HECO T-4
DOCKET NO. 03-0XXX

TESTIMONY OF
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HAWAIIAN ELECTRIC COMPANY, INC.

Subject: Planning/Project Need

INTRODUCTION

Q. Please state your name and business address.

A. My name is Shari Y. Ishikawa and my business address is 820 Ward Avenue, Honolulu, Hawaii.

Q. What is your present position with the Hawaiian Electric Company, Inc. ("HECO")?

A. I am the Principal Transmission Planning Engineer in the Transmission Planning Division in the Power Supply Department. My educational background and experience are provided in HECO-400.

Q. What is the scope of your testimony?

A. My testimony will address the need for the East Oahu Transmission Project, which includes an explanation of the following:

1) Project Need Summary
2) Koolau/Pukele and Downtown Line Overload Situations
3) Pukele substation reliability concern
4) Downtown substation reliability concern
5) Effectiveness of the three alternatives considered
6) Alternatives reviewed to address both the overload and reliability concerns
7) Alternatives reviewed to address the Koolau/Pukele overload situation only
8) Selected alternative and future planning considerations

PROJECT NEED SUMMARY

Q. What is the East Oahu Transmission Project?

A. The East Oahu Transmission Project ("EOTP") addresses several transmission problems that can affect system reliability. The EOTP was initiated as a result of a study conducted in July 1991 titled, "East Oahu 138KV Requirements." This study was updated in August 1992 and again in March 1998. The issues identified in these studies included:

1) The Koolau/Pukele Overload Situation;
2) The Downtown Overload Situation;
3) The Pukele Substation Reliability Concern; and
4) The Downtown Substation Reliability Concern.

An explanation of each of the four concerns is described in more detail later in my testimony.

<u>HECO Transmission System</u>

Q. Describe how power is transported to the customer.

A. Transmission lines at varying voltages are used to transport power to the customer. Currently the highest voltage used by HECO to transport power is the 138kV Transmission system. The 138kV Transmission System is shown in HECO-401. The 138kV transmission lines allow efficient transmission of large amounts of power from the power plants, where power is generated, to all major load centers. Transmission substations at these major load centers have transformers that "step down" the 138kV voltage to the 46kV sub-transmission voltage. HECO-402 shows HECO's 46kV transmission system. From there, local area substations further reduce the voltage from 46kV to HECO's 12kV and 4kV local distribution voltages.

Q. Describe the characteristics of HECO's 138kV Transmission System.

A. Bulk power from Leeward Oahu power plants is transmitted to the East Oahu Service Area over two major transmission corridors, which are shown in HECO-403. The Northern Transmission Corridor extends from Kahe Power Plant to the

Halawa Substation, Koolau Substation and the Pukele Substations, where it currently ends. With the completion of the two Waiau-Ewa Nui 138kV Transmission lines in 1995 the Southern Transmission Corridor was extended from the Kahe Power Plant to the Waiau Power Plant and Iwilei, School Street, and Archer Substations. The Southern Transmission Corridor was recently extended to the Kamoku Substation through the installation of two 138kV transmission lines from Archer Substation to Kewalo Substation and the installation of a 138kV transmission line from Kewalo Substation to Kamoku Substation. The Archer-Kewalo-Kamoku transmission facilities are used to serve the load in the Kakaako and Ala Moana areas, which include the Hawaiki Towers, a portion of the Ala Moana Shopping Center and the Hawaii Convention Center.

Q. How are the corridors linked together?

A. The two corridors are linked together by transmission lines between power plants and substations connected to the Northern and Southern Corridors. Below is a table, which lists the lines that connect various transmission facilities and allow power that serves the load to pass between the Northern and Southern Corridors depending on the configuration of the system.

Table 1: Transmission Lines Interconnecting the Northern and Southern Corridors

Line Name	Northern Corridor	Southern Corridor
Kahe-Waiau	Kahe Power Plant	Waiau Power Plant
Kahe-Waihiawa-Waiau	Kahe-Wahiawa 138kV	Waiau-Wahiawa 138kV
Waiau-Koolau #1	Koolau Substation	Waiau Power Plant
Waiau-Koolau #2	Koolau Substation	Waiau Power Plant
Halawa-Makalapa	Halawa Substation	Makalapa Substation
Halawa-School	Halawa Substation	School Street Substation
Halawa-Iwilei	Halawa Substation	Iwilei Substation

Interconnections between the Northern and Southern Corridors form a ring of transmission lines that provide reliable power to the West Oahu Service Area.

However as shown in HECO-403, no similar connection exists to provide reliable power to the East Oahu Service Area. HECO's plan has been to build upon existing facilities installed to serve the local load growth through the Archer-Kewalo-Kamoku projects and close the existing gap between the Northern Transmission Corridor and the Southern Transmission Corridor on the East Side of Oahu, providing added reliability to the Eastern and Windward portions of Oahu. The East Oahu Service Area represents 56% of HECO's total load and is shown in HECO-404.

HECO Transmission Planning

Q. Describe HECO's Transmission Planning Process.

A. Long-term analyses covering time periods ranging from 6-20 years and short-term analyses covering a period of 5 years or less are conducted. The analyses utilize load flow programs, which model the characteristics of the actual 138kV system. The load flow simulations are forward looking simulations and are used to determine voltages at substation busses and the amount of current flowing through the 138kV transmission lines based upon load forecasts at the substations and various configurations of the HECO system. Transmission Planning Criteria violations and transmission concerns are identified. Solutions are formulated and load flow simulations are used to test the solutions against HECO's Transmission Planning Criteria. Transmission projects are recommended using the HECO Transmission Planning Criteria as a minimum guideline. Recommendations are also based upon other factors including 1) engineering design criteria, 2) operational experience, 3) risks involved and 4) financial constraints.

East Oahu Transmission Studies

Q. Has HECO conducted studies to address the reliability of the East Oahu Service

Area as mentioned above?

A. Yes, the East Oahu 138KV Requirements study in July of 1991 was completed and was subsequently updated in August of 1992 in a study entitled the "East Oahu 138KV Requirements Updated." The study outlined at least four concerns for the East Oahu Service Area, that remain relevant today including:

1) The Koolau/Pukele Overload Situation;
2) The Downtown Overload Situation;
3) The Pukele Substation Reliability Concern; and
4) The Downtown Substation Reliability Concern.

Q. Did HECO act upon the results of this study?

A. Yes, as Mr. Wong addresses in HECO T-2, a routing study was completed and a public scoping and input process was initiated, which included the formation of a Community Advisory Committee ("CAC"). HECO T-2 explains that additional CAC meetings were held to evaluate various alternatives that would either defer or eliminate the construction of a 138kV transmission line between the Kamoku and Pukele Substations and reports such as the June 1995, Kamoku-Pukele 138kV Transmission Line Alternatives Study ("CH2M HILL Alternatives Study"), updated in April 2000 and the August 1994 Kamoku-Pukele 46kV Alternatives Study were completed. Through the routing study, the public input process and the various analyses, HECO identified the 138kV partial underground, partial overhead transmission line from Kamoku-Pukele as the preferred alternative, and HECO submitted an application for a Conservation District Use Permit ("CDUP") in 1995 to the Department of Land and Natural Resources ("DLNR"). HECO subsequently entered into an extensive Environmental Impact Statement ("EIS") process. Due to the passage of time for the EIS process, the East Oahu 138KV

Requirements Updated study was updated in March 1998 as the East Oahu Requirements Update Study, which contained to identify the four transmission concerns. As a follow-up to the CH2M HILL Alternatives Study, HECO also completed the March 2000 Review of the Distributed Generation Alternatives to the Kamoku-Pukele Line. In 2002, HECO's application for a CDUP was denied thus HECO could not proceed with the 138kV partial underground, partial overhead transmission alternative.

Q. What has HECO done as a result of the 2002 decision?

A. As discussed in Mr. Joaquin's testimony, HECO T-1, a HECO Executive Team was formed and the team requested an update of various studies and reports such as the March 1998 East Oahu Transmission Requirements Update Study. The East Oahu Transmission Project Alternatives Study Update (the "2003 East Oahu Alternatives Study Update"), which was prepared by HECO's Planning & Engineering Department under my direction, was finalized in December 2003.

The HECO Executive Team also requested a study to analyze in more detail the possible options (other than constructing a new 138kV transmission line, or new 46kV sub-transmission circuits) for addressing the Koolau/Pukele line overload problem, even if the options would not resolve the Pukele service area reliability concern. Our report, entitled the East Oahu Transmission Project: Alternatives to the Koolau/Pukele Transmission Line Overload Problem (the "East Oahu Transmission Project: Options to the Koolau/Pukele Transmission Line Overload Problem"), also was finalized in December 2003. A summary of the analysis is included later in my testimony.

Q. What was the purpose of the 2003 East Oahu Alternatives Study?

A. The purpose of the update was to document the analyses and re-evaluate the

138kV and the 46kV transmission alternatives previously identified in the various East Oahu studies and include two other 46kV transmission alternatives that were derived as a result of the analyses.

Q. What are the findings in the updated study?

A. The updated study continues to identify the four transmission concerns previously identified in the 1991 East Oahu Requirements Study, August 1992 update and March 1998 update. The Koolau/Pukele and Downtown overload dates have changed in each study update and HECO has been fortunate that the large load growth predicted in the early 1990's did not materialize at that time. The December 2003 update study, which uses the August 2002 Load Forecast, projects that the overload situations in the Koolau/Pukele area will occur in the 2005 time frame and HECO will need to install a transmission alternative to mitigate the overload situation very soon. Four 138kV alternatives and the 46kV network and 46kV radial alternatives, which were previously studied, were re-evaluated and two additional 46kV alternatives were identified and evaluated. The updated study also suggests a change in cycle from a slow load growth cycle to an accelerating load growth cycle. Actual transformer loadings for the Koolau/Pukele area are described later in my testimony.

<u>Alternatives</u>

Q. What transmission alternatives are included in the 2003 East Oahu Alternatives Study?

A. The four 138kV alternatives and two 46kV alternatives that were identified in previous East Oahu transmission studies include:

1) The Kamoku-Pukele 138kV transmission line
2) The School-Pukele 138kV transmission line

3) The Halawa-Pukele 138kV transmission line
4) The Halawa-Koolau-Pukele 138kV transmission line
5) The 46kV network alternative
6) The 46kV radial alternative

In addition, two other 46kV transmission alternatives (the Kamoku 46kV Underground Alternative and the Kamoku 46kV Underground Alternative – Expanded) were derived as a result of the analyses and evaluated. Three alternatives from the eight alternatives listed here were selected by the HECO Executive Team and presented at various community meetings for public input.

Q. Have the transmission alternatives changed from previous studies?

A. In 1992-1994, through the CAC described in HECO T-2, fourteen 138kV line alternatives (11 Kamoku-Pukele 138kV alternatives with different alignments and configurations, a School-Pukele 138kV alternative, a Halawa-Pukele 138kV alternative and a Halawa-Koolau-Pukele 138kV alternative) and two 46kV line alternatives (a 46kV radial alternative and a 46kV network alternative) were identified and were described in the Final EIS. HECO selected one of the Kamoku-Pukele 138kV line alternatives, a 138kV partial underground, partial overhead transmission alternative from Kamoku Substation to Pukele Substations via Waahila Ridge as the preferred alternative. The Kamoku-Pukele 138kV Underground Alternative (using either high-pressure fluid-filled ("HPFF") or cross-linked polyethylene ("XLPE") cable technology) included in the 2003 East Oahu Alternatives Study was previously analyzed in the Final EIS. Two additional 46kV alternatives, one an expanded version of the other, were also identified and included in the 2003 study.

Q. Why were three out of the eight alternatives presented to the community?

A. Three alternatives with different degrees of effectiveness were presented to the community through a public input process. This process is described in the testimony of Mr. Alm, in HECO T-12. As a practical mater, three alternatives would be described and presented to the public in the public review process. The reasons for screening out the other 138kV and 46kV alternatives were straightforward and reasonable and HECO wanted to put forth alternatives that were viable taking into consideration the technical feasibility of the alternatives, the permits required which affect the schedule of the alternatives, and the costs for the alternatives. Through the screening process, HECO was able to identify three viable alternatives to pursue for the EOTP.

Q. Describe the screening process used to select three alternatives that were presented at the public meetings?

A. Three out of the four 138kV transmission alternatives and two out of the four 46kV alternatives were screened out by the HECO Executive Team. In the case of the 138kV transmission alternatives, the School-Pukele, Halawa-Pukele and Halawa-Koolau-Pukele 138kV alternatives were not carried forward for public input for a number of reasons: (1) because when comparing each of the three alternatives to the Kamoku-Pukele 138kV alternative, the costs for these projects were higher, (2) all three alternatives required a greater amount of time for installation exposing the HECO system to a longer period of risk for overload conditions, (3) each of the three alternatives required the installation of more than one 138kV line, which would result in a longer time period for permit approvals, and (4) two of the 138kV alternatives, the Halawa-Pukele 138kV and the Halawa-Koolau-Pukele 138kV alternative, did not address the Downtown overload situation in the event the Honolulu Power Plant ("HPP") was retired.

Q. Describe how the 46kV network and 46kV radial alternatives were screened out.

A. The 46kV network and 46kV radial alternatives were not carried forward for presentation to the public, because (1) in comparing these two alternatives to the 46kV Kamoku Underground alternatives, (2) the costs for the 46kV network and 46kV radial alternatives were higher than the costs for the 46kV Kamoku Underground alternatives, and (3) the 46kV network alternative required the installation of a 138kV transmission line, as well as an extensive amount of sub-transmission facilities and only partially addressed the Archer Substation reliability.

Q. List the three alternatives that were carried forward to the public input process.

A. The three alternatives are:

1) The Kamoku-Pukele 138kV Underground Alternative;
2) The Kamoku 46kV Underground Alternative; and
3) The Kamoku 46kV Underground Alternative – Expanded.

Q. What occurred after the public input process was completed?

A. A report on the public input process and finalized information regarding the various non-transmission options and results of the public input process were presented to the Executive Team at HECO. HECO T-6 provides a detailed description of the conduit, cable and other transmission equipment that will be installed for each of the three alternatives. A step-by-step description of how each alternative will be utilized to operate the HECO system is described later in my testimony.

Q. What are the differences in effectiveness of the three alternatives presented to the HECO Executive Team?

A. From an engineering standpoint, the Kamoku-Pukele 138kV Underground

Alternative is the best long-term solution for solving all the transmission overloads and reliability concerns outlined earlier. The Kamoku 46kV Underground Alternative is adequate to reduce the Koolau/Pukele line overload situation, defers the Downtown line overload situation for several years, provides partial back-up of the load served by the Pukele Substation (although some customers would still incur a 6-second outage if the second Koolau-Pukele 138kV transmission line experienced a forced outage while the first Koolau-Pukele 138kV line was out for maintenance) and provides partial back-up of the load served by the Downtown Substations. The advantage of this alternative is that it can be installed sooner, although the duration of its effectiveness is not as long as that of the Kamoku-Pukele 138kV Underground Alternative. The Kamoku 46kV Underground – Expanded Alternative solves the Koolau/Pukele line overload situation, defers the Downtown line overload situation for several years, provides complete back-up to the load served by the Pukele Substation and provides partial back-up of the load served by the Downtown Substations. The advantage of the Kamoku 46kV Underground-Expanded alternative is that it can be installed sooner than the Kamoku-Pukele 138kV underground alternative, although it will require more time to install this alternative (unless this alternative is installed in two phases as is now planned) than the non-expanded Kamoku 46kV Underground alternative. The duration of its effectiveness is not as long as that of the Kamoku-Pukele 138kV Underground alternative, however, it provides complete back up to the Pukele Substation, which is one of HECO's concerns.

Q. Has HECO considered or analyzed any non-transmission options that might address some or all of the transmission system concerns to be addressed by the EOTP?

A. Yes. As part of the planning and permitting for a 138 kV transmission line between the Kamoku and Pukele Substations, HECO undertook and/or commissioned an extensive analysis of potential options in 1995, and updated the analyses in 2000.

In 1995, HECO's contractor for the EIS for the proposed Kamoku-Pukele 138kV Transmission line, with input from the CAC established for the project in early 1993 and from HECO, conducted a review and analysis of alternatives to a 138 kV transmission line between the Kamoku and Pukele Substations. The 1995 CH2M HILL Alternatives Study was included in the Final EIS (in Volume 2) as Appendix C1. (This study also evaluated a number of 138 kV and 46 kV line alternatives to installing a 138 kV transmission line between the Kamoku and Pukele Substations.) The study was updated in April 2000, and the update is contained in Section 10-A of the Final EIS (in Volume 1A). The study update reflects the results of a Review of the Distributed Generation Alternatives to the Kamoku-Pukele Line ("DG Alternatives Study") completed by HECO in March 2000. The results of the 1995 alternatives analysis, as updated in 1995, are described on pages 3-49 through 3-62 of the Final EIS.

Q. In general, what was the conclusion?

A. As stated earlier, the four transmission concerns included the Koolau/Pukele and Downtown service area line overload problems, the Pukele service area reliability concern, and the Downtown service area substation reliability concern. In general, the analysis concluded that, for reasons related to cost, feasibility, practicality and effectiveness, the transmission line was the preferred alternative. For example, none of the options could resolve the Pukele reliability concern, unless the entire load (of approximately 200 MW, for approximately 60,000 service accounts) in the Pukele service area could be displaced, or backed up in the event of a loss of the two 138 kV transmission lines currently providing power to the Pukele substation. The analysis indicated why displacing or backing up the Pukele service area load would be infeasible and/or impractical (due to factors such as the lack of available sites), particularly in the near-term, or cost-prohibitive if the siting and other feasibility issues could be resolved. I will summarize some of the findings with respect to the alternative energy, distributed generation and demand-side management options ("DSM") considered in the analysis later in my testimony.

Q. Did HECO do any further analyses after the CDUP was denied for the Kamoku-Pukele 138 kV partial underground/partial overhead (via Waahila Ridge) preferred alternative.

A. Yes. First, HECO retained a consultant to review the potential for and practicability of doing "live line maintenance" on Oahu. Live line maintenance (which is generally referred to as "live working" in the industry) involves doing maintenance work on (and even replacing) distribution and transmission facilities without de-energizing the distribution and transmission lines. The consultant was asked to analyze in more detail the potential for doing live line maintenance on the 138 kV transmission lines serving the Koolau and Pukele substations, since the Koolau overload situation and the Pukele reliability concern generally (although not exclusively) arise when a transmission line has to be taken out of service (i.e., de-energized) for maintenance. The consultant's conclusions are summarized in the testimony of Mr. Stewart in HECO T-5.

Second, we analyzed in more detail the possible options (other than constructing a new 138 kV transmission line, or new 46 kV sub-transmission circuits) for addressing the Koolau/Pukele line overload problem, even if the options would not resolve the Pukele service area reliability concern. The options analyzed included increasing the current carrying capacity of existing lines (at least for planning purposes), reducing the Koolau/Pukele service area load (or peak load) by targeting additional DSM, load management, DG and combined heat and power ("CHP") system penetration in the service area (beyond that expected to result from current programs and efforts), adding renewable energy generation in the service area, and using live working techniques to avoid taking the three existing 138 kV transmission lines providing power to the Koolau Substation out of service for maintenance. The analysis is included in the study finalized by HECO's Planning & Engineering Department in December 2003 entitled "East Oahu Transmission Project: Options to the Koolau/Pukele Transmission Line Overload Problem" ("Koolau/Pukele Overload Options Study"). The options analyzed in the study also are discussed later in my testimony.

In addition, HECO and its electric utility subsidiaries serving the counties of Maui and Hawaii, filed an application on October 10, 2003 in Docket No. 03-0366 requesting approval of each Company's proposed CHP Program and related tariff provision (Schedule CHP, Custom-Sited Utility-Owned Cogeneration Service). Under the CHP Program and Schedule CHP, the Companies propose to offer combined heat and power systems ("CHP systems") to eligible utility customers on the islands of Oahu, Maui and Hawaii as a regulated utility service. (The Companies also indicated that they would request approval on a contract-by-contract basis for CHP system projects that fall outside the scope of the proposed program.) If the program is approved, HECO anticipates that the program will accelerate the rate at which CHP systems are installed on Oahu, and projects that HECO and third parties would install 10 MW by the end of 2006, and another 15 MW could be installed by the end of 2010. This contrasts with the assumed rate for DG penetration in HECO's August 2002 load forecast of 1MW per year (or 7 MW from 2004 through 2010). The 2003 East Oahu Alternatives Study discussed in my testimony includes an analysis of the possible impact of this aggressive CHP Program on the load forecast used for the EOTP analyses.

Q. Can HECO implement any of these options in place of the 138kV transmission line or 46kV transmission alternatives?

A. As discussed later in my testimony, the options to increase the current carrying capacity of transmission lines can be problematic and will place the HECO system at an increased risk of experiencing an overload situation. There has been considerable development and even more potential for new technologies for Hawaii, however, there is also a need for increased transmission capacity. The bottom line is that it is not really a question of whether we should pursue cost effective DSM and CHP programs, or add cost effective renewable resources, or maintain and improve the reliability of our transmission system. HECO should pursue all of these objectives. HECO is aggressively promoting the installation of cost effective DSM measures through its PUC-approved DSM programs, and has filed new LM programs. HECO is seeking approval of a major CHP program, which would place HECO and its subsidiaries at the forefront of utilities promoting the installation of energy efficient CHP systems, if the program is approved. HECO and its subsidiaries, including its new renewable energy subsidiary, are actively seeking to acquire capacity and energy generated from renewable resources at both the utility and customer (through solar water heating) levels.

Nonetheless, neither DSM, nor CHP (and DG), nor renewable resources can eliminate or cost effectively address the East Oahu transmission problems and concerns that will be addressed by the proposed 46 kV project.

Q. What is HECO's selected alternative?

A. In consideration of numerous factors described in HECO T-1, the HECO Executive Team selected the Kamoku 46kV Underground – Expanded Alternative, to be implemented in two phases.

138kV LINE OVERLOAD SITUATION

Q. Using the load flow analyses outlined earlier, what system problems were identified in the 2003 East Oahu Alternatives Study?

A. Based on the latest long-term load forecast, two overload situations identified: 1) the Koolau/Pukele line overload situation and 2) the Downtown line overload situation.

HECO Load Forecast

Q. What load forecast assumption is used in the load flows, which identified the overload situations?

A. The 2003 East Oahu Alternatives Study and the Koolau/Pukele Overload Options Study used the latest long-term forecast, which was the August 2002 Long-Term Sales and Peak Forecast (as shown in HECO-409). The August 2002 Long-Term Sales and Peak Forecast includes a Base forecast (most likely scenario), a High Forecast and a Low Forecast.

Q. Of the three forecasts (i.e. Base, High or Low), which was used to identify the projected timing of the Koolau/Pukele and Downtown overload situations?

A. The Base forecast is used to identify the overload situations. Sensitivity analyses are also conducted to identify the effect of higher and lower load growth rates on the overload situation.

Q. Does the August 2002 Long-Term Sales and Peak Forecast provide area specific load forecasts? For example does it forecast the loads for the Koolau/Pukele area?

A. No, the Long-Term forecast provides an overall system forecast. Load flows for planning studies assume a pre-determined load distribution at the substations based on historical data. Load growths of these substations is estimated to grow at the same rates as the overall system load growth rates, as forecast in the long-term forecasts. I will describe the methodology used to develop the load forecast for the load flows later in my testimony.

Q. Are different load centers on the HECO system, such as the West Side, growing at faster rates than the East Side load centers?

A. A trend analysis using historical substation data from 1994 through 2002 was performed and is shown below.

Table 2: HECO LOAD DISTRIBUTION BY LOAD CENTER

	% OF SYSTEM DAY PEAK LOAD									
YEAR/ LOAD CENTER	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**AV.**
Downtown	27	25	26	27	27	28	27	27	26	27
Koolau/Pukele	32	31	30	29	30	31	30	30	30	30
Central	19	19	19	19	18	17	18	18	18	18
West	23	25	25	24	25	24	26	25	26	25

The table shows the percent of total system load for the four main load centers on Oahu. The percentages have remained fairly consistent from year to year and there is no evidence that one particular area of the HECO system is growing at a faster rate compared to the others. Therefore, the current methodology of applying the overall system load growth rate to pre-determined load distributions (based on historical data) is a reasonable approximation of future load growth at each substation and area specific load forecasts are not required.

Day and Evening Peaks

Q. Explain the characteristics of a typical HECO daily load profile.

A. HECO-410 is a graph of a HECO daily load profile. HECO typically has two peaks. One peak, which typically occurs around 1:00 p.m., and is referred to as the "Day Peak", and a second typically occurs around 6:00 p.m. in the evening, and is referred to as the "Evening Peak".

Q. Which peak is used in the transmission planning studies referred to in your testimony?

A. The Day Peak is used, even though it is lower than the Evening Peak. The Koolau/Pukele and Downtown overload situations occur during the contingency where one 138kV transmission line is out for maintenance and HECO loses a second 138kV transmission line. Maintenance on a transmission line usually is scheduled during the day, where the 138kV transmission line is taken out of service at about 9:00 a.m. and is returned to service by 2:00 p.m. or prior to the Evening Peak.

Q. Is this a reasonable approach for planning the transmission system?

A. Using the Day Peak for these planning studies is a less conservative approach then using the worst-case condition, which would be to use the Evening Peak forecasts. However, returning the line to service prior to the evening peak is a normal HECO practice, and utilizing the Day Peak for planning purposes is a reasonable approach. At the same time, it should be recognized that it is not always possible to restore a line to service prior to the Evening Peak.

Q. Have there been instances in the past where a transmission line on maintenance could not be restored in time for the Evening Peak?

A. Yes, there have been 10 instances since 1996 in which an outage has extended beyond the normal maintenance outage time for about a day or longer. All these were for unplanned or forced outage conditions. Most of the instances shown involved the 138kV transmission lines supplying either the Koolau/Pukele load center or the Downtown load center.

Table 3: Extended Transmission Outages

DATE	CIRCUIT	REASON	DURATION (DAYS)
5-Apr-03	Koolau-Pukele	Structure Failure	4.5
22-Dec-02	Makalapa-Airport	Insulator Failure	1.0
14-Sep-02	Kahe-Halawa #2	Shield Wire Failure	1.0
02-Dec-01	Kahe-Halawa #1	Shield Wire Failure	1.3
25-Oct-01	Waiau-Koolau #1	Unknown	1.1
09-Oct-00	Halawa-Koolau	Insulator Flashover	2.6
08-Aug-00	Halawa-Koolau	Insulator Flashover	1.0
11-Mar-99	Halawa-Koolau	Insulator Flashover	1.0
22-Aug-98	Halawa-Iwilei	Insulator Flashover	2.8
15-Feb-96	Halawa-Koolau	Insulator Flashover	2.0

<u>Application of the Load Forecast For the Analyses</u>

Q. Describe how the August 2002 long-term forecast was used in the load flow analysis.

A. The Koolau/Pukele Overload Options Study (pages 13-16) explains in detail how the August 2002 long-term forecast was used in the load flows. To summarize the information, historical load demand in MW was collected for the Koolau, Pukele and Downtown Substations. This MW demand represents the load at the substations coincident with the 2002 Day Peak. The load was multiplied using the load growth factor for the Day Peak from the August 2002 long-term forecast. The result is a calculation of the load demand of the Koolau/Pukele and Downtown load centers for future years. The load in MVA is also estimated using information from the load flow simulations. Some adjustments were made to the combined Koolau Substation and Pukele Substation load because of maximum MVA capabilities at substations such as Pukele. These adjustments are described in the referenced study (pages 13-16).

Q. How are the load demands of the Koolau/Pukele and Downtown load centers used in the load flow analyses?

A. The load demand calculations are placed into the load flow and simulations are performed. The results of the load flows show the resulting current and voltages on the system as a result of the load demands at substation busses and the injection of power from generating units. Load flows are done for various years within the study period and line currents on the 138kV transmission lines are compared against normal and emergency current ratings of the lines. In the case of the Koolau/Pukele overload, the current through a single line feeding the Koolau Substation (when one line is out for maintenance and another line becomes unavailable for any reason) will exceed its emergency rating when the combined load at the Koolau and Pukele Substations is greater than 362 MW.

Koolau/Pukele Line Overload

Q. Please explain the Koolau/Pukele line overload situation.

A. There are three 138kV transmission lines providing power to the Koolau Substation. There are two 138kV transmission lines from the Koolau Substation that provide power to the Pukele Substation. Together these two substations provide power to 30% of the load served by HECO on Oahu (including a peak load of 1284 gross MW on October 27, 2003). Based on load flow analyses using the load projections in HECO's August 2002 load forecast, with one 138kV transmission line to the Koolau Substation out of service for maintenance (refer to HECO-405, page 1), if a second 138kV Koolau transmission line becomes unavailable for any reason (refer to HECO-405, page 2), the current flowing through the third 138kV Koolau transmission lines will exceed its emergency current carrying capacity rating during daytime peak load conditions in the year 2005 (shown in HECO-405, page 3).

Q. Is this a violation of HECO's Transmission Planning Criteria?

A. Yes, this violates Section IV.3 of HECO's Transmission Planning Criteria as shown in HECO-406, page 3. Section IV.3 states that no transmission component shall exceed its emergency rating with one generating unit on overhaul, one transmission line out for maintenance and loss of a second transmission line. In the case of the Koolau/Pukele overload, the current flowing through the third 138kV transmission line feeding Koolau Substation exceeds the emergency rating of the line in the year 2005, which is a violation of the criteria.

Q. How does the Koolau/Pukele overload situation impact HECO system reliability?

A. The current flowing through the remaining 138kV transmission line will exceed the emergency rating. The conductor will heat up beyond normal operating parameters and could possible break down and the line could suddenly be lost. Loss of the third 138kV transmission line feeding the Koolau/Pukele area would result in loss of electricity service to 30% of HECO's customers including sub-transmission substations that feed communities such as Kailua, Kaneohe, Kahala, McCully and Waikiki. Refer to HECO-404. The damage caused to the failed transmission line from the overload could lead to a continuous prolonged outage of the line in order to perform the repairs, placing HECO at risk of an additional overload situation.

In the event of a possible overload situation, an Energy Management System ("EMS") program will automatically shed load at the Koolau and Pukele Substations in pre-selected blocks in a pre-selected order associated with the most overloaded transmission line. The program is activated by an overcurrent protection scheme, which will shed load if the current flowing through the Koolau 138kV lines goes above 1640 amps, the emergency rating of the Koolau 138kV transmission lines. Once load is shed, currents are rechecked to see if they have returned to normal, and if the current is still above 1640 amps, additional circuits will be shed.

Q. How is the emergency rating of the conductor determined (i.e. the 1640 amps on the 138kV Koolau transmission lines)?

A. The emergency rating of the conductor is an engineering value based on conductor size, material, and design wind conditions, but does not account for other factors in the field such as: actual weather conditions, the numbers of conductor splices, the age and condition of conductors, the accuracy of CTs in the overcurrent protection scheme, the terrain where the line is installed, etc. Therefore, the Supervising Load Dispatcher or any higher-ranking System Operation personnel may, at their discretion, take precautionary measures and intervene before the overcurrent protection scheme is activated, to avoid larger outages or maintain system integrity. The system operator has the ability to shed individual 12kV and 46kV distribution feeders in the Koolau/Pukele area to decrease the current flow until there is no longer an overload situation.

Q. How much load would HECO have to shed during a line overload situation?

A. The amount of MW would vary, since the load in the Koolau/Pukele area varies throughout the day. An estimated amount of MW at day peak conditions each year is shown in HECO-407.

Q. What would be the duration of the outage?

A. Service would be restored when a second 138kV transmission line feeding the Koolau Substation was placed back in service, which could be a matter of seconds for short-term faults or days for severe line outages. Note that even during situations where only one 138kV transmission line is energized, electricity service to all customers might be restored, at least temporarily. This would occur during time periods after the evening peak and early mornings, when the load demand is low.

Q. Why is it important that HECO not simply rely on remedial measures, such as load shedding, to relieve the overload conditions?

A. Remedial actions such as load shedding should not be relied upon as a long-term solution to line overloading conditions, especially on an island utility system where there are no interconnections. As described in Mr. Pollock's testimony, HECO T-3, some of the lessons learned from major outages that have occurred in North America, and from HECO's 1983 blackout as well, include: (1) there is a need for stronger interconnections, (2) transmission systems should be designed to withstand the most probable outages in order to remain stable, and (3) planning should be done for multiple outages. In HECO's case, a criteria violation including loss of two lines has been identified, which follows the idea of planning for the most probable outages and the need to maintain a robust system to be able to handle multiple line outages. As described later in my testimony, HECO experienced several instances where multiple line outages occurred that resulted in island-wide blackouts or loss of service to nearly the entire island.

In addition, relying on load shedding would not address the Pukele Substation reliability, or the Downtown Substation reliability. Relying on remedial measures also would increase the risk for more significant transmission events to occur on the system. For example, a relay might not operate properly, triggering other transmission lines to trip and causing a cascading sequence of events, where generating facilities begin to shut down, as designed, to protect vital equipment from long-term or permanent damage. These events would lead to major outages and possibly an island-wide blackout.

Q. Why is it important to avoid an island-wide blackout?

A. On an island utility system where there are no interconnection ties to other utilities, there is always a risk that the system may not be able to restart its generating units and quickly restore service to all of its customers. The restart of generation facilities is a very involved, complex and time consuming process. Units require auxiliary power usually taken from the transmission grid in order to restart. In the case of an island-wide blackout, black start units are used, which rely on battery power to start-up because there is no transmission grid to rely on for power. Black start units are smaller units that usually run on diesel fuel. These units are similar to a car where it relies on batteries to start-up and once these units are started, a unit at Kahe and Waiau can be started drawing power from the black start units. Once a large generating unit is on-line, it can feed power to the transmission grid and begin starting other generating units until all customers on the island can be restored. If the black start units fail to start, HECO will not be able to start other generating units and other measures will need to be implemented, which on an island-utility system, may be difficult.

Downtown Line Overload

Q. Describe the Downtown line overload situation.

A. There are two 138kV transmission substations serving the Downtown area, which are the Iwilei Substation and the School Substation. Power to serve the Downtown area can also come from the HPP, when it is on-line. Together, these two substations and the HPP (when on-line) provide power to 26% of the load served by HECO. These transmission substations are fed from three 138kV transmission lines providing power from the Halawa Substation via the Halawa-Iwilei 138kV transmission line and the Halawa-School 138kV transmission line, and from Makalapa Substation via the Makalapa-Airport-Iwilei 138kV transmission line. The Downtown line overload situation is similar to the Koolau/Pukele overload situation. If one of the three 138kV transmission lines to Iwilei or School Substation is taken out of service for maintenance (as shown in HECO-408, page 1), and a second Downtown 138kV transmission line becomes unavailable (as shown in HECO-408, page 2), then the current flowing through the remaining Downtown 138kV transmission line will exceed the emergency current carrying capacity rating during daytime peak load conditions in the year 2023 assuming the HPP is on-line. Refer to HECO-408, page 3. Again, this is a violation of HECO's Transmission Planning Criteria in Section IV.3, because the current flowing through the third 138kV transmission line feeding the Downtown Substations exceeds the emergency rating of the line in the year 2023.

Q. How does the operation of Honolulu Power Plant affect the Downtown line overload situation?

A. When the HPP is operating, power from the plant feeds the neighboring areas and decreases the demand for power from the West Side, which decreases the current flowing through the three 138kV transmission lines feeding School Street and Iwilei Substations. The decrease in current flow defers the overload situation.

Q. In what year does the Downtown overload situation occur if the HPP is not operating?

A. The Downtown overload situation would be accelerated from 2023 to 2006.

Q. Does HECO have plans to retire or not operate the Honolulu Power Plant?

A. HECO's current plan (as discussed in HECO's filed IRP Plan, Docket 95-0347, filed on January 30, 1998) is to continue to operate the HPP. Also, HECO relies on the HPP for voltage support during some line contingency situations.

Q. How does the Downtown line overload situation affect HECO system reliability?

A. The current flowing through the third remaining 138kV transmission line will exceed the emergency rating. In the event of a possible overload situation, the conductor could heat up and could possible break down and the line could suddenly be lost. Loss of the third 138kV transmission line feeding the Downtown area would result in loss of electricity service to 26% of HECO's customers. Refer to HECO-404. The damage caused to the failed transmission line from the overload could lead to a continuous prolonged outage of the line in order to perform the repairs, placing HECO at risk of an additional overload situation. The Halawa-Iwilei, Halawa-School and the Makalapa-Airport-Iwilei 138kV transmission lines feeding the Downtown area 138kV substations do not have overcurrent protection schemes in place. Similar to the Koolau/Pukele overload situation, the Supervising Load Dispatcher or any higher-ranking System Operation personnel may, at their discretion, take precautionary measures and intervene by shedding load using 12kV and 46kV distribution feeders in the

Downtown area to decrease the current flow through the remaining line to a level that does not exceed the emergency rating of the line.

138kV East Oahu Transmission Requirements History

Q. Have the Koolau/Pukele and Downtown overload situations been identified in previous HECO transmission planning studies?

A. Yes, the overload situations have been identified in various studies. A summary of the findings relating to the Koolau/Pukele and Downtown projected overload situations is shown below.

Table 4. Summary of East Oahu 138kV Transmission Planning Studies

	Koolau/Pukele Overload	Downtown Overload	Notes
East Oahu 138 kV Requirements (7/91)	1994	1995	HPP assumed to be retired at the end of 1994
East Oahu 138 kV Requirements Updated (8/92)	1994	1995	Initial Downtown overload (DT OL) in 1989 relieved by load transfer to Archer, HPP assumed to be retired at the end of 1994
HECO Long Range Transmission Study, 1993-2013 (3/94)	1998	2003	DT OL after 1994 if HPP is retired
East Oahu Transmission Requirements Update Study (3/98)	2002	2016	Slower load growth rate, postponed HPP retirement
East Oahu Transmission Project, Alternatives Study Update (9/03)	2005	2023	Slower load growth rate, DT OL 2006 if HPP is retired

As shown in the notes column, the forecasted overload dates have changed due to changing assumptions regarding the retirement of HPP and a slower than forecasted load growth rate.

Benchmark of Koolau/Pukele Area Forecast

Q. Table 4 shows the year of the projected Koolau/Pukele overload changing for each of the studies because of slower than forecasted load growth. How does the August 2002 forecast for the Koolau/Pukele area compare to actual load demand data?

A. A chart of the Base, High and Low forecast is shown in HECO-411. In addition, the chart shows the Base Koolau/Pukele forecast minus the updated CHP forecasts developed for the filed CHP application. The 2002 Day Peak is the starting point of the Koolau/Pukele area forecast and is lower than the forecasted Day Peak load in 2005 of 362 MW, in which the overload situation first occurs. As noted earlier, it should be recognized that there may be situations where a Koolau 138kV transmission line may not be returned to service before the Evening Peak and a line overload could occur if the Evening Peak for the combined load of the Koolau and Pukele Substation is higher than 362 MW and a 138kV line feeding Koolau Substation was down for maintenance and the second 138kV line was suddenly lost.

Q. Were there any Evening Peaks higher than 362 MW in 2002?

A. Yes, 2002 data show that the Koolau/Pukele load demand during the evening period exceeded 362 MW a total of 90 days. If a Koolau 138kV line cannot be returned to service for the evening period, there is already a risk of overload if the second Koolau 138kV line is lost if the load demand at Koolau and Pukele Substations total 362 MW or greater. Historical loads for the Koolau and Pukele Substation show that the evening-time MW load demand from these two substations has exceeded 362 MW on numerous occasions starting from the year 1999.

Q. Are there general guidelines that the HECO System Operators currently follow to minimize the risk of an overload condition?

A. Yes, HECO typically schedules maintenance on the three lines to Koolau Substation during the first half of the year, because the load demand is lower during this period compared to the second half of the year. As an example, comparing the evening peaks in the period from 1999 through 2001, all of the evening-peak exceedances above 362 MW have occurred in the last 6 months of the year. In 2002 the majority (83 out of the 90) of the exceedances occurred in the last 6 months of the year, however there were some events during the first half of the year.

Q. Based on 2003 historical data, what have been the 2003 daytime load demands for the Koolau/Pukele area?

A. The highest system Day Peak of 1256 gross MW occurred on July 25, 2003. The combined load of the Pukele and Koolau Substations coincident with this peak was metered at 358 net MW. However, daytime load demands higher than 358 MW have occurred in 2003 (on days not coincident with the total HECO system Day Peak). For example, on October 3, 2003, at 1:00 pm (Day Peak period) the combined load at Koolau and Pukele Substation totaled 364 MW, and remained at 362 MW or higher (max 391 MW) until 9 pm that night. An investigation of this occurrence was done because, in general, the combined load of Koolau Substation and Pukele Substation is typically highest during the highest Day Peak for the System. The investigation showed that a short circuit on the Archer 42A circuit caused the load normally fed from the Archer Substation to shift to the Pukele Substation. The load shift began on October 3 and the load was shifted back to Archer Substation on October 9, 2003. The high demand at Pukele was due to an outage of another 46kV feeder, however, these types of outages and the need for alternate sub-transmission and transmission paths are additional reasons why the sub-transmission and transmission systems need to be robust enough for these types of outage scenarios.

Q. What are the 2003 evening load demands for the Koolau/Pukele area?

A. As of October 31, 2003, the highest system Evening Peak was 1284 gross MW, which occurred on October 27, 2003. The combined load of the Koolau/Pukele area coincident with the highest Evening Peak was 402 net MW. This confirms that the combined evening load at Koolau and Pukele continues to be higher than the overload threshold and the amount of load demand above the overload threshold of 362 MW is increasing.

Q. Based on information as of October 31, 2003, how many incidents have occurred during the Evening Peak period where the combined load of the Koolau and Pukele Substation exceeded the overload level of 362 MW?

A. Using transformer data from January 1, 2003 through October 31, 2003, the combined load of the Koolau Substation and Pukele Substation exceeded 362 MW for 93 days. All of the incidents (with the exception of the event that occurred on October 3, 2003 at 1:00 p.m., which was described earlier) occurred during the Evening Peak period. Comparing transformer statistics from 2002 with 2003 data shows the number of days above 362 MW is increasing from 2002 to 2003, in addition, the amount of hours that the load is above 362 MW on such days is increasing. This is important, because if an overload situation did occur and large customers were asked to curtail their load, or if electricity service to customers in the area was interrupted to reduce the overload condition, the outage would last for up to 3-5 hours rather than 1 hour. This would have a large impact on businesses in the area.

<u>May 2003 Short-Term Sales and Peak Forecast</u>

Q. How is HECO's short-term forecast used in the analyses?

A. Quarterly short-term forecast such as the May 2003 Short-Term Sales and Peak Forecast shown in HECO-409 are reviewed. In this case, the short-term forecast still remains close to the August 2002 long-term forecast, although the peaks show a slight increase in the load growth rates. In addition, the short-term forecast falls in between the ranges specified for the High and Low 2002 long-term forecast.

Q. What factors indicate that the load growth rates at HECO substations may be increasing compared to decreasing trends as seen by past study updates?

A. Factors that indicate that load growth rates may be increasing include recent announcements by the military of plans to construct additional housing in Hawaii. Other examples include the cruise line Norwegian Star's plans to add two additional cruise ships to the interisland tours, as well as robust home sales because of low interest rates. HECO-412 plots the combined MW load for the Koolau Substation and the Pukele Substation at the time of the system Day Peak, which occurred on 7/25/03 based on 2003 data up until 10/31/03. The graph in HECO-412 plots the combined Day Peak load with the August 2002 forecasted load for the Koolau/Pukele area (base, low and high forecasts) and the May 2003 Short-Term forecast. The 2003 Day Peak load is tracking a path along the high 2002 Long-Term forecast. This data combined with the factors mentioned earlier suggest a change in cycle from a slow load growth cycle as experienced in recent years to an accelerating load growth cycle.

<u>Combined Heat and Power Impacts</u>

Q. Does the August 2002 Long-Term forecast include CHP impacts?

A. The August 2002 Long-Term base forecast includes the estimated impacts of third party cogeneration. Several third party cogenerators have been installed, are in the process of being installed or are being proposed on Oahu. The impact estimates included in the long-term forecast assume approximately 1 MW of cogeneration per year for the 20 year forecast. The third party cogenerators are separate from HECO's program to implement CHP systems. For the purpose of explanation in this testimony, third party cogenerators will be referred to as DG units and CHP refers to HECO's program to install CHP systems.

Q. HECO filed an Application for a CHP Program Docket 03-0366 with the Commission on October 10, 2003? What is the estimated growth rates for DG and CHP systems used in the applications and how do such growth rates differ from the DG/CHP growth rates used in the August 2002 forecasts?

A. The CHP forecast developed for the CHP Program Application estimate that a total of 18.5 MW of CHP/DG can be added by 2008 if the application is approved and that the total will increase to approximately 42 MW of CHP/DG by the year 2022. The 18.5 MW includes both utility-owned CHP systems and third party DG. HECO-413 shows a comparison of the DG forecasts in the base, low and high 2002 Forecasts, the DG assumed in the May 2003 short-term forecast and the DG and CHP systems included in HECO's CHP filing. For the updated analyses, the amount of DG in the Koolau/Pukele area is assumed to be only a portion of the total DG amounts shown in the graph. There is still some uncertainty with respect to PUC approval of the CHP program as to how much of the total forecasted CHP impacts included in the filing will be realized, and the extent to which the impacts will be located in the Koolau/Pukele area. Even if all of the CHP systems were installed in the Koolau/Pukele area, the graph shows that additional measures must be taken to reduce the line overload. HECO continues to pursue the installation of new technologies such as CHP and the installation of transmission facilities in parallel.

PUKELE SUBSTATION RELIABILITY CONCERN

Q. How is the Pukele Substation connected to the HECO 138kV Transmission System?

A. Refer to HECO-401. Two 138kV transmission lines currently feed the Pukele Substation from the Koolau Substation in Kaneohe, on the windward side of Oahu. The two 138kV lines cross the Koolau Mountain Range to connect the Pukele Substation to the rest of the HECO system. Still pictures of portions of the line can be found in HECO-414. The power transported from these two lines is stepped down to the sub-transmission voltage of 46kV by four 80 MVA 138/46kV transformers and transported over eight 46kV feeders that branch out from Palolo Valley to distribution substations in Kahala, Kaimuki, Manoa, Makiki and Waikiki.

Q. What percentage of HECO's total system load is served by the Pukele Substation?

A. The Pukele Substation is the most heavily loaded 138kV substation in the HECO system. Based on 2002 Day Peak load conditions, the Pukele Substation supplies electricity to about 16% or approximately 192 MW of the Oahu load. (The peak served by the Pukele Substation in 2002 during the evening peak period was approximately 391 MW.)

Q. What is HECO's concern with respect to the reliability of the Pukele Substation?

A. If the two lines providing power to the Pukele substation were both out of service, 93% of the customers serviced from the Pukele Substation would incur an outage. Most of our customers in the area extending from Makiki to Waikiki, and from Koolau to Kaimuki, would be out of power until one of the two 138kV transmission lines could be restored to service. We have been fortunate that the second Koolau-Pukele line has not been lost due to a forced outage at the same time that one of the lines is out of service for maintenance, or that both lines have not been forced out of service at the same time. While many parts of the two lines have been renewed and upgraded, the two Koolau-Pukele 138kV transmission lines are substantially 40-years old. Typically, a transmission line experiences an increase in forced outages as the line ages. Securing the reliability of the existing transmission lines requires regular maintenance. Even with visual inspections and maintenance on the Koolau-Pukele 138kV transmission lines, however forced outages still occur. These lines are subject to extreme weather conditions due to the high winds, heavy rains, and salt laden marine air that are prevalent in the coastal Koolau Mountain Range.

Koolau-Pukele 138kV Transmission Line Maintenance Outages

Q. Does HECO take the Koolau-Pukele lines out for maintenance?

A. Yes. Outages have been required to complete tower structure reinforcements and other system improvements, and are required to correct problems identified during interruptions. The two Koolau-Pukele lines have been out a total of 95 days since 1999 to complete reinforcement work on the towers supporting the two lines to the Pukele Substation. Future planned tower reinforcements are not expected, however situations do arise. For instance, HECO will need to schedule an outage of the Koolau-Pukele #1 line later this month or in the first quarter of 2004, in order to permanently repair structure 19, which was damaged on April 5, 2003. The repair will take approximately three weeks and will require daily weekday outages of the Koolau-Pukele #1 line.

Q. How does HECO determine whether maintenance is required on the Koolau-Pukele 138kV transmission lines?

A. HECO conducts quarterly visual inspections on all 138kV transmission lines. In addition, HECO exercises all 138kV breakers on a quarterly basis and test all 138kV relays on an annual basis. HECO will typically attempt to schedule maintenance as a result of these inspections and tests during periods when the risk of a forced outage of the remaining line is not higher due to climate conditions such as high winds. However, maintenance cannot always be delayed, especially when it is required to repair a condition that has resulted from or may cause a forced outage. Also, the two lines run through mountainous, hard-to-access terrain where the weather can be fierce and unpredictable. It has happened that crews working on the Koolau-Pukele lines in the Koolau Mountains have been forced to camp overnight in bad weather because a helicopter was unable to fly in to lift them out.

<u>Outage of two Koolau-Pukele 138kV Transmission Lines</u>

Q. Has there been an instance where both of the Koolau-Pukele lines were unavailable simultaneously, which would cause the loss of service to the Pukele Substation?

A. As I indicated, Hawaii has been fortunate that the second of the two 138kV lines to Pukele Substation has not tripped out of service while the other line was out for maintenance, or out of service due to a forced outage. However, the latter situation very nearly occurred in 1994. In addition, HECO has experienced outages on other parts of the electric transmission system – outages that seemed even less likely. In the case of two major system outages, <u>two</u> lines tripped out at about the same time while another line was out of service for maintenance. The resulting outages had major customer impacts.

Q. Describe the 1994 situation where one of the Koolau-Pukele 138kV lines was out due to a forced outage and HECO was able to avoid a situation of losing the second 138kV line to Pukele Substation.

A. HECO had a near miss situation in 1994. The table below lists the flashover events that occurred on November 21, 1994.

Table 5. 1994 Flashover Incident Summary

DATE	TIME	CIRCUIT	OUTAGE DURATION (minutes)
November 21, 1994	5:41:32 a.m.	Koolau-Pukele #1 138 kv	Instantaneous
November 21, 1994	5:41:48 a.m.	Koolau-Pukele #1 138 kv	Instantaneous
November 21, 1994	6:40:54 a.m.	Koolau-Pukele #2 138 kv	1
November 21, 1994	7:50:55 a.m.	Koolau-Pukele #1 138 kv	1
November 21, 1994	9:28:12 a.m.	Koolau-Pukele #1 138 kv	Instantaneous

In 1994, HECO experienced a high number of insulator flashovers throughout the island, including the Pukele area. The table above shows the sequence of events for November 21, 1994. Of particular interest is the third flashover incident, which did not result in automatic reclosing of the line, which meant the Koolau-Pukele #2 138kV line was de-energized. The system operator assessed the situation and made the decision to close the line back in. If the system operator had not made that decision and had left the line de-energized so that crews could conduct further investigation on the trip of the line, the flashover incident an hour later at 7:50 am on the Koolau-Pukele #1 line would have caused a situation where both Pukele 138kV lines were out and service would have been lost to all of the Pukele area customers.

Q. Describe the two major system outages, where two lines tripped out about the same time while another line was out of service for maintenance.

A. HECO has historically provided a high level of reliable electric service. Nonetheless HECO has experienced multiple line outages in the past, some of which have resulted in severe outages to HECO's customers. For example:

1) In 1988, approximately two-thirds of Oahu experienced an outage while two 138kV circuits were out of service so that a wooden structure supporting both lines could safely be replaced with a steel structure, the CEIP-Waiau 138kV circuit failed causing the line to shut down. A conductor on the Kahe-Halawa #1 138kV circuit failed two seconds later, causing that line to trip, even though the work was being done at a time when one line had enough capacity. An automatic shutdown of most of the island's generating units then occurred resulting in a blackout that lasted up to several hours in some locations.

2) On April 1991, an island-wide power outage occurred while one Kahe transmission line was down for maintenance, two other lines- Kahe-Halawa #1 and Kahe-Wahiawa tripped out of service within 10 minutes of each other. Only a fourth 138kV transmission line remained to export power from Kahe Power Plant. This line was then shut down to prevent damage from overloading. The island's generating units subsequently shut down automatically to prevent damage.

3) As recent as April 4, 2003, the downtown area experienced a double line contingency where the Halawa-Iwilei 138kV transmission line was interrupted for 13 minutes due to a lightning strike and the Halawa-School 138kV transmission line was outaged for 30 minutes due to a breaker failure.

Although simultaneous forced outages on the Koolau-Pukele lines have not occurred, simultaneous forced outages on multiple lines have occurred on other parts of the HECO system. These outages seemed even less likely to occur and the impact of these events caused a large loss of service to the HECO customers.

<u>Impact of an Outage of Pukele Substation</u>

Q. How will customers served by the Pukele Substation be affected if both Koolau-

Pukele 138kV lines are lost?

A. Under the current 138kV transmission system, there are no other 138kV paths to feed the Pukele Substation. Under the current 46kV sub-transmission system, some automatic load transfers will occur to enable Archer Substation to pick up about 7% or about 13 MW of the 192 MW total Day Peak load currently served by Pukele. These customers would experience a service interruption of up to 6 seconds as service is automatically transferred. Another 20% of the Pukele customers may be switched manually onto the Koolau Substation within 2 to 4 hours, which is the planning time allowed for the HECO Primary Troublemen to complete switching at various sites in the field. The remaining 73% of the customer loads served by Pukele have back-up 46kV feeds from another Pukele 46kV feeder. Therefore, total loss of power would occur for those remaining customers in the Pukele service area, extending from Makiki to Waikiki and from Kahala to Kaimuki.

Some customers with emergency generators on site may be able to meet limited power needs during an area blackout. However, typical emergency generators (at a hotel, for example) serve only critical loads such as elevators and emergency lighting. Ultimately the vast majority of customers within the Pukele service area, including most of Waikiki, would be without power until at least one of the two 138kV lines to the Pukele Substation was restored to service. Therefore, maintaining reliable service to Pukele Substation is very important.

Q. Why is it important to maintain reliable service to the Pukele Substation, which is the only transmission substation serving the Waikiki area?

A. The Waikiki area includes large hotels and commercial shopping areas, and a power interruption to these loads would have a major impact on the local and state economies. While every customer is important, realistically we need to be especially cautions about Waikiki, our state's main economic engine. A blackout of Waikiki would be reported around the world creating a "third world" image for our main resort area at a time when Hawaii is positioning itself as a safe, secure domestic destination for relaxation and rejuvenation. In addition, many facilities essential to Hawaii's safety and security, such as the State Civil Defense, area also in this service area, as well as the University of Hawaii at Manoa and Kapiolani Community College. A blackout at the University of Hawaii could impact research and experiments involving millions of dollars. A blackout that incapacitates the Hawaii National Guard and Civil Defense facilities at Diamond Head could have a serious effect on Hawaii's safety and security.

Q. How will other customers outside of Waikiki be affected by the loss of service to Pukele Substation?

A. All customers in the service area would be affected if there were a prolonged outage. The safety and security of our lives are threatened when the power goes out. Condominium and office building elevators stop mid-floor, traffic lights malfunction, security and safety lights may go dark and life supporting health apparatus may not operate. When power is interrupted, day-to-day transactions come to a halt: no lights, computers, faxes, copiers, or air-conditioning; no television and only battery-operated radios. Businesses lose customers.

<u>Duration of Pukele Outage</u>

Q. If two of the 138kV feeds to the Pukele Substation are lost, how long will the customers in the Pukele service area experience an interruption in electricity service?

A. For most customers, the outage in the Pukele service area would last until one of the two 138kV lines providing power to the Pukele Substation could be restored to service. If a line is de-energized to perform maintenance, the system operator can place a call into the maintenance crew to return the line back into service as soon as possible. A line de-energized for routine maintenance can typically be returned to service within the hour based on past HECO experience with the situation.

Q. How long will it take HECO to restore a line that is de-energized because of a forced outage (unexpected outage)?

A. The duration of a forced outage of the Koolau-Pukele line will depend on the severity of the damage to the line. The duration could be instantaneous or within a minute as seen with the 1994 flashover incidents on the Koolau-Pukele lines, or could last days as in the case of the April 5, 2003 outage on the Koolau-Pukele #1 line. The Koolau-Pukele #1 138kV transmission line experienced a continuous outage (including the Evening Peak period) for 4 ½ days due to structure damage. Severe weather conditions could also cause a prolonged outage that could take weeks to repair.

Q. If a prolonged interruption of power to the Pukele Substation occurs, can power be restored using HECO's current 138kV and 46kV system configurations?

A. In the case of a prolonged interruption of power to the Pukele Substation, the load in certain segments of the Pukele service area could be manually switched to other 46kV back-up circuits receiving power from the Koolau Substation. In order to accomplish this switching, a HECO Primary Troubleman would be required to drive out to the locations and do the switching. Presently, about 20% of the total electricity demand of the Pukele Service Area could be restored to service after manual switching operations on the existing 46kV system were implemented. These customers would experience a 2 to 4 hour outages until all the switching could be done to transfer them to these back-up circuits. The majority of the customers served by the Pukele Substation would continue to experience an outage.

Q. Are there reliability concerns with other transmission substations?

A. Koolau Substation is the next most heavily loaded substation at 154 MW or just over 13% of the system load followed by Makalapa Substation at about 10% of total system load. Three 138kV transmission lines serve the Koolau Substation and four 138kV transmission lines serve Makalapa Substation. Only two 138kV transmission lines serve Pukele Substation, which is the most heavily loaded Substation on the HECO system.

Q. Does HECO's planning criteria require a specific amount of lines to serve transmission substations?

A. The number of lines required to supply a substation is not defined in HECO's Transmission Planning Criteria. Section IV.3. reference HECO-406, page 3 of the HECO Transmission Planning Criteria requires that with any transmission line out of service for maintenance and then a second line fails unexpectedly, no transmission component will exceed its emergency rating. The criteria goes on to say that the purpose of this criteria is to help assure that the system will survive and that all loads may not continue to be served. Based upon the testimony of Mr. Pollock in HECO T-3, the HECO criteria are actually less demanding than the NERC criteria. The NERC criteria require that all important loads continue to be served with a single line outage occurring when one line is out for maintenance. The statement in the HECO criteria "All loads may not continue to be served…" is not intended to imply that failing to serve the electrically large and important Downtown core business district and the Waikiki tourism based loads is an acceptable outcome should a transmission line fail while another line is out for maintenance. By way of contrast, the loss of a smaller amount of primarily residential load may be an acceptable outcome based upon the relative impact of the outages. In this way, the planning process can allow experience and judgment to be applied to the system planning process to treat the various load centers with consideration as to size, importance and other factors.

Q. Is the number of lines serving the substation the only concern HECO has with regard to the Pukele Substation reliability?

A. An additional factor that must be considered in the case of the two transmission lines serving the Pukele Substation is the geographic location of the lines as they cross the Koolau Mountains. The very difficult access to the lines, their exposure to corrosive marine air, and the location of the two lines on a common right of way, causes these lines to be at a relatively higher risk for an extended outage than the transmission lines in other areas of the island.

Q. What other factors are considered in determining the reliability of service to the customer?

A. Among the various factors considered in evaluating the reliability of service to a particular 138kV substation, HECO examines the size of the electrical demand being served, the criticality of the electrical demand, and alternative means readily available to serve the demand within the substation's service area in the event the transmission lines are unavailable.

Q. How do these factors affect the Pukele Reliability concerns, when HECO has other substations that are served by two 138kV transmission lines?

A. The reliability of other transmission substations served by only two 138kV transmission lines, for example the Wahiawa Substation and Archer Substation, is of less concern, for a number of reasons. Wahiawa Substation supplies around 10% of the island electricity demand, however, the service area is primarily rural and residential in nature. Further, most of that electricity demand is backed-up by the existing 46kV system in the area. At present, if one transmission line to Wahiawa Substation is out of service for maintenance and the other line fails, approximately four-fifths of the service area's electricity demand will automatically transfer to other 46kV circuits in the area, with those customers experiencing a momentary outage of only 6 seconds. Thus, only one-fifth of the service area electricity demand would remain without electricity until one of the 138kV lines to Wahiawa Substation is restored.

Q. Is HECO concerned about the reliability of the Archer Substation?

A. The Archer substation serves about 8% of the system load, and is located in downtown Honolulu, but only receives power, at present, from two 138kV transmission lines. As a result, there is a concern with respect to the Archer reliability situation. (Archer would have received power from a third 138kV line had HECO been able to complete the Kamoku-Pukele 138kV line.) However, the Archer reliability concern is not as critical as the Pukele reliability concern because 1) the two 138kV lines feeding the Archer Substation are approximately 14 years old compared to the over 40 year old Koolau-Pukele Lines; 2) the two 138kV lines Archer feeds are only 2 miles long, which reduces the exposure to outages compared to the Koolau-Pukele lines, which are approximately 3 times longer; 3) the Archer 138kV feeds are underground lines generally overhead lines are more vulnerable to adverse weather conditions and objects contacting the line, and require more frequent repair, while underground lines tend to have less frequent outages, however faults or problems with underground lines are harder to detect, and take longer and are more costly to repair; and 4) the Pukele Substation is the most heavily loaded substation on the HECO system and serves approximately twice the load of the Archer Substation.

Q. Given the significance of the Pukele Substation, has HECO taken steps to improve the reliability of the substation's power supply?

A. Yes, since the completion of the Archer Substation, some of the customers previously served by the Pukele substation have been moved to Archer Substation. If the Pukele Substation were to lose both 138kV transmission feeds, the transferred customers would not see an interruption in electricity service. The practice of transferring loads from the Pukele Substation is limited by the existing 46kV system and is already reaching its limitations without additional transmission facilities.

Q. Are there other measures that have been implemented?

A. Yes, prior to 1994, the two Koolau-Pukele transmission lines were part of two longer transmission lines, the 19.4-mile Waiau-Koolau-Pukele 138kV line and the 15.7-mile Halawa-Koolau-Pukele 138kV line. Longer lines are more exposed to fault conditions, and under the old substation configuration, faults on the Koolau bus would result in having to de-energize one of the two Pukele substation feeds depending on the location of the fault on the Koolau bus. In 1994, HECO installed additional breakers at Koolau Substation to segment the two lines into the following:

Halawa-Koolau-Pukele 138kV transmission line

1) 9.6-mile Halawa-Koolau line, and
2) 6.1-mile Koolau-Pukele #1 line

Waiau-Koolau-Pukele 138kV transmission line

1) 13.3-mile Waiau-Koolau line, and

2) 6.1-mile Koolau-Pukele #2 line

Q. Did HECO previously consider building a third line to Pukele Substation?

A. Yes, the September 1986 "Pukele 138KV Source Reliability Improvement Study", which was subsequently updated in October 1991, and which recommended the segmentation of the two lines feeding the Pukele Substation, considered building a third line from Halawa Substation to Pukele Substation. The purpose of the 1986 study and the 1991 update were to improve the reliability of the Pukele Substation. At the time the studies were conducted, facilities at Archer, Kewalo and Kamoku Substations were not in place. Therefore, the studies looked specifically at improving the reliability through bus segmentation, which had a considerably lower cost than installing a 138kV transmission line from Halawa Substation to Pukele Substation. (At the time, the most critical transmission projects for HECO involved completion of the Southern Transmission Corridor.) The recommendation in the study also eliminated the only three-terminal transmission line configuration on the HECO system, which is undesirable in a power system because any fault on the line affects three substations, rather than only two substations.

At the same time that HECO proceeded with the installation of the breaker and a half scheme, HECO recognized the importance of providing a third feed to the Pukele Substation in other studies. The East Oahu 138kV Requirements Study, which was done in 1991 (the same year as the update of the Pukele 138kV Source Reliability Improvements Study) looked at the overall reliability of the system and concluded that an additional line to the Pukele Substation would further increase the reliability of the substation. This study already assumed the installation of the breaker and a half scheme at Koolau Substation, which would segment the two lines feeding the Pukele substation.

Since the time of the 1991-1992 studies, HECO has installed the Archer, Kewalo and Kamoku 138kV transmission lines and substations to serve the distribution loads in the area. HECO is able to build upon these existing facilities to provide a third line to Pukele Substation, unlike in the past where a complete new line from Halawa Substation would have been required. Installation of the East Oahu Transmission Project will serve to solve a number of transmission problems and not only the Pukele Reliability problem.

DOWNTOWN SUBSTATION RELIABILITY CONCERN

Q. Are there additional substation reliability concerns on the HECO system?

A. There are three downtown area substations with only two 138kV transmission feeds, including the Archer Substation and the Kewalo Substation and the Kamoku Substation has only one 138kV transmission feed. Refer to HECO-415.

Q. Is there a concern with respect to Archer Substation's reliability?

A. Yes, as discussed earlier, Archer Substation is one of the newer transmission substations on the HECO system and is an enclosed facility located at HECO's Ward Avenue warehouse site. The Archer Substation is fed from the Iwilei and School Street Substations by two underground 138kV lines composed of paper-insulated copper cables in high-pressure, fluid-filled steel pipes, laid in duct lines. These underground lines are considered relatively reliable and are relatively new, however a catastrophic underground duct bank failure could result in loss of power to the Archer Substation for some time depending on the severity of the failure. Installing a third line to the substation would increase the reliability of the substation.

Q. Is there a concern with respect to the reliability of the Kewalo Substation?

A. Kewalo Substation is also one of the newer transmission substations and is located on Kona Street. Two 138kV underground transmission lines supply power to Kewalo Substation, each composed of paper-insulated copper cables in high-pressure, fluid-filled steel pipe laid in duct line from Archer Substation. Kewalo serves customers at the distribution of 25 kV in the Kakaako area. A catastrophic failure to the underground duct bank could result in loss of power to the Kewalo Substation. A third 138kV transmission line to Kewalo Substation would increase the reliability of the substation.

Q. What is the concern regarding Kamoku Substation's reliability?

A. Kamoku Substation is the newest transmission substation and is located on the corner of Date Street and Kapiolani Street. Kamoku Substation is fed from one 138kV underground transmission line, composed of paper-insulated copper cables in high-pressure, fluid-filled steel pipe, laid in duct line. This line brings the power form Archer Substation via Kewalo Substation to Kamoku. The entire Kamoku Substation has a 25 kV back-up system. If the 138kV transmission line feeding the Substation should fail, then the Kamoku Substation load would be transferred to Kewalo Substation. If the two 138kV feeds to Kewalo Substation experience an outage, then both the Kewalo and Kamoku Substations would be unable to serve the load. The Kewalo and Kamoku Substations provide service to Ala Moana Shopping Center, several high-rise luxury condominiums in the area and the Hawaii Convention Center. A second 138kV transmission line to Kamoku Substation would increase the reliability of the substation and provide a second 138kV feed and a third path of electricity for the substation.

Q. Are there concerns regarding the reliability of the three downtown substations as critical as the concerns regarding the Koolau/Pukele line overload and the Pukele Substation reliability?

A. The concerns are not as critical. I contrasted the Pukele and Archer Substation reliability concerns earlier in my testimony. The Kewalo reliability and the Kamoku reliability are not as critical as the Pukele reliability for similar reasons as the Archer Substation. For example 1) the two 138 kV transmission lines feeding the Kewalo Substation (Archer-Kewalo #1 and Archer-Kewalo #2) and the single 138kV line feeding the Kamoku Substation (Kewalo-Kamoku) are only a few years old; 2) the Archer-Kewalo 138kV transmission lines are approximately 10 times shorter than the Koolau-Pukele 138kV lines, which reduces the exposure to outages; 3) the Kewalo-Kamoku 138kV transmission line is only 1.9 miles long and approximately three times shorter than the Koolau-Pukele lines; and 4) the Pukele Substation is the most heavily loaded substation on the HECO system and serves approximately 16% of the HECO system load while the combined substation load served by Kewalo and Kamoku Substation represent less than 1% of the total HECO system.

EFFECTIVENESS OF TRANSMISSION ALTERNATIVES

Three Alternatives for the East Oahu Transmission Project

Q. What are the three alternatives presented to the public and to the HECO Executive Team?

A. HECO presented the Kamoku-Pukele 138kV Underground Alternative, shown in HECO-416, which requires the installation of a 3.6-mile 138kV underground line running from Kamoku Substation to Pukele Substation and two 46kV alternatives:

1) Kamoku 46kV Underground Alternative, which involves the installation of an 80 MVA 138-46kV transformer at Kamoku Substation, a new ductline with two new 46kV circuits installed running from Makaloa Substation to McCully Substation, a new circuit in the area of the intersection of Pumehana Street and Date Street near the Lunalilo Elementary School, two new 46kV underground circuits from the Kamoku Substation onto Date Street, one new 46kV underground circuit on Winam Avenue from Hoolulu Street to Mooheau Avenue in Kapahulu and modification of equipment at various distribution substations. A simplified diagram of the 46kV line connections for the Kamoku 46kV alternative is shown in HECO-417.
2) Kamoku 46kV Underground Alternative – Expanded, which involves the same installations described in the Kamoku 46kV Underground Alternative and an additional 80 MVA 138-46kV transformer at Archer Substation and a new duct bank with three new 46kV circuits installed running from Archer Substation to existing 46kV circuits on King Street and McCully Street. A simplified diagram of the 46kV line connections for the Kamoku 46kV Underground – Expanded Alternative is shown in HECO-419.

Please refer to the testimony of Mr. Wong, HECO T-6, which describe the scope of the projects in more detail. A single line diagram of the existing 46kV system served by the Pukele Substation is shown in HECO-418. The single line diagram can be used to show the changes to the existing 46kV system with the installation of the Kamoku 46kV Underground Alternative or the Kamoku 46kV Underground – Expanded Alternative.

<u>Kamoku-Pukele 138kV Underground Alternative</u>

Q. Describe the operation of the Kamoku-Pukele 138kV Underground Alternative.

A. As described in Mr. Wong's testimony, HECO T-6, the Kamoku-Pukele 138kV Underground Alternative involves the installation of an underground 138kV transmission line between Kamoku Substation and Pukele Substation. The approximate length of the proposed transmission line is 3.6 miles. This alternative provides a 138kV transmission line connecting the Pukele Substation, which is a part of the Northern Corridor, to the Kamoku Substation, which is a part of the Southern Corridor. Power will be able to flow between the Northern and Southern Corridors seamlessly and increase the reliability of the East Side transmission system.

Kamoku 46kV Underground Alternative

Q. Describe the operation of the Kamoku 46kV Underground Alternative.

A. In general, the scope of work for this alternative involves installing 0.9 miles of underground duct line and related work at seven HECO distribution substations (Ena, Kapahulu, Kewalo, Kuhio, Makaloa, McCully, and Waikiki Substations). The single line diagram for this alternative is shown on HECO-417 and can be separated into two sections for the purpose of this explanation. The first section is shown in the bolded connections found on the top half of HECO-417 and involves the installation of an 80 MVA 138/46kV transformer at Kamoku Substation and two 46kV circuits in separate duct lines to connect the new 46kV circuits from the 80 MVA transformer at Kamoku Substation to the existing Pukele 4 overhead 46kV circuit on Date Street in Moilili. In addition, a connection of the existing Pukele 4 overhead 46kV circuit on Mooheau Avenue with the existing Pukele 8 overhead 46kV circuit will be made. The single line diagram also shows that the switch connecting the Pukele 4 circuit to the Pukele Substation will remain in the open position during normal operation of the HECO system. Opening the switch for the Pukele 4 circuit, installing the 80 MVA transformer at Kamoku Substation and installing the new circuits described above will shift all of the load on the Pukele 4 circuit and a portion of Pukele 8 circuit load that is currently served from the Pukele Substation, which is at the end of the Northern Corridor, to the Kamoku Substation, which is in the Southern Corridor.

Q. What will be installed in the second section of this alternative?

A. In the second section of the Kamoku 46kV Underground Alternative, the bolded connections shown on the bottom of HECO-417 show two circuits in a single duct line will be installed and an additional duct line in the McCully area (near Lunalilo Elementary School) with a single circuit replacing three existing smaller sized cables, to connect the existing Archer 46 and Archer 41 underground 46kV circuits at Makaloa Substation with the existing Pukele 2 overhead 46kV circuit near McCully Substation. The two new circuits in a single duct line will upgrade the existing 46 kV system between Makaloa and McCully Substation, by replacing three existing underground cables with larger sized cables. The larger sized cables will provide the capability to transport more power through the cables (fed from the Archer Substation) to serve loads currently served by the Pukele Substation. The installation of the single circuit in a single duct line near Lunalilo Elementary School and various cuts and taps on the existing 46kV overhead circuits around McCully Substation will create the ties between Archer and Kamoku circuits, and the Pukele circuits. The circuit reconfigurations will essentially extend the existing Pukele lines to Archer Substation, so that load can be shifted between the two substations. The single line diagram of the existing 46kV system served by the Pukele Substation in HECO-418 can be compared with the single line diagram of the Kamoku 46kV Underground Alternative in

HECO-417 in order to see the changes made to the existing Pukele circuits.

The single line diagram shows that the switch connecting the Pukele 2 circuit to the Pukele Substation will remain in the open position during normal operation of the HECO system. Opening the switch for the Pukele 2 circuit and installing the circuits just described would shift all existing load from the Pukele 2 circuit currently served by the Pukele Substation, which is at the end of the Northern Corridor, to the Archer 46 and Archer 41 circuits served from the Archer Substation, which is in the Southern Corridor. Refer to Mr. Wong's testimony HECO T-2 for detailed information on the routing and street locations of various duct lines, circuits and overhead lines.

Kamoku 46kV Underground Alternative-Expanded

Q. Describe the operation of the Kamoku 46kV Underground Alternative-Expanded.

A. As described in Mr. Wong's testimony, HECO T-6, the Kamoku 46kV Underground Alternative-Expanded has been separated into two phases. Phase 1 is essentially the same as the Kamoku 46kV Underground Alternative described above. Phase 2 involves the installation of an 80 MVA 138-46kV transformer at Archer substation, and three new underground 46kV circuits (Archer 45, Archer 47 and Archer 48) to connect the new circuits from the 80 MVA transformer at Archer Substation to three existing 46kV circuits (Pukele 7, Pukele 6 and Pukele 5) terminating at the Pukele Substation. (Reference HECO-419) The three new Archer circuits are essentially an extension of the three Pukele circuits to Archer Substation. The new transformer at Archer Substation and the three new circuits will allow the remaining Pukele Substation loads (which would require up to 2 to 4 hours to restore during a prolonged Pukele Substation outage even after the Phase 1 installation) to be transferred from the Pukele Substation to Archer

Substation within 6 seconds. The transfers will occur by activation of automatic transfer switches if the Pukele Substation should lose both Koolau-Pukele 138kV transmission lines. Transfers will also take place through the EMS if various Pukele 46kV circuits require an outage. The Pukele 5-7 circuits will continue to be served by the Pukele Substation during normal operation if this alternative is implemented.

Effectiveness of the Three Alternatives

Q. Will all three alternatives solve the four identified transmission problems?

A. HECO-421 shows that the three alternatives are not equal in effectiveness. The Kamoku-Pukele 138kV Underground alternative shown in HECO-416 is the most effective long-term solution for solving the identified transmission problems. The 46kV alternatives are not as robust as the 138kV alternative, however, these alternatives can be installed in less time than the 138kV alternative and can minimize the length of time in which the HECO system is at risk of an overload situation.

Q. In general, how do these transmission alternatives resolve the four transmission issues described earlier?

A. As explained earlier, the HECO system transports power from generators on the Leeward Side generators along two paths. HECO-403 labels these paths as the Northern and Southern Corridors. Halawa, Koolau and Pukele Substations are in the Northern Corridor. Makalapa, Iwilei, School Street, Archer, Kewalo and Kamoku Substations are in the Southern Corridor. 138kV and 46kV lines can be installed that will allow the loads to shift between corridors in order to avoid transmission criteria violations. Shifting load reduces currents along the single 138kV transmission line still in service to serve the remaining load. Installing additional 46kV lines will provide secondary lines to the 46kV Pukele and Archer circuits, which equates to shifting the load between the Northern and Southern Corridors utilizing 46kV circuits instead of 138kV circuits. Transmission systems on the West Side and Central portions of Oahu currently have enough ties between the Northern and Southern Corridors to be able to serve the load shifts on the East Side.

<u>Kamoku-Pukele 138kV Underground Alternative</u>

Q. Explain how the Kamoku-Pukele 138kV Underground Alternative will resolve the transmission problems identified earlier.

A. Refer to HECO-422, page 1. The Kamoku-Pukele 138kV Underground Alternative provides a permanent 138kV line connecting the Pukele Substation in the Northern Corridor with the Kamoku Substation in the Southern Corridors and completing a loop on the East Side of Hawaii for added reliability. If one of the Koolau 138kV lines is taken out of service for maintenance, HECO will continue to have three lines serving the Koolau Substation. If a second Koolau 138kV transmission line is suddenly lost, the power to serve the Koolau and Pukele Substations can flow from the Northern Corridor through the remaining Koolau 138kV transmission line and from the Southern Corridor through the new Kamoku-Pukele 138kV Underground transmission line without any interruption in electricity service to the customer. This will resolve the Koolau/Pukele line overload situation. Similarly, if one of the Downtown 138kV lines is out of service for maintenance and the second Downtown 138kV line is suddenly lost, the power to serve the Downtown area substations will flow through the remaining Downtown 138kV line via the Southern Corridor and power will flow from the Northern Corridor through Kamoku Substation and Archer Substation to the Iwilei and School Street Substations and an overload will not occur on the third remaining Downtown 138kV line.

Q. Does this 138kV alternative improve the Pukele Substation reliability?

A. Yes, this alternative will provide a third feed to the Pukele Substation. If a situation occurred where both of the Koolau-Pukele 138kV transmission lines are unavailable, the Kamoku-Pukele 138kV Underground transmission line will seamlessly transfer the Pukele load onto the Southern Corridor using Downtown area substations and lines to serve the Pukele load. Customers should not see an interruption in electricity service. If this situation should occur, the Koolau 138kV transmission lines will provide power to the Koolau Substation and the gap between the Northern and Southern Corridors will move between Koolau Substation and Pukele Substation until at least one of the Koolau-Pukele 138kV transmission lines can be restored, eliminating this gap.

Q. Does this 138kV alternative improve the Downtown Substation reliability?

A. The reliability of the Downtown Substations will increase with this alternative because this alternative provides a third 138kV feed to the Archer Substation, connecting the Archer Substation to the Northern Corridor, provides a third 138kV path to Kewalo Substation via Kamoku Substation (which provides the Kewalo Substation with one 138kV feed from the Northern Corridor in addition to the two existing 138kV feeds from Archer Substation in the Southern Corridor) and provides a second 138kV path to Kamoku Substation from Pukele Substation (which provides a 138kV feed from the Northern Corridor in addition to the existing 138kV feed from Archer Substation via Kewalo Substation in the Southern Corridor).

Kamoku 46kV Alternative Effectiveness

Q. How will the shift in load from Pukele Substation to Kamoku and Archer Substations described in the previous section for this alternative affect the 46kV system and resolve the four transmission problems previously identified?

A. With this alternative, approximately 80 MW of existing load, which is served from the Pukele Substation under the existing HECO system configuration, will be transferred from the Northern Corridor to the Southern Corridor and will be served by Archer and Kamoku Substations. Refer to the first slide in HECO 422, page 2. The load shift is expected to remain in this configuration under normal operating conditions and will reduce the combined MW load demand from the Koolau and Pukele Substation to a level below 362 MW. The reduction in combined load will eliminate the Koolau/Pukele overload situation for the 20 years studied in the analyses.

Q. How does this alternative address the Pukele Reliability concern?

A. Under the existing configuration, loss of the two Koolau-Pukele 138kV transmission lines serving the Pukele Substation will cause an interruption of electricity service to customers. If the Kamoku 46kV Underground Alternative is installed, the customers transferred to the circuits served by the Kamoku Substation and Archer Substation should not experience a loss in electricity service if both Koolau-Pukele 138kV transmission lines are unavailable, therefore increasing the reliability to the customers served by these circuits.

Q. Will the remaining customers served by the Pukele Substation be switched over to the Kamoku and Archer Substations if both Koolau-Pukele 138 kV transmission lines are unavailable?

A. If an outage of Pukele Substation occurs, approximately 70 MW (not including the 80 MW of load that will be permanently shifted from Pukele to Archer and Kamoku Substations) of the existing Pukele Substation load will automatically be transferred to the Archer and Kamoku Substations. Customers on Pukele 3, some customers on Pukele 6 and the customers on Pukele 8 circuits will automatically be transferred to the new Kamoku and Archer circuits at the different distribution substations served by the Pukele circuits. For instance, if the Pukele 3 circuit suddenly lost its feed from the Pukele Substation, automatic switching will occur at Kapahulu Substation and Kaimuki Substation to transfer the load from the Pukele 3 circuit onto the new Kamoku circuit. The automatic transfer scheme requires up to 6 seconds for mechanical switches to open and close transferring the load from the primary circuits served from the Pukele Substation in the Northern Corridor to the back-up circuits served from the Kamoku and Archer Substations in the Southern Corridor. Therefore, customers included in the 70 MW block will experience up to a 6-second outage. Refer to HECO-420 for a list of substations that will experience no outages, a 6-second outage and a 2 to 4 hour outage.

Q. Will the remaining load that is not permanently shifted or automatically transferred be restored if the Pukele Substation experiences an outage?

A. During a prolonged outage of the Pukele Substation, HECO Troublemen will be sent out to perform manual switching in the field. The switching will transfer the remaining Pukele load to 46kV feeders at a different part of the Northern Corridor served by the Koolau Substation. The manual switching is expected to require approximately 2 to 4 hours to complete before service is restored to the remaining customers.

Q. If 80 MW of load is shifted to the Southern Corridor (Archer and Kamoku

Substations), will the Downtown overload situation be accelerated?

A. If the 80 MW continues to be served by Archer and Kamoku Substations and two out of the three Downtown 138kV lines are lost, the Downtown overload situation will be accelerated. However, with the installation of the 46kV Alternative, it is HECO's plan to shift the 80 MW back to the Pukele Substation if one of the Downtown 138kV lines is taken out of service for maintenance, or experiences a prolonged forced outage. The single line diagram in HECO-423 shows the transfer of load will occur by closing the switches for the Pukele 4 and Pukele 2 circuits, and opening the switches for the Archer 46 circuit and a switch at Kamoku Substation. This will shift the 80 MW of load served through the Southern Corridor back to the Pukele Substation (Northern Corridor) and will return the HECO 46kV system to its original configuration (where the Downtown Overload is projected to occur in the year 2023 using the August 2002 HECO Base Forecast and assuming the HPP is operating). Also note that with the existing 46 kV sub-transmission system, additional load from Piikoi Substation could be transferred to the Pukele Substation to further reduce the loading on the Downtown area substations as shown in the second slide on HECO-422, page 2. Therefore, the Downtown Overload situation can be deferred for another three years using the August 2002 HECO Base Forecast.

Q. Does the Kamoku 46kV Underground Alternative improve the reliability of the Downtown Substations?

A. This alternative improves service reliability to a portion of the Downtown Substation loads by providing a back-up source of power to 47% of the load (based on 2002 peak load conditions) served by the Archer, Kewalo and Kamoku Substations if Archer should lose its two 138kV transmission feeds.

Q. Compare the effectiveness of the Kamoku 46kV Underground Alternative and the Kamoku-Pukele 138kV Underground Alternative?

A. As described in Mr. Wong's testimony, HECO T-6, the Kamoku 46kV Underground Alternative can be installed sooner than the 138kV alternative. It is estimated that this alternative could be implemented in 2006. In addition, this alternative appears to have less schedule uncertainty and is less expensive to implement when compared to the 138kV alternative. The duration of the effectiveness of the Kamoku 46kV Underground Alternative is not as robust as that of the 138kV alternative. For example, the Kamoku 46kV Underground Alternative defers the Downtown Overload situation by three years, while the 138kV Alternative resolves the Downtown Overload for a planning period beyond 30+ years from the year 2002. In addition, the Kamoku 46kV Underground Alternative will not resolve the Downtown Overload situation in the event that the Honolulu Power Plant is retired or cannot operate. The Kamoku 46kV Underground Alternative provides a back-up to the Pukele Substation if it should lose both Koolau-Pukele 138 kV feeds, although the transfer of load will require 6-second outages for some customers and 2 to 4 hour outages for other customers to complete the auto transfers and manual switching. The Kamoku 46kV Underground Alternative also provides back up to a portion of the load served by the Downtown Substations. The differences in effectiveness are compared in the table found in HECO-421.

Kamoku 46kV Underground Alternative - Expanded

Q. The Kamoku 46kV Underground Alternative-Expanded Phase 2 includes three additional 46kV circuits in addition to the circuits being installed in Phase 1, which is the Kamoku 46kV Underground Alternative. How will the three additional 46kV circuits affect the HECO 46kV system?

A. The addition of the 80 MVA 138-46kV transformer and the three additional circuits shown in HECO-419 will allow all of the remaining Pukele customers that would have experienced an outage lasting up to 2 to 4 hours, to transfer to the Archer Substation circuits using automatic transfer switches. The electricity service to these remaining Pukele customers will be interrupted for up to 6 seconds because of the time required for the automatic transfer equipment to complete the switching. This 46kV alternative is almost equivalent to the Kamoku-Pukele 138kV Underground alternative, except it uses 46 kV circuits to transfer load between the Northern and Southern and does not provide complete back-up to the Downtown area substations.

Q. How effective is the Kamoku 46kV Underground Alternative-Expanded?

A. The installations in Phase 1 reduce the load for the Koolau/Pukele area by 80 MW as explained for the non-expanded 46kV Underground Alternative. Therefore, the Koolau/Pukele overload situation is resolved with this alternative.

Q. Does this 46kV alternative solve the Downtown overload situation?

A. This alternative operates the same as the non-expanded Kamoku 46kV Underground Alternative where the system operator will shift the 80 MW of load plus the additional load from the Archer Substation in the Southern Corridor back to the Pukele Substation, which is in the Northern Corridor. The Downtown overload will be deferred by three years (from 2023 with the operation of Honolulu Power Plant to ~2026) using the August 2002 Base Forecast. The device actions required for the load shift are the same as those described for the non-expanded Kamoku 46kV Underground Alternative. If the Honolulu Power Plant is not in operation, this alternative does not solve the Downtown Overload situation, however, this alternative will defer the Downtown Overload problem until 2009.

Q. Does this 46kV alternative improve the Pukele Substation reliability?

A. All of the customers served by Pukele Substation will have back-up circuits installed and can be transferred to other substations. Refer to HECO-422, page 3. Some customers will not experience an interruption of electricity service while others will experience at most a 6-second outage for automatic switching to occur. The addition of the new Archer 80 MVA transformer and three 46kV circuits in Phase 2 extends current Pukele circuits to Archer Substation and provides back-up feeds to the remaining Pukele circuits whose primary feeds will still be from the Pukele Substation. If both Koolau-Pukele 138kV transmission lines are unavailable, the automatic transfer schemes represented as switches in HECO-424 would shift the Pukele circuits onto their back-up circuits, transferring the load from the Northern Corridor to the Southern Corridor. A list of the substations that should experience no interruption of service and substations that may experience up to 6-second outages are shown in HECO-425.

Q. Does the Kamoku 46kV Underground Alternative-Expanded improve the reliability of the Downtown Substations?

A. This alternative improves a portion of the Downtown Substation loads by providing a back up to 47% of the load served by the Archer, Kewalo and Kamoku Substations (based on 2002 peak load conditions) if Archer should lose its two 138kV transmission feeds. In addition, it is technically feasible to transfer all or most of the load served by Archer Substation to the Pukele Substation based on the current estimated loading at Archer Substation and the capacity of the Pukele transformers, however, there may be low voltage situations on the 46 kV systems and this scenario should be studied further in order to determine whether further steps should be taken to allow the complete transfer of the load at Archer Substation onto Pukele Substation. In the event of a catastrophic failure to the Archer 138kV duct line, HECO could consider transferring the Archer load to the Pukele Substation by transferring load by feeders, insuring low voltage and overload situations do not occur on the 46 kV system, until the Archer 138kV duct line and/or cables can be repaired.

Q. How soon can this alternative be installed compared to the Kamoku-Pukele 138kV Underground Alternative and the Kamoku 46kV Underground Alternative?

A. This alternative can be installed sooner than the Kamoku-Pukele 138kV Underground Alternative, but will require more time to complete than the non-expanded Kamoku 46kV Underground Alternative. Explained in HECO T-6 is a proposal to install this alternative in phases. Phase 1 could be installed sooner in order to address the Koolau/Pukele line overload situation and minimize HECO's exposure to this situation. Phase 2 would provide complete back up to the Pukele Substation.

Q. Compare the effectiveness of the Kamoku 46kV Underground Alternative-Expanded with the Kamoku-Pukele 138kV Underground Alternative and the Kamoku 46 kV Underground Alternative?

A. The expanded alternative is similar to the 138kV Underground line because it resolves the Koolau/Pukele Overload Situation, defers the Downtown Overload Situation, and provides complete back up to the Pukele Substation, although the back up is not seamless like the 138kV Underground Alternative. The expanded alternative minimizes the outage time of Pukele customers who would have experienced 2 to 4 hour outages with the non-expanded 46kV alternative to 6 seconds, and can potentially provide complete back up to the Archer Substation. Kewalo and Kamoku Substations would remain out if both 138kV underground lines feeding Archer Substation were unavailable. The project can be installed in less time than the Kamoku-Pukele 138kV Underground alternative, which reduces the amount of time that HECO is at risk for an overload situation. The project can be completed in two phases to address the Koolau/Pukele Overload situation in the same time frame as the non-expanded Kamoku 46kV Underground Alternative. The complete back up of the Pukele Substation is estimated to take additional time and the estimated installation date for Phase 2 is 2008. The cost of this project is slightly higher than the cost of the Kamoku 46kV Underground Alternative, however, it is less costly than to the Kamoku-Pukele 138kV Underground Alternative.

<u>System Operation Considerations</u>

Q. What effect does the 138kV Kamoku-Pukele Underground Alternative have on System Operations?

A. System Operations will have operational flexibility in managing the operations of the 138kV system on the East Side of Oahu. Transfers of load between the Northern and Southern Corridors during 138kV line contingencies would occur seamlessly with little operator intervention. This alternative and the two 46kV alternatives would largely mitigate the need to limit scheduling of maintenance for the transmission lines serving the Koolau and Pukele Substations to seasonal or off-peak periods.

Q. What effect would the 46kV alternatives have on System Operations?

A. Implementation of either the Kamoku 46kV Alternative or the Expanded

Alternative will maximize the use of the available 46kV circuits and the capacity of the 138-46kV transformers (including the new 138-46kV transformers installed at Kamoku and Archer Substations as part of the 46kV Expanded alternative.) This plan will thereby enhance the reliability of service to area customers.

Q. What changes must System Operations make when maintenance is done on one of the three 138kV transmission lines feeding the School and Iwilei Substations?

A. Limited human intervention is required before one of the three transmission lines serving the Downtown service area is removed from service for maintenance. Some loads would temporarily need to be shifted back to the Pukele Substation during these times. All switching operations for shifting load from the Downtown to Pukele service area can be done remotely via the Energy Management System ("EMS") from the load dispatch office. If switching operations are done properly and unexpected equipment failures are not experienced, customers should not experience an interruption in service while this shifting occurs. This alternative would also require that all 46kV circuits involved in the load shift be in service at the time of the Downtown 138kV line maintenance.

Q. Does the HECO Transmission Planning Criteria have guidelines on manual intervention when planning for the system?

A. Yes, Section IV.3. states "Manual intervention will not be required to meet these conditions." HECO-406, Page 3. This can be interpreted to mean that HECO should select alternatives that do not require manual intervention, such as the 138kV Kamoku-Pukele Underground Alternative, which provides a seamless transfer of power during 138kV line contingencies in the area.

Q. Why is HECO considering a solution that requires manual intervention and appears to be not as robust as the 138kV alternative?

A. The Koolau/Pukele overload situation, the Downtown overload situation, the Pukele Substation reliability concern and the Downtown Substation reliability concern were identified as problems in previous studies. The overloads were identified in studies dating back to 1991. As described in HECO T-2, over the past 12 years, HECO has vigorously pursued the permits for a partial underground, partial overhead 138kV transmission line connecting the Kamoku Substation to the Pukele Substation. This was the recommended long-term solution, and a 138kV connection continues to be the most effective long-term solution. After two environmental impact statements (1998, 2000) and a contested case hearing before the Board of Land and Natural Resources ("BLNR"), the BLNR denied the permit for the overhead section of the Kamoku-Pukele 138kV transmission line. Since then forecasted loads have grown and enough time has passed to where the Koolau/Pukele overload situation is forecast to occur in 2005 although it could occur even sooner. The Pukele Substation reliability concern will continue to be unresolved until connections to the Southern Corridor (whether in the form of a new 138kV line or 46kV line connections) can be implemented. A 138kV underground transmission line would require substantially more time to implement, which would place the HECO system at risk for the additional time required before the long-term alternative can be fully implemented. Because of this, both short-term and long-term solutions need to be considered in resolving the planning criteria violations. Therefore, the 46kV alternatives, which involve manual intervention by the system operator, have been included in the planning studies. These alternatives can be installed sooner, require less permitting, and cost less, although they are not as effective in the long-term.

OPTIONS TO RELIEVE ALL FOUR TRANSMISSION CONCERNS

Q. Has HECO studied other options besides installing the 138kV alternatives or the 46kV alternatives?

A. Options other than the eight transmission alternatives described earlier were studied throughout the earlier community input process and EIS process, and more recently as directed by the HECO Executive Team in the 2002-2003 time frame. These options can be categorized into two broad categories:

1) Options that might address all of East Oahu Transmission problems collectively and
2) Options that only address the Koolau/Pukele overload situation.

Within the two categories, options can be characterized in two ways:

1) Transmission Related Options, which include new or modifications to existing transmission and sub-transmission facilities), and
2) Non-Transmission Options, which are options that solve the transmission problems by other means such as reducing the load served through DG or CHP systems.

In 1995, HECO contracted a consultant, CH2M HILL, to complete (with input from HECO and its CAC) the 1995 CH2M HILL Alternatives Study mentioned earlier in my testimony. The study evaluated transmission alternatives such as the four 138kV and the 46kV radial and 46kV network alternatives described earlier, non-transmission options such as DSM, and generated-related options such as wind, solar and fuel cells. As a result of the study and input from the CAC, HECO completed a review of DG on the HECO system through the DG Alternatives Study completed in March 2000.

Q. What did the CH2M HILL Alternatives study conclude about DSM options?

A. The analysis noted that two of the four transmission problems could be addressed through an aggressive DSM program. The analysis explained how the load growth expected to cause the Koolau/Pukele and Downtown Overload situations already included the load reduction impacts of DSM programs anticipated to be in effect at the time. However, CH2M HILL concluded that island-wide demand for electricity was anticipated to grow by 3% per year and, although HECO's DSM program would dampen the growth, the need for electricity was expected to grow.

Q. Describe the analysis of renewable technologies such as wind and solar, and new technologies such as fuel cells.

A. CH2M HILL cited various wind sites that were closest to the Koolau/Pukele service area, which included Tantalus, Waimanalo and Koko Head areas. The study noted that approximately 3 acres were needed per 500 kW wind turbine. Approximately 1,200 acres of land and over 400 wind turbines would be required to provide complete back up of Pukele Substation and resolve the line overload conditions. Additional transmission facilities would also be required to transport the power into the Koolau/Pukele area and tie into HECO's grid.

With respect to solar energy, the study noted that Hawaii has a large market for the use of solar energy through the use of solar water heaters and heat pump heaters. Hawaii has the highest per capita of solar water heating installations in the United States. Large-scale solar production of energy within East Oahu would require 450 to 700 acres of land per 100 MW plant, which would severely impact vegetation on the island, although other environmental impacts would be minimal. Corrosion from the high salt content in the air was another issue cited.

Fuel cells were discussed in the study, and were described as a developing technology still in the "demonstration stage." Although fuel cells have continued to develop, the technology is still considered to be in the "demonstration stage." There are other obstacles to overcome such as the prevention of accidental spills of the electrolyte medium used for the chemical reactions that are used to generate electricity. The March 2000 DG Alternatives Study also reviewed fuel cells for use as DG units. The conclusion in the study was consistent with CH2M HILL's assessment that the fuel cell technology was still under development, and the study noted issues with widespread use of fuel cells related to high manufacturing costs, durability and reliability of the technology.

Q. What are the conclusions about distributed generation in resolving the four identified transmission problems?

A. The March 2000 DG Alternatives Study focused on the practical issues of installing DG units as an option to the 138kV partial overhead, partial underground line. In order to provide the same reliability as the new 138kV line, approximately 200 MW of DG was required to backup the entire Pukele Substation. Successful implementation of a project of this magnitude would depend upon the availability of land in the Manoa, Palolo, Waialae/Kahala, Kaimuki, Kapahulu, McCully/Moilili and Waikiki area, the development of fuel supply and maintenance resources, interconnection requirements, permitting issues, and the ability to use existing "emergency" back-up generators for this purpose. Costs for DG were estimated to be several times if not more expensive than the partial underground, partial overhead Kamoku-Pukele 138kV transmission line and the conclusion of the study recommended installing the Kamoku-Pukele line because of economic and practical reasons.

Q. Describe the possible locations for DG installations.

A. Conceptually, there are two extremes in locating DG. The distributed generators could be connected to various transmission and sub-transmission substations, and serve the Koolau and Pukele Substation customers through the existing sub-transmission and distribution network, or the DG units would be connected directly to customer loads. In theory, transmission, sub-transmission and distribution facilities and upgrades of such facilities can be deferred as DG connections are made closer to customers, because the electricity will not have to be transported over lines in order to serve the customers. In order to achieve such a deferral the DG units cannot be simply installed, they must be running. If they are not running, then a means of transporting electricity from existing central station generating sources is still required.

Q. Are there existing DG installations in the Koolau/Pukele area.

A. The March 2000 DG study estimated that approximately 39 to 52 MW of emergency generation exists, based on discussion with diesel generator vendors that supply the emergency generators. Emergency generators are used if a loss of electricity service occurs. In order to use its emergency generators, the customer isolates itself from HECO's grid and starts the emergency generator. The generator is typically sized to provide power for elevators, emergency lighting and other critical loads, and is not sized to completely serve the customer's total load.

Existing DG installations can only benefit the customers that installed the DG units. In the event of a loss of generation, the customer isolates itself from the grid, and is not able to provide power to other customers. There is a potential for additional DG installations at commercial customer sites such as hotels and large businesses, however, as seen with existing emergency generator installations, only the customers that installed the DG units will benefit from the added reliability of the DG units. Residential customers would have to purchase and install DG units in order to benefit from DG.

Combined heat and power ("CHP") systems are a form of DG, in which generators are installed on customer sites to serve a portion of their electrical load, and the waste heat from the DG units is used to serve the customers thermal loads (for example, water heating for dishwashing and sterilizing equipment). In order for a CHP system to be cost-effective and efficient, the sizes of the system generally is based on the customer's thermal heating load. In general, the customer's heating load will size the CHP system smaller than the customer's electrical load and the customer will continue to use some electricity from HECO's grid. Because of this, the CHP system installed at the customer site, will provide added reliability to only the individual customer and cannot provide added reliability to other customers served by the Pukele Substation unless every customer in the area installs a CHP system.

Q. If DG units are installed to defer transmission, and/or sub-transmission facilities how will they be operated?

A. The March 2000 DG Alternatives Study noted that in order for the DG to provide the same reliability as the Kamoku-Pukele 138kV partial overhead, partial underground line, the DG devices would have to be connected to the customer and running. Essentially, the transmission facilities would remain as back up to the DG units. In order to address the Koolau/Pukele Overload problem, the DG units would have to be started if one of the Koolau 138kV lines was taken out of service for maintenance in order to prevent the overload situation and provide added reliability. Operating the DG units in this manner would require operating permits different from those currently approved for emergency generators.

Q. Briefly outline the air permit requirements for DG units.

A. Existing emergency generators operate under a non-covered source permit. The basic premise for obtaining this permit is that the generator will only operate in the post-contingency period after the loss of electricity service. Typically non-covered source permits do not require data modeling or an extensive review for approval, because the generator will be operated only in the event of an emergency such as loss of electricity service. DG units that will be operated at all times in order to defer transmission, sub-transmission or distribution facilities, or which will be operated during periods when line maintenance is being performed in order to prevent a line overload (i.e., in pre-contingency as opposed to post-contingency conditions) will require covered source permits. Obtaining covered source permits in the Koolau/Pukele area may be impossible, because of the densely populated areas and high-rise buildings in the area.

OPTIONS TO RELIEVE KOOLAU/PUKELE OVERLOAD SITUATION

Q. Describe the options examined in the 2003 Koolau/Pukele Overload Options Study to resolve only the Koolau/Pukele line overload situation.

A. The purpose of the analysis was to analyze in more detail possible options (other than constructing a new 138kV transmission line, or new 46kV sub-transmission circuits) for addressing the Koolau/Pukele Overload problem. The options analyzed included increasing the current carrying capacity of existing lines (at least for planning purposes), reducing the Koolau/Pukele service area load (or peak load) by targeting additional DSM, Load management, DG and CHP system penetration in the service areas (beyond that expected to result from current programs and efforts), adding renewable energy generation in the service areas and using live working techniques to avoid taking the three existing 138kV transmission lines providing power to the Koolau Substation out of service for maintenance.

Increase Current Carrying Capacity of a Conductor

Q. In describing the Koolau/Pukele overload situation, the emergency current carrying capacity of the line determines if a transmission line is overloaded. How does HECO determine the emergency current carrying capacity of a transmission line?

A. The amount of current that a transmission line can safely carry is influenced by factors such as the geometry of the conductor, the conductor size, its stranding and the material of the conductor. HECO uses standard #1-2038 to calculate the rating for each conductor. Refer to HECO-426. The exhibit shows the emergency current ratings for various conductors, which were calculated using a methodology developed by Shurig and Frick. This methodology has been the basis for most of the electric utility industry's ampacity calculations. Assumptions used in the calculation include 30°C ambient temperature and a 2 ft/sec wind perpendicular to the conductor. The emergency rating assumes a 100°C conductor temperature.

Q. How can the current carrying capacity of a transmission line be increased?

A. Several options can be implemented to increase the current carrying capacity of a transmission line. The options are as follows:

1) Re-conductoring the line,
2) Re-rating of the line, and
3) Re-tensioning the line.

Line Re-conductoring

Q. Please explain how re-conductoring can increase the current carrying capacity of a line.

A. Reconductoring with larger sized conductor is one option that may be considered to increase the current carrying capacity of a transmission line. HECO-426 shows that, as the size of the conductor increases, the normal and emergency current rating of the conductor increases. Reconductoring with experimental high temperature, low sag ("HTLS") conductors, which are relatively smaller-sized cables with the ability to handle higher heating conditions and, therefore, a higher current flow, is another way to increase the current carrying capacity of a transmission line. Using HTLS conductors may not require as many pole or tower replacements or reinforcements compared to reconductoring with a larger sized wire.

Q. Is this a viable alternative to solve the 138kV line overload situations?

A. No, re-conductoring is not a viable option for the following reasons:

1) All six lines would require re-conductoring in order to solve the overload problem, which would subject the HECO system to prolonged maintenance outages of one of the Koolau/Pukele or Downtown lines and increase the possibility of an overload situation occurring if the second Koolau/Pukele or Downtown line should become unavailable.
2) A larger conductor is heavier and the towers and various utility poles may require strengthening or replacement, which would result in additional outage time for the transmission lines and would add to the cost of the reconductoring.
3) HTLS conductors are still in the experimental stage and HECO is conducting some test trials to determine their long-term service lives and effects on system reliability. HTLS conductors also cost 12-15 times more than conventional conductors, such as the 556.5 MCM aluminum

conductors.

4) Re-conductoring of the lines, especially the Koolau/Pukele transmission lines, will be difficult and expensive, because of the logistics of stringing new conductors in the mountainous areas.

Line Re-rating

Q. Explain how line re-rating of the 138kV transmission line will increase the current carrying capacity of the line.

A. Line re-rating can be accomplished through static re-rating and/or dynamic re-rating. Static re-rating involves permanently increasing either the normal and/or emergency current ratings of conductors based on weather conditions that deviate from the assumed 30°C ambient air temperature and 2 ft/sec wind speed. For instance, if historical weather data is collected and a consistent pattern of strong tradewinds greater than 2 ft/sec exists on a regular basis, then additional current could flow through the conductors because the stronger winds will provide additional cooling to the conductors and reduce the risk of overheating the conductors.

Q. Can HECO increase the current carrying capacity of its conductors using static re-rating methods?

A. No, because of the following reasons:

1) Based on past observations, the HECO system peak usually will occur during periods of sustained hot and humid weather, this means that during conditions where HECO is at most risk of an overload situation, coincident weather patterns may not promote cool conditions (i.e., strong tradewinds probably would not be present at these times) to allow additional current to flow through the conductor without overheating the

conductor.

2) HECO's 138kV transmission lines in general, and the Koolau/Pukele lines in particular, are located in areas where different climates can occur. Weather data and line conditions from numerous locations on the transmission line may not be readily available. It should be noted that re-rating of the line would have to account for the line segment with the worst-case conditions, which could have winds at 2 ft/sec.

3) Furthermore, static re-rating will cause HECO to deviate from its design standards for determining transmission conductor ratings based on a 30°C ambient air temperature and 2 ft/sec wind speed. HECO's design standard has maintained an adequate amount of system reliability over the years and is consistent with the assumptions used by many mainland utilities.

Q. What is dynamic re-rating?

A. Dynamic re-rating or Dynamic Line Rating determines the capacity of the transmission line using real-time data inputs such as actual wind speed, ambient temperature, and solar radiation. The concept is that the system operator can take advantage of higher wind conditions at the time they are occurring and increase the rating of the line. Cameras called "sagometers" are mounted on poles to determine the amount of sag in a conductor. If additional sag can safely occur, then additional current can flow through the conductor.

Q. Can HECO increase the current carrying capacity of a conductor using dynamic re-rating methods?

A. No, dynamic re-rating is not recommended for the HECO system because of the following:

1) The line ampacity is determined using real-time data, which cannot easily be incorporated into a long-range planning study.

2) Based on past observations, the HECO system peak usually will occur during periods of sustained hot and humid weather. This means that during conditions where HECO is at most risk of an overload situations, coincident weather patterns may not necessarily promote cool conditions (i.e., strong tradewinds probably will not be present at such times) to allow additional current to flow through the conductor without overheating the conductor.

3) HECO's 138kV transmission lines in general and the Koolau/Pukele lines in particular are located in areas where different climates can occur. Weather data and line conditions from numerous locations on the transmission line route will be required for dynamic re-rating. Installation of equipment would require outages on the six 138kV transmission lines, which will place the HECO system at a higher risk for an overload situation.

Line Re-tensioning

Q. Line Re-tensioning is another method used for increasing the current carrying capacity of a transmission line. What is re-tensioning?

A. Line re-tensioning increases the current carrying capacity by pulling the conductor up so that the conductor-to-ground clearance increases. The increased ground clearance allows the line to carry more current because additional sag can be accommodated, which implies that the conductor can operate at a higher temperature.

Q. Can HECO increase the current carrying capacity of a conductor using line re-tensioning methods?

A. No, because of the following reasons:

1) Some utilities are able to take advantage of re-tensioning because they have lowered their ampacity ratings based on existing low-sag conditions. HECO has not lowered its current carrying capacity ratings based on existing low-sag conditions. The current carrying capacity ratings of HECO's transmission lines are based on the assumption that conductor sag is within the safety standards specified when the conductors were originally installed. Therefore, raising the conductors by re-tensioning the lines and allowing additional sag will not increase the current carrying capacity.

2) Re-tensioning would be difficult, if not impractical in many areas, due to the hazardous terrain and the inability to place the equipment required on the poles and structures to re-tension the line.

3) Portions of the Koolau/Pukele 138kV transmission lines include long spans of conductors as the lines come down off the mountain tops, which places an extremely high amount of force on existing line structures. Re-tensioning would increase this force, which may require tower reinforcement. Even with reinforcement the structures may not be robust enough to accept the amount of force placed on the structures through re-tensioning.

4) HECO also utilizes all-aluminum conductors on most of its 138kV transmission lines in order to mitigate against corrosion. Mainland utilities typically use steel-core conductors, which are stronger than all-aluminum conductors and may be able to take the additional tension on

the line. HECO's all-aluminum conductors could be damaged through re-tensioning.

Reducing the Load Demand in the Koolau/Pukele and Downtown Areas

Q. Another way of mitigating the line overload situations described earlier is to reduce the load demand in the Koolau/Pukele and Downtown areas. How can this be accomplished?

A. This can be accomplished by implementing a sustained DSM program, installing DG units in the area, or installing CHP systems, which will decrease the demand for power from this area and subsequently decrease the current flow through the 138kV transmission lines feeding the Koolau Substation and depending on the amount of DG installed, can defer or resolve the Koolau/Pukele overload situation. The March 2000 Review of the Distributed Generation Alternatives to the Kamoku-Pukele Line reviewed the suitability of using DG as an alternative to installing the Kamoku-Pukele 138kV line. The study concluded that at least 200 MW of DG would be required to provide the same type of reliability to the Pukele Substation as the Kamoku-Pukele 138kV Transmission Line. The study also pointed to other factors of DG installation, which are that current emergency generators are undersized and benefit only the customer that installs the generator. In order for residential customers to benefit from DG, generators would need to be installed on residential properties, since customers with DG units do not feed back on the HECO grid. Additional permitting may be required if the units are operated in a pre-contingency mode. Current emergency generators are operated only after loss of electricity service is experienced.

Q. Has HECO revisited DG options?

A. Yes, HECO recently completed an analysis (Koolau/Pukele Overload Options

Study) to review among other things the DSM, DG, and CHP options available to mitigate the Koolau/Pukele and Downtown line overload situations. The study differs from the March 2000 DG study because it does not consider the Pukele Reliability issue and focuses on the relatively smaller amount of MW required to mitigate only the Koolau/Pukele and Downtown overload situations.

Q. How many MW of DSM/DG/CHP would be needed to address the Koolau/Pukele line overload?

A. The table in HECO-407 shows the amount of MW required to address the overload of the Koolau/Pukele 138kV transmission lines. Approximately 7 MW of DSM/DG/CHP would be required by 2007, and the amount ramps up to 47 MW in year 2022.

Demand Side Management

Q. Can DSM measures be implemented to reduce the load demand in the Koolau/Pukele area and address the Koolau/Pukele Overload situation?

A. At this time, it appears that DSM is not a viable option to resolve the Koolau/Pukele Overload situation because of several reasons. First, load growth on the HECO system can grow at a faster rate than forecasted, if DSM measures based on forecasted loads are implemented to "stay even" with the MW require to address the Koolau/Pukele overload, DSM programs would become inadequate and fall behind the larger than forecasted growth rates and there would be a risk of an overload situation. Second, DSM programs are planned on a system-wide basis and are not target specific. Target specific DSM and LM programs may unreasonably increase program costs depending on market saturation conditions for each area. Third, it appears the cost to implement DSM and LM programs to resolve the Koolau/Pukele Overload situation may be higher than the Kamoku

46kV Underground Alternatives and DSM would not address the Pukele Substation Reliability Concern, or help with the Downtown Overload Situation if the Honolulu Power Plant is unavailable for any reason. The Koolau/Pukele Overload Options Study assumes for comparative purposes that 47 MW of DSM or LM programs can be achieved and does not assess some of the risks involved with relying upon DSM as the only measure to resolve the Koolau/Pukele Overload situation.

Q. How much DSM is included in HECO's load forecasts?

A. The August 2002 Long-Term Forecast, which was used in the load flows to determine the MW of overload per year, already assumes that 5.5 MW of DSM, ramping up to 57.3 MW of DSM, will be implemented for the overall system. Approximately 30% of this was assumed for the Koolau/Pukele area and 26% of this was assumed for the Downtown areas. Currently HECO's DSM programs are not area specific and long-term forecasts estimate based upon reducing the total system peak. Additional DSM programs beyond those included in the long-term forecast would have to be implemented to reduce the load demand and would need to target, the Koolau/Pukele area. Additional study would be required to assess if an adequate market exists in the Koolau/Pukele and Downtown area for additional DSM and LM programs.

Q. What are the estimated costs for DSM and LM programs ?

A. Costs estimates based on current DSM program data estimate additional energy efficiency DSM programs would cost an estimated $56 million to implement and Load Management programs would cost approximately an additional $50 million. The $/KW costs (based on actual program cost data) were used and multiplied by 47 MW (the estimated amount of DSM required to resolve the Koolau/Pukele

Overload situation). These $/KW costs can be found in Appendix B of the Koolau/Pukele Overload Options Study and do not include planning costs or the increase in costs that would most likely occur in order to increase the penetration of DSM for a specific area. If planning costs were added into the total along with an increase in $/KW for area specific DSM programs, it appears the costs for DSM and LM will be greater than the Kamoku 46kV Underground Alternative.

<u>DG at HECO Substation Sites</u>

Q. Can HECO install 47 MW of DG in the Koolau/Pukele area?

A. The most likely sites for HECO-owned DG installations are existing HECO substations. The substations in the Koolau/Pukele area were surveyed to determine the feasibility of installing 1 MW DG units at the substation sites. Details of the substation survey can be found in the Koolau/Pukele Overload Options Study, Appendix C. The site survey concluded that only 19 MW of DG units could be installed.

Q. Were other technologies, such as micro turbines and fuel cells, considered in the study?

A. Yes, the study concluded that a maximum of 19-0.24 MW micro turbines (i.e., a total of 4.56 MW) could be installed at HECO substation sites. This is significantly less than the 47 MW required by 2022. Fuel cells also were considered. However, as explained in the study, fuel cells are not designed for peaking or cycling applications. Therefore, fuel cells would not be viable and fuels cells are still considered a developing technology.

Q. Did the Koolau/Pukele Overload Options Study update the costs for the conventional DG, microturbine, and fuel cell technologies?

A. The Koolau/Pukele Overload Options Study compared the capital costs for the installation of 47 MW for each technology. The estimated costs range from $51 million for diesel-fired internal combustion engines, to $83 million for microturbines, and to $261 millions for fuel cells. The costs listed are estimated capital costs and do not include planning costs, costs for AFUDC, or operations and maintenance costs to operate the facilities.

Q. Is installing DG at HECO substations a viable option to resolve the Koolau/Pukele Overload Situation?

A. No, because the potential amount of DG installations at HECO Substations amounts to only half of the 47 MW required to resolve the overload within the 20-year planning period and it appears that DG is not as cost-effective as the Kamoku 46kV Underground Alternatives. The analysis in Appendix C of the Koolau/Pukele Overload Options Study researched HECO's ability to install DG units at all possible substation sites in the Koolau/Pukele area. There is a potential to install approximately nineteen 1 MW diesel units in the area, which is well below the 47 MW required to resolve the Koolau/Pukele overload conditions. Use of other technologies such as microturbines and fuel cells are not viable because the potential amount in MW is even less than the 19 MW and technologies such as fuel cells are not designed to operate as peaking units, which is the mode of operation required in order to resolve the Koolau/Pukele Overload situation.

<u>Combined Heat and Power</u>

Q. Were CHP applications in the Koolau/Pukele and Downtown areas considered as means to reduce the rate of load growth in these areas?

A. The August 2002 Long-Term Base forecast already assumes 1 MW of DG (third-party installations) per year. HECO filed an application to pursue a utility owned

CHP program in Docket 03-0366 on October 10, 2003. The application included a forecast of utility-owned CHP installations and third party CHP installations. Appendix A of the filed application and the graph on HECO-413 shows the amount in MW of third-party installations and HECO-owned CHP installations forecasted. HECO has estimated that a total of 18.5 MW of CHP would be installed by 2008, with the amount increasing to approximately 42 MW of CHP by year 2022, if its CHP Program is implemented now. The analysis done for the 2003 Koolau/Pukele Overload Options Study assumes that approximately 30% of the total will be installed in the Koolau/Pukele area, and 26% in the Downtown areas, based upon the 2002 load distribution shown in Table 2. The Pukele service area has a relatively high potential for CHP applications. However, even if all of the forecasted DG and CHP projects were to occur in the Koolau/Pukele area, the forecasted 42 MW would not be adequate to resolve the Koolau/Pukele Overload situation. 47 MW are required in the Koolau/Pukele area based on load flow analysis within the 20-year period.

Q. Can the installation of CHP/DG systems provide a practical option to installing transmission facilities to resolve the Koolau/Pukele Overload situation?

A. The installation of DG and CHP systems is not a practical option due to factors such as space and permitting issues, and cost. HECO has filed an application with the PUC for approval for an aggressive CHP program, which will reduce the rate of load growth that has to be served from central station generation. The potential for DG and CHP potential on Oahu is still developing, and HECO needs address the possible overload situation that can already occur based on current Koolau/Pukele evening peak loads and forecasted Day Peak loads.

Combination of DSM/DG/CHP Alternatives

Q. Could HECO implement a combination of DSM, DG, and CHP options in order to address the Koolau/Pukele transmission line overload problem?

A. In theory, it might be possible to defer, but probably not eliminate, the Koolau/Pukele overload problem through some combination of targeted DSM, DG, and CHP installations in the Koolau/Pukele service area. However, there would be substantial uncertainty as to whether the objective could be achieved, given the practical problems with substantially increasing the amount of DSM, DG and/or CHP installed in the area in the near-term, particularly in light of the fact that the overload problem could occur in 2004 during daytime peak periods, and is already at risk of occurring during evening peak periods. The total cost of deferring the overload problem using such measures would probably exceed the cost of the preferred Kamoku 46kV Underground - Expanded Alternative (which will fully address the Pukele reliability concern, with the exception of the customers that will still incur 6-second interruptions); is even more likely to exceed the cost of the Kamoku 46kV Underground Alternative (which would still far better address the Pukele reliability concern than the DSM, DG and CHP option); and clearly would exceed the incremental cost of installing either 46kV alternative. And, at the end of the day, the DSM, DG and CHP option would not address the Pukele reliability concern (with the possible exception of the customers with on-site DG or CHP, assuming their loads could be islanded), or help with the Downtown overload problem if the HPP is unavailable for any reason.

Renewable Energy Projects

Q. Can renewable energy projects such as wind and photovoltaic energy reduce the load demand in the Koolau/Pukele and Downtown areas?

A. As a company, HECO is a strong supporter and developer of photovoltaic ("PV"). HECO has implemented an aggressive solar water-heating DSM program offering rebates and inspections. HECO has also been involved in Sun Power for Schools Project, which installs solar systems at public schools, and is jointly developing a PV park as a demonstration project. PV however, cannot address the Koolau/Pukele overload problem. As explained in the March 2000 DG Alternatives study, PV requires an extensive land area to achieve the capacity required for the Koolau/Pukele transmission line overload problem. Photovoltaic is not available 24 hours a day, so reliable power would be an issue. Wind power faces the same land and wind availability problems and wind resources are not available in the area except for some areas in the Windward Area. Additional transmission facilities would be required to transport the energy from the wind resource to the Koolau/Pukele area. Costs for renewable resources were not evaluated, because of the practical issues involved in implementing renewable options in the Koolau/Pukele area.

<u>Eliminating Outages on a Transmission Line for Maintenance</u>

Q. Can maintenance be performed on a HECO's transmission lines without de-energizing the lines?

A. HECO retained a consultant, EDM International, Inc. ("EDM"), to review the potential for and practicability of doing "live line maintenance" on Oahu. Live line maintenance (which generally is referred to as "live working" in the industry) involves doing maintenance work on (and even replacing) distribution and transmission facilities without de-energizing the distribution and transmission lines. EDM and its Project Team, including Andy Stewart, Dr. George Gala of

EPRISolutions, Inc., and Thomas Harrington and Louis Benedict of TLH Management Services, Inc., were asked to analyze in more detail the potential for doing live working ("LW") on the 138KV transmission lines serving the Koolau and Pukele Substations, since the Koolau overload situation and the Pukele reliability concern generally (although not exclusively) arise when a transmission line has to be taken out of services (i.e., be de-energized) for maintenance. The Project Team's conclusions are summarized in the testimony of Mr. Stewart in HECO T-5.

Q. Can the138kV transmission lines feeding the Koolau/Pukele area and Downtown area substations be maintained using LW practices?

A. In the case of HECO's 138kV system as it is currently configured, the EDM Project Team concluded that LW has, at best, very limited applicability, particularly for the lines serving the Koolau and Pukele Substations, due to constraints imposed by climate, terrain, and facility conditions. These constraints render LW impracticable for all but a very small percentage of the needed maintenance activities. As Mr. Stewart testifies in HECO T-5, the very frequent occurrence of rain and periods of fog, high humidity and unpredictable winds often will prevent the safe use of LW. Remote structures, particularly in the Koolau mountain areas, cannot be accessed by heavy equipment and/or do not have sufficiently large flat areas for use of heavy equipment such as insulated aerial devices with outriggers. Helicopter use is often hindered by fog, rain and strong winds. Many structures lack sufficient mechanical strength to support additional loading posed by climbing and conductor supports (strain sticks) needed for removal of insulators, and would need to be refurbished before LW should be attempted. Few of HECO's lines were designed with the goal of facilitating LW. In particular, none of the lines serving the Koolau and Pukele Substations, which are more than 40 years old, were designed for LW. For this reason, LW is not possible in many situations without prior retrofitting of the existing lines. Taking the lines out of service to retrofit the structures would place the Pukele service area at risk of the very double outage that LW would be attempting to avoid. Also, in most cases LW on HECO's system will be more time consuming and costly than de-energized maintenance.

SELECTED ALTERNATIVE – FUTURE CONSIDERATIONS

Q. What is the selected alternative for the EOTP?

A. The Executive Team considered many factors, which are outlined in Mr. Tom Joaquin's testimony, HECO T-2, and selected the Kamoku 46kV Underground – Expanded Alternative.

Q. What impact does this alternative have on HECO Transmission Planning?

A. The Kamoku 46kV Underground-Expanded Alternative will relieve the Koolau/Pukele Line Overload situation, defer the Downtown Overload Situation by approximately three years, provide complete back-up to the Pukele Substation and provide partial back-up to the Downtown area substations. The Kamoku-Pukele 138kV Underground alternative would have also provided and added generation contingency benefit should the Honolulu Power Plant become inoperable in the near-term. Without the Honolulu Power Plant in operation, the Kamoku 46kV Underground – Expanded Alternative defers the Downtown Line Overload Situations for approximately 3 years to 2009. Additional facilities may be required in this scenario. Some of the options reviewed in the EOTP, which were not readily available or feasible, may become more available in the future to mitigate the Downtown Line Overload.

Q. Do you have any concluding remarks?

A. Yes. There is a real need to install transmission facilities that will help ensure continued reliability of the HECO system. HECO has achieved a good reliability record, in spite of the challenge of operating an isolated, island utility system without interconnections to other systems. But reliability is not achieved by relying on good fortune, it must be based on planning for the future, and adding needed infrastructure in a timely manner.

Q. Does this conclude your testimony?

A. Yes, it does.