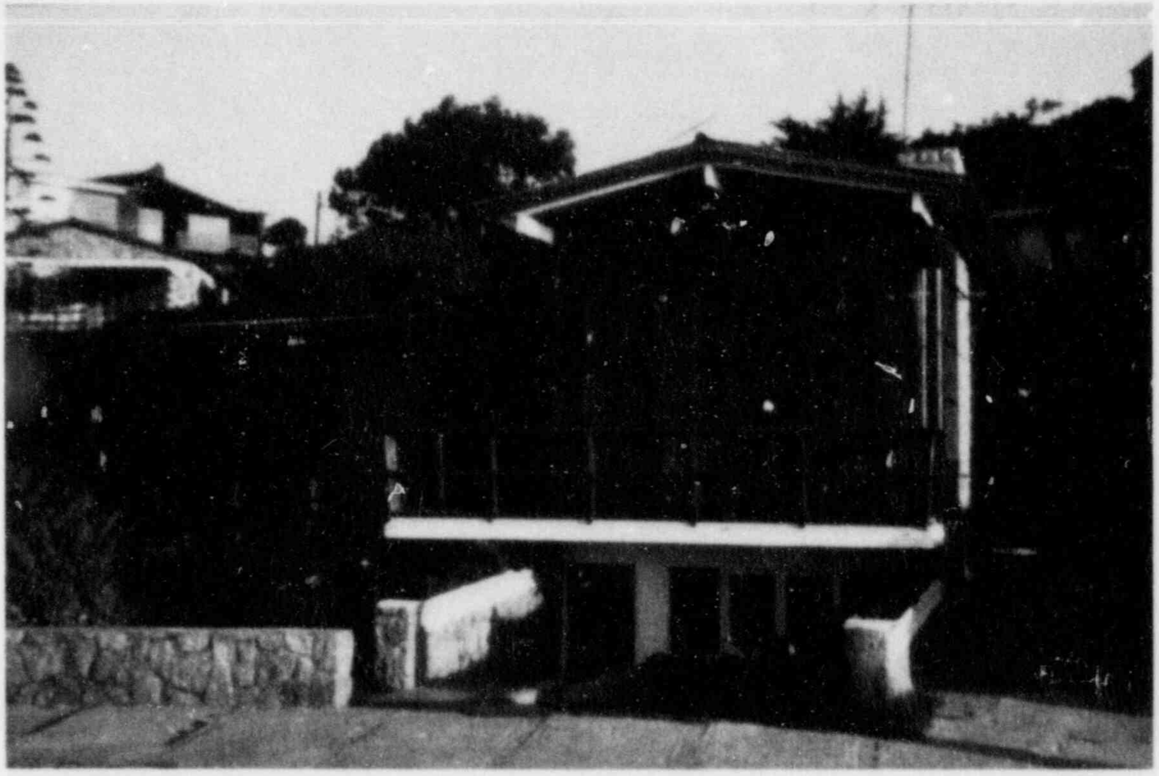


The Claudio Vicuna Hospital experienced large deformations because of its heavy construction and lack of shear walls. Though the damage seems quite severe, most is non-structural and probably repairable (upper photograph). Many concrete columns cracked or spalled, but the reinforcing steel and concrete within them appeared undamaged. The hospital was temporarily abandoned after the earthquake; the heavily damaged portion was still not in use in June.



As expected, older buildings sustained more damage than seismically designed newer buildings. The two buildings in San Antonio shown above were severely damaged and posed dangerous hazards. Hundreds of similar cases were observed throughout Chile.

A large number of the buildings that were damaged and subsequently abandoned were constructed of adobe and unreinforced masonry. These are the same types of buildings that were severely damaged in previous earthquakes, particularly in 1939 when over 40,000 people were killed. The main problem with these types of construction is the difficulty of tying together the floors and walls.



Newer houses of wood, reinforced masonry, and reinforced concrete generally performed well. The house shown in the upper photograph is situated in Algarrobo (between San Antonio and Valparaiso). The second house is masonry and is located across the street from the severely damaged Canal Beagle apartment buildings in Viña del Mar. It and others like it in the area were apparently only lightly damaged.

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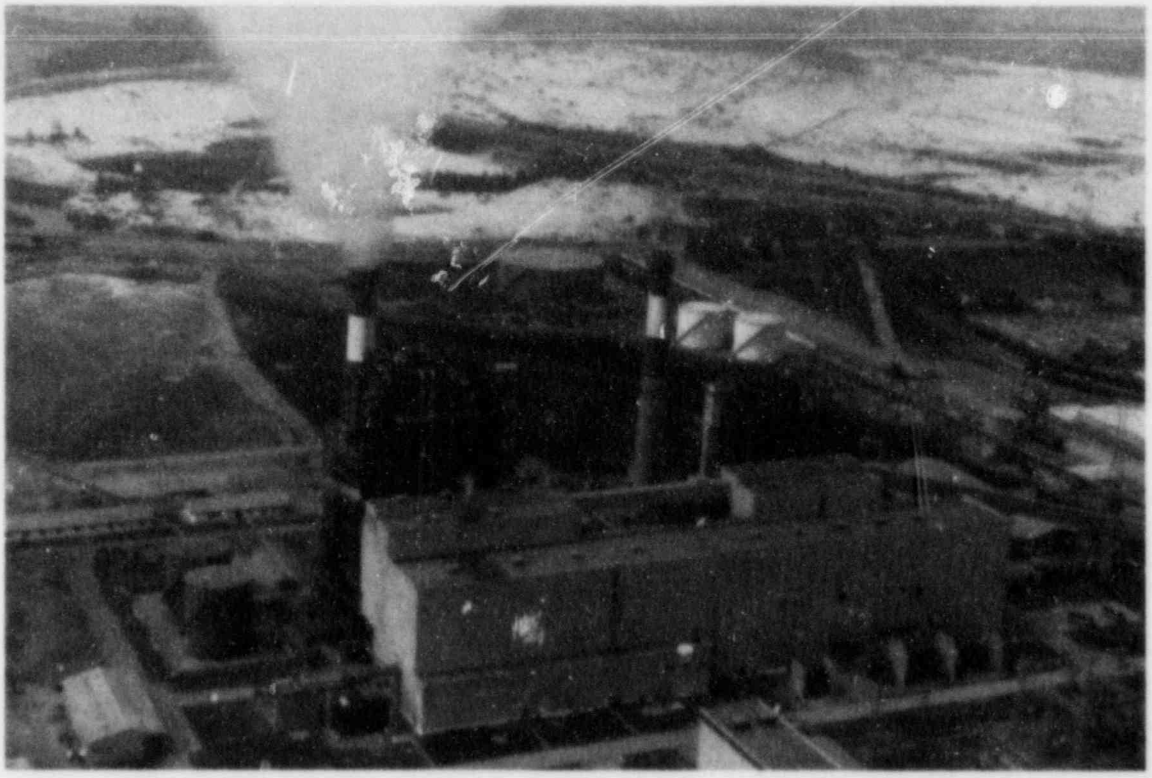
III. INDUSTRIAL FACILITIES

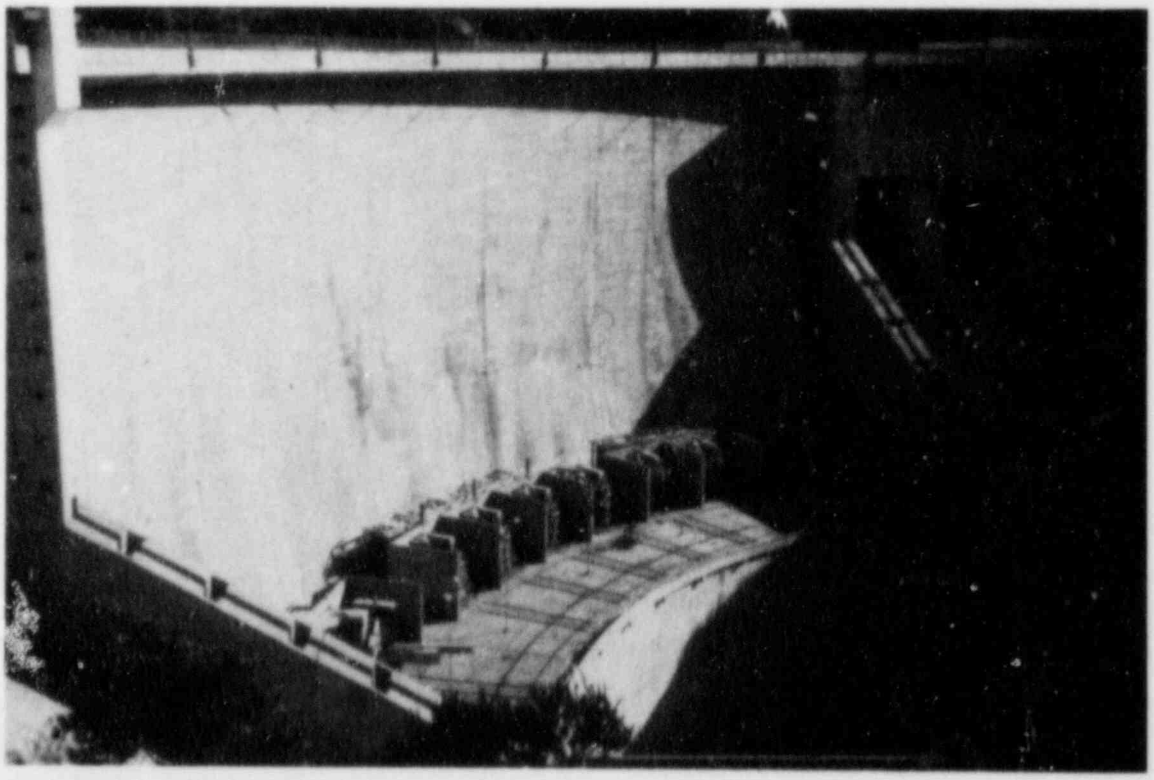
Major industrial facilities in Chile (oil and gas facilities, power plants, etc.) are usually designed with seismic resistant features. Many of the facilities visited by EQE personnel were designed to seismic criteria that are higher than code requirements in California. In almost all cases the inspected Chilean facilities experienced little or no damage of consequence and were back in operation shortly after the earthquake. The good performance of industrial facilities was noted in previous Chile earthquakes.

These facilities typically comprise large, structural steel structures. Because they are flexible and light-weight, steel-frame structures are able to experience extreme earthquake loads without damage. The equipment at these facilities was well anchored (unlike the usual practice in California) and, despite the large motions, little damage was experienced. Properly anchored equipment, such as large transformers, pumps and electrical cabinets, continued operating after the earthquake.

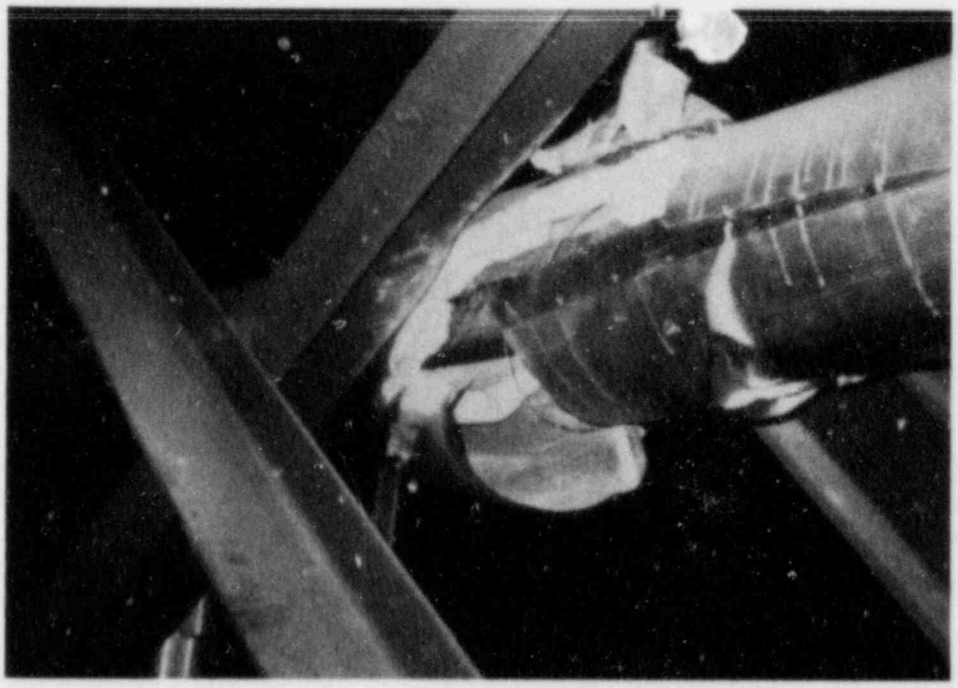
Flexible piping often experienced violent motions and impacted structural elements. Damage, however, was usually limited to pipes which were corroded or pipes which were anchored at two locations that experienced large relative displacements.

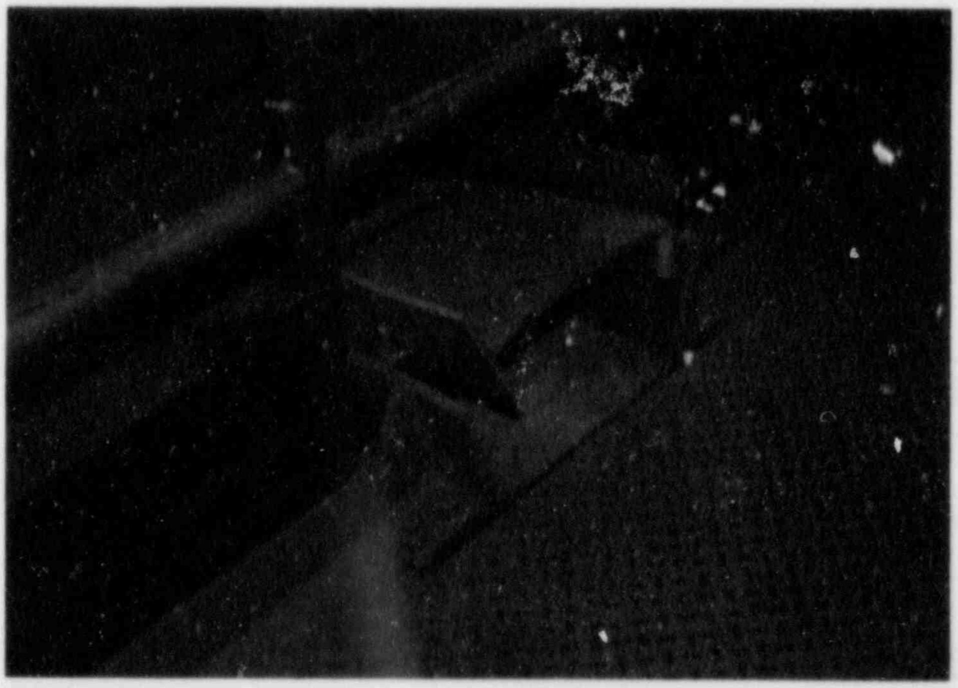
A major exception to the good performance of industrial facilities was the damage to large vertical storage tanks. An average of 10 to 15 percent of tanks failed, often losing their contents. The failures seriously affected facility operations and resulted in large financial losses. Ground failures leading to damage were also common in industrial facilities. Several facilities suffered extensive business interruptions.





Power facilities performed well because of their earthquake resistant designs. The coal fired plants at Las Ventanas (upper photograph), Laguna Verde and Renca (suburb of Santiago), and the hydroelectric plant at Rapel (lower photograph) sustained only minor to moderate damage. These plants began to re-supply power to the region a few hours after the earthquake.





Buildings at power plants are generally large, well designed steel structures. Usually such structures and their interior piping are very flexible and can experience large motions without damage. Piping insulation is often damaged from repeated impacts with adjacent structural elements (see above), but the pipes themselves are rarely damaged. Coal fuel is commonly burned in a large, heavy boiler suspended by rods from the top of a structure which can be up to 150 feet tall. The boilers are allowed to move to prevent high stresses from developing from radical temperature changes during operation. Lateral restraints are often badly deformed during earthquakes (see above), but succeed in protecting the boiler.

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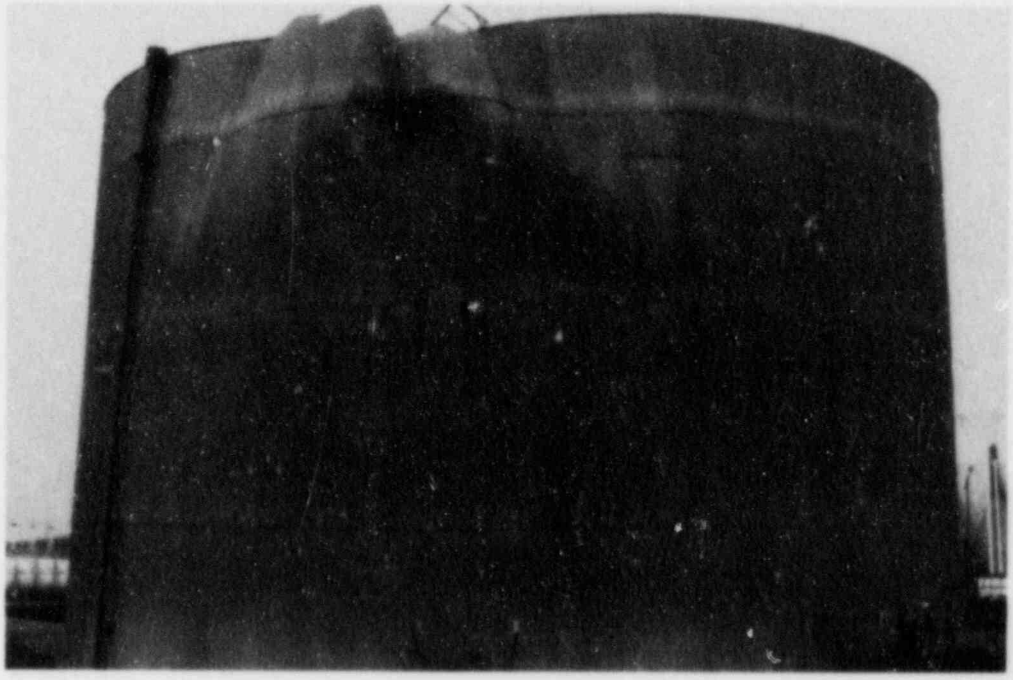
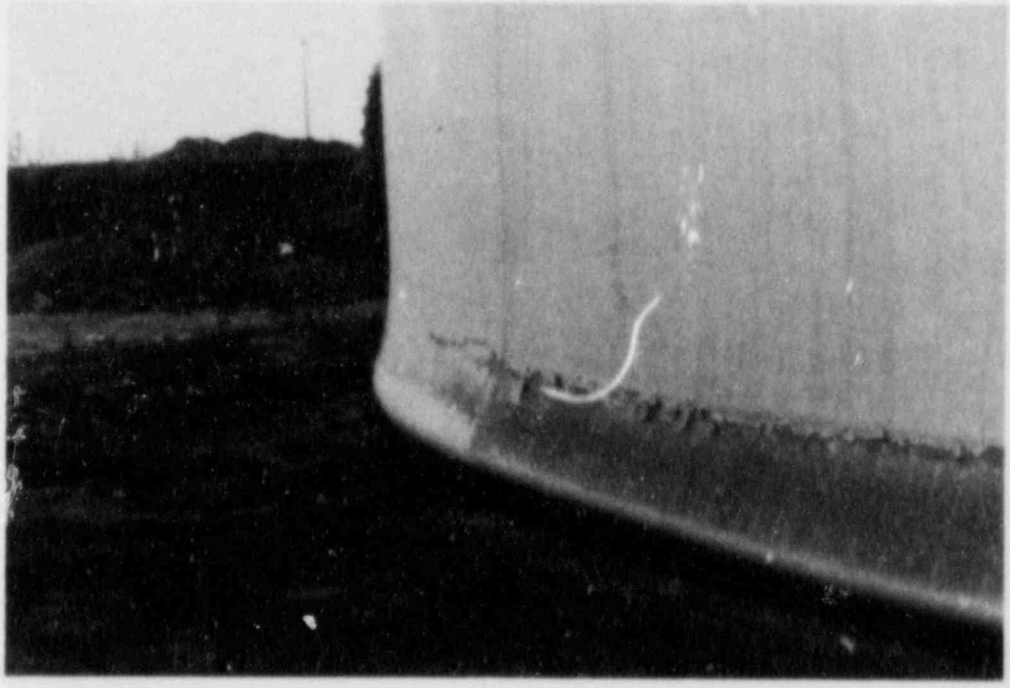
A large petroleum refinery at Con Con includes a boiler plant, many steel columns, long piping runs, equipment, and storage and distribution facilities, including nearly 200 large steel tanks. Except for the large vertical tanks, the plant performed well. Some of the older masonry shop buildings were damaged. The Administration complex (lower photograph) is a series of light one-story steel-frame structures, connected by glass enclosed corridors. No damage to the complex was noted.





The Con Con petroleum refinery sustained severe damage to 12 of 100+ unanchored vertical storage tanks. Some of the tanks collapsed from suction created by the contents emptying quickly through holes opened near the bases of the tanks during the earthquake (top photograph). "Elephant foot" buckling at the base of a tank wall is a common type failure (bottom photo).

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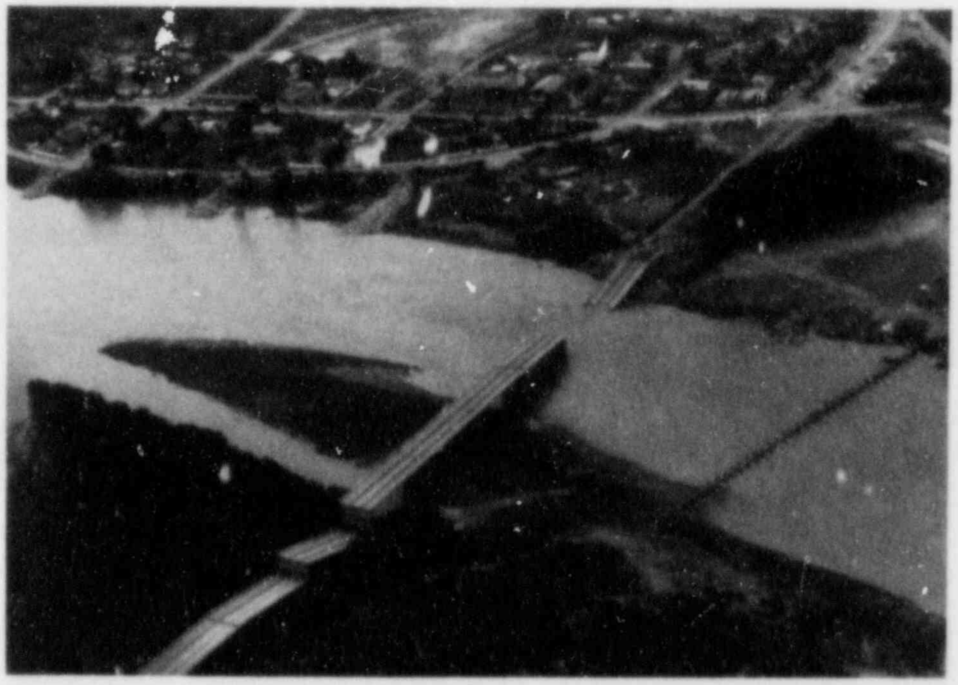
IV. SOIL AND FOUNDATION-RELATED DAMAGE

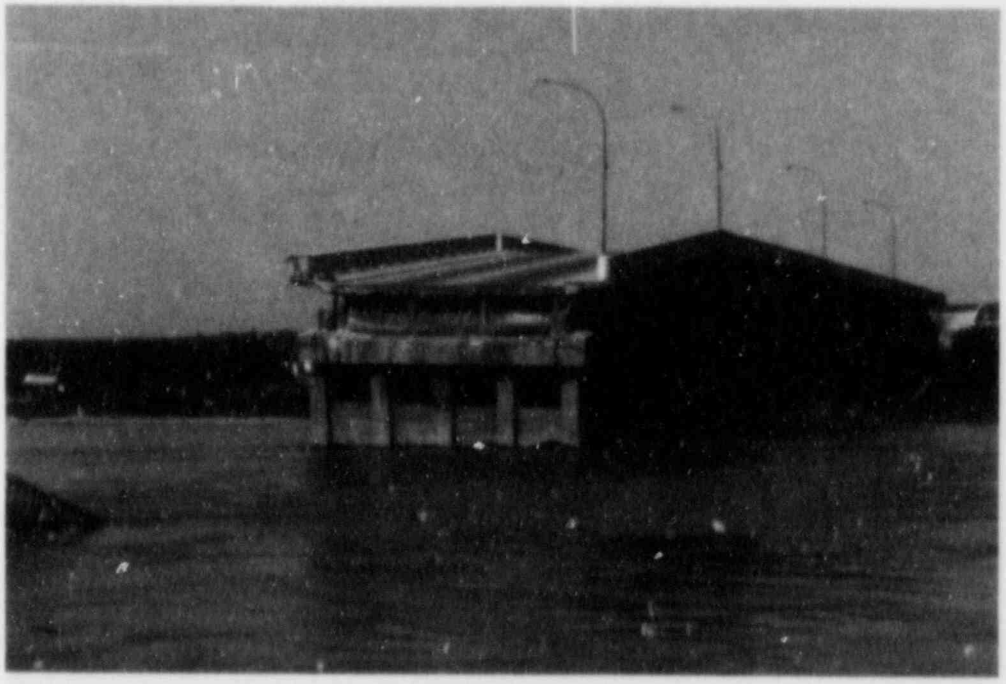
Numerous instances of structures experiencing damage directly related to soil or foundation failures were noted. The most spectacular examples were at the ports of San Antonio and Valparaiso, and at a bridge south of San Antonio.

At the ports, large ship-loading cranes were heavily damaged as a result of liquefaction (the phenomenon in which ground shaking produces a quicksand effect in loose, sandy soils). The cranes overturned or were locked in position. Large storage tanks on landfill areas near ports and buildings were also affected. Port areas in California, as well as buildings built on soft soils or landfill, may experience similar damage during earthquakes.

A large flood during the previous year washed away much of the soil at the footings of the bridge near San Antonio and exposed the pile supporting the bridge piers. No repairs were made. During the earthquake, the weakened piers moved and the bridge collapsed.

Less spectacular but more common soil failures caused heavy damage to structures which were otherwise seismically sound. Slope failure caused houses and a transmission tower to slide downhill. Roads were temporarily closed due to numerous small landslides and collapsed embankments constructed with poor fill. Many underground pipes were damaged under heavy settlement or from ground deformation. Such damage points out the importance of site selection and the need for site specific design criteria.





South of San Antonio, several spans of a bridge over the Maipo River fell as a result of foundation movement. The foundation had been weakened from scouring of the river bottom during a flood in 1984. One of the bridge piers actually toppled and was submerged in the water. The spans are simply supported on the piers and have no restraint against movement in the longitudinal direction. The same bridge sustained damage during the 1971 earthquake. The damage included lateral movement of its spans on its piers.

The main ports at San Antonio and Valparaiso experienced considerable settlement. Significant damage to these ports also occurred during the 1971 earthquake. In San Antonio, liquefaction was responsible for overturned cranes and the subsidence of a portion of the breakwater into the bay.

Six cranes were damaged and a seventh tilted because of soil movement at the port of San Antonio. Vertical soil settlements as much as 6 feet were observed. Lateral spreading of the soils occurred as a result of failed retaining walls. The railroad tracks leading into the port in the photograph above were originally straight.

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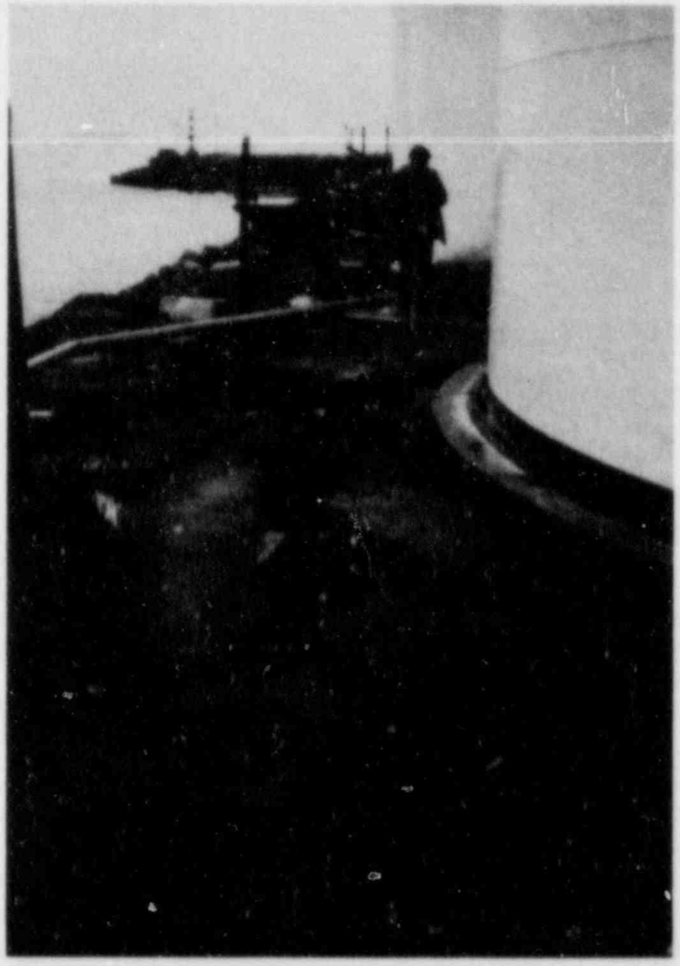

Just north of the port of San Antonio there was a spectacular soil failure beneath some storage tanks (top photograph). Large ground cracks 4 to 5 feet deep and 1 foot wide opened all around the tanks and cracks were observed as far as 20 feet from the tanks. In the port of Valparaiso, large vertical settlements and lateral spreading of soils were observed. The lateral spreading prevented the use of cranes for unloading ships.

The three-story concrete building looks undamaged from a distance. However, the columns for the building experienced differential settlement of approximately 1 foot. The building was abandoned and will most likely be demolished.

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V. EMERGENCY RESPONSE

The Chile earthquake affected more than 6 million people in an area of approximately 20,000 square miles. Many facilities and systems necessary to respond to the emergency were damaged during the initial shock.

The water system was the lifeline most seriously affected. Immediately after the earthquake, power losses at pumping stations disrupted water distribution. Damaged underground pipes and aqueducts disrupted the water supply to sections of coastal cities for 15 days or more. Fortunately, the few fires that occurred were extinguished by using hilltop emergency storage tanks with independent distribution systems or by pumping sea water through hose grids with diesel pumps. During the shortage periods, water was delivered to the affected areas by fire or tank trucks.

The whole region lost utility power immediately after the earthquake. Power was restored to some areas within a few hours and to most users within three or four days. The national electric company utilized power sources outside the region to reestablish the system. In some cases, power restoration was delayed because replacements for damaged plant parts were unavailable. Emergency generators at many industrial facilities, power plants, and hospitals allowed operations to continue at reduced levels.

Hospitals performed poorly. Such facilities are crucial after a major earthquake and should be designed to remain operable. Twenty-two of seventy-nine hospitals were severely damaged. Fourteen percent of all hospital beds were unavailable. People seriously injured in the earthquake and other patients in need of immediate care had to be transferred 80 miles to hospitals in Santiago. Other patients had to be moved to temporary shelters in churches and schools where medical care was provided. Local fire departments performed much of the patient relocation as well as search and rescue operations.

Apparently, no special seismic provisions are required in the design and construction of schools and many were damaged, some collapsed. Since it was Sunday, no injuries occurred. However, in many areas education will be disrupted while new facilities are built and new supplies obtained.

The telephone system generally responded well to the large volume of calls that followed the earthquake. In many areas service was temporarily unavailable where lines were overloaded, delaying connections for several hours. Hospitals, doctors, and some fire departments do not have priority lines and faced the same problems the general public did.

Considering the widespread destruction, the number of human casualties was quite low. Foreshocks, which had been occurring for over a month, heightened public awareness and preparedness. The large foreshock approximately ten seconds before the main shock may have saved many lives. Research has indicated that most injuries were the result of falling non-structural items or inappropriate occupant action. Many individuals, including a woman who fell down stairs while running from a building, were injured in buildings that sustained no structural damage. After the earthquake, most people responded calmly, reflecting their frequent experiences with seismic activity.

There were relatively few fires as a result of the earthquake. Chilean buildings designed of masonry and adobe are more fire resistant than the wood houses built in the United States. Few industries were operating at the time of the earthquake, so few industrial fires were experienced. As power was lost, few electrical fires resulted. Chemical fires were the most common type observed.

Strong local initiatives provided temporary tent housing, food and supplies. Funds raised through television shows were used to purchase supplies, some of which were distributed within a week of the earthquake.

The national government responded immediately by extending the usual curfew and stationing soldiers in commercial areas to prevent looting. However, a national recession and a large foreign debt made large amounts of government funds unavailable. Eventually, assistance was sought and some was received from other countries. But because of the low death toll, the earthquake was downplayed by the foreign press, hence slowing international response.

The Chilean government's approach to the long range problems created by the earthquake has also been slow in developing. Two weeks after the earthquake 375,000 people were homeless. Six weeks later, between 90,000 and 100,000 people were still without homes. Only a small percentage of these people utilized public shelters. As winter arrives, an increased death rate, especially among children and the elderly, is expected. The earthquake's "low" death toll will thus be raised.

In summary, the rapid and comprehensive short-term emergency response is inadequate to the reality of long-term emotional and physical recovery. Among many questions that need to be answered, the following are prominent:

- How will the homeless be housed?
- How will children and the elderly be provided with food and proper medical attention?
- How will homeowners and industry finance rebuilding and an economic recovery?
- What role will the Chilean government play in the recovery process?

Based upon our study of 1985 Chile earthquake and similar earthquakes worldwide, we believe that many people and corporations in California are not prepared to recover emotionally or financially from an event of such magnitude. Few have planned short-term responses and fewer have made provisions to address long range problems. For large corporations, the greatest financial risk may be associated with long-term business interruptions.

The people and government responded rapidly to the most immediate needs created by the earthquake. Soldiers were brought in to prevent looting and the curfew hours were extended. An effort was made to educate the public concerning ways to respond to the earthquake and what type of structural damage is most hazardous. Repairs to damaged structures were in progress upon our arrival. Many people simply moved into tent communities near their damaged houses. When a bridge south of San Antonio collapsed, a temporary pedestrian bridge was quickly constructed.

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Water systems in several coastal cities failed. Fire trucks and rented tank trucks were used to make deliveries to portions of the city without water. Water storage tanks were distributed in some areas. Water service was interrupted for 15 days in most areas and for longer periods in others.

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SUMMARY OF THE SEPTEMBER 19, 1985 MEXICO EARTHQUAKE

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SUMMARY OF THE SEPTEMBER 19, 1985 MEXICO EARTHQUAKE

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San Francisco, California 94105

EQE Incorporated is a San Francisco based firm specializing in earthquake engineering and emergency preparedness planning for business and industry.

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CONTENTS

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1. INTRODUCTION

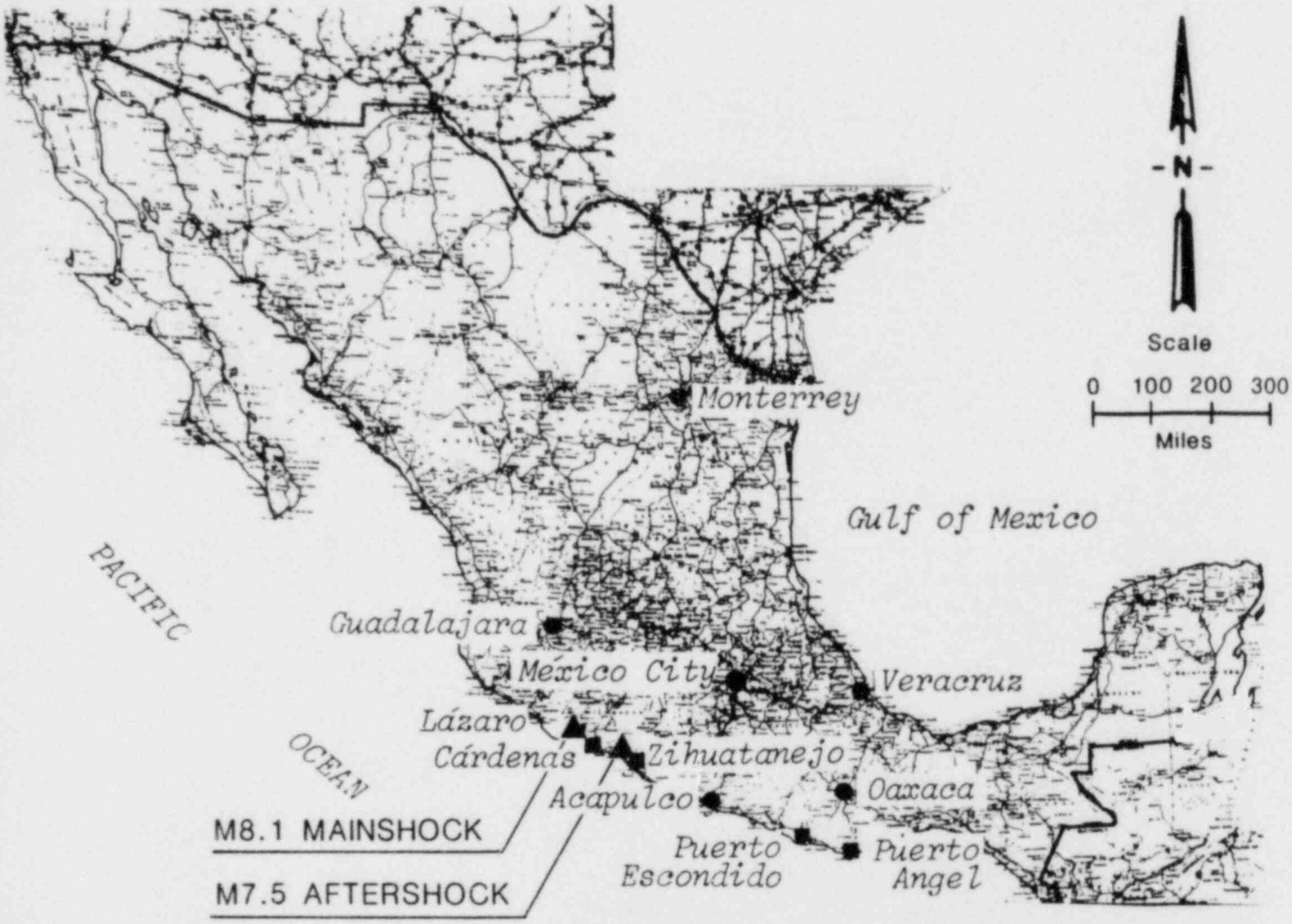
An earthquake of Richter magnitude 8.1 (M8.1) occurred in the state of Michoacan, Mexico on Thursday, September 19, 1985 at 7:18 a.m. local time. The epicenter was approximately 40 miles west of the El Infiernillo Dam on the Balsas River (map follows). On the next day, an aftershock of M7.5 struck approximately 70 miles to the southwest, 15 miles north of Zihuatenejo, in the state of Guerrero at 7:37 p.m. local time.

Early reports indicated extensive damage throughout Guerrero, widespread destruction in heavily populated Mexico City (over 200 miles from the epicenters), and noticeable movement in buildings as far away as Galveston, Texas. Two EQE investigation teams were immediately activated to survey the effects of the earthquake. One went to the epicentral region, the other to Mexico City. The first team arrived in Mexico only a few hours after the M7.5 aftershock.

Though the earthquake affected a large region, severe damage was limited to a few relatively small areas. In the Mexico City metropolitan region, most buildings were undamaged. Damage was concentrated in the downtown area, severely affecting most older highrise buildings, many of which collapsed, killing and injuring thousands of people.

Few buildings near the epicenters collapsed, but many suffered extensive damage, which will be very expensive to repair. In many cases, the cost to repair these buildings will approach 50% of their value. Modern buildings performed well throughout the affected area, demonstrating that well designed and constructed structures can survive major earthquakes without collapse or severe damage.

This report is a preliminary summary of the effects of the earthquake on the people, structures, and country of Mexico. EQE is in the process of collecting and compiling more data to be presented in a more thorough report later.



The epicenter of the main shock of September 19 was located just west of the Rio Balsas, near the town of Lazaro Cardenas on the Pacific coast. Damage from the earthquake occurred in Mexico City, about 250 miles to the northeast; in Acapulco to the south; and in villages near Guadalajara to the north.

2. COMMERCIAL AND RESIDENTIAL BUILDINGS

Modern, well constructed buildings in both Mexico City and the epicentral area performed very well in the earthquake, with no observed collapses. This demonstrates the ability of structures with good seismic design to withstand major earthquakes. In general, the many observed failures of older structures could be attributed to poor seismic detailing of structural members and connections.

Older building construction throughout Mexico typically consists of unreinforced masonry infill panels between lightly reinforced concrete frame members. During earthquakes, unreinforced masonry cracks easily, immediately loses most of its strength, and spalls off, leaving the damaged structure with just the bare concrete frame. This frame, designed with minimal seismic considerations, is flexible and vulnerable to further damage.

The damaged buildings in Mexico City were all in districts constructed on fill over the deepest portions of the ancient Texcoco Lake. The ground motion in this area was a severe low frequency rolling motion, lasting for more than 40 seconds. This frequency of motion caused resonance in the soil and highrises, leading to extreme amplification of the earthquake forces and major damage to older 8 to 15 story highrises.

Shorter, stiffer structures, including cathedrals and houses built in the 18th, 19th, and early 20th centuries, did not experience this structural resonance and were typically undamaged. Taller and newer highrises and buildings situated on firmer soils or bedrock in other parts of Mexico City were also undamaged.

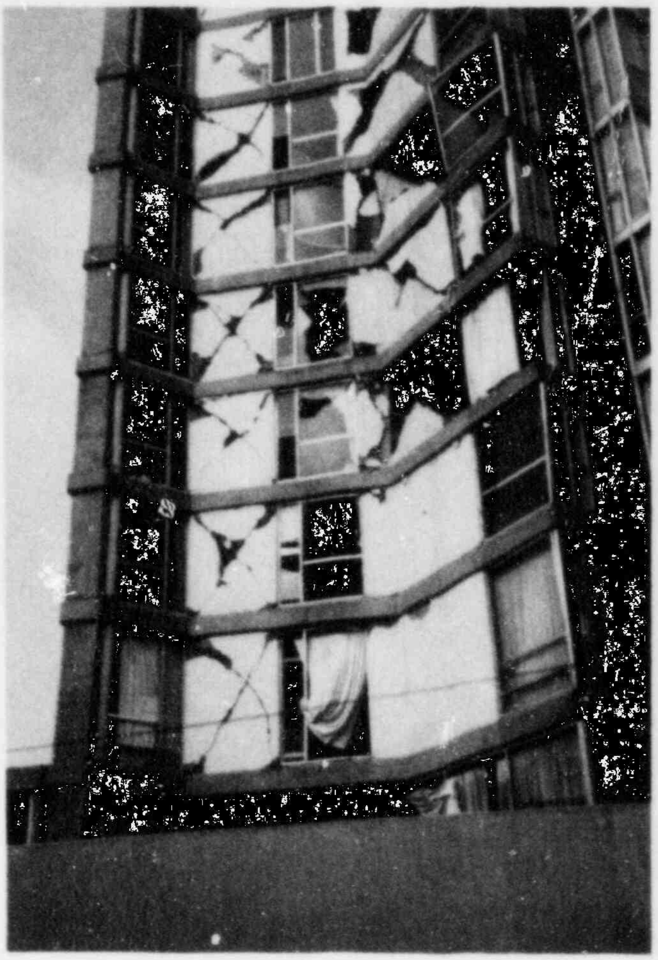
In the coastal areas, a greater variety of buildings were affected by the earthquake due to different soil conditions and proximity to the epicenter. Many buildings suffered significant architectural and structural damage in the towns of Lazaro Cardenas and Ixtapa, requiring evacuation and extensive repairs.

After past earthquakes, many damaged buildings were only cosmetically repaired with plaster and paint. This practice left many structures especially vulnerable to damage during future earthquakes and was one reason for some of the observed damage.

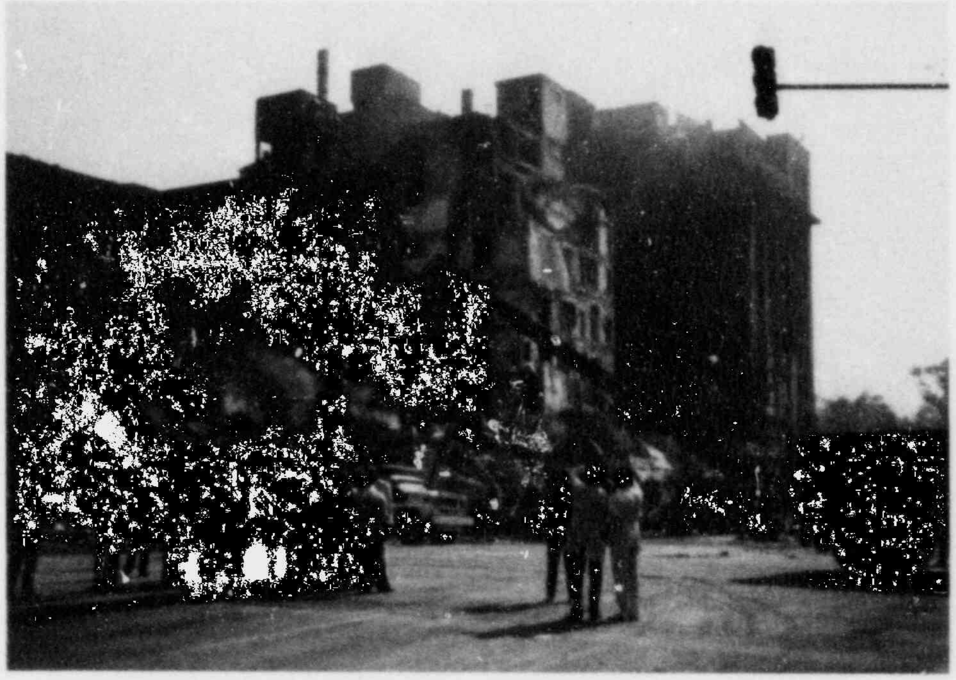
Mexico City. Most of the buildings in this city of 18 million were not damaged by the earthquake. Nonetheless, devastation was obvious as one approached the downtown area.

Mexico City. Most of the damage to the downtown area was concentrated in older highrise structures 8 to 15 stories high. Older lowrise buildings and newer structures had little damage. The structures shown above are very near many buildings that collapsed completely.

Mexico City. Building damage was mostly to concrete frame structures with masonry infills. These buildings either collapsed or were damaged so heavily that they will have to be torn down. The failure modes included pancaking, toppling, and pounding. Pounding damage was due to the flexibility of these framed structures.

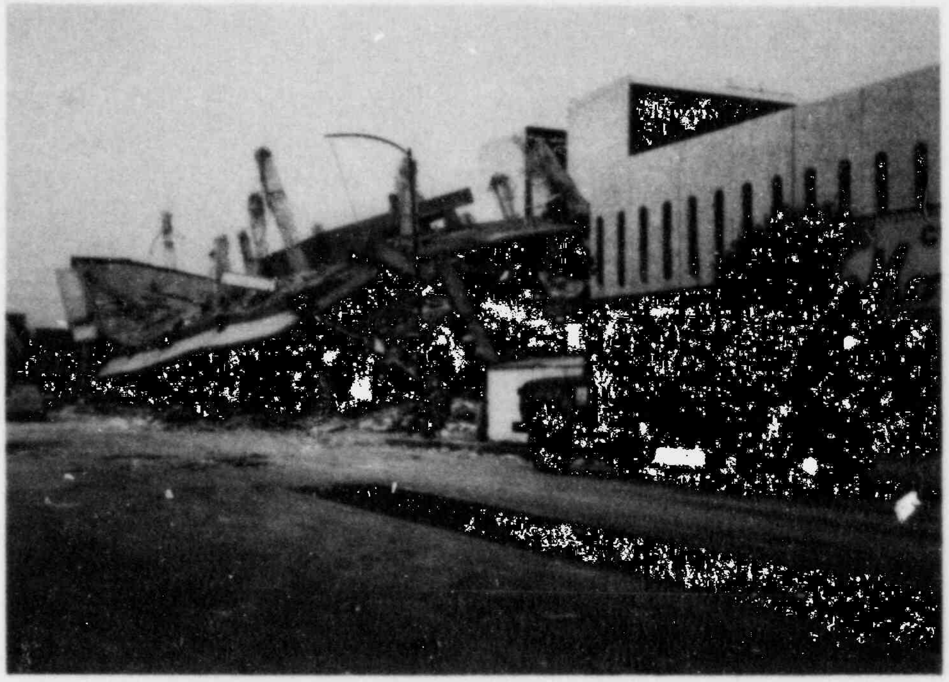


Mexico City. Damage to highrise residential structures in the downtown area was extensive. These buildings were designed with inadequate consideration for earthquake forces and were heavily damaged. Life loss was especially high in these buildings due to the high occupancy (up to 8 persons per unit or more) and the time of day that the earthquake struck (7:18 a.m.).

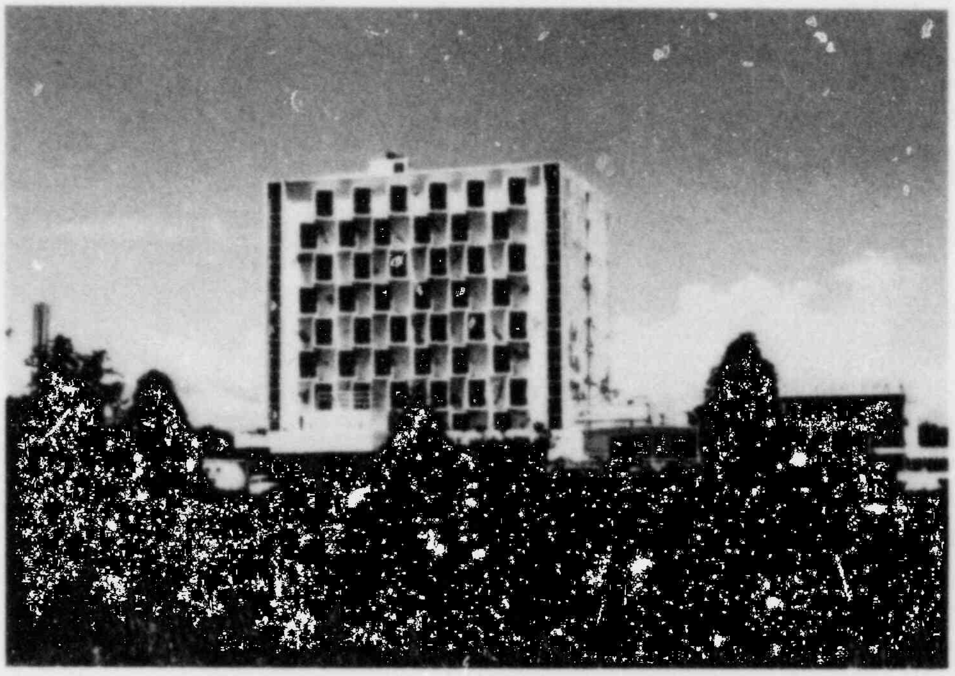


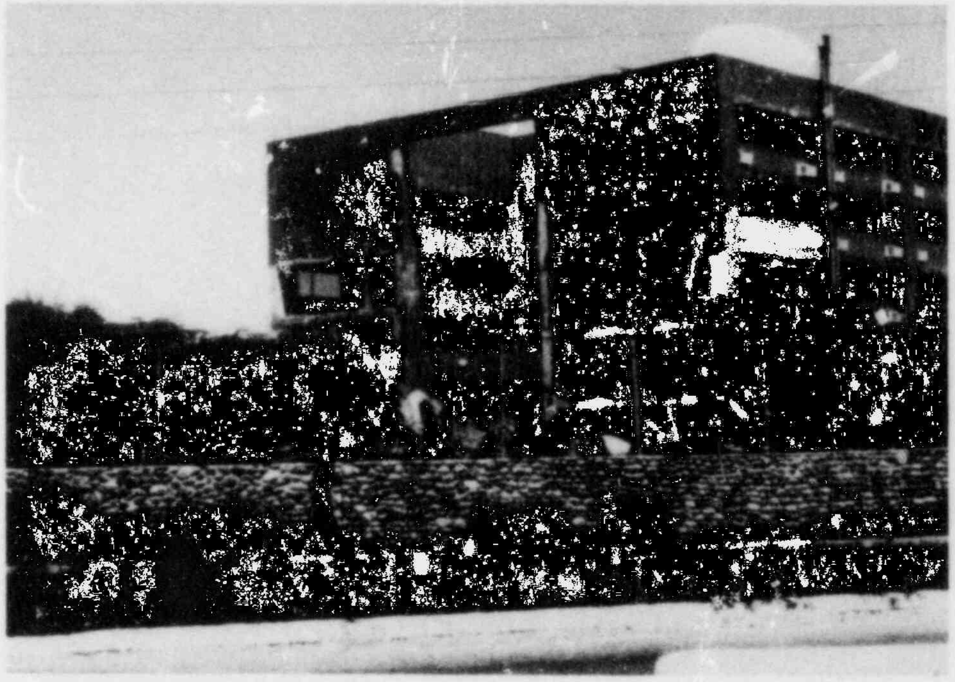
Mexico City. Several hotels in the Zona Rosa district (near the downtown area) suffered major damage or collapsed. The Regis Hotel collapsed and burned, trapping many guests in the rubble. The top floor of the Hyatt Continental's east wing pancaked.

Mexico City. Soil failure occurred beneath some of the damaged buildings on the ancient lake bed. This building toppled and pulled up the foundation and piles. The exposed steel reinforcing bars and spalled concrete of the damaged column illustrate the nonductile design of the building.



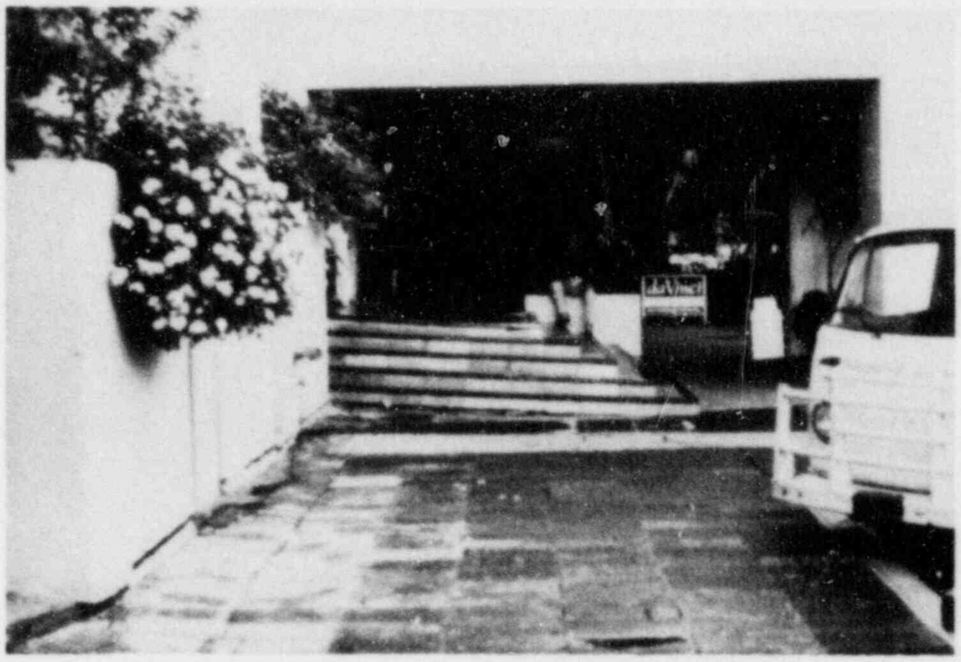
Mexico City. Many government buildings in the downtown area were heavily damaged. The jail/courthouse pancaked, leaving only the protruding columns. Many prisoners were trapped in this collapsed structure. A government building at the corner of Durango and Cuahtemoc streets also suffered major damage, with pancaking of the top floors.



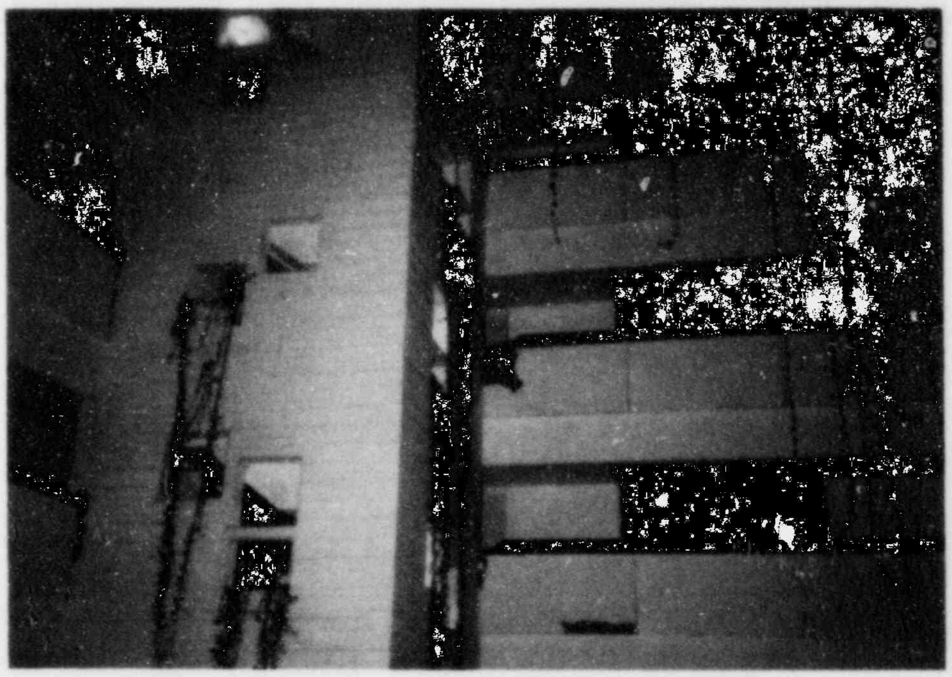


Lazaro Cardenas. This is one of the more developed towns in the epicentral region. Damage was extensive throughout the town and could be seen in about one of every four structures. The top photograph shows severe cracking in the discontinuous shear walls between virtually all the front balconies. The minimal reinforcement in these walls probably prevented collapse of this structure. In the bottom photograph, a complete section of an unreinforced masonry curtain wall fell.

Epicentral Region. Many simple and crude homes are located throughout the sparsely populated epicentral region. These houses were generally built of rough timber posts and unreinforced masonry walls supporting clay tile or straw roofs. Along the Pacific coast between Zihuatenejo and Lazaro Cardenas there were few collapses reported, and none observed. A surprising number of these units had no apparent earthquake damage.



Ixtapa. Two to three inches of ground settlement occurred around the exterior of the Holiday Inn (see previous page). Stairs at the entrance of the hotel tilted considerably. Inside the hotel, goods were thrown from shelves in shops on the ground floor. Damage could be seen in essentially every room of the hotel (cracks on most walls).



Ixtapa. This small, new Pacific coast resort town contains about ten modern reinforced concrete highrise hotels, with two additional hotels currently under construction. All the completed structures had extensive architectural damage to internal walls, exterior masonry curtain walls, and exterior finishes. The Holiday Inn, a modern 12 story highrise, was one of the only hotels that remained open. Even this well-designed building had some structural damage, indicating the severity of the shaking. Fortunately, the area was in the low tourist season and few people were injured.

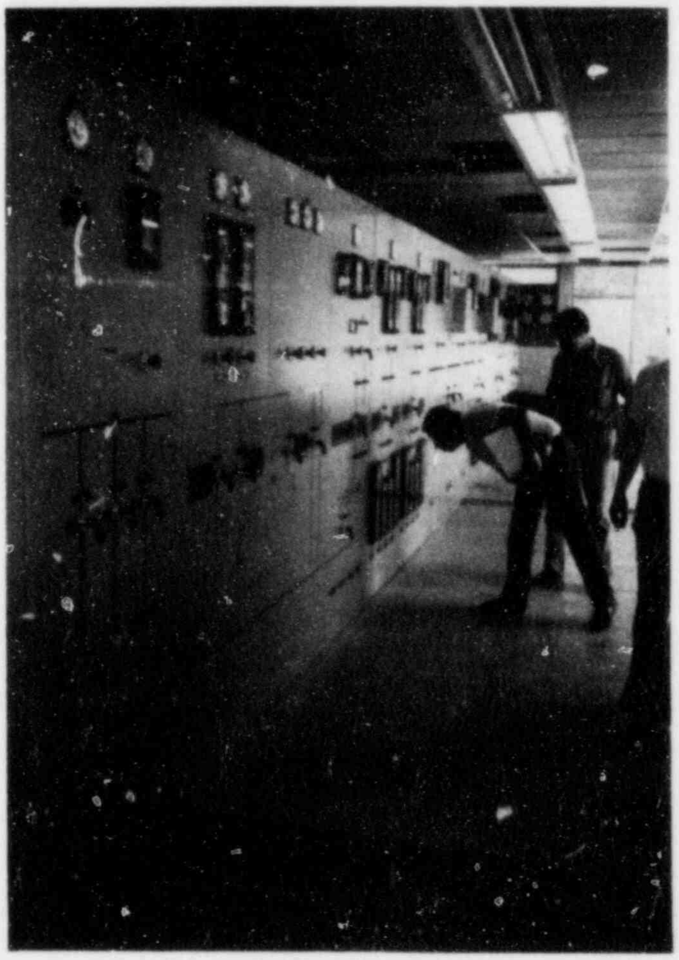
3. INDUSTRIAL AND POWER FACILITIES

There are two major hydroelectric power plants and a large modern steel mill near the epicenters of the main earthquake and the major aftershock. A large fossil-fueled power plant is located close to Mexico City. Smaller substations exist throughout the affected area. These power plants are designed to modern seismic code requirements and include many seismic resistant features. The steel mill consists mainly of large structural steel industrial buildings that are very earthquake resistant.

There was no significant damage to the power generating facilities in the epicentral region. Equipment installations were adequately anchored, and had no damage. All units of the plants operated through the severe ground shaking. Some units were tripped off line by protective systems, signalling problems associated with the power distribution system, such as grounded transmission lines. The well-designed power plant near Mexico City was subjected to weak ground shaking and had no damage.

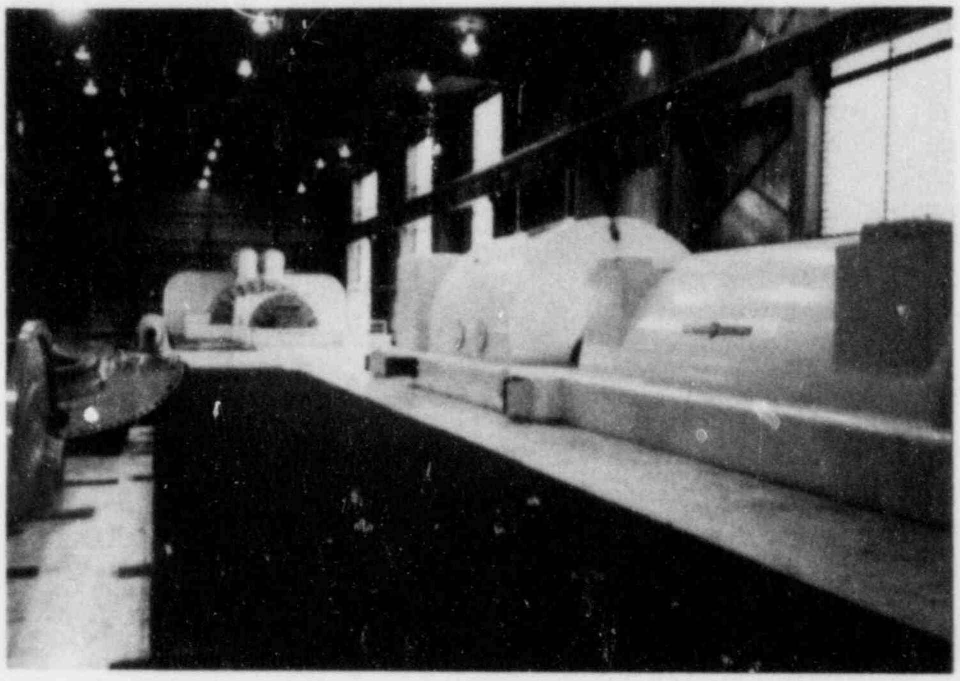
Except for its concrete structures, the steel plant had minimal damage from the earthquake. Equipment damage was limited to high voltage switchyard equipment that caused partial loss of offsite power. The plant's emergency onsite power generating system was put into operation immediately. The only building damage was to a large concrete administration building. All of the many steel frame industrial structures performed exceptionally well. An underground water pipe cracked. Long runs of pipes and cable trays on overhead steel frame structures had no apparent damage.

Jose Maria Morelos Dam. The dam and La Villita power station are located near the mouth of the Rio Balsas, adjacent to the town of Lazaro Cardenas. The earth-filled dam is approximately 150 feet high by 1,000 feet long. Superficial ground cracking occurred at the top of the dam, but there was no significant structural damage. The large array of high voltage equipment in the station switchyard (adjacent to the dam crest) was unaffected by the earthquake, even though this type of equipment is often susceptable to seismic damage.

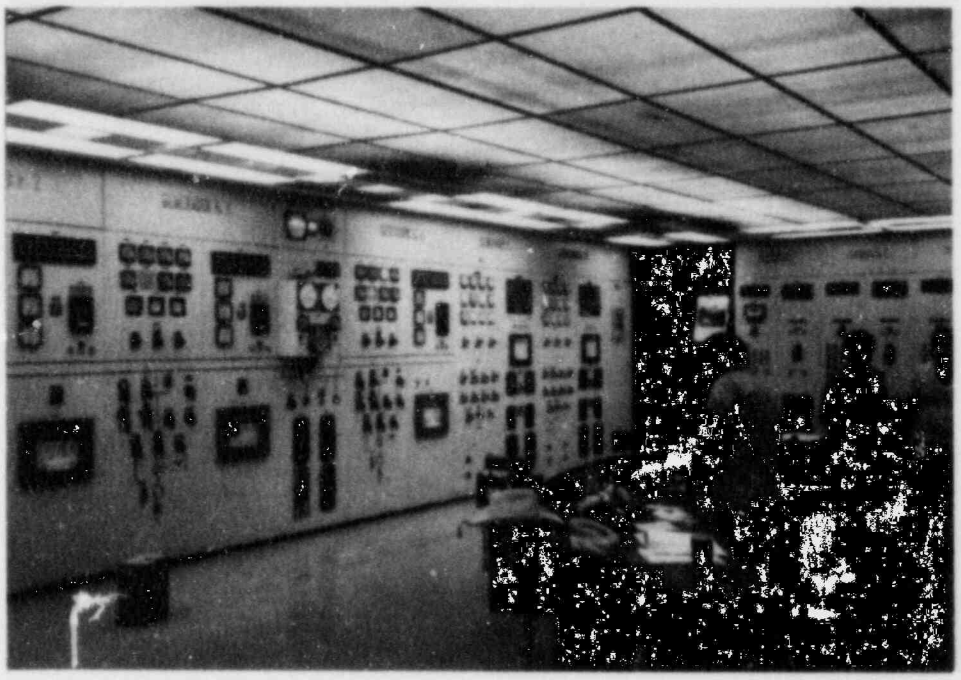


La Villata Power Station. The power station is housed in a large well-constructed steel frame building and consists of four 76 megawatt units. It was completed in 1973. Mechnical and electrical equipment in the station were undamaged by the earthquake. Protective relays disconnected the station from the power grid during the earthquake. Nonetheless, it operated through the earthquake and reconnected with the power grid following a brief damage inspection.

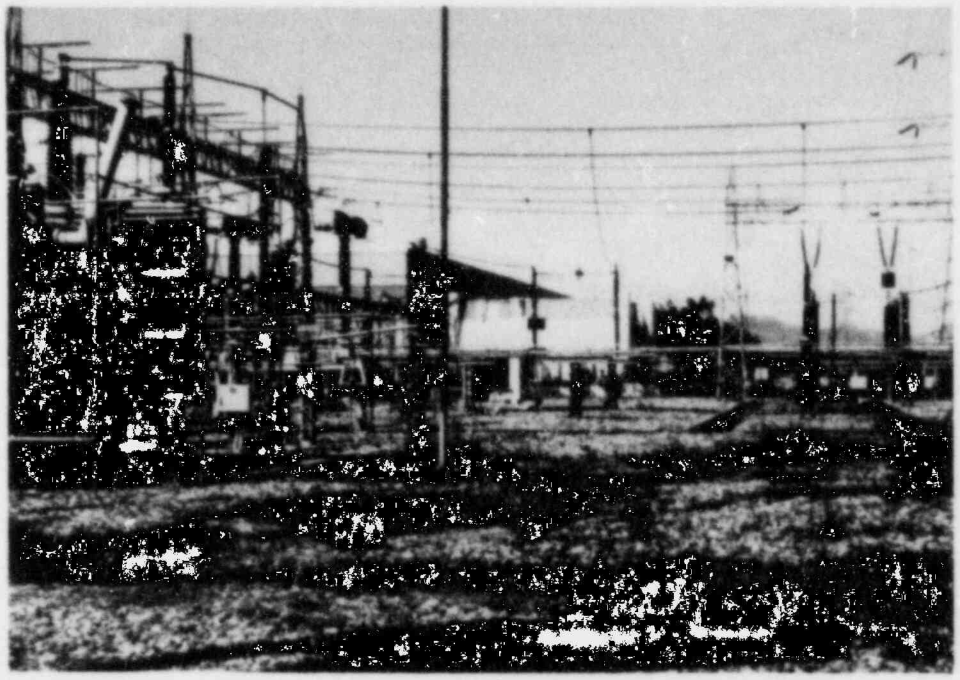
El Infiernillo Dam and Power Station. Located on the Rio Balsas about 20 miles from the Pacific coast, El Infiernillo is an earth-filled dam about 500 feet high by 1,000 feet long. The power station is located at the discharge of the penstock about 1/2 mile downstream of the dam.

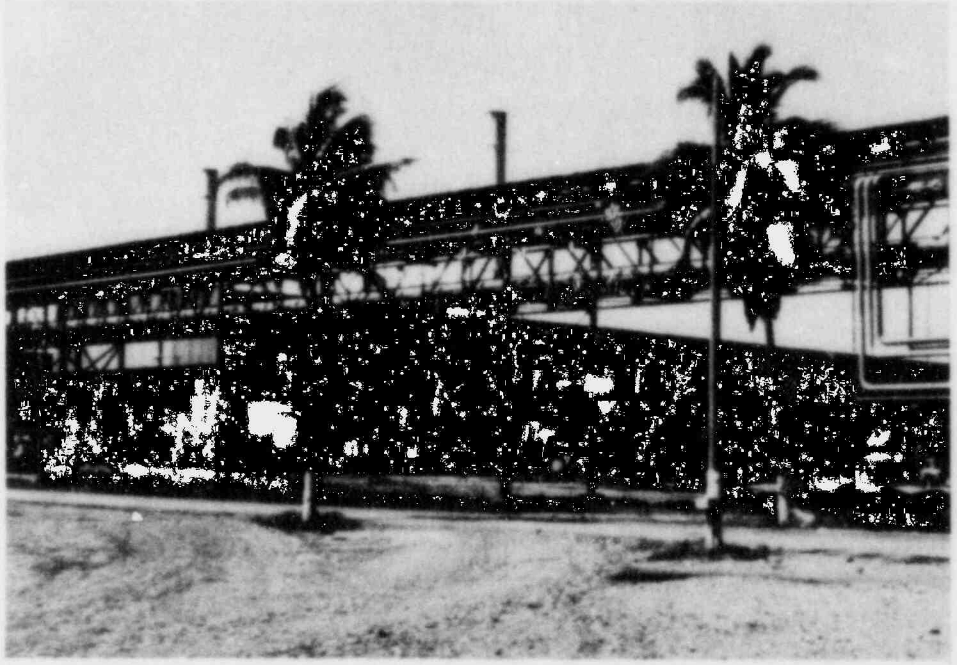


Valle de Mexico ?ower Plant. The operating floor of this fossil power plant is shown. It is located about 20 miles west of Mexico City and is built on a rock site. The plant includes three 150 megawatt units and one 300 megawatt unit. Plant personnel reported minor shaking from the earthquake. Three units were operating at the time of the earthquake; two remained on-line and one disconnected from the power grid due to relay actuation caused by loss of load in Mexico City. There was no damage to the plant.



El Infiernillo Dam and Power Station. Built into the rock face of a hillside, the power station includes four 160 megawatt units and two 180 megawatt units. It was constructed in the mid 1960's. The station disconnected from the power grid during the earthquake due to protective relay action. The operating floor and the control room are shown in the photos above.





SICARTSA Steel Mill. The top photograph shows the switchyard where a disconnector switch similar to the one seen near the center of the photograph fell due to a cracked ceramic insulator. A transformer similar to the one at the left also suffered a cracked oil seal. The lower photograph shows a pipe support structure with a large structural steel building in the background. Both are representative of the types of components located at this plant, all of which performed well during the earthquake. A concrete frame administration building had severe damage to masonry panels and was evacuated.

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4. EMERGENCY RESPONSE AND LIFELINES

Dozens of buildings collapsed and thousands of people were trapped in central Mexico City, requiring a significant and rapid response. The Mexican government immediately called in the armed forces to establish order and assume overall direction of rescue efforts.

The Mexican federal disaster plan designates the army as the central administrative organization for all relief efforts. The national utilities act as the head technical organization in setting priorities for reestablishing essential lifelines. Both have the authority to commandeer private commercial equipment and supplies for relief efforts. The army has overall authority to establish resource use priorities, including those of the utilities, and consequently used the electrical utility radio communication network throughout the relief effort.

The army established immediate control in the damaged areas and cleared access to bring in necessary equipment and supplies. All collapsed buildings were reached within three hours, and most much sooner. First aid stations, sanitation facilities, temporary shelter areas, and water and food distribution centers were quickly organized. The local Red Cross and Salvation Army assisted the Mexican army in setting up temporary hospitals to replace heavily damaged or collapsed hospitals.

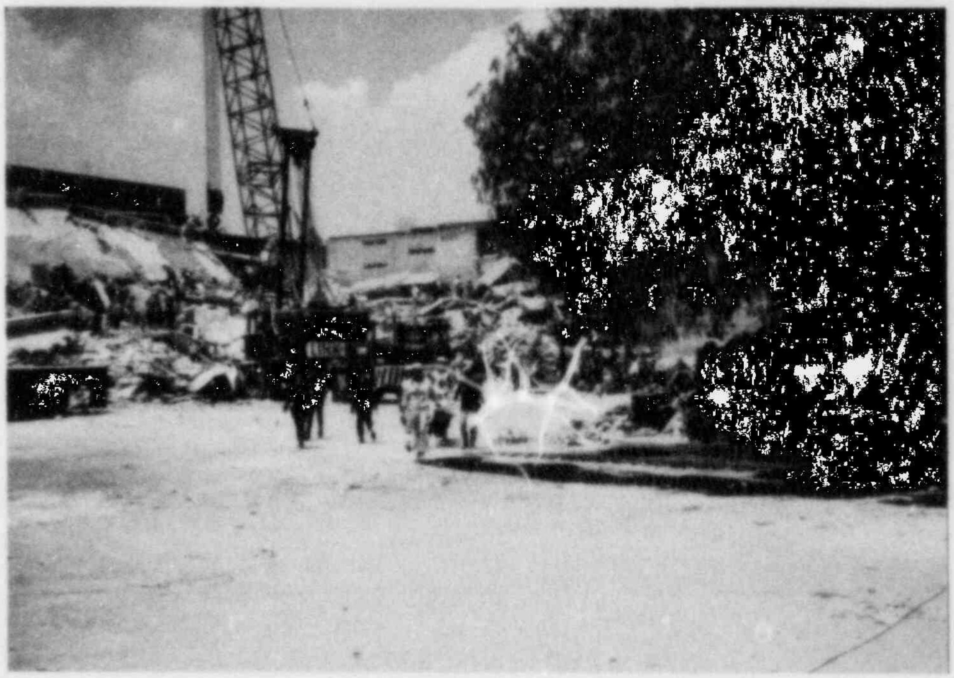
Volunteer rescue teams worked around the clock to find survivors trapped in collapsed buildings. The lack of sufficient heavy equipment slowed this work greatly. Further collapses, and in some instances, additional injuries and deaths, resulted from proper construction equipment not being available. Sonar devices were used at some sites to detect heartbeats of trapped survivors, and people continued to be rescued over a week after the earthquake. This earthquake emphasized the value of experienced search and rescue teams and proper demolition equipment immediately after a major earthquake. The Red Cross and the army sanitation division provided vaccinations and protective gear for rescue workers to lessen the threat of epidemic.

The army posted guards throughout the city to maintain a curfew and prevent looting. The army also had authority for handling and distributing foreign aid during the disaster. They were so overwhelmed with food, medical supplies, and clothing that much of it was never used in the immediate disaster relief programs. Such items as tires for emergency vehicles, however, were in great demand.

The earthquake disrupted most lifelines in the affected area. Broken gas lines were a serious fire threat and resulted in fires in several instances. Water mains broke, leaving many areas without water for days. Underground high voltage cables and overhead lines were damaged by collapsed buildings, leaving many areas without electricity and posing a fire hazard. Many substations were rendered inoperable as a result of transmission line damage. The many redundancies in the power network, however, allowed safe alternate routes to be established, and power was restored in most areas within two hours. Whenever possible, damaged lines were repaired by cable bridging.

International and long distance telephone service into and out of Mexico City was disrupted for several days following the earthquake due to the collapse of a central switching center. The telegraph building also collapsed, with similar consequences.

The preliminary relief effort concentrated on saving lives and establishing necessary lifeline systems. The medium and long term effects of the earthquake are still to be determined. Total fatality figures (currently approaching 10,000) are unavailable until the remaining buildings are excavated. No estimates of economic losses can be established at this time, but they will be staggering, especially when considering the already troubled Mexican economy. Both the social and economic repercussions of this earthquake will be felt throughout Mexico for years to come.



Mexico City. Teams of ambulances waited near heavily damaged areas to pick up survivors found in the destroyed buildings. In the lower photograph, rescue workers ran with an injured child discovered in the wreckage to a nearby first aid station. Slow, laborious rescue efforts such as this continued around the clock for days after the earthquake.

Mexico City. Army personnel in the upper photograph guard goods salvaged from a collapsed building. In the background tents provide shelter to people whose homes were destroyed. The apartment building seen above the trees in the upper right corner was similar to other buildings in the immediate vicinity that collapsed. The lower photograph shows an aid station where food, water, and medical attention were supplied.

Mexico City. Trucks similiar to the one in the upper photograph distributed water to local residents in areas where water supplies were lost. A local Red Cross ambulance used as a mobile immunization station is shown in the lower photograph. Lanes of major streets were cleared for emergency vehicle use only. Emergency vehicles, including many civilian volunteer vehicles, were clearly marked with red banners.

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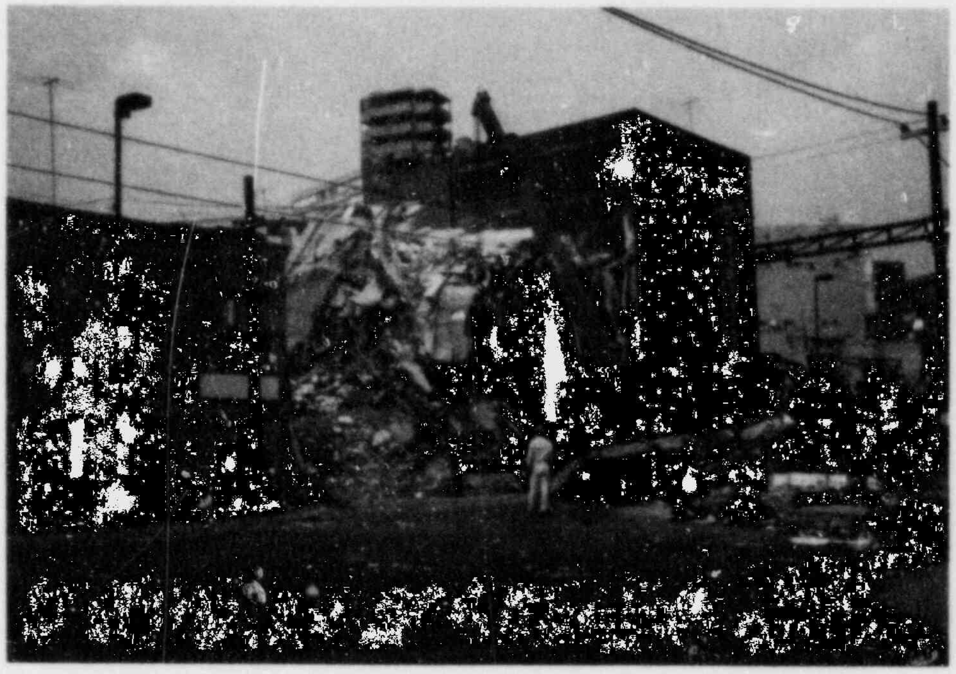
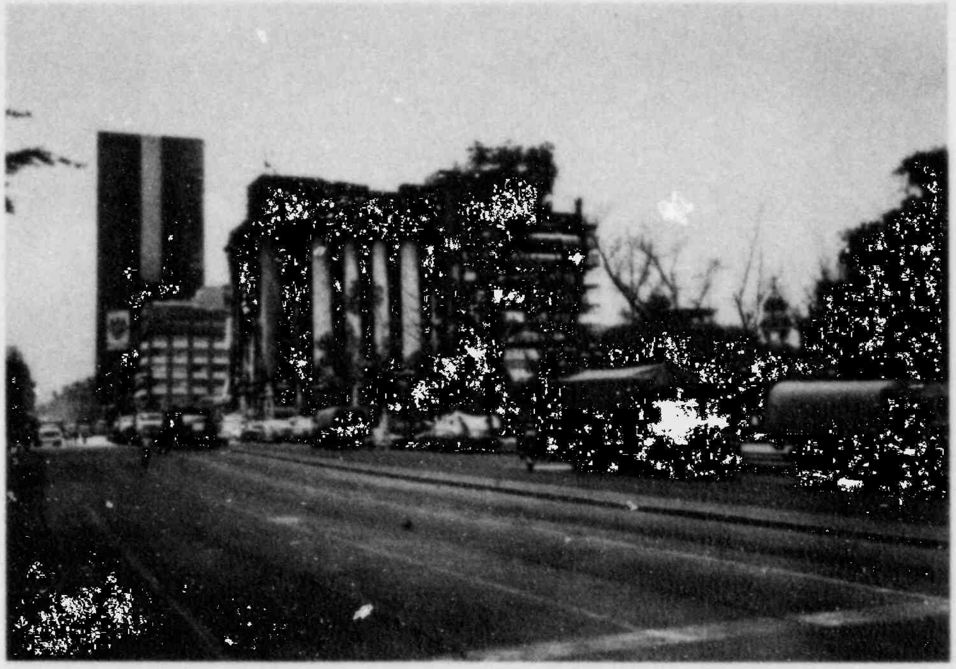
Mexico City. The upper photograph shows army guards and a municipal bus converted to a medical aid station. The guards restricted traffic to emergency vehicles and only allowed rescue workers to pass. Noise was kept to a minimum so that survivors could be heard within the collapsed buildings. In the lower photograph is a navy command center. Such stations were set up throughout the damaged areas.



Mexico City. Heavy construction equipment such as overhead cranes were the most effective in carefully removing rubble from collapsed buildings. Backhoes and bulldozers were not suitable nor safe, but were mainly useful for pushing aside the already removed debris and loading it onto trucks for transportation from the area.

Mexico City. In the upper photograph repair work has begun on broken water and gas mains. The smell of natural gas was evident throughout the damaged areas. The lower photograph shows local residents bailing water from a broken water main. In many areas, water pipes were deliberately dug up and broken so that water could be obtained.



Mexico City. The upper photograph shows two buildings that were damaged from fire originating from ruptured gas lines. These buildings were adjacent to the collapsed Regis Hotel. Collapsed buildings damaged many main power lines and underground cables. In the lower photograph, a pole mounted transformer has damaged supports.