PLANNING AHEAD PROVES INVALUABLE TO THE RAPID RESTORATION OF THE PACIFIC DC INTERTIE AND OWENS GORGE TRANSMISSION LINES

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I. Los Angeles Department of Water and Power

The Los Angeles Department of Water and Power (LADWP) is the largest municipal utility in the United States, serving approximately 1.3 million customers in the Los Angeles area. LADWP supplies power from many sources, including its own hydroelectric and fossil-fueled generating stations and contracts for hydroelectric power from the Pacific Northwest.

As with the entire electric utility industry, LADWP is facing a rapidly changing environment, where increasing efficiency, lowering costs and maintaining reliable service is demanded. One primary objective of LADWP is to ensure the efficiency of operations through better use of existing facilities and optimizing system reliability. A crucial aspect of this objective is the need to plan for emergencies which might interrupt service and require purchasing high cost replacement power. LADWP has an ongoing program of reviewing and updating emergency preparations in the areas of materials, equipment, communications and manpower requirements.

This preparation was put to the test early in 1988 when severe weather conditions and hardware failure combined to cause the loss of 17 towers of the ± 500 KV DC Celilo-Sylmar Poles 3 & 4 (Pacific DC Intertie) and one tower of the adjacent 230 KV Owens Gorge-Rinaldi Line 1 (Owens Gorge). These critical transmission lines bring hydroelectric power to the Los Angeles area and provide nearly 25 percent of LADWP's total energy requirements. This paper presents a summary of LADWP's preparations and how this emergency planning was instrumental in rapidly restoring these lines.

II. PREPARATION

Emergency planning is an ongoing activity involving many areas both within LADWP and in coordination with other utilities. The most critical aspect of this planning is effective communication between all of the parties involved.

II-A. Northwest/Southwest Transmission Reliability Committee

The Northwest/Southwest Transmission Reliability Committee (NSTRC) is a voluntary organization composed of 15 interconnected utilities. The NSTRC's purpose is to exchange information, ideas and experiences relating to transmission design, construction, operation, and maintenance--enhancing the reliability of the interconnected transmission system. The NSTRC promotes a cooperative spirit among member utilities including the sharing of equipment, manpower, and other resources.

The NSTRC's key activities include establishing minimum patrol guidelines, and development of a maintenance matrix detailing each member utility's available manpower, equipment, and material resources. This maintenance matrix along with the cooperation of member utilities proved invaluable to the rapid restoration of the Pacific DC Intertie.

II-B. Engineering

LADWP's management has the following objectives:

Maintain in-house engineering expertise in the design and construction of transmission lines.

Develop and maintain engineering tools needed to enhance the capacity, productivity and economy of the engineering staff.

In the event of a transmission line failure, a competent engineering staff is required to assist operating personnel in the swift restoration of the line. LADWP has determined that urgency and reliability warrant this expertise to be maintained in-house. Therefore, LADWP maintains an engineering staff to provide original design, additions and betterments, and emergency restoration design for transmission lines.

To increase the efficiency and accuracy of the engineering staff, and reduce total job costs, tools such as Computer Automated Engineering (CAE) and Computer Aided Design and Drafting (CADD) are utilized.

The engineering staff maintains the following in a ready status in case of a transmission line failure:

Trained Personnel
Emergency Structure Designs
Design Analysis Equipment (CAE/CADD Devices)
Emergency Materials
Contacts with Material Suppliers
Sagging Equipment
Emergency Radio Equipment

Actual emergency restoration situations, though ill-fated, have afforded engineering the opportunity to scrutinize it's contingency preparations.

Transmission Engineering and Quality Assurance both maintain field-trained engineers on their staff. The training is in areas of field construction safety, transmission line tower climbing, line construction, and sagging. Experience takes place on maintenance jobs, construction projects, and at the Transmission Operating Section's training center (see Figure 1). Engineers training and working with the operating and construction forces has proven to be very beneficial. Both the engineering and construction forces are familiar with the lead/support relationships, each others' abilities and resources, and are better able to function as a smooth and efficient team under emergency situations.

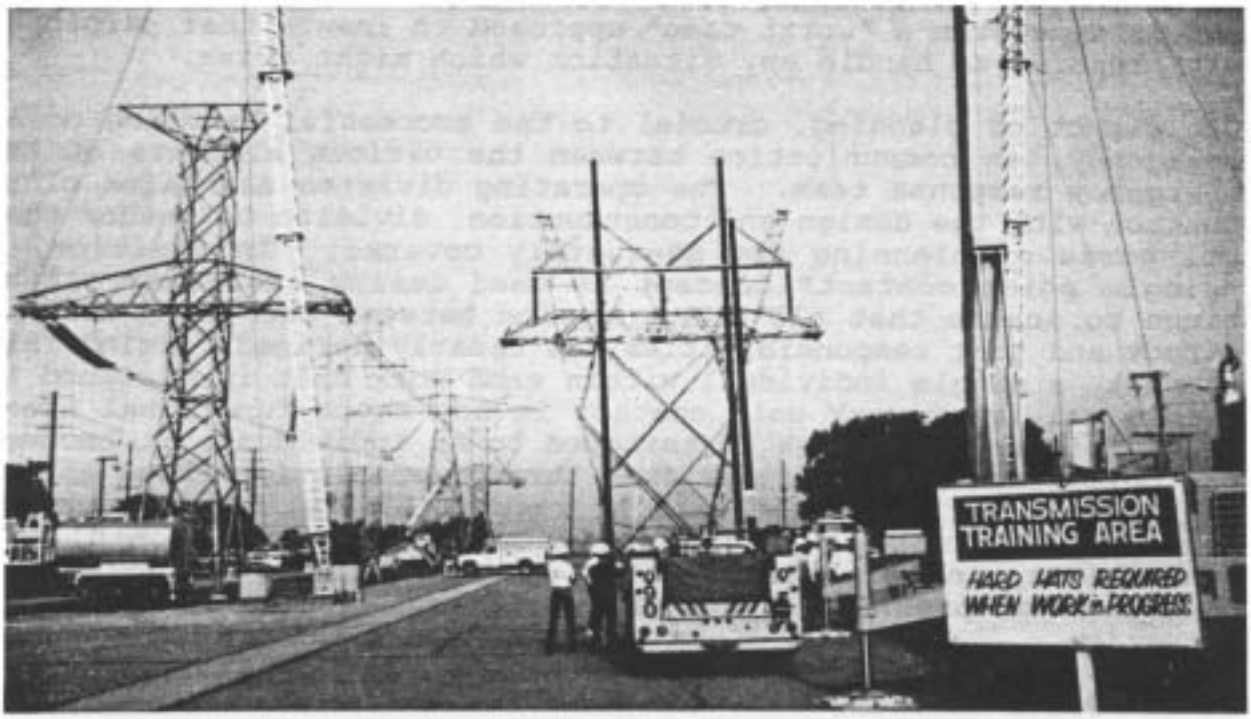


Photo by Robert Dalton

Figure 1

The training facility enables LADWP personnel to train in all phases of construction and maintenance. Various DC (left), AC (center), and temporary (foreground and background) structures are erected in the training facility.

As part of emergency planning, LADWP constantly strives to maintain good working relationships with its material suppliers. This contact insures that LADWP is up-to-date on material availability and the latest technology. In case of emergency, this relationship provides a known contact at each supplier so that assistance can be requested. These supplier contacts have also aided LADWP in developing customized equipment to meet specific requirements. Maintaining a good working relationship with suppliers proved beneficial during the Pacific DC Intertie emergency as LADWP was able to quickly access available resources.

II-C. Operating

In addition to the work done by engineering, the operating division spends considerable time and effort preparing for potential emergencies. The operating division strives for a reliable supply of electricity by constantly reviewing and upgrading its manpower, materials and equipment to meet the anticipated demands of an emergency. Training is a critical part of this preparation and is done from a "worst case" approach to insure that personnel are prepared to handle any situation which might arise.

One aspect of planning, crucial to the successful handling of an emergency, is communication between the various elements of the emergency response team. The operating division maintains close contact with the design and construction division to insure that all areas of planning are adequately covered. In addition, a "single point contact" concept is used during emergency situations to insure that all communication between each work unit is direct and that responsibilities are clearly defined. Using this concept, a single individual within each work unit is assigned to handle all inter-work unit contact in any major functional area. In addition, once a task is assigned to an individual, it becomes the obligation of that individual through completion--thus establishing a clearly defined path of responsibility. This approach dramatically improves the efficiency of inter-work unit communications, an area which--if not properly coordinated--can become a major problem in the hectic environment of an emergency situation.

II-D. Prior Incident

LADWP's emergency planning was tested in July 1987 when an unspecified system fault interrupted service on the the Pacific DC Intertie. Line operators were able to identify the general location of the fault in the Owens Valley region of Northern California. Operating division crews, on the following morning, discovered that two structures of the Pacific DC Intertie, approximately 225 miles north of Los Angeles, had been brought to the ground by vandals.

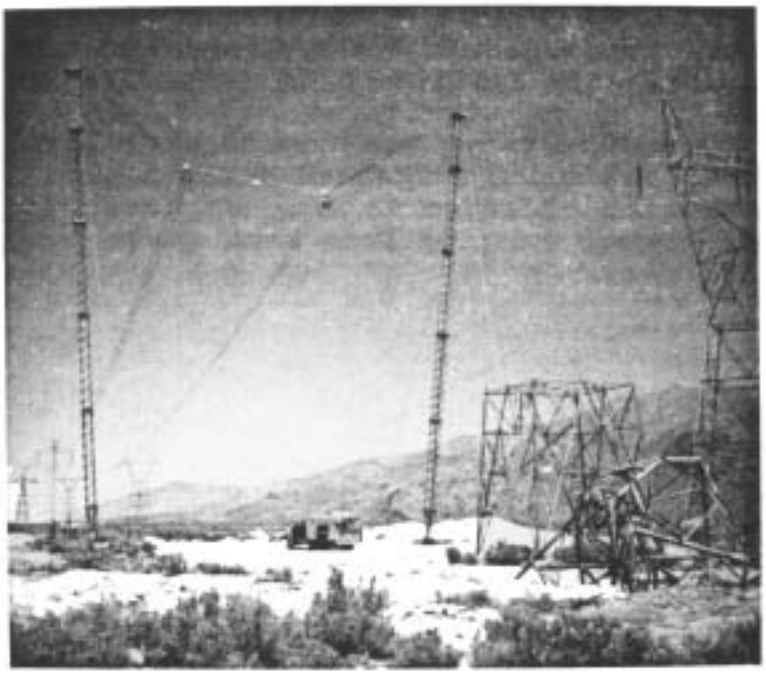


Figure 2

The light angle tower (right, foreground) was replaced with an emergency structure. The guyed permanent tower, which sustained minimal damage, was re-erected (left, background). A few months after the incident, the emergency structure was replaced with a new permanent tower.

Two of the four guy wires supporting a tangent tower had been cut, bringing that tower down and destroying a self-supporting light angle structure immediately to the south. Minor damage occurred to several towers immediately to the north and south of the downed structures.

LADWP initiated the Transmission Emergency Response Plan and immediately began transporting the necessary manpower, materials and equipment to the site from Los Angeles. The line was reenergized in less than two days (see Figure 2). Valuable lessons were learned with this emergency, such as the importance of effective communications, the need for adequate stocks of emergency materials, and the value of coordinated efforts by all personnel.

III. The Incident

In January of 1988 the emergency planning and preparation of LADWP was put to an extreme test. On January 14, a severe storm passed through the Owens Valley region of Central California (see Figure 3). Service on the Pacific DC Intertie and the adjacent Owens Gorge line was lost during the storm. On Friday morning, January 15, inspection of these lines revealed that 17 towers of the Pacific DC Intertie and 1 tower of the Owens Gorge line were on the ground.

It is believed the incident began with the failure of Pacific DC Intertie Tower 164-1 (see Figure 4). This tower moved 100 feet across the right-of-way, into the adjacent Owens Gorge line and destroyed one Owens Gorge tower. The Pacific DC Intertie failure cascaded north, taking out 13 guyed structures and one self-supporting structure. To the south, two guyed towers were lost. Additional towers to the north and south sustained damaged ground wire peaks. Six Gorge towers, in addition to the one destroyed Owens Gorge tower, sustained damage ranging from bent tower members to collapsed ground wire peaks.

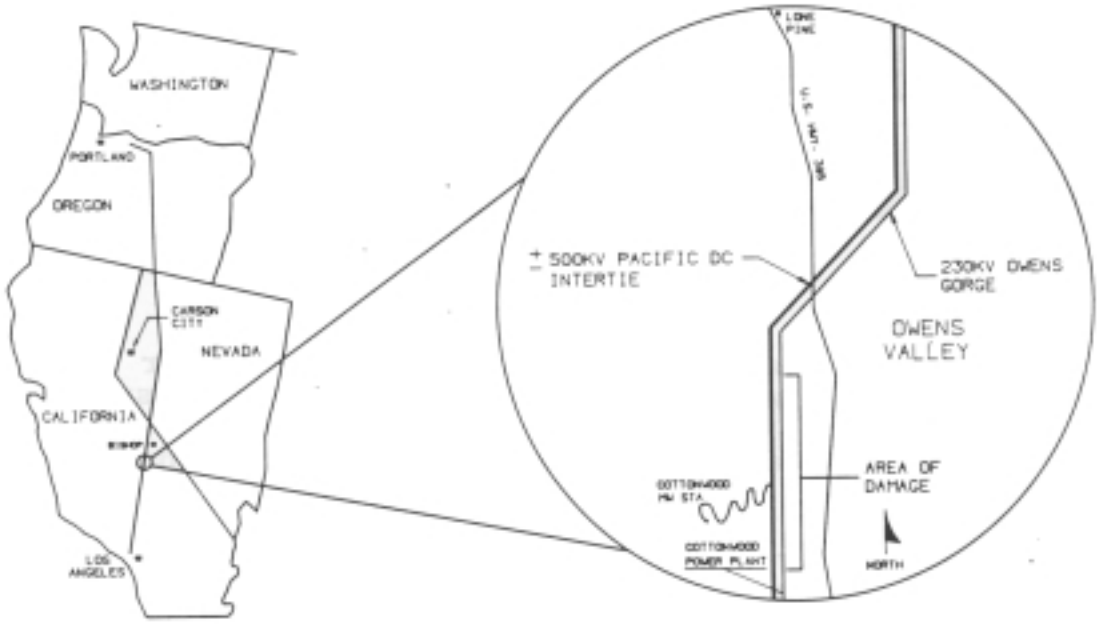


Figure 3

The 846 mile Pacific DC Intertie was originally built in 1968-69 from the Pacific Northwest to Southern California. North of the Nevada-Oregon border, the line is owned and maintained by the Bonneville Power Administration. South of the Nevada-Oregon border, the line is collectively owned by Southern California Edison, LADWP, and the cities of Burbank, Glendale and Pasadena. LADWP is responsible for maintaining the line south of the Nevada-Oregon Border. In the Owens Valley area, as shown in the inset, the Owens Gorge line runs parallel to the Pacific DC Intertie.

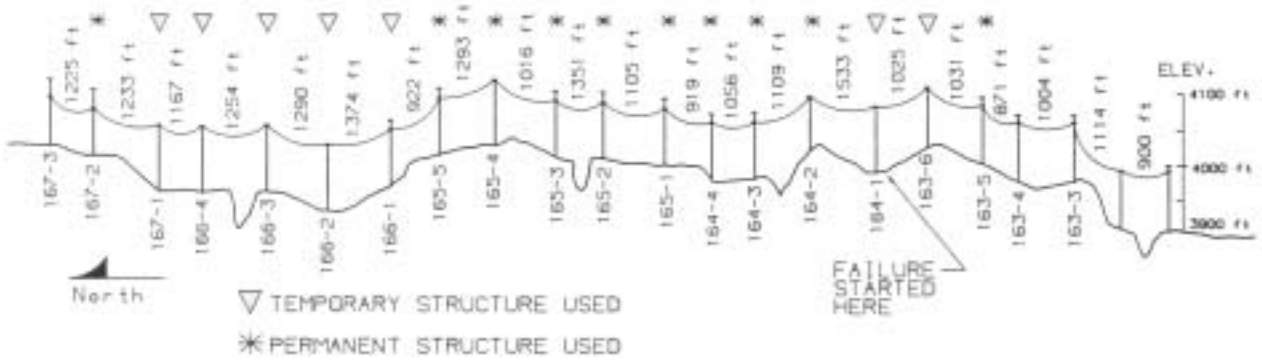


Figure 4

The terrain profile above shows the damaged section of the Pacific DC Intertie.

III-A. The Cause

The probable cause of the emergency was the failure of both windward guy fittings of Tower 164-1. The failure was due to extreme temperature and wind loading conditions which exceeded the original design criteria (see Figure 5). Although the cause of this emergency is important, the primary focus of this paper is on the actions which were taken to restore the lines to service. All utilities face the possibility of emergency situations and the lessons learned from this incident may prove helpful.

Figure 5

This figure shows a typical guy hardware failure. 15 of the 16 guyed towers which went down exhibited a similar failure of one or two guy fittings. LADWP is currently undertaking a program of changing out these fittings.

III-B. Response Day 1

At 6:53 am, on January 15, 1988 the Pacific DC Intertie and the Owens Gorge transmission lines relayed. Within minutes, the northern area transmission superintendent was notified of a possible problem. He requested a weather check along the Pacific DC Intertie right-of-way and a helicopter reconnaissance of the lines to locate the problem.

At 7:11 am, the Los Angeles area transmission superintendent and a northern area supervisor were informed of a possible problem and that both lines were locked out. The northern area supervisor indicated that there were high winds in the Owens Valley area.

By 7:54 am, the load dispatcher reported that the Owens Gorge line indicated continuity from Rinaldi Receiving Station to the Cottonwood Power Plant. The northern area supervisor ordered the line to be reconnaissanced from the Cottonwood Power Plant northward (see Figure 3).

The first report of damage was received at approximately 8:31 am indicating that four towers were down just north of the Cottonwood Power Plant. Shortly afterward, an LADWP telecommunication employee, en route to correct microwave equipment misaligned during the storm, reported that numerous towers were down in the vicinity of the Cottonwood Microwave Station.

The superintendents of the transmission operating section activated the Transmission Emergency Response Plan. The northern area superintendent and a Los Angeles area supervisor flew by helicopter to the emergency site to survey the damage, arriving at 11:36 am. The Los Angeles area transmission superintendent and the fleet operations superintendent organized the immediate transportation of essential equipment and material. In addition, the single point contact procedure was activated. Engineering, construction, fleet services, telecommunications, and material warehouses were informed of the damage and instructed to assign a support coordinator.

After arriving at the site, the northern area superintendent surveyed the area to determine the extent of the damage and to establish restoration priorities. The initial priorities were to secure the area to create a safe environment and prevent further damage, set up communications, establish a marshaling/material yard, and start a search for available material.

It was soon apparent that there were not enough Pacific DC Intertie towers in LADWP's system stock to replace all of those damaged. In addition, LADWP did not have sufficient emergency restoration structures to complete a temporary restoration.

The eastern area transmission superintendent implemented the Northwest/Southwest Transmission Reliability Committee's (NSTRC) assistance plan. Utilities listed on the maintenance matrix who stocked emergency restoration structures were contacted. Nevada Power, Salt River Project, San Diego Gas and Electric, and Utah Power and Light responded to LADWP's request by delivering emergency restoration structures to the damage site within 24 to 48 hours. In addition, Bonneville Power Administration offered to supply guyed replacement towers that could have been used temporarily, if there was a need.

Local crews arrived on site that afternoon and started the tasks of securing the area and creating a safe environment. Local lodging facilities and food establishments in Lone Pine were notified of the possible requirements.

All supervisors were instructed to report to the damage site by 6:30 am, on January 16th. All crews were instructed to report to their normal work locations and wait for instructions.

III-C. Response Day 2

Early into day two, major tasks for the temporary restoration were separated between the Owens Gorge line restoration and the Pacific DC Intertie restoration. The northern area superintendent took charge of the entire operation and also oversaw the Owens Gorge restoration. The Los Angeles area superintendent oversaw the Pacific DC Intertie restoration. As support for both of these operations, the fleet operations superintendent coordinated all on site manpower, materials, equipment (inventory control), lodging, and food requirements. The eastern area superintendent, normally located in Boulder, Nevada, traveled to Los Angeles to coordinate support activities.

Several transmission operating section crews traveled to the site and started work on various assignments, while a few crews stayed in Los Angeles to load material.

A command post was set up at Cottonwood Power Plant for coordination and communications.

IV. Temporary Restoration

Daily activities after day two of the temporary restoration would be too numerous and repetitive to list individually. The major milestone activities and time for completion are shown on the bar chart of Figure 6.

Two activities which were carried out on a daily basis were morning and evening supervisors meetings. These meetings covered the day's activities, focusing on safety, coordination, and special training, if required.

Establishing a marshaling yard was begun immediately to store material and equipment needed for the restoration (see Figure 7). Another activity that began immediately was clearing debris from the right-of-way and patrol roads (see Figure 8). Other major milestones listed on the temporary restoration bar chart are discussed under either the Pacific DC Intertie restoration or the Owens Gorge line restoration.

Maintaining a safe working environment and avoiding working conflicts were difficult priorities due to the many activities being carried out simultaneously. Periodic poor weather conditions and personnel fatigue from working long hours also contributed to the difficulty; however, there were no major incidences or injuries during the entire restoration.

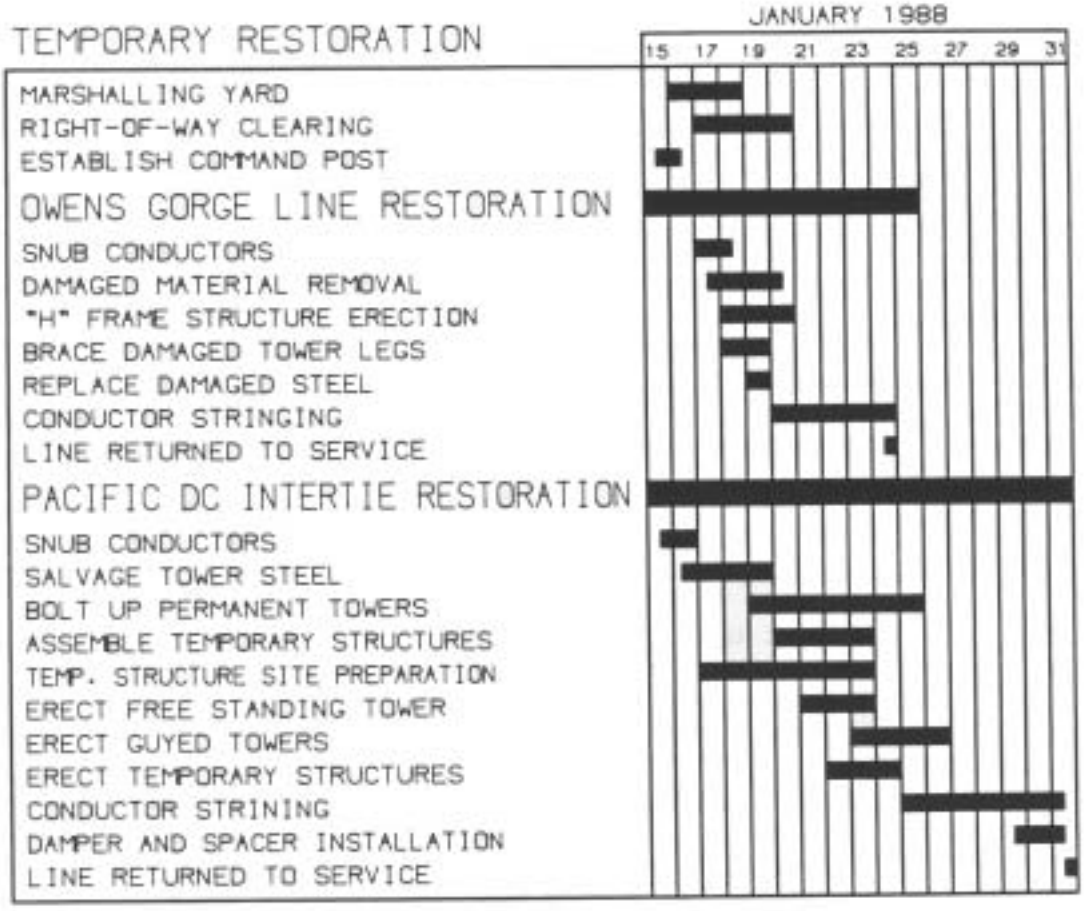


FIGURE 6

Figure 7

The marshaling yard was set up about midway along the damaged area. As materials and equipment began to arrive it was sorted, inventoried and stored in the marshaling yard until required. Power and telephone service was provided to the yard by local residents.

Figure 8

Many of the DC towers collapsed across existing access roads making it essential to clear new roads. Since much of the collapsed steel was salvageable, care had to be taken during removal to prevent further damage. In the background is the only self-supporting tower that collapsed.

IV-A. Owens Gorge Line

The decision to restore the Owens Gorge line first was based on two major factors. First, the Pacific DC Intertie was not carrying a large capacity because the spring run-off in the northwest had not started and lower cost hydroelectric power was not yet available. Second, water flowing through the Los Angeles Aqueduct is used to drive the Owens Owens Gorge Hydroelectric Plants. To let this water flow without obtaining the available power would have been costly. Therefore, it was beneficial to first return the Owens Gorge line to service.

Damaged critical steel members of towers were replaced with new steel members made in LADWP steel fabrication shops in Los Angeles. Towers with damaged legs were braced with wood poles to prevent the legs from buckling (see Figure 9).

Figure 9

Each damaged tower was fully inspected for bent steel or other structural problems. In several cases wood braces were used instead of replacement steel in order to save time and speed the line back into service.

The one collapsed Owens Gorge tower was not salvageable and had to be replaced. Since no towers of that type were in stock, this tower was temporarily replaced with two wood "H" frame type structures. The "H" frame structures were placed on both sides of the downed tower to allow for the future erection of the permanent tower without removal of the "H" frame structures.

Installation of insulators, hardware and stringing travelers was performed simultaneously with tower repair. After all sections of the line were either permanently or temporarily repaired, the stringing operation began immediately.

Conductor sagging was directed and checked by Transmission Engineering and Quality Assurance engineers. Sag values were calculated in Los Angeles using original line design criteria and were transmitted to the restoration site via computer modem.

The Owens Gorge line was available for service on January 24, 1988, nine days after the emergency began. Although outages would be taken on this line to help facilitate the restoration of the Pacific DC Intertie, aqueduct water could be released and power produced during the night time hours. The temporary restoration of the Owens Gorge line involved replacement of one destroyed tower, repair of six damaged towers, and restringing of 22,000 feet of 954 kcmil "Cardinal" conductor. The restoration took approximately 52 people, working for 9 days.

IV-B. Pacific DC Intertie

Because 15 of the 16 collapsed Pacific DC guyed towers did not fail in buckling, a substantial amount of tower steel was salvaged and re-used. All of the downed towers were inspected and acceptable sections were taken to the marshaling yard. Sections were inventoried and matched with other salvaged or new tower steel to form complete towers.

Enough salvaged and new tower steel was available to replace ten of the 17 destroyed towers, thus only seven emergency structures were required. The seven emergency structures were placed in the most level terrain areas and offset from the permanent tower location to maintain electrical guy clearance to the Owens Gorge line and to facilitate their initial erection and allow for their future replacement by the permanent towers. As emergency structures from NSTRC utilities arrived on site, they were color coded to insure that they would be returned to their proper owner.

The emergency structure configuration used by LADWP consisted of two 106 foot columns with a chainette insulator arrangement supporting the conductor (see Figure 10).

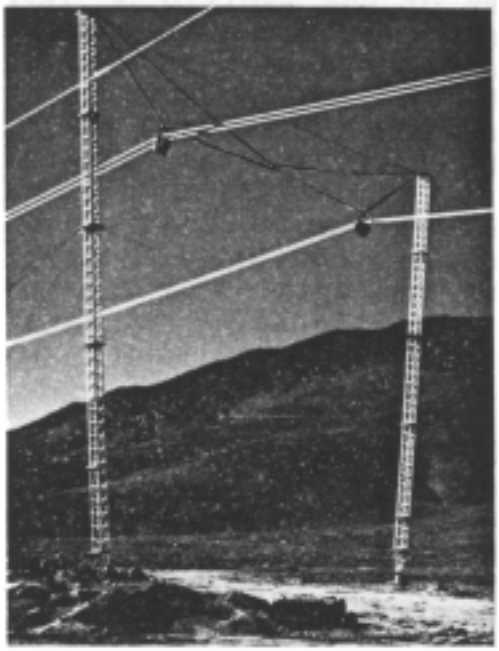


Figure 10

The emergency structure was guyed at the top and at the 64 foot level using a total of 36, 7/16 inch guy wires and 6 direct buried, concrete plug anchors. An additional guy was used to connect the two columns at the 64 foot level. To compensate for the ground slope and to keep the top of the structure approximately level, the height of the uphill columns were varied using the modular sections.

The restoration structure design was modified for the two pole DC conductor configuration, from a standard three phase AC configuration, by removing the center phase. Because of this new configuration, and the severe loading conditions, LADWP requested the manufacturer's assistance in analyzing the structure, and a modified computer analysis program was supplied in two days.

After emergency structure locations were prepared, the structures were transported to the sites and pre-assembled complete with insulators, stringing travelers, and guy wires. Each structure was erected using two cranes, one on each column. With three crews working simultaneously, five of these structures were erected in a single 10 hour period.

Using salvaged steel and newly made steel, nine permanent guyed towers and one free standing tower were assembled and erected. The permanent guyed towers were erected completely assembled with insulators and stringing travelers attached. The one free standing tower was assembled on the ground, and then erected, section by section.

As the structures were being erected, pads were built for the stringing equipment. The conductor tensioner was placed between Towers 165-5 and 165-4. Two conductor pulling pads were built, one north of tower 167-2 and the second south of tower 163-5.

The 96,000 feet of 2312 kcmil "Thrasher" conductor required for the restoration was available from LADWP's stock. LADWP had previously standardized on the use of this conductor size, and purchased spare conductor during a previous construction job. This planning proved invaluable during the restoration.

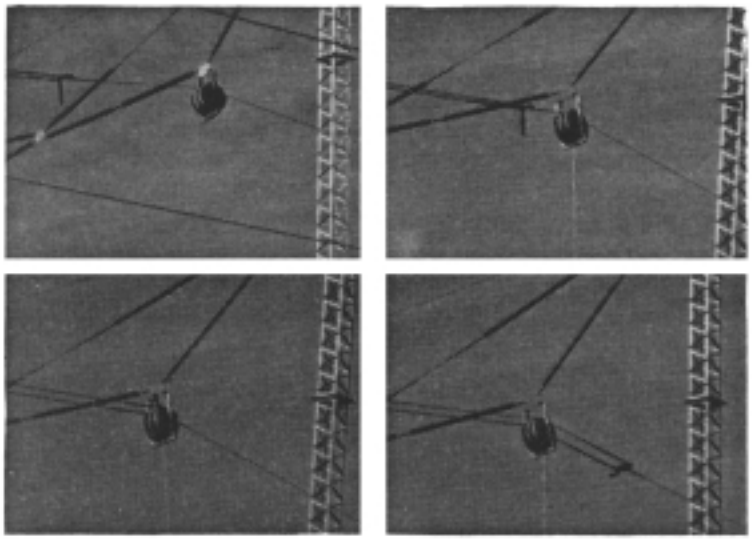
On Tuesday, January 28th, both poles of the Pacific DC Intertie were strung north of the tension site. The new east and west conductors were pulled from the tensioner, through one permanent guyed tower, five emergency structures, and another permanent guyed tower (see Figure 11). The new conductors were spliced to the existing conductors at the pulling site, and then sagged.

The conductor pull south of the tensioner was through seven permanent towers, two emergency structures, and another permanent guyed tower. The new conductors were then spliced at the pulling and tensioner sites. Sagging was performed from the tensioner site to a deadend structure located two spans south of the southern pull site.

Extra insulator bells and adjustable links were added to the deadend insulator-hardware strings to compensate for the additional span length caused by the emergency structure offset. It was hoped that during the permanent restoration these extra insulators could be removed, eliminating the need to cut and redeadend the conductor. Although this attempt worked for the most

part, determining the exact unstressed conductor length in the spans of the temporary restoration and the permanent configuration was difficult. Span lengths and elevations taken from original plan and profile drawings were accurate only to the foot. In the future, survey crews will verify elevations and span lengths to 1/10 of a foot to increase the accuracy of these calculations.

Figure 11



LADWP's stringing operation represented the first time the chainette insulator assembly of the emergency structures had experienced stringing. This sequence of photographs shows the running board coming from the longest span of 1374 feet. The running board caused minimal swing in the chainette assembly.

The final operation involved clipping the conductors into several of the permanent structures. The conductors were left in the travelers on the emergency structures. Dampers were installed on both sides of all towers and all spans had spacers installed.

On January 31, the Pacific DC Intertie was returned to service. Within sixteen days of outage, and seven days after the restoration of the Owens Gorge line, LADWP had replaced 17 destroyed towers, repaired several additional towers and installed 96,000 feet of new conductor. During the peak of activity approximately 130 employees were at work restoring both lines.

V. Final Restoration

Planning for the final restoration of both the Pacific DC Intertie and the Owens Gorge line began immediately after the completion of the temporary restoration. New steel for the destroyed towers and replacement hardware had been ordered during the early stages of the emergency. This material was available in less than two months after the initial failure for the Pacific DC Intertie and in about four months after the initial failure for the Owens Gorge line.

V-A. Pacific DC Intertie

On the Pacific DC Intertie, it was necessary to develop a method of erecting the permanent towers while minimizing the required outage time. The proposed method involved assembling and erecting the permanent towers, transferring the conductors from the temporary structures, and dismantling and removing the temporary structures. A computer model of the temporary and permanent structures, including guy wires and conductors, was developed by Transmission Engineering in order to determine the feasibility of this method (see Figure 12). The model verified that the offset placement of the temporary structures during the emergency restoration was sufficient to allow for the proposed permanent restoration procedure.

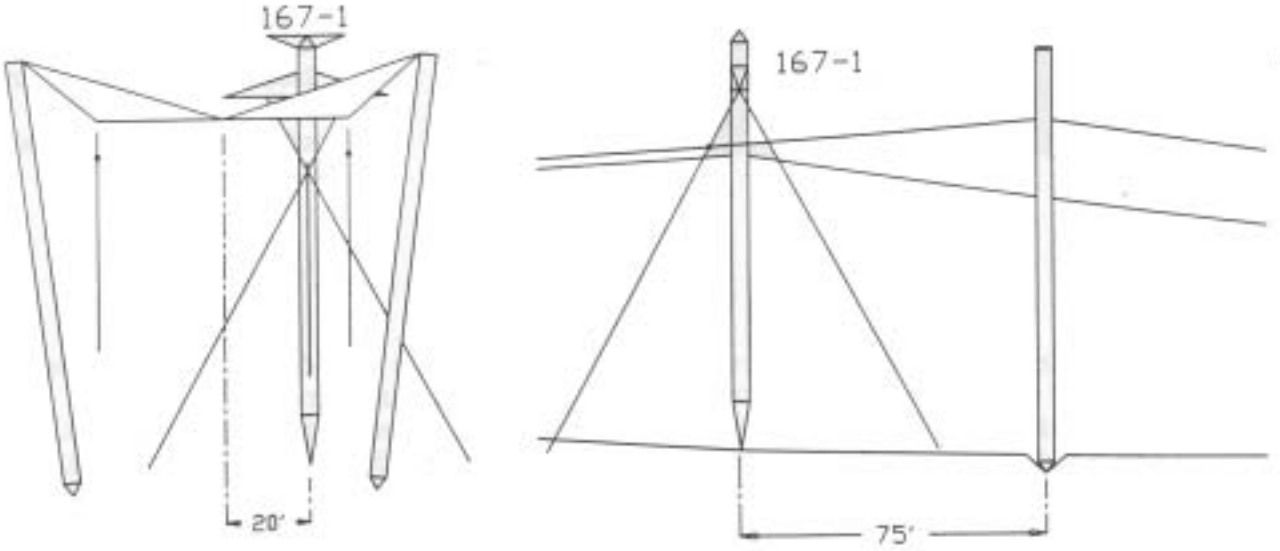


Figure 12

Both a two dimensional (shown above) and a three dimensional computer model of the temporary and permanent structures verified that the planned restoration work method was feasible. These models also aided in determining the proper placement of the required equipment.

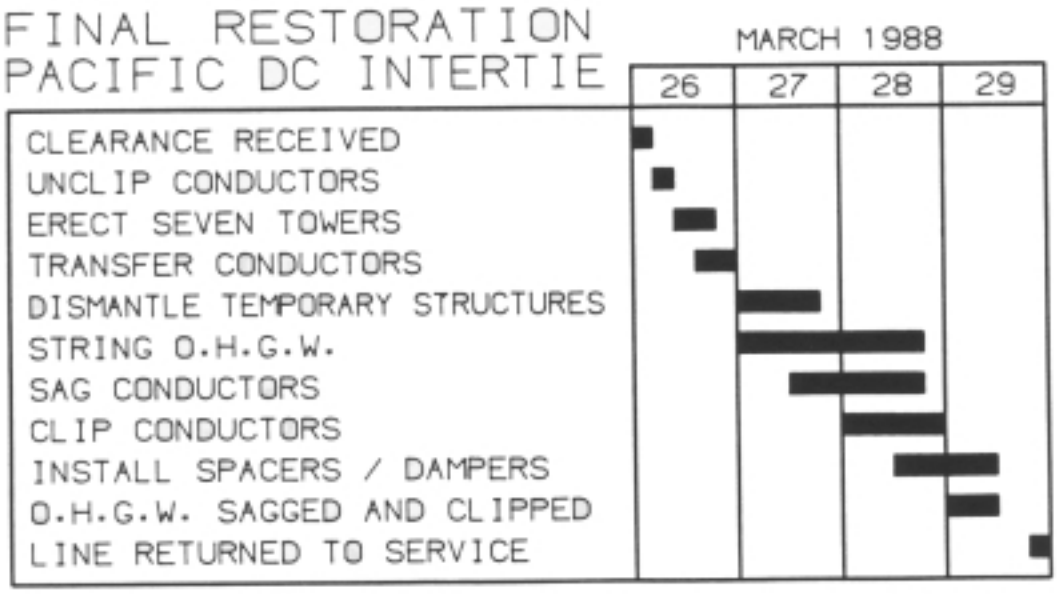


FIGURE 13

Permanent restoration of the Pacific DC Intertie took place in March, 1988. The bar chart in Figure 13 summarizes the major activities and the time for completion of this restoration.

During the week of March 13, 1988, crews assembled seven permanent guyed towers and prepared them for erection. Final preparations for the permanent restoration were made March 24-25. These preparations included moving equipment and materials to the job sites, setting cranes and aerial lift equipment, and completing quality assurance corrections.

On March 26, shortly after midnight, necessary clearances were received on the Pacific DC Intertie and the Owens Gorge line. Working grounds were installed to isolate the restoration and the final restoration began.

During the first day of the outage all seven of the permanent guyed towers were erected (see Figure 14). The work was conducted using three simultaneous operations and proceeded smoothly, due primarily to careful planning. Once the permanent towers had been erected, the conductor was transferred from the temporary structures without incident (see Figure 15).

During the second day of the outage the emergency structures were dismantled, sorted and inventoried according to their color coded ownership. 26,000 feet of overhead ground wire, not replaced during the temporary restoration, was installed. One pole of the DC line was sagged and marked for clipping.

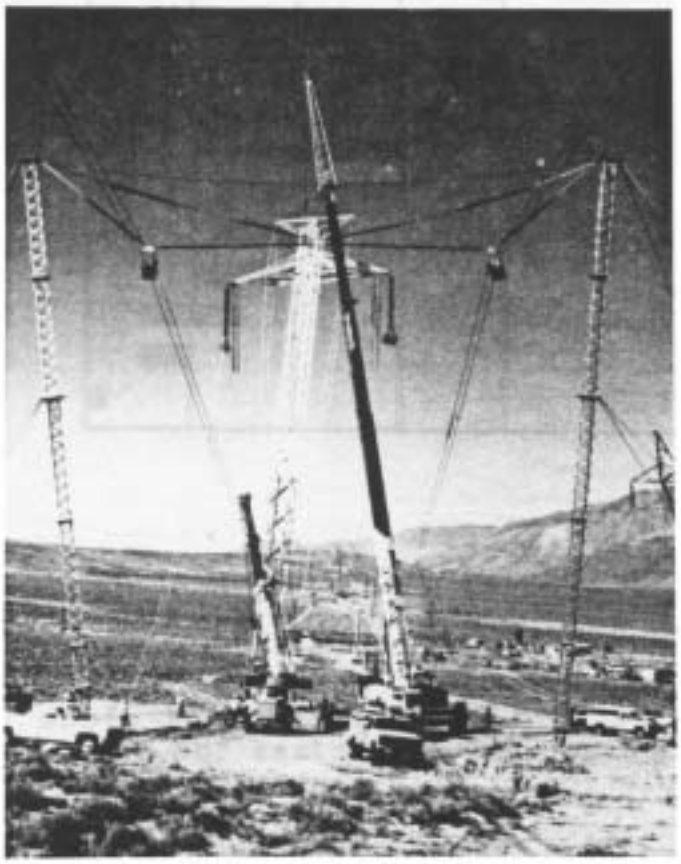
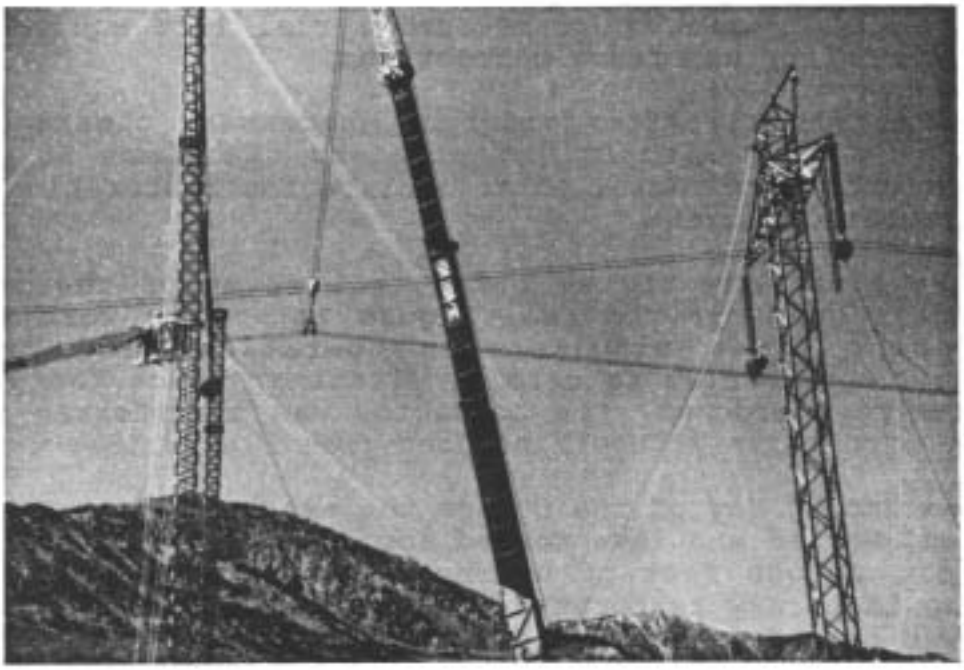


Figure 14

A 90 ton Grove crane was used to raise the permanent towers between the two poles of the DC line. A smaller crane was used at the base of the permanent tower to position it on the foundation. Once upright, the four guys of the permanent tower were used to plumb and secure the structure.

Figure 15

The same 90 ton crane used to erect the tower was used to transfer the conductors from the temporary structure to the permanent tower (below). Once the conductors had been transferred, the 90 ton crane moved to the next structure while additional crews began disassembling and removing the temporary towers.



During the third day of the outage the second pole of the DC line was sagged and marked for clipping. Both poles were deadended and clipped in. Spacers and dampers were installed on six spans. An additional 13,000 feet of overhead ground wire was installed, spliced and prepared for sagging. Temporary roads, used during the restoration, were returned to natural contour.

On the fourth and final day of clearance the overhead groundwire was sagged, deadended and clipped in. Spacers and dampers were installed on the remaining 12 spans. Quality assurance checks were completed and working grounds were removed. The clearance was turned in at 2:22 pm, and the Pacific DC Intertie was energized at 10:34 pm, March 29, 1988.

The clearance for the permanent restoration was planned for five days but it took less than four. Again, cooperation between various disciplines and careful planning eliminated many potential problems and made for a smooth operation. Approximately 100 employees worked to complete the final restoration of the Pacific DC Intertie.

The emergency structures borrowed through the NSTRC program were returned to the loaning utilities within two weeks after the permanent restoration.

V-B. Owens Gorge Line

The final restoration of the Owens Gorge line involved activities to install one new tower, remove two temporary wood pole structures, adjust conductor in the middle and western phases, and string overhead ground wire (see Figure 16). Three separate outages were scheduled to complete this work, with final restoration accomplished by July 5, 1988. More time was required to complete the Owens Gorge line restoration than the Pacific DC Intertie because of material supply problems.

During the week of May 7, 1988 in preparation for the first scheduled outage, the newly acquired steel lattice tower was partially assembled. The footings and tower stubs for this tower, damaged during the initial failure, were repaired.

During assembly of the tower, one steel member was found to be misfabricated and the first outage had to be re-scheduled to allow time for the fabrication and delivery of a corrected member.

The second scheduled outage was taken on the Pacific DC Intertie and Owens Gorge line on June 18, 1988 to allow for the erection of the new Owens Gorge tower and removal of two temporary "H" frame wood pole structures (see Figure 17).

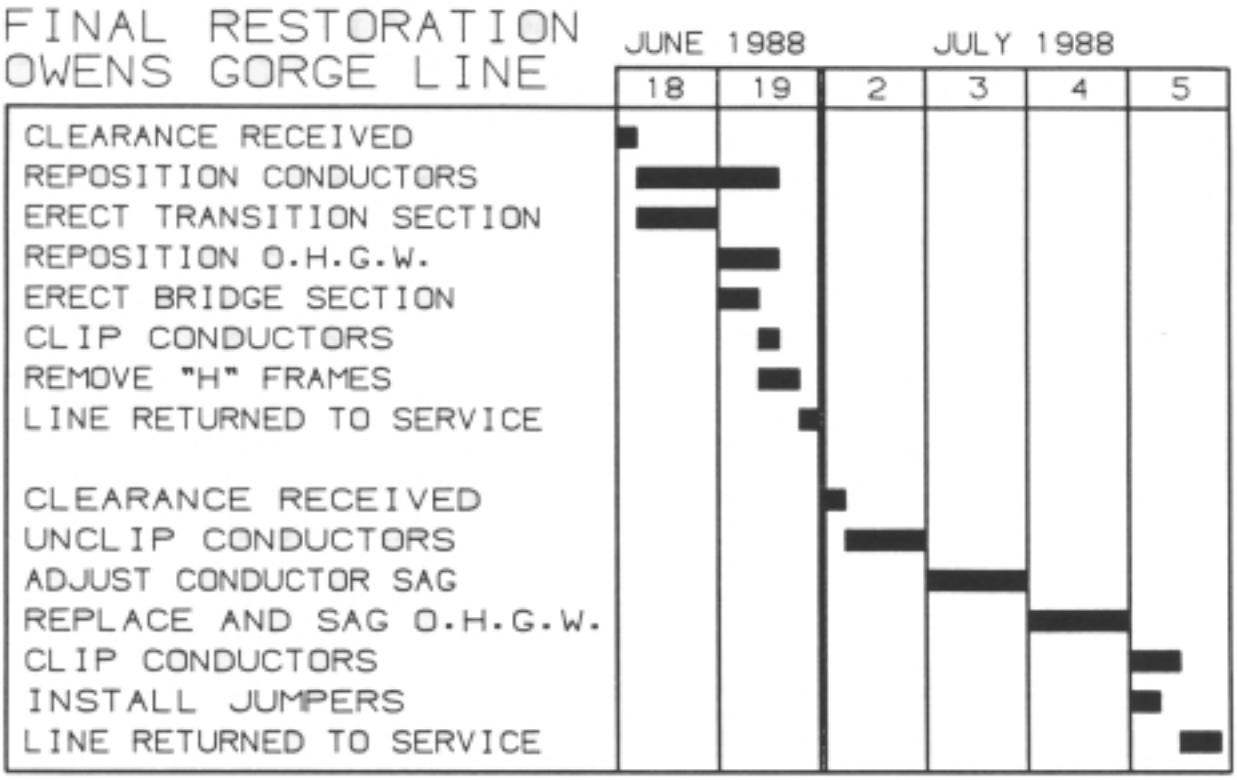


FIGURE 16

During this outage, two splice plates necessary to hold the tower body together did not fit properly. Fortunately, LADWP had spare plates, and the erection proceeded with only a half day delay.

After the new tower was partially erected, the middle phase conductor was positioned within the window of the unfinished tower. With the conductor insulator assemblies attached, the bridge was then installed to complete the erection (see Figure 18). Subsequent to this, the outside conductors and overhead ground wires were installed into the newly erected tower. Finally the suspension insulator strings were plumbed and the temporary wood pole structures were removed. Clearance was issued to energize the Owens Gorge line during the evening of June 19, 1988.

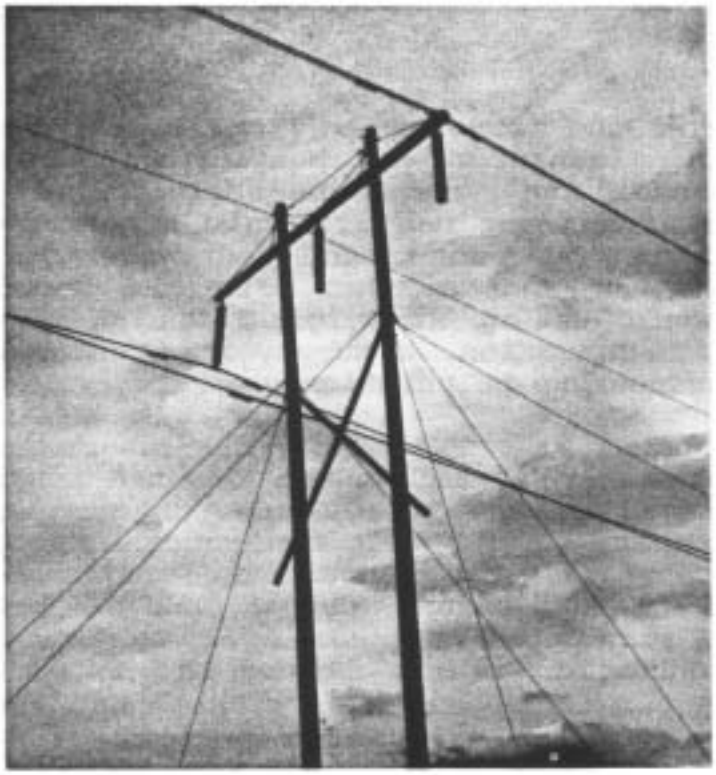
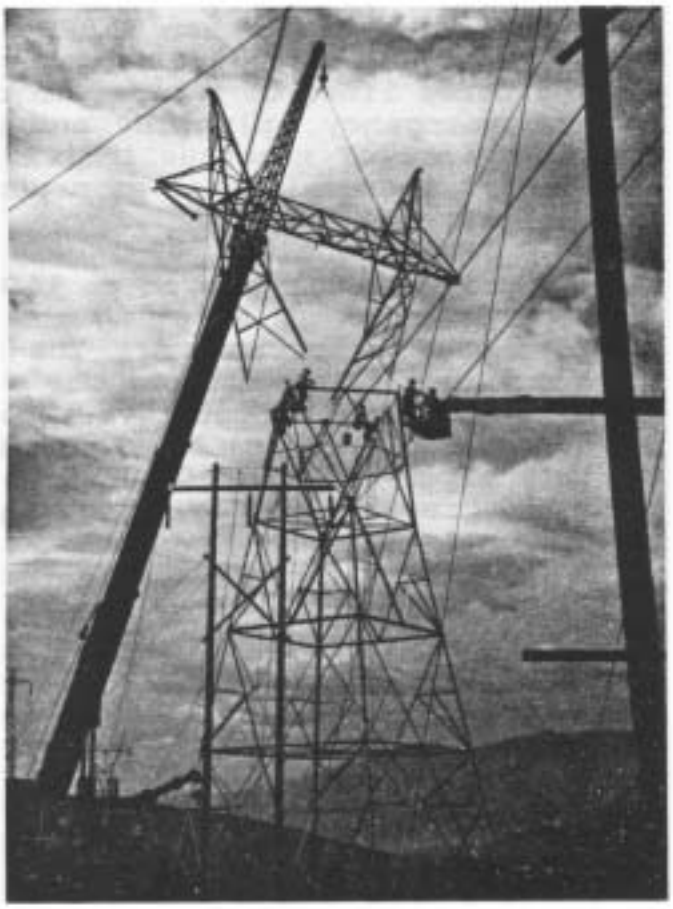


Figure 17

Conductor and groundwire was constrained at the temporary "H" frame structures, to allow the new suspension type tower to be erected. Being able to erect this new tower without removing the conductors reduced the required outage time.

Figure 18

This overview shows the new replacement tower being erected between and the temporary structures. Also shown is the proximity of the equipment to the structures.



It should be noted that during the temporary restoration of the Owens Gorge line, a significant amount of engineering went into assuring that the conductor would not have to be spliced during the final restoration. The proper sag was difficult to determine, since each phase had varying amounts of new conductor. Temporary restoration sagging was done so that after the final restoration the conductors would end up at original design tensions. After the temporary restoration, a survey crew checked the sags and verified the engineering calculations.

The third scheduled outage began July 2, 1988. The insulator plumb was checked and corrected for several towers located north and south of the newly replaced tower, to allocate the proper amount of conductor in each span. After this was accomplished, the conductor was clipped into place. To complete the final restoration, new overhead groundwire was strung, sagged, and clipped in to replace the badly stretched and damaged westerly groundwire. The easterly groundwire was not damaged and no work was required on it. On July 5, the outage was released and the line was placed in service.

VI. Conclusions

The loss of 18 towers on LADWP's Pacific DC Intertie and Owens Gorge lines in January, 1988 represented a major emergency. Restoring these lines to service in only two weeks was made possible by the emergency planning and preparation done by LADWP, the combined work of numerous individuals both within and outside of LADWP, and the assistance of several other utilities and material suppliers.

This experience has proven to LADWP that emergency planning is a critical element in ensuring the economic and reliable delivery of power to its customers. The importance of direct and effective communications between the various elements in the restoration team, and a cooperative atmosphere between utilities cannot be overstated. It is LADWP's hope that the information presented in this paper will be of value to other utilities in their planning and preparation for emergency situations.