10.3.3 Electrical Equipment

(1) Selection of Major Equipment

Lower Kihansi Power Station has an effective head of 813.0 m, a maximum available discharge of 22.2 m^3/sec (or 7.4 m^3/sec when 1 unit is used), with the power station output of 153,000 kW. With these design features, only Pelton turbine can be used. It is judged that based on the estimated cost, power system size and the unit sized in existing power stations that there will be little adverse effect on the power system even if a 3-unit design is selected. A cost study is done to compare the relative advantage of vertical shaft type and horizontal shaft type, and the vertical shaft type is selected because of its higher economy. The comparison of vertical shaft and horizontal shaft design is given in Table 10-9.

i) It is generally easier to overhaul turbines and generators with the horizontal shaft type as compared to the vertical shaft type. However, the elevation of the turbine center has to be raised by 1.0 m with the horizontal shaft type, with corresponding reduction of effective head.

ii) When the horizontal shaft design is selected, either the single-wheel, 2-nozzle Pelton turbine or the two-wheel, 4-nozzle Pelton turbine are selected. Under the current plan, the speed of a single-wheel, two nozzle Pelton turbine must be 360 rpm due to the limit placed on the specific turbine speed. This makes the geometry and weight of the turbine increase, with increased cost.

In addition, the performance of a 2-nozzle turbine at partial load is inferior to that of 4-nozzle turbine.

Although the speed of a horizontal shaft, two-wheel 4-nozzle turbine is 514 rpm., which is the same as a vertical shaft, four-nozzle turbine, the horizontal shaft turbine is larger in weight and more expensive than a vertical shaft turbine.

iii) Generally speaking, the dimensions of powerhouse becomes larger with the horizontal shaft turbine as compared with the case of vertical shaft turbine. Under the current plan, the floor area of the powerhouse is 480 m^2 larger than with the vertical shaft turbine when horizontal shaft, single-wheel, 2-nozzle Pelton turbine or horizontal shaft, 4-nozzle Pelton turbine is selected. Based on the above analysis, the vertical shaft, 6-nozzle Pelton turbine is selected which has more merit.

The turbine unit selected is the vertical shaft, single-wheel, 6-nozzle turbine (VP-1R6N), each having a 52,000 kW output and 750 rpm. speed.

The generator unit selected is 3-phase, AC synchronous generator with 57,000 kVA capacity. The power factor of the generators of the Lower Kihansi Power Station is selected at 0.9 (lag) to realize higher economy. This is based on the consideration that, although the power factor of generators of existing power stations is at 0.85 (lag), and the reactive power needed for the regulation of power system voltage is currently not quite sufficient, the power system voltage near Iringa Substation is relatively high, and the reactive power supply from Iringa Substation is sufficient for voltage control of this area. The generator voltage is selected at 11 kV which is the most suitable value for the capacity of the generators. The capacity of the main transformer is selected at 19,000 kVA, and 10 outdoor type, single phase oil filled transformers (including 1 spare transformer) are installed in the outdoor switchyard to raise the 11 kV generator voltage to 220 kV transmission voltage.

The switchyard is an outdoor, and it is constructed at a location adjacent to the powerhouse. The transmission line is designed as a 220 kV, double circuit line, which runs from Lower Kihansi Power Station for approximately 113 km and is connected to the 220 kV bus of Iringa Substation. In future, the Upper Kihansi Power Station is connected to one circuit of the line by "pi" connection.

The control system for the switchyard is to be the one-man control system, by which the operating personnel stationed in the power station can control the switchyard equipment.

The control system is to be so designed that the Upper Kihansi Power Station can be remotely controlled from Lower Kihansi Power Station in future.

The major electrical equipment of Lower Kihansi Power Station are indicated below:

- Turbine

Type	Vertical shaft Pelton turbine (6-nozzle)
Number of units	3
Rated effective head	813.00 m
Water discharge	7.4 m^3/sec (22.2 m^3/s with 3 units)
Rated output	52 MW
Revolving speed	750 rpm

- Generator

Type	3-phase, AC, synchronous generator
Number of units	3
Capacity	57 MVA (with 0.9 lagging power factor)
Revolving speed	750 rpm
Frequency	50 Hz
Voltage	11 kV

- Main Transformer

Type	Outdoor, single-phase transformer
Number of units	10 (including 1 spare transformer)
Capacity	57 MVA (19 MVA x 3 +1)
Voltage	11 kV

- Switchyard

Bus type	Double bus
Bus	Aluminum cable
Number of lines	2 circuits
Voltage	220 kV
Conductor type	AAC 400 mm^2
Section	Lower Kihansi Power Station to Iringa Substation

- Interconnection Lines

Number of circuits	3 circuits
Number of Bays	3
Voltage	220 kV
Conductor type	ACSR 380 mm^2
Section	Main transformer to switchyard

- Transmission Line

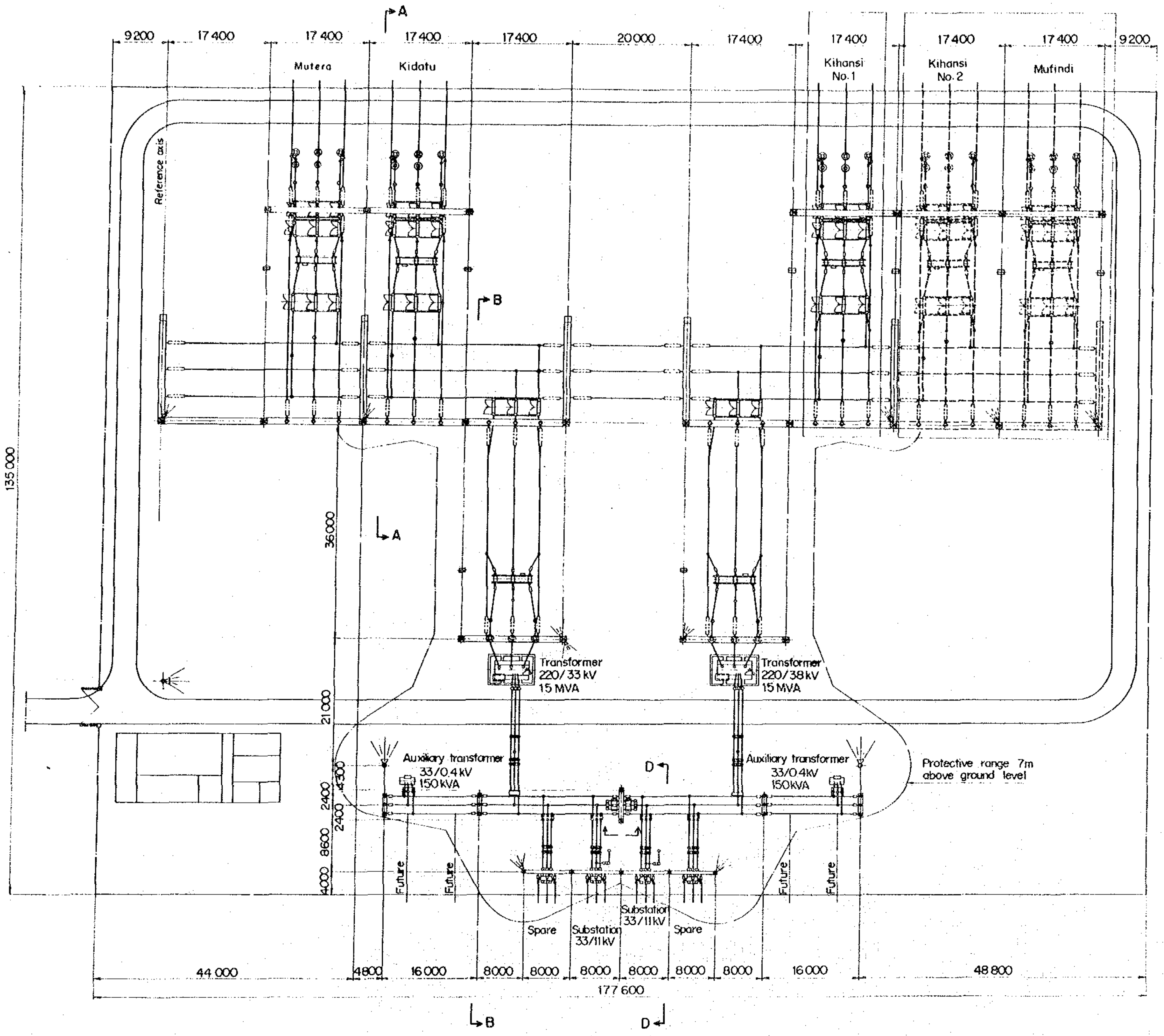
Total length	113 km
Number of circuits	Double circuits
Voltage	220 kV
Conductor type	ACSR 380 mm^2
Section	Lower P.S. - Upper P.S. - Iringa S.S.

(2) Expansion of Existing Iringa Substation Switchyard

The double circuit transmission lines from Lower Kihansi Power Station shall be connected to the switchyard of Iringa Substation (which is to be modified to a double bus configuration in future). At present, Iringa Substation has facilities for 3 circuits of 220 kV transmission lines (Mtera, Kidatu and Mufindi) and double circuit of 33 kV lines.

Additional space required for connection of the double circuit transmission line interconnecting Kihansi system is already provided in this switchyard.

The equipment layout in Iringa Substation is given in Fig. 10-41, and the related Kihansi electric power system diagram in Fig. 10-42.

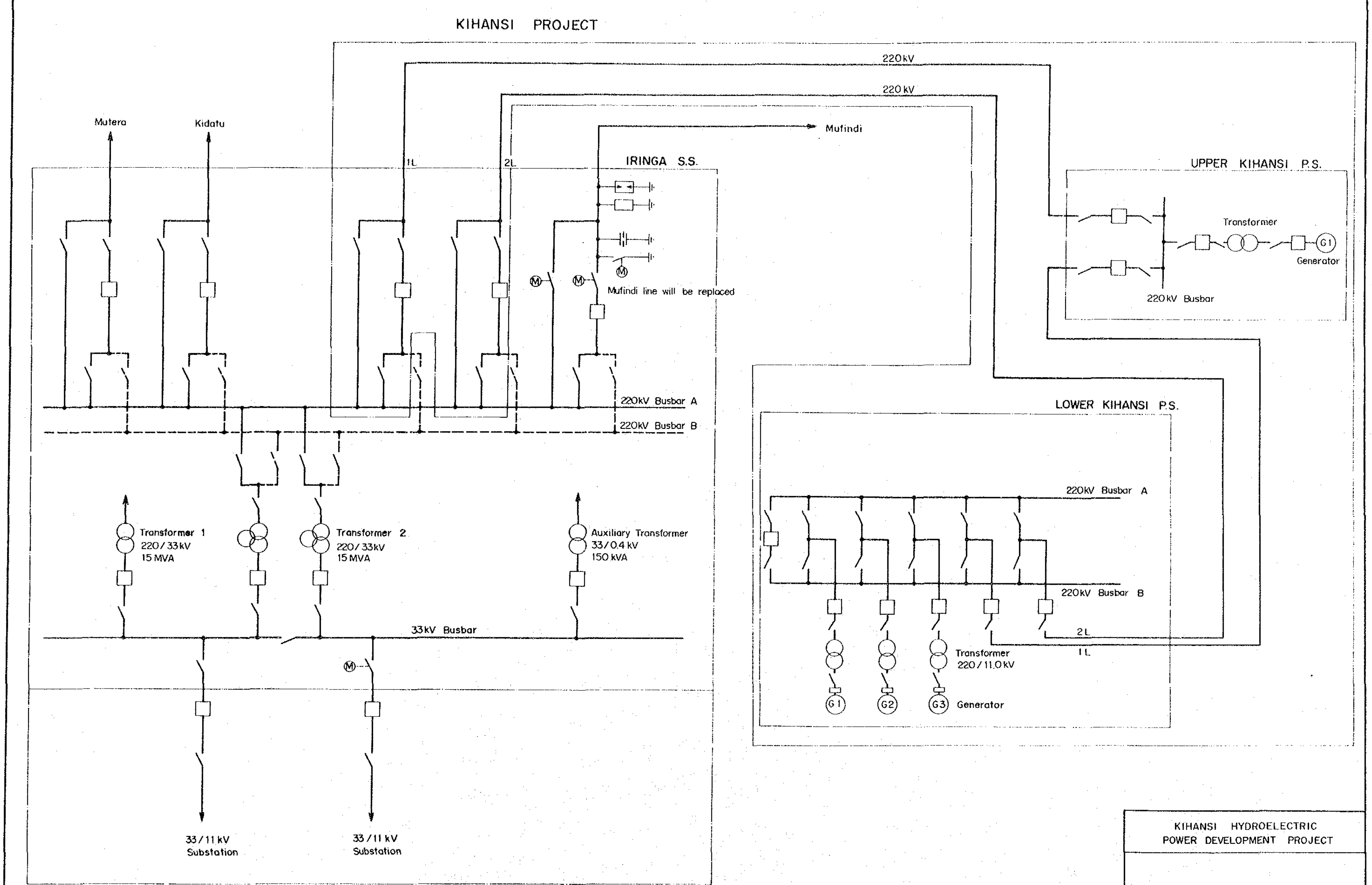


KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

IRINGA SUBSTATION

GENERAL ARRANGEMENT

Fig. 10 - 41	DATE :



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

KIHANSI ELECTRIC POWER SYSTEM DIAGRAM

Fig. 10 - 42	DATE :

Table 10-9 Comparison Table of Pelton Type Water Turbine

Turbine Type	Vertical Shaft 4-Nozzle (VP-1R4N)	Horizontal Shaft 4-Nozzle (HP-2R4N)	Note
Specification			
Rated Effective Head (m)	813.0	813.0	
Maximum Water Discharge (m^3/sec)	7.4	7.4	
Turbine Output (kW)	52,000	52,000	
Speed (rpm)	750	600	
Generator Capacity (kVA)	57,000	57,000	
Construction Cost (%)			
Electrical Equipment	100	132	
Civil Structures	100	113	

(3) Main Generator Circuit

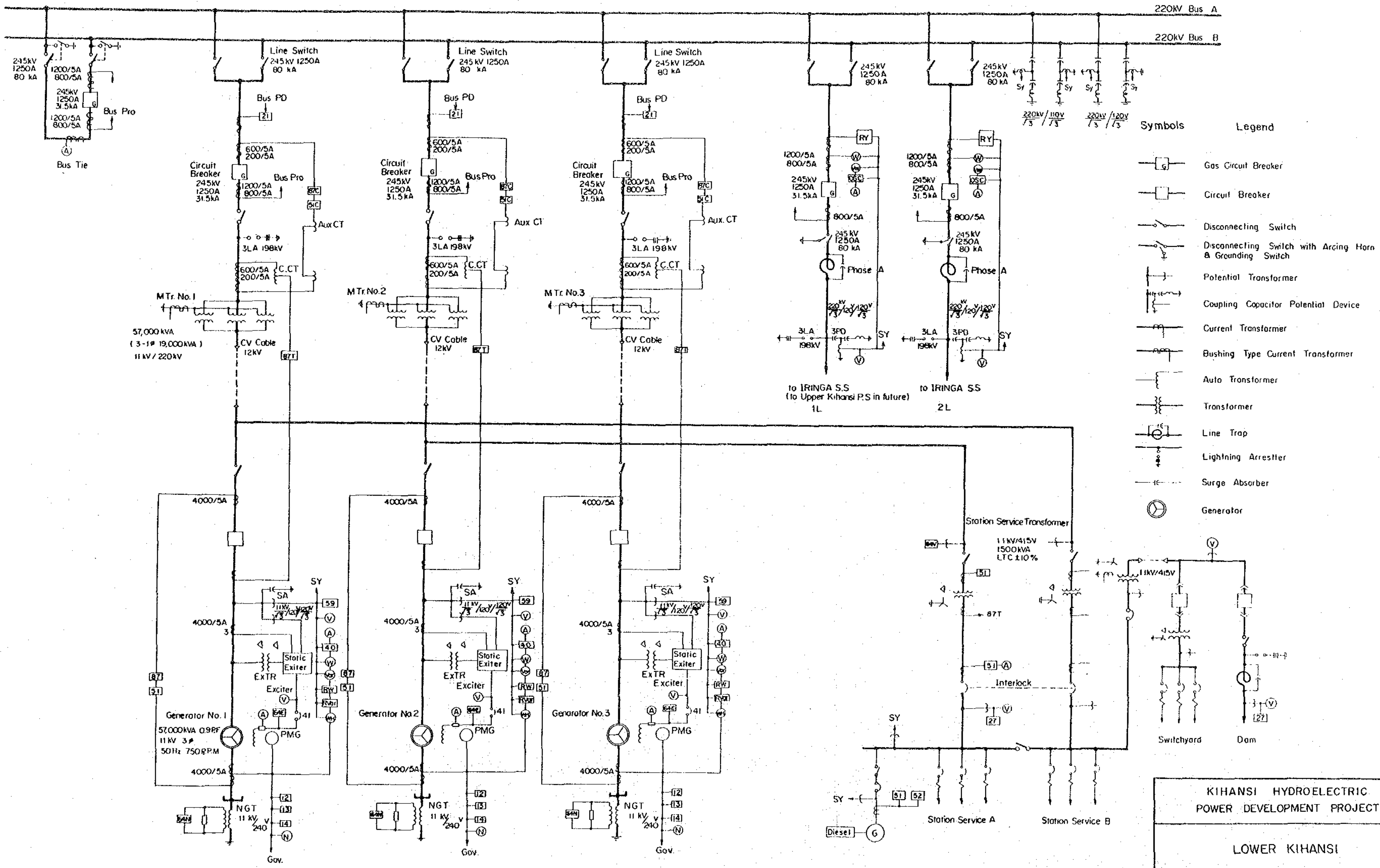
The main generator circuits are to be low-voltage-side synchronized, unit type circuits to enhance reliability and maintainability, and to assure station service power supply.

The main generators and main transformers are to be connected by power cables, and the main transformers and switchyard are connected by overhead lines. Single line diagram is shown in Fig. 10-43.

(4) Interconnection Overhead Line

The interconnection overhead lines are the 3-circuit, 220 kV overhead lines that connect the 9 main transformers, 3 of each composing a 19,000 kVA capacity, to the outdoor switchyard.

KIHANSI PROJECT (LOWER)



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOWER KIHANSI SINGLE LINE DIAGRAM

Fig. 10 - 43 | DATE ;

The conductors of this overhead lines are 380 mm^2 ACSR and the lines connect the transformer to the switchyard bay at the shortest possible route. Each transmission line circuit is to be shielded by G.S 70 mm^2 overhead ground wires, which are connected to the grounding system of the switchyard.

(5) Electrical Equipment of Powerhouse

The powerhouse is a semi-underground design, with the erection bay located next to the generator hall of the powerhouse.

The turbine-generator units are to be installed with each axis separated by a distance of 14 m, equipped with related auxiliary equipments.

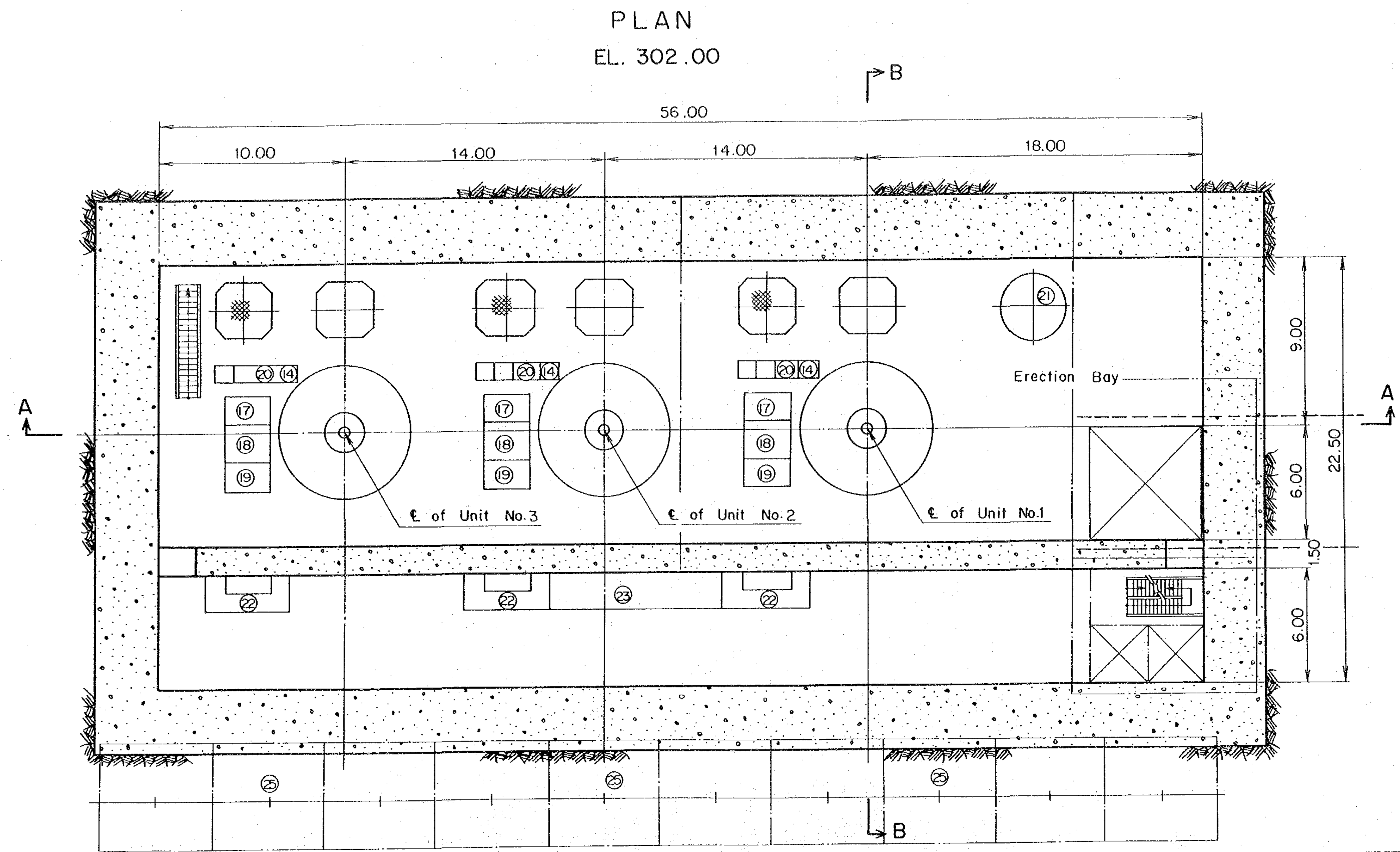
An overhead traveling crane is installed in the main equipment hall of the building, and a gantry crane for transportation of parts into the erection bay is installed outside the powerhouse. The main transformers are installed outside the powerhouse.

The equipment layout in the powerhouse is presented in Fig. 10-44 through Fig. 10-48.

(6) Electrical Equipment in Switchyard

The switchyard is constructed next to the powerhouse facing the Kihansi River, to make best use of the geographical conditions of the site, and the double circuit, 220 kV transmission line is to extend to the upper stream side of the left bank of the river. The 11 kV distribution line for operation of dam is to be constructed in parallel with the 220 kV transmission line.

The equipment layout in the switchyard is presented in Fig. 10-49 and Fig. 10-50.



LEGEND

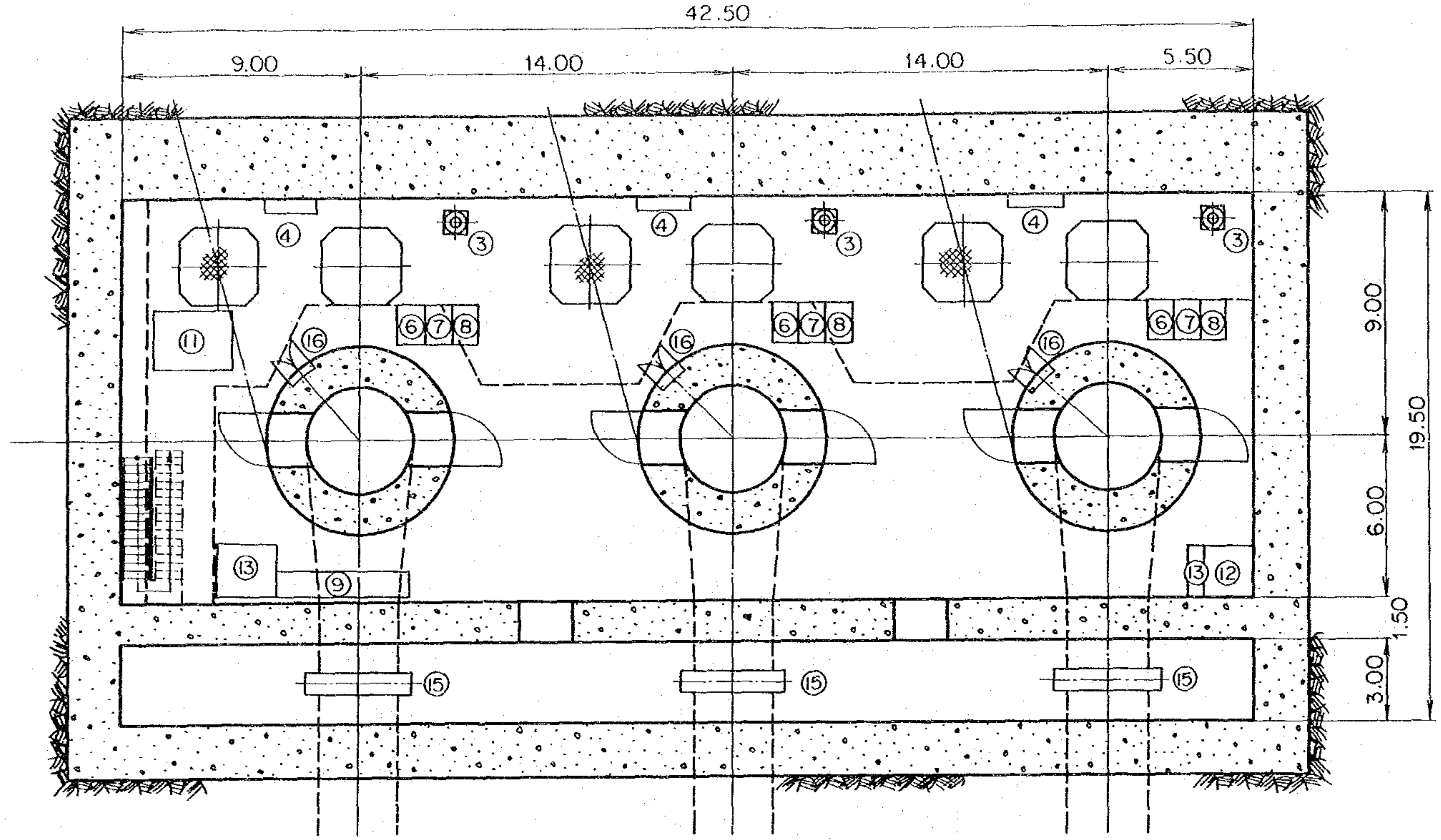
⑰ Excitation Transformer Cubicle
⑱ Bus Cubicle
⑲ Disconnecting Switch Cubicle
⑳ Static Exciter Cubicle
㉑ Rotor Pit
㉒ Generator Bus Cubicle
㉓ Station Sirvice Cubicle
㉔ Overhead Travelling Crane
㉕ Main Transformer Yard
㉖ Cable Spreding Room
㉗ Cubicles Room
㉘ Control Room
㉙ Battery Room

KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOWER KIHANSI POWERHOUSE GENERATOR FLOOR PLAN

Fig. 10 -44 | DATE :

PLAN
EL. 298.00



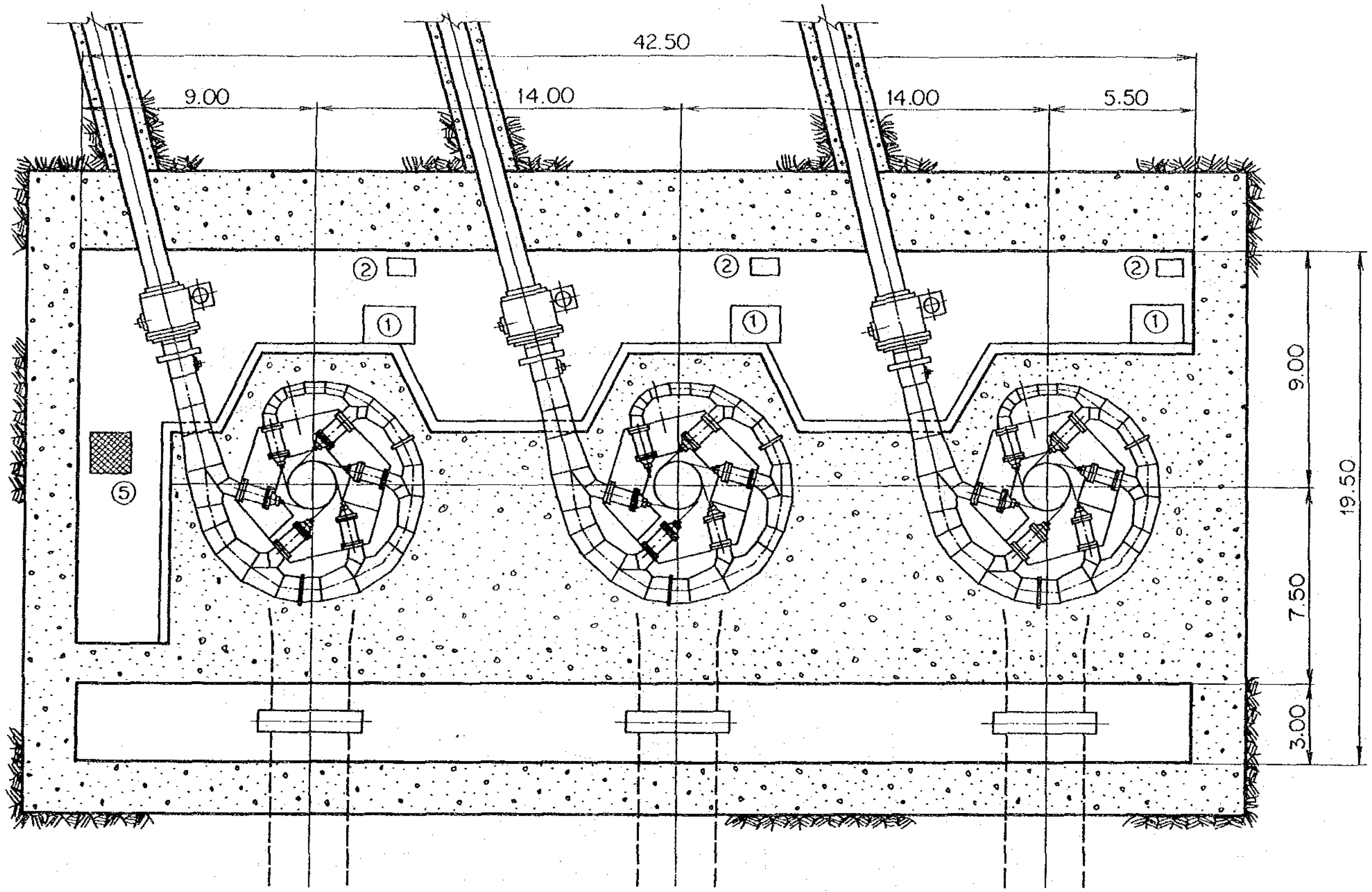
LEGEND

(1) Oil Sump Pump with Oil Pressure Pump
(2) Oil Drainage Tank with Pump
(3) Oil Pressure Tank
(4) Control Center for Aux. Equipment
(5) Drainage Pit
(6) Speed Governor Cabinet (1) (Electric Part)
(7) Speed Governor Cabinet (2) (Mechanical Part)
(8) Turbine Control Cabinet
(9) Fire Extinguisher of Generator
(10) Compressed Air System
(11) Oil Treatment System
(12) Station Service Transformer
(13) C.B. Cubicle
(14) Generator Neutral Grounding Transformer Cubicle
(15) Tailrace Gate
(16) Water Piping Pit

KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT	
LOWER KIHANSI POWERHOUSE TURBINE FLOOR PLAN	
Fig. 10-45	DATE:

PLAN

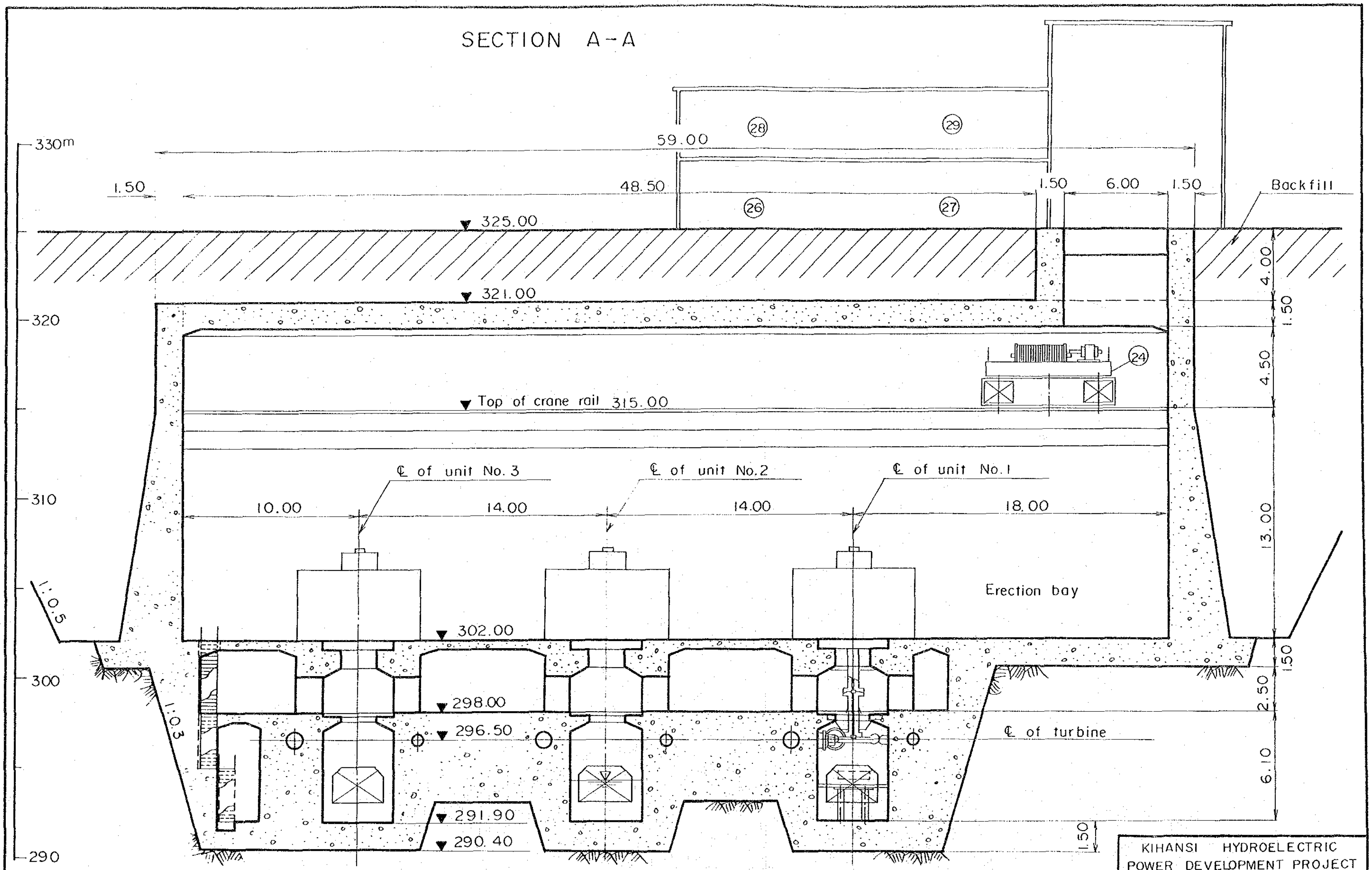
EL. 296.50



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOWER KIHANSI POWERHOUSE TURBINE LEVEL PLAN

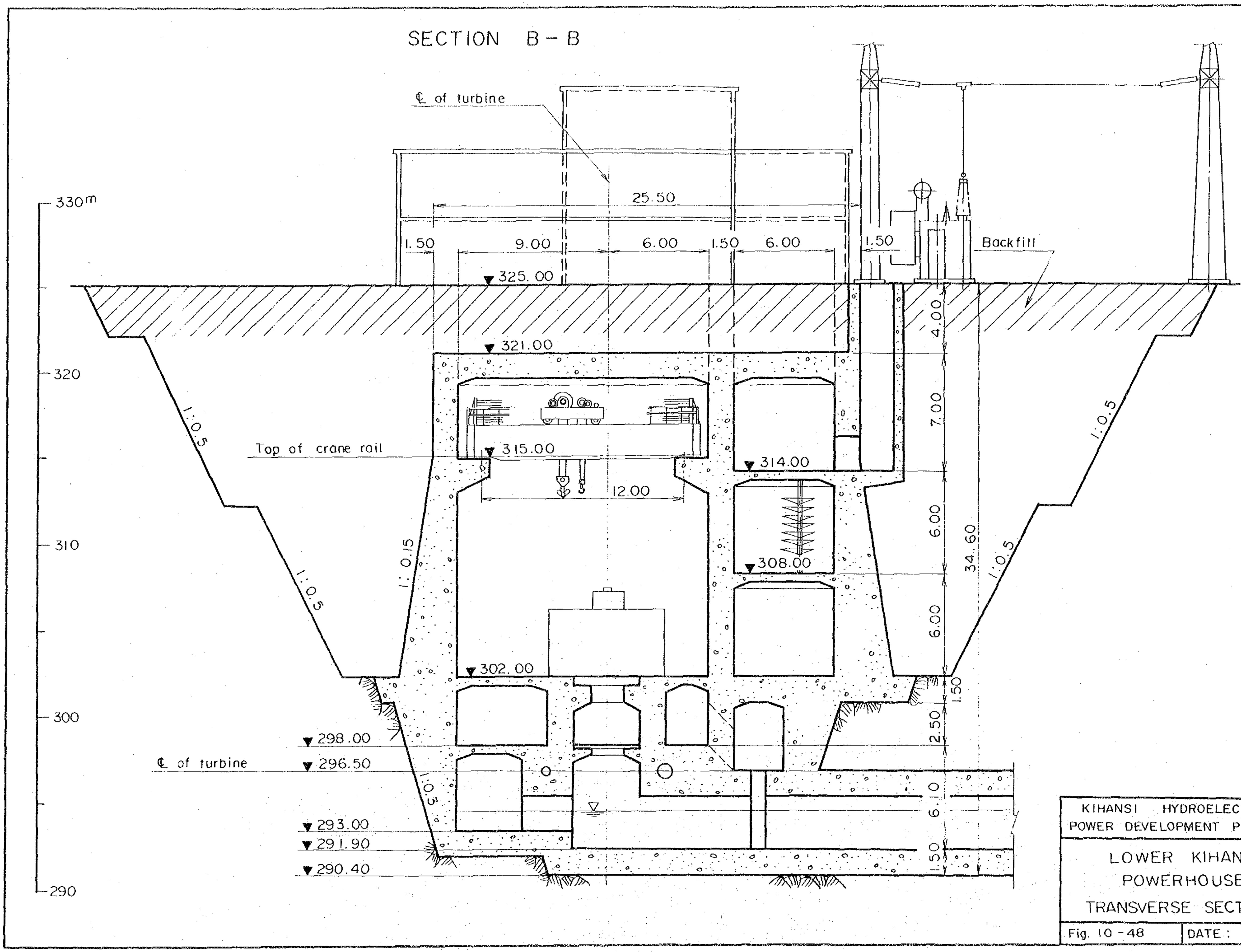
Fig. 10 -46 | DATE:



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOWER KIHANSI POWERHOUSE LONGITUDINAL SECTION

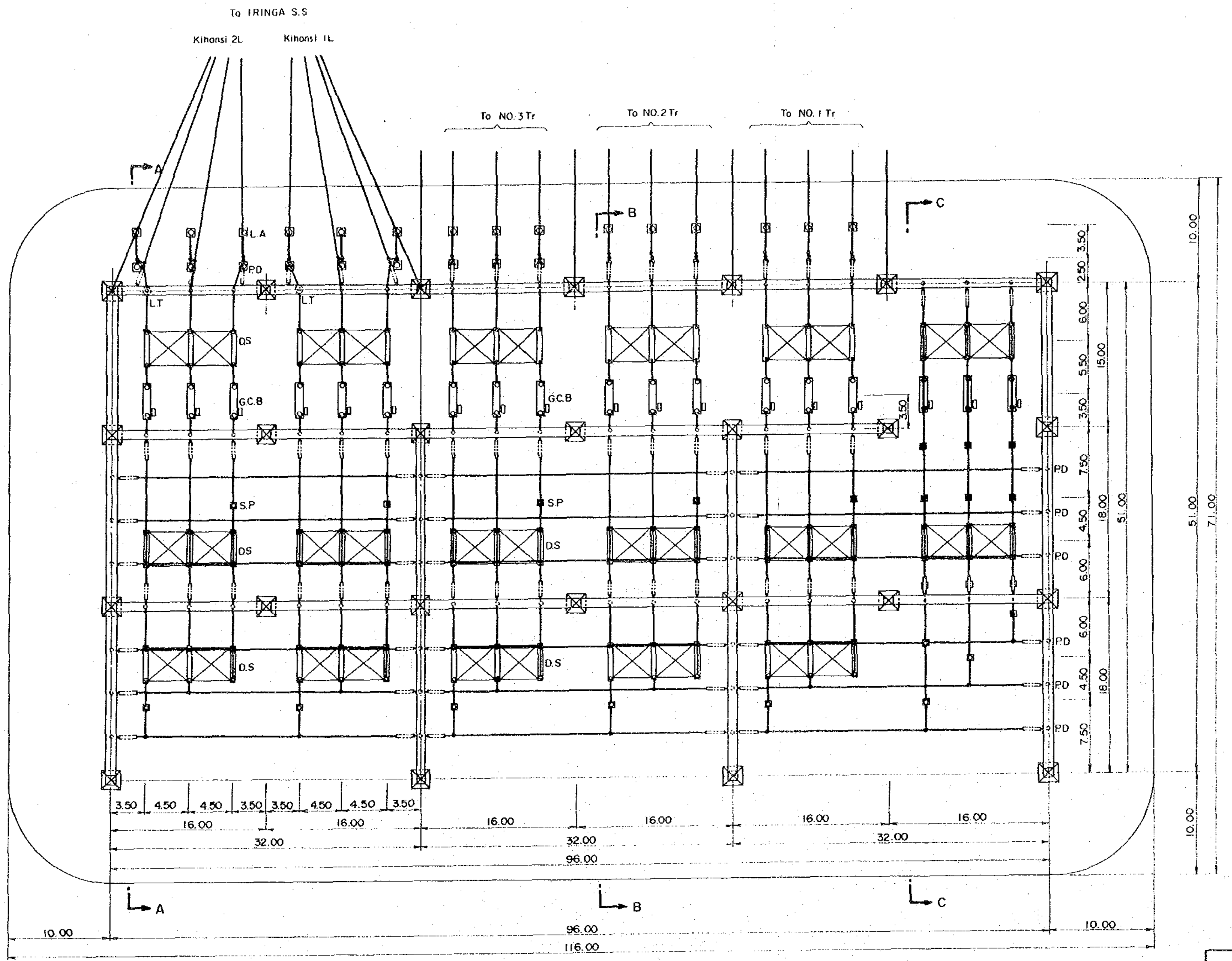
Fig. 10 – 47 | DATE:



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOWER KIHANSI POWERHOUSE TRANSVERSE SECTION

Fig. 10 - 48 | DATE :

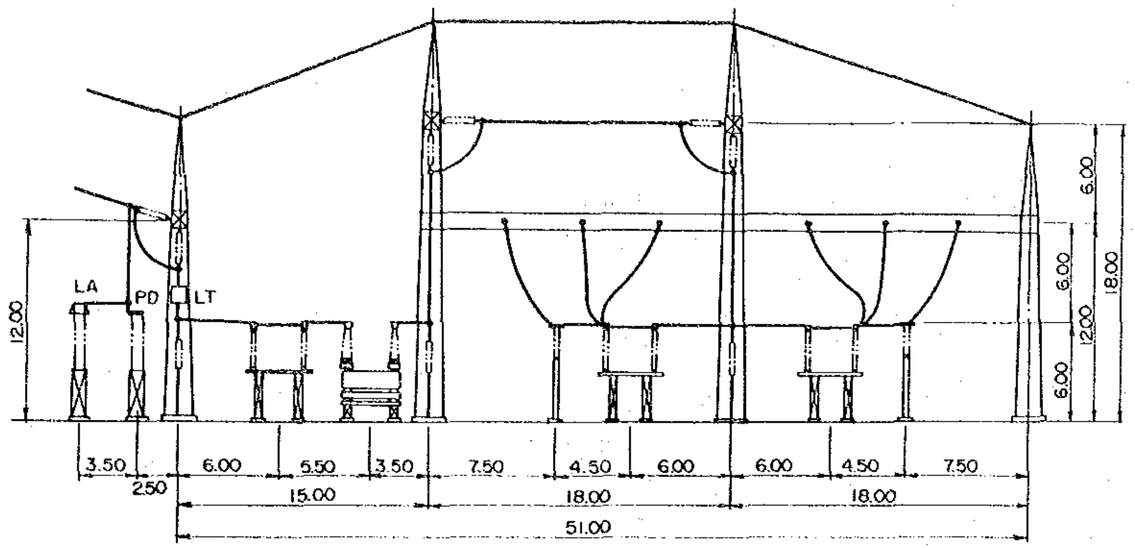


KIHANSI HYDROELECTRIC
POWER DEVELOPMENT PROJECT

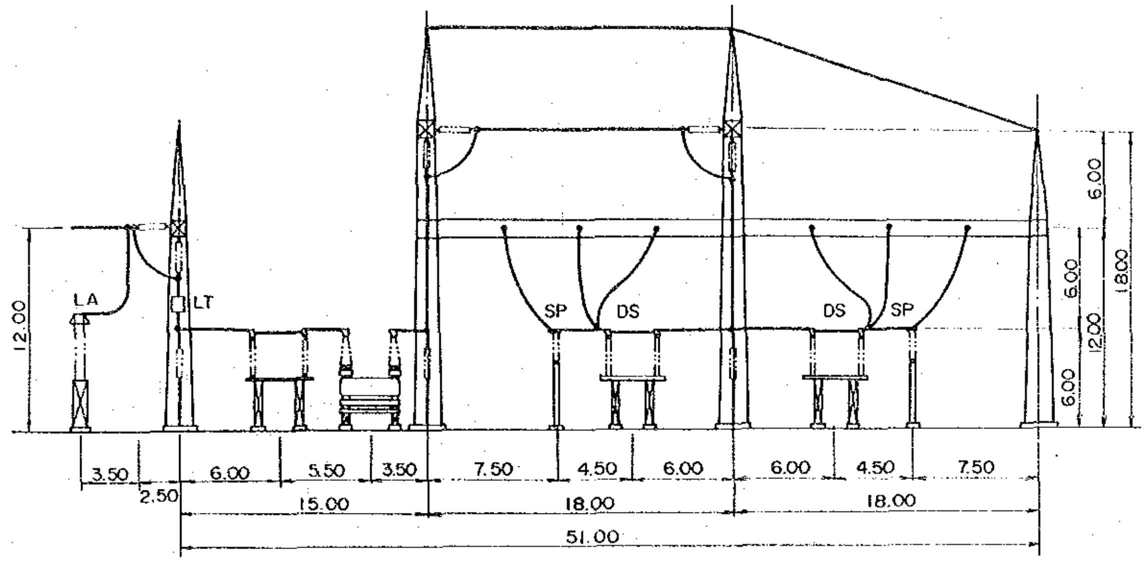
LOWER KIHANSI
SWITCHYARD PLAN

Fig. 10 - 49	DATE :

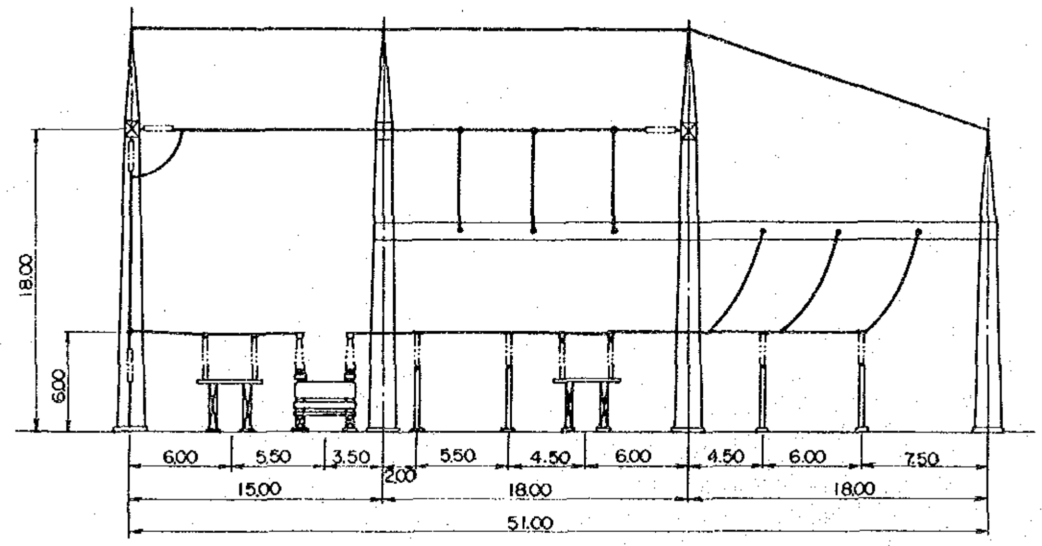
Section A – A



Section B – B



Section C – C



KIHANSI HYDROELECTRIC
POWER DEVELOPMENT PROJECT

LOWER KIHANSI
SWITCHYARD SECTION

Fig. 10 - 50	DATE ;

(7) Communication Equipment

i) Design Conditions

a) The communication equipment is designed with the assumption that Lower Kihansi Power Station is operated with operators stationed, because it is manned for operation for sometime to come.

b) The information and data of this Power Station is to be transmitted to the neighboring Iringa Substation, so that the Power Station is monitored and supervised by SCADA System which is installed at Ubungo Central Load Dispatching Office.

ii) Development of Communication Channels

The communication circuits are to be developed in pace with the construction of power stations and transmission lines. The communication channels which are required for the operation of the 220 kV transmission line from the Lower Kihansi Power Station to the nearby Iringa Substation are to be completed. The sections and numbers of circuits of these communication channels are as described below.

The following channels are to be established between Lower Kihansi Power Station and Iringa Substation by means of power line carriers.

Load Dispatching Telephone Channel	1 channel
Maintenance Work Telephone Channels	3 channels
PLC Protection Signal Transmission Channels	2 channels

Load Dispatching Signal Transmission Channel — 1 channel

In addition, a VHF base station is to be established at Iringa Substation to provide the telephone channels for transmission line maintenance. An automatic telephone exchange system is to be installed at Lower Kihansi Power Station to provide telephone service for maintenance and to create paging circuits for maintenance works in the Power Station.

iii) Outline of Communication Equipment

The outline of communication equipment which are required for the construction of the above communication channels is described below.

a) Power Line Carrier Units

Three units of 2-channel power line carrier terminal equipment are installed in Lower Kihansi Power Station and Iringa Substation respectively, and the inter-circuit coupling type coupling devices, covering the both circuits of transmission line, are to be installed at both ends.

b) Power Line Carrier Protective Relay Terminal Equipment

A total of four power line carrier protective relay terminal equipment is installed at Lower Kihansi Power Station and Iringa Substation for protection of the double circuit transmission line.

c) Load Dispatching Signal Terminal Equipment

One load dispatching signal terminal equipment is installed at Lower Kihansi Power Station to provide communication channels reaching Iringa Substation so that the signals are exchanged with the SCADA System at Ubungo Central Load Dispatching Office.

d) Automatic Telephone Exchange System

One, 100-channel automatic telephone exchange system is installed at Lower Kihansi Power Station.

e) Line Maintenance VHF System

A VHF base station equipment is installed at Iringa Substation, and two car-borne radio units and two portable radio units are to be procured.

f) Paging System

One paging system is installed at Lower Kihansi Power Station.

g) DC Power Supply System

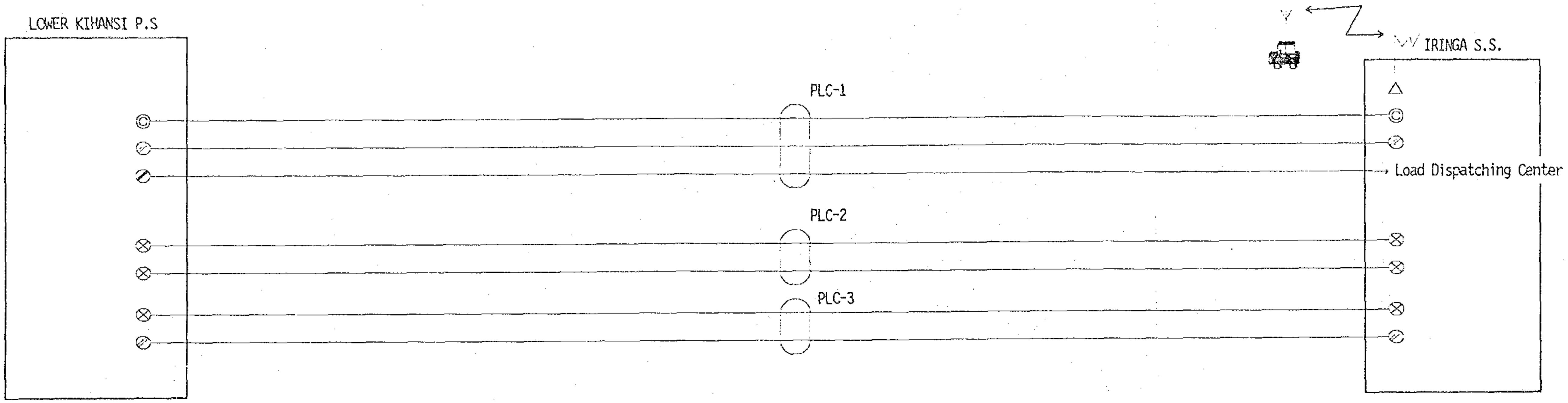
One DC power supply system each, consisting of batteries and battery charging unit, is installed at Lower Kihansi Power Station and Iringa Substation.

The equipment to be installed and their features are given in Table 10-10 below.

Table 10-10 A List of the Communication Facilities on Lower Kihansi Project

Equipment	Features	Lower Kihansi P.S.	Iringa S.S.
Power Line Carrier Terminal Equipment	10 W, 2-channel type	3	3
Coupling Devices for the above	Inter-circuit coupling	1	1
PLC Protective Relay Terminal Equipment		2	2
Load Dispatching Signal Terminal Equipment	SCADA slave station	1	-
Automatic Telephone Exchange	100 channels	1	-
Line Maintenance VHF Base Station	150 MHz, 100 W	-	1
VHF Car-Borne Unit	150 MHz, 10 W	-	2
VHF Portable Unit	150 MHz, 5 W	-	2
Paging System	2 kW, 100 sets	1	-
Tone Ringer	10 channels	1	1
Battery Charger Unit	48 V, 100 A	1	1
Batteries	48 V, 500 AH	1	1

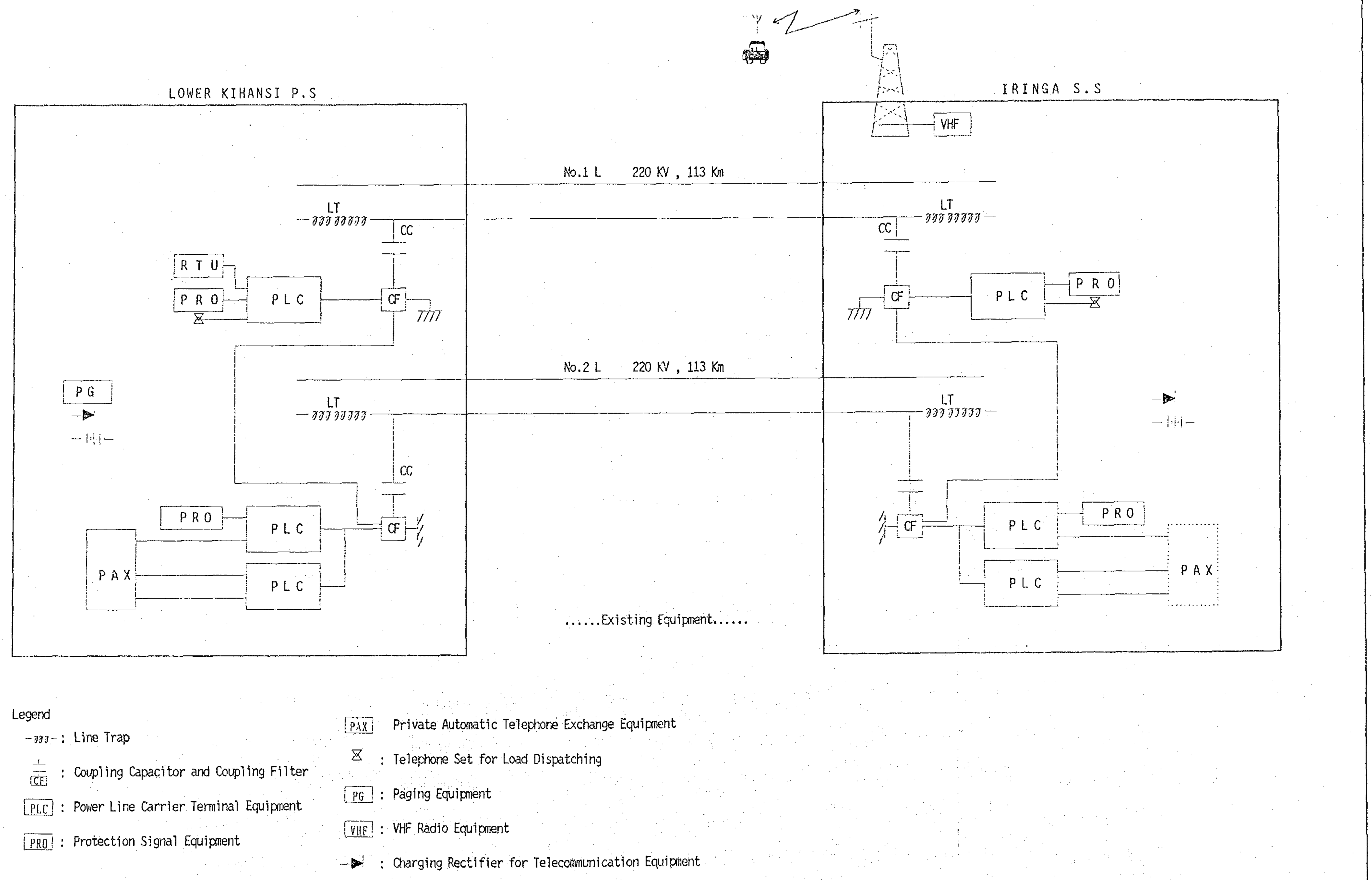
Fig. 10-51 Lower Kihansi Project Telecommunication System (1)



Legend

- ◎—: Load Dispatching Telephone Circuit
- ⊗—: Administration Use Telephone Circuit
- ⊘—: Data Transmission Circuit for Teleprotection
- ⊘—: Data Transmission Circuit for SCADA

Fig. 10-52 Lower Kihansi Project Telecommunication System (2)



10.3.4 Transmission Line

(1) Meteorological Conditions

The meteorological conditions to be applied in the feasibility design are determined to be as follows by use of the available meteorological data (Table 10-11) along the route of the transmission line together with the existing design conditions in Tanzania as a reference.

a) Temperature, highest: +35°C
average: +20°C
lowest : -1°C

b) Humidity, average: 70%

c) Wind velocity, max. : 44.2 m/sec

d) Rainfall, max. : 260 mm/month
average: 54 mm/month
min. : 0 mm/month

e) IKL, average: 62 days/year

f) Seismic acceleration: 0.1 G

(2) Construction Criteria

The following conditions are assumed in the feasibility design.

a) Route : Lower P.S. - Upper P.S. - Iringa S.S.

b) Total length : Approx. 113 km

Table 10-11 Meteorological Data

Month	Temperature	Extremes		Humidity	Rainfall			Mean Number of Days of	
	Mean (°C)	Highest (°C)	Lowest (°C)	0600 (%)	Mean (mm)	Highest (mm)	Lowest (mm)	Rain (>1mm) (Days)	Thunder (Days)
January	20.8	31.0	11.5	79	138	260	21	13	10
February	20.7	30.3	10.2	81	115	204	39	12	9
March	20.6	29.5	9.5	79	130	230	25	14	11
April	20.5	30.8	10.6	76	63	250	16	9	5
May	19.8	30.6	8.7	68	10	41	0	3	1
June	18.7	30.2	5.6	62	1	11	0	0	0
July	18.2	29.0	4.5	63	0	2	0	0	0
August	18.6	29.9	6.5	60	1	10	0	0	0
September	20.2	30.9	8.8	55	1	7	0	0	0
October	21.4	33.4	9.2	53	4	23	0	0	1
November	22.2	33.0	10.5	57	27	130	1	3	4
December	21.6	32.8	11.7	72	159	361	41	12	11
Year	20.3	33.4	4.5	67	649	1,089	466	66	62

Note: Meteorological Station; Iringa Airport, Latitude 07°40'S
Longitude 35°45'E
Altitude 1,420 meters

c) Voltage : 220 kV

d) Capacity of transmission: 200 MW

e) Conductor size : To result in voltage loss less than 10% and transmission loss less than 5% at a power factor of 0.95

f) Number of circuit : Double

g) Tower : Lattice-type tower

(3) Wind Load

The maximum wind velocity for the transmission line area is estimated as 44.2 m/sec from the existing design conditions and the life of the tower and a return period of thirty-five years. The wind pressure for the line with these conditions is calculated by the following equation.

$$P = V^2 \cdot C/16$$

where

P : Wind pressure for wire, etc. (kgf/m^2)
V : Maximum wind velocity (m/sec)
C : Air resistance coefficient

The wind pressure value for each object is derived by the equation as follows:

Conductor : 122 kgf/m^2 (C = 1.0)
Overhead ground wire: 134 kgf/m^2 (C = 1.1)
Insulator unit : 171 kgf/m^2 (C = 1.4)
Tower : 300 kgf/m^2 (C = 1.65 x 1.5)

For the wind pressure on aerial cable reduction ratios of 100% for those less than 200 m span and 60% for those more than 300 m span are assumed.

(4) Insulation Designs

The insulation is designed by taking into account an assumed basic condition of the 220 kV transmission line for nominal voltage with effective grounding system (direct grounding), together with switching surge voltage and commercial-frequency abnormal voltage.

This results in the requirement of 250 mmϕ x 12 units insulator pieces per string; however, fourteen units per string are to be the actual number considering the lack of data for contamination losses and consistency with existing lines.

Suspension Units: 14 units
Tension Units : 15 units

Clearance Diagram and Insulator Design are given in Figs. 10-53 and 10-54.

The permissible salt deposition for this number of insulators is approximately 0.03 mgf/cm^2.

Table 10-12 lists the recommended insulator characteristics.

(5) Lightning-proof Designs

Since the area for the transmission line has extremely high isokeraunic level (IKL's)(average 62 days). The overhead ground wire is to be a two line wire throughout the line route with a shielding angle of less than fifteen degrees in order to reduce direct lightning hits on the line.

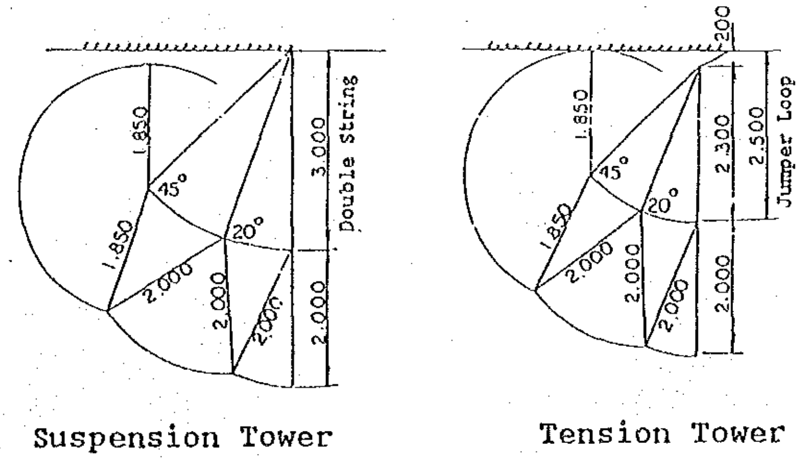
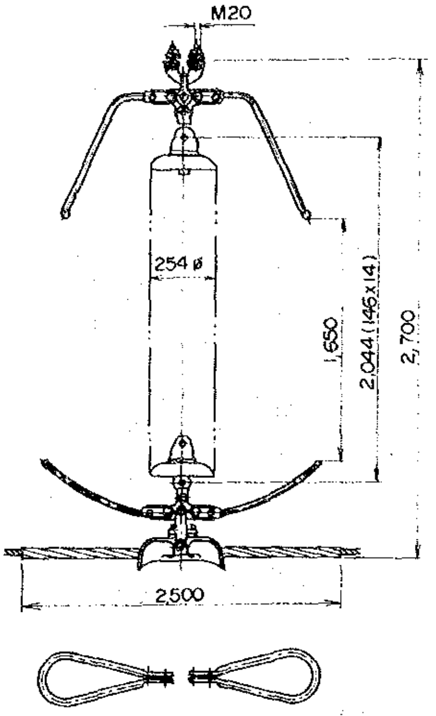
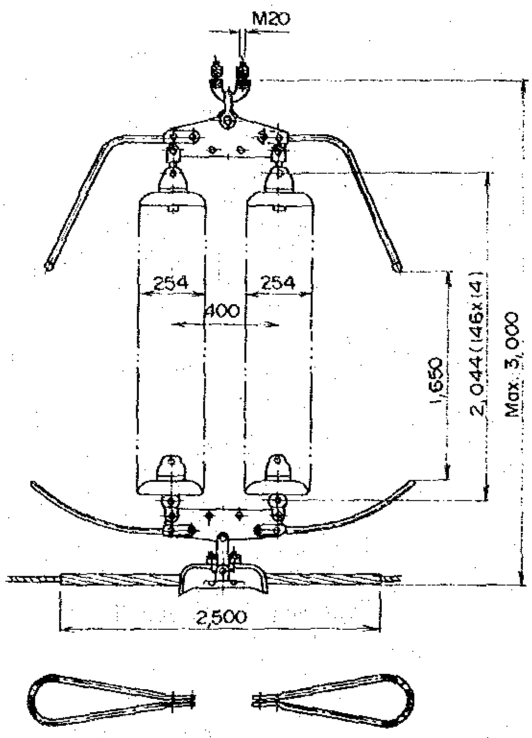


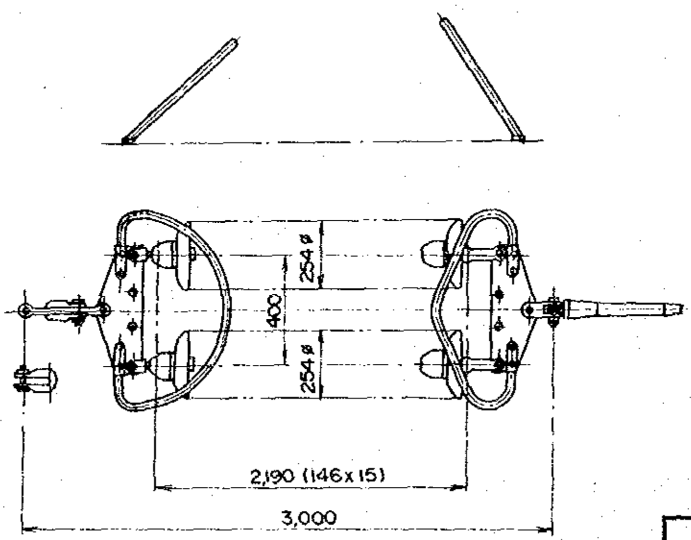
Fig. 10-53 Clearance Diagram



1. Single Suspension Insulator Set



2. Double Suspension Insulator Set



3. Double Tension Insulator Set

KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT	
INSULATOR STRING ASSEMBLY	
Fig. 10 - 54	DATE

Table 10-12 Characteristics of Insulator Disk

Items	Specification
IEC Type	U80BL
Type	Ball and Socket
Quality	Porcelain
Diameter	254 mm
Unit Spacing	146 mm
Creepage Distance	280 mm
Electromechanical Failing Load	8,000 kg
Pancture Voltage	110 kV
Ball and Socket Size	16A mm
Net Weight	5.5 kg

The grounding resistance of the tower is to be made less than ten ohms, in order to reduce back flashover.

(6) Clearance between Conductors

The recommended clearances between conductors, and between conductor and overhead ground wire are as follows:

a) Clearance between conductors is designed normally as 4.6 m for the span less than 600 m and 5.6 m for the span between 600 m and 800 m.

b) By assuming a lightning current of 80 kA, the minimum clearance between conductor and overhead ground wire is designed as 8 m for the standard span. The clearance diagram of the tower is presented in Figs. 10-55 (1) and 10-55 (2).

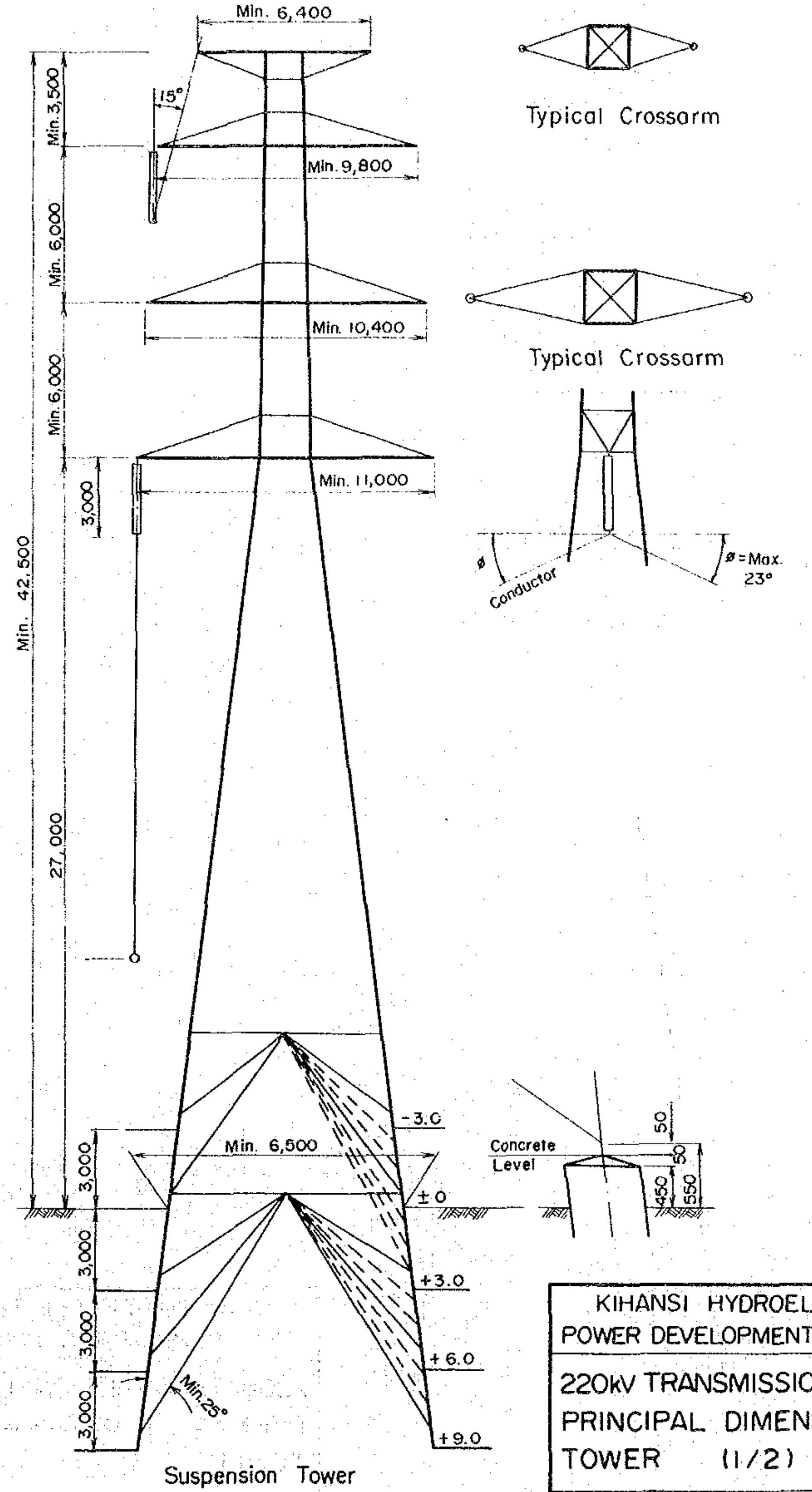
(7) Design of Conductor

Based on an overall assessment of factors such as transmission capacity, corona troubles, current capacity in case of failures, economical factors, handling ease in construction works and previous experiences in Tanzania, ACSR 380 mm^2 (Bison) is recommended for the project.

The characteristics are shown in Table 10-13 and outline of the design is as follows:

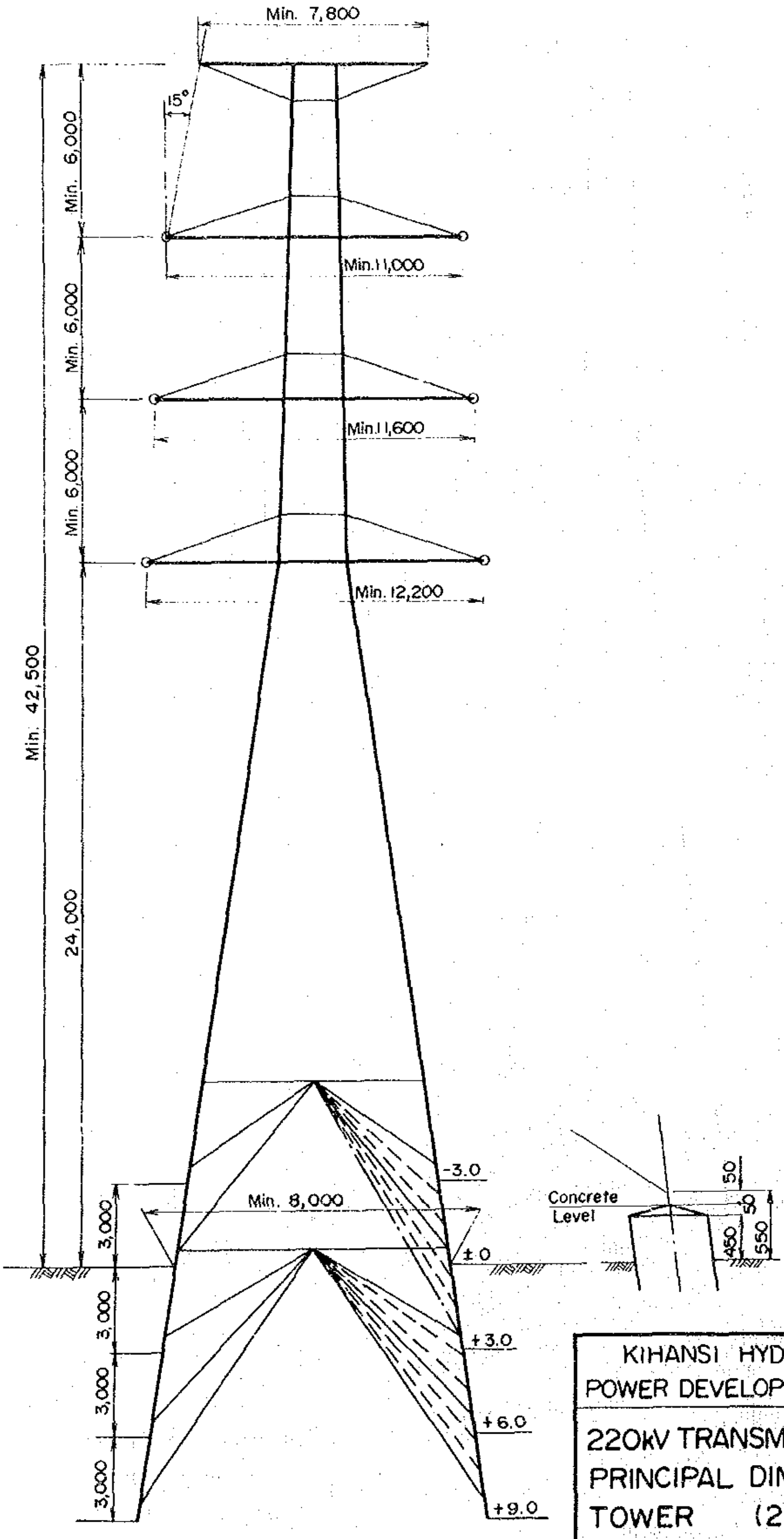
i) Transmission Capacity (P)

$$P = \sqrt{3}\ E\ I\ \cos\phi$$



Suspension Tower

KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT	
220kV TRANSMISSION LINE PRINCIPAL DIMENSION OF TOWER (1/2)	
Fig. 10-55-(1)	DATE



Tension Tower

KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT	
220kV TRANSMISSION LINE PRINCIPAL DIMENSION OF TOWER (2/2)	
Fig.10-55-(2)	DATE

where

- E: Transmission voltage (kV)
- $\cos\phi$: Power factor
- I: Permissible current (A)

The transmission capacity of ACSR Bison is approximately 215 MW at 75°C.

ii) Momentary Current Carrying Capacity

By neglecting the heat dissipation from the conductor by reason that fault current is momentary, the permissible current for ACSR Bison in accidents such as ground short-circuiting is determined as 25 kA with 2 second current duration.

This permissible instantaneous current is much greater than the fault current.

iii) Maximum Surface Gradient at Conductor Surface

The maximum surface gradient, of ACSR Bison conductor is approximately 15.5 kV/cm and it is not significant in terms of corona losses or radiation troubles.

iv) Design of Tension and Sag

The working conditions need to be determined from maximum and usual working tensions. The safety factor for maximum working tension is assumed to be more than 2.5 times as much as minimum tensile strength of the conductor and usual tension for standard span (at annual average temperature and no wind) is assumed to be less than twenty percent (20%) of minimum tensile strength of the conductor.

Table 10-14 shows the results.

Table 10-13 Characteristics of Conductor (380 mm² ACSR)

Items		Contents
Code name		Bison
Type		ACSR
Size		380 mm²
Composition	Alumi.	54/3.0 Nos/mm
	Steel	7/3.0 Nos/mm
Diameter		27.0 mm
Calculated sectional area	Alumi.	381.7 mm²
	Steel	49.5 mm²
	Total	431.2 mm²
Unit weight		1,383 kg/km
Rated strength		12,330 kgf
DC resistance at 20°C		0.07574 /km
Coeff. of liner expansion		19.5×10^{-6} Ω/°C
Modulus of elasticity		7,990 kgf/mm²

Table 10-14 Dip and Tension at Each Assumption (380 mm² ACSR)

Assumption	Conditions		s = 200 m		s = 400 m		s = 600 m	
	Temp. (°C)	Wind (kgf/m²)	Tension (kgf)	Dip (m)	Tension (kgf)	Dip (m)	Tension (kgf)	Dip (m)
1	0	122	4,900 (39.74)	3.65				
2	0	73.2 (122x0.6)	3,969 (32.19)	3.04	3,514 (28.50)	13.73	3,403 (27.60)	31.90
3	20	0	2,406 (19.51)	2.87	2,029 (16.46)	13.65	1,955 (15.86)	31.93
4	75	0	1,527 (12.38)	4.53	1,765 (14.31)	15.70	1,832 (14.86)	34.09

Note: ( ) Safety factor

Each supporting point is to be equipped with a damper for reducing fatigue caused by conductor vibrations. Also, the base of suspension clamps are to be equipped with armor-rods.

(8) Design of the Overhead Ground Wire

Aluminium clad steel wire (AC) of 70 mm^2 diameter is recommended for the overhead ground wire due to the consideration of momentary current capacity, shielding of low tension voltage lines against the fault current of ground short-circuiting accidents, mechanical characteristics and economical factors. Table 10-15 shows the characteristics.

The outline of the design is described below.

i) Momentary Current Capacity

The momentary current carrying capacity (0.25 sec) for AC 70 mm^2 is calculated as 12 kA by neglecting the heat dissipation from the wire. And it satisfies the design condition of the ground short-circuiting current.

ii) Design of Tension and Sag

The overhead ground wire installation conditions are determined from maximum working tension, usual working tension and relaxation ratio between conductor and overhead ground wire sag.

The design is examined by assuming the safety factor for maximum tension to be more than 2.5 times as much as minimum tensile strength of the overhead ground wire, usual tension for standard span (at annual average temperature and no wind) to be less than twenty-five percent of minimum tensile strength, and usual relaxation ratio of the overhead ground wire sag against the conductor sag (dg/dc) to be less than 80%.

Table 10-16 shows the results.

Each supporting point is to be equipped with a damper for reducing fatigue caused by wire vibrations.

(9) Design of Supporting Structure

The standard wind pressure is 122 (100%) kgf/m^2 for conductors and 300 kgf/m^2 for towers in the existing design conditions of Tanzania. These values are appropriate judging from the meteorological data and operation records of existing transmission lines.

(10) Design of Foundation of Supporting Structure

The foundation of supporting structure is to be designed according to the ground conditions, which are to be examined through geological surveys.

Geological surveys for the construction of transmission lines are necessary to obtain information to construct reliable and the most economical supporting structures and for construction safety. As the results of the survey are crucial in the economical and safety aspects of the construction work of overhead transmission lines, it is important to choose an appropriate method for the survey.

Judging from the results of the field survey for transmission line, either "the Pad Type" or "the Rock Anchor Type" can be adopted for the foundation. The details of the foundation are necessary to be designed in a definite design study.

Table 10-15 Characteristics of Overhead Ground Wire (AC 70 mm²)

Items	Contents
Type	AC
Nominal sectional area	70 mm²
Composition	7/3.5 Nos/mm
Diameter	10.5 mm
Calculated sectional area	67.35 mm²
Unit weight	448.2 kg/km
Rated strength	7,880 kgf
Coeff. of liner expansion	13.9 x 10^{-6}/°C
Modulus of elasticity	12,900 kgf/mm²

Table 10-16 Dip and Tension at Each Assumption (AC 70 mm²)

Assumption	Conditions		s = 200 m		s = 400 m		s = 600 m	
	Temp. (°C)	Wind (kgf/m²)	Tension (kgf)	Dip (m)	Tension (kgf)	Dip (m)	Tension (kgf)	Dip (m)
1	0	134	2,600 (32.88)	2.84				
2	0	80.4 (134x0.6)	2,369 (30.09)	2.02	2,024 (25.09)	9.45	1,855 (23.54)	23.18
3	20	0	1,969 (24.99)	1.13	1,246 (15.81)	7.18	967 (12.72)	20.87
4	40	0	1,748 (22.18)	1.28	1,144 (14.52)	7.83	933 (11.84)	21.63

Note: ( ) Safety factor

Chapter 11 CONSTRUCTION PROGRAM AND CONSTRUCTION COST

Chapter 11

CONSTRUCTION PROGRAM AND CONSTRUCTION COST

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Chapter 11 CONSTRUCTION PROGRAM AND CONSTRUCTION COST

11.1 Construction Program and Construction Schedule

11.1.1 Basic Conditions

The structures planned for the Upper Kihansi Project are a center impervious core rockfill dam of a height of 95 m, waterways such as a headrace tunnel of total length of approximately 640 m and a penstock of total length of approximately 510 m, and a powerhouse. The structures for the Lower Kihansi Project consist of a concrete gravity dam of height of 35 m, waterways comprising a headrace tunnel and penstock of total length of approximately 4,200 m, and a powerhouse.

The matters influencing the construction program and construction schedule of this Project are as described below.

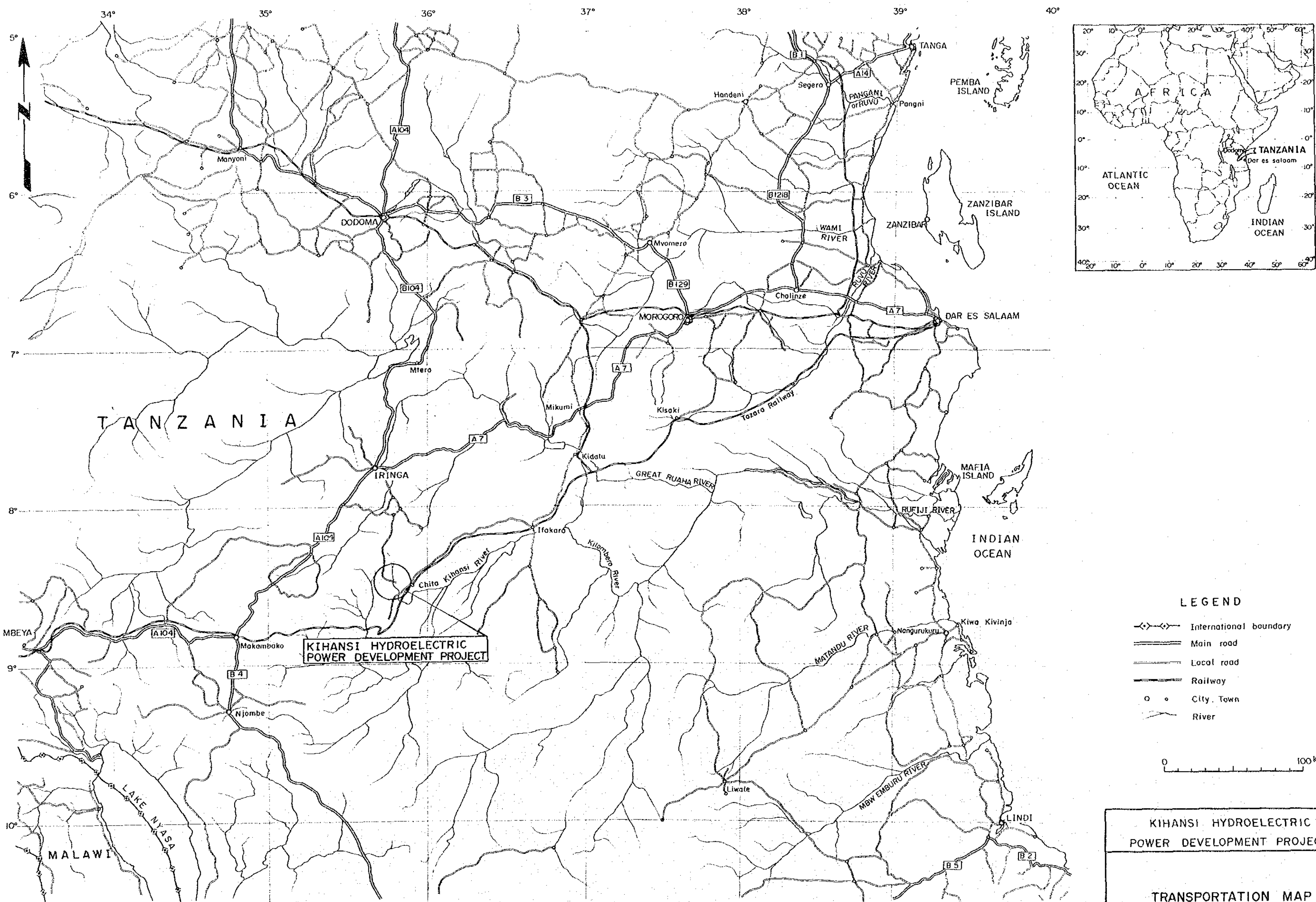
(1) Meteorology

The meteorological conditions for this Project are as described in Chapter 6.

The Construction schedule is set up assuming that it is generally possible for embankment of the rockfill dam and placement of dam concrete to be done throughout the year.

(2) Transportation Route

Transportation routes from Dar Es Salaam to the Project site, as shown in Fig. 11-1, may be broadly divided into a route relying entirely on roads and a route going part way by railway as far as Chita and from there to the project site by road.



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

TRANSPORTATION MAP

Fig. II-1	DATE;

The conditions of road and railway are described below.

i) Road from Dar Es Salaam to Mikumi

The road from Dar Es Salaam to Mikumi is National Highway A7 of width 8 m having a length of approximately 317 km and is an arterial highway of Tanzania. The entire route is paved and it has no problem as a transportation route.

ii) Road from Mikumi to Lower Kihansi Power Station

The road from Mikumi to Lower Kihansi Power Station via Kidatu, Ifakara, and Chita is a main provincial road of minimum width 3 m and total length 231 km. The road is unpaved and for transportation of heavy articles, electrical equipment, mechanical equipment, etc., there are several places between Kidatu and Ifakara such as bridges requiring reinforcement to be done. The route between Chita and Lower Kihansi Power Station presently is under road reinforcement work, and after this reinforcement work there will be no problems in using as a transportation route.

iii) Road from Mikumi to Iringa

The road from Mikumi to Iringa is a mountainland part of National Highway A7 with a minimum width of 4.5 m and a length of 184 km. The entire length of the road is paved and there is no problem as a transportation road.

iv) Road from Iringa to Uhafiwa

The road from Iringa to Uhafiwa is a provincial road of minimum width 3.5 m and a length of 123 km. The road is unpaved, and in order to transport heavy articles it is necessary for works such as widening and reinforcing to be done almost over the entire length.

v) Road from Uhafiwa to Upper Kihansi Dam

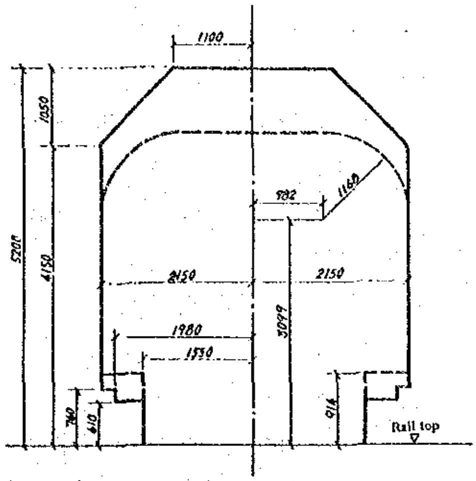
The distance from Uhafiwa to Upper Kihansi Dam is approximately 15 km. There is presently no road at this route and it is necessary for new construction to be done.

vi) Road from Upper Kihansi Dam site to Lower Kihansi Powerhouse

The distance from the Upper Kihansi Dam site to the Lower Kihansi Powerhouse via Upper Kihansi Powerhouse and Lower Kihansi Dam is approximately 35 km. There is presently no road and it is necessary for a new road to be constructed.

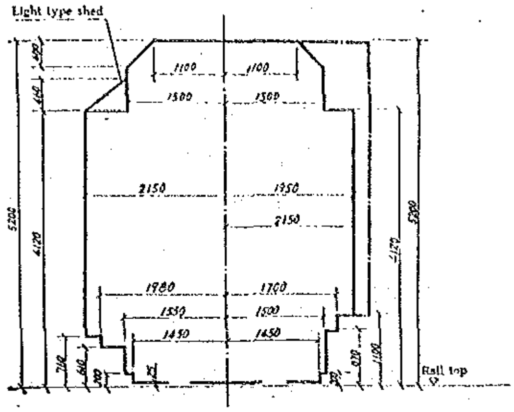
vii) Railway from Dar Es Salaam to Chita

The TAZARA Railway runs from Dar Es Salaam to Zambia via Chita. This is a trunk railway line and the transportation limits are as shown in Fig. 11-2. Transportation to Zambia of heavy articles such as 3-phase transformers has been experienced on this railway in the past. This railway has crane equipment of 120-ton capacity, and by transferring this crane facility to Chita Station, any problem about rail transportation between Dar Es Salaam and Chita does not exist.



——— Clearance for bridges

··········· Minimum clearance for the existing railways in Zambia



Main line and station tracks where out-of-gauge goods may pass　　Ordinary station tracks

—·— Clearance for structures

—·— Clearance for structures in shunting yard

Fig. 11-2 Clearance of Railway

In view of the road and railway situations described above, the problems during construction are the stable supply of materials such as cement and steel, and the safe and sure transportation of heavy articles such as turbines and generators.

When the economics, implementation of the construction program according to plans, and future maintenance and administration of the dams and power stations are considered, the transportation plans for the Project are as follows:

i) Upper Kihansi Project

Transportation is to be mainly by road from Dar Es Salaam to the Upper Kihansi Project site via Mikumi and Iringa, but partly by railway from Dar Es Salaam to Chita with road transportation for the remainder from Chita to the Upper Kihansi Project site.

ii) Lower Kihansi Project

Transportation is to be by railway from Dar Es Salaam to Chita with road transportation for the remainder from Chita to the Lower Kihansi Project site.

(3) Port and Harbor

The nearest port is that of Dar Es Salaam, the capital city. There are no obstacles to landing of construction machinery and electromechanical equipment at this port.

(4) Construction Materials

The principal construction materials are the following:

i) Cement

Basically, cement to be used is to be imported product. However, for auxiliary work such as temporary facilities work, supplying is done mainly from the cement plant at Dar Es Salaam.

ii) Aggregates

Aggregates are mainly to be manufactured using material from a quarry west of the Upper Kihansi powerhouse and partly re-using the material from excavation work.

iii) Steel

The principal steel materials are to be imported.

(5) Electric Power for Construction

The principal electric power facilities for construction are to be as follows:

i) Upper Kihansi Project

Electric power is to be supplied by diesel generating facilities for construction until Lower Kihansi Power Station starts operation, and after Lower Kihansi Power Station starts operation, electric power from that station is to be supplied to complete the Project.

Electric power facilities for construction are to be provided at the three locations of powerhouse site, dam site, and aggregate plant site. The locations of receiving ends are the following:

Powerhouse receiving end ... headrace tunnel, penstock, powerhouse, and tailrace tunnel

Dam receiving end .... dam, spillway and intake

Other .... aggregate plant

ii) Lower Kihansi Project

Electric power for construction of the Lower Kihansi Project is supplied using diesel generating facilities for construction provided at the powerhouse site, with electric power transmitted to the receiving ends by distribution lines for construction. The receiving ends are to be the following:

Dam receiving end .... dam and intake