TESTIMONY OF
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EDM INTERNATIONAL, INC.

Subject: Live Working

INTRODUCTION

Q. Please state your name and business address.

A. My name is Andrew H. Stewart and I am the President of EDM International, Inc. ("EDM"). My business address is 4001 Automation Way, Fort Collins, Colorado.

Q. Are you a registered professional engineer?

A. No. I have undergraduate and graduate degrees in civil engineering and have passed the Engineer in Training examination. However, the focus of the work I have performed since completing graduate studies has not entailed design work requiring professional registration, therefore, I have not taken the professional engineer's examination. My educational background and experience are provided in HECO-500.

Q. Are you a member of any professional organizations?

A. Yes, I am a member of the American Society of Civil Engineers, and the Institute of Electrical and Electronics Engineers.

Q. Please briefly describe your work experience.

A. I received a Bachelor of Science Degree in Civil Engineering from the University of Rhode Island in 1981, where I received the Academic Excellence Award; and in 1984 I received a Master of Science Degree in Civil Engineering from Colorado State University, where I was a research associate on the EPRI-sponsored project entitled, "Reliability-Based Design of Transmission Line Structures." I joined EDM as a Senior Research Engineer in 1983 and since then my work has involved development, implementation and training related to inspection and test methods, analysis procedures, maintenance plans, performance metrics, and new technologies focused in two areas of the electric utility industry. The first focal area is the inspection, maintenance and performance of transmission and distribution lines, and the second is the thermal rating of overhead transmission lines. The description of my work experience that follows emphasizes the first focal area as it pertains more directly to this testimony.

For the past 20 years I have been actively involved in the development and implementation of various aspects of asset management programs directed at cost-effectively extending the useful life and optimizing the performance of overhead facilities. Relevant experience includes:

- Performing technical and managerial activities associated with the inspection, assessment, maintenance, analysis, upgrading and refurbishment of tens of thousands of miles of utility lines.
- Providing training on the inspection, assessment and maintenance of overhead lines for more than 15 years.
- Managing an EPRI sponsored initiative to improve the state-of-the-art of inspection and assessment methods for overhead lines.
- Managing the development of the maintenance standards and transmission circuit availability performance monitoring system for the transmission line and substation facilities (69kV through 500kV) of the investor owned utilities in California that are now under the operational control of the California Independent System Operator ("ISO"). This system is an integral part of the ISO's Transmission Control Agreement with FERC.
- Authoring numerous publications and presentations related to the inspection, maintenance and operation of overhead lines.
- Founding and serving as a member of the Board of Directors of INTEC Services Inc., a majority owned subsidiary of EDM, which provides transmission and distribution line inspection and maintenance services for

utility clients.

Recent relevant experience includes:

- Serving as one of the primary lecturers for EPRI's Inspection and Assessment Methods for Overhead Transmission Line Equipment Workshop.
- Developing an asset management plan for a northwestern utility.
- Authoring several chapters of a new reference book entitled "Guidelines for the Inspection and Assessment of Overhead Transmission".
- Co-authoring a new chapter for the Third Edition of the EPRI AC Transmission Line Reference Book on the topic of "Considerations for Inspection, Maintainability And Refurbishment". This chapter will include subchapters on "Designing for Inspection and Maintainability", for which I will be the lead author and "Optimizing the Design for Effective Live Working" for which George Gela will be the lead author. Dr. Gela is mentioned herein as he is also part of the Project Team that conducted the live line maintenance study for HECO as described below.
- Serving as the current Chairman of the IEEE Task Force on the Management of Existing Overhead Lines.

Q. Please describe your duties and responsibilities at EDM.

A. I have two roles at EDM, Technical and Corporate. In my technical capacity, I serve as one of the senior technical personnel responsible for managing and performing projects for electric utility industry clients. In my role as President, I have corporate duties commensurate with that position.

Q. Do you specialize in any particular area?

A. Yes, the majority of my technical activities are focused within two areas: 1) the inspection, maintenance and performance of transmission and distribution lines, and 2) thermal rating of overhead transmission lines.

Q. What is the scope of your testimony?

A. My testimony will address the use of live line maintenance/live working on HECO's 138 kV transmission system, with emphasis on the applicability and practicability of using live working methods for the lines serving the Koolau and Pukele Substations.

LIVE WORKING STUDY

Q. Please explain what you mean by "live working"?

A. "Live work(ing)" is the performance of maintenance, construction, or testing on equipment and circuits that are energized or that may become energized. The terms "live work(ing)" (LW) and "live line maintenance" (LLM) are used interchangeably throughout the electric utility industry to refer to work on or near energized or potentially energized lines. LW is the more common current terminology. However, LLM is also used and LLM was the terminology used by HECO at the inception of its energized maintenance program.

Q. What live working evaluation were you and your firm retained to do for HECO?

A. HECO contracted EDM to evaluate the potential use and need for LW techniques on HECO's 138 kV transmission system. The scope of work for our evaluation entailed examination of if, when, where, and how LW methods could be used on HECO's 138 kV transmission system. Particular emphasis was placed on assessing the applicability and practicability of LW methods for the transmission lines serving the Koolau and Pukele Substations. As a result, our evaluation encompassed the examination of both the practical and the theoretical aspects and constraints of the use of LW on HECO's system.

Q. Why was this LW evaluation initiated by HECO?

A. HECO began using LW techniques in the 1980s, however, transmission system changes and additions have been made since then that have altered the need for and benefits received from this work method on its system. This, coupled with other planned near term additions/changes that may further impact the need and benefits, prompted HECO to initiate this independent assessment of the use of LW.

Q. How was your team selected to do the evaluation?

A. EDM was selected because of its expertise related to overhead transmission system inspection and maintenance. To supplement the capabilities of EDM's staff, EDM brought three subcontractors onto its Project Team. The subcontractors are Dr. George Gela of EPRISolutions, Inc., and Mr. Thomas L. Harrington and Mr. Louis Benedict of TLH Management Services Inc. Dr. Gela is a recognized expert in LW techniques, and Mr. Harrington and Mr. Benedict of TLH Management Services are very familiar with HECO's 138 kV transmission system and work practices. Mr. Harrington has gained familiarity with HECO's transmission system through many years of providing construction management and project management services to HECO and Mr. Benedict was the supervisor of the LW personnel at HECO prior to retiring in the late 1990s.

Because some of the technical and safety issues associated with the use of LW play such a prominent role in the findings from EDM's study, it is worthwhile for me to review some of Dr. Gela's credentials before providing information on the details of the LW investigation and the Project Team's findings and recommendations.

Dr. Gela obtained his Ph.D. in Electrical Engineering from the University of Toronto in 1980. Prior to joining EPRISolutions in 1990, he worked in a variety of capacities in the high-voltage arena. He provided consulting services, worked in the manufacturing industry and was an Assistant Professor in Electrical Engineering at Ohio State University and a Visiting Professor at the University of Toronto. Since joining EPRISolutions, one of his focal areas of consulting and research and development has been LW. He has established himself as a world leader in this area. He is the lead author of several documents on LW that are used by utilities throughout the world, including references on application of LW techniques, field guides on LW methods and designing lines to facilitate LW, and reference information on safe working conditions. He has also been the principal investigator on several research projects directed at developing new LW techniques and tools for performing energized maintenance and protecting line workers. Dr. Gela is actively involved in several professional organizations including the Institute of Electrical and Electronics Engineers (IEEE), CIGRE (The International Council on Large Electric Systems) and, perhaps most notably as relates to this testimony, the International Electrotechnical Commission (IEC), where he is the International Chairman of the technical committee on LW.

Q. What are the results of the LW evaluation?

A. The results are included in our report entitled "Evaluation of the Applicability and Practicability of Live Working (LW) Methods for Hawaiian Electric Company, Inc.'s (HECO) 138 kV Transmission System" (December 2003), which is attached as Exhibit 7 to the Application in this proceeding.

The balance of my testimony summarizes the results of the LW Study, and includes:

- An overview of the application of LW by electric utilities.

- A summary of pertinent findings, conclusions and recommendations from EDM's investigation.

<u>Overview of the Application of LW by Electric Utilities</u>

Q. When is LW used by electric utilities?

A. LW is the preferred method of maintenance where system integrity, system reliability, and operating revenues are at a premium and removal of a specific circuit from service is not acceptable. An example of this would be when a line is being used as a medium to enable a wholesale power transaction between the line's owner and an interconnected utility, or when power is being wheeled across a line during a wholesale power transaction between two entities, neither of which owns the line. In these instances, economic impacts associated with a line outage could include lost revenue from wheeling charges, and/or costs to purchase replacement power. Another example of a situation where LW is useful is for radial lines to small municipalities that must remain energized, even during maintenance, to avoid disruption of service to essential facilities such as hospitals, law enforcement, fire departments, and intrusion alarms. Live work may also be beneficial in construction and storm damage repair. Furthermore, LW is necessary and unavoidable in some cases, such as when stringing over or under energized circuits or stringing adjacent to parallel energized circuits.

Q. Is LW always the preferred method?

A. No. While there are many reasons for using LW methods, LW does <u>not</u> represent the most efficient or cost-effective solution for all situations. A proper perspective on LW is that it is a valuable tool for use in certain situations. LW is not a panacea, nor is it the best solution for every situation.

Q. What is necessary for workers to safely perform LW?

A. If workers are to perform LW, they must have knowledge of LW rules and regulations to ensure their safety and the safety of others. In addition, to perform LW safely, workers must maintain phase-to-phase and phase-to-ground minimum approach distances between energized parts and grounded objects for the specific voltage being worked. Insulating tools are used to bridge the air gap between energized parts and ground, and between parts energized at different voltages. Work on de-energized facilities often requires similar qualifications, since de-energized facilities that are close to energized parts can acquire significant voltages through electric and magnetic induction. For this reason, de-energized work is also included in the broad area of "live work."

Q. How do you determine whether it is practical to use LW?

A. Investigating the practical aspects of using LW methods (in this case, on HECO's transmission system) requires taking into consideration factors such as weather, terrain, and other environmental conditions, access by heavy equipment, operational constraints, and personnel recruitment, training, equipping and retention requirements.

<u>Summary of Pertinent Results from EDM's Investigation</u>

Q. Please summarize the Project Team's key findings.

A. The Project Team's key findings, conclusions and recommendations are included in the following list:

- HECO exercised diligence and prudence in the formulation and evolution of its LW program.
- LW does not represent a practicable work method for the majority of the maintenance needs of the lines serving the Koolau and Pukele Substations due to the constraints imposed by climate, facility conditions and access.

Therefore, HECO should consider system additions/changes to enhance the ability to obtain hold-offs on the lines serving these substations.

- There are other portions of HECO's system where LW is not a practicable solution for maintenance due to line or structure configurations, mechanical/structural conditions, and deterioration of components.
- The improved ability to schedule outages that occurred with the addition of key new 138kV lines to the system in the mid-1990s diminished the need for LW practices on much of the 138 kV system because de-energized maintenance techniques could be utilized on a line without creating an unreasonable impact on system reliability in the event of a concurrent unplanned/forced outage on another line.
- Significantly more work can be accomplished on HECO's system in a given period of time using de-energized maintenance techniques than LW techniques. And, when large-scale replacement of components is warranted, scheduling de-energized work represents a more cost-effective solution than LW work due to factors including labor efficiencies.
- Currently, there are a few areas of HECO's system and situations that could continue to benefit from the availability and use of LW. Therefore, HECO should consider reestablishing the basic level LW skills for use on a limited basis.

<u>APPLICABILITY OF LW TO HECO'S TRANSMISSION SYSTEM</u>

Q. To what extent is LW applicable to HECO's system in general, and to the 138 kV transmission lines serving the Koolau and Pukele Substations in particular?

A. LW does not represent a realistic or practicable work method for the majority of the maintenance needs of the lines serving the Koolau and Pukele Substations due to the constraints imposed by climate, terrain, and facility conditions. While availability of the LW skill may, on infrequent occasions, have value for performing individual tasks on these lines, the aforementioned constraints render LW impracticable for all but a very small percentage of the needed maintenance activities. Therefore, LW would have little impact on the availability of these facilities. De-energized work methods should be considered the primary approach for performing maintenance on these facilities.

The aforementioned lines are not the exception. There are other significant portions of HECO's system where LW is not a practicable or cost-effective solution for the majority of maintenance due to line or structure configurations, mechanical/structural conditions, and deterioration of components. This is particularly the case for areas where scheduled outages can currently be obtained without putting the reliability of the system at unreasonable risk. Further, as HECO seeks to optimize the use of available resources including budgets, time, manpower, equipment, tools, etc., a prudent conclusion is that de-energized line work is the preferred solution for most maintenance requirements on these facilities.

<u>Climate</u>

Q. Why is climate an important consideration?

A. LW is normally not performed in inclement weather conditions, such as:

- High humidity (at several utilities, LW is typically not performed when humidity exceeds 85%)
- Rain or drizzle

- Strong winds (while there are no specific or general limits, many utilities stop work when the crew finds it difficult to control long insulating tools)
- Fog
- Thunder is heard, or lightning is seen within about 5 miles

In addition, to prevent exhaustion and fatigue-related hazards, many utilities avoid LW, or interrupt work when the ambient temperature reaches high levels. No general guidelines as to the stop-work temperature levels are available and the decision to stop work is left up to the crew and the supervisor. These restrictions may clearly apply to many sections of the lines serving the Koolau and Pukele Substations, especially during the hot summer months. Unfortunately, very hot days often coincide with high air-condition loads, which may strain system resources and prevent de-energizing of lines for maintenance.

Q. How does climate impact the use of LW on Oahu?

A. The diverse nature of Oahu's climate presents some unique challenges for LW. This is especially true for the lines in the Koolau Mountains where the conditions are ideal for accelerated corrosion, and where the high frequency of precipitation, fog, clouds, and high humidity can all hinder the ability to access the lines, and work safely using LW methods.

In addition to the climate/environmental constraints in the mountains, there are other areas on HECO's system where climate/environmental characteristics impact line maintenance needs and practices. For example, lines traversing agricultural lands are subject to contamination from fertilizers, pesticides, and burning of agricultural fields. Lines in the coastal plains are regularly exposed to salt laden air, salt fog, and salt spray. Lines in these areas may require relatively frequent maintenance and wholesale replacement of certain components in order to maintain reliability. Such tasks must often be performed on de-energized lines rather than using LW methods for safety reasons.

Q. How did the Project Team assess the impact of precipitation?

A. To enable a somewhat more quantitative assessment of the impact of precipitation on the ability to use LW methods on the lines serving the Koolau and Pukele Substations, precipitation data were obtained from the US Geological Survey (USGS) office on Oahu. These data were analyzed and the Project Team found a very high occurrence of precipitation in the vicinity of the subject mountain lines; ranging up to measurable precipitation being recorded on more than 85% of the days in a calendar year. The high occurrences of precipitation indicate that it would be difficult to count on the ability to use LW for the maintenance of these lines, particularly the portions of the lines at higher elevations. It is also important to recognize that the duration of the occurrence of precipitation - which is not provided by rain gauge data - is not important in the evaluation of the possibility of using LW. It is sufficient to note that precipitation has occurred on particular days, because on those days LW tasks would not be performed, or would need to be interrupted if initiated before precipitation occurred.

Q. Is measurable precipitation the only impediment to LW?

A. No. Fog, clouds and high humidity can all hinder the ability to access lines, and to work safely using LW methods. Rain gauges, however, only record measurable precipitation. Therefore, in addition to the days with measurable precipitation, it is likely that there would be additional days with higher than acceptable humidity (at several utilities, LW is typically not performed when humidity exceeds 85%), fog, or clouds that would further hinder the ability to use LW techniques. Additionally, the unpredictable nature of the winds in the mountains adds to the complication of accessing the mountain lines using helicopters and using LW methods.

Terrain

Q. Why is terrain important?

A. Terrain is an important consideration for LW because it affects accessibility by personnel and/or heavy equipment to lines and structures, as well as the availability of flat zones needed for staging areas. Terrain is often a limiting factor for determining the modes of accessing and working on structures and spans, particularly for utilities, such as HECO, that have lines in rugged terrain. Access to structures is a major deterrent to LW at HECO. In inaccessible mountainous areas, insulating boom aerial devices such as the Condor cannot be used due to lack of access roads and flat areas near structures. Significant portions of the lines serving the Koolau and Pukele Substations are located in this type of rugged terrain and cannot be accessed with wheeled vehicles. Therefore, performing LW from an insulated aerial device such as the Condor is not feasible.

Q. What did your Project Team do to investigate the terrain traversed by HECO's transmission system?

A. During January 2003, the Project Team conducted an airborne (helicopter) inspection of select transmission lines and substations. The focus of this inspection was the transmission lines serving the Koolau and Pukele Substations. The inspection served to confirm the configuration of the structures in the lines, terrain, access conditions, and the impact of the aggressive climate in the vicinity of these lines on the conditions of the structures, hardware, insulators, conductors and shield wires.

Q. Can helicopters be used for LW?

A. Some utilities perform LW in remote, difficult access areas from work platforms attached to helicopters, however, due to the unpredictable nature of the weather (winds, rain, and fog) in the vicinity of these lines, this is not a dependable option. Therefore, while helicopters may be used to gain access to these lines when weather conditions allow, maintenance work is then performed by climbing the structures. However, climbing may not be viable due to the condition of structures and to prevailing environmental conditions.

Facility Conditions

Q. What is the relevance of facility conditions?

A. Line/structure configuration and condition are vital considerations when assessing the applicability and practicability of LW. Most structures on the five lines serving the Koolau and Pukele Substations are wood H-frame, wood poles (guyed multi-pole structures) and aluminum lattice structures. There are also many steel lattice structures. In general, when wood and steel structures whose configurations meet the requirements for safe working distances are in adequate condition, LW can be performed via climbing or from an insulating aerial device. However, HECO's aluminum structures are not designed for the additional structural loading of several linemen and tools (such as strain and support sticks) used in LW and retrofitting/reinforcement would be required before LW could be safely performed.

Q. Why is condition a factor?

A. Aluminum and steel structures are subject to severe corrosion in HECO's service territory environment; bolts corrode, seize and disintegrate, and angle structural members corrode to the point of perforation. Wood structures are subject to relatively rapid deterioration due to decay and termite damage. This not only dictates the need for maintenance and repair of the structures, but also hinders climbing and LW in general until repairs are made to the structures. Also, accumulation of algae and moss on structures, both metal and wood, makes the structures slippery and renders climbing very treacherous. These difficulties exist both in LW and de-energized work, but the consequences of a slip during LW can be more severe due to the close proximity of energized equipment.

Economic Considerations

Q. Are economics an issue when assessing the use of LW?

A. Yes. Economics and the responsible utilization of available resources should not be overlooked when weighing various approaches to maintenance. Although LW has proven to be a valuable resource for accomplishing maintenance functions throughout the electric utility industry, LW is not the optimum solution for all maintenance functions, nor is it necessarily practicable for all situations and tasks. The unique attributes of each utility's electric system should be considered when seeking to identify cost-effective approaches to system maintenance.

Q. What factors are considered in evaluating the economics of LW?

A. In evaluating the economics of LW versus de-energized work methods, the following points are generally considered:

- Man-hour costs, including labor for switch opening and/or tagging (this can be a high cost element in the case of remote unmanned substations, or substations with difficult access)
- Time to complete the task(s), including access to the worksite, and setup and teardown of equipment
- Loss of revenue due to service interruptions
- System stability for "N", "N-1", and "N-2" operating conditions

- Work functions to be performed
- Anticipated weather conditions for the location and time the work function will be performed
- Available labor force, including skills and training, and availability of supervisors
- Urgency to correct the problem relative to other tasks that are assigned to the available crews
- Customer impact, for example, types of customers facing interruption and cost of interruption to the customer that may be transferred to the utility through legal action

In addition, secondary costs such as equipment and tool maintenance and testing, and training to maintain skills must be taken into account.

Q. Is loss of revenue always a factor?

A. No. If an electric system can operate with one or more lines or segments of a line de-energized to enable maintenance work without putting any customers out of service, loss of revenue does not have to be factored into the economic evaluation.

Q. Is it possible to assess the economics of doing LW without looking at the unique characteristics of the utility's system?

A. No. The last five items listed above will always be unique to each operating system and should only be evaluated by experienced operating personnel familiar with their specific system. Equipment and tool maintenance and testing costs are relatively well-known, and fixed cost items can usually be treated as adders to the bottom line.

Q. What factors need to be evaluated in assessing the economics of LW for HECO's system?

A. Listed below are several additional factors about HECO's system that when considered collectively with previously discussed issues such as climate and terrain indicate that the economics of LW are not favorable for the majority of maintenance needs on HECO's 138 kV system.

- Most of the 138 kV system on Oahu is capable of operating in an N-1 condition without impacting customer loads except during heavily loaded periods. Hence, planned outages can be taken without putting the system reliability at an unreasonable risk.
- Because HECO is the sole provider of electricity to its customers and its system is not interconnected with the transmission systems of other utilities, as is often the case with mainland utilities, HECO is only required to serve its customers' load. Therefore, while it is possible that HECO may incur some costs for not being able to use economic dispatch during certain scheduled maintenance outages, HECO is not at risk for the more substantive transaction costs associated with wheeling of power.
- HECO's system incorporates a large number of 138 kV structure family types with a significant number of modified structure types within several of the families. This requires study of each structure to be worked and planning of task details, and hinders standardization of LW tools, procedures and training.
- While it is possible that some individual tasks can be performed as quickly using LW methods as de-energized methods once a high level of proficiency is attained with LW skills, it is not unreasonable to expect that the man-hours required to perform common individual line maintenance tasks (e.g., insulator replacement) using LW methods will be from two to five times greater than those required to perform the same tasks under de-energized conditions.

Therefore, more work can be accomplished on HECO's system in a given period of time using de-energized maintenance techniques than LW techniques. HECO found that its line crews could accomplish anywhere from three to seven times the volume of work in a given time period with a line de-energized than with it energized.

- The climatic conditions in portions of HECO's system, such as in the vicinity of the lines serving the Koolau and Pukele Substations, are very aggressive (i.e., from the perspective of the deterioration of the condition of line components) and lead to relatively rapid deterioration of the condition of line hardware which dictates near wholesale replacement of certain line components (e.g., insulators and shield wires) on a periodic basis. When large-scale replacement of components is warranted, de-energized work usually represents a more cost-effective solution than LW due to several factors, including labor efficiencies.

Q. Can you provide an example of where the large-scale replacement of components might be warranted?

A. Yes. For example, insulator hardware in some of the mountain lines may last as few as five years before corrosion progresses to the point that its severity warrants replacement of the insulators. With this short of an interval between periods of large-scale replacement of components in certain portions of the system, the need to use LW in the interim (i.e., between these large-scale maintenance activities) would be quite limited, particularly if other needed maintenance had already been performed concurrent with the larger-scale replacement activities. It is often more cost-effective to perform wholesale component replacement tasks (e.g., replacement of insulators on a series of consecutive structures) with multiple line crews using de-energized work methods. Further, the nature of some of the deterioration is such that de-energized replacement would be necessary before LW could be safely performed.

Summary

Q. Please summarize your testimony with respect to the practicability of LW for HECO.

A. LW should only be regarded as one of several tools in a utility's arsenal and should be used only when appropriate based on consideration of the unique characteristics of each utility's situation and lines. In the case of HECO's 138 kV system as it is currently configured, LW has, at best, very limited applicability and offers limited benefits (particularly for the lines serving the Koolau and Pukele Substations) for the foreseeable future due to the following, previously discussed factors.

- Climatic conditions. For portions of the system, the very frequent occurrence of rain and periods of fog, high humidity and high temperatures, unpredictable winds and occurrence of lightning will prevent the safe use of LW.
- Access to worksites. Remote structures, particularly in mountainous 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.
- Physical condition of structures and hardware. Due to high preponderance of corrosion, decay, or termite damage many structures lack sufficient mechanical strength to support additional loading posed by climbing and conductor supports (strain sticks) needed for removal of insulators. These structures would need to be refurbished before LW should be attempted.

- "LW-unfriendly" construction. 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 were designed for LW. For this reason, LW is not possible in many situations without prior retrofitting of the existing lines.
- Economic and system conditions. HECO is not faced with transaction costs for outages on its system. Also, in most cases LW on HECO's system will be more time consuming and costly than de-energized maintenance. Further, outages to enable de-energized maintenance can be scheduled in most areas of the system without exposing the reliability of the system to an unreasonable level of risk.

Q. In summarizing your conclusions, you indicated that the continued availability of LW could be beneficial for HECO in some circumstances. What is the basis for this conclusion?

A. While LW does not represent a viable solution for the majority of HECO's 138kV transmission line maintenance needs, there are a few areas of the system that could continue to benefit from the availability and use of LW. These areas include any of the lines for which LW is practicable based on the aforementioned considerations and which serve transmission substations that are currently fed by only two lines. For example, in the Barber's Point area, the AES-CEIP and the Kalaeloa-Ewa Nui transmission lines could benefit from LW. Further, the ability to use LW during certain emergency situations may facilitate prevention of blackouts and/or a reduction in the duration of outages that could not otherwise be avoided. For these reasons one of our Project Team's recommendations is that HECO consider reestablishing the basic level LW skills on 138 kV transmission lines for use on a limited basis. As part of this assessment, however, HECO must weigh the economics to determine whether the costs for reestablishing and maintaining the program can be justified.

HECO'S SYSTEM

Q. In order to address your last point, please summarize your understanding with respect to the current configuration of HECO's system.

A. The current configuration of HECO's system is such that two major 138 kV transmission corridors are used to transmit bulk power from the power plants in western Oahu to the service area in eastern Oahu. The northern corridor extends from the Kahe Power Plant through the Halawa and Koolau Substations, and ends at the Pukele Substation. The southern corridor extends from the Kahe Power Plant through the Waiau Power Plant and Iwilei, School Street, and Archer Substations, and ends at the Kamoku Substation. The 138 kV transmission lines between the Kahe Power Plant, the Halawa Substation, and the Waiau Power Plant cross-link these two corridors. The two corridors together with the connecting lines form loops of 138 kV transmission lines that provide operational flexibilities and reliable power to the western portion of the Oahu service area. The operational flexibilities enabled by the loop are such that in most cases a line in this portion of the service area can be de-energized without putting system security at an unreasonable level of risk. However, a similar situation does not exist for the eastern portion of the Oahu service area.

Q. What addition to HECO's system would help address this situation?

A. The addition of a line connecting the Kamoku and Pukele Substations, or an alternative to this line that accomplishes some of the same basic system needs, will bolster security in the eastern portion of the Oahu service area and enable greater operational flexibility. Currently, the Pukele Substation is only connected to the northern corridor by two lines; if one of the two lines is removed from service and the other fails, the Pukele Substation would be without power. It is the Project Team's understanding that addition of a line between the Kamoku and Pukele Substations, or an alternative addition or modification that accomplishes some of the same basic system needs, would address this limitation and also mitigate a potential problem with overloading of lines providing power to the Koolau Substation. The overload risk is expected to occur if, during periods of high loads in the summer/fall, one of the lines serving the Koolau Substation is taken out of service and a failure of another line serving the station occurs (N-2 contingency).

The planned connection of the Pukele and Kamoku Substations, or an alternative to a line connecting the two substations, would significantly enhance the ability to obtain hold-offs on lines serving the Koolau and Pukele Substations, particularly in the summer and fall, without placing the system at undue risk. This represents a significant enhancement to the ability to perform transmission line maintenance, as LW is not a practicable and dependable option for performing the majority of the maintenance that will be required on the lines serving these substations.

HECO'S EXPERIENCE WITH LW

Q. Your first conclusion was that HECO exercised diligence and prudence in the formulation and evolution of its LW program. When and why did HECO initiate its program?

A. HECO initiated its 138kV LW program in the late 1980s in response to increasing demands on its system due to load growth, system configuration, and operational constraints which caused it to become increasingly difficult to schedule line outages to enable de-energized work on certain portions of the system. Establishment of a LW program was also one of the recommendations contained in a report prepared by Stone and Webster Management Consultants, Inc. (SWMC) following an investigation of the HECO blackout that occurred on July 13, 1983. It is the Project Team's assessment that HECO exercised diligence and prudence in the formulation its LW program. Program development was supported with an adequate level of financial, personnel, equipment, and training resources, and the LW program evolved in a reasonable and rational fashion in response to HECO's changing needs.

Q. How did the program evolve?

A. By the end of the third quarter of 1989, two LW crews had been established and trained. Before LW could commence, significant portions of the 138 kV system needed to be refurbished and components retrofit to facilitate LW. In addition, structure configurations and weather constraints, particularly for the mountain lines, resulted in a significant amount of de-energized maintenance work being done by the two LW crews during this period. LW methods were used on energized facilities on a limited basis mostly to enable LW skills to be maintained. The significant level of work performed on the transmission system resulted in noticeable improvements in conditions and decreased the frequencies of failures of line components.

The LW program peaked in the mid-1990s at which point strategic new 138 kV lines were constructed and energized to improve the capacity and security of power transfer capabilities from the western portion of Oahu to the largest load centers. These new lines (Waiau-CIP 138kV transmission lines) added significant operational redundancy and flexibility to much of the 138 kV system, thereby allowing the scheduling of outages (hold-offs) on a significant portion of the system. Therefore, maintenance tasks could be performed de-energized without having an unreasonable impact on system reliability in the event of a concurrent unplanned/forced outage. These system additions decreased the need for LW.

The addition of the Waiau-CIP lines to the 138 kV system in 1995 removed many restrictions on the ability to obtain hold-offs on much of the system and diminished the need for LW, however, HECO continued to maintain the LW skills. Another factor that impacted transmission maintenance was that during the early to mid 1990s, the condition of the distribution system was beginning to deteriorate and required more attention; therefore, resources from the LW program were redirected to focus on the distribution system.

Q. How did the addition of the two Waiau-CIP lines diminish the need for LW?

A. Prior to this addition there were only four lines, all in the northern corridor, available to transfer power from the western end of Oahu to the major load centers in the east. Only one line could be taken out of service at a time without exposing the system to an unacceptable level of risk. The Waiau-CIP lines increased the number of available lines to six. These two new lines, in the southern corridor, together with lines interconnected with the northern and southern corridors created an important loop around the western portion of the Oahu service area. Because HECO can operate reliably with only three of the lines from western Oahu in service without any generation load shift, the Waiau-CIP lines added significantly more operating flexibility. The operational flexibilities enabled by the loop are such that in most cases a line in this portion of the service area can be de-energized without putting system security at an unreasonable level of risk.

Q. Does HECO currently perform work on energized 138 kV lines?

A. No. At this time, HECO performs de-energized maintenance on 138 kV lines. LW skills have for the most part been lost due to:

- Movement of personnel
- Attrition
- Addition of system redundancies that allow de-energized work
- Poor condition of structures and components in select lines that must be repaired before LW can be attempted; these repairs will require that the lines be de-energized.

Q. Does HECO still have a separate LW Division?

A. No. The LLM Division itself was merged with the Construction and Maintenance Division within about two years ago.

FUTURE PLANS FOR LW

Q. Has HECO given up on LW?

A. No. My understanding is that HECO is in the process of revising and refining its transmission line maintenance program. The structure and design of this program is still under development, but there are some aspects of this process that are worthy of note as relates to the application of LW methods on the transmission system. First, there is concerted effort across relevant departments to develop and implement a systematic process for coordinating line maintenance activities with outages associated with generation unit overhauls; previously this was done on an informal, unstructured basis. The objective of this coordination is to optimize the maintenance activities performed on lines while they are out of service due to the generation unit overhauls through a process of preplanning and scheduling. This represents a cost-effective and prudent way to manage risk, and it also has the associated side-effect of reducing the need for LW. Second, there is a genuine desire to retain LW skills if the cost-benefit ratios can be justified. Therefore, an internal investigation was initiated, of which our study was an essential part, to examine how a LW program could be structured so that there would be a pool of qualified LW capable craft personnel to draw from when LW needs arise without having to incur the costs associated with maintaining a separate LW division.

Q. What is the recommendation of your Project Team?

A. The Project Team believes that HECO should consider reestablishing the basic level LW skills on 138 kV transmission lines for use on a limited basis on those portions of the system that could benefit from its use and during emergency situations where it may facilitate prevention of blackouts and/or a reduction in the duration of outages that could not otherwise be avoided. HECO will need to determine if the cost for reestablishing these skills can be justified based on the potential benefits to be realized.

Q. What factors would have to be considered in determining whether work should be done using LW methods, or whether a line should be de-energized?

A. Factors such as safety, system constraints, man-hour requirements, weather conditions, and urgency to correct the problem/condition should be considered and weighed in order to determine which work method is most appropriate.

As a result, in order to have a safe and successful maintenance program, the individuals responsible for evaluating and making the decisions on whether to use LW or de-energized methods must be experienced line personnel that are familiar with the electric system being assessed, capable of identifying the tasks that need to be performed, and properly accounting for, albeit subjectively, the considerations described above.

Q. What will HECO need to do to maintain a LW program?

A. HECO recognizes that to maintain an active program, the LW method must be utilized with sufficient frequency to enable skills to be maintained, even if that means occasionally using these methods where de-energized work is less costly. Also, crews may be required to use LW work methods on occasion even when lines are de-energized. This represents a proactive and effective approach to maintaining LW skills.

PRIOR LW RECOMMENDATIONS

Q. The investigation conducted by EDM's Project Team is not the first third-party effort that has addressed the issue of LW on HECO's 138 kV system, is it?

A. The Project Team is aware of reports prepared by three other third parties: the first report (mentioned earlier) that mentioned that HECO should consider establishing a LW program was prepared by Stone and Webster Management Consultants, Inc. (SWMC) following an investigation of the HECO blackout that occurred on July 13, 1983; the second was prepared by Southern Engineering International, Inc. (SEI) as part of a contract with HECO to assist with the development of a LW program, and; the third report was prepared by Power Technologies, Inc. (PTI) following its investigation of the April 9, 1991 island wide outage.

Q. What did SWMC recommend with respect to LW?

A. SWMC's report included a recommendation that HECO train at least two transmission line crews to perform LW on the 138kV lines as a means for improving system security by enabling certain lines to remain in service during maintenance. This recommendation was reasonable given the configuration and condition of the 138 kV system at the time that SWMC prepared its report. It is the Project Team's assessment that HECO was responsive to SWMC's recommendation.

Q. What was the scope of SEI's work with respect to LW?

A. SEI assisted HECO with several aspects of implementing a LW program, including assessing the existing transmission system design, preparing a report on its findings, and implementing LW training. Based on review of SEI's proposal and report, EDM's Project Team found that HECO had not requested SEI to conduct a detailed investigation of the practicability of LW for all of HECO's 138 kV lines. Rather, it appears that HECO sought assistance from SEI in building a foundation for an effective LW program. The first phase of SEI's effort was designed to investigate safety, operation, and maintenance regulations, existing system design and hardware for adaptation to LW, and personnel needs and qualifications. The project was not designed or intended to have SEI consider site-specific factors and details such as individual line access, individual structural condition adequacy, environmental/meteorological conditions in specific locales, nor how the addition of new lines to the system might impact the use and need for LW on a facility-by-facility basis. These considerations were beyond SEI's scope. Therefore, the responsibility for addressing these issues remained with HECO.

As a result, HECO personnel were left with the task of addressing factors such as the diverse climate which HECO's system traverses, the economics of implementing and maintaining a LW program, the ability to use LW techniques during periods when the system is heavily loaded, the challenge of assessing the conditions of structures for safe climbing and additional mechanical loading imposed on members during LW (and, if necessary, repair or reinforcement of deficient structures prior to work), and the need for or potential impact of LW on circuit and system availability/reliability in the context of the current configuration of the 138kV system.

Q. Was HECO optimistic about the extent to which LW methods could be employed on its system?

A. I would say that HECO was overly optimistic. During the investigative and formative stages of HECO's LW program, there were misperceptions among HECO personnel regarding the pervasive use of LW techniques by mainland utilities. Later, HECO's own surveys showed that many utilities did not employ LW techniques and that many others used LW only on a limited basis (e.g., for those transmission facilities whose availability is critical to system security or for which de-energized work would have resulted in transaction costs being incurred). Utilities that used LW techniques for the majority of their transmission system maintenance were the exception rather than the norm. For those utilities that were not faced with transaction costs (e.g., lost revenue from wheeling charges, and/or costs to purchase replacement power to fulfill wheeling obligations) or placing their systems at unacceptable levels of risk, few used LW techniques on a regular basis if they also had the option of scheduling outages and performing de-energized work. LW is not the optimal option for every maintenance task. Rather, it is an available tool that a utility may choose to include in its arsenal of operational and maintenance strategies.

Q. Did the Project Team review PTI's report?

A. The Project Team reviewed both PTI's report that summarizes findings and recommendations based on its investigation of the April 9, 1991 island wide outage, and the November 19, 1993 report that HECO prepared and submitted to the PUC in response to PTI's report. HECO challenged PTI's findings and recommendations on several issues associated with the April 9, 1991 outage investigation. HECO also correctly qualified that some of PTI's recommendations might go down in priority if other recommendations were implemented and that the priorities of adopting and implementing specific recommendations may change over time.

The Project Team found many of the recommendations in PTI's report to be fully reasonable, however, the Project Team also believes that HECO appropriately challenged some of PTI's recommendations regarding the universal use of LW as discussed below. The Project Team also concurs with HECO's assessment that PTI's cost estimates to implement some of its recommendations were too low. Further, the Project Team concurs with the results of HECO's inquiries to other utilities doing extensive live-line work that it may not be possible, practical, or cost-effective to do all work using live-line techniques as recommended by PTI.

Q. What was PTI's ultimate "recommendation" with respect to LW?

A. PTI made several recommendations regarding HECO's LW program including a statement that HECO should implement the "concept" of doing all work on the 138 kV system using LW methods, i.e., 100% LW implementation. HECO, appropriately, took exception to this recommendation as well as others offered by PTI regarding LW.

Q. Why do you say that HECO appropriately took exception to this recommendation?

A. The recommendations pertaining to LW presented in PTI's report appear to be based primarily on consideration of technical/engineering factors and did not adequately account for other practical and economic considerations. A simple example of this limitation in PTI's assessment is that EDM's Project Team finds no evidence in PTI's report that readily accessible climatic data, such as the rain gauge data that I cited earlier, were utilized in formulating the recommendations presented in PTI's report.

The Project Team finds this recommendation to be problematic, particularly given the superficial level of effort allocated to the LW investigation in PTI's proposal (i.e., one half week on Oahu and a total of one man week of effort to assess both the tree trimming and LLM programs). There are a number of substantial barriers to using LW on portions of HECO's system, as addressed in our report, that call into question the prudence and reasonableness of this recommendation by PTI.

Q. Please explain.

A. When evaluating the applicability and practicability of various line maintenance methodologies, there are technical/engineering considerations such as the adequacy of clearances between energized components or between an energized component and a grounded component, and the strength/capacity of structures that must be accounted for when assessing whether LW is theoretically feasible. Additionally, there are other factors that must be considered to make an informed decision about whether LW is reasonable, practicable and cost-effective for a specific task, facility, system and/or situation.

From the perspective of the two aforementioned technical/engineering considerations, the configurations of the majority of HECO's 138 kV transmission lines are such that it is theoretically possible to use LW techniques for maintenance, even though the majority of the existing transmission lines and structures comprising the system were not designed to facilitate widespread use of LW. It appears that these two technical factors were the primary considerations of PTI (and SEI) in their assessments of the feasibility of using LW methods on HECO's 138 kV system.

However, an assessment of the adequacy of the configurations is only one part of the evaluation criteria that must be considered. A thorough and complete assessment of the applicability and practicability of LW must include an investigation and review of both the technical/engineering considerations and the practical aspects of using LW methods on HECO's transmission system, taking into consideration factors such as weather, terrain, and other environmental conditions, access by heavy equipment, facility conditions, operational constraints, and personnel recruitment, training, equipping and retention requirements. It is the consideration of some of these issues that distinguishes the investigation conducted by EDM's Project Team from the studies conducted by SEI and PTI.

Our Project Team sought to balance theoretical possibilities of applying LW to HECO's 138 kV system with what is safe and reasonable, given practical considerations that include the particular operational needs and configuration of HECO's transmission system, existing system facilities, the unique terrain and weather conditions, and program cost-effectiveness.

Q. Why was it important for your Project Team to conduct extensive interviews, to review structural diagrams, and to personally "fly" HECO's system as part of its evaluative process?

A. An investigation based on written documentation alone may enable a reasonable assessment of what is possible from a theoretical perspective, but it may fall short of addressing what is practicable. A thorough investigation must include developing an understanding of the issues and constraints faced by an organization and the details of the facilities for which they are seeking to investigate the use of a particular technology or work practice. This is especially true for HECO because of the unique constraints faced by an island utility (e.g., no interconnections, and diverse climate, terrain and environmental conditions in a compact system). These unique constraints coupled with the labor constraints of a relatively small utility create a very different set of conditions than those typically faced by a larger utility that has a larger work force and power exchange agreements with its neighbors.

SUMMARY

Q. Please summarize your testimony.

A. LW does not represent a practicable work method for a significant portion of HECO's maintenance needs. Therefore, LW should be regarded as one of several tools in HECO's arsenal and should be used only when appropriate. LW has very limited applicability and offers limited benefits for HECO's 138 kV system as it is currently configured, particularly for the lines serving the Koolau and Pukele Substations, for the foreseeable future due to many factors discussed in my testimony.

Currently there are a few areas of HECO's system and situations that could continue to benefit from the availability and use of LW. HECO should consider reestablishing the basic level LW skills on 138 kV transmission lines for use on a limited basis in these situations.

Q. Does this conclude your testimony?

A. Yes, it does.