LOAD INCREASE AND SYSTEM DEVELOPMENT

In order to establish the first long-term plan, it is necessary, as mentioned above, to study well enough the fundamental approach for system development and the immediate measures to be taken.

In this chapter, we present our feeling of load increase and system development, and some discussions of the formation of electric power facilities in Indonesia.

1. ECONOMIC DEVELOPMENT AND LOAD INCREASE

(1) Economic growth and load increase

(a) The rate of economic growth and the level of income per capita

It is reasonable to estimate a continuous population increase of 2.5% per annum over the long period of time in Indonesia.

Considering the possibility of achievement of investment ratio up to about 15% which is the actual level of investment in the developing nations of the E C A F E region, we can expect the increase of productivity, and can estimate the actual rate of economic growth of about 6% per annum and increase of income per capita from present \$80 to \$140–170 in 1990. Based on these figures, we made a rough estimate of load increase. The detailed figures are shown in Table 1.

(b) Estimated peak load and level of electrification

We estimate the average practical load increase (including the load on industrial self-generation plants) at about 10–12.5 percent per annum, which means that the peak load in 1980 will be about 3 times as large as the peak load in 1970, and the peak load in 1990 will be 6–10 times. Namely, peak loads, which are 215 MW in 1960 and 510 MW in 1970, are estimated to be 1,320–1,650 MW in 1980 and 3,100–5,100 MW in 1990. In this case, the level of electrification in the whole Indonesia is estimated to rise to about 9 percent in 1980 and 15–20 percent in 1990 from 3 percent in 1970.

(c) The structure of load and the proportion of industrial self-generation units

One of the characteristics of the load structure at present is the small proportion of industrial load comparing with other countries in the E C A F E region, even if the loads on industrial self-generation units which occupy about 35 percent of the total load in Indonesia are included. Though electrification is going to be promoted, it is possible to expect that the proportion of industrial load is going to be increased.

In this process, if the power sources and systems of PLN are strengthened, the proportion of industrial self-generation units may decrease little by little after moving sideways.

Supposing that the proportion of industrial self-generation units of 35% at present will decrease to about 33–30 percent in 1980 and 25 percent in 1990, the total peak load of PLN systems will increase to about 3 times in 1980 as large as the load in 1970 and about 9–10 times in 1990.

Year	1960 (Actual)	1970 (Probable)	1980 (Estimated)	1990 (,,)
Total Peak Load	215^{MW}	510^{MW}	1,320–1,650^{MW}	3,100–5,100^{MW}
Peak Load of PLN systems	165	330	880–1,160	2,350–3,800
Peak Load on Industrial Self-Generation Units	50	180	440–490	750–1,300

(d) Load curve

As regards the load curve of PLN systems, which has the shape of "higher at night and lower in the daytime" because of many fixed rate consumers at present, it seems that, with the increase of meter rate consumer and of industrial loads, the load curve will have the shape of "higher in the evening and lower at night" as seen in many semi-industrialized countries.

(2) Regional economic development and load increase

(a) Three regions in the Island of Java

There are three regions in the Island of Java, which have large plain and major harbours of Djakarta, Surabaja and Semarang. On 1970 the peak load of PLN systems in each region will be as follows.

Estimation of Economic Activity and Peak Load

Year	1960	1970		1980		1990
o Economic Growth Rate (A)	(2.8%)		5.0%		6 - 7.5%	
Rate of Population Increase	(2.5%)		2.5%		2.5%	
Rate of Increase in per Capita Income	(0.3%)		2.5%		3.5 - 5.0%	
Proportion of Investment to G. N. P.	(7.5%)		9.0%		15.0%	
Proportion of Incremental G. N. P. to Investment	(0.37)		0.55		0.40 - 0.50	
Per Capita Income		$80		$100		$140 - 170
o Rate of Increase in Peak Load (B)	9.0%		10 - 12.5%		9 - 12%	
Elasticity (B/A)	3.2		2.0 - 2.5		1.5 - 1.6	
Peak Load	215MW	510MW		1,320 - 1,650MW		3,100 - 5,100MW
Proportion of Peak Load on Self-Owned Generators to the Total Peak Load	29%	35%		33 - 30%		25%
o Peak Load of P. L. N. Systems (C)	165MW	330MW		880 - 1,160MW		2,350 - 3,800MW
Rate of Electrification		3%		9		15 - 20%
o Peak Load of P. L. N. in the Island of Java (D)		270MW		770 - 1,010MW		2,100 - 3,400MW
Rate of Increase			-14.3%		11 - 12.2%	
Proportion of Java (D/C)		85%		87%		90%
o Peak Load of Largest P. L. N. System (West Java)		170MW		520 - 680MW		1,400 - 2,400MW

Note: — an underline indicates a main variable

( ) a parenthesis indicates the average figure between 1962 - 1966

West Java (XI, XIII)	170 MW
East Java (IX)	60
Central Java (X)	40

In general, it is most essential for regional economic development to have connections with other industrial regions by some effective means of transportation and communication. From this point of view, as West Java is open for Sumatra and other Asian countries and has large cities which are closely related in economic activities, it is a primary region with the greatest possibilities, and West Java is followed by East Java and Central Java.

i) West Java

The great possibilities of West Java are derived from the following factors;

- Djakarta is the political, economical, and cultural center of Indonesia.
- Djakarta is closely connected with Bandung by mean of transportation.
- West Java has a large educated population, which means a potential consumer market and the source of manpower for industries.

  Note: Many investments by foreign companies are made in this region at present.

Based on the above-mentioned factors, electrification will be promoted and the peak load of West Java will be after twenty years about 11 times as large as the peak load in 1970, while the average for the whole country will be about 7 times.

We estimate the peak load of PLN system in West Java as 170 MW in 1970, 520-680 MW in 1980 and 1,400-2,400 MW in 1990. At that time, a single system with the peak load of around 2,000 MW will be realized.

ii) East Java

Possibilities of development in East Java are thought to be second to West Java judging from the following factors:

- There is a largest plain where the rising of productivity of agriculture is expected.
- Surabaja is a base for integration of Selebes and Irian, and continues to have the traditional function of a transit port.
- The locations of the basic industries such as the cement, fertilizer and paper industries are promoted at present.

Based upon the above-mentioned factors, we estimate the peak load of PLN systems in East Java to be 60 MW in 1970, about 240 MW in 1980 (about 4 times as large as the peak load in 1970) and about 600 MW in 1990 (about 10 times as large as the peak load in 1970).

iii) Central Java

Considering that the industries in Central Java consist of agricultural, traditional (textile and so on) and sightseeing industries, and that Central Java has not so much close relations pips with other two regions of the Island of Java, it seems that the rate of economic development which is accompanied by the increase of electric consumption is lower than in the other two regions.

Based on the above-mentioned factors, we estimate the peak load of PLN systems in Central Java as 40 MW in 1970, about 160 MW in 1980 (about 4 times as large as the peak load in 1970) and about 350 MW in 1990 (about 8.8 times as large as the peak load in 1970).

(b) Sumatra

The characteristics of the economy of Sumatra are economic activities within an isolated area and the connections with other regions mainly by ships.

i) In the area of Palembang, the load increase is expected considering the following factors.

- The expantions of large scale factories which are related to the utilization of oil and natural gas

- The increase of citizens' incomes caused by the regional development which is promoted by the expansion of the large scale factories.

- Development of consumption industries based upon the increase of income.

ii) In the area of Padang, considering that some cities are connected with each other by railways and roads, and that the systematic regional development is going to be promoted following the electric power development of Batang Agam, it is possible to expect the formation of electric power system in the future.

But, it seems that the increase of load is not going to be so large because the industrialization of mountainous area with few consumers is very difficult.

2. POWER SYSTEM DEVELOPMENT

(1) Outlook on system development

(a) General

i) According to the estimation of the consumption of electric power, the Island of Java will still be the main power market and the proportion of its electric power consumption in Indonesia will tend to be higher than the present proportion of 85 percent. In 1990, for example, the peak load in the Island of Java will be about 3,000 MW while those in other islands will be only 400 MW or less.

ii) Power systems will be developed mostly in the Island of Java. In the rest of the Island, most of the power supplies will still be isolated except for Sumatra where power systems of certain scales will be formed in some areas.

iii) In the Island of Java, the largest system will be developed in West Java.

It is expected that the present independent systems of West, Central and East Java will be interconnected with each other, but the integration of all systems into one would still need a careful feasibility sutdy.

(b) Three rigions of the Island of Java

b-1 West Java

i) As mentioned before, the load in West Java is estimated to be as large as 1,900 MW in 1990.

The characteristics of load distribution will be as follows;

- The accelarated concentration of load on Djakarta
- Steady increase of load in Bandung in connection with Djakarta
- The prospective development of a new industry in Tjirebon

ii) The total estimated capacity of hydro power resources surveyed and exploited so far in this region is about 850 MW.

The total hydro power of 1,300 MW would be considered in anticipation of the exploition of potential sites at the Indian Ocean side and others.

iii) Even if such hydro power development is realized, it would be further necessary to have the thermal power of 1,100 MW assuming that the avilable hydro power capability for the system peak load will be 80 percent of the installed capacity.

We think that the careful study of the selection of the unit capacity of thermal power generators is very important and that 250 MW class unit will be proper unit capacity for the West Java system in 1990. Thermal power plants will be located mostly along the coast near Djakarta and some in Tjirebon depending upon the development of the area.

iv) Judging from the distribution of loads and the location of power sources, as mentioned above, the power transmission lines from the hydro power plants around the Tjitarum and for the Tjimanuk to Djakarta will form the trunk lines of the system. The bulk power supply for Djakarta will be made by a loop of a transmission lines which surrounding the city, as is the case with other large cities in the world. The main thermal power plants and the transmission lines from the hydro power plants will be connected to this Djakarta loop power transmission line.

The voltage of the trunk lines will be 150KV, and for the transmission line between Tjitarum hydro power plants and Djakarta, E.H.V may be introduced.

v) The secondary power transmission systems of 70 KV will be fully developed. This development would promote the rural electrification.

b-2 East Java

i) The load in 1990 is estimated as 600 MW and a large portion of the load will center around Surabaja. The major potential hydro power sources in this region have already been surveyed. As the result of surveys, approximately 260 MW are estimated to exist including about 120 MW for Karangkates, some along the Bengawan Solo and some in the eastern part of the region.

Even if it is necessary to carry out further surveys, the potential hydro power is assumed to be around 300 MW and the proportion of hydro power to the total power sources would be about 40 percent.

ii) The major power plants will be the Karangkates hydro power plants and the thermal power plants around Surabaja, and transmission line of 150 KV between these two power sources will be the trunk line in this region.

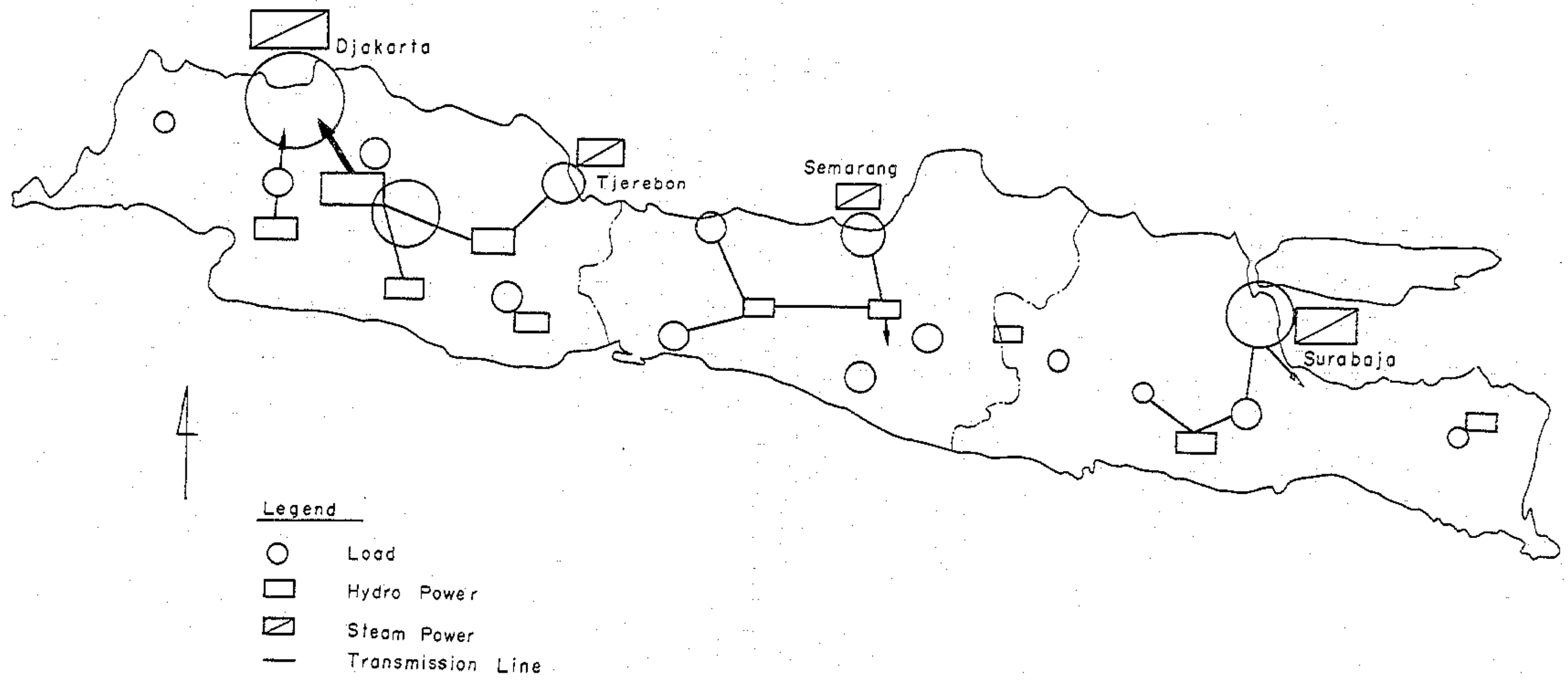
There is a possibility of interconnecting the systems of East and Central Java in a small scale in relation to the exploitation of hydro power resources along the Bengawan Solo. All isolated power supply systems in this region will be dissolved by the extension of 70 KV system.

b-3 Central Java

i) The peak load will be 350 MW in 1990 and will be almost equally distributed among the main cities of this region.

Power System Developement In Java Island

Rigion	West		Central		East	
Year	1970	1990	1970	1990	1970	1990
Load (MW)	170	1900	40	350	60	600
Hydro (MW)	220	1300	40	200	40	300
Steam (MW)	50	1100	—	300	50	450
Total (MW)	240	2400	40	500	90	750
Max. System Voltage (KV)	150	E.H.V	30	150	70	150



The potential hydro power is considered to be around 200 MW including the possibility of the development of the Seraju which needs the future surveys. Consequently, the ratio of the hydro to the thermal will be about 4 to 6.

The location of the thermal power plant will be in Semarang.

ii) The system development in the region is dependent upon the location and the scale of hydro power sources to be exploited, because the distribution of load is flat.

Among various possibilities, it is most likely that the system will be formed in such a way as to connect the hydro power sources around Garung to Semarang, to Tegal & Pakalongan, and to Tjilatjap respectively. The system voltage will be 150 KV.

In regard to the Tjirebon thermal power project and the hydro power development around Tasikmalaja, both in West Java, it is considered feasible to interconnect Tegal with Tjirebon as well as Tjilatjap with Tasikalaja.

After the completion of interconnections, this system will be more closely tied to the West Java system. The main system formation in this region needs further studies.

The extension of 70 KV secondary system in this region will interconnect all the existing isolated systems, as in the other regions.

(c) Sumatra

i) In Sumatra, systems in certain scales will be developed in four regions, that is, Medan, Padang, Palembang and Tandjung Karang.

The construction time and the scale of the system formation will be greatly influenced by such factors as the regional economic and industrial development and the increase and decrease of privately owned power plants.

ii) Around Medan, Padang, and Tandjung Karang, there are rich hydro power resources, and along with their exploitation corresponding with the regional and industrial developments, power systems will be formed.

iii) In other regions, as a rule, the number of isolated power supply system will continuously increase. To cope with this situation, great efforts will be made for developing small systems connected with medium or small power sources of hydro power and thermal power, to promote the electrification and decrease the number of diesel power plants.

(2) Some Discussions on the problems concerning system development

(a) Hydro Power

i) In Indonesia hydro power reasources already exploited are only around 300 MW in spite of its aboundant precipitation rainfall and favorable topography.

In view of the efficient utilization of water resources, more efforts are desired for hydro power development.

The hydro power development can be justified, if hydro power has the higher economical priority than the thermal power development.

Therefore, it is urgently necessary to survey the potential hydro power and to know the quantity of hydro power which can be economically exploited after making rough designs.

ii) In hydro power development, it is necessary to enhance the economic value of projects as well as to increase the quantity of power. For this purpose, it is necessary to take part in the comprehensive development of river basin or to construct micro hydro power plants as local power sources by making use of irrigation canals.

iii) In the Island of Java, as the load will be increased by ten times in twenty years, the development of large scale hydro power sources will be realized in the near future when they prove to be economical.

And development of large hydro power sources will significantly affect the system formation. Therefore, a general survey of potential power should be started as soon as possible for the Island of Java.

iv) As it will take some time before the general survey will be completed, feasibility studies on the sites already surveyed should be promptly pushed forward. Such sites are the Tjitarum, the Tjimanuk and the second stage of Kali Brantas. As soon as a project is justified, the preparation for construction should be started.

v) In islands other than Java, it is important to select hydro power sites of a certain scale which can well meet the local demand. In Medan, Padang, and Tandjung Karang, for instance, it seems to be possible that the economical sites are found and easily exploited to supply the power in place of diesels and to promote the electrification.

vi) The feasibility of a large scale project like the Asahan project should be studied in view of the national economy together with the possibility of developing industries which consume a large quantity of electric energy.

(b) Thermal power

i) Thermal power plants should be planned considering the possibilities of the economical hydro power development so that the overall economy and reliability of power supply may be achieved.

It is desirable to take advantage of the thermal power development as there is only a few restriction in the selection of the plant sites and the construction period is not so long.

ii) It is urgently necessary to complete the construction of thermal power plants in major cities like Semarang and Palembang where the shortage of power is serious.

iii) In the Island of Java, judging from the amount of potential hydro power resources and the long construction period of hydro power plants, it seems that the thermal power plants must be constructed successively.

Therefore, it is desirable to start the studies of the following projects and also to proceed with the preparation for the constructions, if necessary. The project to be studied are second thermal power plant in Djakarta, the extension of Perak power station and a new power plant in Tjirebon.

iv) The addition or new installation of diesel units for local power supply should be planned in according with the priority based on proper criteria.

It is also important to make a comparative study between diesel and hydro power developments.

v) In the planning of the thermal power plants, the privately owned power stations should also be considered. The planning must be coordinated and integrated in order to make the power generation more economical as a whole.

It would be necessary for the government to establish a policy whether or not PLN should construct a thermal power plant to supply power mainly to the specific large scale industry when its development is planned.

vi) The construction of thermal power plants using natural gas or coal as a fuel would be one of the problems to be studied.

However, a thorough examination is required as to the quantity of reserves, production cost, and transportation and transmission cost of these natural resources.

(c) Power transmission system

i) With the development of power sources, including especially hydro power sources of large scales, the trunk lines of power transmission systems will be formed and gradually interconnected with each other in accordance with the necessity.

ii) One of the urgent problems is to decide on the power transmission plan of Karangkates for which, we think, the most proper voltage to be adopted is 150 KV.

iii) The feasibility of the interconnection of systems must be studied based on the economic comparisons which are made considering all the systems concerned. The inter-connection of two systems in Central Java is thought to be urgently necessary.

iv) The integration of small systems into a large system and the formation of local power transmission networks in conjunction with the construction of new power plants must be studied in the same way as stated in the foregoing paragraph.

The early studies and decisions should be made on the interconnection of Madiun and Kali Konto in East Java and on the formation of a system for Batang Agam Project in West Sumatra.

v) As to the isolated power supplies in the Island of Java, the feasibility of power supplies from the integrated systems should be examined. This can be done by means of extending the sub-transmission lines or the distribution lines.

It seems also appropriate to make a study on the possibility of sending power from Surabaya to Madura instead of installing additional diesels to meet the load increase in the island.

(d) Power distribution system

i) It is of great importance to establish a consolidated standard of the basic design of power distribution system considering the characteristics of power distribution facilities.

In order to achieve the economical and flexible expansion of networks, we think the adoption of overhead lines in larger scale is most appropriate.

ii) The power distribution voltages should be determined based on the economic examination considering the necessary measures for the transitions, if any, from the existing voltages. In this case, it is also important to pay a special attention to the necessity of standardization of electric apparatus and appliances throughout the Indonesia.

It is dangerous to take local measures without the standardization of voltages throughout the Indonesia.

iii) For the primary distribution voltage, 6 KV employed at present seem appropriate in principle, considering the use of over-head lines.

iv) For the customers voltage, an early and careful study is necessary. It is considered to be essential to make a survey on the existing equipment like electric appliances and the wiring in customer's promises as a basis of the voltage study.

v) It is urgent to establish a basic design of urban distribution networks for major cities like Djakarta, Surabaya and Bandung, based on the results obtained from the foregoing studies.

Appendix 3–1

ALLOCATION OF MANAGEMENT RESPONSIBILITIES
FOR
OPERATION OF SYSTEM AND FACILITIES (TENTATIVE)

PLN head office	Exploitasi office
Clarification of basic philosophy and approach Formulation of rules and standards (Example) Basic approach for system operation - economical operation - frequency regulation - voltage regulation - operation of transmission system - protection system	Execution and enforcement based on the basic approach Formulation of the standard method for operation (Example) Taking of concrete measures - formulation of the standard method for the operation of water system and reservoir - voltage standard - operation rules - adjustment of relays
Formulation of the annual and long-term. plan for the balancing of load and supply Clear presentation of annual operation policy Coordination among Exploitasi offices	Formulation of the draft plan Formulation and implementation of the operational plan

PLN head office	Exploitasi office
	(Example) - short-term adjustment plan for load and supply - reservoir utilization plan - inspection and overhaul plan
Survey and statistical analysis from the standpoint of the whole enterprise and their feedbacks to Exploitasi offices	Survey and statistical analysis of system and facilities as well as their operation
(Example)	(Example)
Comparisons of faults among various Exploitasi (Analysis and counter-planning)	Detailed analysis of faults and counter-planning

Appendix 3–2

OPERATION AND MAINTENANCE OF LOAD-RATIO CONTROL TRANSFORMER

PREFACE

Various measures may be effectively prepared for improvement of power supply conditions in Java Island of which ergent improvement is certainly required.

In due consideration of the present power supply facilities in Java Island, one of the most efficient methods for the time being will be the use of the Load-Ratio Control transformers which will largely improve power supply condition. (Which will be abberiviated as LRTr hereinafter).

The following paragraphs describe necessity, operation, and maintenance procedures of the LRTr which will be effective to improve the power supply situation immediately.

(1) Desirable voltage regulation in power station

(2) Voltage regulating operation in substation

(3) Automatic operation of voltage regulator

(4) Inspection and maintenance of load ratio controls

1. DESIRABLE VOLTAGE REGULATION IN POWER STATION

Fluctuation of power voltage to be supplied to customers must be as small as possible to supply adequate voltage to customers.

Major causes of the voltage fluctuation in the customer's premises are:

a. Fluctuation of power plant output

b. Voltage drop in transmission line

c. Voltage drop in high voltage distribution line

d. Voltage drop in low voltage distribution line while, the following medium are usually provided to compensate the power supply fluctuation.

a. Adjustment of power plant output voltage

b. Improvement of transmission equipments

c. Adjustment of substation output voltage

d. Improvement of distribution equipments

e. Installation of voltage regulator in distribution line

To implement the improvement plan in the most economic way, scale of the existing facilities, actual operating condition and other factors must be taken in account. However, we understand that the utilization of the LRTr's installed in major power substations to improve regulation of the station outputs will be the most effective way for the present power distribution system of RLN.

The improvement of power voltage regulation must be effected in two phases, effective use of the existing LRTr's, and installation of the transformers with LRTr which are capable of voltage compensation to the extent at least ± 10% to newly constructed stations.

2. VOLTAGE REGULATING OPERATION IN SUBSTATION

The voltage regulating system in substations may be classified in two types, the direct operation system, and the automatic operation system.

Summary of these operation systems is;

a. Direct operation system

b. Automatic operation system

(1) Direct operation system

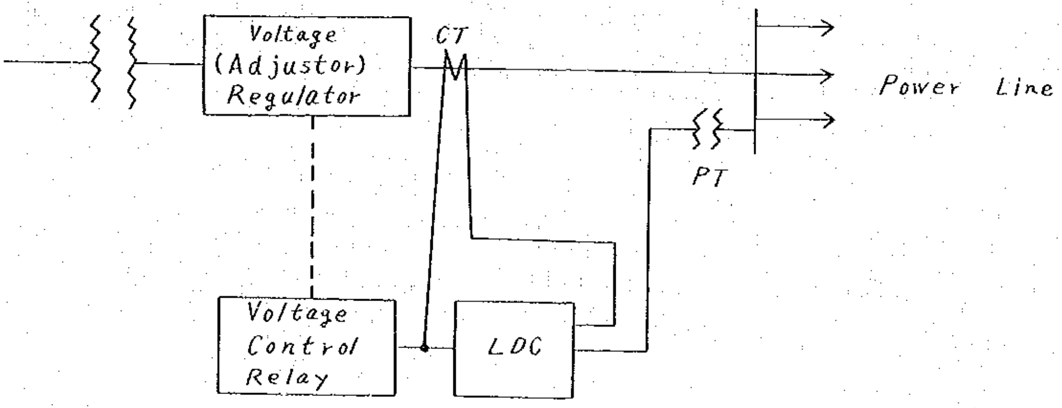
In the direct operation system, control switches of the voltage regulator in substation are manually controlled, in order to maintain output voltage so that the voltage will be adequate to load at the time, by operator in the substation.

(2) Automatic operation system

By the automatic system, the output voltage of substation is retained in an automatic way so that the voltage in customer's premise will be maintained in a certain range. One of the automatic operation system is known as the Line Drop Compensation (LDC) system. Summary of the system will be explained in the following article.

The LDC system was primarily developed to control voltage regulation of generators. Voltage at a certain point of line connected to a generator can be maintained at a constant level, by a certain measure which compensates the voltage drop caused by the line impedance between the generator and the point. The voltage drop which is a function of the line impedance and the generator output power, or the load to the generator, can be compensated by this method. The LDC system is an application of this principle to the automatic voltage regulation. In this system, the line drop which is considered to be present in actual line is stimulated inside of the control device. The control device operates to maintain the voltage across the load, or the generator output minus the stimulated line drop voltage, to a constant level.

The automatic line drop compensation is effected, in substation in the following manner. As shown in the figure below, a current transformer (CT), a potential transformer (PT) for the control, a set of voltage control relays, and a line drop compensator (LDC) are combined to automate the voltage compensation.



a. Voltage control relay (Ry).

Line voltage is stepped down by the potential transformer (PT) to the voltage coil of the voltage control relay which closes contacts "Voltage Down" if the supplied voltage is higher than the predetermined level, or closes the "Voltage Up" contacts, if the supplied voltage is lower than the preset level. Closure of these contacts drives the voltage adjustor to decrease, or increase, output voltage of the substation.

b. LDC

A longer line length and a larger load increase the line drop, thus, the voltage at the customer's premises can not be maintained constant if the substation output level is retained constant. Thus, the power station output level must be varied in accordance with the load variation. In other words, the output voltage must be increased when the load is large, and be reduced when the load is small. However, as described above, amount of the line drop differs with cable length, or location of each customer, it is almost impossible to output a voltage so that all the customer's voltages will be retained constant. To solve this problem practically, the settling level of the automatic compensation is generally determined to the average point of the load variation, and setting of LDC control level and tap adjustment of pole transformers must be effectively coordinated.

Viewed from quantity and operating condition of LRTr's in PLN, it is suggested to employ, for the time being, the direct operation system in which the voltage adjustor is manually controlled, and to perform the coordination of the substation output voltage and tap switching of pole transformers so that the supplied voltage will be practically stabilized against the following load conditions.

- Output voltage at heavy load
- Output voltage at light load
- Output voltage at medium load

In future, the automatic operation system described in item (2) above, should be employed for better stabilization of power supply voltage and better service for customers.

3. AUTOMATIC OPERATION OF VOLTAGE REGULATOR

Certain devices must be prepared for the automated operation of LRTr. The devices, and their estimated cost, required for the automatic operation of LRTr are tabulated as follows.

	Quantity	Cost ($)	Remarks
(1) Material Cost		2,400	
L D C	1	50	
Voltage Control Relays	1 set	700	
Power Distribution Panel	1	550	400mm x 2,300mm
Control Cable	1 set	800	For a site, 1,000m apart from the panel
Others	1 set	300	Scheduled to use the existing CT and PT.
(2) Construction Expense	1 set	900	
(3) Transportation Cost, etc.	1 set	100	
Total		3,400$	

NOTE: These costs are estimated from current prices in Japan.

4. INSPECTION AND MAINTENANCE OF LOAD RATIO CONTROLS

Purpose of inspection and maintenance of LRTr is to maintain the initial performance and to prevent troubles. To attain this purpose, operators must be intimated with structure and operation of the Load Ratio Controls, and be skilled in adequate maintenance of the device. If a defective point should be found, or a trouble should occur, cause of the trouble must be clarified and be repaired completely, and immediate contact to the manufactures, if possible, is desirable.

Wear of switching contacts and deterioration of oil in regulator room are inevitable, from structure of itself, for the Load Ratio controls.

Therefore, the inspection and maintenance of;

a. Adjustment of tap switching contact

b. Filtration of oil in load ratio control room, and

c. Lubrication to movable parts

are essential, in general, to maintain the LRTr's in good condition.

Desirable inspection and maintenance of LRTr's will be described emphasizing on those conducted by major power supply companies in Japan.

The inspection and maintenance may be classified in three categories, they are;

a. Patrol inspection

b. Regular inspection and maintenance

c. Temporarily inspection and maintenance

Basic conceptions on method and part to check, and remedy will be shown in the following tables.

(1) Patrol inspection

The patrol inspection is to patrol condition of the load-time tap switching devices, during they are in operation, and to check their operation externally.

The patrol inspection should be emphasized on irregularities which are only detectable by human sense, for example, irregular noise and smell, or discoloration of parts, etc.

Items to be actually implemented in the patrol inspection are listed in the following Table 1.

These inspection and maintenance may be performed with power supplied to the motor control device, however, electric shock should be properly prevented in these cases. Be sure not to short-circuit the live parts by oil feeder or screwdriver.

In normally operating devices, the motor may start operation during the inspection, in accordance with a signal from the control panel. It is desirable to open the power circuit during inspection.

(2) Regular inspection

The regular inspection is to inspect the devices at a certain regular interval, to provide correct maintenance of the load-time tap switching devices.

The interval of regular inspection is determined by period of use of the device, or by frequency of the device operation. Items and contents of the inspection to be performed regularly are listed in the following Table 2.

(3) Temporarily inspection

The temporarily inspection is an inspection to be conducted, beside the patrol and regular inspections, for a particular or emergent purpose. The aforesaid description is the standards for operation and maintenance of LRTr which are subject to modification in accordance with actual condition of sites, i.e. type of device, condition of existing devices, and power supply condition, etc. Therefore, operators on sites must be well trained and acquainted with materials supplied from manufacturers of transformers, and if necessary, invite the manufacturer's engineer for technical orientation to expect smooth operation and administration of power supply. Also, the inspection and maintenance of LRTr's will have to be performed in nearfuture by the company operators without aid of manufacturers.

Table 1. Patrol Inspection

Division of Devices	Part to Check	Check Item	Remedy	Remarks
Tap selector	Switching taps, valves, and flanges	Oil leak, particularly leakage from welded or jointed portions of tank, valves, and oilmeter.	Determine cause of the oil leakage, and provide measure as quick as possible.	Oil leakage is a major cause of defective transformer operation.
	Oil meter	Meter indication. Error or irregularity in indication.		
	Temperature meter	Meter indication. Error or irregularity in indication		
	Others	Other irregularities. Overflow of oil, smoke, or irregular noise.		
Load ratio control switch	Tank and valves	Rafer to the above item "taps valves, and flanges."		
	Oil meter	Refer to the above item "Oil meter";		
	Desiccant (Moisture absorber)	Condition of desiccant. Breathing (moisture absorption) condition and discoloration of desiccant.	Replace moistened (discolored) desiccant.	
	Supporting insulator	External condition. Damage, crack, dust adhered on insulator surface. Corona due to these defects.	Remove and clean insulator being dusted.	

Division of Devices	Part to Check	Check Item	Remedy	Remarks
	Others	Check flickering, and refer to the same item in the tap selector above.		
Drive mechanism	Rate meter	Number of operation. For automatic operation, the operation meter reading is recorded at a regular interval, and compared irregularity excessively large or small operation. (The automatic operation device, in Japan, regularly operates at a rate of 30 to 50 times per day.)	1) If the operating times is excessively larger than normal record, faulty adjustment of relay sensitivity is the major cause. Readjustment of the relay is required. If the number of operation is excessively small, the rate meter may be defective, or defective sensing circuit may be the cause. Replace or repair. The defective recording may result from defective switching circuit. In this case, stop operation of the device, and repair the switch.	Approximatly equall number operation under normal load will indicate that the voltage adjustment is normal.
	Tap indicator	Indicator Check the indicator stops in proper position.	If the indicator is out of the normal safety position, it indicates or alarms erroneous tap position. Cause of the defect must be checked in the following manner. (a) Return the indicator (and tap) by manually turning the handle. (b) When the manual	Limit switches are provided for the upper and lower limits of the tap selection, and selection of taps beyond these limits is prohibited. To prevent danger, when the limit switch

Division of Devices	Part to Check	Check Item	Remedy	Remarks
			handle operates smooth, there will be no mechanic trouble. If it is not smooth, or generate noise during the correction, the mechanism must be inspected. (c) Try to select one tap higher and one tap lower by using the manual switch for proper operation. (d) If the manual operation of the switch is impossible, adjust the mechanism in the following manner. i) Check blown fuse or disconnection in the electric control circuit. ii) Check control voltage. (The control voltage is normally higher than the rated voltage by 10 or 15%.) iii) Check motor, electro-magnetic switch, and breaker circuits. (Particularly check the electromagnetic switch contacts.) iv) Check switch contacts. v) Check brake operation. (e) If the tap selector stops between	is not normal, the limit protection device is provided for some types of the devices.

Division of Devices	Part to Check	Check Item	Remedy	Remarks
			selection of particular taps, check the following. i) Wear and contact of brake shoe. Check friction is normal. ii) Check switches operate at their normal position. iii) Check time-limit operation of the relay. iv) Check self hold circuit of the relay, and the pilot switch)	
	Motor brake	Noise during normal operation. Irregular noise during operation is detected only by the human sense. (Check noise generated during one operation cycle starting from closure of the electromagnetic switch, gear engagement of reduction mechanism, and to open of the switch.)	Usually, insufficient lubrication of bearing, irregular wear of gears, brake shoes, or switch contacts, mixing in of foreign matters, and break of these parts are the cause of irregular noise. Defective contact of brake armature may be the cause. 2) Lubrication oil must be properly and regularly supplied to determined parts. Be sure not to split oil to the electromagnetic switch and brake shoe. 3) If contact of brake shoe armature is defective, finish the contact surface by an emery paper.	Three-phase or single-phase motors are usually employed. In some cases, the brake is installed inside of the motor. Surface pressure of the brake shoe must be re-adjusted if slip condition of the part excessively deviates from normal value. For the devices to which the brake is not provided, natural brake effect is

Division of Devices	Part to Check	Check Item	Remedy	Remarks
				usually considered.
	Transmission mechanism	(1) Noise during the switching operation. Check irregular noise.	Irregular noise is generated mainly by excentricity of transmission gear shafts, faulty engagement of gears, insufficient lubrication, break or other damage of these parts. It is desirable to suspend repair until the succeeding regular operation stop for maintenance, and to leave the device so that it will operate at a fixed tap until the routine repair.	Workmanship of repair of the transmission mechanism largely influences tap selection operation. For complete repair of the mechanism, contact to the manufacturer is desirable.
		(2) Prevention of dust and rust invasion Check dust adhered to the transmission mechanism, and rust on the surface.	Remove dust from the transmission mechanism, simultaneously, brush surface by an emery paper to remove rust. Paint proper rust-proof coating, or apply oil. It is desirable to paint the rust proof agent to shafts or joints from where plating has been peeled off.	The space heater should be used only in the highest humidity season. Excessive drying may adversely affect wirings and switches.

Division of Devices	Part to Check	Check Item	Remedy	Remarks
Limit switch mechanism	Switches relays wiring	Switching operation switching operation. Rigidity of terminal connection.		These parts should be repaired at the regular maintenance.

Table 2. Regular Inspection

Device Division	Part to Check	Check Item	Check Interval	Remedy	Remarks
Road Ratio control switch	Contacts main and arc contacts	Contact conditions check main and arc contact condition	100,000 operations	1) Firm contact and sufficient contact pressure are essential. 2) As rough surface of the main contact results from defective contact, defect in mechanism, and wear of arc contacts, contact the manufacturer for repair.	
	Arc Shoot	Dust adhered on surface, File (metalic) powder, or break or crack.	100,000 operations	Clean the arc shoe surface by using a dry cloth. If the surface cracken or broken, replace.	
	Insulator Oil	Dielectric strength and	By necessary	Filtrate or replace oil, if defective.	For a reference dielectric strength of over 20kV may be sufficient.
	Others	Bolts and pins. Loose bolts, broken or missing spring, washer, and stopper of pin.	100,000 operations	Tighten loosen parts after ensuring the parts are located in correct position. Contact manufacturer, and repair or supply the broken or missing parts.	
Drive mechanism	Motor and brake	Measure insulation resistance.	Once/Year	Measure insulation to the ground. If the resistance is excessively poor, check the cause.	For a reference, the resistance 1MΩ or more (when measured by a 500V megger, at 20°C) will be sufficient.

Device Division	Part to Check	Check Item	Check Interval	Remedy	Remarks
Drive mechanism	Transmission mechanism (Exposed parts)	1) Condition of wear Check wear of gears, shafts, and other sliding parts. 2) Mechanical condition of parts. Check loose, deformation, and break of all parts.	Once/year	If parts are excessively worn such that adversely affect proper operation, replace the worn parts. If a defective part should be found, immediately replace. Check cause of the defect, and remove the cause so that the same trouble will not be repeated.	
Control device	Switches	Check contact. Check contact condition and wear of switch, and electromagnetic switch.	Once/year	Replace switch, if excessively worn. Defective contact may be corrected by adjustment of switch spring. Replace switch, if the spring adjustment failed to correct switch contact.	Check contact of switches thoroughly, since defective contact may result in false operation of the system.
	Relays	Contact condition and operation characteristics. Check wear of contacts of the voltage adjustment relay, time limit relay, and auxiliary relay. Check these relays operate normal.	Once/year	Since the voltage control relay operates very frequently, operating characteristics varies with consumption of contact. Check operation of the relay in addition to the contact condition.	

Device Division	Part to Check	Check Item	Check Interval	Remedy	Remarks
	Wirings	Measure insulation resistance and check tightening of terminal connections.	Once/year	Measure insulation to the ground, and, if excessively poor, check and repair the cause.	For a reference, the insulation of a new part should be, when external connections are disconnected, 1M or more (measured by a 500V megger, at 20°C).
Protection devices	Oil level alarm	Operation of the alarm device. Check operation of float, electrical contacts, auxiliary relay, alarm, and sensing circuit.	Once/year	Check float for smooth operation. Replace excessively worn parts or defective contacts.	
	Congestion alarm device	Operation of the congestion alarm. Check float, electrical contacts, auxiliary relay, alarm, and sensing circuits.	Once/year	Check if the sensing of congestion is normally performed after the preset operation time of the relay.	It is desirable to set the time-limit to be approx. 2 times of time required to switch one tap.
	Others	Operating condition of other parts.	Once/year		If particular protection devices are installed, observe their instruction manual.
	Mechanical parts	Check leakage, irregular noise, rust, or loose parts.	Once/year	Replacement of packings in jointed parts, tighten jointed parts, and remove rust.	

Device Division	Part to Check	Check Item	Check Interval	Remedy	Remarks
	Pressure gauge	Check accuracy.	Once/2 years	Allowable tolerance of the gauge accuracy is ± 1 division of the smallest graduation.	
	Filtration meter		By necessary	Replace the meter if the filtration pressure becomes twice or more of the specified pressure.	
	Insulation oil	Check dielectric strength.	By necessary	If the dielectric strength of oil is still defective after filtration, replace.	Nominal dielectric strength of oil is 20kV.

Appendix 3–3

A DETERMINATION OF 30 KV STEEL TOWERS IN CENTRAL JAVA TO 70 KV SYSTEM

PREFACE

In this brochure, applicability of steel towers existing in the 30KV transmission lines in the Central Java to the 70KV system was determined. According to our calculation, the steel towers are applicable to the 70KV system provided that the towers are slightly modified and the present conductors, copper, 50mm² in area, are replaced with those of 75mm² in area. The determination, however, had to base on assumptions to a considerable extent and calculations were made on two typical steel tower structures (Fig. 1 and Fig. 2), because we did not have sufficient information on initial design conditions of the existing system. The calculation method is also applicable to other tower types, however, these calculation made under such restricted conditions, should be used to determine only the basic policy on the construction, and much more detailed data should be prepared for implementation of the project and recalculation of those described in this brochure.

1. INSULATION DESIGN AND CLEARANCE

1.1 NUMBER OF INSULATORS

Design conditions used for determination of number of required insulators for the voltage boost are as follows.

(1) To use the most common suspension type insulators, 254mm x 146mm.

(2) Since typhoon and salt damage derived therefrom are very scarece in Java Island, deterioration of withstanding voltage due to contamination of insulator was neglected.

(3) Insulation strength required for insulators is to withstand BIL and switching surge voltage.

a) BIL of a 70KV system is 400KV.

The rated impulse flashover voltage of a suspension insulators* is 415KV for a 4-string insulator and 495KV for a 5-string insulator. Assuming the ratio of withstanding voltage to flashover voltage to be 0.9, the withstanding voltage of the insulators becomes 372KV or

445KV for the 4- or 5-string insulator. Therefore, 5-string insulators are required to withstand the BIL, 400KV.

* Rated value in EEI-NEMA.

b) It is a common practice, in a 70KV non-effective neutral grounding system, to determine the switching surge voltage factor to be 3.3. The switching surge voltage is calculated as;

Switching surge voltage = Maximum allowable voltage

$$\times \frac{\sqrt{2}}{\sqrt{3}} \times 3.3 = (70 \times 1.2) \times \frac{\sqrt{2}}{\sqrt{3}} \times 3.3 = 226\text{KV}$$

Experimental data in Japan shows that the withstanding voltage of suspension insulators to the switching surge is 220KV for 3-string insulator and 290KV for 4-string insulator. Therefore, a 4-string insulator is sufficient to withstand the switching surge voltage of 226KV, however, it is not desirable to design a system at the minimum rating. In order to provide a sufficient operational margin, or to protect the transmission from flashover even if an insulator in the strings may cause deterioration of insulation resistance, it is recommended to use 5-string insulators in the system.

(4) As a conclusion, a string of five suspension type insulators, sized 254mm x 146mm, should be used to boost the transmission voltage to 70KV.

1.2 CLEARANCE DISTANCE

(1) The Clearance of wire from supporting material should be determined in coordination with insulation level of insulators.

In this respect, the Clearance in normal operation (normal clearance) becomes a rod gap coordinating to the impulse flashover voltage of insulators. The rod gap of which impulse flashover voltage is equal to the impulse flashover voltage of 5-string insulator, i.e. 495KV, is 750mm*. The normal clearance should, therefore, be 750mm.

* A value shown in EEI-NEMA.

(2) The Clearance when insulators are swung by a strong wind and approach to the supporting material (clearance for abnormal case) need not to be so large, or 750mm, since such abnormal conditions will not occur so frequently, but line insulation must, in any condition, withstand the switching surge voltage. In this respect, the abnormal case clearance, should be 450mm, the lod gap of which withstands 226KV, i.e. the switching surge voltage at 70KV line as is described in CIGRE S.C. No.15.

1.3 CLEARANCE DIAGRAM

In accordance with practice in Japan, the clearance diagram for suspension insulators was drawn in the following conditions.

(1) For swinging angle of insulator string between 0 and 20 degrees, the normal clearance must be reserved.

(2) For swinging on insulator string by 40 degrees, arithmetic average of the normal and abnormal clearances must be held.

(3) The abnormal clearance must be held at the swinging of insulator string by 55 degrees.

The clearance diagram drawn for a string of insulator, which is composed of five insulators and is 146mm x 5 + 300mm in total length, is shown in Fig. 3.

NOTE: In Japan, the maximum wind velocity rated for design of transmission line is 40m/s, on the other hand, the rating allows use of the suspension type steel tower provided that the swinging angle of insulator string is retained within 55 degrees at a wind velocity of 20m/s. Applying the Japanese rating to your system directly, the maximum swinging angle in Java, where the maximum wind velocity is smaller than Japan, may be reduced. However, if the clearance should be set smaller, or the cross-arm length is shortened, minimum distance for safety of operators climbing on the tower may not be assured, and theoretical base of the rating which allows use of reduced wind velocity for calculation of the clearance is not always clear. From these points of view, we recommend to use the swinging angle established through long experience in Japan.

1.4 DETERMINATION OF BASIC STRUCTURE

(1) Basic structure of tower top for TYPE-A and TYPE-B towers in Figs. 1 and 2, which is determined in accordance with the clearance diagram, is shown in Fig. 4.

(2) As shown in Fig. 4, the TYPE-B steel towers can be used for the 70KV system without modification of the basic structure.

(3) As for the TYPE-A towers, clearance required for the 70KV operation is insufficient. Vertical interval of cross-arms must be increased from 1500mm to 2250mm, and arm length (from the center line of Tower) must, also, be increased from 1700mm to 2000mm.

(4) Either of the following two methods may be used for modification of the TYPE-A towers, although both of these methods involve certain disadvantage in different phases.

a) To extend the tower top structure leaving the lowest cross-arm in the present position.

In this method, the present line height is almost retained, but the extension adversely affects the tower strength.

b) To lower the middle and bottom cross-arms in the present and leave the cross-arms for ground wire and top conductor at the position.

This method increases the tower strength, but the transmission line height is considerable lowered. Since the tower strength and transmission line height from the ground level are not clarified at present, the modification of TYPE-A towers will be determined for both the plans (a) and (b) in this brochure. (Refer to Fig. 1)

2. TRANSMISSION LINE DESIGN

2.1 TYPE AND SIZE OF CONDUCTORS

(1) Hard-drawn copper stranded conductor will be used for the following determination, and cross sectional area of the conductor will be increased from 500m^2 to 75mm^2. Galvanized steel stranded conductor, 35mm^2 in area, will be used for the overhead ground wire.

(2) Characteristics of Conductors

Type & Size	Com-position	Calcu-lated Cross Section Area	Exter-nal Dia-meter	Weight	Tensile Strength	Thermal Expan-sion Coeffi-cient	Elastic Modulas
	mm	mm^2	mm	kg/km	kg	/°C	kg/mm^2
Hard-drawn copper stranded, 50mm^2 in area	19/1.8	48.36	9.0	435.1	1,960	17x10^{-6}	12x10^3
Hara-drawn copper stranded, 75mm^2 in area	7/3.7	75.25	11.1	677.0	2,910	17x10^{-6}	12x10^3
Galvanized steel stranded, 35mm^2 in area	7/2.6	37.16	7.8	293.3	3,010	12x10^{-6}	17.5x10^3

2.2 DESIGN CONDITIONS

Design conditions used for the determination are as follows.

(1) In due consideration of the reported monthly average temperature in Java, 25.8 to 26.8°C and yearly average, 26.4°C, assumed the average temperature as 25°C.

(2) Determined the maximum wind velocity to be 20m/s, since typhoon is very scarce in Java.

(3) The maximum conductor temperature which is used to calculate the transmission line is rated to be 45°C in Japan where the average temperature is 15°C. For this calculation, the maximum conductor temperature was determined to be 55°C, since the average temperature of Java island is 10°C higher than that in Japan.

(4) Ice or snow coating to conductors is neglected in the calculation.

(5) In Japan, the safety factor of maximum working tension of conductor, with regard to specific tensile strength thereof and the hypothetical weather conditions, is rated to be 2.2. The safety factor in Japan was applied to the present calculation. In other words, the transmission lines were assumed to be installed so that they would hold the safety factor 2.2, with regard to the tensile strength, at temperature 25°C and wind velocity 20m/s.

(6) Sag of the overhead ground wire was also determined in accordance with the rating in Japan, that is, the ground wire is to be installed so that the wire maintain the sag of 80% of the sag of other wires.

(7) Span of the transmission line was assumed to be 300 meters.

2.3 MAXIMUM WORKING TENSION AND SAG

(1) The following formula which is developed approximating the catenary curve of the lines to a parabolic curve of the lines to a parabolic curve was used to calculate the sag and tension of the lines.

$$f_2^2 \left\{ f_2 - (K - \alpha t E) \right\} = M$$

$$d_2 = \frac{\delta q_2 S^2}{8 f_2}$$

where

$$f = \frac{T}{A}$$

$$\delta = \frac{W}{A}$$

$$K = f_1 - \frac{(q_1 \delta)^2 S^2 E}{24 f_1^2}$$

$$M = \frac{(q_2 \delta)^2 S^2 E}{24}$$

T : Tension of the wire (kg)

A : Cross Sectional Area of Wire Wire (mm^2)

W : Weight of Wire in a Unit Length (kg/m)

S : Line Span (m)

E : Elastic Modulas (kg/mm^2)

α : Thermal Expansion Coefficient of of Wire (/°C)

$q = \frac{\sqrt{W^2 + Wm^2}}{W}$

Wm : Wind Pressure in a Unit Wire Length (kg/m)

t : Difference of Reference Temperature and Calculating Temperature (°C)

d : Sag of Line (m)

Suffixes 1 and 2 represents, respectively, the reference and the calculation conditions.

(2) The wind pressure increase in proportion to square of wing velocity, and the wind pressure to a line at wind velocity of 40m/s is usually calculated as 100kg/m², in Japan. Therefore, the wind pressure to a line when wind velocity is 20m/s is calculated as;

$$100\text{kg/m}^2 \times (\frac{20\text{m/s}}{40\text{m/s}}) = 25\text{kg/m}$$

(3) Calculation of sag of a 50mm² hard-drawn copper stranded conductor

a) Maximum working tension: 1,960kg/2.2 = 890kg

b) Sag and tension at 25 °C

$$f_1 = \frac{890}{48.36} = 18.40\text{kg/mm}^2$$

$$\delta = \frac{0.4351}{48.36} = 0.0090\text{kg/m-mm}^2$$

$$Wm = 25 \times 9.0 \times 10^{-3} = 0.225\text{kg/m}$$

$$q_1 = \frac{\sqrt{0.4351^2 + 0.225^2}}{0.4351} = 1{,}125 \qquad q_2 = 1{,}000$$

$$t = 25°\text{C} = 0$$

$$k = 18.40 - \frac{(1{,}125 \times 0.009)^2 \times 300^2 \times 12 \times 10^3}{24 \times 18.40^2}$$

$$= 18.40 - 13.61$$

$$= 4.79$$

$$M = \frac{(1 \times 0.009)^2 \times 300^2 \times 12 \times 10^3}{24} = 3650$$

$$f_2^2 \left\{ f_2 - (4.79 - 17 \times 10^{-6} \times 0 \times 12 \times 10^3) \right\} = 3650$$

Therefore

$$f_2 = 17.17\text{kg/mm}^2 \qquad T_2 = 17.17 \times 48.36 = 830\text{kg}$$

$$d_2 = \frac{0.009 \times 1 \times 300^2}{8 \times 17.17} = \underline{5.90\text{m}}$$

c) Sag and Tension at 55°C

$t = 55°C - 25°C = 30°C$, and other conditions are identical to those used in b).

$$f_2^2 \left\{ f_2 - (4.79 - 17 \times 10^{-6} \times 30 \times 12 \times 10^3) \right\} = 3650$$

Therefore,

$$f_2 = 14.97\text{kg/mm}^2 \qquad T_2 = 14.97 \times 48.36 = 724\text{kg}$$

$$d_2 = \frac{0.009 \times 1 \times 300^2}{8 \times 14.97} = \underline{6.76\text{m}}$$

(4) Calculation of sag of a 75mm² hard-drawn copper stranded conductor (No. 1)

a) Maximum working tension; 2910kg/2.2 = $\underline{1320\text{kg}}$

b) Sag and tension at 25°C;

$$f_1 = \frac{1320}{75.25} = 17.85\text{kg/mm}^2$$

$$\delta = \frac{0.677}{75.25} = 0.0090\text{kg/m-mm}^2$$

$$Wm = 25 \times 11.1 \times 10^{-3} = 0.2775\text{kg/m}$$

$$q_1 = \frac{\sqrt{0.677^2 + 0.2775^2}}{0.677} = 1{,}080$$

Similar to the case in (3), $t = 0$

$$K = 17.85 - 13.75 = 3.83 \qquad M = 3650$$

$$f_2^2 \left\{ f_2 - (3.83 - 0) \right\} = 3650$$

Therefore,

$$f_2 = 16.78\text{kg/mm}^2 \qquad T_2 = 16.78 \times 75.25 = 1262\text{kg}$$

$$d_2 = \frac{0.009 \times 1 \times 300^2}{8 \times 16.78} = \underline{6.04\text{m}}$$

c) Sag and tension at 55℃;

t = 55°C – 25°C = 30°C, other conditions are identical to those used in b).

$$f_2^2 \left\{ f_2 - (3.83 - 17 \times 10^{-6} \times 30 \times 12 \times 10^3) \right\} = 3650$$

Therefore,

$$f_2 = 14.97\text{kg/mm}^2 \qquad T_2 = 14.97 \times 75.25 = 1127\text{kg}$$

$$d_2 = \frac{0.009 \times 1 \times 300^2}{8 \times 14.97} = \underline{6.76\text{m}}$$

(5) Sag and tension of galvanized steel stranded conductor, 35mm² in area

a) Sag of this wier should be 80% of that of the conductor wire which is 5.90m for the 50mm² wire and 6.04m for the 75mm² wire at 25°C. Therefore, the sag of the overhead ground wire is calculated as 5.90m x 0.8 = 4.72m.

b) Maximum working tension

$$\delta = \frac{0.2933}{37.16} = 0.00794\text{kg/m-mm}^2$$

$$Wm = 25 \times 7.8 \times 10^{-3} = 0.195\text{kg/m}$$

$$q_1 = 1. \qquad q_2 = \frac{\sqrt{0.2933^2 + 0.195^2}}{0.2933} = 1.201$$

$$f_1 = \frac{\delta q_1 S^2}{8d_1} = \frac{0.00794 \times 1 \times 300^2}{8 \times 4.72} = 18.91\text{kg/mm}^2$$

$$K = 18.91 - \frac{(1 \times 0.00794)^2 \times 300^2 \times 17.5 \times 10^3}{24 \times 18.91^2}$$

$$= 18.91 - 11.52 = 7.39$$

$$M = \frac{(1.201 \times 0.00794)^2 \times 300^2 \times 17.5 \times 10^3}{24} = 5955$$

$$t = 0$$

$$f_2^2 \left\{ f_2 - (7.39 - 0) \right\} = 5955$$

Therefore,

$f_2 = 20.96\text{kg/mm}^2$ $\qquad$ $T_2 = 20.96 \times 37.16 = \underline{779\text{kg}}$

$$\text{Safety Factor} = \frac{3010}{779} = 3.86$$

(6) Calculation of sag of 75mm² hard-drawn copper stranded conductor (No. 2 .... for reduced working tension)

In due consideration of a possibility that the strength of existing towers may be insufficient to bear the increase of conductor size, sag of the wires, when the maximum working tension of wires is reduced by that used for the existing 50mm² wires, is calculated as follows;

a) Maximum working tension; <u>890kg</u>

b) Sag and tension at 25°C;

$$f_1 = \frac{890}{75.25} = 11.83\text{kg/mm}^2$$

$\delta = 0.0090\text{kg/m-mm}^2$ $\qquad$ $q_1 = 1.080$ $\qquad$ $t = 0$

$$K = 11.83 - \frac{(1.080 \times 0.009)^2 \times 300^2 \times 12 \times 10^3}{24 \times 11.83^2}$$

$$= 11.83 - 30.30 = -18.47$$

$$M = 3650$$

$$f_2^2 \left\{ f_2 - (-18.47 - 0) \right\} = 3650$$

Therefore,

$f_2 = 11.10\text{kg/mm}^2$ $\qquad$ $T_2 = 11.10 \times 75.25 = 835\text{kg}$

$$d_2 = \frac{0.009 \times 1 \times 300^2}{8 \times 11.10} = \underline{9.13\text{m}}$$

c) Sag and tension at 55°C;

$$t = 55°C - 25°C = 30°C$$

$$f_2^2 \left\{ f_2 - (-18.47 - 17 \times 10^{-6} \times 30 \times 12 \times 10^3) \right\} = 3650$$

Therefore,

$$f_2 = 10.23\text{kg/mm}^2 \qquad T_2 = 10.23 \times 75.25 = 770\text{kg}$$

$$d_2 = \frac{0.009 \times 1 \times 300^2}{8 \times 10.23} = \underline{9{,}90\text{m}}$$

d) Maximum working tension of galvanized steel stranded conductor

$$\text{Sag at } 25°C = 9.13 \times 0.8 = 7.30\text{m}$$

$$f_1 = \frac{\delta q_1 S^2}{8d_1} = \frac{0.00794 \times 1 \times 300^2}{8 \times 7.30} = 9.66\text{kg/mm}^2$$

$$K = 9.66 - \frac{(1 \times 0.00794)^2 \times 300^2 \times 17.5 \times 10^3}{24 \times 9.66^2}$$

$$= 9.66 - 44.19 = -34.53$$

$$M = 5955 \qquad t = 0$$

$$f_2^2 \left\{ f_2 - (-34.53 - 0) \right\} = 5955$$

Therefore,

$$f_2 = 11.39\text{kg/mm}^2 \qquad T_2 = 11.39 \times 37.16 = \underline{423\text{kg}}$$

3. STRENGTH OF STEEL TOWER

3.1 DESIGN CONDITIONS

(1) Basic design conditions used for determination of the tower strength are the following two types;

Normal condition;	Temperature 25°C, wind velocity 20m/s, and no breaking of wire.

Abnormal conditions; Temperature 25°C, wind velocity 20m/s, and breaking of ground wire or one of conductor wires.

(2) Combination of load, strength of individual members, margin in design value, and other details of the design were based on JEC-127 "Design standards for Power Transmission steel Tower" in Japan.

(3) Assumed loading conditions are;

Load Span:	300m
Load from vertical angle:	Ten per cent of the maximum working tension of power conductor and overhead ground wires.
Wind Pressure to Steel Tower:	In Japan, the wind pressure to the tower at wind velocity 40m/s is rated to be 290 kg/m². The wind pressure at wind velocity 20m/s is calculated as $290 \times (\frac{20}{40})^2 = 72.5 kg/m^2$.
Horizontal Angle:	3°
Unbalance in Tension:	Taking the reduction of tension due to slip of clamp or swinging of insulator string in consideration the unbalance in tension must not exceed 0.6 times of the maximum working tension.
Weight of Insulator string:	70kg per a string
Wind Pressure to Insulator String:	15kg per a string

(4) The structural strength calculation was conducted for the following five cases.

Case a : TYPE-A, original, and conductor size $50mm^2$
Case b : TYPE-B, plan "b", and conductor size $50mm^2$
Case c : TYPE-A, plan "b", and conductor size $75mm^2$
Case d : TYPE-A, plan "a", and conductor size $75mm^2$
Case e : TYPE-B, original, and conductor size $75mm^2$

3.2 STRUCTURAL CALCULATION

(1) Results of the structural calculations conducted based on the aforesaid conditions are shown in Figs. 5 to 14.

(2) To evaluate these figures, the following points must be taken in account.

a) In the columns "Max Stress", 100% of the normal stress or 67%, (1/1.5) of the abnormal stress, whichever larger, is described. Therefore, by determining strength of members and bolts so that it will satisfy the condition, S.F. = 1.0, they will directly satisfy the requirements in JEC-127 "Design Standards for Power Transmission steel Tower". (For cross-arm members, 100% of the abnormal stress is applied to the Max. Stress of these members.)

b) P in the columns "L" for main Post denotes pitch of panels.

c) Figures described in columns "P" and "q" shows stresses of a wire, conductor wire line or overhead ground wire, of which stress will become the largest when breaking of wire occured.

d) Members of the tower shown by thick lines in the steel tower diagram represent those to be newly added. For bolts used in the existing towers, we are not informed in detail of their size and number, the figures described are based on our assumption necessary for the structural strength calculation.

3.3 REINFORCEMENT

(1) As seen in Figs. 5 to 14, structural strength of tower members, both TYPE-A and TYPE-B, are sufficiently large to bear the size-up of conductors to 75mm^2 and voltage boosting to 70KV system, provided that the following partial modification.

a) TYPE-A Towers

Plan "a" : Extension of main structure by 1.5m, replacement of cross-arms, and change in arm position.
Plan "b" : Replacement of cross-arms and change of position thereof.

b) TYPE-B Towers: Modification is not required.

(2) Structural strength of TYPE-A towers is sufficiently large for modification plans a and b. The modification plan b will be easier to carry out, provided the transmission lines are retained sufficiently high.

(3) Replacement of bolts, however, may be necessary, if number and/or size of bolts are smaller than those described in the Stress Tables. (Since the size and number of bolts used in the existing towers are unknown, field investigation will be required)

(4) If the voltage boosting is to be carried out in different conditions from those described in these assumed conditions, for example, use of larger size conductors or towers are required to withstand larger wind velocity than 20m/s, the stress Tables in Figs. 5 to 14 must be re-calculated to meet the requirement, and further reinforcement may be required. (To ease calculation of structural strength for different load conditions, the Stress Table include table of unit strength.)

(5) Strength of towers other than TYPE-A and TYPE-B can be calculated in the same manner.

4. FOUNDATION STRENGTH

4.1 DESIGN CONDITIONS AND PREREQUISITIONS

(1) Loads applied to foundation of towers were limited to the compressive load and lifting (or Tensile) loads transmitted from the tower structure. The horizontal load of which value is comparatively small in these examples or towers which are small and to bear low wind velocity and load condition, was neglected, because normal concrete foundations are sufficiently strong to bear the horizontal load.

(2) It is assumed that the compressive load to the foundation is completely born by bearing power of soil below the foundation, whereas, the lifting load to foundation is also born by weight of the foundation, and weight of soil above the foundation (including friction of soil equivalently converted into gravity).

(3) In accordance with the JEC-127, "Design Standards for Power Transmission Steel Towers", safety factor of the foundation was determined to be 2.0 for normal (no breaking of wire) load and 2.0/1.5 for abnormal load (one wire broken).

(4) Calculation method of the foundation strength also based upon the formula described in the JEC-127, as follows.

Compressive Force : $\frac{q'}{F} \geqq \frac{C + G + Ws}{A}$

Lifting Force : $\frac{\gamma' (Ve - V'c) + G}{F} \geqq T$

where q' : Compression strength of soil

F : Safety factor

C : Compressive force derived from upper structure calculated from loading conditions.

G : Weight of foundation (t).

W_2 : Weight of soil directly above foundation (t)

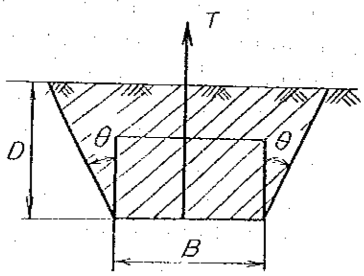
A : Bottom surface area of foundation. (m^2)

T : Lifting force derived from upper structure, calculated from the loading conditions. (t)

γ' : Equivalent weight of soil in unit volume (t/m^3)

Vc : Volume of soil in the frustum of pyramid above foundation and calculated from the effective angle of soil. (m^3)
For a foundation of which bottom surface is a square, the volume Vc is calculated as:
$Vc = D\,(B^2 + 2BD\tan\theta + \frac{4}{3}D^2\tan^2\theta)$

Vi : Volume of foundation under the ground level. (m^3)



(5) Type of soil on the site was assumed to be equal to type A in the following table, described in JEC-127.

Type of Soil		Effective Angle (θ) against Lifting Force	Equivalent Weight of Soil in Unit Volume γ' (t/m^3)	Strength of Soil against Compression bearing q' (t/m^2)
Type A	Under-ground water level is sufficiently low, highly resistive soil. Mountain, hard farm, or waste land.	30°	1.6	60
Type B	Highly resistive soil, contains a small under-ground water. Soft farm.	20°	1.5	40
Type C	Low resistive soil, underground water level is high. Ordinary rice field.	10°	1.4	20
Type D	Non resistive soil, under-ground water level is high. Normally piling is required.	0°	1.3	10

(6) Referring to the steel tower diagram supplied from Indonesia, type of the foundations are assumed to be the square concrete shown in Fig. 15.

(7) Structural strength of foundations was calculated in the following two cases.

Case d: TYPE-A tower, modified in plan a, and conductor size 75mm^2.

Case e: TYPE-B tower, and conductor size 75mm^2.

4.2 STRUCTURAL CALCULATION

(1) From foundation stress shown in Fig. 6 and 10, the compressive and lifting loads transmitted from tower are calculated as shown in the table below.

Case		Compressive Load C (t)	Lifting Load T (t)
d	TYPE–A	8.80	7.22
e	TYPE–B	5.67	3.08

Note: The loads shown in the table represent the 100% of normal load or 100/1.5% of abnormal load, whichever larger. Therefore calculation using the safety factor 2.0 satisfies requirement shown in item 4.1 (3).

(2) Constants of soil were, based on item 4.1 (5), assumed as follows.

$\theta = 30°$, $\gamma' = 1.6\ (t/m^3)$ $q' = 60\ (t/m^2)$

(3) Volume and weight of foundation

Unit volume weight of concrete foundation including steel structure is assumed to be 2.3 t/m^3.

Case d: From Fig. 15,

$$\text{Volume of foundation } Vc = \frac{1}{3} \times 2.5 \times (1.1^2 + 1.1 \times 0.25 + 0.25^2) = 1.29m^3$$

$$\text{Weight of foundation } G = 1.29 \times 2.3 = 2.97^t$$

Earth covered volume of foundation V'c is;

$$V'c = 1.29 - \text{volume of foundation above ground} \fallingdotseq 1.29 - 0.25^2 \times 0.1 \fallingdotseq 1.28m^3$$

Case e: From Fig. 15,

$$\text{Volume of foundation } Vc = 2.0^2 \times 0.4 + \frac{1}{3} \times 1.2$$

$$\times (2.0^2 + 2.0 \times 0.6 + 0.6^2)$$

$$+ \frac{1}{3} \times 1.1 \times (0.6^2 + 0.6 \times 0.4 + 0.4^2)$$

$$= 1.60 + 2.22 + 0.28 = 4.10\text{m}^3$$

$$\text{Weight of foundation } G = 4.10 \times 2.3 = 9.43^t$$

Earth covered volume of foundation V'c is;

$V'c = 4.10 -$ volume of foundation above ground
$\fallingdotseq 4.10 - 0.4^2 \times 0.1 \fallingdotseq 4.08\text{m}^3$

(4) Weight of soil directly above bottom surface of foundation

The volume of soil above the foundation bottom surface is calculated by subtracting the earth covered foundation volume from the product of bottom surface area and height of foundation. The soil weight Ws is calculated by multiplying the specific weight of soil γ' and the soil volume.

Case d: Soil volume above foundation bottom surface
$= 1.1^2 \times 2.5 - 1.28 = 1.75\text{m}^3$
Soil weight Ws "
$= 1.75 \times 1.6 = 2.80^t$

Case e: Soil volume above foundation bottom surface
$= 2.0^2 \times 2.7 - 4.08 = 6.72\text{m}^3$
Soil weight Ws "
$= 6.72 \times 1.6 = 10.74^t$

(5) Volume of frustum of pyramid above the base surface of foundation calculated from the effective angle of soil.

Case d: $$Ve = D\,(B^2 + 2BD\tan\theta + \frac{4}{3} D^2 \tan^2\theta)$$

$$= 2.5 \times (1.1^2 + 2 \times 1.1 \times 2.5\tan 30° + \frac{4}{3}$$

$$\times 2.5\tan^2 30°) = 17.9\text{m}^3$$

Case e: $Ve = 2.7 \times (2.0^2 + 2 \times 2.0 \times 2.7\tan 30° + \frac{4}{3} \times 2.7^2 \tan^2 30°) = 36.3m^3$

(6) Foundation strength in case d

Compression Strength:

$$\frac{q'}{F} = \frac{60(t/m^2)}{2} = 30\ (t/m^2)$$

$$\frac{C + G + Ws}{A} = \frac{8.80^{(t)} + 2.97^{(t)} + 2.80^{(t)}}{1.1^2 (m^2)} = 12.04$$

Therefore, $\frac{q'}{F} > \frac{C + G + Ws}{A}$ O.K.

The foundation strength is sufficiently larger than calculated compressive force.

Lifting Force Strength:

$$\frac{\gamma' (Ve - V'c) + G}{F} = \frac{1.6^{(t/m^3)} \times (17.9^{(m^3)} - 1.28^{(m^3)}) + 2.97^{(t)}}{2}$$

$$= 14.8^{(t)}$$

$T = 7.22^{(t)}$

Therefore, $\frac{\gamma'(Ve - V'c) + G}{F} > T$ O.K.

The lifting force strength of foundation is sufficiently larger than lifting force.

(7) Foundation strength in case e.

Compressive Strength:

$$\frac{q'}{F} = \frac{60(t/m^2)}{2} = 30(t/m^2)$$

$$\frac{C + G + Ws}{A} = \frac{5.67^{(t)} + 9.43^{(t)} + 10.74^{(t)}}{2.0^2 (m^2)} = 6.46^{(t)}$$

Therefore, $\frac{q'}{F} > \frac{C + G + Ws}{A}$ O.K.

The compressive strength of the foundation is sufficiently larger than applied compression.

Lifting Força Strength:

$$\frac{\gamma'(Ve - V'c) + G}{F} = \frac{1.6^{(t/m^3)} \times (36.3^{(m^3)} - 4.08^{(m^3)}) + 9.43^{(t)}}{2}$$

$$= 30.4^{(t)}$$

$$T = 3.08^{(t)}$$

Therefore, $\frac{\gamma'(Ve - V'c) + G}{F} > T$ O.K.

The lifting force strength of foundation is sufficiently larger than lifting force to be applied.

4.3 REINFORCEMENT

(1) These calculations proved that reinforcement of foundation is not necessary for the Case d (TYPE-A tower, modified in plan a, and conductor size 75mm²) and Case e (TYPE-B tower, conductor size 75mm²). For the other design conditions (plan b, or smaller conductor size, 50mm²), the load applied to foundation is smaller than that used for the calculations, and much more structural margin is reserved.

(2) If the prerequisions used for the calculations differ with the existing conditions (for example, the soil type is class B or C, or the foundations size smaller), reinforcement of the foundations may be required. Particularly, the soil condition naturally differs with site location, and the classification of soil in Japan will not always be applicable to Indonesia. For implementation of the project, a further investigation of soil type and re-calculation of the foundation strength is recommended.

5. TRANSMISSION LINE HEIGHT ABOVE GROUND

5.1 SAG OF WIRE AT MAXIMUM TEMPERATURE

(1) Sag of wire at the maximum temperature (assumed to be 55°C) is calculated from item 2.3 "Maximum Working Tension and Sag".

(Span: 300m)

Conductor Size		Maximum Working Tension	Sag at 55°C (m)
Hard-drawn Copper Stranded	50mm²	890kg	6.76
"	75mm²	1320kg	6.76
(Reference Value) "	75mm²	890kg	(9.90)

(2) According to the table above, dip of wires is equally regardless of wire size, provided that they are strung with proper working tension. However, if the 75mm² wires are strung with the working tension equal to that of 50mm² wires, the dip increases by approximately 3.1m.

5.2 DETERMINATION OF TRANSMISSION LINE HEIGHT ABOVE GROUND

(1) Reduction of line height due to increase of insulator string length.

The voltage boosting requires increase of insulators from 3-string for the 30KV system to 5-string. Increase of two insulators per string increases total length of the string by 2 x 146mm, or 292mm. Further, the voltage boosting and re-stringing of wire may increase clamps and fixtures of larger size. The increase of insulator length will have to be determined to be 0.4m.

(2) Reduction of Transmission line Height due to Modification of Tower.

According to plan b, position of the middle and bottom cross-arms must be lowered, and transmission line height above ground is reduced.

The reduction in height, from Fig. 1, is 1.5m.

(3) Reduction of Line Height due to Increase of Sag.

As shown in item 5.1, sag of the 75mm² wire is equal to that of the existing 50mm² wires, so long as the wires are strung with the rated working tension.

Therefore, reduction of line height in this respect is zero.

(4) Total reduction of line height

Through the determinations in items (1), (2), and (3) above, the total reduction of line height is estimated as:

When TYPE-A towers are modified in plan b	1.9m
All other cases	0.4m

(5) Determination of line height above ground

Height of the bottom cross-arm, from Figs. 1 and 2, is 19.85m for TYPE-A towers and 18.5m for TYPE-B towers. Assuming the total length of insulator string as 1.0m, the minimum wire height above flat ground and span, 300m, is calculated as follows.

TYPE-A : (Height of Bottom Cross-Arm) – (Insulator Length)
– (Sag of Wire) = 19.85 – 1.0 – 6.76 ÷ 12.1m

TYPE-B : (Height of Bottom Cross-Arm) – (Insulator Length)
– (Sag of Wire) = 18.5 – 1.0 – 6.76 ÷ 10.3m

Taking the reduction in height described in item (4) into account, the transmission line height after the voltage boost becomes as follows.

TYPE-A tower, plan a:	11.7m
TYPE-A tower, plan b:	10.2m
TYPE-B tower:	9.9m

In accordance with Technical Standards for Electrical Devices in Japan, the transmission line height of 70KV line is rated as 6 meters for average area, and 5 meters for mountain or other sites to which men enters scarecely. The calculated heights above hold a sufficient margin when compared to the ratings.

6. CONCLUSION AND INVOLVED PROBLEMS

6.1 CONCLUSION

(1) Voltage boosting from 30KV to 70KV in the power transmission lines in Central Java and size-up of conductors from 50mm^2 to 75mm^2 are both possible.

(2) The following modifications must be conducted for the voltage boosting.

a) Increase number of insulators, 250mm standard suspension type, by 5-strings.

b) Cross-Arm length and position of TYPE-A towers must be changed, otherwise, clearance will become insufficient.

c) For towers other than TYPE-A and TYPE-B, structural strength of the tower and foundation must be determined, and if necessary structure must be modified. (Viewing from results of the calculations for towers TYPE-A and TYPE-B, however, the range of modification for other tower types will be comparatively small.)

d) Since initial design conditions, detailed structure, and ground conditions of the transmission lines are not sufficiently clear, field survey of routes, soil quality investigation, actual stringing condition of wires, sketch of tower structure, test boring, or other detailed investigations will be necessary in advance implementation of voltage boost construction.

The assumptional prerequisitions used in this determination and factors not described in this brochure must also be determined in accordance with the result of field investigation.

(3) For structural strength, the existing towers are estimated carrying a sufficient strength to bear much higher load, for example use of 100mm^2 wires.

6.2 INVOLVED PROBLEMS

As described before, the determination described in this brochure based upon assumptional prerequisitions to a considerable extent. For proper implementation of the project, a thorough investigation of actual data and verification with the conditions used in this determination report are essential. The major assumptions made for this determination are;

(1) Wind velocity that is assumed to be 20m/s. (The maximum average wind velocity for 10 minutes is rated to 40m/s in Japan which includes influence of typhoon and the largest value that may occur once in 50 years. We have been informed that no typhoon would occur in Indonesia, and reduced the maximum wind velocity by the value based on the information.)

(2) Stringing condition of wires, that is, safety factor 2.2, at temperature 25°C and wind velocity 20m/s. (According to the Technical Standards for Electrical Devices in Japan, the safety factor at average temperature and maximum wind velocity is rated as 2.2 for copper wire and 2.5 for other materials. The stringing tension may often reduced for particular purposes such as reduction of load to steel tower.)

(3) The determination based on ground condition where a comperatively unrolling hill site.

(In much more undurating sites, vertical angular load to tower will increase, and in rice fields, the strength of foundation must be increased.)

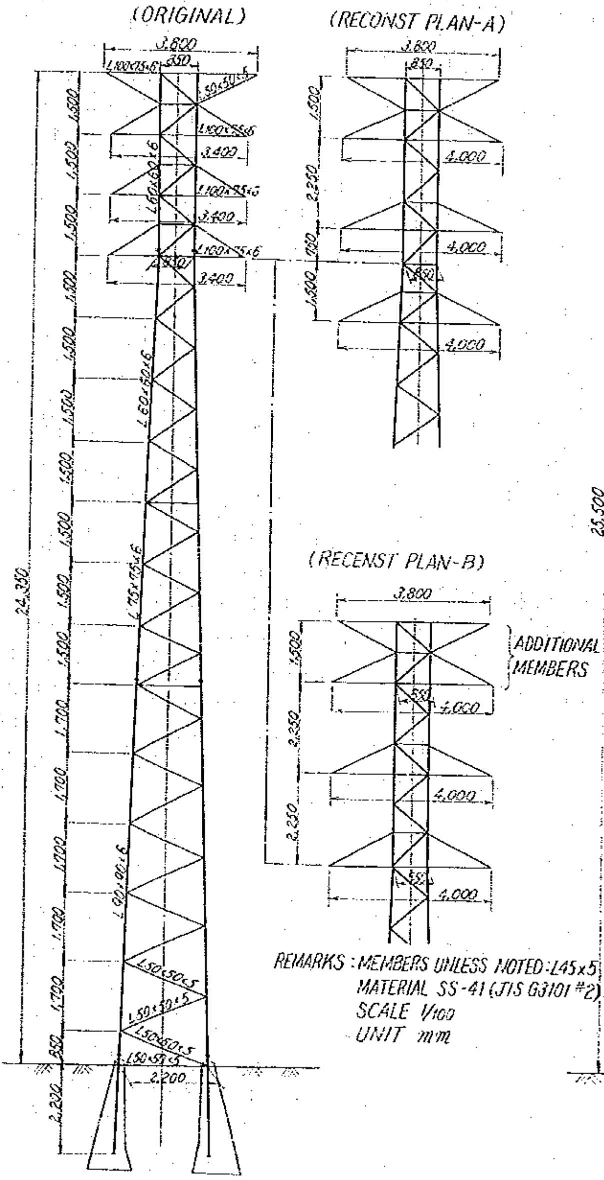
(4) For abnormal condition used in calculation of tower strength, breaking of an optional wire was assumed.

(5) Contamination of insulator was neglected in calculation of number of required insulators. (The insulator withstand normal voltage to ground against adhesion of slat up to approx. 70mg/insulator.)

(6) The load span, partial structure of steel tower (position of joints, or member size), dimensions of foundation, and temperature condition include a considerable extent of assumption.

(7) Other uncertain conditions were assumed based on ratings and practices in Japan.

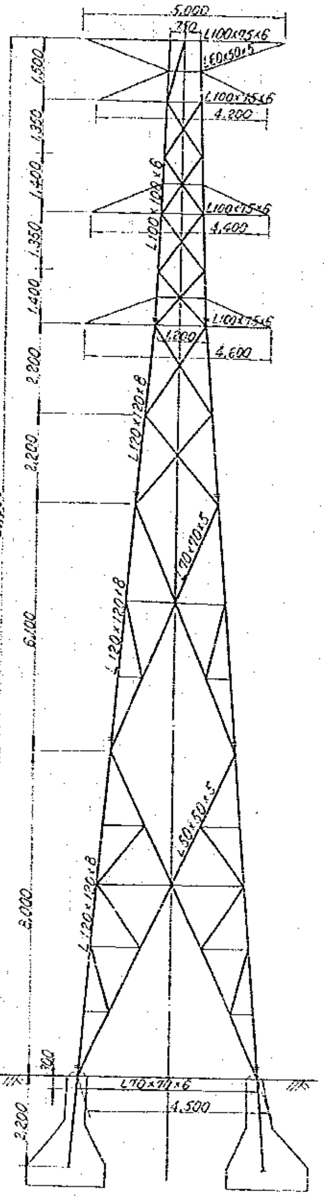
FIG. 1 TYPE-A TOWER
(SUSPENSION TYPE)



REMARKS : MEMBERS UNLESS NOTED : L45x5
MATERIAL SS-41 (JIS G3101 #2)
SCALE 1/100
UNIT mm

(TIANG SANGGA)

FIG. 2 TYPE-B TOWER
(SUSPENSION TYPE)



(TIANG PENEGANG)

FIG 3. CLEARANCE DIAGRAM

SCALE 1/100

UNIT mm

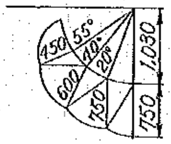
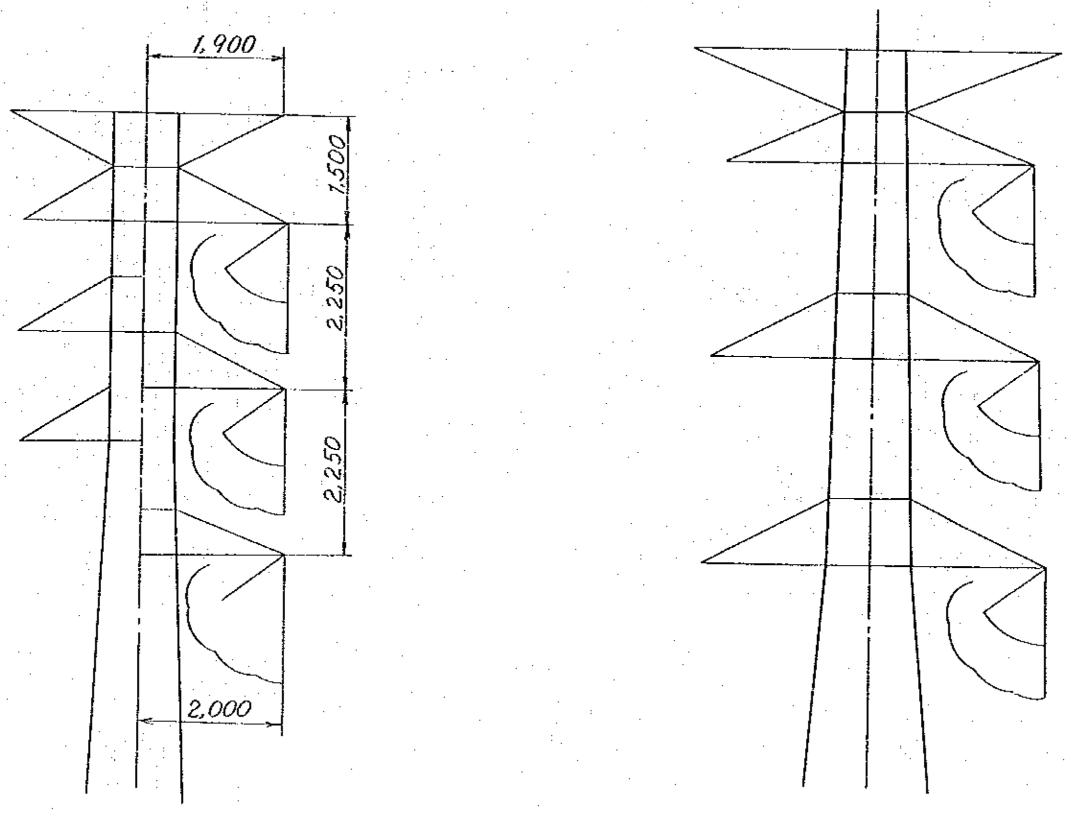


FIG 4. TAWER SPACING

SCALE 1/100

UNIT mm



TYPE-A

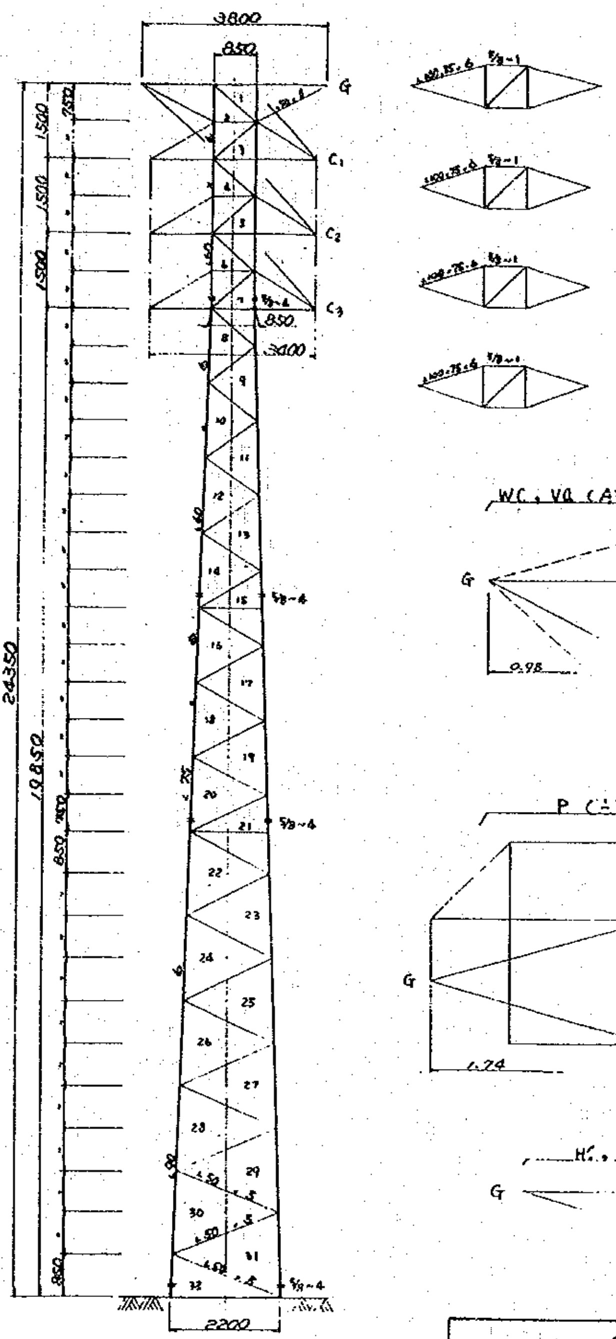
ORIGINAL RECONST PLAN

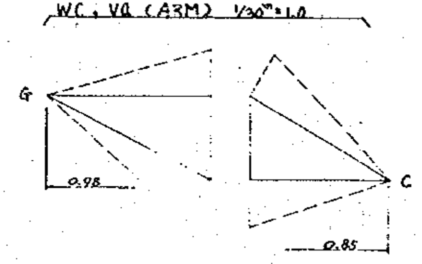
TYPE-B

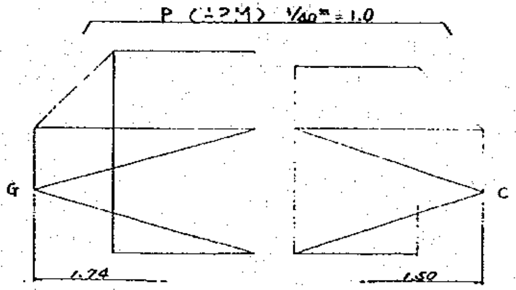
LOADING IN (kg)							
WEIGHT OF TOWER	WIND ON TOWER	VERTICAL LOAD	VERTICAL ANGLE	HORIZONTAL LOAD	HORIZONTAL ANGLE	WORKING TENSION	TORSION
WT	HT	WC	Va	HC	Ha	P	Q
1 LEG	1 FACE	1 LEG	1 LEG	1 FACE	1 FACE	1 FACE	1 FACE
	9	44	39	59	41	234	522
	15	103	45	83	47	267	534
	15	103	45	83	47	267	534
200	19	163	45	83	47	267	534
	21						
280	26						
	30						
360							
	34						
	39						
550							

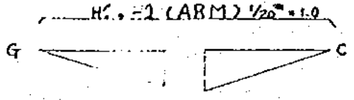
OUTLINE DRAWING AND STRESS DIAGRAMS FOR TYPE-A TOWER

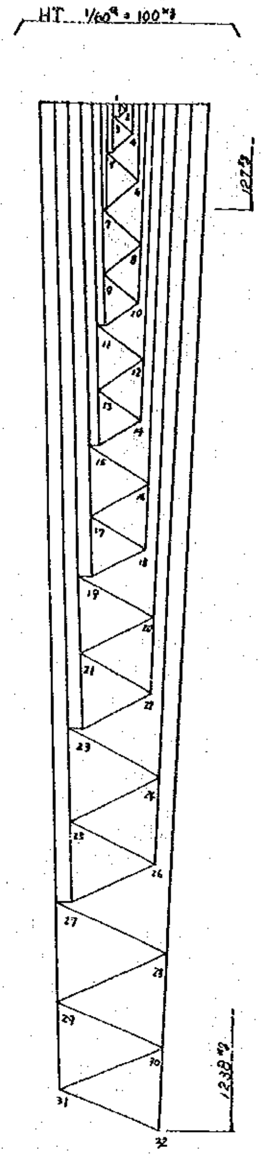
(SCALE 1/100)

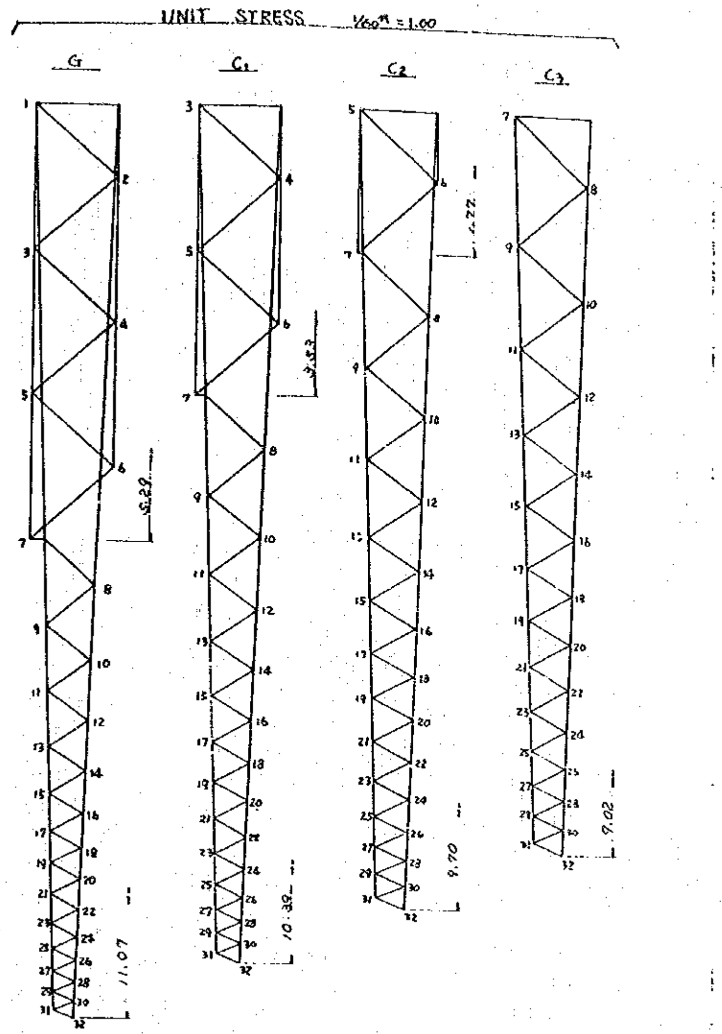



WC + Va (ARM) 1/30m = 1.0


P (ARM) 1/40m = 1.0


HC + Ha (ARM) 1/20m = 1.0


HT 1/60t = 100kg


UNIT STRESS 1/60t = 1.00

CALCULATION OF LOAD (kg)			
WEIGHT OF CONDUCTOR	G	0.2933 × 300	88
	C	0.4351 × 300 + 70	206
VERTICAL ANGLE	G	779 × 0.1	78
	C	890 × 0.1	89
WIND ON CONDUCTOR	G	25 × 7.8 × 10⁻³ × 300	59
	C	25 × 9.0 × 10⁻³ × 300 + 15	83
HORIZONTAL ANGLE	G	2 × 779 × 0.0262	41
	C	2 × 890 × 0.0262	47
WORKING TENSION	G	779 × 0.6	467
	C	890 × 0.6	534
TORSION	G	467 × 1.7 ÷ (2 × 0.85)	522
	C	534 × 1.7 ÷ (2 × 0.85)	534

DESIGN CONDITIONS		
VOLTAGE		30 KV
CIRCUITS		2 cct
SPAN		300 m
HORIZONTAL ANGLE		3°
VERTICAL ANGLE		0.1 P
WIND PRESSURE ON TOWER		72.5 kg/m²
〃 〃 ON CONDUCTOR		25 kg/m²
CONDUCTOR	KIND	50 mm²
	DIAMETER	9.0 mm
	UNIT WEIGHT	0.4351 kg/m
	MAX. TENSION	890 kg
GROUND WIRE	KIND	35 mm²
	DIAMETER	7.8 mm
	UNIT WEIGHT	0.2933 kg/m
	MAX. TENSION	779 kg
INSULATOR	KIND	254mm × 146m × 5
	WEIGHT	70 kg
	WIND ON INS.	15 kg

NOTES:

1. MEMBERS UNLESS NOTED L45 × 5
2. BOLTS UNLESS NOTED #1/2φ ~ 1
3. MATERIAL
   ALL MATERIAL IS "SS-41"
4. SCALE 1/100
5. UNIT mm
6. DATE 31-MAY-'69
7. CASE NO. A (TYPE A ORIGINAL COND. 50mm²)
8. DRAWING NO. 10-1

Fig-5

STRESS TABLE FOR TYPE-A TOWER

	MARK	UNIT STRESS					STRESS TABLE										TOTAL STRESS				EXISTING MEMBERS						REINFORCING MEMBERS										MARK	
											Hc		Ha		P	q	BROKEN WIRE CONDITION		NORMAL CONDITION	MAX. STRESS	STRENGTH OF MEMBERS						STRENGTH OF MEMBERS						STRENGTH OF BOLTS					
		G	C_1	C_2	C_3	$\Sigma_3^1 C$	WT	HT	Wc	Va	G	C	G	C	G = 234 C = 267	G = 522 C = 534	100 %	67 %			MEMBERS	L	LK	LK/R	STRENGTH	S.F	MEMBERS	L	LK	LK/R	STRENGTH	S.F	DIAM.	NO.	STRENGTH	S.F		
											59	83	41	47																								
MAIN POST	7	5.29	3.53	1.77		5.30	0.20	0.13	0.35	0.17	0.31	0.44	0.22	0.25	G 1.24		3.31	2.22	2.07	2.22	∟60×6	75	70	60	9.04	4.07		75	70				5/8	4	7.81	3.51	7	MAIN POST
	15	8.34	7.14	5.96	4.76	17.86	0.28	0.41	″	″	0.49	1.47	0.34	0.84	G 1.95		6.30	4.22	4.35	4.35	″	P150	P135	74	8.25	1.89		P150	P135				″	4	″	1.79	15	
	21	9.55	8.62	7.67	6.72	23.01	0.36	0.66	″	″	0.56	1.91	0.39	1.08	C_1 2.30		7.78	5.21	5.48	5.48	∟75×6	P150	P135	59	11.58	2.11		P150	P135				″	4	″	1.42	21	
	32	11.08	10.40	9.71	9.03	29.14	0.55	1.24	″	″	0.65	2.42	0.45	1.37	C_1 2.78		9.98	6.69	7.20	7.20	∟90×6	P170	P155	56	14.22	1.97		P170	P155				″	4	″	1.08	32	
BRACING	1 - 2	1.35						0.01			0.08		0.06		G 0.32	G 0.70	0.85	0.57	0.15	0.57	∟45×5	115	105	120	2.72	4.77		115	105				1/2	1	1.21	2.12	1 - 2	BRACING
	2 - 3	1.35						0.01			0.08		0.06		G 0.32	G 0.70	0.85	0.57	0.15	0.57	″	115	105	120	″	4.77		115	105				″	1	″	2.12	2 - 3	
	3 - 4	1.35	1.35			1.35		0.03			0.08	0.11	0.06	0.06	C_1 0.36	C_1 0.72	1.06	0.71	0.34	0.71	″	115	105	120	″	3.83		115	105				″	1	″	1.70	3 - 4	
	4 - 5	1.35	1.35			1.35		0.03			0.08	0.11	0.06	0.06	C_1 0.36	C_1 0.72	1.06	0.71	0.34	0.71	″	115	105	120	″	3.83		115	105				″	1	″	1.70	4 - 5	
	5 - 6	1.35	1.35	1.35		2.70		0.05			0.08	0.22	0.06	0.13	C_2 0.36	C_2 0.72	1.26	0.84	0.54	0.84	″	115	105	120	″	3.24		115	105				″	1	″	1.44	5 - 6	
	6 - 7	1.35	1.35	1.35		2.70		0.05			0.08	0.22	0.06	0.13	C_2 0.36	C_2 0.72	1.26	0.84	0.54	0.84	″	115	105	120	″	3.24		115	105				″	1	″	1.44	6 - 7	
	7 - 8	0.83	0.98	1.10	1.27	3.35		0.06			0.05	0.28	0.03	0.16	C_3 0.34	C_3 0.68	1.26	0.84	0.58	0.84	″	115	105	120	″	3.24		115	105				″	1	″	1.44	7 - 8	
	8 - 9	0.76	0.90	1.04	1.16	3.10		0.06			0.04	0.26	0.03	0.15	C_1 0.31	C_3 0.62	1.16	0.78	0.54	0.78	″	115	105	120	″	3.48		115	105				″	1	″	1.55	8 - 9	
	9 - 10	0.70	0.83	0.95	1.10	2.88		0.06			0.04	0.24	0.03	0.14	0.29	0.59	1.10	0.74	0.51	0.74	″	120	110	126	2.52	3.40		120	110				″	1	″	1.63	9 - 10	
	10 - 11	0.65	0.77	0.90	1.01	2.68		0.05			0.04	0.22	0.03	0.13	0.27	0.54	1.01	0.68	0.47	0.68	″	125	115	132	2.33	3.42		125	115				″	1	″	1.78	10 - 11	
	11 - 12	0.61	0.73	0.86	0.95	2.54		0.07			0.04	0.21	0.02	0.12	0.25	0.51	0.97	0.65	0.46	0.65	″	130	115	132	″	3.58		130	115				″	1	″	1.86	11 - 12	
	12 - 13	0.58	0.68	0.80	0.90	2.38		0.07			0.03	0.20	0.02	0.11	0.24	0.48	0.91	0.61	0.43	0.61	″	130	115	132	″	3.82		130	115				″	1	″	1.98	12 - 13	
	13 - 14	0.55	0.65	0.75	0.85	2.25		0.06			0.03	0.19	0.02	0.11	0.23	0.45	0.86	0.58	0.41	0.58	″	135	120	137	2.16	3.72		135	120				″	1	″	2.08	13 - 14	
	14 - 15	0.50	0.60	0.70	0.80	2.10		0.06			0.03	0.17	0.02	0.10	0.21	0.43	0.84	0.56	0.38	0.56	″	140	125	143	1.99	3.55		140	125				″	1	″	2.16	14 - 15	
	15 - 16	0.49	0.57	0.68	0.78	2.03		0.09			0.03	0.17	0.02	0.10	0.21	0.42	0.83	0.56	0.41	0.56	″	145	130	149	1.83	3.27		145	130				″	1	″	2.16	15 - 16	
	16 - 17	0.45	0.55	0.64	0.74	1.93		0.08			0.03	0.16	0.02	0.09	0.20	0.40	0.78	0.52	0.38	0.52	″	150	135	155	1.69	3.25		150	135				″	1	″	2.32	16 - 17	
	17 - 18	0.44	0.53	0.61	0.70	1.84		0.08			0.03	0.15	0.02	0.09	0.19	0.37	0.74	0.50	0.37	0.50	″	155	140	160	1.59	3.18		155	140				″	1	″	2.42	17 - 18	
	18 - 19	0.41	0.50	0.59	0.66	1.75		0.08			0.02	0.15	0.02	0.08	0.18	0.35	0.70	0.47	0.35	0.47	″	160	145	166	1.47	3.13		160	145				″	1	″	2.57	18 - 19	
	19 - 20	0.40	0.48	0.58	0.64	1.70		0.10			0.02	0.14	0.02	0.08	0.17	0.34	0.70	0.47	0.36	0.47	″	165	150	172	1.37	2.92		165	150				″	1	″	2.57	19 - 20	
	20 - 21	0.39	0.46	0.55	0.61	1.62		0.10			0.02	0.13	0.02	0.08	0.16	0.33	0.68	0.46	0.35	0.46	″	170	155	178	1.28	2.78		170	155				″	1	″	2.63	20 - 21	
	21 - 22	0.38	0.45	0.53	0.60	1.58		0.10			0.02	0.13	0.02	0.07	0.16	0.32	0.66	0.44	0.34	0.44	″	175	160	183	1.21	2.75		175	160				″	1	″	2.75	21 - 22	
	22 - 23	0.37	0.43	0.50	0.58	1.51		0.10			0.02	0.13	0.02	0.07	0.15	0.31	0.65	0.44	0.34	0.44	″	180	160	183	″	2.75		180	160				″	1	″	2.75	22 - 23	
	23 - 24	0.35	0.41	0.49	0.55	1.45		0.13			0.02	0.12	0.01	0.07	0.15	0.29	0.64	0.43	0.35	0.43	″	185	165	189	1.14	2.65		185	165				″	1	″	2.81	23 - 24	
	24 - 25	0.34	0.40	0.46	0.54	1.40		0.13			0.02	0.12	0.01	0.07	0.14	0.29	0.64	0.43	0.35	0.43	″	195	175	200	1.02	2.37		195	175				″	1	″	2.81	24 - 25	
	25 - 26	0.32	0.38	0.45	0.50	1.33		0.12			0.02	0.11	0.01	0.06	0.13	0.27	0.59	0.40	0.32	0.40	″	200	180	206	0.96	2.40		200	180				″	1	″	3.02	25 - 26	
	26 - 27	0.31	0.36	0.44	0.49	1.29		0.12			0.02	0.11	0.01	0.06	0.13	0.26	0.58	0.39	0.32	0.39	″	205	185	212	0.90	2.30		205	185				″	1	″	3.10	26 - 27	
	27 - 28	0.30	0.35	0.43	0.46	1.24		0.15			0.02	0.10	0.01	0.06	0.12	0.25	0.57	0.40	0.34	0.40	″	210	190	218	0.85	2.12		210	190				″	1	″	3.02	27 - 28	
	28 - 29	0.29	0.34	0.42	0.45	1.21		0.15			0.02	0.10	0.01	0.06	0.12	0.24	0.58	0.39	0.34	0.39	″	215	195	223	0.81	2.07		215	195				″	1	″	3.10	28 - 29	
	29 - 30	0.28	0.33	0.40	0.44	1.17		0.14			0.02	0.10	0.01	0.05	0.12	0.24	0.56	0.38	0.32	0.38	∟50×5	220	200	205	1.08	2.84		220	200				″	1	″	3.18	29 - 30	
	30 - 31	0.27	0.32	0.39	0.43	1.14		0.14			0.02	0.09	0.01	0.05	0.11	0.23	0.54	0.36	0.31	0.36	″	225	205	210	1.02	2.83		225	205				″	1	″	3.36	30 - 31	
	31 - 32	0.26	0.31	0.39	0.42	1.11		0.13			0.02	0.09	0.01	0.05	0.11	0.22	0.52	0.35	0.30	0.35	″	230	205	210	″	2.91		230	205				″	1	″	3.46	31 - 32	
ARM	G MAIN	AV 1.02		AP 1.82		AH 0.52			-0.09	-0.08	0.03		0.02		0.85		-1.07 0.90			-1.07 0.90	∟100×75×6	155	140	87	10.66	11.14		155	140				5/8	1	1.95	1.82	MAIN	ARM
	G TIE	1.13							0.10	0.09									0.19	0.19	∟50×5	170	155	159	1.80	9.47		170	155				1/2	1	1.21	6.34	TIE G	
	G DIAG			0.99											0.42		0.42	0.28		0.28	∟45×5	120	110	126	2.52	9.00		120	110				″	1	1.21	4.32	DIAG	
	C MAIN	0.90		1.59		0.53			0.19	0.08		0.04		0.02	0.85		1.18			1.18	∟100×75×6	135	120	75	9.72	8.23		135	120				5/8	1	1.95	1.65	MAIN	
	C TIE	-1.03							-0.21	-0.09									-0.30	-0.30	∟45×5	150	135	155	4.06	13.52		150	135				1/2	1	1.21	4.04	TIE C	
	C DIAG			0.71											0.38		0.38	0.25		0.25	″	120	110	126	2.52	10.08		120	110				″	1	1.21	4.84	DIAG	
FOUND.	comp.	11.07	10.39	9.70	9.02	29.11	0.55	1.24	0.35	0.17	0.65	2.42	0.45	1.37	C_1 2.77		9.37	6.68	7.20	7.20																	comp.	FOUND.
	up-lift	″	″	″	″	″	– ″	–	– ″	0	″	″	″	″	″		8.00	5.36	5.23	5.36																	up-lift	

COMBINATION OF STRESS

MEMBERS	CONDITIONS		WT	HT	WC	Va	HC	Ha	P	q
MAIN POST	NORMAL		○	○	○	○	○	○		
	ABNORMAL		○	○	○	○	○	○	○	
BRACING	NORMAL	FRONT		○			○	○		
		SIDE		○						
	ABNORMAL	FRONT		○			○	○		○
		SIDE		○					○	○

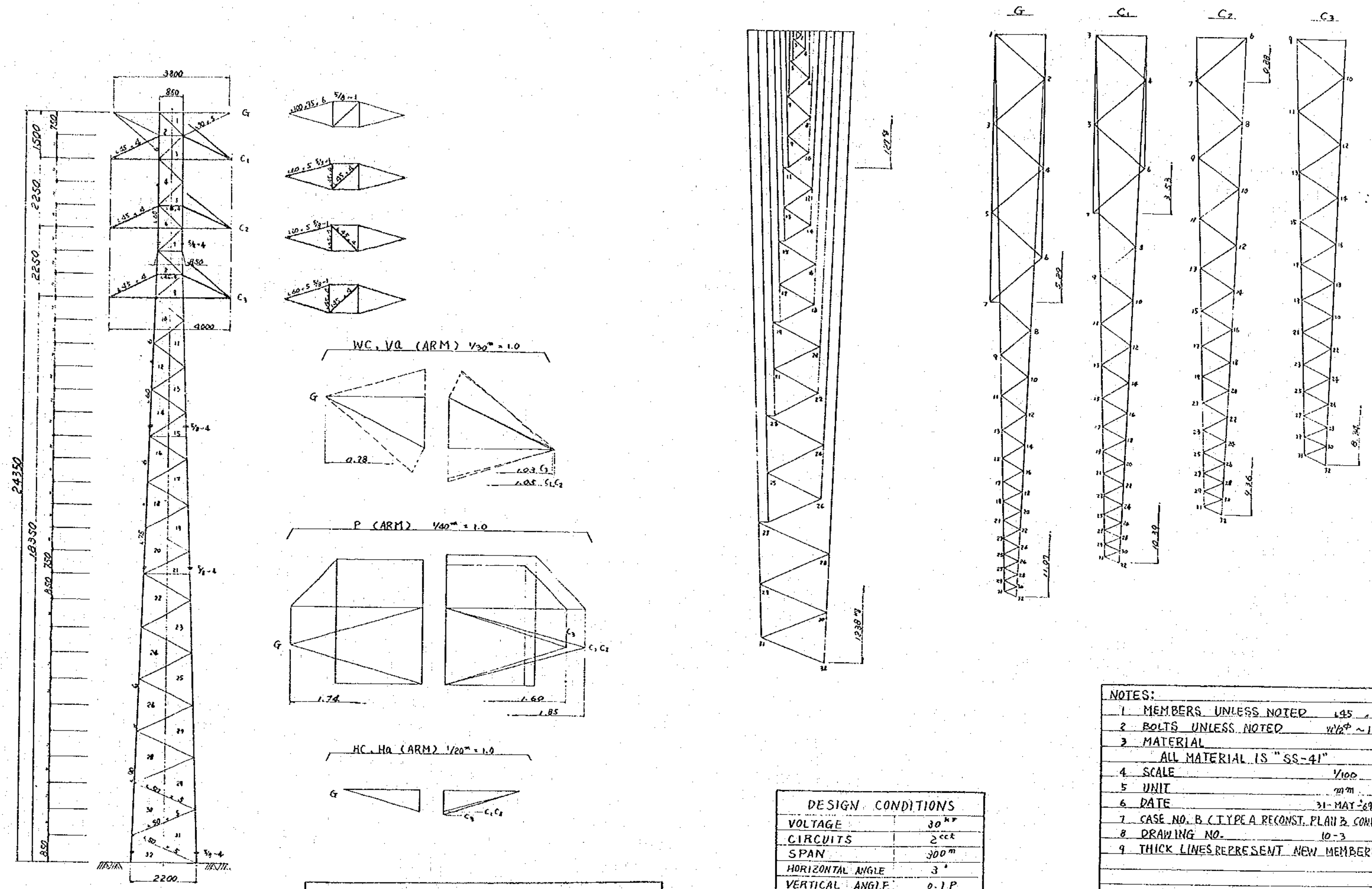
NOTES:

1. MATERIAL .... ALL MATERIAL IS "SS-41"
2. UNIT .... TON
3. DATE .... 31-MAY-'69
4. CASE NO. A (TYPE A ORIGINAL COND 50$^{mm^2}$)
5. DRAWING NO. 10-2

Fig - 6

LOADING IN (Kg)							
WEIGHT OF TOWER	WIND ON TOWER	VERTICAL LOAD	VERTICAL ANGLE	HORIZONTAL LOAD	HORIZONTAL ANGLE	WORKING TENSION	TORSION
WT	HT	WC	Va	HC	Ha	P	θ
1 LEG	1 FACE	1 LEG	1 LEG	1 FACE	1 FACE	1 FACE	1 FACE
	9	44	39	59	41	234	522
	15	103	45	83	47	267	628
	15						
		103	45	83	47	267	628
200	19						
		103	45	83	47	267	561
	21						
280	26						
	30						
360							
	34						
	39						
550							

OUTLINE DRAWING AND STRESS DIAGRAMS FOR TYPE-A TOWER
(SCALE 1/100)



CALCULATION OF TORSION (Kg)						
ARM	MOMENT	DEPTH	TORSION			
G	467 × 1.9 × 1/2 = 444	0.85	522			
C1	534 × 2.0 × 1/2 = 534	0.85	522	628		
C2	534 × 2.0 × 1/2 = 534	0.85	522	628	628	
C3	534 × 2.0 × 1/2 = 534	0.952	466	561	561	561

CALCULATION OF LOAD (Kg)			
WEIGHT OF CONDUCTOR	G	0.2933 × 300	88
	C	0.4351 × 300 + 70	206
VERTICAL ANGLE	G	779 × 0.1	78
	C	890 × 0.1	89
WIND ON CONDUCTOR	G	25 × 7.8 × 10⁻³ × 300	59
	C	25 × 9.0 × 10⁻³ × 300 + 15	83
HORIZONTAL ANGLE	G	2 × 779 × 0.0262	41
	C	2 × 890 × 0.0262	47
WORKING TENSION	G	779 × 0.6	467
	C	890 × 0.6	534
TORSION	G		
	C		

DESIGN CONDITIONS		
VOLTAGE		30 kV
CIRCUITS		2 cct
SPAN		300 m
HORIZONTAL ANGLE		3°
VERTICAL ANGLE		0.1 P
WIND PRESSURE ON TOWER		72.5 kg/m²
〃 ON CONDUCTOR		25 kg/m²
CONDUCTOR	KIND	50 mm²
	DIAMETER	9.0 mm
	UNIT WEIGHT	0.4351 kg/m
	MAX. TENSION	890 kg
GROUND WIRE	KIND	35 mm²
	DIAMETER	7.8 mm
	UNIT WEIGHT	0.2933 kg/m
	MAX. TENSION	779 kg
INSULATOR	KIND	254mm, 146mm, 5
	WEIGHT	70 kg
	WIND ON INS.	15 kg

NOTES:
1 MEMBERS UNLESS NOTED ∟45 × 5
2 BOLTS UNLESS NOTED M16φ ~ 1
3 MATERIAL
ALL MATERIAL IS "SS-41"
4 SCALE 1/100
5 UNIT mm
6 DATE 31-MAY-'69
7 CASE NO. B (TYPE A RECONST. PLAN B COND. 50mm²)
8 DRAWING NO. 10-3
9 THICK LINES REPRESENT NEW MEMBERS

Fig -7

STRESS TABLE FOR TYPE-A TOWER

	MARK	UNIT STRESS					STRESS TABLE										TOTAL STRESS				EXISTING MEMBERS						REINFORCING MEMBERS										MARK
											Hc		Ha		P	δ	BROKEN WIRE CONDITION		NORMAL MAX.		STRENGTH OF MEMBERS						STRENGTH OF MEMBERS						STRENGTH OF BOLTS				
		G	C1	C2	C3	Σ C	WT	HT	Wc	Va	G 59	C 83	G 41	C 47	G=234 C=267	G=522 C1=628 C2=628 C3=561	100 %	67 %	CONDITION	STRESS	MEMBERS	L	LK	LK/R	STRENGTH	S.F	MEMBERS	L	LK	LK/R	STRENGTH	S.F	DIAM.	NO.	STRENGTH	S.F	
MAIN POST	7	5.29	3.53	0.87		4.40	0.20	0.13	0.35	0.17	0.31	0.37	0.22	0.21	G=1.24		3.20	2.14	1.96	2.14	∟60 × 6	75	70	60	9.04	4.22		75	70				5/8	4	7.81	3.65	7
	15	8.34	2.14	5.38	3.58	16.10	0.28	0.41	〃	〃	0.49	1.34	0.35	0.76	G=1.95		6.10	4.09	4.15	4.15	〃	P150	P135	74	8.25	1.98		P150	P135				〃	4	〃	1.88	15
	21	9.55	8.62	7.19	5.95	21.56	0.36	0.66	〃	〃	0.56	1.79	0.40	1.01	C1=2.30		7.60	5.09	5.30	5.30	∟75 × 6	P150	P135	59	11.58	2.18		P150	P135				〃	4	〃	1.47	21
	32	11.08	16.40	9.37	8.35	28.12	0.55	1.24	〃	〃	0.65	2.33	0.47	1.32	C1=2.78		9.86	6.61	7.08	7.08	∟90 × 6	P170	P155	56	14.22	2.01		P170	P155				〃	4	〃	1.10	32
BRACING	1-2	1.35						0.01			0.08		0.06		G	G 0.70	0.85	0.57	0.15	0.57	∟45 × 5	115	105	120	2.72	4.77		115	105				1/2	1	1.21	2.12	1-2
	2-3	1.35						0.01			0.08		0.06		G	G 0.70	0.85	0.57	0.15	0.57	〃	115	105	120	〃	4.77		115	105				〃	1	〃	2.12	2-3
	3-4	1.35	1.35			1.35		0.03			0.08	0.11	0.06	0.06	C1 0.36	C1 0.85	1.19	0.80	0.34	0.80	〃	115	105	120	〃	3.40		115	105				〃	1	〃	1.51	3-4
	4-5	1.35	1.35			1.35		0.03			0.08	0.11	0.06	0.06	C1 0.36	C1 0.85	1.19	0.80	0.34	0.80	〃	115	105	120	〃	3.40		115	105				〃	1	〃	1.51	4-5
	5-6	1.35	1.35			1.35		0.05			0.08	0.11	0.06	0.06	C1 0.36	C1 0.85	1.23	0.82	0.38	0.82	〃	115	105	120	〃	3.32		115	105				〃	1	〃	1.47	5-6
	6-7	1.35	1.35	1.33		2.68		0.05			0.08	0.22	0.06	0.13	C2 0.36	C2 0.84	1.38	0.92	0.54	0.92	〃	115	105	120	〃	2.95		115	105				〃	1	〃	1.31	6-7
	7-8	0.83	0.98	1.21		2.19		0.06			0.05	0.18	0.03	0.10	C2 0.32	C2 0.76	1.18	0.79	0.42	0.79	〃	115	105	120	〃	3.44		115	105				〃	1	〃	1.53	7-8
	8-9	0.76	0.90	1.11		2.01		0.06			0.04	0.17	0.03	0.09	C2 0.30	C2 0.70	1.09	0.73	0.39	0.73	〃	115	105	120	〃	3.72		115	105				〃	1	〃	1.65	8-9
	9-10	0.70	0.83	1.01	1.22	3.06		0.06			0.04	0.25	0.03	0.14	C3 0.33	C3 0.68	1.20	0.80	0.52	0.80	〃	120	110	126	2.52	3.15		120	110				〃	1	〃	1.51	9-10
	10-11	0.65	0.77	0.97	1.15	2.89		0.05			0.04	0.24	0.03	0.14	C3 0.31	C3 0.65	1.15	0.77	0.50	0.77	〃	125	115	132	2.33	3.02		125	115				〃	1	〃	1.57	10-11
	11-12	0.61	0.73	0.89	1.09	2.71		0.07			0.04	0.22	0.03	0.13	C3 0.29	C3 0.61	1.10	0.74	0.49	0.74	〃	130	115	132	〃	3.15		130	115				〃	1	〃	1.63	11-12
	12-13	0.58	0.68	0.83	1.00	2.51		0.07			0.03	0.21	0.02	0.12	0.27	0.56	1.01	0.68	0.45	0.68	〃	130	115	132	〃	3.42		130	115				〃	1	〃	1.78	12-13
	13-14	0.55	0.65	0.79	0.94	2.38		0.06			0.03	0.20	0.02	0.11	0.25	0.53	0.95	0.64	0.42	0.64	〃	135	120	137	2.16	3.37		135	120				〃	1	〃	1.89	13-14
	14-15	0.50	0.60	0.75	0.90	2.25		0.06			0.03	0.19	0.02	0.11	0.24	0.50	0.91	0.61	0.41	0.61	〃	140	125	143	1.99	3.26		140	125				〃	1	〃	1.98	14-15
	15-16	0.49	0.57	0.71	0.85	2.13		0.09			0.03	0.18	0.02	0.10	0.23	0.48	0.90	0.60	0.42	0.60	〃	145	130	149	1.83	3.01		145	130				〃	1	〃	2.01	15-16
	16-17	0.45	0.55	0.68	0.80	2.03		0.08			0.03	0.17	0.02	0.10	0.21	0.45	0.85	0.57	0.40	0.57	〃	150	135	155	1.69	2.96		150	135				〃	1	〃	2.12	16-17
	17-18	0.44	0.53	0.65	0.76	1.94		0.08			0.03	0.16	0.02	0.09	0.20	0.43	0.81	0.54	0.38	0.54	〃	155	140	160	1.59	2.94		155	140				〃	1	〃	2.24	17-18
	18-19	0.41	0.50	0.60	0.73	1.83		0.08			0.02	0.15	0.02	0.09	0.19	0.41	0.77	0.52	0.36	0.52	〃	160	145	166	1.47	2.83		160	145				〃	1	〃	2.33	18-19
	19-20	0.40	0.48	0.59	0.70	1.77		0.10			0.02	0.15	0.02	0.08	0.19	0.39	0.76	0.51	0.37	0.51	〃	165	150	172	1.37	2.68		165	150				〃	1	〃	2.37	19-20
	20-21	0.39	0.46	0.56	0.68	1.70		0.10			0.02	0.14	0.02	0.08	0.18	0.38	0.74	0.50	0.36	0.50	〃	170	155	178	1.28	2.56		170	155				〃	1	〃	2.42	20-21
	21-22	0.38	0.45	0.55	0.66	1.66		0.10			0.02	0.14	0.02	0.08	0.18	0.37	0.73	0.49	0.36	0.49	〃	175	160	183	1.21	2.47		175	160				〃	1	〃	2.47	21-22
	22-23	0.37	0.43	0.54	0.64	1.61		0.10			0.02	0.13	0.02	0.08	0.17	0.36	0.71	0.48	0.35	0.48	〃	180	160	183	〃	2.52		180	160				〃	1	〃	2.52	22-23
	23-24	0.35	0.41	0.49	0.60	1.50		0.13			0.02	0.12	0.01	0.07	0.16	0.34	0.69	0.45	0.35	0.46	〃	185	165	189	1.14	2.48		185	165				〃	1	〃	2.63	23-24
	24-25	0.34	0.40	0.48	0.57	1.45		0.13			0.02	0.12	0.01	0.07	0.15	0.32	0.67	0.45	0.35	0.45	〃	195	175	200	1.02	2.27		195	175				〃	1	〃	2.69	24-25
	25-26	0.32	0.38	0.46	0.55	1.39		0.12			0.02	0.12	0.01	0.07	0.15	0.31	0.65	0.44	0.34	0.44	〃	200	180	206	0.96	2.18		200	180				〃	1	〃	2.75	25-26
	26-27	0.31	0.36	0.45	0.53	1.34		0.12			0.02	0.11	0.01	0.06	0.14	0.30	0.62	0.42	0.32	0.42	〃	205	185	212	0.90	2.14		205	185				〃	1	〃	2.88	26-27
	27-28	0.30	0.35	0.43	0.52	1.30		0.15			0.02	0.11	0.01	0.06	0.14	0.29	0.64	0.43	0.35	0.43	〃	210	190	218	0.85	1.97		210	190				〃	1	〃	2.81	27-28
	28-29	0.29	0.34	0.40	0.50	1.24		0.15			0.02	0.10	0.01	0.06	0.13	0.28	0.62	0.42	0.34	0.42	〃	215	195	223	0.81	1.92		215	195				〃	1	〃	2.88	28-29
	29-30	0.28	0.33	0.39	0.49	1.21		0.14			0.02	0.10	0.01	0.06	0.13	0.27	0.60	0.40	0.33	0.40	∟50 × 5	220	200	205	1.08	2.70		220	200				〃	1	〃	3.02	29-30
	30-31	0.27	0.32	0.38	0.46	1.16		0.14			0.02	0.10	0.01	0.05	0.12	0.26	0.58	0.39	0.32	0.39	〃	225	205	210	1.07	2.61		225	205				〃	1	〃	3.10	30-31
	31-32	0.26	0.31	0.37	0.45	1.13		0.13			0.02	0.09	0.01	0.05	0.12	0.25	0.55	0.37	0.30	0.37	〃	230	205	210	1.02	2.76		230	205				〃	1	〃	3.27	31-32
ARM	G MAIN	AT-1.02		AP 1.32		AH 0.52			-0.09	-0.08	0.03		0.02		0.85		-1.07 0.90			-1.07 0.90	∟100 × 75 × 6	155	140	87	10.66	11.84		155	140				5/8	1	1.95	1.82	MAIN
	G TIE	1.13							0.10	0.09									0.19	0.19	∟50 × 5	170	155	159	1.80	9.47		170	155				1/2	1	1.21	5.37	TIE G
	G DIAG			0.89											0.42		0.42	0.28		0.28	∟45 × 5	120	110	126	2.52	9.00		120	110				〃	1	〃	4.32	DIAG
	C1 MAIN	1.09		1.92		0.51			0.22	0.10		0.04		0.02	1.03		1.41			1.41							∟60 × 5	165	150	127	3.41	2.42	5/8	1	1.95	1.38	MAIN C1
	C1 TIE	-1.20							-0.25	-0.11									-0.36	-0.36							∟45 × 4	180	160	182	-3.33	9.25	1/2	1	1.21	3.36	TIE
	C2 DIAG			0.95											0.51		0.51	0.34		0.34							〃	120	110	125	2.08	6.12	〃	1	〃	3.56	DIAG C2
	C3 MAIN	1.08		1.68		0.52			0.22	0.10		0.04		0.02	0.90		1.28			1.28							∟60 × 5	160	145	123	3.64	2.84	5/8	1	1.95	1.52	MAIN
	C3 TIE	-1.18							-0.24	-0.11									-0.35	-0.35							∟45 × 4	180	110	182	-3.33	9.53	1/2	1	1.21	3.46	TIE C3
	C3 DIAG			0.78											0.42		0.42	0.28		0.28							〃	130	115	131	1.92	6.86	〃	1	〃	4.32	DIAG
FOUND.	COMP.	11.07	10.39	9.36	8.34	28.09	0.55	1.24	0.35	0.17	0.65	2.33	0.46	1.32	2.77		9.84	6.59	7.07	7.07																	COMP.
	UP-LIFT	〃	〃	〃	〃	〃	〃	〃	〃	0	〃	〃	〃	〃	〃		7.87	5.27	5.10	5.27																	UP-LIFT

COMBINATION OF STRESS

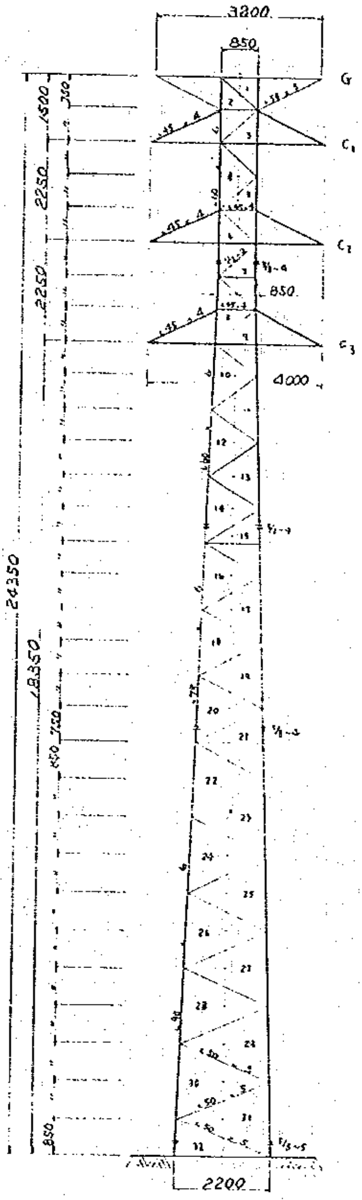
MEMBERS	CONDITIONS		WT	HT	WC	Va	HC	Ha	P	δ
MAIN POST	NORMAL		○	○	○	○	○	○		
	ABNORMAL		○	○	○	○	○	○	○	
BRACING	NORMAL	FRONT		○			○	○		
		SIDE		○						
	ABNORMAL	FRONT		○			○	○		○
		SIDE		○					○	○

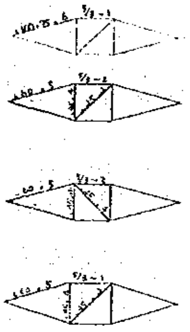
NOTES:
1. MATERIAL ALL MATERIAL IS "SS-41"
2. UNIT TON
3. DATE 31-MAY-'69
4. CASE NO. B (TYPE A RECONST. PLAN B COND. 50mm²)
5. DRAWING NO. 10-4

Fig -8

LOADING IN (kg)							
WEIGHT OF TOWER	WIND ON TOWER	VERTICAL LOAD	VERTICAL ANGLE	HORIZONTAL LOAD	HORIZONTAL ANGLE	WORKING TENSION	TORSION
WT	HT	WC	VA	HC	HA	P	q
1 LEG	1 FACE	1 LEG	1 LEG	1 FACE	1 FACE	1 FACE	1 FACE
	9	44	39	59	41	234	522
	15	137	66	93	69	396	932
	15						
		137	66	93	69	396	932
	19						
200		137	66	93	69	396	832
	21						
280	26						
	30						
360							
	34						
	37.1						
550							

OUTLINE DRAWING FOR TYPE-A TOWER
(SCALE 1/100)





CALCULATION OF TORSION (kg)						
ARM	MOMENT	DEPTH	TORSION			
G	467 × 1.9 × 1/2 = 444	0.85	522			
C1	792 × 2.0 × 1/2 = 792	0.85	522	932		
C2	792 × 2.0 × 1/2 = 792	0.85	522	932	932	
C3	792 × 2.0 × 1/2 = 792	0.952	466	332	332	832

DESIGN CONDITIONS		
VOLTAGE		70 KV
CIRCUITS		2 cct
SPAN		300 m
HORIZONTAL ANGLE		3°
VERTICAL ANGLE		0.1 P
WIND PRESSURE ON TOWER		72.5 kg/m²
〃 ON CONDUCTOR		25 kg/m²
CONDUCTOR	KIND	75 mm²
	DIAMETER	11.1 mm
	UNIT WEIGHT	0.6770 kg/m
	MAX. TENSION	1320 kg
GROUND WIRE	KIND	35 mm²
	DIAMETER	7.8 mm
	UNIT WEIGHT	0.2933 kg/m
	MAX. TENSION	779 kg
INSULATOR	KIND	254 mm × 146 mm × 5
	WEIGHT	70 kg
	WIND ON INS.	15 kg

Fig - 9

CALCULATION OF LOAD (kg)			
WEIGHT OF CONDUCTOR	G	0.2933 × 300	88
	C	0.6770 × 300 + 70	273
VERTICAL ANGLE	G	779 × 0.1	78
	C	1320 × 0.1	132
WIND ON CONDUCTOR	G	25 × 7.8 × 10^{-3} × 300	59
	C	25 × 11.1 × 10^{-3} × 300 + 15	98
HORIZONTAL ANGLE	G	2 × 779 × 0.0262	41
	C	2 × 1320 × 0.0262	69
WORKING TENSION	G	779 × 0.6	467
	C	1320 × 0.6	792

NOTES:

1. MEMBERS UNLESS NOTED — L45 × 5
2. BOLTS UNLESS NOTED — M16 ~ 1
3. MATERIAL — ALL MATERIAL IS "SS-41"
4. SCALE — 1/100
5. UNIT — mm
6. DATE — 31-MAY-'69
7. STRESS DIAGRAMS IS SHOWN THE "DRAWING NO. 10-3"
8. CASE NO. C (TYPE A RECONST. PLAN B. COND. 75 mm²)
9. DRAWING NO. 10-5
10. THICK LINES REPRESENT NEW MEMBERS

STRESS TABLE FOR TYPE- A TOWER

	MARK	UNIT STRESS					STRESS TABLE									
		G	C1	C2	C3	$\Sigma_3^1 C$	WT	HT	Wc	Va	Hc G 59	Hc C 98	Ha G 41	Ha C 69	P G=234 C=396	Q G=522 C1=932 C2=932 C3=832
MAIN POST	7	5.29	3.53	0.87		4.40	0.20	0.13	0.32	0.17	0.31	0.43	0.22	0.30	C1 1.40	
	15	8.34	7.14	5.38	3.58	16.10	0.28	0.41	0.46	0.24	0.49	1.58	0.34	1.11	C1 2.83	
	21	9.55	8.62	7.19	5.75	21.56	0.36	0.66	〃	〃	0.56	2.11	0.39	1.49	C1 3.41	
	32	11.08	10.40	9.37	8.35	28.12	0.55	1.24	〃	〃	0.65	2.76	0.45	1.94	C1 4.12	
BRACING	1-2	1.35						0.01			0.08		0.06		G 0.32	G 0.70
	2-3	1.35						0.01			0.08		0.06		G 0.32	G 0.70
	3-4	1.35	1.35			1.35		0.03			0.08	0.13	0.06	0.09	C1 0.53	C1 1.26
	4-5	1.35	1.35			1.35		0.03			0.08	0.13	0.06	0.09	C1 0.53	C1 1.26
	5-6	1.35	1.35			1.35		0.05			0.08	0.13	0.06	0.09	C1 0.53	C1 1.26
	6-7	1.35	1.35	1.33		2.68		0.05			0.08	0.26	0.06	0.18	C2 0.53	C2 1.74
	7-8	0.83	0.98	1.21		2.19		0.06			0.05	0.21	0.03	0.15	C2 0.48	C2 1.13
	8-9	0.76	0.90	1.11		2.01		0.06			0.04	0.20	0.03	0.14	C2 0.44	C2 1.03
	9-10	0.70	0.83	1.01	1.22	3.06		0.06			0.04	0.30	0.03	0.21	C3 0.48	C3 1.02
	10-11	0.65	0.77	0.97	1.15	2.89		0.05			0.04	0.28	0.03	0.20	C3 0.46	C3 0.96
	11-12	0.61	0.73	0.89	1.09	2.71		0.07			0.04	0.27	0.03	0.19	C3 0.43	C3 0.91
	12-13	0.58	0.68	0.83	1.00	2.51		0.07			0.03	0.25	0.02	0.17	0.40	0.83
	13-14	0.55	0.65	0.79	0.94	2.38		0.06			0.03	0.23	0.02	0.16	0.37	0.78
	14-15	0.50	0.60	0.75	0.90	2.25		0.06			0.03	0.22	0.02	0.16	0.36	0.75
	15-16	0.49	0.57	0.71	0.85	2.13		0.09			0.03	0.21	0.02	0.15	0.34	0.71
	16-17	0.45	0.55	0.68	0.80	2.03		0.08			0.03	0.20	0.02	0.14	0.32	0.67
	17-18	0.44	0.53	0.65	0.76	1.94		0.08			0.03	0.19	0.02	0.13	0.30	0.63
	18-19	0.41	0.50	0.60	0.73	1.83		0.08			0.02	0.18	0.02	0.13	0.29	0.61
	19-20	0.40	0.48	0.59	0.70	1.77		0.10			0.02	0.17	0.02	0.12	0.28	0.58
	20-21	0.39	0.46	0.56	0.68	1.70		0.10			0.02	0.17	0.02	0.12	0.27	0.57
	21-22	0.38	0.45	0.55	0.66	1.66		0.10			0.02	0.16	0.02	0.11	0.26	0.55
	22-23	0.37	0.43	0.54	0.64	1.61		0.10			0.02	0.16	0.02	0.11	0.25	0.53
	23-24	0.35	0.41	0.49	0.60	1.50		0.13			0.02	0.15	0.01	0.10	0.24	0.50
	24-25	0.34	0.40	0.48	0.57	1.45		0.13			0.02	0.14	0.01	0.10	0.23	0.47
	25-26	0.32	0.38	0.46	0.55	1.39		0.12			0.02	0.14	0.01	0.10	0.22	0.46
	26-27	0.31	0.36	0.45	0.53	1.34		0.12			0.02	0.13	0.01	0.09	0.21	0.44
	27-28	0.30	0.35	0.43	0.52	1.30		0.15			0.02	0.13	0.01	0.09	0.21	0.43
	28-29	0.29	0.34	0.40	0.50	1.24		0.15			0.02	0.12	0.01	0.09	0.20	0.42
	29-30	0.28	0.33	0.39	0.49	1.21		0.14			0.02	0.12	0.01	0.08	0.19	0.41
	30-31	0.27	0.32	0.38	0.46	1.16		0.14			0.02	0.11	0.01	0.08	0.18	0.38
	31-32	0.26	0.31	0.37	0.45	1.13		0.13			0.02	0.11	0.01	0.08	0.18	0.37
ARM	G MAX	AN-1.12		AP 1.82		AH0.32			-0.09	-0.08	0.03		0.02		0.85	
	TIE	1.13							0.10	0.09						
	DIAG			0.89											0.42	
	C1 MAX	1.09		1.92		0.51			0.30	0.14		0.05		0.04	1.52	
	TIE	-1.20							-0.33	-0.16						
	C2 DIAG			0.95											0.75	
	MAX	1.08		1.68		0.52			0.29	0.14		0.05		0.04	1.33	
	C3 TIE	-1.18							-0.32	-0.16						
	DIAG			0.78											0.67	
FOUND	COMP.	11.07	10.38	9.36	2.34	22.67	0.55	1.24	0.46	0.24	0.65	2.75	0.45	1.34	C1 4.11	
	UP-LIFT	〃	〃	〃	〃	〃	−〃	〃	−〃	0	〃	〃	〃	〃	〃	

	MARK	TOTAL STRESS				EXISTING MEMBERS STRENGTH OF MEMBERS						REINFORCING MEMBERS STRENGTH OF MEMBERS						STRENGTH OF BOLTS				MARK
		BROKEN WIRE CONDITION 100 %	67 %	NORMAL CONDITION	MAX. STRESS	MEMBERS	L	LK	LK/R	STRENGTH	S.F	MEMBERS	L	LK	LK/R	STRENGTH	S.F	DIAM.	NO.	STRENGTH	S.F	
MAIN POST	7	3.48	2.33	2.08	2.33	L60×6	75	70	60	9.04	3.88		75	70				5/8	4	9.81	3.35	7
	15	7.73	5.18	4.90	5.18	〃	P150	P135	74	8.25	1.59		P150	P135				〃	4	〃	1.50	15
	21	9.68	6.49	6.27	6.49	L75×6	P150	P135	59	11.58	1.18		P150	P135				〃	4	〃	1.20	21
	32	12.41	8.31	8.29	8.31	L90×6	P170	P155	56	14.22	1.71		P170	P155				〃	5	9.76	1.17	32
BRACING	1-2	0.85	0.57	0.15	0.57	L45×5	115	105	120	2.72	4.77		115	105				1/2	1	1.21	2.12	1-2
	2-3	0.85	0.57	0.15	0.57	〃	115	105	120	〃	4.77		115	105				〃	1	〃	2.12	2-3
	3-4	1.65	1.11	0.39	1.11	〃	115	105	120	〃	2.45		115	105				〃	1	〃	1.09	3-4
	4-5	1.65	1.11	0.39	1.11	〃	115	105	120	〃	2.45		115	105				〃	1	〃	1.09	4-5
	5-6	1.67	1.12	0.41	1.12	〃	115	105	120	〃	2.42		115	105				〃	1	〃	1.08	5-6
	6-7	1.87	1.25	0.43	1.25	〃	115	105	120	〃	2.16		115	105				〃	2	2.42	1.93	6-7
	7-8	1.63	1.09	0.50	1.09	〃	115	105	120	〃	2.49		115	105				〃	1	1.21	1.11	7-8
	8-9	1.50	1.01	0.47	1.01	〃	115	105	120	〃	2.69		115	105				〃	1	〃	1.19	8-9
	9-10	1.66	1.11	0.64	1.11	〃	120	110	126	2.52	2.26		120	110				〃	1	〃	1.09	9-10
	10-11	1.56	1.05	0.60	1.05	〃	125	115	132	2.33	2.22		125	115				〃	1	〃	1.15	10-11
	11-12	1.51	1.01	0.60	1.01	〃	130	115	132	〃	2.30		130	115				〃	1	〃	1.19	11-12
	12-13	1.37	0.92	0.54	0.92	〃	130	115	132	〃	2.53		130	115				〃	1	〃	1.31	12-13
	13-14	1.28	0.86	0.50	0.86	〃	135	120	137	2.16	2.51		135	120				〃	1	〃	1.40	13-14
	14-15	1.24	0.84	0.49	0.84	〃	140	125	143	1.99	2.37		140	125				〃	1	〃	1.44	14-15
	15-16	1.21	0.81	0.50	0.81	〃	145	130	149	1.83	2.26		145	130				〃	1	〃	1.49	15-16
	16-17	1.14	0.76	0.47	0.76	〃	150	135	155	1.69	2.22		150	135				〃	1	〃	1.59	16-17
	17-18	1.08	0.72	0.45	0.72	〃	155	140	160	1.59	2.20		155	140				〃	1	〃	1.68	17-18
	18-19	1.04	0.70	0.43	0.70	〃	160	145	166	1.47	2.10		160	145				〃	1	〃	1.93	18-19
	19-20	1.01	0.68	0.43	0.68	〃	165	150	172	1.37	2.01		165	150				〃	1	〃	1.78	19-20
	20-21	1.00	0.67	0.43	0.67	〃	170	155	178	1.28	1.91		170	155				〃	1	〃	1.80	20-21
	21-22	0.96	0.64	0.41	0.64	〃	175	160	183	1.21	1.89		175	160				〃	1	〃	1.89	21-22
	22-23	0.94	0.63	0.41	0.63	〃	180	160	183	〃	1.92		180	160				〃	1	〃	1.92	22-23
	23-24	0.91	0.61	0.41	0.61	〃	185	165	189	1.14	1.87		185	165				〃	1	〃	1.98	23-24
	24-25	0.87	0.58	0.40	0.58	〃	195	175	200	1.02	1.76		195	175				〃	1	〃	2.08	24-25
	25-26	0.85	0.57	0.39	0.57	〃	200	180	206	0.96	1.68		200	180				〃	1	〃	2.12	25-26
	26-27	0.81	0.54	0.37	0.54	〃	205	185	212	0.90	1.66		205	185				〃	1	〃	2.24	26-27
	27-28	0.83	0.56	0.44	0.56	〃	210	190	218	0.85	1.51		210	190				〃	1	〃	2.16	27-28
	28-29	0.81	0.54	0.39	0.54	〃	215	195	223	0.81	1.50		215	195				〃	1	〃	2.24	28-29
	29-30	0.78	0.52	0.37	0.52	L50×5	220	200	205	1.08	2.07		220	200				〃	1	〃	2.32	29-30
	30-31	0.74	0.50	0.36	0.50	〃	225	205	210	1.02	2.02		225	205				〃	1	〃	2.42	30-31
	31-32	0.72	0.48	0.35	0.48	〃	230	205	210	1.02	2.12		230	205				〃	1	〃	2.52	31-32
ARM	G MAX	-1.07 0.90			-1.07 0.90	L90×75×6	155	140	87	10.66	11.84		155	140				5/8	1	1.95	1.82	MAX
	TIE			0.19	0.19	L50×5	170	155	159	1.80	9.47		170	155				1/2	1	1.21	6.57	TIE G
	DIAG	0.42	0.28		0.28	L45×5	120	110	126	2.52	9.00		120	110				〃	1	〃	4.32	DIAG
	C1 MAX	2.05			2.05							L60×5	165	150	127	3.41	1.66	5/8	2	3.90	1.90	MAX C1
	TIE			-0.49	-0.49							L45×4	180	160	137	-3.33	6.80	1/2	1	1.21	2.41	TIE
	C2 DIAG	0.75	0.50		0.50							〃	125	110	125	2.08	4.16	〃	1	〃	2.42	DIAG C2
	MAX	1.85			1.85							L60×5	160	145	123	3.64	1.96	5/8	1	1.95	1.05	MAX
	C3 TIE			-0.48	-0.48							L45×4	180	160	137	-3.33	6.94	1/2	1	1.21	2.52	TIE C3
	DIAG	0.62	0.42		0.42							〃	130	115	131	1.92	4.57	〃	1	〃	2.88	DIAG
FOUND	COMP.	12.39	8.30	8.28	8.30																	COMP.
	UP-LIFT	10.13	6.79	6.02	6.79																	UP-LIFT

COMBINATION OF STRESS

MEMBERS	CONDITIONS		WT	HT	WC	Va	HC	Ha	P	Q
MAIN POST	NORMAL		O	O	O	O	O	O		
	ABNORMAL		O	O	O	O	O	O	O	
BRACING	NORMAL	FRONT		O			O	O		
		SIDE		O						
	ABNORMAL	FRONT		O			O	O		O
		SIDE		O					O	O

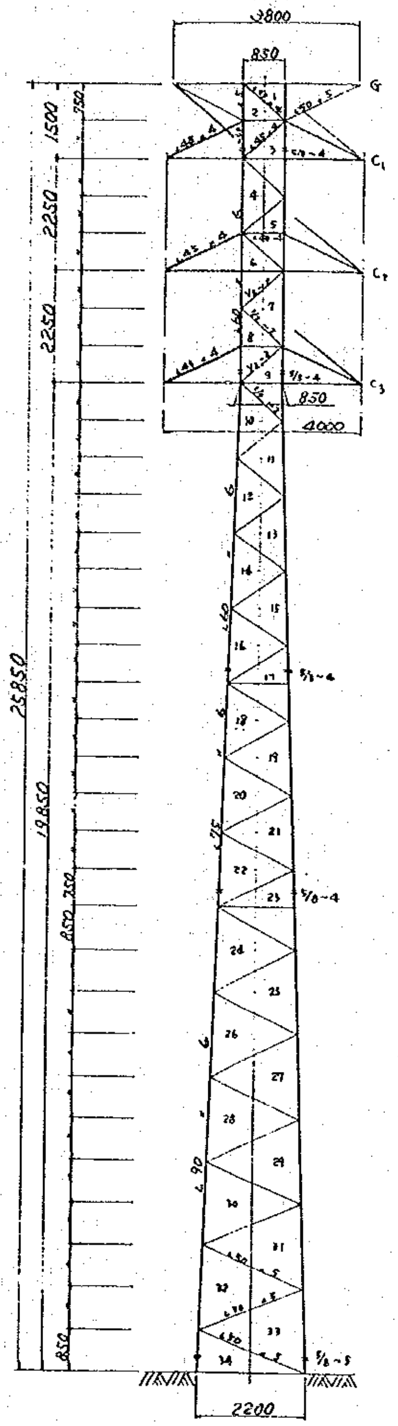
NOTES:
1. MATERIAL ALL MATERIAL IS SS-41
2. UNIT TON
3. DATE 31-MAY-'69
4. CASE NO. C (TYPE A RECONST. PLAN B COND. 75$^{m/s}$)
5. DRAWING NO. 10-6

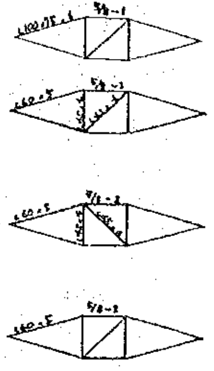
Fig - 10

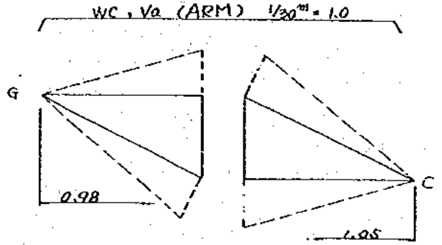
LOADING IN (kg)							
WEIGHT OF TOWER	WIND ON TOWER	VERTICAL LOAD	VERTICAL ANGLE	HORIZONTAL LOAD	HORIZONTAL ANGLE	WORKING TENSION	TORSION
WT	HT	WC	Va	Hc	Ha	P	q
1 LEG	1 FACE	1 LEG	1 LEG	1 FACE	1 FACE	1 FACE	1 FACE
	9	44	39	59	41	234	522
60	15	137	66	98	69	396	932
	17	137	66	98	69	396	932
220	19	137	66	98	69	396	932
	21						
300	26						
	30						
380							
	34						
	39						
570							

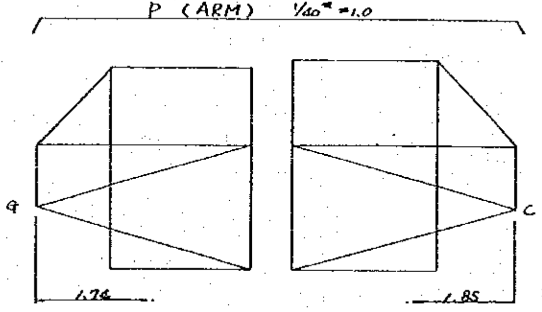
OUTLINE DRAWING AND STRESS DIAGRAM FOR TYPE-A TOWER

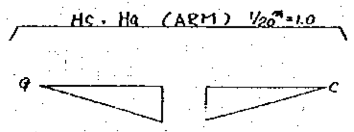
(SCALE 1/100)

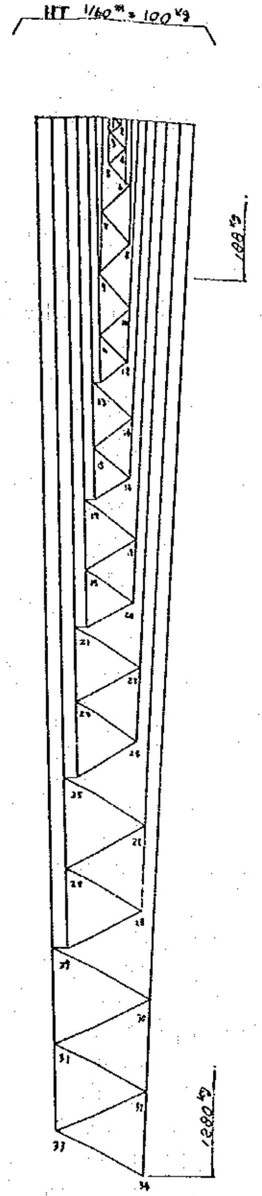


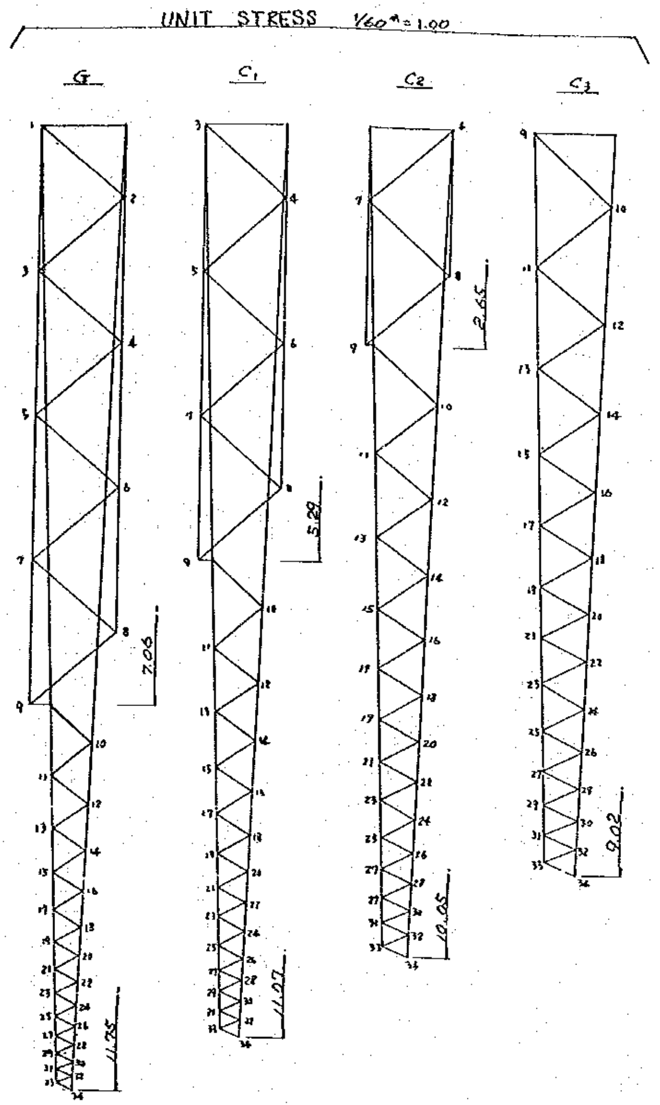



WC , Va (ARM) 1/20m = 1.0


P (ARM) 1/40m = 1.0


Hc , Ha (ARM) 1/20m = 1.0


HT 1/60m = 100kg


UNIT STRESS 1/60m = 1.00

CALCULATION OF LOAD (kg)			
WEIGHT OF CONDUCTOR	G	0.2933 × 300	88
	C	0.6770 × 300 + 70	273
VERTICAL ANGLE	G	779 × 0.1	78
	C	1320 × 0.1	132
WIND ON CONDUCTOR	G	25 × 7.8 × 10⁻³ × 300	59
	C	25 × 11.1 × 10⁻³ × 300 + 15	98
HORIZONTAL ANGLE	G	2 × 779 × 0.0262	41
	C	2 × 1320 × 0.0262	69
WORKING TENSION	G	779 × 0.6	467
	C	1320 × 0.6	792
TORSION	G	467 × 1.9 ÷ (2 × 0.85)	522
	C	792 × 2.0 ÷ (2 × 0.85)	932

DESIGN CONDITIONS		
	VOLTAGE	70KV
	CIRCUITS	2cct
	SPAN	300m
	HORIZONTAL ANGLE	3°
	VERTICAL ANGLE	0.1P
	WIND PRESSURE ON TOWER	72.5 kg/m²
	〃 ON CONDUCTOR	25 kg/m²
CONDUCTOR	KIND	75mm²
	DIAMETER	11.1mm
	UNIT WEIGHT	0.6770 kg/m
	MAX. TENSION	1320kg
GROUND WIRE	KIND	35mm²
	DIAMETER	7.8mm
	UNIT WEIGHT	0.2933 kg/m
	MAX. TENSION	779kg
INSULATOR	KIND	254mm × 146mm × 5
	WEIGHT	70kg
	WIND ON INS.	15kg

NOTES:
1. MEMBERS UNLESS NOTED ∟45 × 5
2. BOLTS UNLESS NOTED M 1/2φ ~1
3. MATERIAL
ALL MATERIAL IS SS-41
4 SCALE 1/100
5 UNIT mm
6 DATE 31-MAY-'69
7 CASE NO. D (TYPE A RECONST. PLAN A COND. 75mm²)
8 DRAWING NO. 10-7
9 THICK LINES REPRESENT NEW MEMBERS

Fig - 11

STRESS TABLE FOR TYPE-A TOWER

	MARK	UNIT STRESS G	C₁	C₂	C₃	Σ'₃C	STRESS TABLE WT	HT	Wc	Va	Hc G 59	Hc C 98	Ha G 41	Ha C 69	P G=234 C=336	g g=522 C=932	TOTAL STRESS BROKEN WIRE CONDITION 100 %	67 %	NORMAL CONDITION	MAX. STRESS	EXISTING MEMBERS STRENGTH OF MEMBERS MEMBERS	L	LK	LK/R	STRENGTH	S.F	REINFORCING MEMBERS STRENGTH OF MEMBERS MEMBERS	L	LK	LK/R	STRENGTH	S.F	STRENGTH OF BOLTS DIAM	NO.	STRENGTH	S.F	MARK
MAIN POST	3	1.76					0.06	0.02	0.18	0.11	0.10		0.07		G 0.41		0.95	0.64	0.54	0.64							L60×5	75	70	57	7.69	12.00	5/8	4	7.81	12.07	3
	9	2.06	5.29	2.65		7.94	0.22	0.19	0.46	0.24	0.42	0.78	0.29	0.55	C₁ 2.09		5.24	3.51	3.15	3.51	L60×6	75	70	60	9.04	2.57		75	70				〃	4	〃	2.22	9
	17	9.55	8.95	6.56	4.76	19.67	0.30	0.46	〃	〃	0.56	1.93	0.39	1.36	C₁ 3.31		9.01	6.04	5.70	6.04	〃	P150	P135	74	8.25	1.36		P150	P135				〃	4	〃	1.29	17
	23	10.56	9.60	8.15	6.92	24.47	0.38	0.71	〃	〃	0.62	2.40	0.43	1.69	C₁ 3.20		10.73	7.19	6.93	7.19	L75×6	P150	P135	59	11.58	1.61		P150	P135				〃	4	〃	1.08	23
	34	11.76	11.07	10.06	9.03	30.16	0.57	1.28	〃	〃	0.69	2.96	0.48	2.08	C₁ 4.33		13.14	8.80	8.76	8.80	L90×6	P170	P155	56	14.22	1.61		P170	P1[illegible]				〃	5	9.76	1.10	34
BRACING	1-2	1.35						0.01			0.08		0.06		G 0.32	G 0.70	0.85	0.57	0.15	0.57							L45×4	115	105	[illegible]	2.24	3.93	1/2	1	1.21	2.11	1~2
	2-3	1.35						0.01			0.08		0.06		G 0.32	G 0.70	0.85	0.57	0.15	0.57							〃	115	105	[illegible]	〃	3.93	〃	1	〃	2.11	2~3
	3-4	1.35	1.35			1.35		0.03			0.08	0.13	0.06	0.09	C₁ 0.53	C₁ 1.26	1.65	1.11	0.39	1.11	L45×5	115	105	120	2.72	2.45		115	105				〃	1	〃	1.09	3~4
	4-5	1.35	1.35			1.35		0.03			0.08	0.13	0.06	0.09	C₁ 0.53	C₁ 1.26	1.65	1.11	0.39	1.11	〃	115	105	120	〃	2.45		115	105				〃	1	〃	1.09	4-5
	5-6	1.35	1.35			1.35		0.03			0.08	0.13	0.06	0.09	C₁ 0.53	C₁ 1.26	1.65	1.11	0.39	1.11	〃	115	105	120	〃	2.45		115	105				〃	1	〃	1.09	5~6
	6-7	1.35	1.35	1.35		2.70		0.05			0.08	0.26	0.06	0.19	C₂ 0.53	C₂ 1.26	1.90	1.27	0.64	1.27	〃	115	105	120	〃	2.14		115	105				〃	2	2.42	1.90	6~7
	7-8	1.35	1.35	1.35		2.70		0.05			0.08	0.26	0.06	0.19	C₂ 0.53	C₂ 1.26	1.90	1.27	0.64	1.27	〃	115	105	120	〃	2.14		115	105				〃	2	〃	1.90	7~8
	8-9	1.35	1.35	1.35		2.70		0.05			0.08	0.26	0.06	0.19	C₂ 0.53	C₂ 1.26	1.90	1.27	0.64	1.27	〃	115	105	120	〃	2.14		115	105				〃	2	〃	1.90	8~9
	9-10	0.68	0.85	1.05	1.27	3.17		0.06			0.04	0.31	0.03	0.22	C₃ 0.50	C₃ 1.18	1.84	1.23	0.66	1.23	〃	115	105	120	〃	2.31		115	105				〃	2	〃	1.96	9-10
	10-11	0.61	0.77	0.95	1.16	2.88		0.06			0.04	0.28	0.03	0.20	C₃ 0.46	C₃ 1.08	1.69	1.13	0.61	1.13	〃	115	105	120	〃	2.40		115	105				〃	1	1.21	1.07	10-11
	11-12	0.57	0.70	0.90	1.10	2.70		0.05			0.03	0.26	0.02	0.19	C₃ 0.44	C₃ 1.03	1.58	1.06	0.55	1.06	〃	120	110	126	2.52	2.38		120	110				〃	1	〃	1.14	11-12
	12-13	0.51	0.62	0.80	1.01	2.43		0.05			0.03	0.24	0.02	0.17	0.42	0.94	1.45	0.97	0.51	0.97	〃	125	115	132	2.33	2.40		125	115				〃	1	〃	1.24	12-13
	13-14	0.48	0.60	0.78	0.95	2.33		0.07			0.03	0.23	0.02	0.16	0.39	0.89	1.40	0.94	0.51	0.94	〃	130	115	132	〃	2.47		130	115				〃	1	〃	1.28	13-14
	14-15	0.46	0.56	0.74	0.90	2.20		0.07			0.03	0.22	0.02	0.15	0.36	0.84	1.33	0.89	0.49	0.89	〃	130	115	132	〃	2.62		130	115				〃	1	〃	1.36	14-15
	15-16	0.43	0.55	0.68	0.85	2.08		0.06			0.03	0.20	0.02	0.14	0.34	0.79	1.24	0.83	0.45	0.83	〃	135	120	137	2.16	2.60		135	120				〃	1	〃	1.45	15-16
	16-17	0.41	0.51	0.65	0.80	1.96		0.06			0.02	0.19	0.02	0.14	0.32	0.75	1.18	0.79	0.43	0.79	〃	140	125	143	1.99	2.52		140	125				〃	1	〃	1.53	16-17
	17-18	0.39	0.50	0.63	0.78	1.91		0.09			0.02	0.19	0.02	0.13	0.31	0.73	1.18	0.79	0.45	0.79	〃	145	130	149	1.83	2.31		145	130				〃	1	〃	1.53	17-18
	18-19	0.37	0.45	0.59	0.74	1.78		0.08			0.02	0.17	0.02	0.12	0.29	0.69	1.10	0.74	0.41	0.74	〃	150	135	155	1.69	2.28		150	135				〃	1	〃	1.63	18-19
	19-20	0.35	0.44	0.55	0.70	1.69		0.08			0.02	0.17	0.01	0.12	0.28	0.65	1.05	0.70	0.40	0.70	〃	155	140	160	1.59	2.27		155	140				〃	1	〃	1.73	19-20
	20-21	0.34	0.41	0.54	0.66	1.61		0.08			0.02	0.16	0.01	0.11	0.26	0.62	1.00	0.67	0.38	0.67	〃	160	145	166	1.47	2.19		160	145				〃	1	〃	1.80	20-21
	21-22	0.32	0.40	0.51	0.64	1.55		0.10			0.02	0.15	0.01	0.11	0.25	0.60	0.99	0.66	0.39	0.66	〃	165	150	172	1.37	2.07		165	150				〃	1	〃	1.83	21-22
	22-23	0.30	0.39	0.50	0.61	1.50		0.10			0.02	0.15	0.01	0.10	0.24	0.57	0.95	0.64	0.38	0.64	〃	170	155	178	1.28	2.00		170	155				〃	1	〃	1.89	22-23
	23-24	0.30	0.39	0.50	0.60	1.49		0.10			0.02	0.15	0.01	0.10	0.24	0.56	0.94	0.63	0.38	0.63	〃	175	160	183	1.21	1.92		175	160				〃	1	〃	1.92	23-24
	24-25	0.29	0.37	0.46	0.58	1.41		0.09			0.02	0.14	0.01	0.10	0.23	0.54	0.90	0.60	0.36	0.60	〃	180	160	183	〃	2.01		180	160				〃	1	〃	2.01	24-25
	25-26	0.27	0.35	0.45	0.55	1.35		0.13			0.02	0.13	0.01	0.09	0.22	0.51	0.89	0.60	0.33	0.60	〃	185	165	181	1.14	1.90		185	165				〃	1	〃	2.01	25-26
	26-27	0.26	0.34	0.44	0.54	1.32		0.12			0.02	0.13	0.01	0.09	0.21	0.50	0.87	0.58	0.37	0.58	〃	195	175	200	1.02	1.76		195	175				〃	1	〃	2.08	26-27
	27-28	0.25	0.31	0.41	0.50	1.22		0.13			0.01	0.12	0.01	0.08	0.20	0.47	0.81	0.54	0.34	0.54	〃	200	180	206	0.96	1.77		200	180				〃	1	〃	2.24	27-28
	28-29	0.25	0.30	0.40	0.49	1.19		0.11			0.01	0.12	0.01	0.08	0.19	0.46	0.79	0.53	0.33	0.53	〃	205	185	212	0.90	1.69		205	185				〃	1	〃	2.28	28-29
	29-30	0.24	0.30	0.39	0.46	1.15		0.15			0.01	0.11	0.01	0.08	0.18	0.43	0.79	0.53	0.36	0.53	〃	210	190	211	0.85	1.60		210	190				〃	1	〃	2.28	29-30
	30-31	0.23	0.29	0.38	0.45	1.12		0.14			0.01	0.11	0.01	0.08	0.18	0.42	0.77	0.52	0.35	0.52	〃	215	195	223	0.81	1.55		215	195				〃	1	〃	2.37	30-31
	31-32	0.22	0.28	0.36	0.44	1.08		0.14			0.01	0.11	0.01	0.07	0.17	0.41	0.75	0.50	0.34	0.50	L50×5	220	200	205	1.08	2.16		220	200				〃	1	〃	2.42	31-32
	32-33	0.21	0.27	0.35	0.43	1.05		0.13			0.01	0.10	0.01	0.07	0.17	0.40	0.72	0.48	0.32	0.48	〃	225	205	210	1.02	2.12		225	205				〃	1	〃	2.52	32-33
	33-34	0.20	0.26	0.34	0.42	1.02		0.13			0.01	0.10	0.01	0.07	0.17	0.39	0.71	0.48	0.32	0.48	〃	230	205	210	〃	2.12		230	205				〃	1	〃	2.52	33-34
ARM	G MAIN	AT-1.02		AP 1.12		AH 0.32			-0.09	-0.08	0.03		0.02		0.35		-1.07 0.90			-1.07 0.90	L100×75×6	155	140	87	10.66	11.84		155	140				5/8	1	1.95	1.82	MAIN
	G TIE	1.13							0.10	0.09									0.19	0.19	L50×5	170	155	159	1.80	9.47		170	155				1/2	1	1.21	6.37	TIE G
	G DIAG			0.89											0.42		0.42	0.28		0.28	L45×5	120	110	126	2.52	9.00		120	110				〃	1	〃	4.32	DIAG
	C MAIN	1.09		1.92		0.51			0.30	0.14		0.05		0.04	1.52		2.05			2.05							L60×5	165	150	127	3.41	1.66	5/8	2	3.90	1.90	MAIN
	C TIE	-1.20							-0.33	-0.16									-0.49	-0.49							L45×4	180	160	182	-3.33	6.30	1/2	1	1.21	2.47	TIE C
	C DIAG			0.95											0.75		0.75	0.50		0.50							〃	120	110	125	2.08	4.16	〃	1	〃	2.42	DIAG
FOUND	comp.	11.75	11.07	10.05	9.02	30.14	0.57	1.28	0.46	0.24	0.69	2.95	0.48	2.08	C₁ 4.33		13.13	8.80	8.75	8.80																	comp.
	up-lift	〃	〃	〃	〃	〃	−〃	〃	−〃	0	〃	〃	〃	〃	〃		10.77	7.22	6.39	7.22																	up-lift

COMBINATION OF STRESS

MEMBERS	CONDITIONS		WT	HT	Wc	Va	Hc	Ha	P	g
MAIN POST	NORMAL		○	○	○	○	○	○		
	ABNORMAL		○	○	○	○	○	○	○	
BRACING	NORMAL	FRONT		○			○	○		
		SIDE		○						
	ABNORMAL	FRONT		○			○	○		○
		SIDE		○					○	○

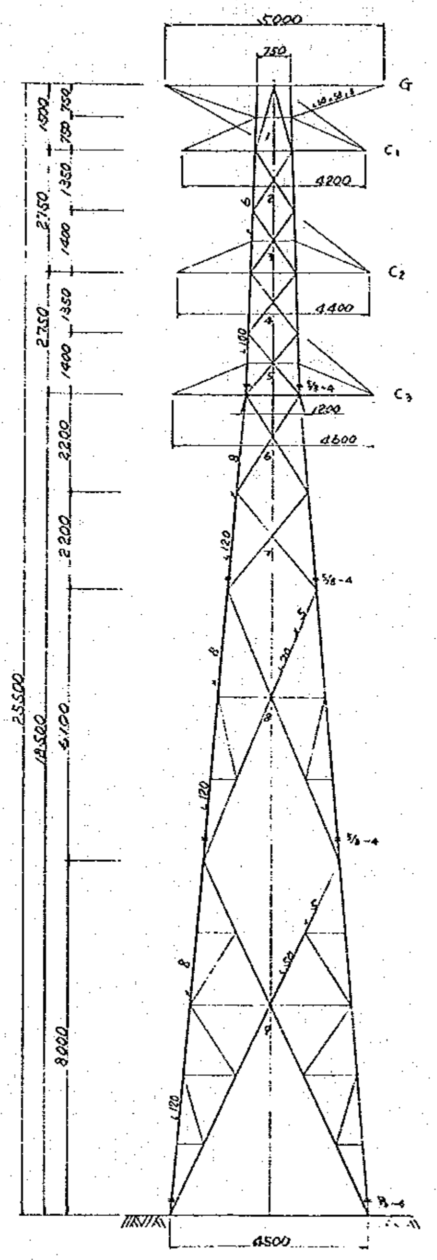
NOTES:
1. MATERIAL — ALL MATERIAL IS "SS-41"
2 UNIT — TON
3 DATE — 31-MAY-'69
4 CASE NO. D (TYPE A RECONST. PLAN A COND. 75"")
5 DRAWING NO. — 10-8

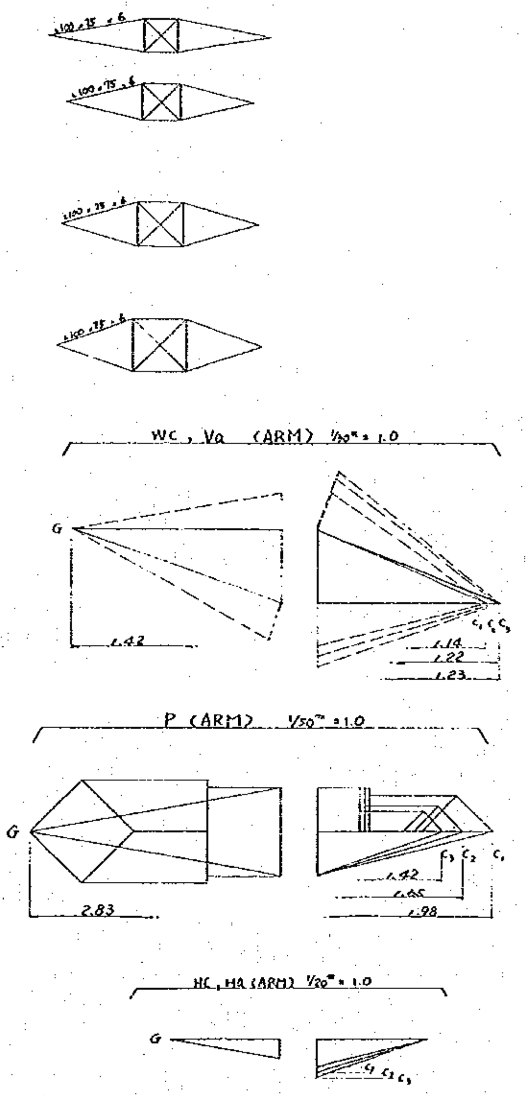
Fig - 12

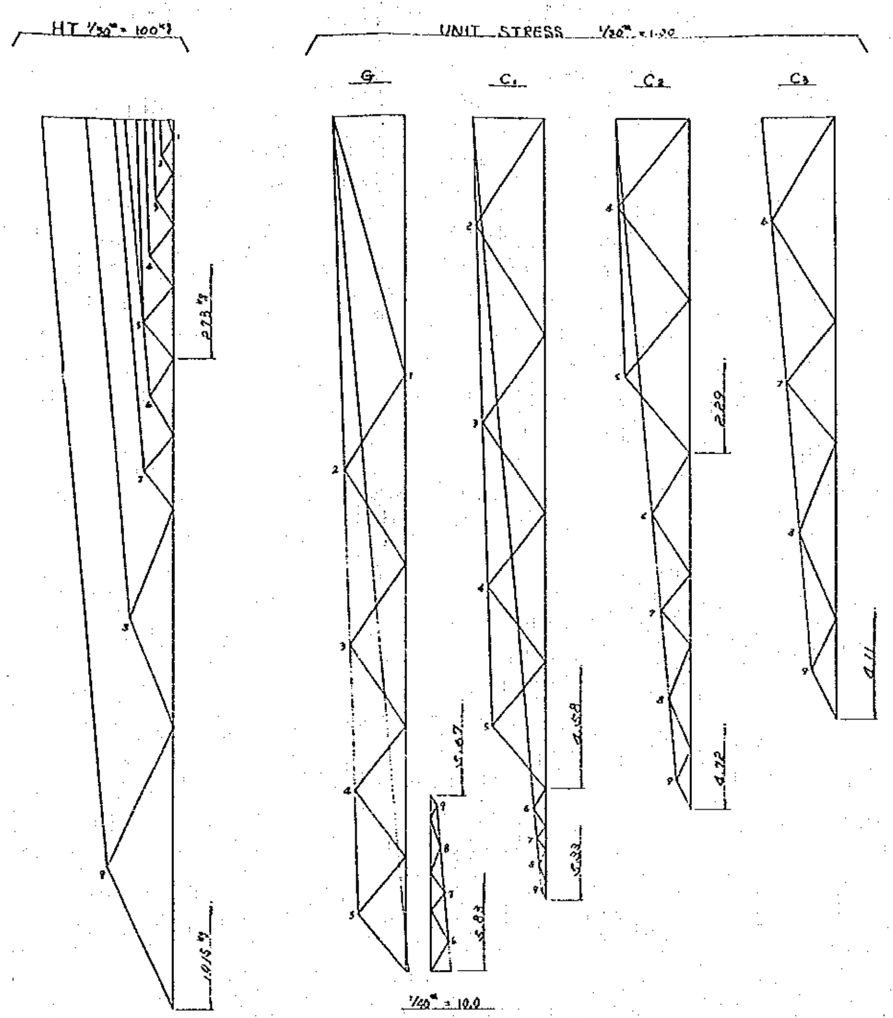
LOADING IN (Kg)							
WEIGHT OF TOWER	WIND ON TOWER	VERTICAL LOAD	VERTICAL ANGLE	HORIZONTAL LOAD	HORIZONTAL ANGLE	WORKING TENSION	TORSION
WT	HT	WC	Va	HC	Ha	P	θ
1 LEG	1 FACE	1LEG	1LEG	1 FACE	1 FACE	1 FACE	1 FACE
	11	44	39	59	41	234	779
	19	137	65	98	69	396	983
	16						
	20	137	66	98	69	376	851
	18						
340	28	137	66	98	69	376	759
	28						
470	64						
700	101						
1010							

OUTLINE DRAWING AND STRESS DIAGRAMS FOR TYPE-B TOWER

(SCALE 1/100)







CALCULATION OF LOAD (Kg)			
WEIGET OF CONDUCTOR	G	0.2733 . 300	88
	C	0.6770 . 300 + 70	273
VERTICAL ANGLE	G	779 . 0.1	78
	C	1320 . 01	132
WIND ON CONDUCTOR	G	25 . 7.8 . 10⁻³ . 300	59
	C	25 . 11.1 . 10⁻³ . 300 + 15	98
HORIZONTAL ANGLE	G	2 . 779 . 0.0262	41
	C	2 . 1320 . 0.0262	69
WORKING TENSION	G	779 . 0.6	467
	C	1320 . 0.6	792
TORSION	G		
	C		

CALCULATION OF TORSION						
ARM	MOMENT	DEPTH	TORSION			
G	467 . 2.5 . ½ = 584	0.750	779			
C₁	792 . 2.1 . ½ = 832	0.866	690	983		
C₂	792 . 2.2 . ½ = 871	1.023	571	813	851	
C₃	792 . 2.3 . ½ = 911	1.200	487	673	726	759

DESIGN CONDITIONS		
VOLTAGE		70 KV
CIRCUITS		2 cct
SPAN		300 m
HORIZONTAL ANGLE		3°
VERTICAL ANGLE		0.1 P
WIND PRESSURE ON TOWER		72.5 kg/m²
〃 ON CONDUCTOR		25 kg/m²
CONDUCTOR	KIND	75 mm²
	DIAMETER	11.1 mm
	UNIT WEIGHT	0.6770 kg/m
	MAX TENSION	1320 kg
GROUND WIRE	KIND	35 mm²
	DIAMETER	7.8 mm
	UNIT WEIGHT	0.2933 kg/m
	MAX TENSION	779 kg
INSULATOR	KIND	254 mm, 146 mm, 5
	WEIGHT	70 kg
	WIND ON INS.	15 kg

NOTES:

1. MEMBERS UNLESS NOTED ∟45 × 5
2. BOLTS UNLESS NOTED M ½ φ ~ 1
3. MATERIAL
   ALL MATERIAL IS SS-41
4. SCALE 1/100
5. UNIT mm
6. DATE 31-MAY-'69
7. CASE NO. E (TYPE B ORIGINAL COND 75 mm²)
8. DRAWING NO. 10-9

Fig -13

STRESS TABLE FOR TYPE-B TOWER

MARK		UNIT STRESS G	UNIT STRESS C_1	UNIT STRESS C_2	UNIT STRESS C_3	UNIT STRESS $\Sigma_1^3 C$	STRESS TABLE WT	HT	Wc	Va	Hc G (59)	Hc C (98)	Ha G (41)	Ha C (69)	P (G=234, C=316)	θ (G=779, C_1=983, C_2=851, C_3=752)
MAIN POST	5	5.43	4.15	1.77		5.92	0.34	0.23	0.46	0.24	0.32	0.58	0.23	0.41	C_1 1.64	
	7	6.78	4.96	3.37	1.82	10.13	0.47	0.40	"	"	0.40	0.99	0.28	0.70	" 1.96	
	8	6.74	5.12	3.98	2.85	11.95	0.70	0.57	"	"	0.40	1.17	0.28	0.92	" 2.43	
	9	6.70	5.29	4.53	3.79	13.61	1.01	0.85	"	"	0.40	1.33	0.28	0.74	" 2.09	
BRACING	1	1.84						0.08			0.11		0.08		G 0.43	G 1.43
	2	0.78	0.89			0.89		0.03			0.05	0.09	0.03	0.66	C_1 0.35	C_1 0.89
	3	0.68	0.75			0.75		0.04			0.04	0.07	0.03	0.05	C_1 0.33	C_1 0.74
	4	0.58	0.65	0.80		1.45		0.05			0.03	0.14	0.02	0.10	C_2 0.32	C_2 0.68
	5	0.52	0.56	0.68		1.24		0.05			0.03	0.12	0.02	0.09	C_2 0.27	C_2 0.58
	6	0.03	0.15	0.49	0.22	1.46		0.05			0.01	0.14	0.01	0.10	C_3 0.32	C_3 0.62
	7	0.02	0.10	0.31	0.53	0.94		0.05			0.01	0.09	0.01	0.06	C_3 0.21	C_3 0.40
	8	0.02	0.12	0.38	0.64	1.14		0.13			0.01	0.11	0.01	0.08	C_3 0.35	C_3 0.49
	9	0.01	0.06	0.22	0.38	0.66		0.18			0.01	0.06	0.01	0.05	C_3 0.15	C_3 0.29
ARM	MAX	AT-1.44		AP2.16		AH0.51			-0.13	-0.11	0.03		0.02		1.34	
	G TIE	1.52							0.13	0.12						
	DIAG			0.81											0.38	
	MAX	1.18		2.04		0.51			0.32	0.16		0.05		0.04	1.62	
	C_1 TIE	-1.27							-0.35	-0.17						
	DIAG			0.57											0.45	
	MAX	1.27		1.72		0.52			0.35	0.17		0.05		0.04	1.36	
	C_2 TIE	-1.37							-0.37	-0.18						
	DIAG			0.40											0.32	
	MAX	1.30		1.30		0.53			0.35	0.17		0.05		0.04	1.19	
	C_3 TIE	-1.40							-0.38	-0.18						
	DIAG			0.31											0.25	
FOUND	COMP.	5.67	5.33	4.72	4.11	14.16	1.01	1.02	0.46	0.24	0.33	1.39	0.24	0.98	" 2.11	
	UP-LIFT	"	"	"	"	"	- "	"	- "	0	"	"	"	"	-	

MARK		TOTAL STRESS BROKEN WIRE CONDITION 100%	BROKEN WIRE CONDITION 67 %	NORMAL CONDITION	MAX. STRESS	EXISTING MEMBERS STRENGTH OF MEMBERS MEMBERS	L	LK	LK/R	STRENGTH	S.F
MAIN POST	5	4.45	2.98	2.81	2.98	∟100 × 6	70	65	33	17.40	5.84
	7	5.30	3.95	3.94	3.95	∟120 × 8	220	200	84	20.74	5.25
	8	6.67	4.47	4.64	4.64	"	245	220	92	19.11	4.12
	9	7.60	5.09	5.51	5.51	"	165	150	63	24.33	4.41
BRACING	1	1.64	1.10	0.21	1.10	∟45 × 5	155	140	160	1.59	1.44
	2	1.13	0.76	0.26	0.76	"	85	75	86	3.83	5.03
	3	0.97	0.65	0.23	0.65	"	90	80	92	3.64	5.60
	4	1.02	0.68	0.34	0.68	"	90	80	92	"	5.35
	5	0.89	0.60	0.31	0.60	"	90	80	92	"	6.07
	6	0.93	0.62	0.31	0.62	"	150	135	155	1.69	2.72
	7	0.62	0.42	0.27	0.42	"	155	140	160	1.59	3.78
	8	0.83	0.56	0.34	0.56	∟70 × 5	260	235	169	2.28	4.07
	9	0.60	0.40	0.31	0.40	∟50 × 5	180	160	164	1.69	4.22
ARM	MAX	-1.63 1.37			-1.63 1.37	∟100 × 75 × 6	215	195	121	6.60	4.14
	G TIE			0.25	0.25	∟60 × 50 × 5	225	205	210	1.02	4.08
	DIAG	0.38	0.25		0.25	∟45 × 5	55	50	57	4.28	1.71
	MAX	2.19			2.19	∟100 × 75 × 6	170	155	96	9.89	4.51
	C_1 TIE			-0.52	-0.52	∟45 × 5	190	170	195	-4.06	7.51
	DIAG	0.45	0.30		0.30	"	60	55	63	4.28	14.28
	MAX	1.97			1.97	∟100 × 75 × 6	180	160	99	9.52	4.83
	C_2 TIE			-0.55	-0.55	∟45 × 5	190	170	195	-4.06	7.38
	DIAG	0.32	0.21		0.21	"	70	65	74	4.22	2.01
	MAX	1.80			1.80	∟100 × 75 × 6	180	160	99	9.52	5.28
	C_3 TIE			-0.56	-0.56	∟45 × 5	195	175	200	-4.06	7.25
	DIAG	0.25	0.17		0.17	"	85	75	86	3.83	2.25
FOUND	COMP.	7.78	5.21	5.67	5.67						
	UP-LIFT	4.60	3.08	2.49	3.08						

MARK		REINFORCING MEMBERS STRENGTH OF MEMBERS MEMBERS	L	LK	LK/R	STRENGTH	S.F	STRENGTH OF BOLTS DIAM.	NO.	STRENGTH	S.F	MARK
MAIN POST	5		70	65				5/8	4	7.81	2.62	5
	7		220	200				"	4	"	1.98	7
	8		245	220				"	4	"	1.68	8
	9		165	150				"	4	"	1.41	9
BRACING	1		155	140				1/2	1	1.21	1.10	1
	2		85	75				"	1	"	1.59	2
	3		90	80				"	1	"	1.86	3
	4		90	80				"	1	"	1.77	4
	5		90	80				"	1	"	2.00	5
	6		150	135				"	1	"	1.95	6
	7		155	140				"	1	"	2.88	7
	8		260	235				"	1	"	2.16	8
	9		180	160				"	1	"	3.02	9
ARM	MAX		215	195				5/8	2	3.90	2.39	MAX
	G TIE		225	205				1/2	1	1.21	4.84	TIE G
	DIAG		55	50				"	1	"	4.84	DIAG
	MAX		170	155				5/8	2	3.90	1.78	MAX
	C_1 TIE		190	170				1/2	1	1.21	2.32	TIE C_1
	DIAG		60	55				"	1	"	4.03	DIAG
	MAX		180	160				5/8	2	3.90	1.98	MAX
	C_2 TIE		190	170				1/2	1	1.21	2.20	TIE C_2
	DIAG		70	65				"	1	"	5.96	DIAG
	MAX		180	160				5/8	2	3.90	2.16	MAX
	C_3 TIE		195	175				1/2	1	1.21	2.16	TIE C_3
	DIAG		85	75				"	1	"	2.12	DIAG
FOUND	COMP.											COMP.
	UP-LIFT											UP-LIFT

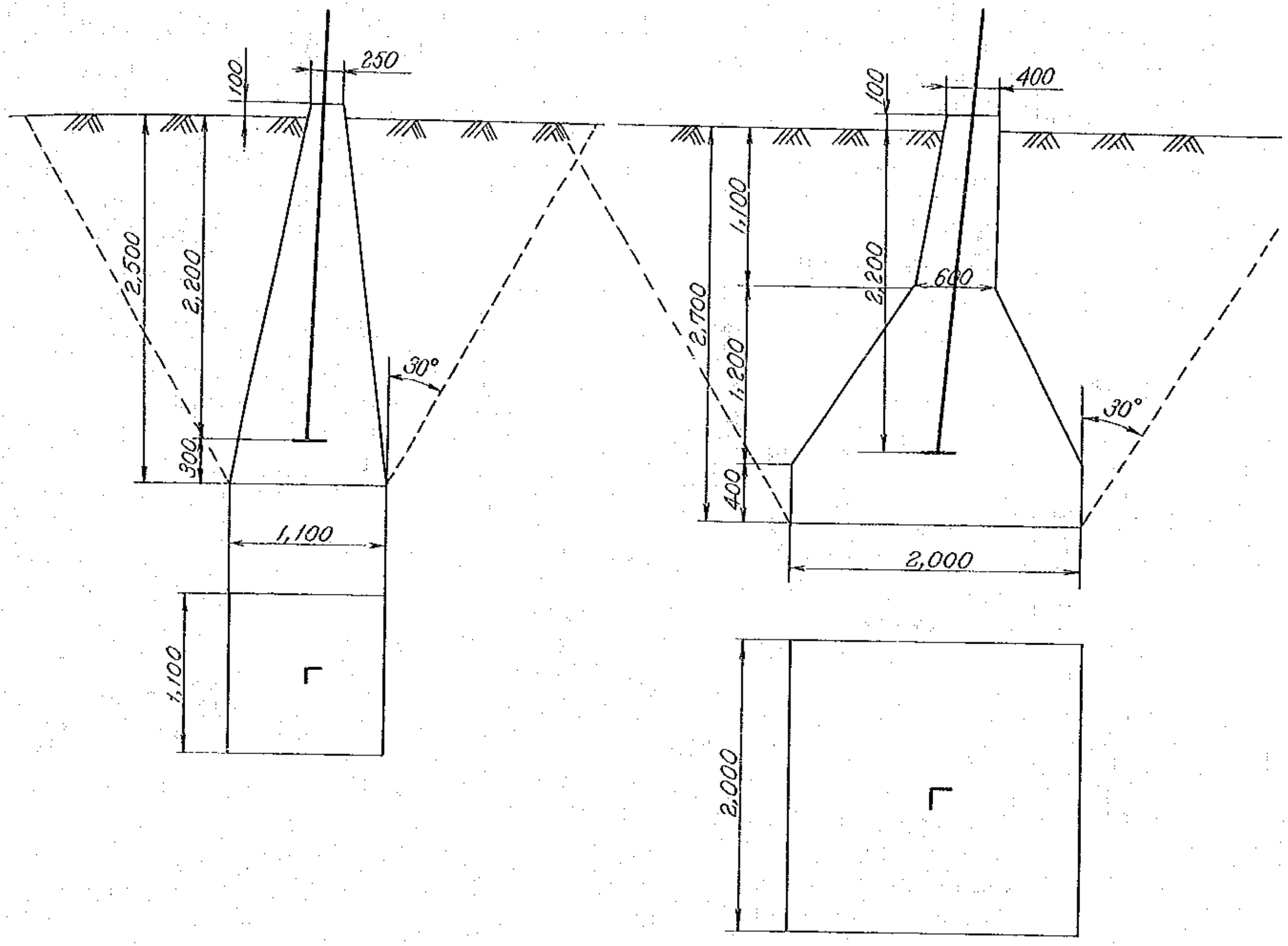
COMBINATION OF STRESS

MEMBERS	CONDITIONS		WT	HT	WC	Va	HC	Ha	P	θ
MAIN POST	NORMAL		○	○	○	○	○	○		
	ABNORMAL		○	○	○	○	○	○	○	
BRACING	NORMAL	FRONT		○			○	○		
		SIDE		○						
	ABNORMAL	FRONT		○			○	○		○
		SIDE		○					○	○

NOTES:
1. MATERIAL ALL MATERIAL IS SS-41
2. UNIT TON
3. DATE 31 - MAY - '69
4. CASE NO. E (TYPE B ORIGINAL COND. 75***)
5. DRAWING NO. 10-10

Fig - 14

Fig. 15 Tower Foundation
Scale 1/50
Unit mm


TYPE-A Tower

TYPE-B Tower

PERFORMANCE CALCULATION CHECK OF PRIOK UNITS 1 AND 2

Priok units 1 and 2 are operated without HP heaters.

We considered such operating condition uneconomical compared with the case of using HP heaters.

We tried to calculate the economic estimates of the case without heaters, comparing with the case of using HP heaters.

1. Priok units 1 and 2 started commercial operations in 1962/1964. At that time, the mean thermal efficiency of both units was recorded as follows:

    - Generator output 20 MW
    - Boiler efficiency 90%
    - Turbine heat rate 2,760 Kcal/KWH
    - Plant efficiency 28.1%

2. Recently, the actual record of Priok unit 2 without HP Heaters is as follows:

    - Generator output 22 MW on April 6, 1968
    - Steam evaporation is 96 Ton/H at boiler outlet
    - Fuel consumption is 7.8×10^3 Kg/H
    - Heat value of fuel is 10,000 Kcal/Kg
    - Boiler outlet steam enthalpy is 62.5 Kg/cm²g, 500°C
      817 Kcal/Kg
    - Boiler inlet water enthalpy is 130°C, 131 Kcal/Kg
      Boiler efficiency is calculated as follows:

$$\text{Boiler efficiency} = \frac{(817 - 131) \times 96 \times 10^3}{10 \times 10^3 \times 7.8 \times 10^3} = 84.5\%$$

Plant efficiency is calculated as follows:

$$\text{Plant efficiency} = \frac{22 \times 10^3 \times 860 \times 10^3}{7.8 \times 10^3 \times 10 \times 10^3} = 24.2\%$$

Turbine efficiency = 0.242/0.845 = 28.7%

3. Comparison

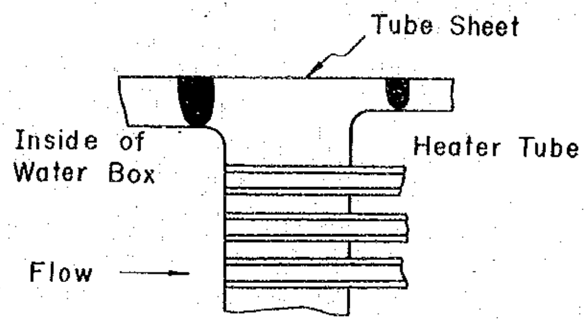
In the case of using HP heaters, the plant efficiency is 28.7%, but the plant efficiency without heater is 24.2%.

The detailed comparison is shown in the following table.

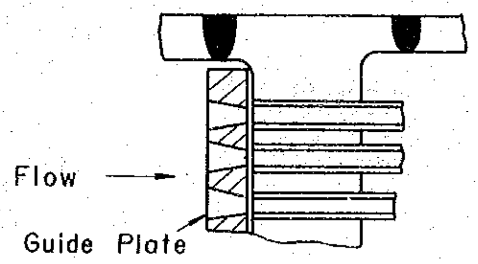
		Boiler Eff. %	Turbine Eff. %	Plant Eff. %
A.	With HP heater of Priok unit 1 and 2	90	31.1	28.1
B.	Without heater	84.5	28.7	24.2
	Difference (A–B)	5.5	2.4	3.9

Appendix 3-5

Conceptional Drawings of High Pressure Feedwater Heater equipped with Guide Plate or Flow Diffuser at Priok Units 1and 2

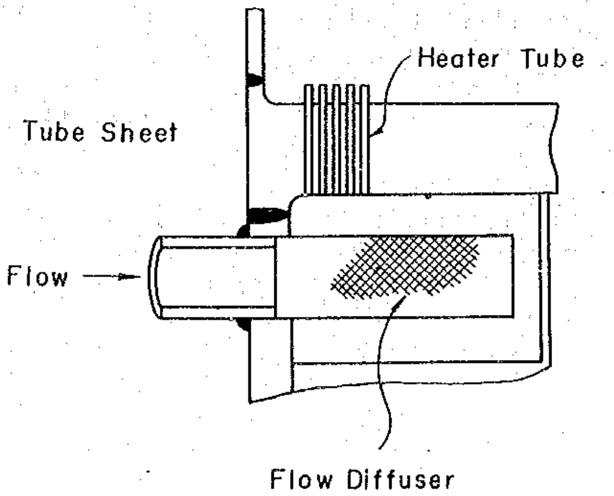


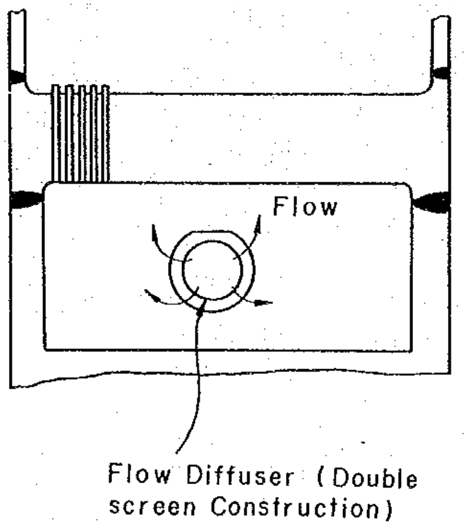
Drawing of Conventional Type
High Pressure Feedwater Heater



Drawing of Conventional Type
High Pressure Feedwater Heater
with Additional Installation of
Guide Plate

Drawing of High Pressure Feedwater Heater with Additional Installation of Designed Flow Diffuser





CONDENSER PERFORMANCE CHECK OF PRIOK STEAM POWER STATION

Priok steam power station was designed by MAN - SIEMENS group of Germany, but the basic design data of condenser performance is not described enough in the technical specifications prepared by the group.

We tried to calculate the condenser performance in the following methods:

1. Basic data

The required data for the analysis of condenser performance is selected from the heat balance and the technical specifications.

(1)	Cooling water temperature at condenser inlet	30°C
(2)	Condenser water quantity at condenser outlet	88,410 Kg/H
(3)	Design value of condenser vacuum	not given
(4)	Cooling water quantity at condenser inlet	5,500 m³/H

(5) Heat duty of condenser

Heat input of condenser is the following:

• Main Steam from the Turbine	77,970 Kg/H x 535 Kcal/Kg ≑ 41.8 x 10^6 Kcal/H
• Air Ejector steam	260 Kg/H x 747.5 Kcal/Kg = 0.2 x 10^6 Kcal/H
• Low Press Heater Drain	10,280 Kg/H x 51.1 Kcal/Kg = 0.53 x 10^6 Kcal/H
• Total Heat Duty	42.53 x 10^6 Kcal/H

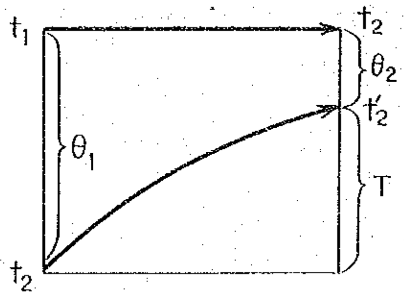
(6) Design Data of Condenser

• Cooling surface	2,300 m²

• Tube size	23 mm x 1 mm x 7,065 mm
• No of tubes	4,560
• Sea water velocity in condenser tube	1.93 m/sec

2. Calculation of condenser performance

The condenser performance is calculated using the basic data as follows:



where: Q = Heat duty of condenser

w = Quantity of sea water for cooling

w = Quantity of condensate water

i_1, i_2 = Enthalpy of cooling water at condenser inlet and outlet

i_1, i_2 = Enthalpy of condensator water at condenser inlet and outlet

Q (Heat duty of condenser) must be balanced as following formula:

$$Q = w\,(i_2 - i_1) = w\,(i_2 - i_1)$$

from the basic data

$$w = 5{,}500\ m^3/H \times 1{,}025\ t/m^3 \times 10^3 = 5.69 \times 10^6\ Kg/H$$

$$Q = 42.53 \times 10^6\ Kcal/H$$

$$i_2 - i_1 = \frac{Q}{w} = \frac{42.53 \times 10^6}{5.69 \times 10^6} = 7.46\ Kcal/Kg$$

Sea water temperature of inlet condenser is showing at 30°C

$i_1 = 30$ Kcal/Kg

$i_2 = i_1 + 7.46 \approx 37.5$ Kcal/Kg

$t_2 = 37.5°C$

$T = t_2 - t_1 = 7.5°C$

The following formula can be applied for the calculation of the mean temperature of heat exchanger.

$$Q = K \cdot A \cdot \frac{\theta_1 - \theta_2}{\log_e \frac{\theta_1}{\theta_2}} \quad \cdots\cdots \quad (1)$$

$$\theta_1 = \theta_2 + \Delta T \quad \cdots\cdots \quad (2)$$

from formula (1) and (2) we can get the formula (3) as follows:

$$Q = K \cdot A \, \frac{\Delta T}{\log_e \frac{\theta_2 + \Delta T}{\theta_2}} \quad \cdots\cdots \quad (3)$$

Then, the formula (3) can be modificated as follows:

$$\log_e 1 + \frac{\Delta T}{\theta_2} = \frac{K \cdot A \cdot \Delta T}{Q} \quad \cdots\cdots \quad (4)$$

Q_2 can be calculated from the formula (4) as follows:

$$e^{\frac{K \cdot A \cdot \Delta T}{Q}} = 1 + \frac{\Delta T}{\theta_2}$$

$$\theta_2 = \frac{\Delta T}{e^{\frac{K \cdot A \cdot \Delta T}{Q}}}$$

From the basic data, the following figures can be inserted into the symbols of the above formula.

where: $e = 2.718$

A = condenser cooling surface is 2,300 m^2

K = coefficient of thermal conductivity is 2,790 Kcal/m^2 H°C (assumed)

Q = heat duty of condenser is 42.53×10^6 Kcal

ΔT = temperature rise of cooling water is 7.5°C

If the above figures are inserted into the above formula, the mean temperature of heat exchanger and others can be calculated as follows:

$$\frac{K \cdot A \cdot \Delta T}{Q} = \frac{2{,}790 \times 2{,}300 \times 7.5}{42.53 \times 10^6} = 1.13$$

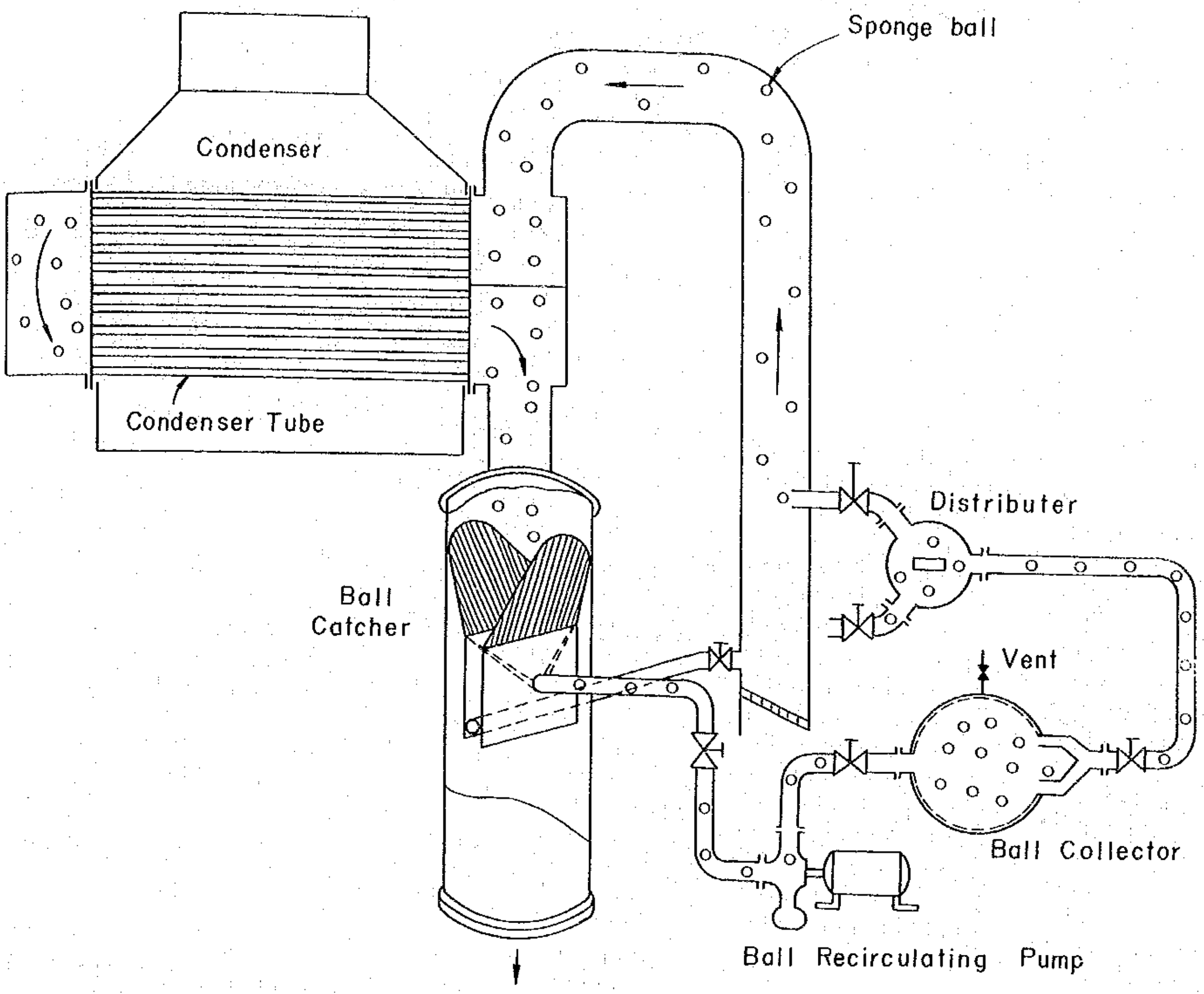
$$\theta_2 = \frac{7.5}{e^{1.13} - 1} = \frac{7.5}{3.1 - 1} = 3.6°C$$

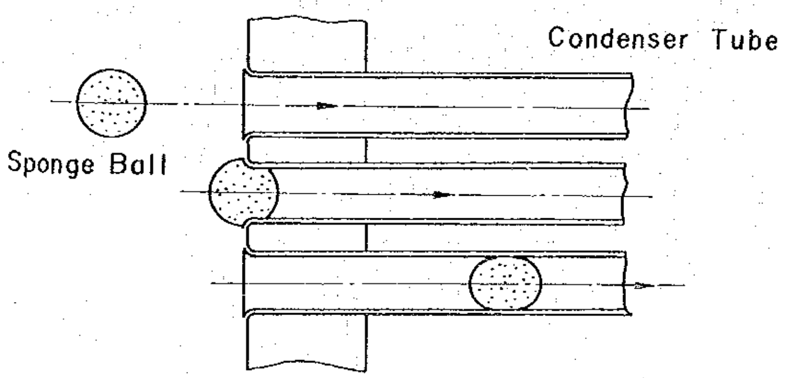
$$t_2 = 37.5 + 3.6 = 41.1°C$$

The saturated temperature at about 0.080 Kg/cm^2 absolute is 41.1°C. When condensate water is saturated at the above temperature of condenser hotwell, condenser vacuum will be raised to 2.3 Hg absolute. Consequently, the condensers of Priok units 1 and 2 were designed at condenser vacuum of 2.3 inches Hg absolute.

Appendix 3 - 7

Flow Diagram of Condenser Tube Continuous Cleaning Device for Priok Units 1and 2





TECHNICAL INFORMATION FOR FEEDWATER TREATMENT AT PRIOK UNITS 1 AND 2

1. Calculation method for chemical injection

(1) Injection of deoxygen chemicals

a. Continuous chemical injection pump

The capacity of continuous injection pump described in the specification of Priok units 1 and 2 is as follows.

$$\underset{(126)}{Na_2SO_3} + \underset{(16)}{\tfrac{1}{2}O_2} \rightarrow Na_2SO_4\downarrow$$

The value of dissolved oxygen of 0.05 ppmiis quoted from the actual operating record. Na_2SO_3 settled more than two times in amount of dissolved oxygen is injected. The necessary actual pump capacity for 100 T/h of feedwater is as follows.

$$100 \times 10^3 \times 0.05 \times 10^{-6} \times 2 \times 126/16 = 0.08 \text{ Kg/h}$$

Taking account of the injection of 5% of Na_2SO_3 solution, the actual pump capacity is calculated as follows.

$$0.08/0.05 = 1.6 \text{ l/h}$$

b. Intermittent injection pump (Injecting Na_2SO_3 at starting period of a boiler)

This pump is provided to inject 10 ppm of SO_3^{2-} at starting period of a boiler

$$100 \times 10^3 \times 10 \times 10^{-6} \times 126/80 = 1.6 \text{ Kg/h of } Na_2SO_3$$

If 5% solution of Na_2SO_3 is injected the actual pump capacity is to be as follows.

$$1.6 \times 1/0.05 = 32 \text{ l/h}$$

(2) Injection of chemicals for PH control

In order to inject Na_2SO_3 to obtain 15 ppm of PO_4^{3-} in boiler water with in 30 minutes. The actual pump capacity is to be as follows.

$$30 \times 10^3 \times 15 \times 10^{-6} \times \frac{60}{30} \times \frac{164}{95} = 1.5 \text{ Kg/h}$$

Total water amount in boiler $\qquad$ Na_3PO_4/PO_4

If 5% solution of Na_3PO_4 is injected the actual capacity is to be as follows.

$$1.5 \times \frac{1}{0.05} = 30 \text{ l/h}$$

2. Cost of injection chemicals and injection pumps

(1) Price of injection chemicals

Prices of injection chemicals for feedwater treatment at similar class of units in Japan as Priok units 1 and 2 are shown in the following table. (This price are showned as FAS price.)

(Unit ¥/Kg)

Kind of Chemicals	Price
Na_2SO_3	Approx. 70
60% $N_2H_4 \cdot H_2O$	400
$Na_3PO_4 \cdot 12H_2O$	60
$O(C_2H_4)_2NH$	600

(2) Price of chemical injection pump assembly

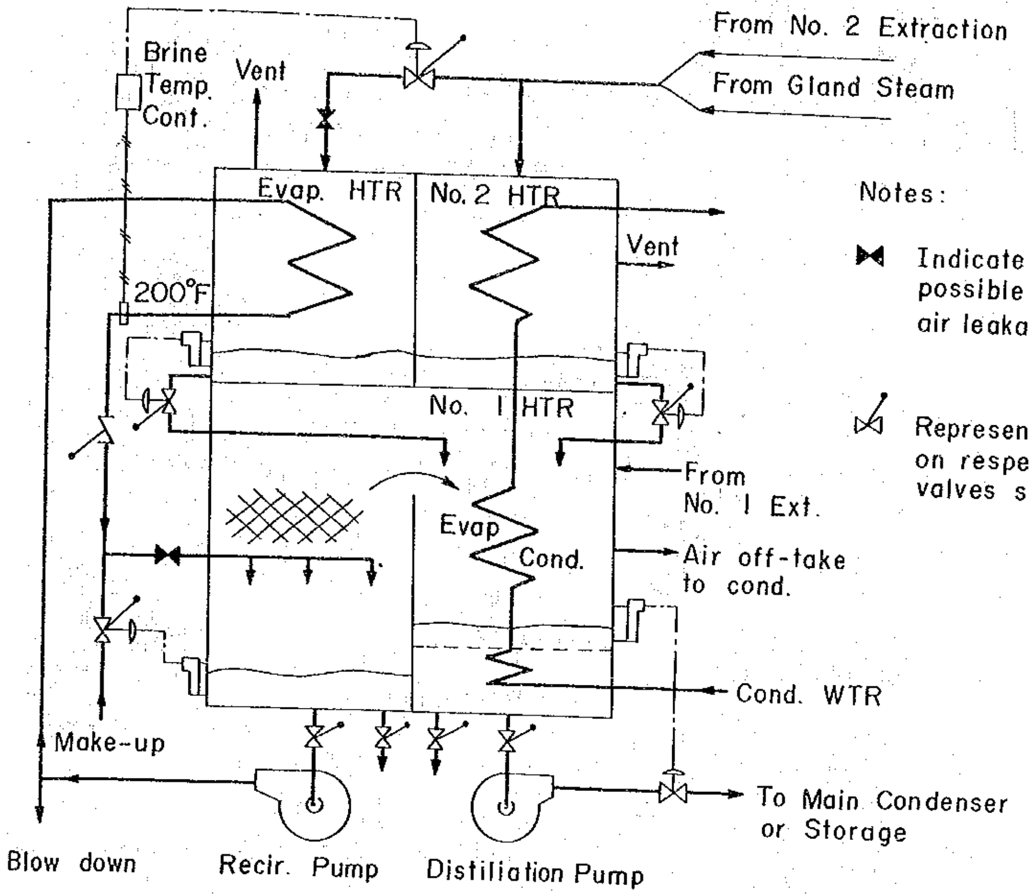
Price of chemical injection pumps for feedwater treatment for similar class of units in Japan as Priok units 1 and 2 are shown in the following table. (This price are showned as FAS Price.)

(Unit ¥)

Capacity of Pump	Price of Pump	Price of Accessary	Total Prices
1.6 l/h (Del. Press 3 Kg/cm^2) or 30 l/h (Del. Press 65 Kg/cm^2)	Approx. 700 x 10^3	Approx. 600 x 10^3	Approx. 1,300 x 10^3

Appendix 3-9

Check Points of Flash Evaporator Unit for Perak Units 1 and 2

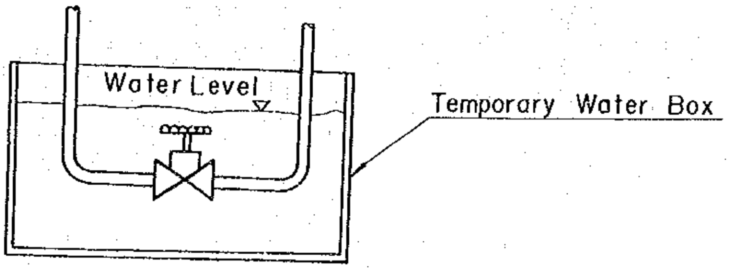


Notes:

⧓ Indicate that it may be possible to prevented air leakage by new valves

⋈ Represent that air leakage on respective existing valves should be checked

Conceptional Drawing on Air Leakage Checking Method



Appendix 3–10

TEST REPORT FOR PRIMARY SUPERHEATER TUBE CORROSION ON THE BOILER OF PERAK STEAM POWER STATION

This is the report by Ishikawajima-Harima Heavy Industries Co., Ltd., a licensee of Foster Wheeler Corporation, on the results of investigation of Perak Steam Power Station's superheater sample pieces.

We are reporting herein under result of our investigation on superheater tube corrosion which occurred in the boiler fabricated by Foster Wheeler Corporation, of Perak Steam Power Station Indonesia.

We received two specimens of the superheater tube and investigation was performed along these specimens subjected to following inspection items.

1. INSPECTION ITEMS

(1) Macrography

(2) Dimensional inspection

(3) Chemical analysis

(4) Micro-structure inspection

(5) X-ray inspection

Note: Inspected points are shown in Fig. 1.

2. RESULTS

2-1 MACROGRAPHY

Inner surface of tested two specimens are shown in Photo. 1 and Photo. 2 respectively.

Some large pitting corrosion was observed in both of them, and it rusted inner surface of them in red and brown. We could not guess exactly when the brown rust had grown, but judging from its condition it might occur after specimens were sampled and have no relation to subjected pitting corrosion.

2.2 DIMENSIONAL INSPECTION

Since the specimens were not perfect cylindrical tube, outside diameter could not be measured exactly but it was considered as a part of 63.5 mm (2½ inches) outside diameter tubes. It was sure the superheater tube had been scarcely swelled.

Reduction of the tube thickness due to abnormal phenomena such as corrosion, erosion or creep was not found.

Result of the inspection is shown in Fig. 2.

2.3 CHEMICAL ANALYSIS

Result of chemical analysis is shown in Table 1.

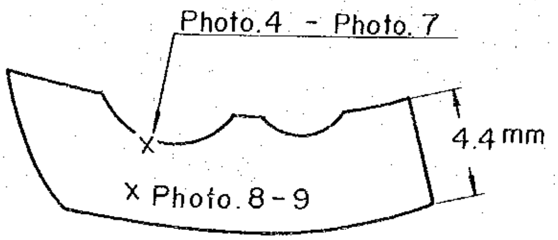
Material of the specimens were not specified, however from the result of chemical analysis we could guess it was equivalent to ASTM A213-61T T12 and met its material specification. Besides, ASTM A213-61T T12 is equivalent to JIS (Japanese Industrial Standards) STBA22.

We believe that selection of the tube material was reasonably considered as a superheater tube.

2.4 MICRO-STRUCTURE INSPECTION

Pictures of micro-structure were taken at near the points where pitting corrosion had occurred.

These points are shown in schematic drawing below and pictures are shown in Photo. 4 - Photo. 9



X indicaotes position of the mirror.

Photo. 4 shows the bottom of pitting corrosion and enlarged parts of Photo. 4 are shown in Photo. 5 - Photo. 7.

Photo. 8 shows section of the tube and enlarged part is shown in Photo 9.

Judging from these pictures, thermal defect is not found and abnormal temperature rise of the tube had not occurred.

A micro-crack and a corrosion of grain boundary were not found around bottom of the pitting corrosion. Corrosion had occurred uniformly to grain boundary and grains itself. Therefore we supposed stress corrosion had not occurred.

2.5 X-RAY INSPECTION

In order to inspect the property of scale on the inner surface of pitting corrosion, X-ray micro analyzer was used. Result of the inspection is shown in Photo 10.

On the absorbed electron image, white large part which covers two thirds of the image shows base metal.

Black part in center of the white part shows pitting corrosion and scale is observed along the base metal.

It is verified by X-ray image of Fe that main component of the scale is Fe.

As for Cr and Mo, these elements issued from base metal are naturally caught.

Concerning S, Mn, Si, P and Na, they have also no major problem.

But segregation of Cu is observed in scale on the picture of Cu, its numerical judgement is very difficult but some abnormal condition are observed.

3. CONSIDERATION

Judging from observation, primary factor of pitting corrosion might not be caused by erosion.

As for material, it was normal and phenomenon of overheated swelling was not found. However it was not clarified whether segregation had occurred or not in base metal of the tube.

On the other hand, we could hardly suppose that pitting corrosion had depended on abnormal segregation except in case of generally observed micro-segregation.

Because in the latter case the segregation occurs generally along the milling direction but pitting corrosion results in rounded shape. Furthermore, any trace of abnormal segregation was not found by microscope.

According to the results of X-ray microanalyzer inspection, Cu-separation was observed, this will mean that copper might have been brought with water from outside of the boiler rather than copper as impurities of material might have separated.

If copper exists, ferrous near the copper will be electrochemically corroded.

4 CONCLUSION

As described above, we can suppose that pitting corrosion had not been caused by erosion or segregation but had been caused by corrosion.

We heard that the boiler was operated and laid every three months and in those periods any special attention for corrosion such as N_2 filling was not paid.

Therefore, in horizontal superheater tubes drain might remain and air might enter when laying up the boiler.

Due to above reasons we suppose that it started to rust and formed pitching, furthermore local circuit occurred on inside surface of tube and pitching was encouraged seriously. Separation of the copper also might make progress on the pitting corrosion seriously.

5. 3 PROCEDURES FOR IMPROVEMENT

It is the best way to run the boiler without shutting off through a year. If it is impossible, we will recommend following procedures to keep the boiler safely when laying up.

(1) Drying up the boiler . . . . . (fill the boiler with N_2 gas)

(2) Full filling up the boiler with water . . . . . (add hydrazine)

(3) Adding hydrazine to water and filling rest space with N_2 gas.

Pictures of Macrography

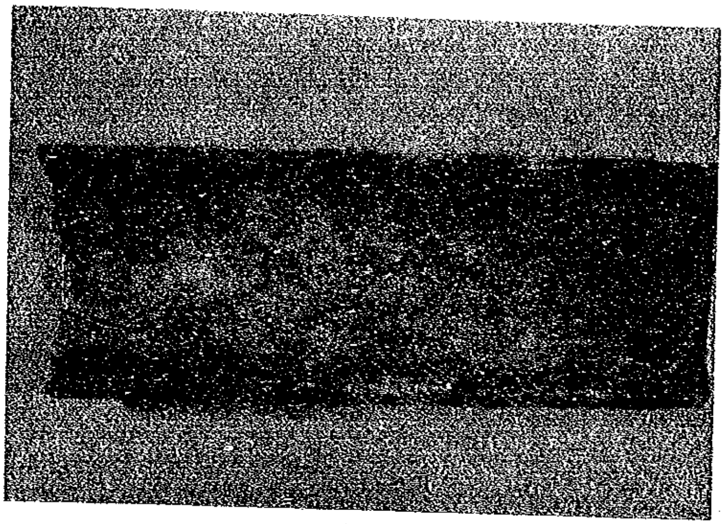


Photo 1

Inner surface

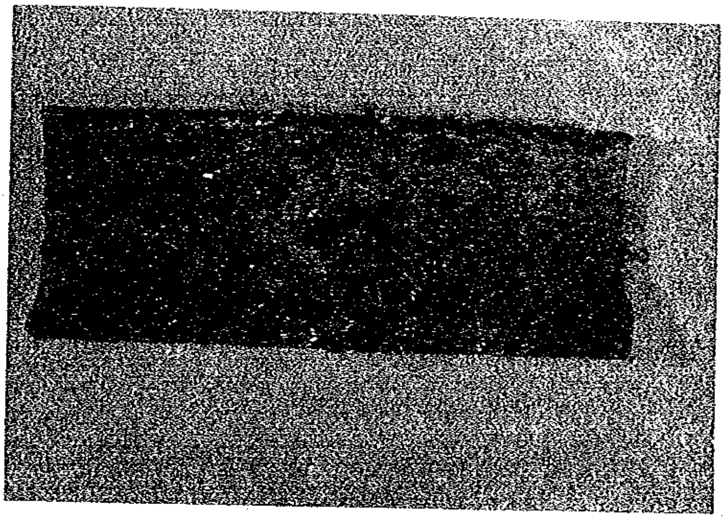


Photo 2

Inner surface

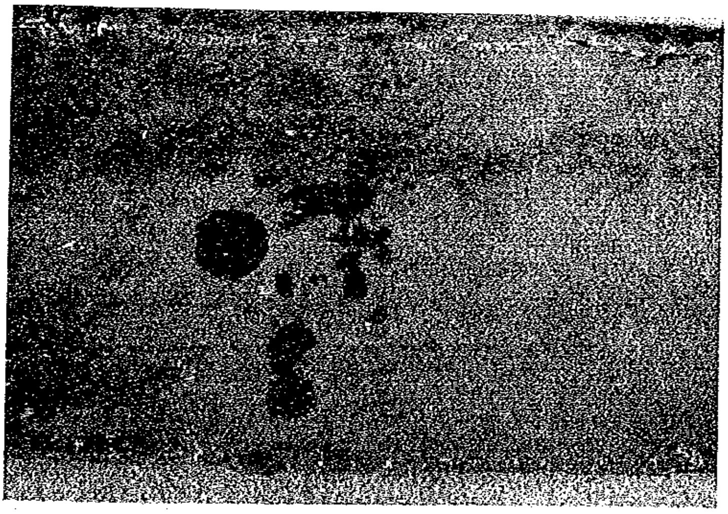


Photo 3

Enlarged part of Photo 2

Fig. 1 Sampling points

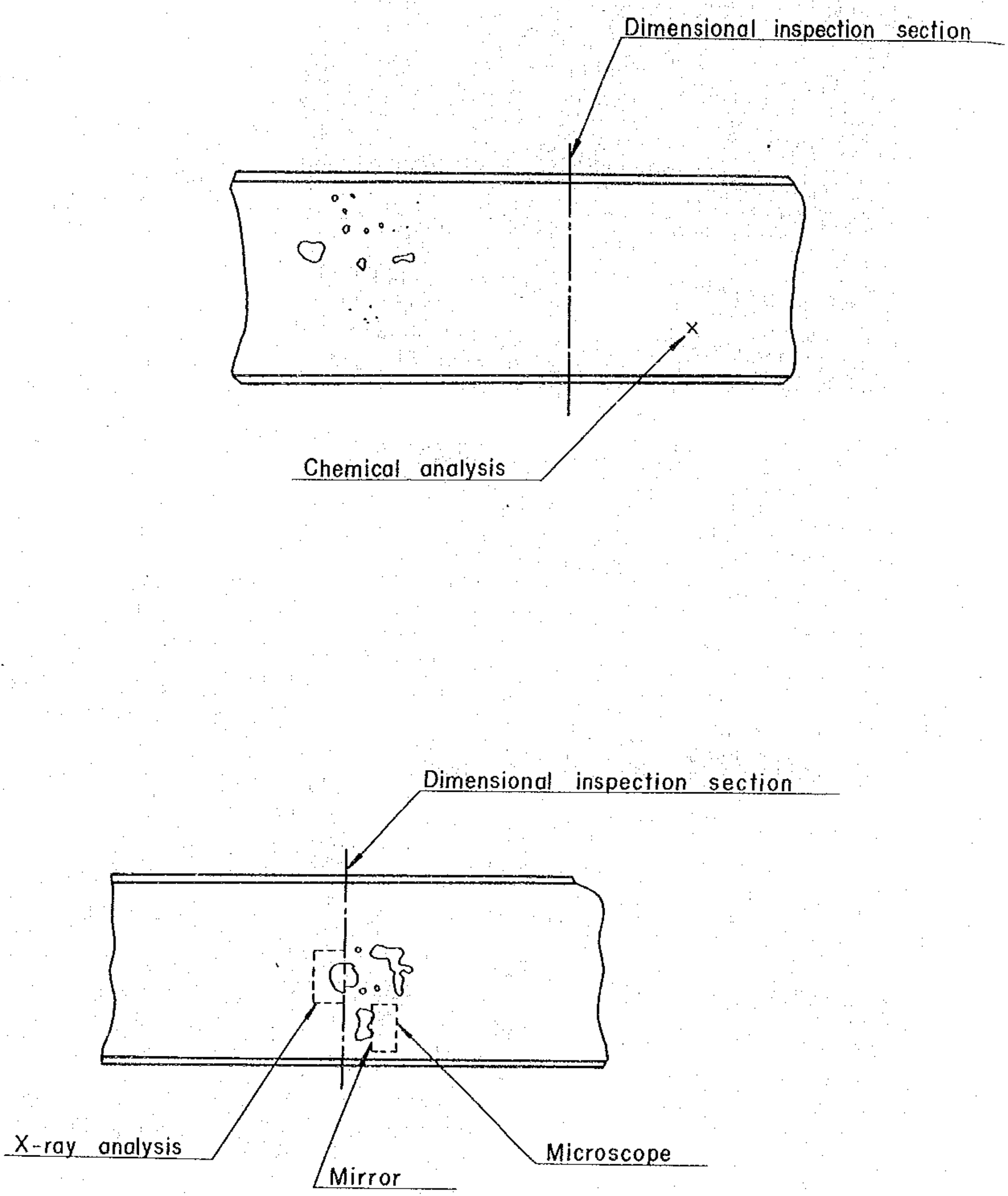
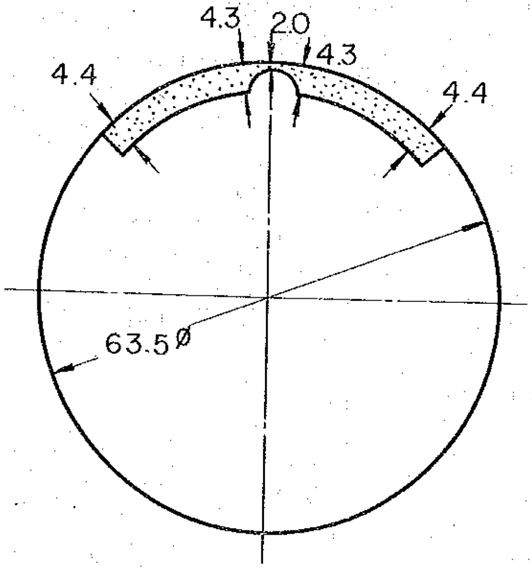
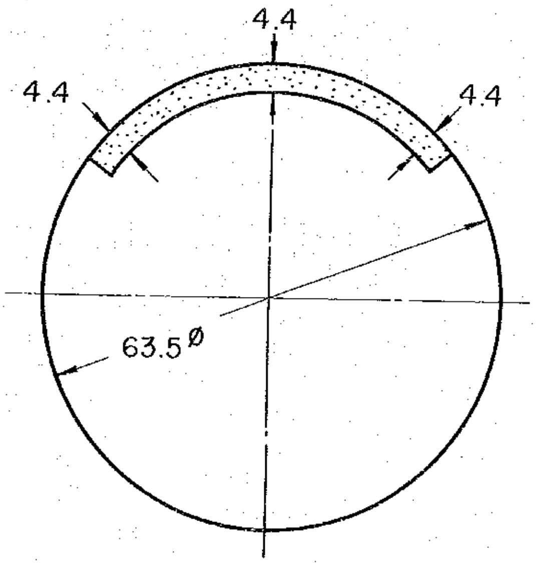


Fig. 2 Result of dimensional inapection

Nominal dimenaion (aupposed) 63.5Ø x 3.5^t mm
or 4.0^t mm





Micro structure

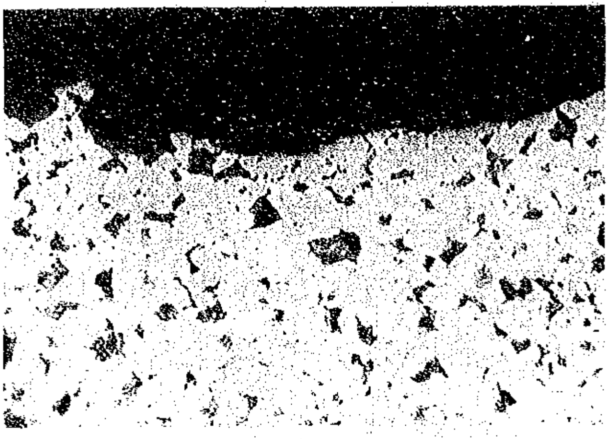


Photo 4 x 100

Photo 5 x 500

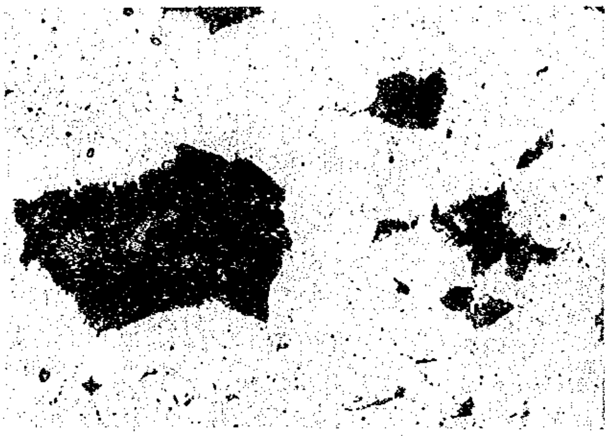


Photo 6 x 500

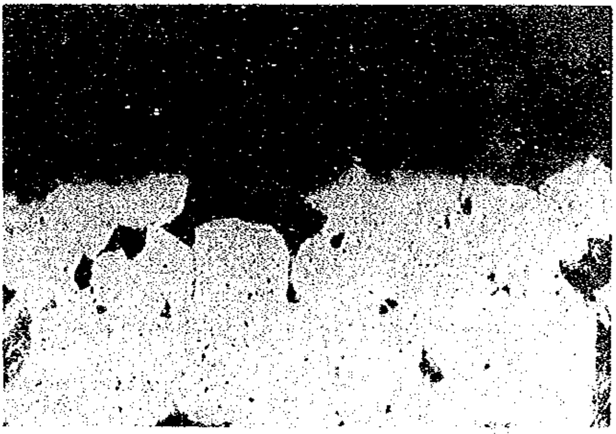


Photo 7 x 500

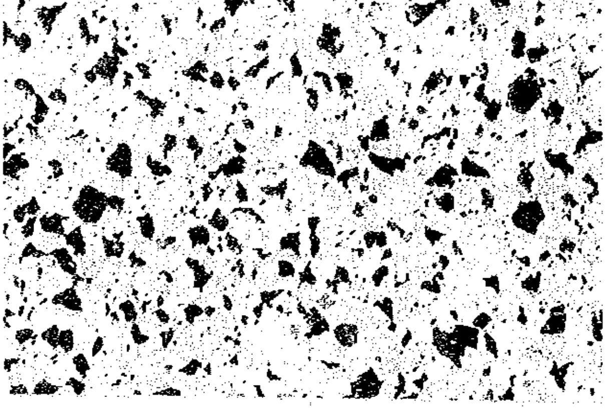


Photo 8 x 100

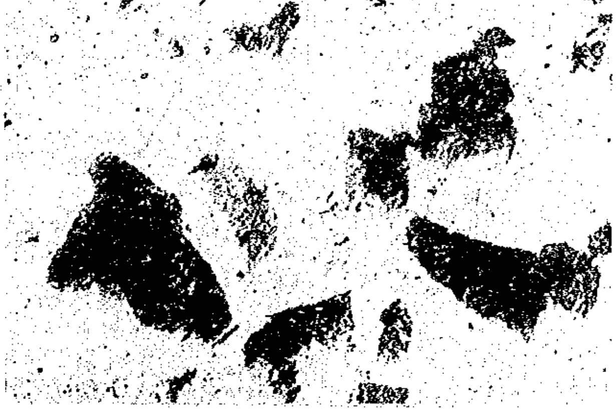
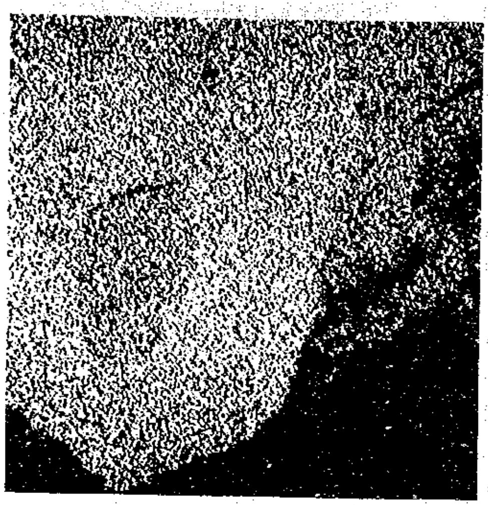


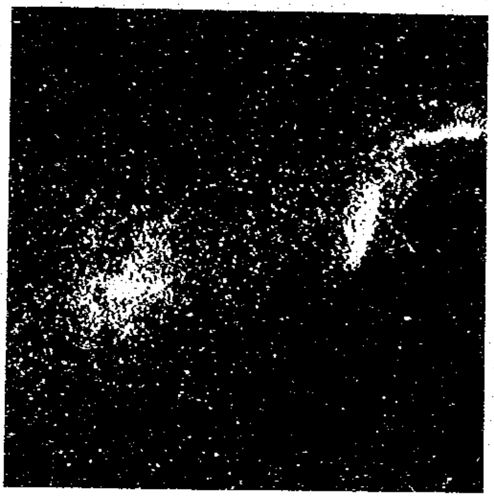
Photo 9 x 500

Photo 10 X-ray image

Absorbed electron image x 600

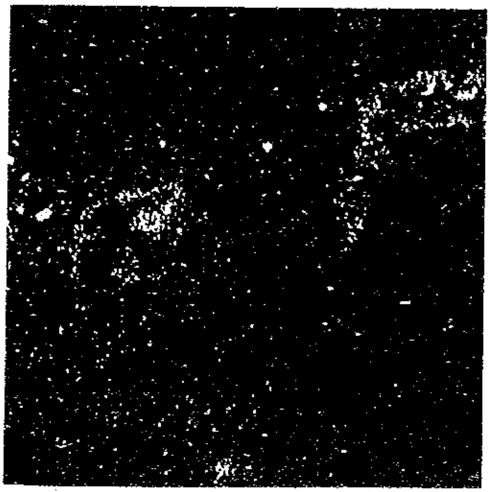


Fe X-ray image x 600

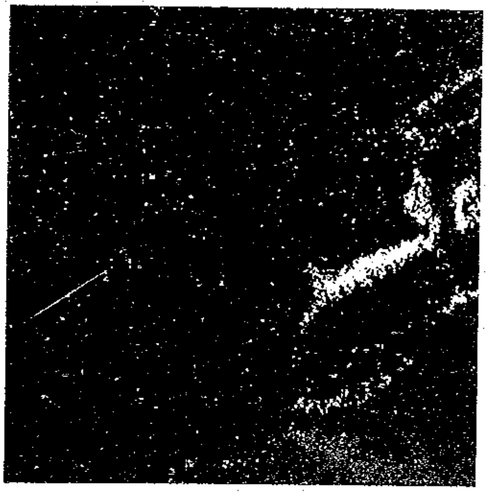


Mo X-ray image x 600

Cr X-ray image x 600

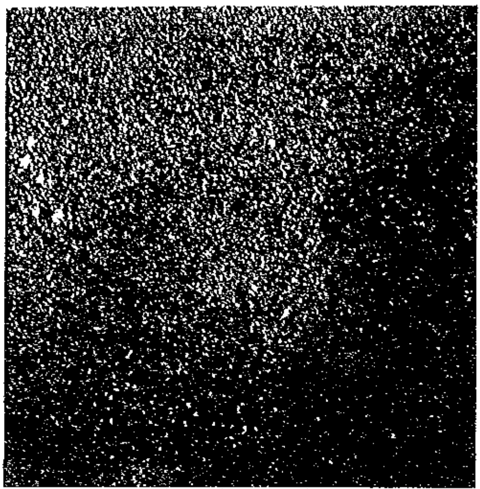


S X-ray image x 600

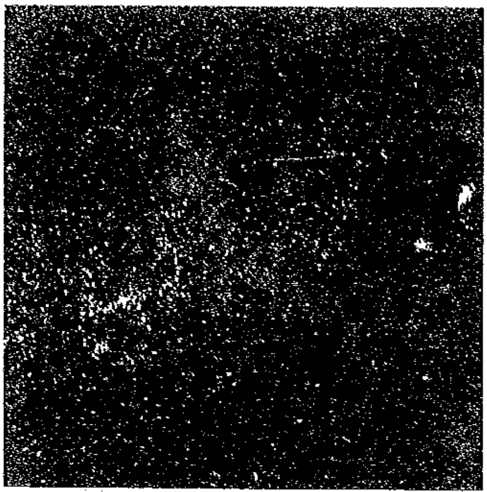


Cu X-ray image x 600

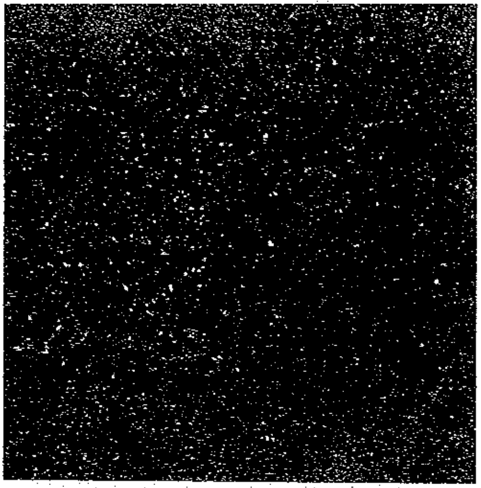
Photo 10 (cont'd)



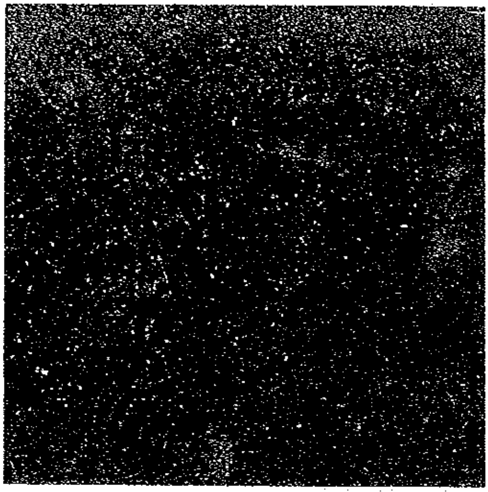
Mn X-ray image x 600



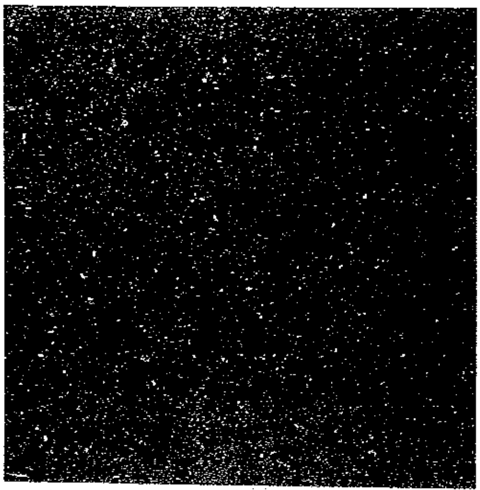
Si X-ray image x 600



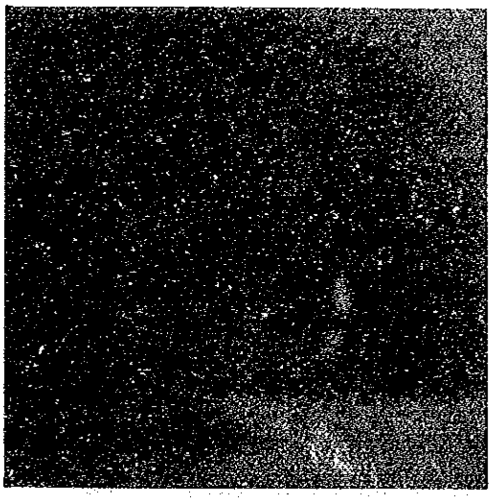
Ca X-ray image x 600



P X-ray x 600



Na X-ray image x 600

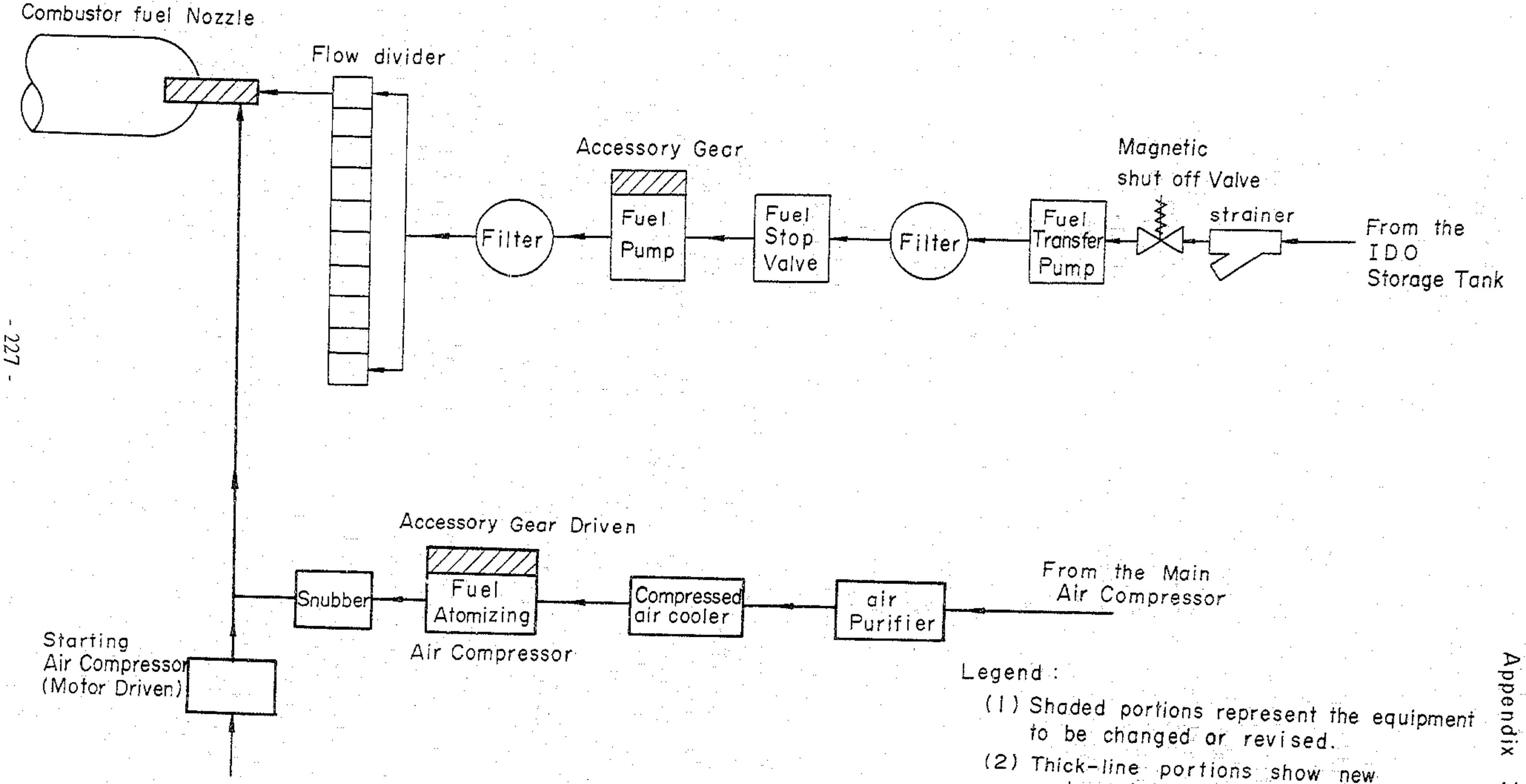


Mg X-ray image x 600

Table 1 The result of chemical analysis
(base metal of tube)

Content \ Material	Subjected Specimen	FOR REFERENCE	
		ASTM A213-61T T-12	JIS G 3462 STBA22
C	0.093	less than 0.15	less than 0.15
Si	0.18	less than 0.50	less than 0.50
Mn	0.48	0.3 - 0.61	0.3 - 0.60
P	0.008	less than 0.045	less than 0.035
S	0.013	less than 0.045	less than 0.035
Ni	0.053	–	–
Cr	1.03	0.8 - 1.25	0.8 - 1.25
Mo	0.53	0.44 - 0.65	0.45 - 0.65
Cu	0.065	–	–

Fuel Supply System Diagram for Semarang Gas Turbine revised to Island Diesel Oil Firing

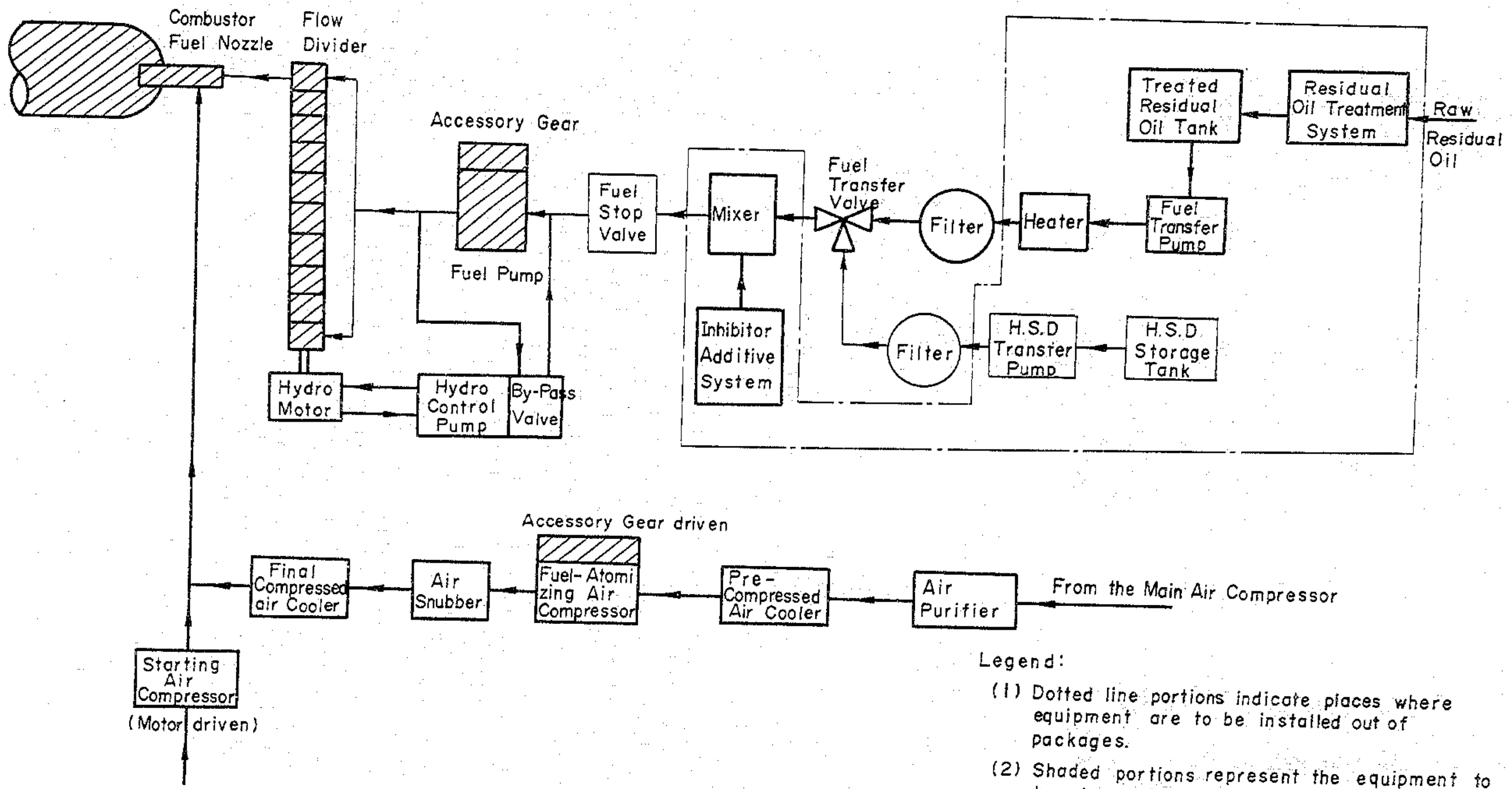


Legend :

(1) Shaded portions represent the equipment to be changed or revised.

(2) Thick-line portions show new equipment to be added.

Fuel Supply System Diagram for Semarang Gas Turbine revised to Residual Oil Firing



Legend:

(1) Dotted line portions indicate places where equipment are to be installed out of packages.

(2) Shaded portions represent the equipment to be changed or reversed.

(3) Thick-line portions show new equipment to be added.