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LIMA DISASTER PREPAREDNESS REPORT

VOLUME III:

Electricity

by

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in collaboration with

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for

Office of U. S. Foreign Disaster Assistance

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The Lima Disaster Preparedness Report has 15 sections:

Volume I:	Methodology Employed
Volume II:	Port of Callao Infrastructure Security and Emergency Evacuation Needs
Volume III:	Electricity
Volume IV:	Water and Sewerage
Volume V:	Heavy Equipment Rehabilitation and Maintenance
Volume VI:	Airport and Aircraft Resources
Volume VII:	Education
Volume VIII:	Food
Volume IX:	Housing
Volume X:	Health
Volume XI:	International Donor Coordination
Volume XII:	Critical Abstracts from the Literature: A field perspective on major earthquakes: Peru, 5-31-70 Nicaragua, 12-23-72 Guatemala, 2-4-76
Volume XIII:	Review of Earthquake Prediction by Brian Brady
Volume XIV:	Other Issues
Volume XV:	Summary

FOREWORD

This is one section of a fifteen volume report concerning disaster preparedness in Lima, Peru. It was researched in Lima by a team of disaster specialists during the period July - November, 1981, for the Agency for International Development's Office of U. S. Foreign Disaster Assistance and USAID Mission in Peru. The report is supplemented by a considerable number of maps, charts and resource documents which are located in the USAID/ Peru Disaster Preparedness Resource Library in Lima.

June 1982

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INTRODUCTION/EXECUTIVE SUMMARY

This report describes Lima's electrical system, managed by a public power authority, ELECTRO-LIMA; and aspects of the City's fire-fighting system, which is managed by a volunteer fire department called the BOMBEROS (FIREMEN). It also discusses the availability and usefulness of portable energy-generating equipment after a possible disaster.

ELECTRO-LIMA, formerly a privately-held corporation, was acquired by the Government of Peru in 1968, and is now part of the national ELECTRO-PERU system, falling under the Ministry of Energy and Mines. Lima's power is drawn from six hydroelectric plants (part of an inter-connected national network) and a small thermal plant. Energy is transmitted to Lima principally through 220,000 volt overhead lines. The current is processed through five transformation centers where power is stepped down to 60,000 volts; then through 27 primary substations, where power is again stepped down to 30,000 or 10,000 volts; and finally through 5,300 secondary substations, where power is stepped down to 220 volts. In the entire system, about 70% of the cables -- especially low-tension wires -- are underground; about 30% are overhead.

ELECTRO-LIMA serves about 700,000 customers. But the main energy consumer in Lima is industry, whose 6,500 customers consume 50% of all power. Another 25% is consumed by a larger number (75,000) of commercial customers. The overwhelming majority (88%) of ELECTRO-LIMA's clients -- domestic consumers -- use only about 20% of the energy. About three-quarters of all domestic households have direct electrical service.

Within the category of "industrial consumers", industries highly vulnerable to fires -- textiles, chemicals and fuels, and wood and paper -- account for 42% of industry's daily consumption.

Although maximum consumption of electricity occurs between 8AM and Midnight, there is strong demand from industrial and other consumers 24-hours

a day.

In previous earthquakes in the region, particularly in Managua (1972), concern was expressed about fires raging out of control in industrial zones. Some fires originated from short circuits; some others may have originated from arson. But these fires, which consumed industrial areas, and housing areas with both wood and adobe construction, engaged the energies of rescue and relief workers for up to a week after the earthquake.

A study by a Peruvian disaster specialist from the National Engineering University suggests that short circuits, leakages of chemicals, escape of flammable gas, and faulty electrical equipment would be major sources of fires after an earthquake. Short-circuit fires occur frequently in Lima even without earthquakes, resulting in substantial economic loss and suspension of employment for a population already suffering from severe unemployment.

Peruvian experts consulted in connection with the report expressed concern about Lima's vulnerability to short-circuit origin fires after an earthquake. In normal times, about 40% of the City's fires are caused by short circuits, and some believe the number and magnitude would increase considerably after an earthquake in both industrial and low-income residential neighborhoods, and possibly even in schools and hospitals. Electrocutions may likely occur where relatives and rescuers rush in to save victims buried in the rubble and make contact with electrical wires or metal or water conducting current.

The ability of the volunteer fire department -- the BOMBEROS -- to combat fires after an earthquake would be limited, as streets will be choked with traffic, rubble, flooding, and other obstacles; the water pressure -- a chronic problem for firefighters in Lima -- would likely be too low to permit efficient activity; and many fire stations would collapse before firefighting equipment could be removed from them.

Thus, reducing the risk of fires after earthquakes is a top priority of ELECTRO-LIMA, the BOMBEROS, Port and other industrial officials, and engineers and professionals concerned with this danger throughout the City.

At the moment, ELECTRO-LIMA has a modern, adequate security system. When massive short-circuits are produced, and when current surpasses the maximum tolerance for which its wire conductor was designed, relays open at the nearest substation, cutting off the power supply. But this system requires a degree of maintenance and control which ELECTRO-LIMA cannot always implement. Also this system requires that individual factories and homes have their own electrical security systems, but most do not. The shut down follows the massive short circuits -- it does not precede them. Thus, there are some vulnerabilities in the system.

One area for potential improvement is in timing of the automatic shut-down of the system in the event of an earthquake. This strategy would strengthen the security system and would be a redundant or partially redundant with the existing system. In essence, it would provide for the automatic shut-down of the electrical distribution system from the moment an earthquake reached a pre-determined magnitude. Thus, the shut-down would precede the massive short-circuits, resultant fires and electrocutions which could otherwise occur.

One system for implementing this suggestion would be the connection of accelerographs to the five major transformation centers through which all current for the City must flow. These accelerographs would be mounted and calibrated to automatically interrupt the flow of current from the transformation centers when an earthquake passed the equivalent, for example, of a 6.0 Richter level. This type of system would be harmonious with the principles currently followed by ELECTRO-LIMA and national Civil Defense policy. This report examines the possible disadvantages of such a system, but finds that they are considerably outweighed by its safety and security advantages.

Another recommendation focuses on the potential for preparing a strategy, in advance of an earthquake, for post-disaster operations. Specifically, it is recommended that a list of critical facilities, by priority, for each sector (health, water production, etc.) be developed and shared with ELECTRO-LIMA. These lists would allow ELECTRO-LIMA to plan in advance for the rational, prioritized use of their resources after an earthquake; and would permit its technicians to respond more rapidly in the event of a disaster, even if advance contingency plans had not been made.

There are approximately 150 generators with a capacity of under 100KVA, and about 11 with a capacity of over 100KVA, available for emergency operations. While the 100KVA+ category is limited, the report recommends caution in the provision of generating equipment from international sources. However, if necessary, a small number of generators could be provided for key facilities if generators which match the technical specifications required in Lima can be airlifted.

Because of the degree of professional skill of ELECTRO-LIMA's own staff of technicians and managers, it is not recommended that technical assistance in the electrical area be provided after a disaster. Similarly, ELECTRO-LIMA reports that it has adequate supplies of wiring and other emergency supplies. But if technical assistance or special equipment is required, ELECTRO-LIMA would not hesitate to request them. For this, and for on-going preparedness operations, a list of contacts in ELECTRO-LIMA, the BOMBEROS, and other related public and private sector institutions is provided at the conclusion of the report.

ELECTRICITY AND FIRE DANGERS IN LIMA

This report describes two inter-related areas germaine to disaster preparedness and the planning for post-disaster operations in Lima: the electricity system, which is managed by a public power authority, ELECTRO-LIMA; and the City's fire-fighting capability, which is managed by volunteer fire department called the BOMBEROS. It will also discuss matters related to post-disaster operations, such as availability of portable energy-generating equipment.

ELECTRO-LIMA

Until 1968, ELECTRO-LIMA was a privately held corporation. About 70% of its stock was owned by Swiss and about 30% by Peruvian interests. In 1968, the Government of Peru acquired 99.9% of the shares. Thus, today ELECTRO-LIMA is a branch of the Government-owned and operated ELECTRO-PERU system, falling under the Ministry of Mines and Energy.

Despite its public ownership, ELECTRO-LIMA retains its private-sector oriented staff and significant operating autonomy. It has its own Board of Directors.

This brief summary of ELECTRO-LIMA's normal activities will be divided into three parts: generation of energy, transmission of electricity and distribution and consumption of power in Lima. Map I* on the following page provides a general overview of the geographical area of ELECTRO-LIMA's responsibilities and the location of some of the principal generation and transmission sites which will be discussed.

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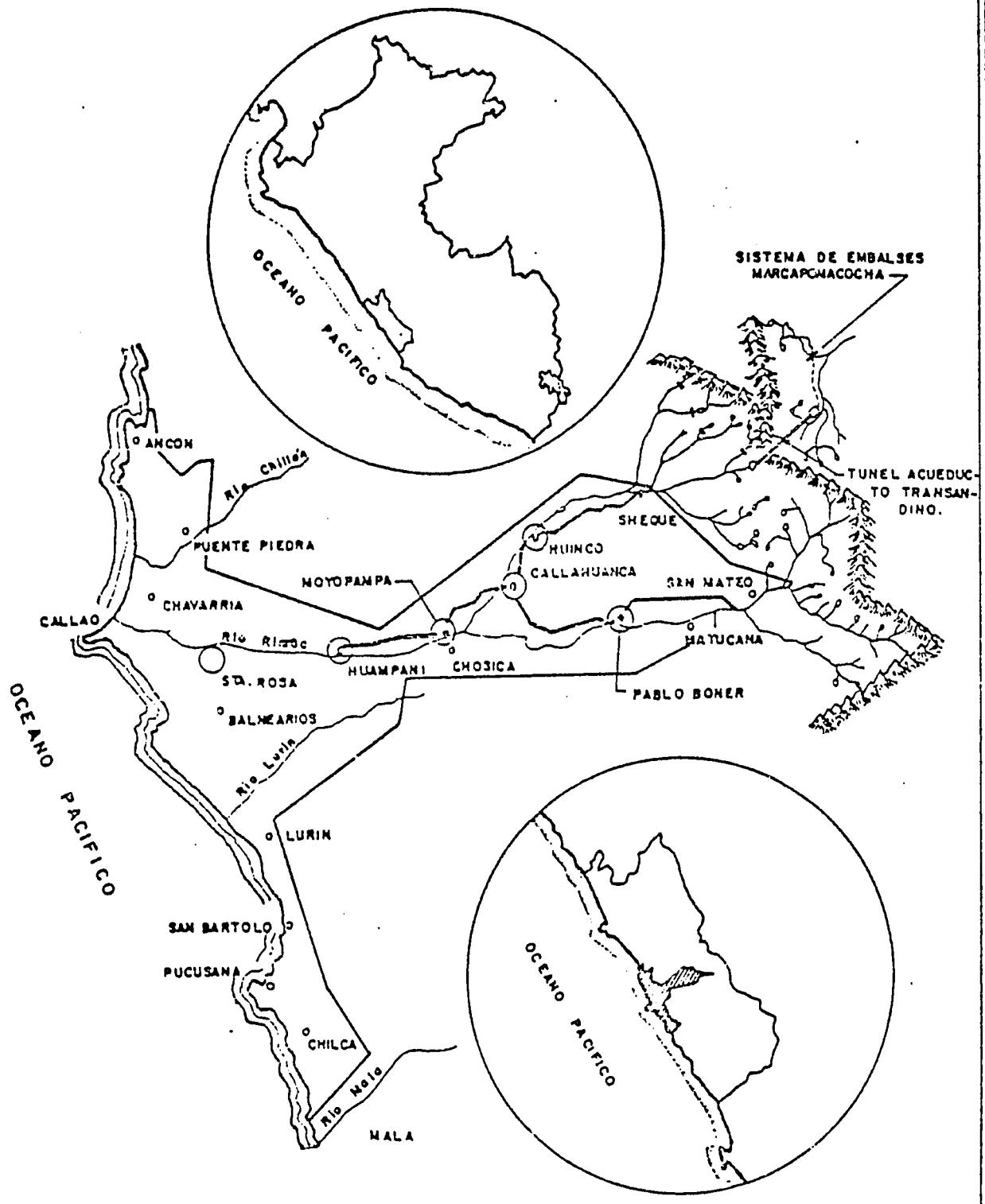
* Maps and charts concerning ELECTRO-LIMA's activities are drawn from Datos Estadisticos - 1980, Sector Energía y Minas, ELECTRO-LIMA, Empresa Estatal Asociada del Sub-Sector Eléctrico Nacional.

CENTRALES DE GENERACION Y ZONA DE RESPONSABILIDAD



ZONA DE RESPONSABILIDAD COMPRENDIDA ENTRE ANCON POR EL NORTE CHILCA POR EL SUR Y SAN MATEO POR EL ESTE (294,049 Has.)

Section I: Generation

Lima receives energy generated by six hydroelectric plants and one thermal plant.

The hydroelectric plants are based on a series of nineteen mountain lakes which have a total holding capacity of approximately 170 million cubic meters of water. ELECTRO-LIMA controls the captation and storage of this water, which is used to compensate for seasonally drier periods, thus assuring year-round production of energy and water for the population of Lima.

In 1980, the amount of water stored through this system at the end of each month was as follows:

January	78.8 million m^3	July	91.2 million m^3
February	92.0	August	72.4
March	107.4	Sep.	54.5
April	125.4	Oct.	55.7
May	119.8	Nov.	60.9
June	107.4	Dec.	73.6

Chart I on the following page illustrates graphically the seasonal variations in actual water stored in the lake system and their comparison with the total storage capacity. This ifnormation is plotted over the period 1976 through 1980.

The six hydroelectric plants which provide energy to Metropolitan Lima are part of the national electrical network. While the output of some plants is channeled predominantly into Lima, only a part of the others is used in that area. However, because almost all of the plants are tied into the same national network, the City benefits from the potential for intro-system substitution should one or two of its customary plant suppliers be put out of action (through disaster, equipment breakdown, or other emergency).

Chart I

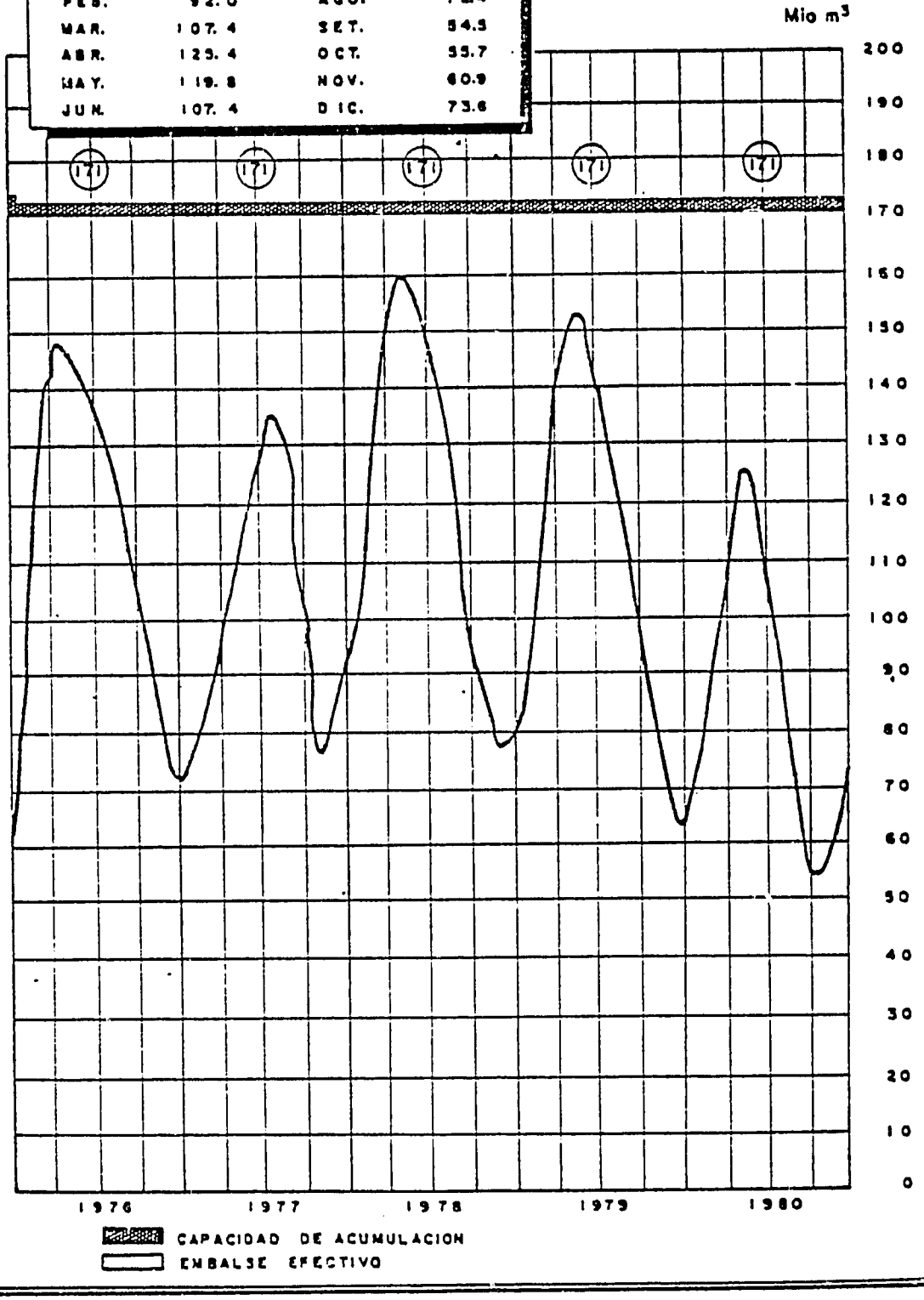
CAPACIDAD DE ACUMULACION Y EMBALSE EFECTIVO DE LAS LAGUNAS DE REGULACION

(En millones de m^3 a fin de mes)

1980

EMBALSE EFECTIVO A FIN DE MES

	Mio m^3		Mio m^3
ENE.	78.8	JUL	91.2
FEB.	92.0	AGO.	72.4
MAR.	107.4	SET.	54.5
ABR.	125.4	OCT.	55.7
MAY.	119.8	NOV.	60.9
JUN.	107.4	DIC.	73.6



The hydroelectric and thermal plants supplying Lima produce energy in the following amounts and proportions:

	Amount	Proportion of Total
Mantaro	1600 GW	42%
Huinco	715	19%
Matucana	570	15%
Moyopampa	415	11%
Callahuanca	355	7%
Huampani	140	4%
Santa Rosa (Thermal)	3	-
	3790 GW	100%

Chart II illustrates graphically the relative production of each plant by month. The Santa Rosa Thermal Production Plant is not included as a proportion of the total because of its relative insignificance.

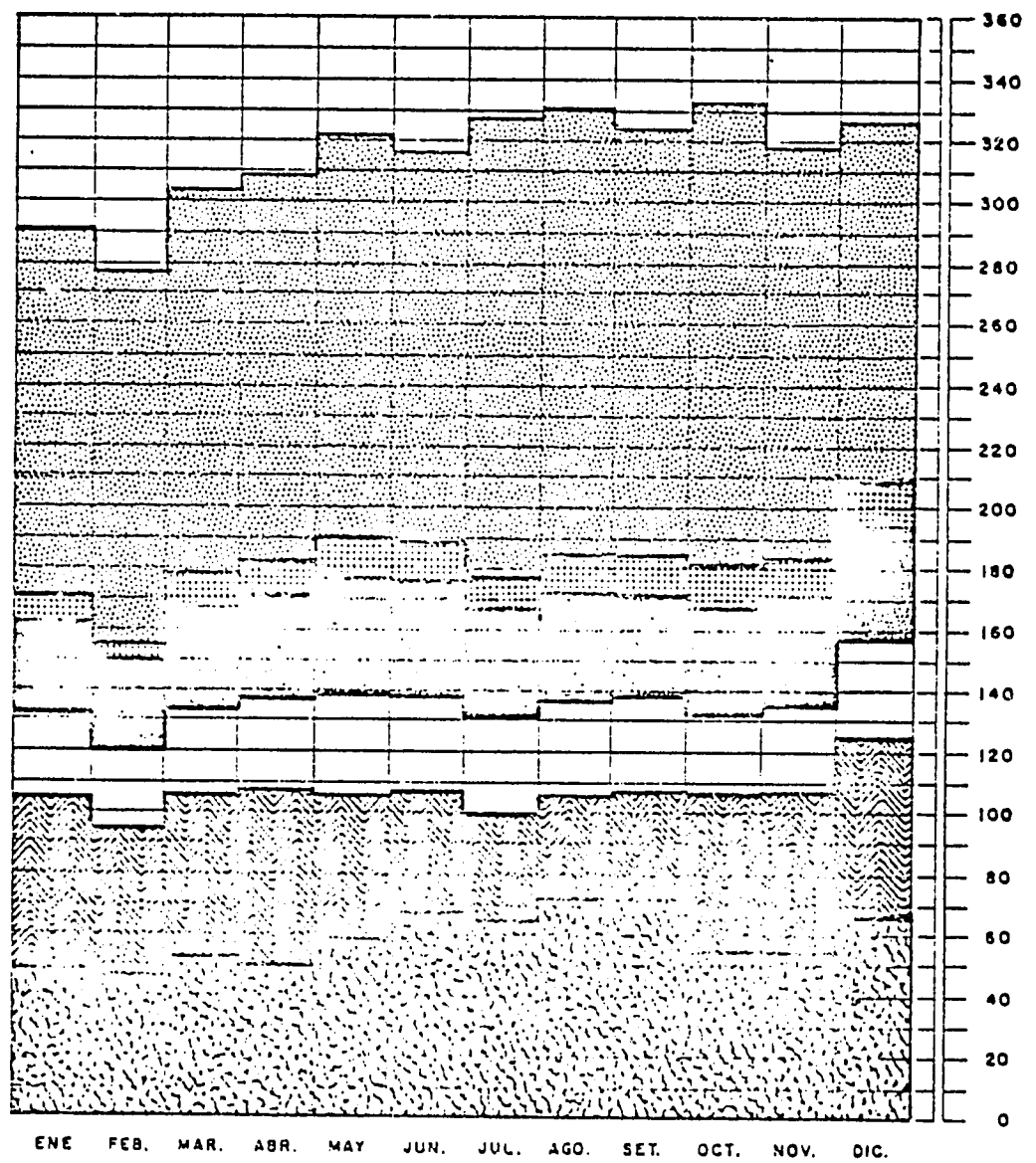
Section II: Transmission

Chart III provides a graphic presentation of the manner in which energy is transmitted from the hydroelectric plants (shown at the top of the chart) to the City.

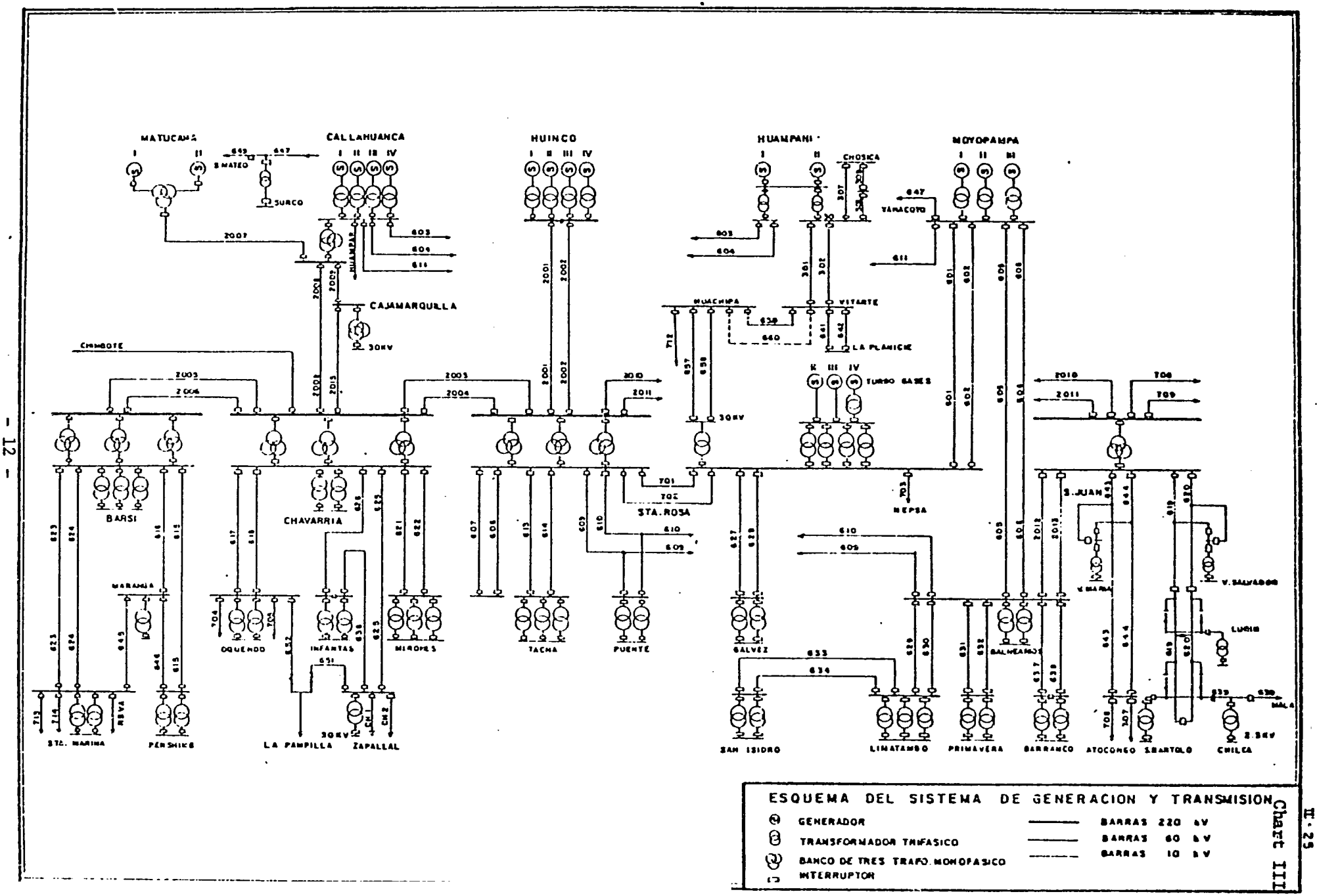
Electricity from the plants is transmitted to Lima principally through high-tension overhead lines carrying 220,000 volts. These lines feed an electrical ring around the City, the entry point for which are the five major Transformation Centers (Centros de Transformación), where transmission is stepped down from 220,000 volts to 60,000 volts.

Chart II

GENERACION MENSUAL POR CENTRALES
1980



NO SE PRESENTA LA PRODUCCION TERMICA DE LA CENTRAL SANTA ROSA, POR SU MINIMA SIGNIFICACION (2.8 GWh)


MATUCANA
CALLAHUANCA
HUINCO
HUAMPANI
MOYOPAMPA
S.MATEO
SURCO
CHOSICA
YANACOTO
CAJAMARQUILLA
CHIMBOTE
MACHIPA
VITARTE
LA PLANICIE
TURBO GASES
BARSI
CHAVARRIA
STA.ROSA
NEPSA
S.JUAN
V.MARIA
V.SALVADOR
LUCIA
MARANGA
OQUENDO
INFANTAS
MIROPES
TACNA
PUENTE
GALVEZ
BALMEANO
STC. MARINA
PERSHING
LA PAMPILLA
ZAPALLAL
SAN ISIDRO
LIMATAMBO
PRIMAVERA
BARRANCO
ATOCONCO
SBARTOLO
CHILCA
ESQUEMA DEL SISTEMA DE GENERACION Y TRANSMISION
GENERADOR
TRANSFORMADOR TRIFASICO
BANCO DE TRES TRAFO. MONOFASICO
INTERRUPTOR
BARRAS 220 kV
BARRAS 60 kV
BARRAS 10 kV
Chart III

Within Lima, there are 27 primary substations which receive electricity from these Transformation Centers (at 60,000 volts) and step the power down to 30,000 volts, 10,000 volts, and, in one case, directly to 2,300 volts. Chart IV at the following page provides a list of each of the Transformation Centers and Primary Sub-Stations, the number of units, capacity of each, and total KVA capacity of each station. Map II, which because of size is a separate attachment, shows the geographical location within the City of each of these centers and stations.

Final distribution of power is channeled through approximately 5,300 secondary substations throughout Lima, where the power is stepped down from 10,000 to 220 volts.

The relative capacity at each type of center is illustrated on Chart V.

Almost all transmission of power from the hydroelectric plants to the Transformation Centers and to the Primary Sub-Stations is handled by overhead cables. In fact, of approximately 1,600 kilometers of high tension cables (2.3 KV through 220 KV), 1,500 -- about 92% -- are overhead lines. These lines include transmission from plants to Transformation Centers and from such centers to the Primary Sub-Stations within the City of Lima (see Map II).

Further distribution tends to be through underground wiring: of 9,200 kilometers remaining, about 7,400 -- 81% -- are underground. Nevertheless, 1,800 kilometers of wiring -- or 19% -- is also overhead. Chart VI and VII illustrate in greater detail the breakdown of such distribution among low, medium and high tension lines, contrasting distribution among these three levels for 1975, 1979 and 1980.

Comparing the two charts, it can be concluded that the overall breakdown of ELECTRO-LIMA wiring is as follows:

Total Underground Cables	7,500 kilometers	(68%)
Total Overhead Cables	3,500 kilometers	(32%)
GRAND TOTAL	11,000 kilometers	(100%)

POTENCIA INSTALADA EN CENTROS DE TRANSFORMACION
(EN KVA)
1980

CENTRO DE TRANSFORMACION	NUMERO DE UNIDADES	POTENCIA UNITARIA EN KVA	POTENCIA TOTAL EN KVA
220/60 KV			
SANTA ROSA	9 (monof.)	28,333	255,000
	6 (monof.)	28,333	170,000
CHAVARRIA	3 (monof.)	40,000	120,000
SAN JUAN	3 (monof.)	40,000	120,000
BARSI	6 (monof.)	40,000	240,000
			905,000
60/30 KV			
SANTA ROSA	1	17,200	17,200
ZAPALLAL	1	17,200	17,200
			34,400
60/10 KV			
BALNEARIOS	2	17,200	34,400
BARRANCO	1	25,000	25,000
BARSI	2	25,000	50,000
CHAVARRIA	1	25,000	25,000
GALVEZ	2	25,000	50,000
INFANTAS	2	17,200-8,750	25,950
LIMATAMBO	2	25,000	50,000
LURIN	1	7,200	7,200
MIRONES	3	25,000	75,000
OQUENDO	1	17,200	17,200
PERSHING	2	25,000	50,000
PRIMAVERA	2	25,000	50,000
PUENTE	2	25,000	50,000
SAN BARTOLO	1	5,000	5,000
SANTA MARINA	2	17,200-25,000	42,200
SAN ISIDRO	1	25,000	25,000
SANTA ROSA	3	17,200	51,600
SURCO	1	5,000	5,000
TACNA	2	25,000	50,000
VILLA M.DEL TRIUNFO	1	17,200	17,200
VILLA "EL SALVADOR"	1	12,500	12,500
MARANGA	1	7,000	7,000
			725,250
30/10 KV			
LA PLANICIE	1	7,200	7,200
ÑAÑA	1	5,000	5,000
			12,200
60/2.3 KV			
CHILCA	1	5,000	5,000
			5,000
TOTAL GENERAL			1'681,350

POTENCIA INSTALADA EN LOS CENTROS DE TRANSFORMACION, SUB ESTACIONES Y GRUPOS DE TRANSFORMADORES AEREOS (EN KVA)

1980

RELACION DE TRANSFORMACION EN KV	POTENCIA TOTAL EN KVA	%
220/60	905,000	35.17
60/30	34,400	1.34
60/10	725,250	28.18
60/2.3	5,000	0.19
30/10	28,441	1.11
30/2.3	29,724	1.15
10/2.3	20,580	0.80
10/0.23	803,822	31.23
2.3/0.23	21,353	0.83
	2'573,570	100.00

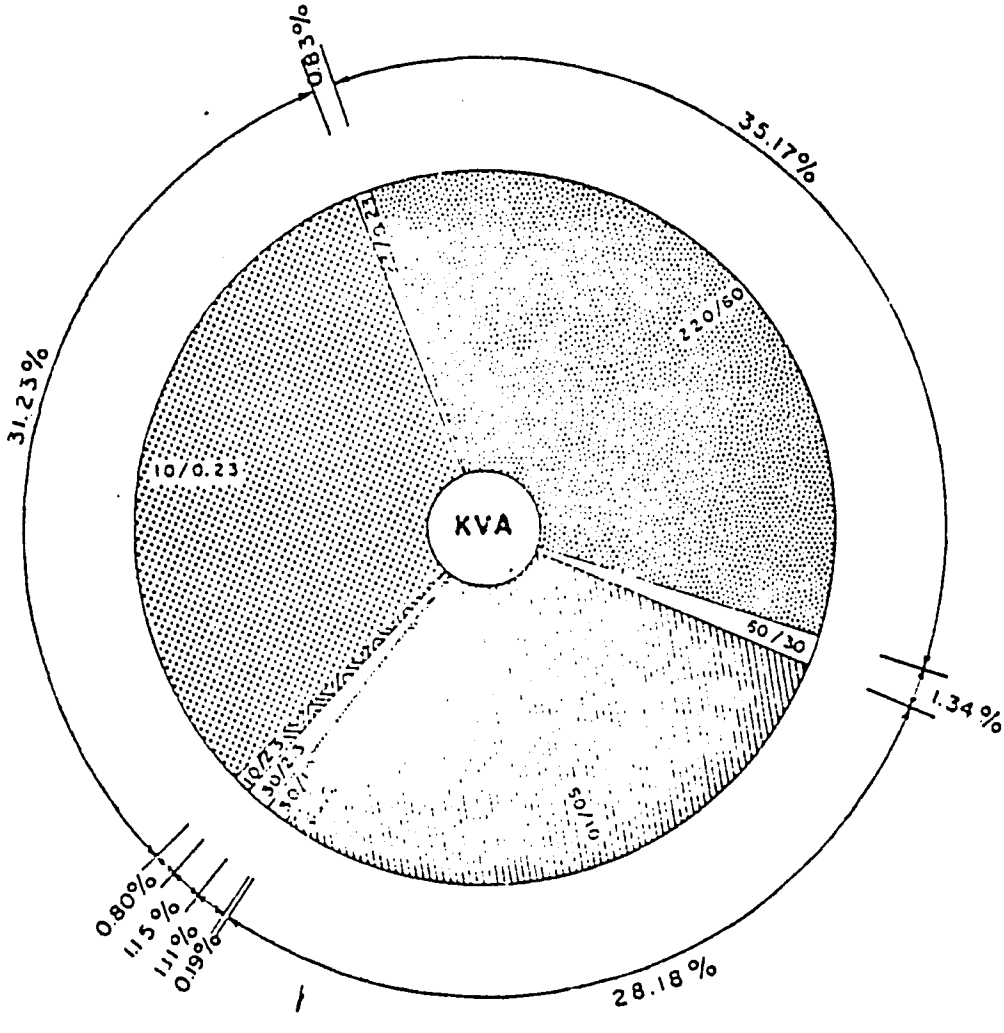
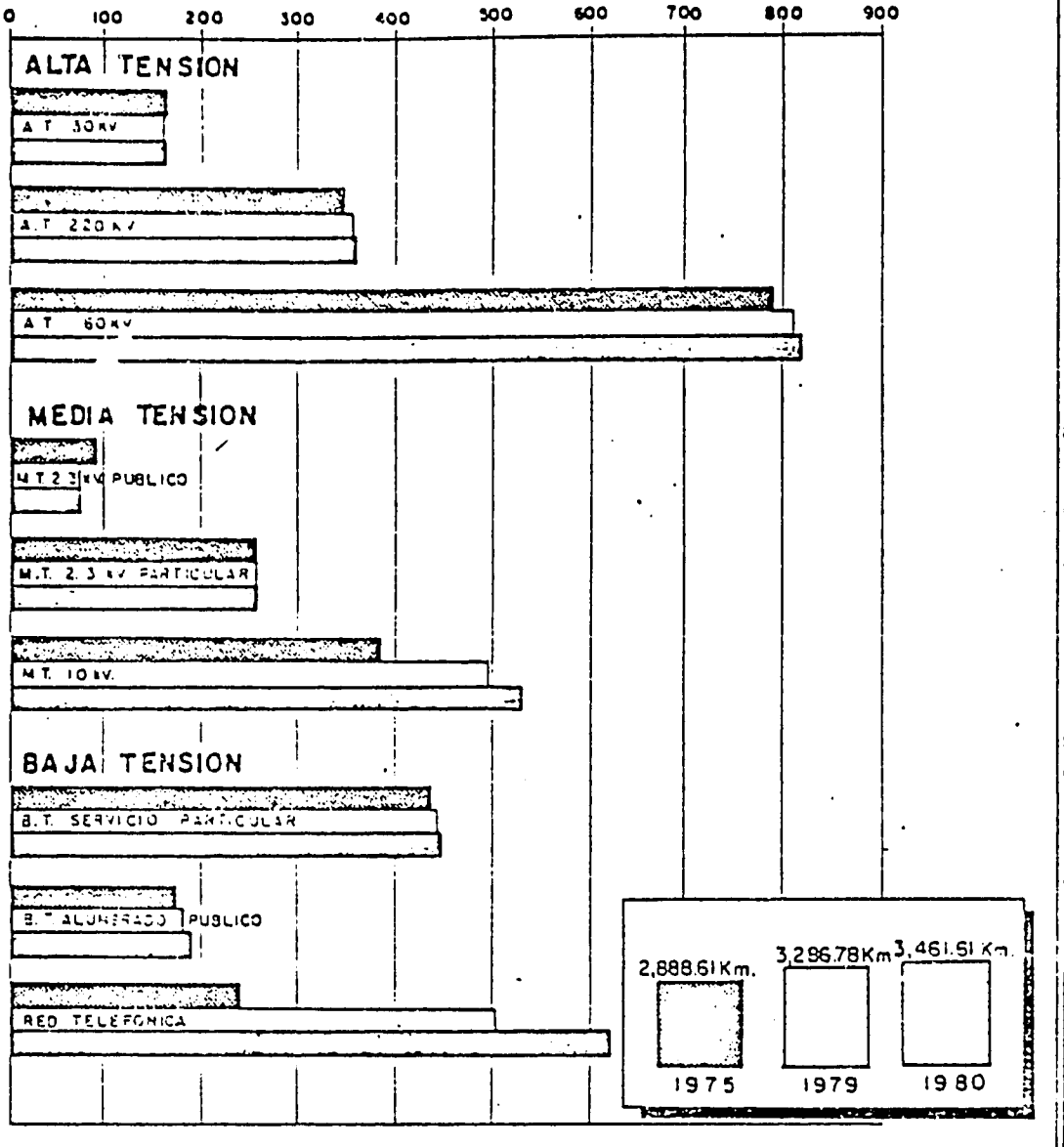


Chart VI

REDES AEREAS

(Km. DE TERNA)



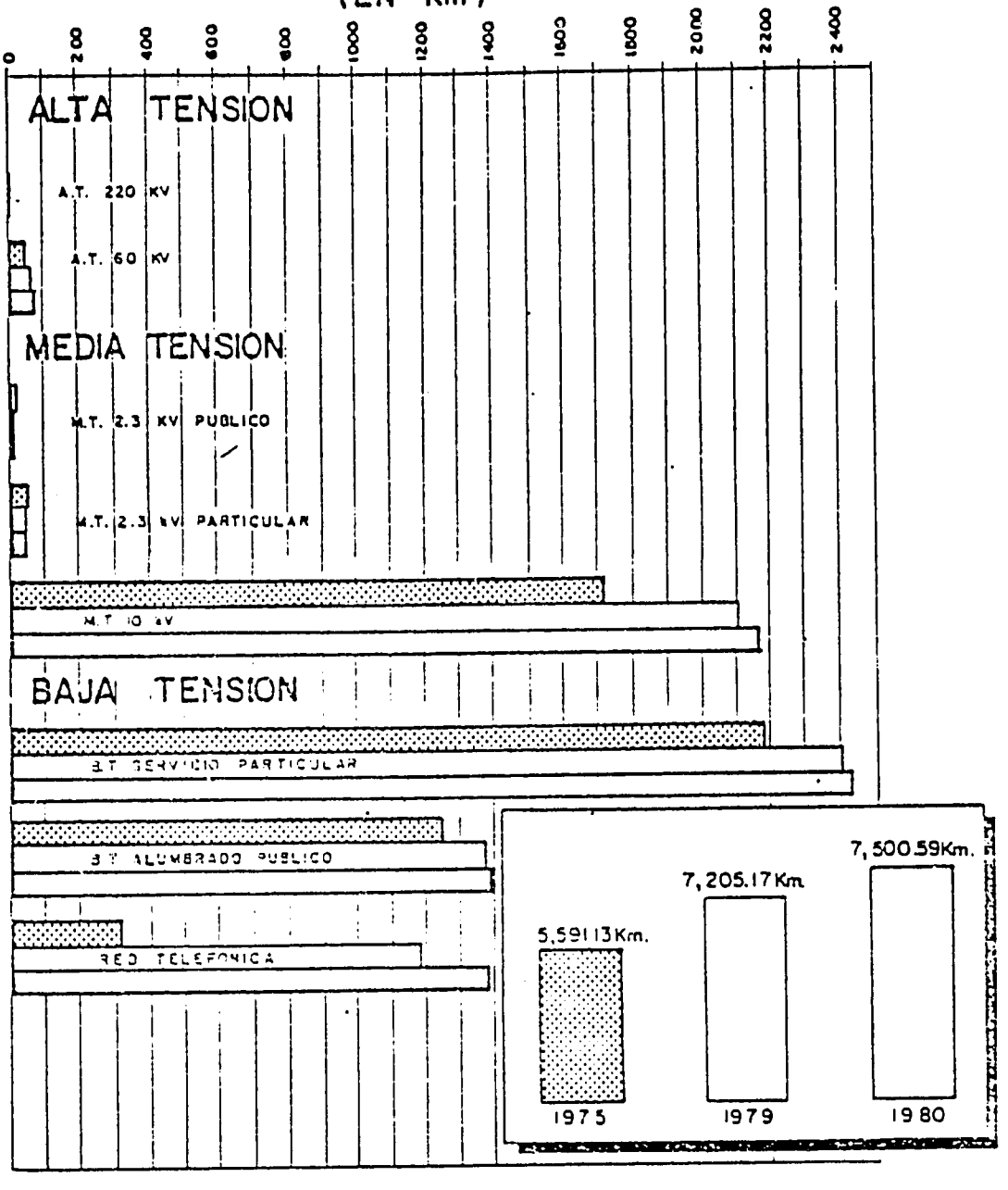
REDES AEREAS (En Km. de Terna)

TIPO DE CABLE	1975	1979	1980	INCREMENTO 1979/1980
A.T. 30 kV.	164.27	159.98	159.98	—·—
A.T. 220 kV.	344.85	356.65	360.01	0.94 %
A.T. 60 kV.	788.79	811.58	819.16	0.93 %
M.T. 2.3 kV. PUBLICO	93.80	73.08	73.08	—·—
M.T. 2.3 kV. PARTICULAR	256.59	256.69	256.69	—·—
M.T. 10 kV.	384.67	498.02	531.12	6.65 %
B.T. SERVICIO PARTICULAR	436.43	444.14	447.38	0.73 %
RED TELEFONICA *	240.62	503.62	621.92	23.49 %
B.T. ALUMBRADO PUBLICO	178.59	183.02	192.27	5.05 %
TOTAL	2,888.61	3,286.78	3,461.61	5.32 %

* EN Km./par

Chart VII

REDES SUBTERRANEAS
(EN Km)



REDES SUBTERRANEAS (EN Km.)

TIPO DE CABLE	1975	1979	1980	INCREMENTO 1979 / 1980
A.T. 220 KV	—·—	1.88	1.88	—·—
A.T. 60 kV	57.32	57.58	64.05	11.24 %
M.T. 2.3 kV PUBLICO	6.35	5.65	5.65	—·—
M.T. 2.3 kV PARTICULAR	44.81	44.51	44.51	—·—
M.T. 10 kV	1,725.64	2,117.47	2,173.62	2.65 %
B.T. SERVICIO PARTICULAR	2,188.96	2,404.59	2,437.56	1.37 %
B.T. ALUMBRADO PUBLICO	1,257.43	1,376.32	1,387.82	0.84 %
RED TELEFONICA. *	310.62	1,197.17	1,385.50	15.73 %
TOTAL	5,591.13	7,205.17	7,500.59	4.10 %

* EN Km /par

Section III: Distribution and Consumption

The consumption of electrical energy in Lima can best be illustrated as follows:

SECTOR	% OF POWER CONSUMED	NUMBER OF CUSTOMERS	% OF TOTAL CUSTOMER
Industrial	50%*	6,658	0.9%
Commercial	27%	75,510	11.0%
Domestic	21%	619,162	88.0%
Public Lighting	2%	2,726	0.1%
TOTAL	100%	704,056	100.0%

Chart VIII demonstrates the evolution of this pattern from 1970-1980.

As an approximate indication of the number of individual households served, some unpublished statistics developed by the Oficina de Estadistica, Ministerio de Vivienda, provide interesting comparative data. These figures trace the number of households served from 1961 and 1972, based on actual census data, to 1980, which is a projection based on trends and some sampling:

Type of Service	1961		1972		1980	
Individual Household	278,700	80%	478,300	76%	715,000	73%
No Service	66,200	20%	147,800	24%	264,600	27%
TOTAL	344,900	100%	626,100	100%	979,600	100%

ELECTRO-LIMA figures indicate 619,000 families are receiving electricity services based on their billing records. Ministry of Housing estimates that 715,000 families are receiving such service. A part of the difference may be accounted for by clandestine connections, i.e., illegal line connections which are common in low-income inner-city (tugurio) and expansion area (pueblos jóvenes) zones.

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* According to a study published by UNI in 1977, 2.9% of the City's energy is consumed by the water well system.

Chart VIII

CANTIDAD DE USUARIOS CLASIFICADOS POR GRUPOS DE CONSUMO

GRUPOS DE CONSUMO	1979	1980	INCREMENTO	
DOMESTICO	599,086	619,162	20,076	3.4%
COMERCIAL Y OTROS	71,618	75,510	3,892	5.4%
INDUSTRIAL	6,404	6,658	254	4.0%
ALUMBRADO PUBL.	2,670	2,726	56	2.1%
TOTAL	679,778	704,056	24,278	3.6%

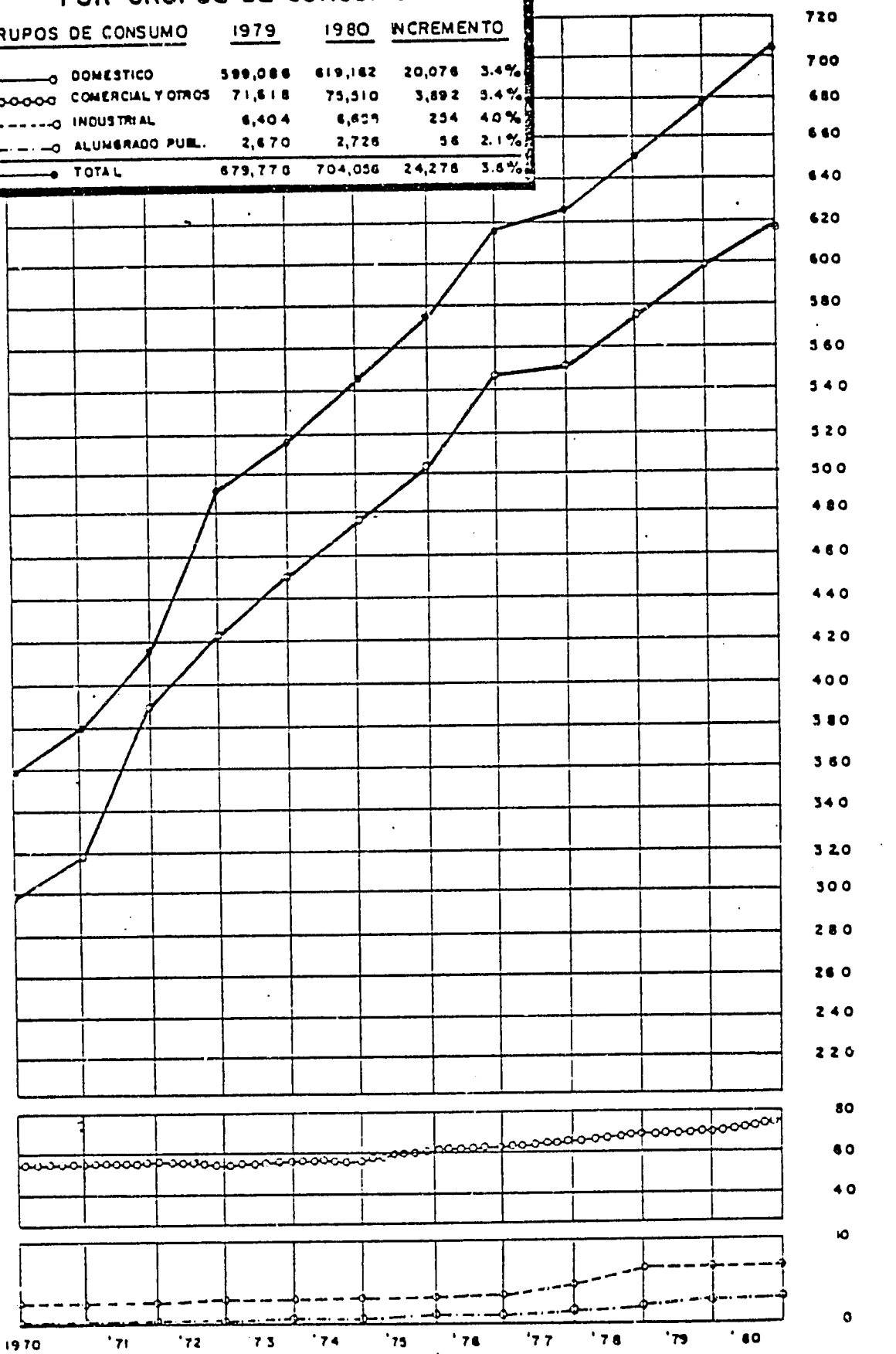


Chart IX illustrates the relative proportion of sales of electricity, by sector, for the 1970 - 1980 period, in millions of Soles.

The demand for electricity in Lima is strong throughout the twenty-four hours of each day. Hours of maximum demand are from 8AM until nearly midnight. However, the industrial sector places a strong demand on electrical production during all 24-hours of the day, as illustrated in Chart X. This chart analyzes energy consumption by hour for the "maximum demand" day for 1980: December 9, 1980. The reader's attention is drawn especially to the industrial and domestic consumption sectors, which operate on a round-the-clock basis, as these will relate to discussions of fire vulnerability which follow in this report.

Because industry is a major and vulnerable consumer in the City -- more detailed data is included. Specifically, Chart XI shows the relative consumption of various types of industries in Lima. Industries which are particularly vulnerable to fires are textiles, chemicals, fuels, wood and paper. Their relative proportion of consumption is as follows:

Textiles	249.8 GWh
Chemicals and Fuel	251.2
Wood and Paper	30.3
	531.3 GWh

Thus, these three selected industries (which do not exhaust the list of most vulnerable ones) account for 42% of the total of 1260.4 GMh consumed by industry each day.

Chart IX

FACTURACION POR GRUPOS DE CONSUMO

(En Mio. SOLES)

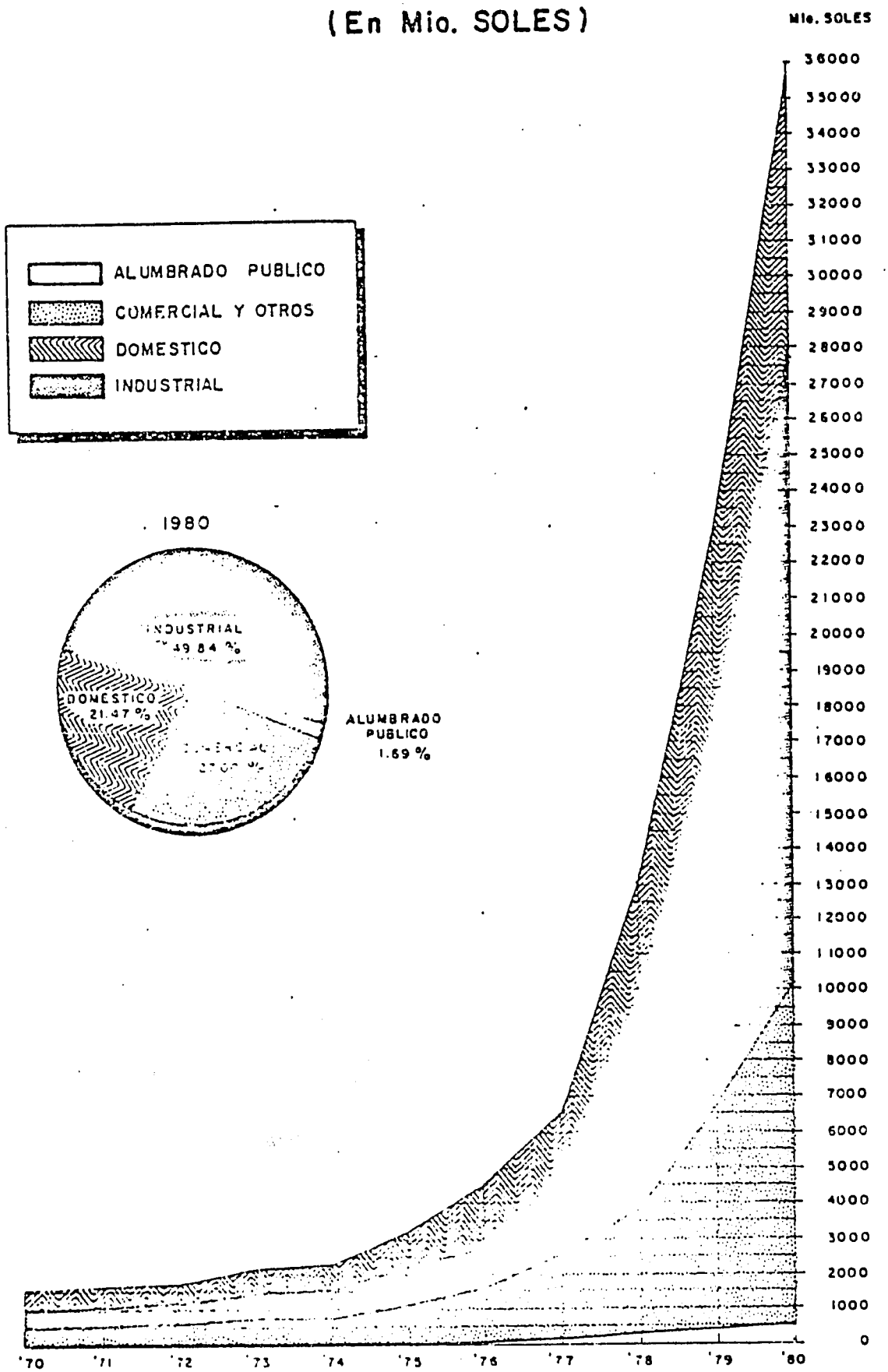


Chart X

DISTRIBUCION DIARIA DE LA DEMANDA

DIAGRAMA REPRESENTATIVO AÑO 1980

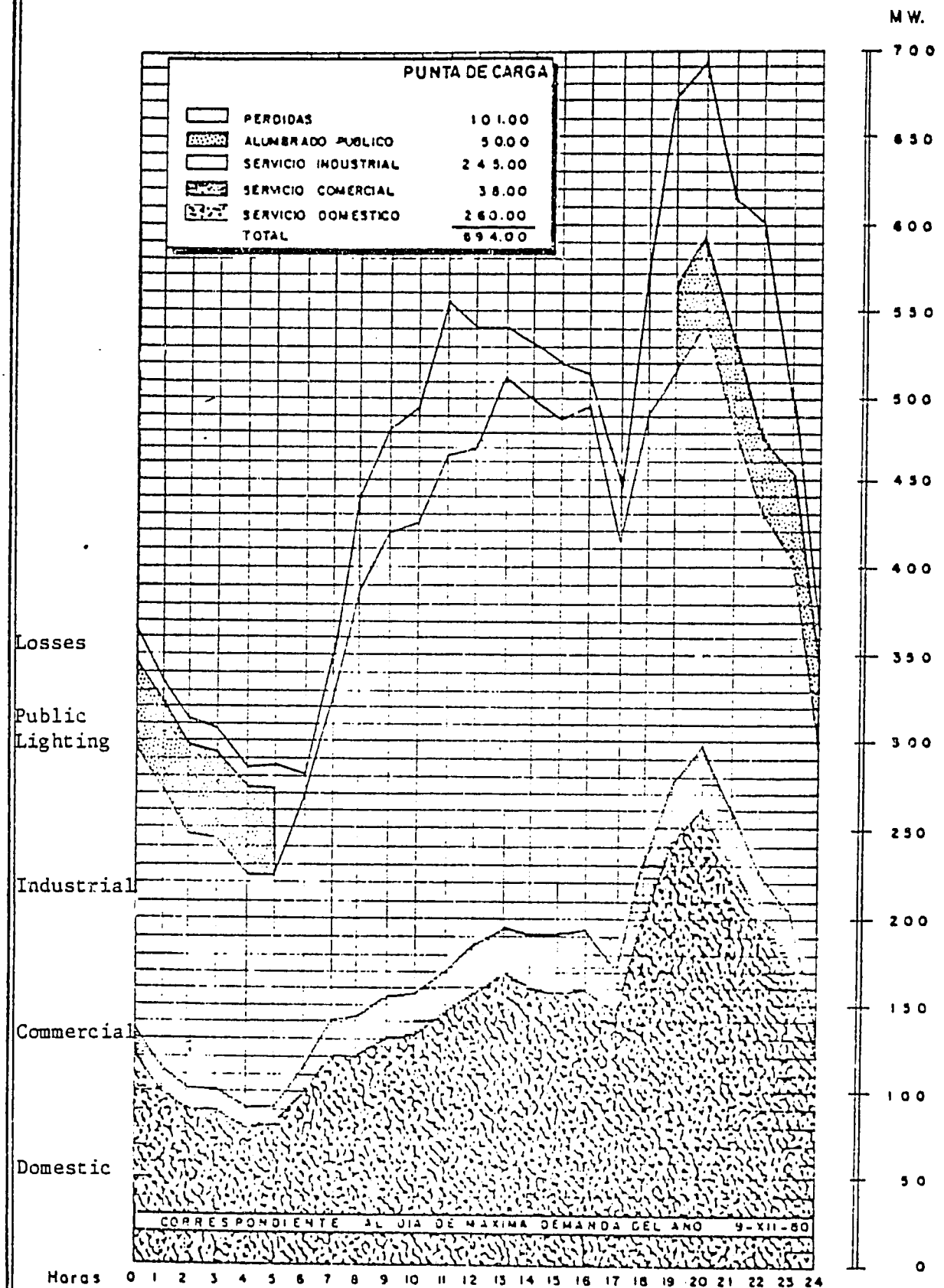
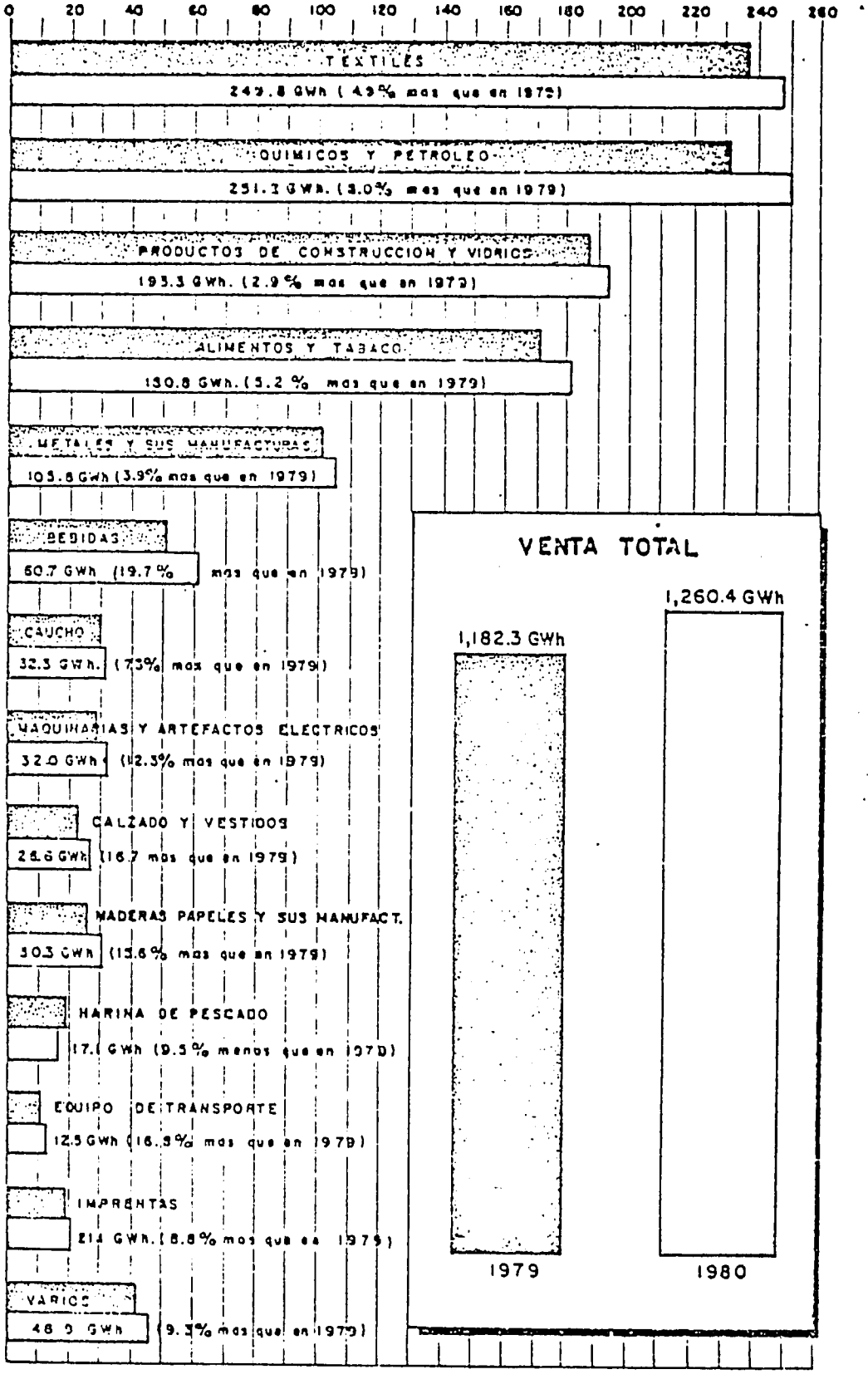


Chart XI

PRINCIPALES INDUSTRIAS DE LA CONCESION CON CARGA MAYOR DE 50 KW.

(EN GWh)



REVIEW OF LITERATURE: DANGER OF FIRES AND ELECTROCUTIONS

The Managua Case

Early reports on the Managua, Nicaragua earthquake of December 23, 1972, suggest that fires presented a serious problem to rescue and recovery efforts.

The U.S. Southern Command's after-action report, for example, states that:

> Fires created by downed power lines and ruptured fuel cells raged uncontrolled throughout the city for over 24 hours. Broken water mains and streets clogged with debris prevented the mounting of any coherent fire-fighting effort.
>
> The USARSO disaster relief and recovery operation began on 23 Dec 72. The 518th Engineer Company (Augmented) was dispatched to Managua on the 25th of December and were immediately set to work cleaning streets and constructing a firebreak.

Lieutenant Colonel Billy J. Chance, Commander of the Disaster Response Team on the scene, similarly reports that "one of the earliest tasks for the 518th Engineer Company, which arrived on December 26 was to construct a 12-block firebreak."

In a summary report on the record of the Disaster Area Survey Team in Latin America, some further recommendations are provided:

> Immediately following the earthquake numerous fires broke out due to electrical sparks and propane and oxygen gas explosions. With the streets blocked by rubble, water in critical demand, and the water distribution system destroyed, local firefighters could do little. Initial relief operations concentrated on emergency medical treatment of the injured and bulldozing firebreaks throughout the city.
>
> ...Dangling hot wires had been the principal cause of fires in Nicaragua.

Dr. S. Ted Algermissen, representative of the U.S. Geological Survey, commented on the Managua fires based on his personal observations. He indicated that the number and magnitude of fires was not caused only because many buildings were constructed of wood. Buildings constructed of materials which

were not flammable were consumed by fire as well, as wooden floors, ceilings, and other flammable materials inside the buildings caught fire.

Other observers, such as Frederick C. Cuny, Executive Chairman of INTERAECT, suggest that many of the fires might have been the product of arson by the industrialists themselves. As many did not have earthquake insurance, but suffered damages nevertheless, they sought to invoke their fire insurances by setting their buildings aflame. The number of such cases, however, is not known.

The Kuroiwa Study

In 1977, the National Engineering University produced a study written by Ing. Julio Kuroiwa Horiuchi, a Peruvian engineer who has taken a special interest in earthquake-related matters. The principal causes of fires after earthquakes suggested by the study are:

- Short circuits
- Breaks or leakages in containers of flammable liquids
- Electrical equipment which falls over
- Escaping of flammable gas from leaky tubing
- Sparks produced in an explosive atmosphere

The study highlights the special danger to local industries because of the large variety of machinery and equipment and the presence of raw material and flammable materials -- as well as the density of workers around the area, any one of whom can inadvertently cause a fire.

On the other hand, even in the best of times, water for combating fires is in short supply and pressure is low:

> Es notorio la desproporción entre la cantidad y disposición de los hidrantes contra incendio y la población actual.

Ing. Kuruiwa's assessment of the capacity of the BOMBEROS -- the

city's volunteer fire department, is pessimistic and highlights "despite its outstanding efforts" its lack of adequate equipment -- a problem emphasized more strongly by the BOMBEROS themselves.

Finally, the study points out that fires are investigated with great dedication in Tokyo because of the danger of life fires and short circuits in the event of an earthquake.

In a personal interview Ing. Kuroiwa elaborated on the risk of fire. As a private consultant, one of his principal activities is to advise industrialists on the vulnerabilities of their plants to earthquakes. In general, he finds that electrical wiring is a weak point in such industries: sub-stations often located right in the factory are faulty; high tension lines run through precarious building materials; internal distribution lines are often defective.

He also considers buildings constructed of quincha (cane with mud walls) and lumber in the structure to be very flammable. Such buildings are predominant in the densely populated inner-city tugurio zones.

The Daily Press

Outbreaks of short-circuit fires do not await earthquakes. During the short period of this field study, numerous such fires were reported each week.

One such fire occurred on September 28. A mattress factory, called THE PARADISE, went up in flames as a result of a short circuit, causing over S/20 million in damages. According to the Manager of the plant in one article (LA PRENSA, 29 September 1981), "the BOMBEROS were delayed by 45 minutes in arriving" at the scene of the fire. "Moreover, their waterpumps ran out in minutes because of the size of the fire." The chronic lack of water in this major industrial area (Avenida Argentina) was the subject of a bitter complaint by the Commander of the BOMBEROS after the fire.

Another typical example was the fire on September 25 in the "EL ORIENTE" furniture factory, which caused S/20 million in losses to its uninsured owner.

The fire started at about 5AM, caused by an electrical short circuit.

Other electrical problems highlighted during one fifteen day period during the study were the three blackouts suffered by the city, the last of which occured in late September as well. At that time, two fires were caused, one by dangling hot wires just before the blackout. During the blackouts, numerous persons were trapped in elevators. However, the BOMBEROS were required to intervene in only 18 such cases and this was accomplished with efficiency.

ESAL's Earthquake Plan

Concern for fires after earthquakes is also reflected in the emergency plan of the city's water authority, ESAL (Empresa de Saneamiento de Lima)*.

> ...Efforts to combat fires, whose probable cause would be a catastrophe, should be supported with the best (water support which ESAL can provide). This situation, latent with danger for the Capital, would occur principally in the pueblos jóvenes on the margins and in industrial installations which handle flammable materials.

Finally, civil defense educational materials stress the danger of fires to the City.

> "Effects of Earthquakes. The greatest destruction is caused ... (among others) ... by fires produced by short circuits, or overturned fuel or flammable liquids... or (electric) cables or posts which fall over.
>
> If you're in the street, stay away from posts with electrical cables. After the earthquake, disconnect the electricity ... and don;t touch electrical posts or cables..."

Excerpts of these materials appear on pages 29 and 30,

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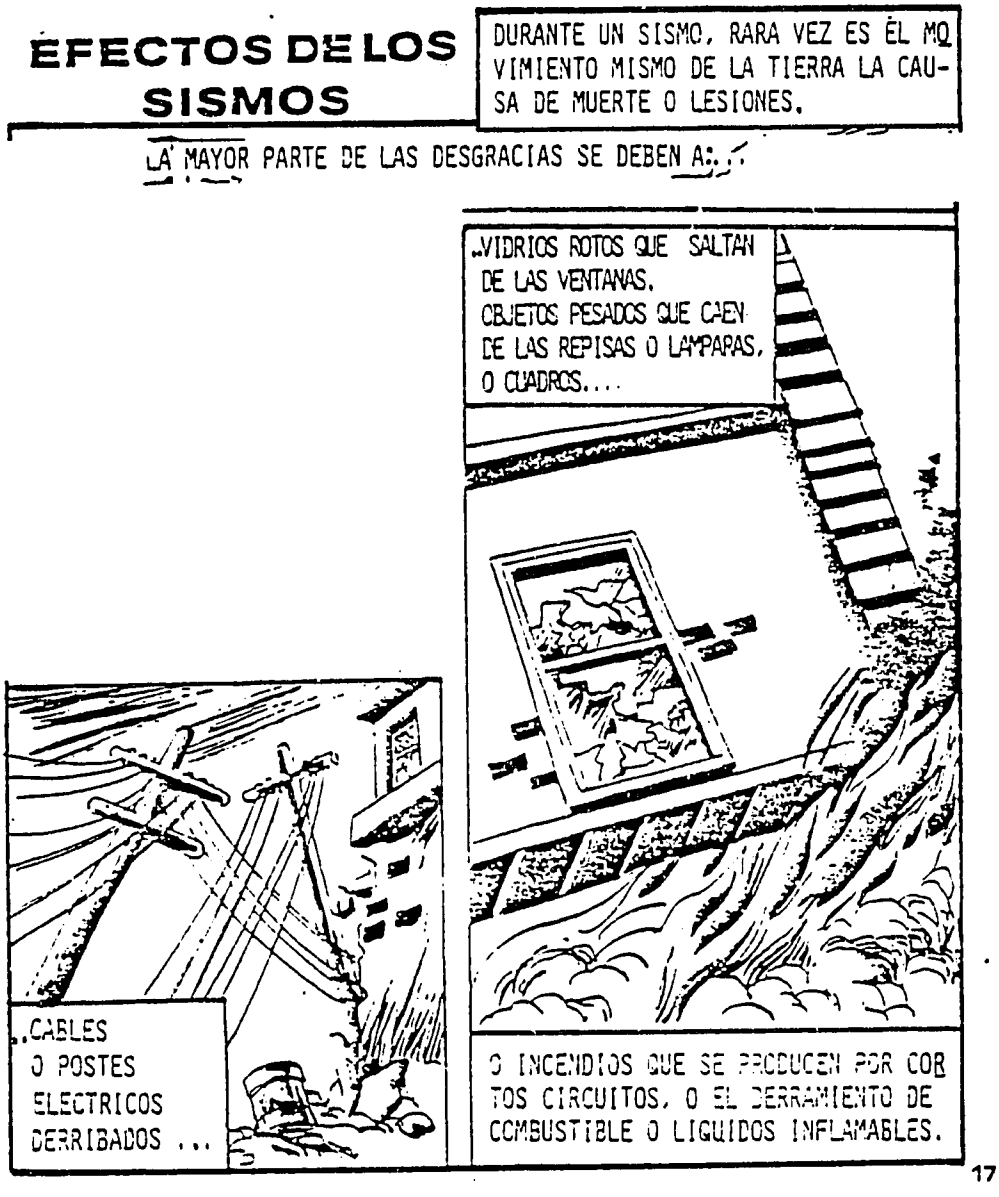
* ESAL's new name is now SEDAPAL (Servicio Departamental de Agua Potable of Alcantarillado de Lima) and its umbrella institution is SENAPA (Servicio Nacional de Agua Potable of Alcantarillado)

In summary, literature concerning previous disasters and assessments of the vulnerability of Lima to post-earthquake short-circuit and other fires suggest that serious danger exists. Yet the literature is limited in scope and detail and provides an incomplete although disturbing analysis.

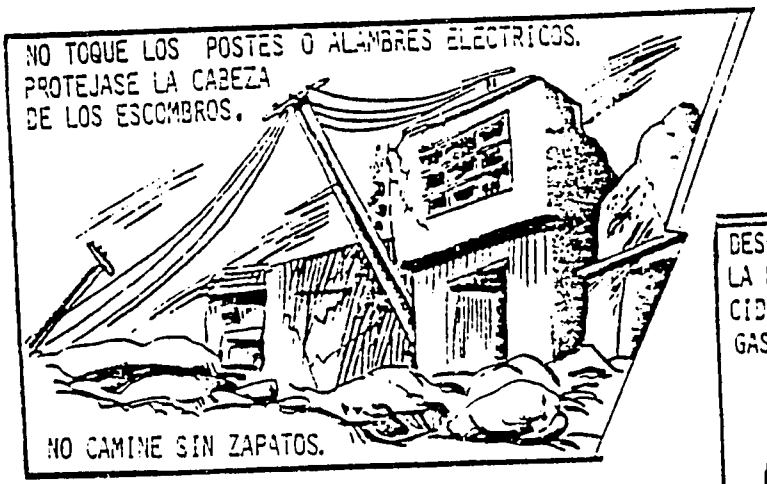
Further assessment was undertaken as part of this through a series of thirty personal interviews with Peruvian and international experts in fields of electricity and public and industrial security.

EXTRACT

From: Los Sismos: Que Hacer Antes, Durante y Después
Ediciones y Promociones Educativas, September, 1981
(Education for Civil Defense, Private Sector Publication)



DESPUES DEL SISMO



LIMA'S VULNERABILITY TO SHORT-CIRCUIT FIRES AFTER AN EARTHQUAKE

Lima's vulnerability to fires after an earthquake is the concern most frequently raised in discussions with a wide variety of professionals from different backgrounds. While it is impossible to quantify the number of such fires which might occur, this section will attempt to summarize and synthesize the views of the agencies most directly concerned with the issue, including ELECTRO-LIMA, the volunteer fire department (BOMBEROS), military, housing, community development, international electrical experts, and others, in the following format:

- Precise nature of the vulnerability
- City's capacity to combat fires in such an event
- ELECTRO-LIMA's current seismic security system

VULNERABILITY

According to the BOMBEROS, 40% of the fires generated in Lima each day in normal times are the result of short-circuits, which is the largest single cause of fires. These short-circuits arise from defective wiring and inadequate electrical security systems. Their magnitude ranges from small fires within private homes to massive factory fires and explosions of dynamite factories. In the view of Comandante Carlos Camino Rivera, the Deputy Commander of the organization, the share of fires attributable to short-circuits after a major earthquake would increase to 70%.

Where, exactly, does the vulnerability lie?

1. Industries

ELECTRO-LIMA officials express the view that private industry in Lima have not focused on the need for electrical security. The fire in the mattress factory several weeks ago was raised as an example of an avoidable disaster if

electrical security systems were functioning properly.

The Director of the Sociedad de Industrias indicates that the major source of fires in industry are short-circuits and that the number of such fires would increase after an earthquake.

A civil engineer in the private sector who has dedicated efforts to disaster preparedness over many years comments that the mentality of the plants is to invest as little money as possible in the structure and electrical systems. There are no official standards for industrial safety. Some of the insurance companies (he is on the Board of Directors of one) are beginning to offer incentives to plants whose wiring meets certain standards, but so far there has been little effect.

Recently, the FAMESA (Fábrica de Mechas, S. A.) factory on the outskirts of Lima suffered a short-circuit fire which caused an explosion of a part of their storage facilities. This factory produces explosives, but fortuitously their security system protected 90% of their explosives from further damage. Although only 10% of their stocks were affected, the explosion was felt throughout the city of Lima. Had the rest of their stock ignited, the result would have been a major catastrophe for the city.

Both the German and Dutch Governments have electrical experts in Lima at the moment working on two aspects of electrical development: the German Mission is working on the elaboration of a Master Plan for the country's electrical network; the Dutch Mission is providing technical assistance to improve technical training for electrical specialists.

Electrical and other engineers from both missions agreed that industrial fires were "highly probable" after an earthquake.

-- Fuel, chemical and flammable inventory storage can be ignited directly by short-circuits (and sometimes indirectly by fires they cause).

Storage facilities for these commodities do not have adequate security measures. In some cases, even if water were available, it would be of little value in fighting some of these fires.

-- Both major industries and back-yard industries are vulnerable, and one expert highlighted the location of these smaller, backyard industries right in the middle of low-income, flammable inner-city housing areas.

One example of such vulnerability is the Port of Callao, a complex containing dangerous fuel, chemical, oxygen and other gas tanks, as well as an LPG line into the ocean used for pumping into and out of ocean-going vessels; grain silos with potentially explosive grain dust and particles in the air; and others. Port management and security authorities are worried about the potential for short-circuit fires in the area after an earthquake, as their security systems are not as advanced as is felt necessary. A small explosion in some port areas could have a chain reaction (example: gas and flammable chemical storage is located right next to the silos). In the Port of Callao, the lives of thousands of port workers would be placed in jeopardy by such an event.

2. Low-Income Housing

Two main types of low-income housing were highlighted among concerns for post-earthquake fires;

- The inner-city tenements, tugurios, are considered dangerous because of consistently defective wiring. Most of the current wiring was installed before the use of electrical appliances on the current scale was imagined. This wiring was designed for a few light bulbs, but not for the televisions and other appliances currently using them. As a result, the casing for this wiring has been overheated and melted or cracked to the point where much wire is exposed.

The wiring is also badly installed. It runs exposed along

the dried cane which forms the base of quincha houses, dried and rotten timbers in the roofs and floors, and highly flammable room partitions, curtains and other substances within the densely populated houses.

The quality of the cane-based quincha housing varies throughout the City. In El Callao, for example, but also in Barrios Altos, La Victoria, and Rímac, the cane is no longer contained by mud packed on either side: the mud has fallen off, and the dried cane is exposed. As quincha is a rather light material, it may tend to survive an earthquake better than an adobe house, but would be more vulnerable to burning (from short-circuits, kitchen flames, etc.).

Each building should have its own electrical security system -- fuse boxes, for example. But in practice, where such security systems exist, they have been tampered with and no longer serve the purpose for which they were intended. Aggravating this problem, many of the electrical lines in the low-income areas are "lineas clandestinas" -- illegal taps into the ELECTRO-LIMA network with electric lines strung in the air and within the houses, crossing each other, and with no security. (There is little ELECTRO-LIMA has been able to do about this problem.)

- Newer Pueblos Jóvenes. These small settlements are comprised of numerous dry wood and dry cane mat houses. Generally, houses there would be built of five dry cane mats -- four used as walls and one as a ceiling, and it is often these houses which have the clandestine electrical connections. These areas are highly susceptible to fires. According to Ministry of Housing officials, one such settlement, Ruggia, has had about three fires every two years for the last ten years. These fires have generally destroyed 50% of the settlement's 582 estera-mat homes. Up to about 30% - 40% of these fires were caused by short-circuits; the balance by kitchen explosions and other causes.

Aggravating the problem, especially in the tugurio areas, is the report by several medical officials that many of their severe or fatal burn cases are children who have been locked up in their rooms during the day while the parents, who have no other place to leave them, go out to work. Once the fires start, the children cannot escape.

3. Electrocutions Another danger of the City to electrical problems after an earthquake is electrocutions. In industries and in low-income and other housing, the danger exists, and is aggravated by the potential of falling electrical and street-lighting cables. If potential victims are wearing shoes, their chances for survival increase; but many people, especially in more vulnerable areas, may not be wearing shoes. Both electrical lines and airborne transformers would be sources of such electrocutions.

The potential for severe injury or death are divided into four threshholds; depending on the amount of current and the physical condition of the victim:

- Level of current at which people can feel it, which is about 1/1000th of an amp ($\simeq$ 3 volts).
- Level II: Causes muscular contraction, for example, hand closes around wire and cannot unclench.
- Level III: Breathing stops - danger of suffocation
- Level IV: Heart stops

Their are high, medium and low-tension airborne and other cables throughout Lima which could have any of the above effects.

4. Schools and Hospitals The danger of fires and electrocutions are not limited to housing and industry, but exists in schools and hospitals as well. Two experts on school electricity asserted that school wiring is at least as bad as that mentioned in the foregoing paragraphs, but the dangers are aggravated by the density of children in the schools. In one training center for electrical technicians, the wiring is exposed; outlets have no covers; and 30 amp fuses

have been replaced with dangerously thicker ones, so all the wires are overloaded. The interiors are replete with flammable supplies, room dividers, metal which could act as a conductor of current, and potential wire-crossing near water. Some of the schools are also built of quincha. Asked to assess the danger in the schools, one technician commented, "it's all a matter of luck at each school."

Similar, though less severe danger, was illiminated by the Infrastructure Director of the Ministry of Health.

In summary, Lima's vulnerability to fires from short-circuits -- the major cause of fires in normal times -- would be magnified during an earthquake. Industries, low-income housing, schools and hospitals would be vulnerable to fires, and the population at large would be vulnerable to electrocution. Electrical consumption, though varied during the day, is very substantial during all 24-hours.

This is not the only area of vulnerability to fires, of course. Open flames in kitchens (depending on the time of day), kerosene or other gas explosions, sparks caused by falling metal, would all be potential causes of fire.

Each respondent placed a slightly different emphasis and degree of vulnerability on the various areas described above. But all agreed that fire and electrocution after earthquakes with short-circuits as their cause, was a serious problem.

Still, it should be clarified that the picture which emerges is not that of a "city set aflame" but rather of a risk of major fires in industrial areas, and a larger number of proportionately smaller fires in houses, especially in the low-income areas. The idea of one massive fire consuming the city does not seem indicated.

LIMA'S CAPACITY TO COMBAT POST-EARTHQUAKE FIRES

Were such a large number of fires to occur, what would be the capacity of the BOMBEROS to combat them?

In normal times, the BOMBEROS complain that they have only enough manpower and equipment to combat about half of the fires reported to them. The amount of time required by the BOMBEROS to reach a fire varies, but for example in the one (perhaps extreme) case of the major mattress company fire it was reported as 40 minutes.

Once the BOMBEROS reach the fires in normal times, the amount of water and water pressure in the city system is often inadequate to supply their pumps and hoses. Their water supply may last only a few minutes before it begins to diminish.

There are a number of problems which could severely aggravate an already bad situation after an earthquake:

1. If such an event occurs during working hours, all the major and minor roads of the city will be completely blocked within five minutes and for a period of at least six hours thereafter. Mobility of the BOMBEROS would be severely restricted, as families in the grip of fear and panic seek to verify whether their children, spouses, parents, in-laws, brothers, and their homes, are in tact.

2. It would be likely in such a major event that the water system would be affected, diminishing the supply and pressure still further, or eliminating it altogether.

3. The ability of the public to communicate with the BOMBEROS by telephone would be severely reduced. Phone lines after about one minute will be completely jammed with calls of families trying to verify the condition of relatives or property.

4. The BOMBEROS have a total of 23 fire stations, 15 in Lima and 8 in Callao (see Chart at following page). Of these, they judge that many will be inoperable because of an earthquake. In the following breakdown, stations are divided into two categories:

CATEGORY A (station is sufficiently safe to allow fire-fighting equipment to exit after an earthquake, called "safe") and CATEGORY B (station likely to collapse, called "unsafe").

City Zone	Total No. of Stations	CATEGORY A "Safe"	CATEGORY B "Unsafe"
Lima	15	5	10
Callao	8	1	7
	23	6 (26%)	17 (74%)

Note: A description of the city's fire hydrant network is provided under the water sector.

The stations which the BOMBEROS consider particularly safe are:

(a) Comandancia General, including the medical unit and Company 14

(b) Lince (near the telephone company), Company No. 4

(c) Chorrillos, Rescue Unit, Company 6

(d) Magdalena, Company 36

(e) Miraflores, Company 28

FIRE STATIONS IN LIMA METROPOLITANA:

LIMA

BOMBEROS

22a Comandancia de Area-Lima
Central Radio-Alarma
358 R Oquendo (Breña)..... 32-2232
Compañias:
Roma No 2 560 Junin..... 27-0486 ... Barrios Altos
France No 3 240 Moquegua..... 27-9161 ...
Lima No 4 455 M Candamo (Lince).... 71-6442 Lima
Garibaldi No 6
389 Av Olaya (Chorrillos)..... 67-0729
Victoria No 8
597 A Deustua (La Victoria)..... 23-5945
597 A Deustua (La Victoria)..... 24-5865
Salvadora Lima No 10
1027 Union..... 28-0288 ... Lima
Cosmopolita No 11 574 Junin ..... 27-0489 ... Barrios Altos
Jose Olaya No 13
227 Lima (Chorrillos)..... 67-0638
Internacional No 14
358 R Oquendo (Breña) 23-1100
Miguel Grau No 16
106 Plza Espinoza (barranco)..... 67-0031
Rimac No 21
836 Trujillo (Rimac)..... 81-3183
Miraflores No 28
172 Av Mrcal Caceres (Miraflores) 45-7447
Chosica No 32
142 Tumbes (Chosica)..... 91-0694
Magdalena No 36
s/n Av Sucre y Alcazar (P Libre). 31-4760
San Martin de Porres No 65
501 Av Caqueta (S Martin de Porres) 81-5012

CALLAO

21a Comandancia de Area-Callao
Central Radio-Alarma
472 Av S Peña ..... 29-2612 ... Callao
Compañias:
Union Chalaca No 1
375 Av Dos de Mayo..... 29-0210 ... Callao
375 Av Dos de Mayo..... 29-0748
Italia No 5
1120 A Ugarte (La Perla)..... 29-0318
Garibaldi No 7 375 Av Dos de Mayo.. 29-0212 ... Callao
Salvadora Callao No 9
246 P Ruiz Gallo 29-0319
Callao No 15
151 Heros (Bellavista)..... 29-0320
La Punta No 34
122 Plza Bolognesi (La Punta).... 29-2998
Antonio Alarco No 60
191 Los Condores ..... 51-4830 ... Callao
Peru No 18 137 Puno..... 65-5183 ... Callao
476 Av S Peña..... 65-9915 ... Callao

The general policy of the BOMBEROS is to make their new stations seismic-resistant and to locate them in areas with easier access to the road network, rather than right in the center of heavily-trafficked areas. In the meantime, one option which could be considered would be to reinforce some of the stations. However, although the BOMBEROS have volunteer engineers, masons, supervisors and technicians, as well as volunteer labor, they do not have funds for the purchase of materials for this purpose.

In the medical sector, the capacity to respond to a large volume of severe burn cases is very limited. and was estimated by both Army and Air Force officials as up to 100 cases for all Lima. The reason for this is that equipment, medicines and supplies for burn cases are expensive, and as they do not usually get a volume of burn cases, it is not worthwhile to stock them. Some hospitals reportedly turn down third degree burn cases because the cost of caring for them is so high. While this aspect of disaster response is covered in more detail under the medical section of this report, it needs to be kept in mind as a response-constraining reality and still further justification for reducing to the minimum the number of severe burn cases which could be produced by fires and explosions resulting from a major earthquake.

ELECTRO-LIMA's CURRENT SECURITY SYSTEM

At the moment, ELECTRO-LIMA has a modern, adequate security system. This system functions on the basis of electrical relays. When massive short circuits are produced, and when the wiring conducting the current surpasses the maximum tolerance for which it was designed, relays open at the nearest substation, cutting off the supply of power. This system works not only at the secondary substations. If sufficient short circuits were produced in a large enough number of substations, a primary substation would be cut off. If such short circuits were massive enough, they could even shut-down the

transformation centers.

Of course, such systems require maintenance and control, and given the tremendous work burden borne by ELECTRO-LIMA, this may not be as frequent as it desires. Also, at times, a system may malfunction. For example, last year a truck crashed into a high-tension wire inside Lima. Although the circuit was opened, the wire continued to burn the cement pole for some time before the substation system cut-off.

The problem is, however, that for the type of security needed, the individual home or industry must have its own equipment and must use it properly. This is beyond ELECTRO-LIMA's ability to control and is the area where the real vulnerability begins.

One potential element which could be strengthened is the timing of the security system, i.e., the electrical relay system is designed to act after massive short circuits have been produced. Because of the small amount of time required for fires to begin, this could mean that the security system goes into effect after some fires have begun, as in the industrial fires described earlier.

Historically, ELECTRO-LIMA's policy has been to try to keep the electrical current flowing at all times. During one earthquake the Santa Rosa Transformation Center units were damaged, thus automatically shutting down the current throughout the City. Thereafter, the company contracted with a private firm to incorporate a shock-absorption capacity designed to permit the continuing distribution of energy. While this improvement will permit ELECTRO-LIMA to resume vitally needed energy, it will also diminish the possibility of a city-wide cut-off as early as possible.

In terms of reconnection of the system, it is ELECTRO-LIMA's policy to reconnect energy only after a field check to insure that there has not been any damage.

ELECTRO-LIMA's attitude is that any measure which can be taken to improve any aspect of their security system, including the application of newly developed technology to the task, is welcome. Where security is concerned, redundancy or partial redundancy or back-up systems are considered desirable, especially if electrical fires can be avoided. This attitude has opened the door for discussion of such a possibility, described in the next section.

STRENGTHENING THE SECURITY SYSTEM

On September 18, the Executive Secretary of the National Committee for Civil Defense wrote to the General Manager of ELECTRO-LIMA (Oficio No. 1839/DC/SE (11.2), formalizing the official policy of the Committee on the electrical system:

> "We know that (your) security system for high voltage lines is very advanced; but were a seismic movement to occur, the greatest electrically-related problem that would emerge would be caused by the age and poor state of the installations in some districts of Lima, whether (through) short-circuits, fires, electrocutions, etc.
>
> "Based on the foregoing, the level which is most worrisome is low-voltage or domestic (consumption). A way to automatically cut the current, especially in the critical areas of Lima, in the event of a substantive seismic event should be studied."*

Based on this policy, numerous discussions were undertaken with ELECTRO-LIMA concerning the type of system which would be used. These discussions were supplemented by consultation in the professional electrical and safety-oriented community of Lima.

Based on technical inputs from these groups, it was determined that one possible way to reduce the risk of short-circuit fires and electrocutions at a fairly low cost would be to install accelerographs at each of the five ELECTRO-LIMA Centros de Transformación and the Primary Sub-Station "Santa Marina" in El Callao.

These units would send an impulse to the ELECTRO-LIMA control equipment when a certain peak level of seismic activity were reached which would automatically shut off the system before short circuits were produced. It would strengthen the overall ELECTRO-LIMA system and would be partially redundant with the current system.

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* Copy of the official letter appears on the following pages, together with the Civil Defense request that USAID pursue this and other preparedness matters.

"Año Bicentenario de la Rebelión Emancipadora
de Túpac Amaru y Micaela Bastidas"

COMITE NACIONAL DE DEFENSA CIVIL
SECRETARIA EJECUTIVA

Lima, 18 SET. 1981

Oficio Nº 1839 DC/SE (11.2)

Señor
Gerente General de
ELECTRO LIMA.

Asunto : Riesgos eléctricos y rehabilitación de fluído eléctrico en caso de sismos.

Ref. : DL Nº 19338 del 28 MAR 72.

De acuerdo al simulacro de emergencia, realizado el 14 de Julio de 1981, se vió la necesidad de una mayor coordinación de esta Secretaría Ejecutiva y su prestigiosa Empresa.

Estamos concientes de que el sistema de protección de las líneas de alta tensión es muy avanzada; pero al ocurrir un movimiento sísmico el mayor problema de origen eléctrico que podría presentarse se derivaría de la antiguedad de las instalaciones y al mal estado de las mismas en algunos distritos de Lima, llámase corto circuito, incendio, electrocutamiento, etc.

Por lo expuesto, el nivel que más preocupa es la distribución de baja tensión o la electricidad doméstica, debiendo estudiarse la forma de un corte automático de corriente, sobre todo en las zonas críticas de Lima, al ocurrir un movimiento sísmico de consideración.

Asimismo, habría que estudiar la reapertura del servicio en forma racional, de acuerdo a los riesgos existentes y que se activen luego de la ocurrencia de un movimiento sísmico.

COMITE NACIONAL DE DEFENSA CIVIL
SECRETARIA EJECUTIVA

Teniendo en cuenta estas consideraciones, estimaré se sirva nombrar un representante técnico para estudiar los planes y acciones necesarias para minimizar los posibles daños y agilizar la rehabilitación eléctrica de Lima Metropolitana , al ocurrir un sismo de magnitud.

Dios guarde a Ud.

ATT/csf

COMITE NACIONAL DE DEFENSA CIVIL
SECRETARIA EJECUTIVA

Lima, 18 SET. 1981

Oficio Nº 1840 DC/SE (11.2)

Señor
LEONARD YAEGER
Director de la Agencia para el
Desarrollo Internacional AID.

Asunto : Solicita cooperación técnica internacional.

Tengo el agrado de dirigirme a Ud., para manifestarle lo siguiente:

1. De acuerdo a las conversaciones sostenidas con el Sr. ROBERT GERSONS experto de la AID, esta Secretaría Ejecutiva considera conveniente enfocar dos problemas que podrían presentarse en caso de ocurrir un sismo de gran magnitud en Lima Metropolitana.

2. Entre éllos tenemos, el problema eléctrico de Lima en caso de ocurrencia de un movimiento sísmico.

3. Asimismo , de producirse un tsunami en las partes bajas de la costa de Lima, el problema de evacuación, en las acciones de preparación y prevención.

4. Por lo expuesto, teniendo en cuenta estas consideraciones, solicito a Ud. tenga a bien disponer las acciones que permitan contar con el apoyo necesario por su Institución, que significa de mucho interés para esta Secretaría Ejecutiva.

Dios guarde a Ud.

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The principles used to establish the cut-off levels, as proposed by the Instituto Geofísico Peruano (IGP) would be the following:

- The cut-off level would not exceed that at which a precarious adobe building might suffer some minimum damage;

- The units would be calibrated to cut the power in accordance with the weakest area of the zone served by the Centro de Transformación;

- Based on data collected from the accelerographs over the years, additional refinements and calibrations should be added to modify these levels.

In general, a 0.1G level for the cut-off has been proposed. Care must be taken to insure that the level is conservative enough to insure that 1.5 - 2 seconds are allowed for the cut-off to take effect. Yet the cut-off point must not be so low that the system would be activated with frequently occurring seismic movements which do not threaten the safety of the city.

A maximum level somewhat equivalent to a 6.0 Richter movement would be ideal for such a cut-off.

The type of unit judged adequate for the purposes described above would be similar to the KINEMETRICS Digital Strong Motion Accelerograph, Unit DSA-1, with internal time code generator and pre-event memory (PEM). Recommended spare parts and supplies should be included for each of the six sets. Further specifications for the unit appear at the following page. More precise specifications and modifications required, if any, can be provided by IGP.

As reference materials, four print-outs of accelerographs which recorded previous earthquakes in Lima are included herewith as Charts XIII, XIV, XV, and XVI. They refer to the 1974 (two print-outs), 1970 and 1966 earthquakes.

CORRECTED ACCELERATION.VELOCITY.DISPLACEMENT
LIMA.PERU EARTHQUAKE OF OCTOBER 3.1974 -1421 GCT
CASA DR HUACO. L COMP
ACCELEROGRAM IS BAND PASS FILTERED BETWEEN .050 - .070 AND 25.00 - 27.00 CYC/SEC
• PEAK VALUES ACCEL=192.3 CM/SEC/SEC.VELOCITY=-20.48 CM/SEC.DISPL=7.930 CM

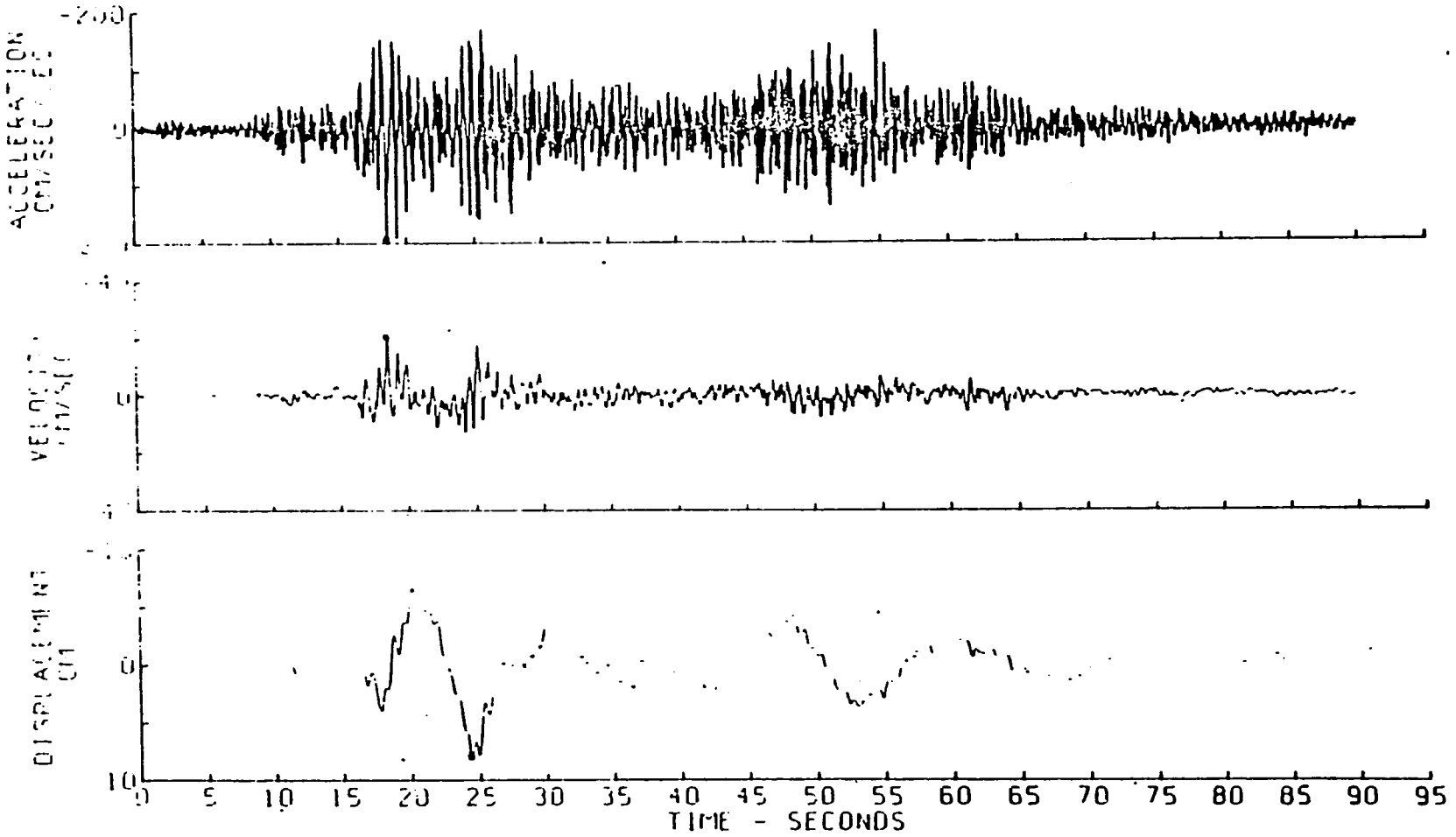

Chart XIII

CORRECTED ACCELERATION.VELOCITY.DISPLACEMENT
LIMA.PERU EARTHQUAKE OF OCOTBER 3.1974 - 1421 GCT
INSTITUTO GEOFISICO DEL PERU.UP COMP
ACCELEROGRAM IS BAND PASS FILTERED BETWEEN .050 - .070 AND 25.00 - 27.00 CYC/SEC
• PEAK VALUES ACCEL=99.75 CM/SEC/SEC.VELOCITY=-7.030 CM/SEC.DISPL=-5.810 CM

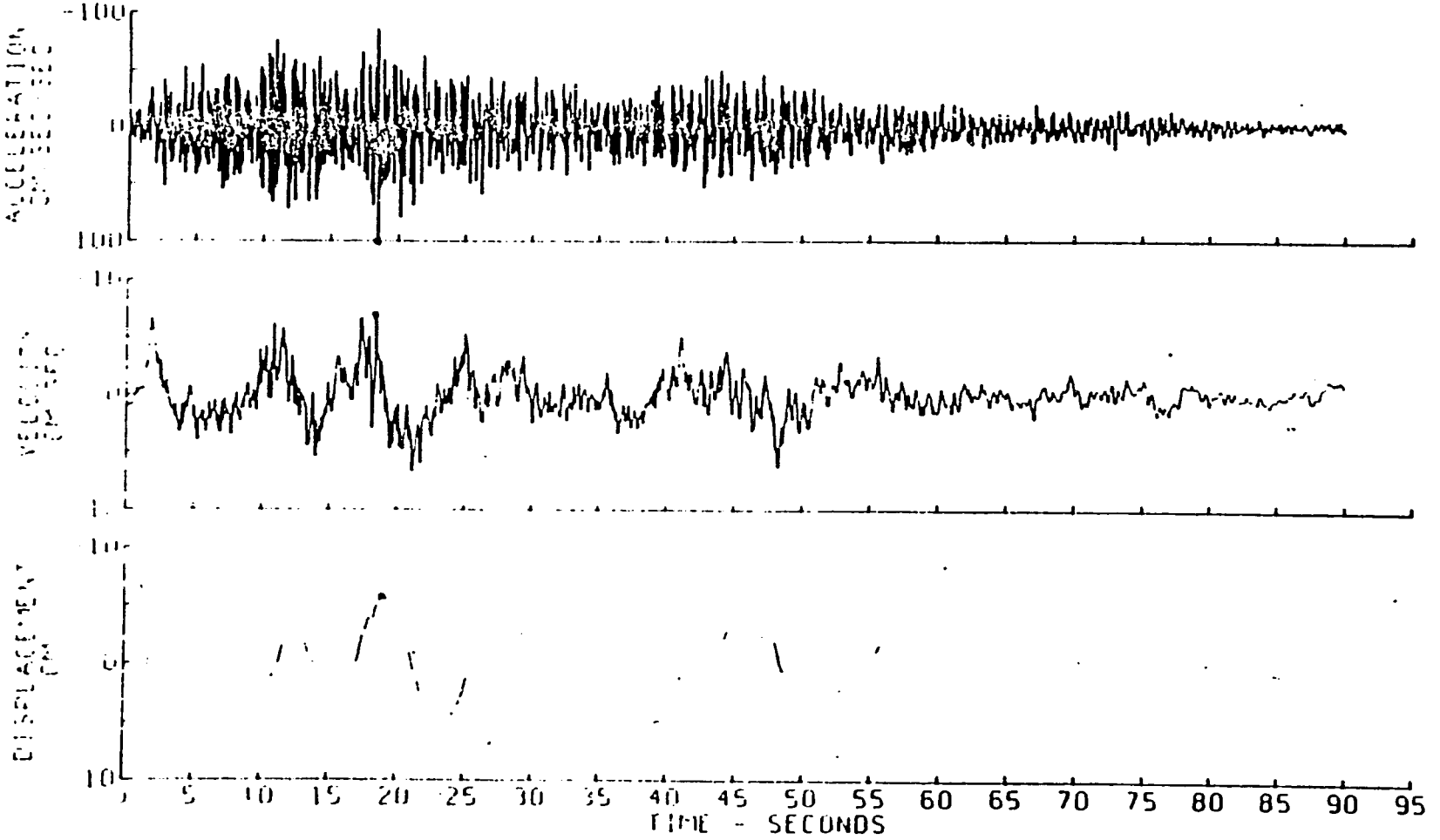

Chart XIV

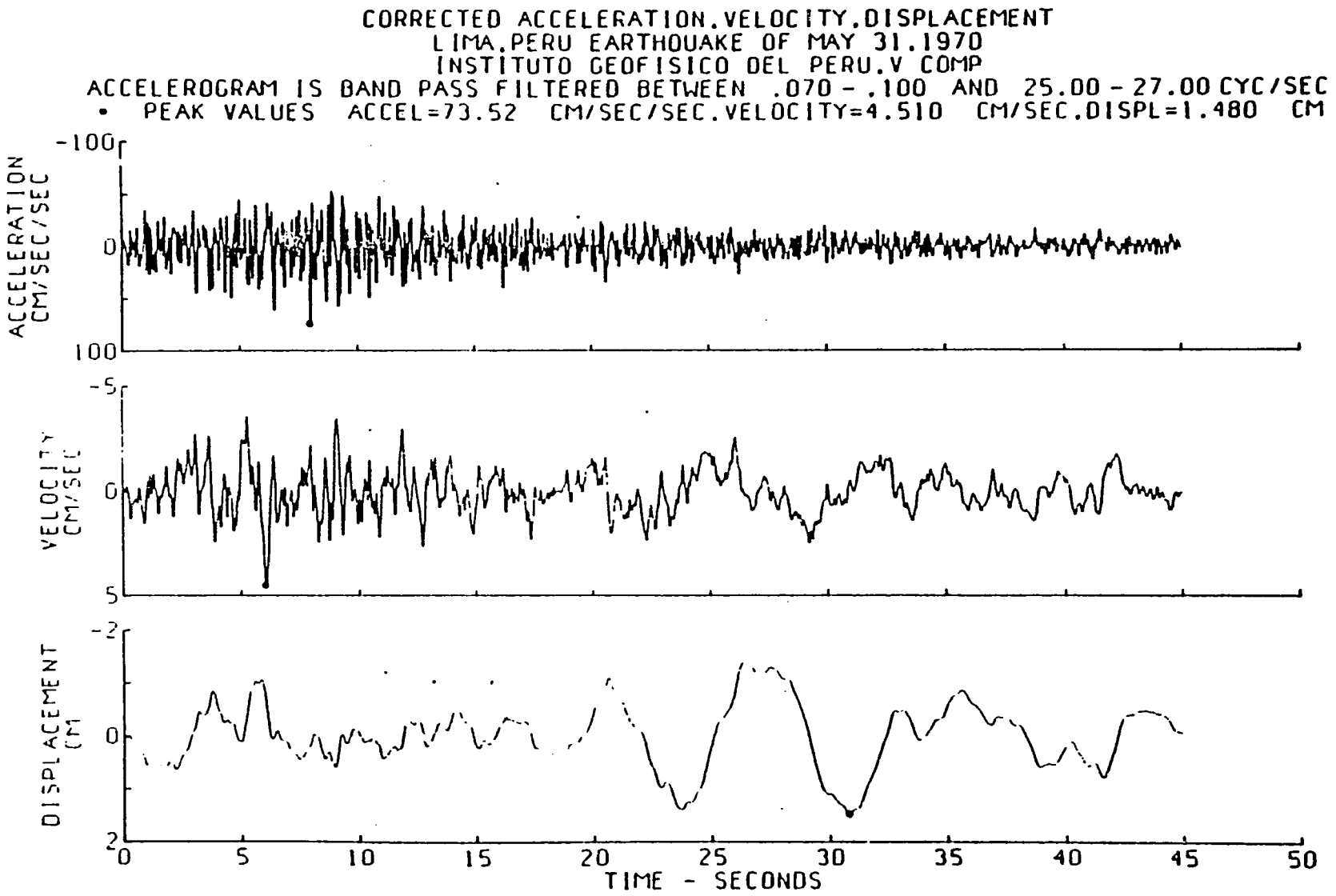
CORRECTED ACCELERATION.VELOCITY.DISPLACEMENT
LIMA.PERU EARTHQUAKE OF MAY 31.1970
INSTITUTO GEOFISICO DEL PERU.V COMP
ACCELEROGRAM IS BAND PASS FILTERED BETWEEN .070 - .100 AND 25.00 - 27.00 CYC/SEC
• PEAK VALUES ACCEL=73.52 CM/SEC/SEC.VELOCITY=4.510 CM/SEC.DISPL=1.480 CM
ACCELERATION CM/SEC/SEC
-100
0
100
VELOCITY CM/SEC
-5
0
5
DISPLACEMENT CM
-2
0
2
0
5
10
15
20
25
30
35
40
45
50
TIME - SECONDS

Chart XV

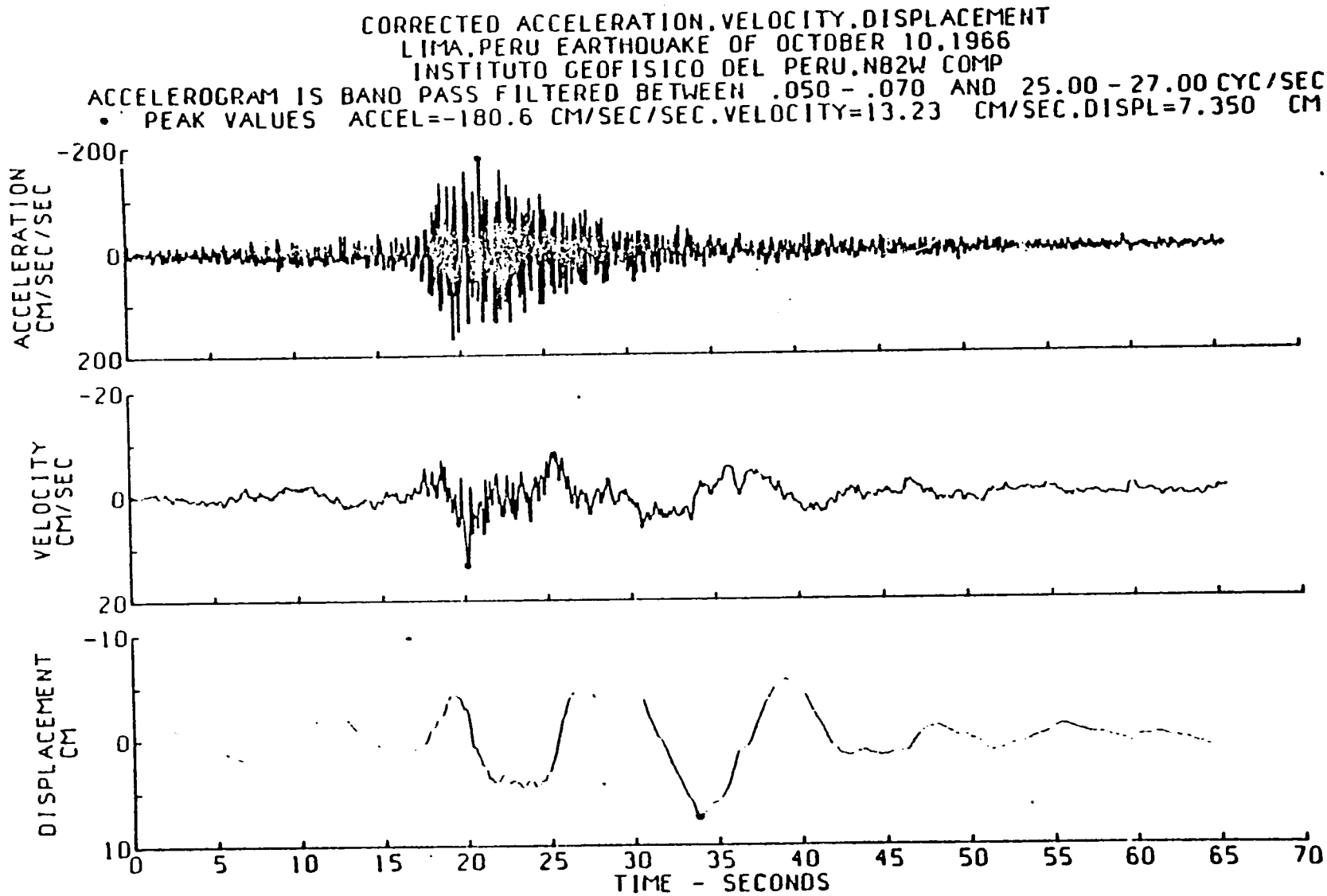
CORRECTED ACCELERATION.VELOCITY.DISPLACEMENT
LIMA.PERU EARTHQUAKE OF OCTOBER 10.1966
INSTITUTO GEOFISICO DEL PERU.N82W COMP
ACCELEROGRAM IS BAND PASS FILTERED BETWEEN .050 - .070 AND 25.00 - 27.00 CYC/SEC
• PEAK VALUES ACCEL=-180.6 CM/SEC/SEC.VELOCITY=13.23 CM/SEC.DISPL=7.350 CM
ACCELERATION CM/SEC/SEC
-200
0
200
VELOCITY CM/SEC
-20
0
20
DISPLACEMENT CM
-10
0
10
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
TIME - SECONDS

Chart XVI

The initial cut-off criteria would be the same City-wide except for the Callao "Santa Marina" sub-station, which would have a significantly lower threshold for cut-off, because of the significantly higher risk of life and property concentrated around the port. (See letter of November 13, 1981, from the Port Administrator to ELECTRO-LIMA, at the following page.)

Assets of the Automatic Cut-off System

The advantage of the automatic cut-off system would be that on a city-wide basis the risk of short-circuit fires and electrocutions in the event of a major earthquake would be reduced significantly.

The post-disaster burden placed on the BOMBEROS and other rescue authorities would be lightened considerably, and a greater proportion of such forces would be liberated to work on more constructive rescue and relief tasks.

The damage to industry, and, of particular concern, the elimination of jobs which such fires could cause, would be significantly reduced, accelerating economic and employment recovery by the private sector.

Panic by the population, and loss of personal property through fires, would be reduced. The amount of temporary shelter material and recoverable resources from rubble would be increased.

After such an event, the availability of water could be severely restricted. By reducing the number of fires which would require water to be extinguished, the supply of water which is available is safeguarded for more constructive purposes.

One of the greatest dangers to rescue workers is that of electrocution as they rush in to save other victims of the earthquake. They tend to believe that electrical wires are dead when they are still, in fact, hot. By shutting off the current universally, this risk is eliminated. (However, care must be taken to warn people in each district when power will be reconnected.)

Oficio Nº 4238-81 TC/ENAPU/TMC/AD.-

Callao, 13 de Noviembre de 1981.

Señor
Ing. LUIS GAMOZA DE ZAVALA
Sub-Gerente de Producción de
ELECTRO - LIMA
Presente.-

Tengo el agrado de dirigirme a Ud. para hacer de su conocimiento que habiéndose establecido coordinaciones con el Ingeniero ROBERT GERSONY, Asesor de la Embajada de Norteamérica sobre medidas preventivas para casos de sismos, nos hemos informado que existe un estudio referente a la instalación de gatillos sísmicos para corte automático de suministro de energía eléctrica en vuestros centros de distribución, siendo el caso que de acuerdo al análisis de riesgos de nuestros "Puntos Críticos", nos es sumamente necesario contar con dicho servicio para programar el corte de suministro a nuestro Muelle No. 7 cuando se produzcan movimientos sísmicos que lleguen al Grado 2 de la Escala de Mercalli Modificada, y que para el resto del Terminal Marítimo del Callao se active en el Grado 4 de la misma Escala.

Esperamos conocer su apreciación de factibilidad de contar con dicho servicio, así como su respectivo costo.

En caso de no ser factible el servicio solicitado, igualmente le agradeceremos su opinión respecto a la mejor solución.

Atentamente,

C.P.C. ESTEBAN CICIRELLO MIGLIORI

ADMINISTRADOR

ECM/ada.
Comité Seguridad Base Naval del Callao
Ing. ROBERT GERSONY ←
Sr. Sub-Administrador
Sr. Jefa Div. Seguridad
Sr. Jefe Div. Ingeniería
Secc. Electricidad.
Archivo.

While the current security system in ELECTRO-LIMA is good, this system would help to strengthen it. It is difficult to quantify the benefits of such a system to Lima. But it is not inconceivable that it could save lives and substantial property.

Liabilities of the Automatic Cut-off System

There are two areas of concern which have been examined and discussed with all authorities:

1. Elevators An energy cut-off would leave numerous persons trapped in elevators, especially during working hours. However, this danger is balanced by the following:

- The BOMBEROS indicate that almost all elevators in Lima are produced by SCHINDLER and OTIS corporations. They are subject to two major problems:

(a) Mechanical failure In an earthquake, the counterweights can get derailed, at which point the elevator's automatic brakes are applied. While this could present a problem, it would happen in any case, whether or not there was an electrical cut-off. However, the fact that the danger of fires has been reduced by the automatic cut-off means that persons trapped in elevators are not likely to be suffocated from smoke or fumes of such fires.

In fact, the BOMBEROS argue that applying the automatic cut-off system would also accelerate the rescue of elevator passengers by diminishing the need for activation of the automatic brakes allowing the manual operation of the elevators or the BOMBEROS' emergency energy units.

(b) Electrical failure: Elevators are all designed with manually-operated systems which permit them to be lowered to nearby floors for exit. In addition, the BOMBEROS have mobile power units which they can also apply.

In a recent two-hour blackout in Lima, there were over eighteen cases of people trapped in elevators who required BOMBERO assistance. However, there were no injuries or ill-effects. The BOMBEROS expressed the view that

"there is little or no danger to people from elevators stopping ...they may be detained for a while, and they may panic, but they will basically be all right".

Many of the city's elevators are in the more affluent districts, such as Miraflores, where less damage to elevator-equipped buildings is expected because of soil and construction quality. More vulnerable low-income areas, where power could not be quickly re-established, have few such elevators.

On balance, it is the view of the authorities that the elevator risk is not of such substance as to warrant the greater risks of suffocation, fire and electrocution.

One particular elevator in Lima is a serious concern. However, this elevator causes concern at all times, not just as a disaster risk: the SCHINDLER elevator in the Centro Cívico, in downtown Lima, which serves as the express to the upper floors, is not provided with escape hatches during the course of its long upward express journey. If it should be stuck in between the ground and its first upper floor exit, it might take 4 - 5 hours to rescue passengers. This building was constructed by the Instituto Peruano de Seguridad Social, and despite protests by the BOMBEROS and the elevator manufacturer itself, the design was not modified to permit such escape. According to the BOMBEROS, provision for such escape could have been made at negligible additional cost.

(There are a number of other security problems in the Centro Cívico building, which suffered a major fire on February 5, 1975. In the last two years, the BOMBEROS have received about ten emergency calls, mostly for burning air-conditioners, generators, and other motors.)

2. Panic/Night-Time Evacuation This concern is strictly limited to hours of darkness and has been discussed intensively with Guardia Civil, BOMBEROS, a large number of municipal and other officials, and with the

Operations Staff of the National Civil Defense System when it still existed. The conclusions are as follows:

-- If the earthquake is of a severe magnitude, either the massive short-circuits produced would within minutes shut the system down or reasonable concern for public safety would obligate ELECTRO-LIMA to discontinue all power distribution until an assessment by zone could be made. Re-establishment of energy would take some time in this case.

The cut-off system would simply eliminate deaths and injuries from electrocution and risk of fires. Both of these factors would themselves generate significant panic but are eliminated by the cut-off.*

-- If the earthquake is of a minor magnitude, people are left in darkness and some panic could occur. However, buildings are not tumbling down on them, high tension and distribution cables are not falling on them, sparks are not flying, etc. It is an entirely different type of situation where risks are significantly minimized.

The BOMBEROS commented that the callejones -- the tenement buildings referred to -- have no lighting in most cases anyhow. They add that the cut-off system would not be effected until the earthquake reached a certain peak level, so that by that time people can be oriented. The danger of electrocution in these buildings is particularly high.

To test this assertion, the Disaster Preparedness Team made a night-time surveillance visit to the tugurios, from midnight to 5AM. It found that about

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* Typically after earthquakes people are electrocuted or injured when they rush into buildings to rescue other persons or property, which begins even after the earthquake is over. The BOMBEROS state that even in normal times they will not send their men into a fire unless the power has been disconnected. In both earthquake and normal fires, water and metal which conduct electricity multiply these dangers.

60% of the callejones have no lighting whatever or no more than one bulb, not always replaced when burnt out. In many cases, this lighting would be extinguished by the seismic movement itself. The findings seemed to support the BOMBEROS' assertion that on balance the automatic cut-off remains highly desirable.

3. Looting The Guardia Civil, BOMBEROS and others agree, based on concrete previous experiences that looting would not be immediate and spontaneous. They expect a minimum 12-hour lull period before such activity would begin. Clearly the effect of the cut-off for this problem is strictly a night-time concern.

However, even if the previous patterns did not repeat themselves, which is considered a remote possibility, the cut-off would have no effect on looting because:

-- If the earthquake is of a very severe magnitude, energy will have to be cut off anyhow or, eventually, the massive short-circuits will force the system to shut down. Reasonable concern for public safety and fires would obligate ELECTRO-LIMA to discontinue operations until an intensive survey of each zone could be made.

Thus, in this case, the cut-off has no effect on looting.

-- If the earthquake is of minor magnitude, power will be re-established so quickly that looting would not occur.

4. Shutting down consumption of electricity in Lima on a large scale would automatically shut down the power generation plants in turn. However, electrical experts asserts that re-establishing hydroelectric (Lima's main source) power production could require as little as less than a minute.

5. Skepticism has been expressed that the cut-off would not discourage industry owners intent on setting fire to their own factories (an action known

as "turco circuitos" in Lima). However, the absence of electricity in the entire zone might serve as a disincentive to do so because the owner might have difficulty in claiming short-circuits as the cause of the "accidental" fire.

In summary, after a careful review of the benefits and possible liabilities of the automatic cut-off proposal, all persons interviewed on this subject favored the automatic cut-off system (many thought it already existed). Such a cut-off is already national Civil Defense policy.

PROPOSAL: ELECTRO-LIMA/IGP/USAID Cooperative Project

On the basis of the foregoing, a proposal has emerged for a project in technical cooperation among the major responsible agencies with the blessing of Civil Defense authorities. This project would allow for the procurement of six DSA-1 units. These units would be installed as described in the foregoing sections, with five at Centros de Transformación and one at the Santa Marina Primary Sub-Station, El Callao.

The IGP has proposed some operational principles which should be followed:

(a) Cut-off point should be based on the peak acceleration level at which buildings would actually begin to collapse within the zone.

(b) Based on readings from the accelerographs themselves, the levels should be refined and adjusted over the years so that the system takes effect only in the case of absolute necessity.

The cut-off point would be one which would occur with a projected frequency of once in every five or ten years. It would be designed to offer the desired level of protection with the absolute minimum nuisance occurrence.

Each unit would be technically monitored, maintained and controlled by the IGP. The units would fit into the IGP's uniform equipment policy, i.e., as all their other equipment being purchased is from KINEMETRICS (for example the new earthquake sensing network for central Peru), they would have the tools, experts

and some spare parts in their shop required to provide the maintenance.

Installation expenses, such as the cement foundation and housing for each unit would be provided by ELECTRO-LIMA.

The cost of the six units themselves (each estimated in September 1981, at about US$7,000) would be shared between ELECTRO-LIMA and USAID. This small disaster preparedness project would be proposed to USAID jointly by the IGP and ELECTRO-LIMA.

PREPARING FOR POST—DISASTER OPERATIONS: Assessment of Needs

In preparing for post-disaster operations, two potential contingencies need to be considered:

(a) That ELECTRO-LIMA's power generation, transmission and distribution network are essentially (although not completely) in tact so as to permit continuing service to critical facilities; and

(b) That ELECTRO-LIMA's generation, transmission and distribution network are so damaged that service to critical facilities will be substantially delayed.

In considering these two possibilities -- which are only two "clear" possibilities in a range of possible variables -- ELECTRO-LIMA's own assessment of the vulnerability of their system has been taken into account. This assessment reasons as follows:

1. An earthquake with such a major impact in Lima would probably not have an impact so widespread as to affect all of the power production plants which supply Lima. In addition, the entire Peru electrical network is interconnected to permit re-channeling of energy from far-away generation sites into Lima. Thus, while one or two generation plants, at most, could be so damaged as to not permit generation of electricity, ELECTRO-LIMA should be able to maintain at least a minimum supply of energy to the City.

2. Earthquakes themselves do not have a history of toppling the aerial high-tension transmission lines used to transmit energy from generation plant into Lima. On occasion, through rockfalls or terrorist attacks, one or even two towers have collapsed. In areas vulnerable to rockfall, special metal shields have been placed on towers to preclude recurrence. However, if such major cables were to collapse, the number would be limited and ELECTRO-LIMA could, within 24 hours, repair them to permit continued functioning. As in the foregoing paragraph, the network is so extensive that supply of minimum

current would still be possible.

3. The Transformation Centers, as they are located inside Lima, would be vulnerable, but all reasonable steps have been taken to absorb seismic shocks in order to permit continued provision of energy.

4. A substantial number of distribution lines (nearly 70%) are underground, especially within Lima. These lines are waterproofed and flexible. There seems little likelihood of massive damage to them.

5. There could be severe damage to some, but not all primary and secondary sub-stations.

In a massive catastrophe, ELECTRO-LIMA's ability to provide energy in Lima would be very limited. Other than such a case, ELECTRO-LIMA could provide energy.

Based on the above analysis, two options are explored: the possibility that ELECTRO-LIMA can provide energy, and the possibility that it cannot. This analysis is used also in the water and sewage sector and in the health sector.

POSSIBILITY A: ELECTRO-LIMA CAN SUPPLY CRITICAL FACILITIES

In order to prepare for this contingency, ELECTRO-LIMA must have a list of prioritized critical facilities -- hospitals, water wells, fuel pumps, the water treatment plant, communications facilities -- which should receive emergency service.

There are several ways in which such service can be provided: ELECTRO-LIMA can use a discrete circuit from the nearest sub-station to the critical facility. In most cases, such lines exist already, and the reconnection can be made without providing energy to the area around it, which may still contain fire or electrocution risks.

There is a possibility that ELECTRO-LIMA can route its energy through

other sub-stations in the immediate area, using emergency overhead wiring which they have.

In particular cases, ELECTRO-LIMA might be able to provide energy through one of their generators (see following section on generator inventory).

However, two important pieces of information* need to be prepared in advance of such a disaster:

-- The list of critical facilities, by priority, for each sector. The development of such lists is discussed in the respective sector reports.

-- A map showing the three sub-stations nearest the critical facility, to allow analysis of what the best strategy for reconnection would be. ELECTRO-LIMA would be pleased to assist in this analysis, but cannot begin working until some basic information has been collected. Once a graphic illustration of the problem is produced, various strategies can be considered.

POSSIBILITY B: ELECTRO-LIMA CANNOT SUPPLY CRITICAL FACILITIES

If ELECTRO-LIMA cannot provide energy for more than 24 - 48 hours -- say, perhaps, for 30 days -- Lima will have to rely on alternative sources of energy. The two particular types of energy generators would be either (a) Diesel/ Gasoline Generators, or, (b) gear head drives hooked up with diesel engines for water wells. For the water sector, which is particularly critical, this issue is discussed in the respective volume of this study.

However, a survey has been conducted with respect to the availability of generators in Peru. On the following pages, a recapitulation and individual charts for the three major generator owners -- the Army, the BOMBEROS, and ELECTRO-LIMA -- are presented as Charts XVII through XX. Although some

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* These are mini-research projects (like the AID-funded food supply study) which would have costs of less than US$5,000 but which require intensive follow-up, guidance and technical assistance. They are included herein and proposed for such development during a future disaster-preparedness activity.

private industries and other national agencies may have some generation equipment, it seems doubtful based on what data has been collected that the number of such units would be adequate to make a difference in energy requirements. (The Air Force, for example, indicated that it would have one 60 KVA generator available).

The specificatinns for most generators used in Peru are:

English	Spanish
60 cycle	60 cíclos
Three-Phase	Tri-fásica
220 volts	220 voltíos

It should be kept in mind that generators which will operate wells and heavy equipment need to have a stronger capacity than the normal operating capacity in Horsepower of the well. As a simple rule of thumb Horsepower: KVA is converted on a 1 : 0.746 ratio. But at times more power may be needed to start the motor.

Chart XVII

RECAPITULATION

AVAILABILITY OF GENERATORS AFTER AN EARTHQUAKE IN LIMA

Capacity	Definitely Available (BOMBEROS, ELECTRO-LIMA)	Availability Probable (Peruvian Army)	TOTAL
1 KVA - 10KVA	97	20	117
20 - 39 KVA	0	25	25
40 - 75 KVA	0	20	20
100 - 140 KVA	0	5	5
150 - 350 KVA	4	0	4
700 KVA	1	0	1
1000 KVA	1	0	1

Note: The Peruvian Army has two substantial generators -- 250 KVA and 210 KVA, respectively. However, they are located and required in the Hospital Militar in Lima.

Chart XVIII

CUERPO DE BOMBEROS/VOLUNTEER FIRE DEPARTMENT

GRUPOS ELECTROGENOS/GENERATORS

Number of Units	Capability in KVA
2	6 KVA
10	3 KVA
46	1.5 KVA
15	1 KVA
73	

All above were purchased in 1980, "GILLETTE" Brand.

The BOMBEROS also have 12 older units of between 1 KVA and 3 KVA.

ELECTRO-LIMA GRUPOS ELECTROGENOS/GENERATORS

Number of Units	Capability in KVA
24	2 - 5 KVA
4	150 -350 KVA
1	700 KVA
1	1000 KVA
30	

EJERCITO PERUANO/PERUVIAN ARMY

GRUPOS ELECTROGENOS/GENERATORS

Potencia (KVA) Power (KVA)	Número de Unidades Number of Units		Marca Brand	Comentarios Comments
		(SUBTOTAL)		
250	1		PETROW	Hospital Militar Lima
210	1		SUPERIOR	Hospital Militar Lima
		(2)		
138	1		CATERPILLAR	
100	10		CATERPILLAR	
100	1		STEWARD-STEVENSON	
		(12)		
75	3		JOHN DEERE	
75	2		ASPERAL	
		(5)		
60	4		CATERPILLAR	
60	4		FORD-MARKON	
60	2		JOHN DEERE	
60	1		POLAR	
60	1		POLAR	
		(12)		
50	10		LISTER	
50	7		JOHN DEERE	
50	2		CATERPILLAR	
50	1		ALLIS-CHALMERS	
50	1		BUDA	
		(21)		
45	2		CATERPILLAR	
45	4		KUNZ & ROOT	
40	4		CATERPILLAR	
48	1		PUMALUX	
		(11)		
36	1		LISTER	
32	1		LISTER	
30	26		CATERPILLAR	
30	5		LISTER	
30	2		PUMALUX	
30	1		JOHN DEERE	
30	1		NEWAGE	
30	1		JETA	
		(38)		

25	1		CATERPILLAR
25	1		BUSCH
22	1		DEUTZ
21	2		RUSTON
20	6		LISTER
20	1		DEUTZ
20	1		GENERAL ELECTRIC
20	1		PUMALUX
		(14)	
16	1		LISTER
		(1)	
0 - 20 Mayormente 1.5/10	Aproximado:	30/50	Varias

ANALYSIS/ANALISIS

POTENCIA KVA 20+
POWER 20+ KVA

Número Total de Unidades: Total Number of Units:	112	
Marcas: Brands:	49	CATERPILLAR
	23	LISTER
	13	JOHN DEERE
	27	VARIAS/VARIOUS
	112	
Total KVA: Total KVA:	5,621	

Disponibilidad:
Availability:

Normalmente, 25% en servicio/malogrados
Normally, 25% are in service/not working

Probablemente, 30/40% no podría prestarse a servicio de emergencia - se los necesitan donde esten.

Probably, 30/40% could not be used for emergen service - they're needed where they are.

530

Los grupos del Hospital Militarde Lima serían requieridos donde están
The generators in the Hospital Militar de Lima would be required where they are.

USAID POST-DISASTER OPTIONS

In electricity/energy sector, there are a number of post-disaster activities in which USAID could become involved. However, it is felt that the disaster mitigation project (assisting in the automatic electrical cut-off proposal) and disaster operations planning (assisting and encouraging the identification of prioritized critical facilities, and a map which would help permit rapid emergency electrical connection) offer significantly greater rewards.

Such options as exist, offer mainly symbolic, rather than substantive relief:

(a) Should ELECTRO-LIMA be seen to be unable to reconnect energy for at least two to three weeks, and even if this is not the case, USAID can expect to receive requests for generators. The number of such generators which can be provided will do little to relieve the overall problems: a 150 KVA generator could make one water well function, or a part of one hospital. Such equipment is heavy, expensive, and of short-term value. It is an option. Care should be taken, however, to insure that the specifications of the particular installation which the generators will support are harmonious with the specifications of the generators AID can supply.

(b) Technical assistance can be provided, for example, by an electricity expert. However, ELECTRO-LIMA, has a sophisticated technical capacity, and the technical problems -- while enormous in magnitude -- are simple in character. A technical assistance person might simply get in the way. In addition, the German and Dutch Missions have such experts in Peru and might be in a better position to supply technical experts familiar with the Peruvian scene before the U. S.

(c) The preparedness team suggested that ELECTRO-LIMA develop a list

of emergency supplies -- wiring, morceteria, etc, -- which might be needed in an emergency. ELECTRO-LIMA feels, however, that their on-hand supply would be more than adequate to cope with an emergency. Their warehouse, they report contains complete supplies for new electrical distribution systems. These supplies would be used in an emergency. They can also obtain some supplies through local purchase. By the time outside supplies arrived, they say, they could even have used fallen cables and rigged them up adequately for emergency service.

However, this is an option which can be kept in mind. If such parts are needed, care should be taken, if possible, to take note of the regular suppliers in the United States, part numbers, catalogue numbers, and full specifications which will insure that the right item arrives.

Further, as with all shipment of such materials, they should be delivered directly by U.S. representatives to ELECTRO-LIMA officials from the airport, and not channeled through third- and fourth-parties.

(d) In the long-term, USAID might want to assist in some aspect of infrastructure reconstruction. But that is outside the scope of the report.

In summary, if AID wishes to assist this sector -- and there are some interesting opportunities to do so -- the time to do so is in the mitigation and preparedness, not in the response stages.

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The following pages provide names, addresses and comments concerning contacts in the general field of energy and electricity.

They would correspond to the following projects:

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