

THE ISLAMIC REPUBLIC OF PAKISTAN

**DETAILED DESIGN STUDY
ON
WEST WHARF
THERMAL POWER PLANT PROJECT**

FINAL REPORT-I

VOLUME 3

JANUARY 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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THE ISLAMIC REPUBLIC OF PAKISTAN

DETAILED DESIGN STUDY

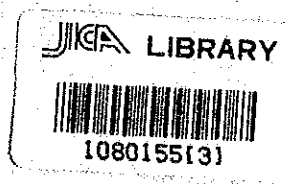
ON

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WEST WHARF THERMAL POWER PLANT PROJECT

DETAILED DESIGN STUDY

DRAFT FINAL REPORT - I

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I. General

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1. Building Dimensions

1) Building Area 4,181.6 m²

2) Floor Area

5th Floor 55.6 m²4th Floor 1,726.4 m²Operating Floor 4,181.6 m²Mezzanine Floor 4,181.6 m²Ground Floor 4,181.6 m²

Total 14,326.8 m²

3) Building Height (T/S) GL+27.1 m

4) Building KVolume 102,057.6 m³

2. Structure

1) Main Structure : Steel

2) Foundation : Reinforced concrete mat foundation

3) Slab : Concrete slab and grating floor

4) Wall : Concrete Wall and precast concrete wall

3. Structural Design Method

3.1 Superstructure

- 1) All frames in longitudinal direction are designed with vertical braced frames.
- 2) All frames in transverse direction are designed with vertical braced and open frames.
- 3) The bracing system will utilize x-braces or portal braces and the brace members are designed for compression and tension.
- 4) Every end joint of every girder is assumed to be a pin joint except that of a roof truss.
- 5) Every bottom of every column is assumed to be a pin support.
- 6) Every member including a roof truss is replaced to a line element.
- 7) Every structural analysis is based on elastic stiffness.

4. Design Criteria and Code

- 1) "Design Standard for Steel Structure", Architectural Institute of Japan(AIJ), 1970
- 2) "Standards for Calculation of Reinforced Concrete Structure", AIJ, 1982
- 3) "Standards for Structural Design of Building Foundation", AIJ, 1974
- 4) "Manual for Loads of Buildings", AIJ, 1981

5. Structural Materials and Allowable Stresses

1) Qualities of materials

Structural steel : JIS G3101 SS41, JIS G3106 SM41 or equivalent — $F=2400\text{kg/cm}^2$

High Strength Bolt : JIS B1186 F10T or equivalent

Concrete : $F=210\text{kg/cm}^2$ (compressive strength of 28 days)

Reinforcement : Deformed bar, ASTM A615 Grade 40 or equivalent — $F=2800\text{kg/cm}^2$

2) Physical constants of structural steel

Modulus of elasticity $E=2.1 \times 10^6 \text{ kg/cm}^2$

3) Allowable stresses

Allowable stresses for each materials are shown in Table 5.1 to 5.7.

Table 5.1 Allowable Unit Stresses of Steel

	Allowable Unit Stress (t/cm ²)
Allowable Tensile Stress f_t	$f_t = \frac{F}{1.5} = 1.6$
Allowable Shear Stress f_s	$f_s = \frac{F}{1.5 \sqrt{3}} = 0.92$
Allowable Compressive Stress f_c	when $\lambda \leq \Lambda$ $f_c = \frac{(1 - 0.4(\lambda/\Lambda)^2)F}{\gamma}$ when $\lambda > \Lambda$ $f_c = \frac{0.277F}{(\lambda/\Lambda)^2}$ where $\gamma = 3/2 + 2/3 \cdot (\lambda/\Lambda)^2$ $\Lambda = \sqrt{\frac{\pi^2 E}{0.61F}}$: Critical slenderness ratio
Allowable Bending Stress f_b	$f_b = \text{Max}(f_{b1}, f_{b2})$, but not more than f_t $f_{b1} = (1 - 0.4 \frac{(l_b/i)^2}{C \cdot \Lambda^2}) f_t$ $f_{b2} = \frac{900}{(l_b \cdot h/\Lambda_r)}$ where $C = 1.75 - 1.05 \left(\frac{M_2}{M_1}\right)^2 + 0.3 \left(\frac{M_2}{M_1}\right)^2$, but not more than 2.3
Allowable Bending Stress of Bearing Plate f_{b3}	$f_{b3} = \frac{F}{1.3} = 1.85$

- Notes: 1. Each allowable stress indicated in this table is permanent.
 2. Temporary allowable stresses are 1.5 times as much as those in this table.
 3. Allowable bending stress f_b is that for a shape steel, a plate girder and another built-up member which are bended around the principal axis of maximum moment of inertia. This is not, however, applied to box section.
 4. Symbols in this table are defined as follows:
 λ : Slenderness ratio for compression member
 l_b : length of compressive side flange between supports
 h : Depth of beam (cm)
 A_f : Cross sectional area of compressive side flange (cm²)
 i : Radius of gyration of area of Tee section, comprising compressive side flange and one-sixth of depth of beam, around the axis of web (cm)

Table 5.2 Allowable Unit Stresses in Welded Joints (t/cm²)

Welding Position	Permanent Stresses					Temporary Stresses
	Groove Weld				Fillet Weld	
	Tension	Compress	Bending	shear		
(1)	1.44	1.44	1.44	0.83	0.83	Permanent stresses x 1.5
(2)	1.20	1.20	1.20	0.70	0.70	

Notes: (1) Flat or horizontal in the shop
 (2) Overhead or vertical in the shop and flat or horizontal in the field

Table 5.3 Allowable Strength per Medium Bolts (SS41)

Bolt Nominal Dia.	Dia. of Bolt Hole (mm)	Bolt Gross Area (cm ²)	Permanent Strength			Temporary Strength (t)
			Shear (t)		Tension (t)	
			Single shear	Double shear		
M12	12.5	1.13	1.02	2.03	1.36	Permanent Stresses x 1.5
M16	16.5	2.01	1.81	3.62	2.41	
M20	20.5	3.14	2.83	5.65	3.77	
M22	22.5	3.80	3.42	6.84	4.56	
M24	24.5	4.52	4.07	8.14	5.42	

Table 5.4 Allowable Strength per High Strength Bolts (F10T)

Bolt Nominal Dia.	Dia. of Bolt Hole (mm)	Bolt Effect. Area (cm ²)	Permanent Strength			Temporary Strength (t)
			Shear (t)		Tension (t)	
			Single shear	Double shear		
M16	17.0	1.57	3.02	6.03	6.23	Permanent Stresses x 1.5
M20	21.5	2.45	4.71	9.42	9.73	
M22	23.5	3.03	5.70	11.4	11.8	
M24	25.5	3.53	6.78	13.6	14.0	

Table 5.5 Allowable Unit Stresses of Concrete (kg/cm²)

Stresses		Permanent Stresses					Temporary Stress	
		Compress	Shear	Bond			Compress	Shear Bond
				A	B	C		
Materials								
Normal Concrete F _c =210	Plain bar	70	7.0	8.4	12.6	8.4	P.Stress	P.S.
	Deformed bar			14.0	21.0	14.0		
Normal Concrete F _c =250	Plain bar	80	7.5	9.0	13.5	9.0	x 2.0	x 1.5
	Deformed bar			15.6	23.5	15.6		

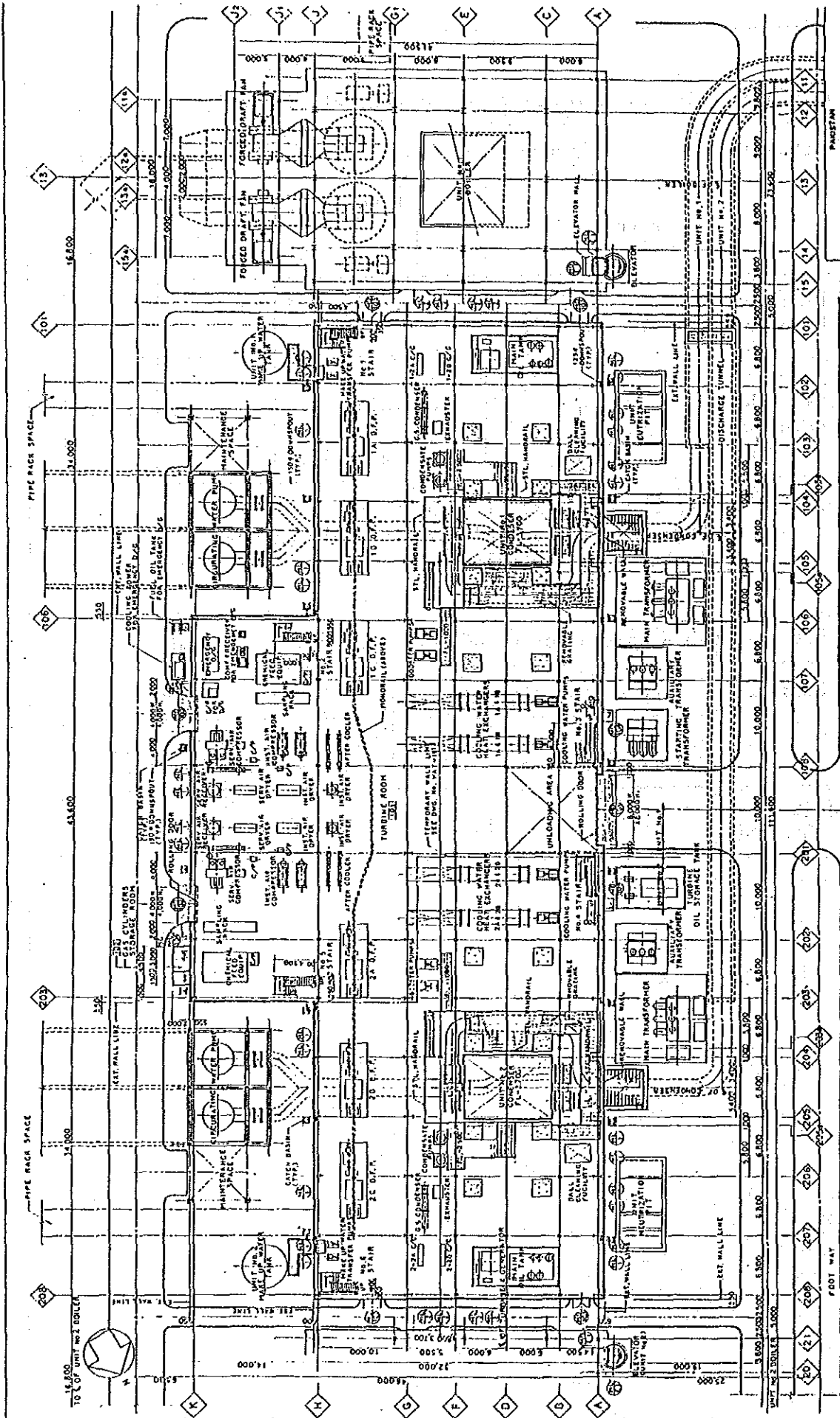
Remarks A : Top bar of flexural members
 B : Bar, except "Item A", of flexural members
 C : Anchors and lap splices

Table 5.6 Allowable Unit Stresses of Reinforcing Bars (kg/cm²)

Stresses	Permanent Stresses		Temporary Stresses	
	Tension Compression	Shear Rein- forcement	Tension Compression	Shear Rein- forcement
Deformed bar ASTM A615 Grade40	1850	1850	2800	2800

6. General drawing

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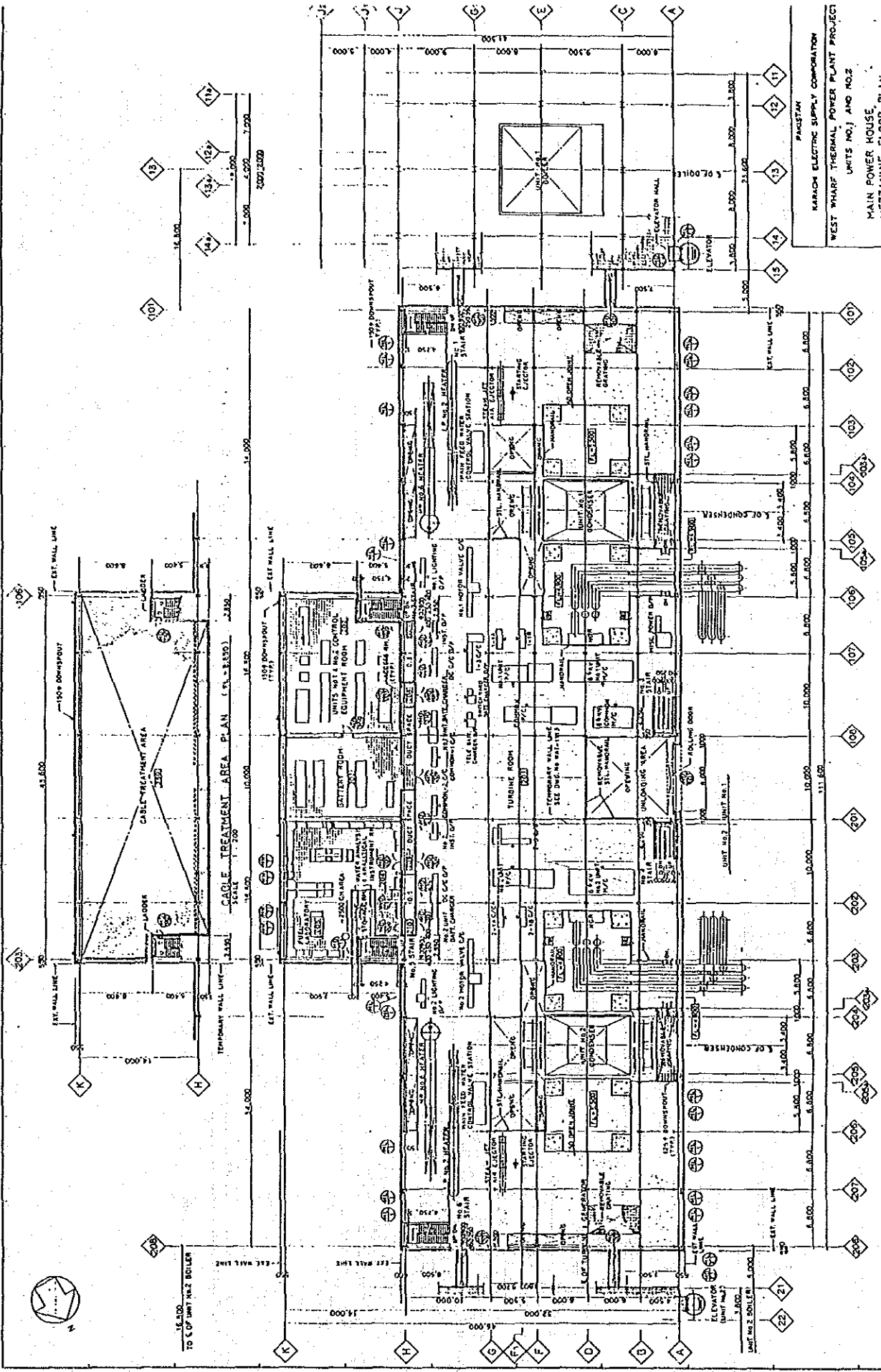


KAWASU ELECTRIC SUPPLY CORPORATION
 WEST WHARF THERMAL POWER PLANT PROJECT
 UNITS NO.1 AND NO.2
 MAIN POWER HOUSE
 GROUND FLOOR PLAN
 JAPAN INTERNATIONAL COOPERATION AGENCY

GRAPHIC SCALE
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 SCALE 1:100

GROUND FLOOR PLAN (F.L.S.D.)
 SCALE 1:100

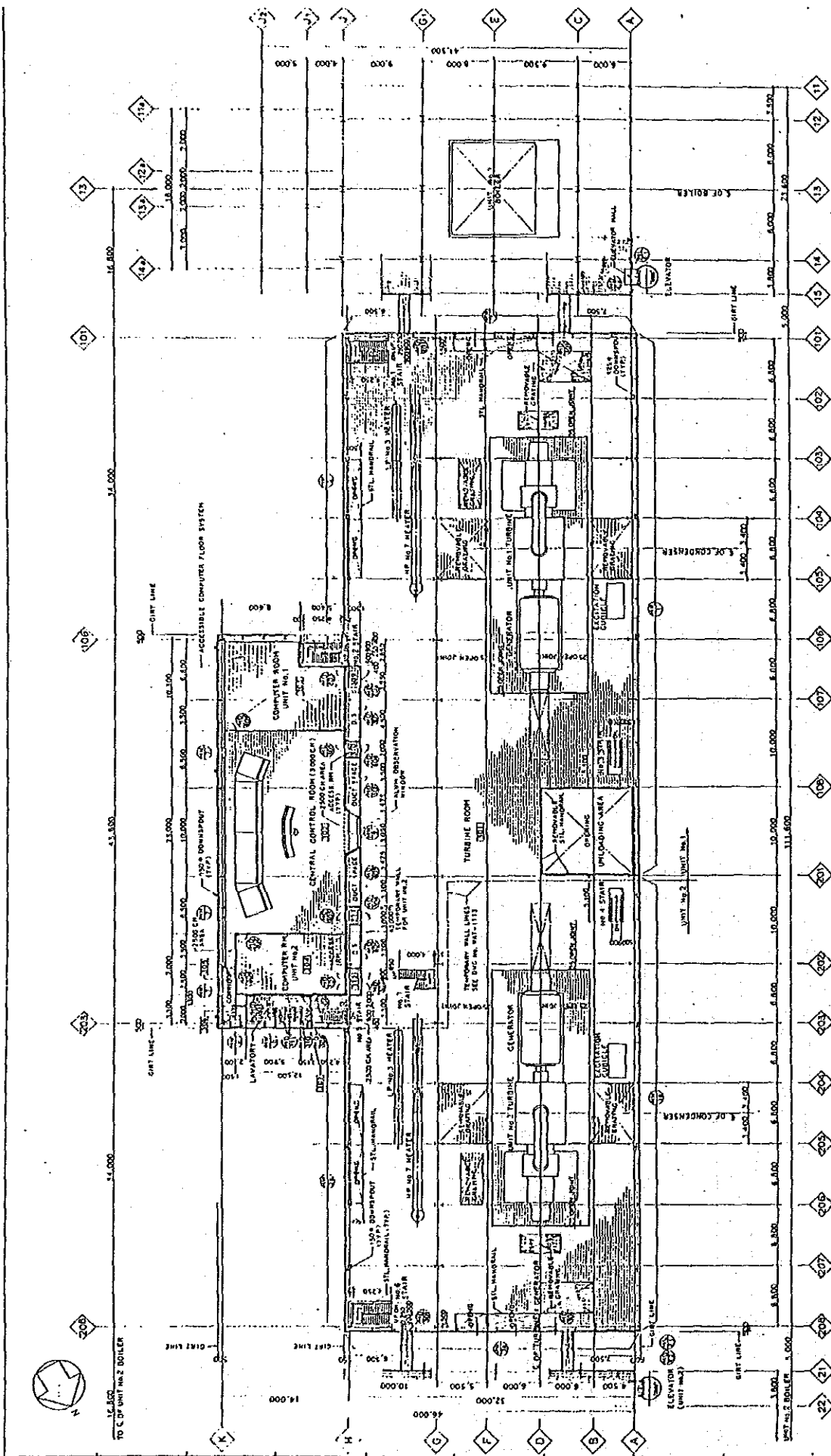
FOOT WAY
 PUBLIC ROAD



MARUCHI ELECTRIC SUPPLY CORPORATION
 WEST WHARF THERMAL POWER PLANT PROJECT
 UNITS NO. 1 AND NO. 2
 MAIN POWER HOUSE
 MEZZANINE FLOOR PLAN
 JAPAN INTERNATIONAL COOPERATION AGENCY

GRAPHIC SCALE
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 SCALE 1:200

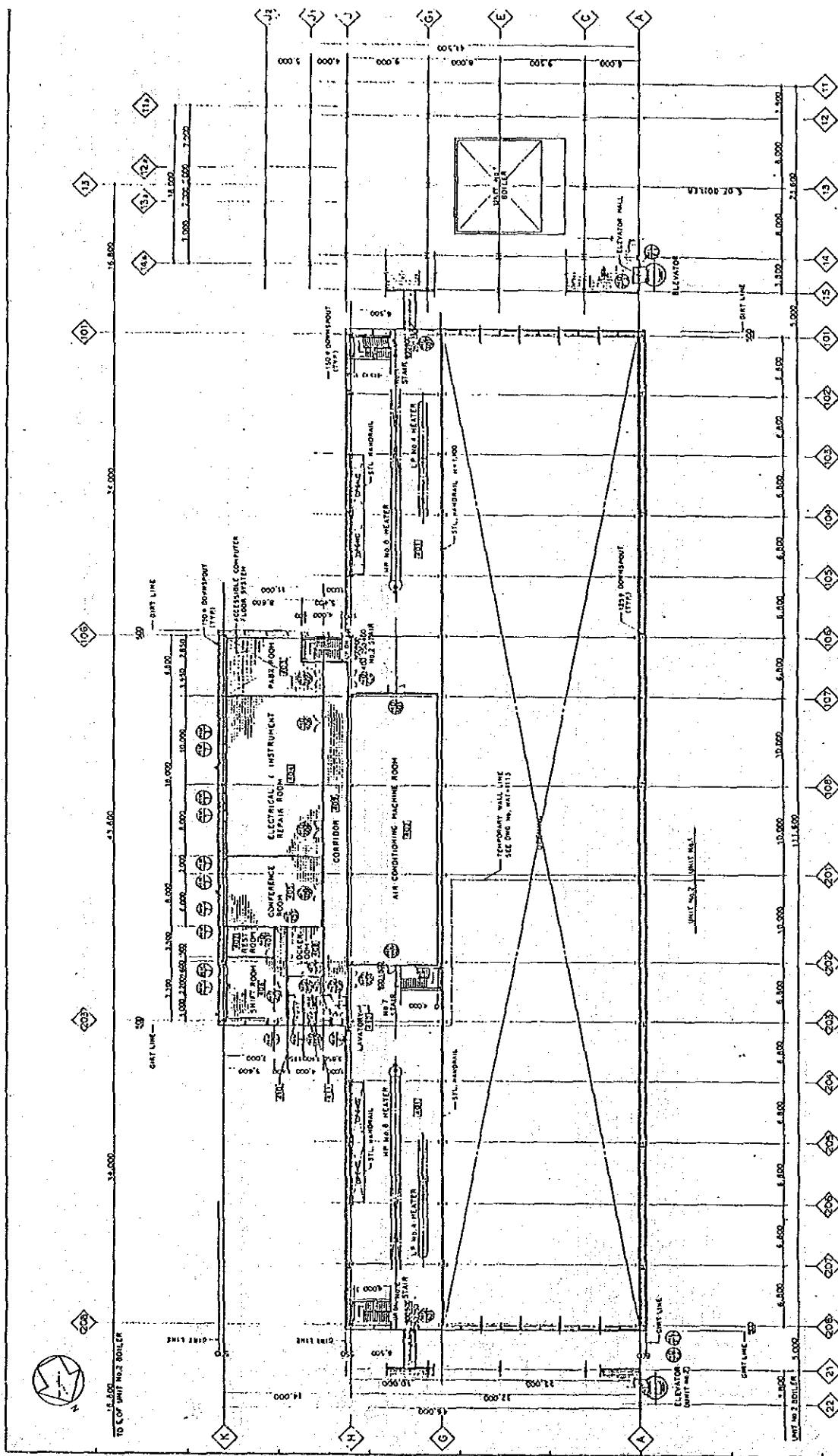
MEZZANINE FLOOR PLAN (F.L. = 1.500)
 SCALE 1:200



PAKISTAN
 KARACHI ELECTRIC SUPPLY CORPORATION
 WEST WHARF THERMAL POWER PLANT PROJECT
 UNITS NO. 1 AND NO. 2
 MAIN POWER HOUSE
 OPERATING FLOOR PLAN
 JAPAN INTERNATIONAL COOPERATION AGENCY

GRAPHIC SCALE
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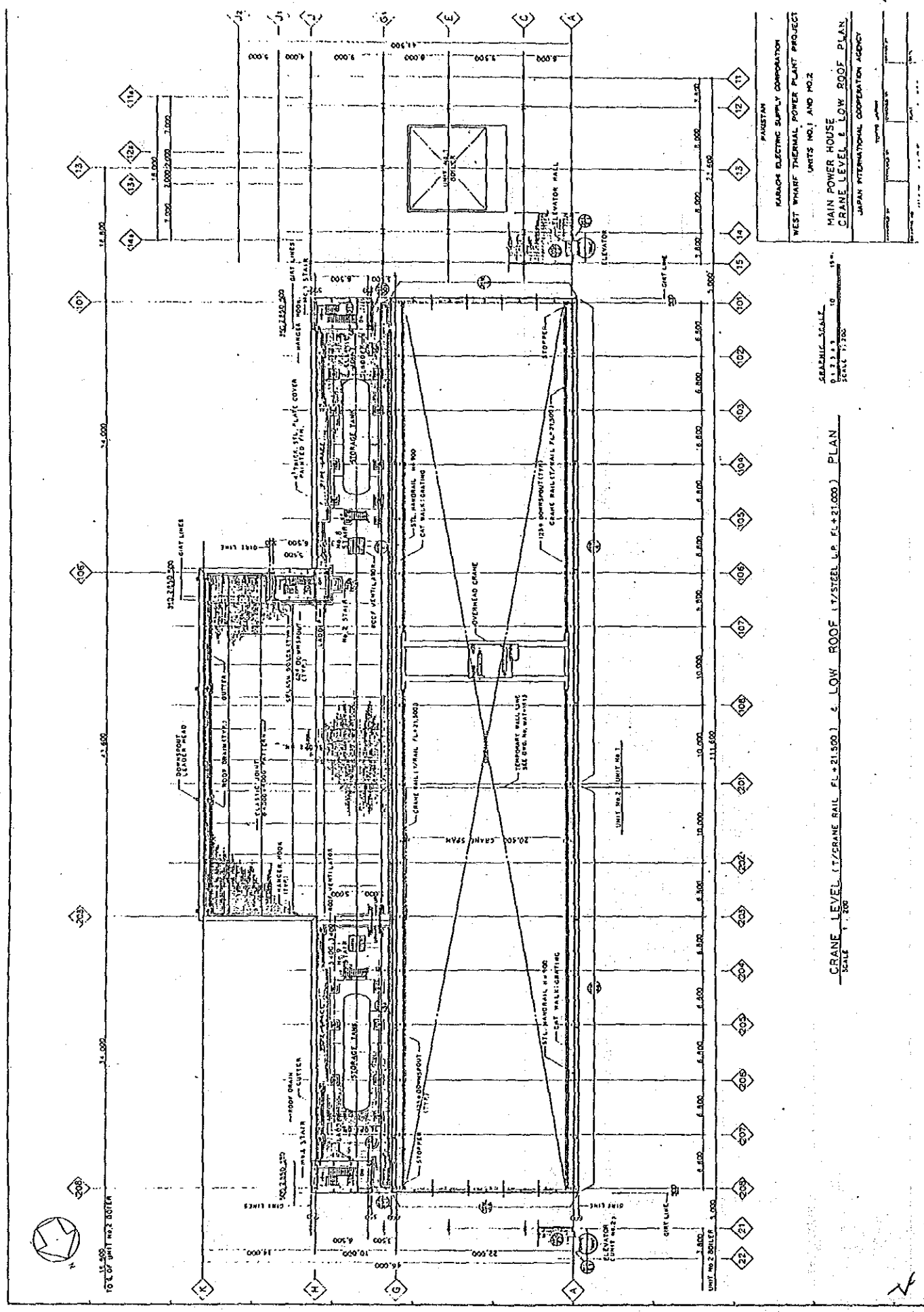
OPERATING FLOOR PLAN (FL. +11,000)
 SCALE 1:200



PAKISTAN
 KARACHI ELECTRIC SUPPLY CORPORATION
 WEST WHARF THERMAL POWER PLANT PROJECT
 UNITS NO. 1 AND NO. 2
 MAIN POWER HOUSE
 FORTH FLOOR PLAN
 JAPAN INTERNATIONAL COOPERATION AGENCY

GRAPHIC SCALE
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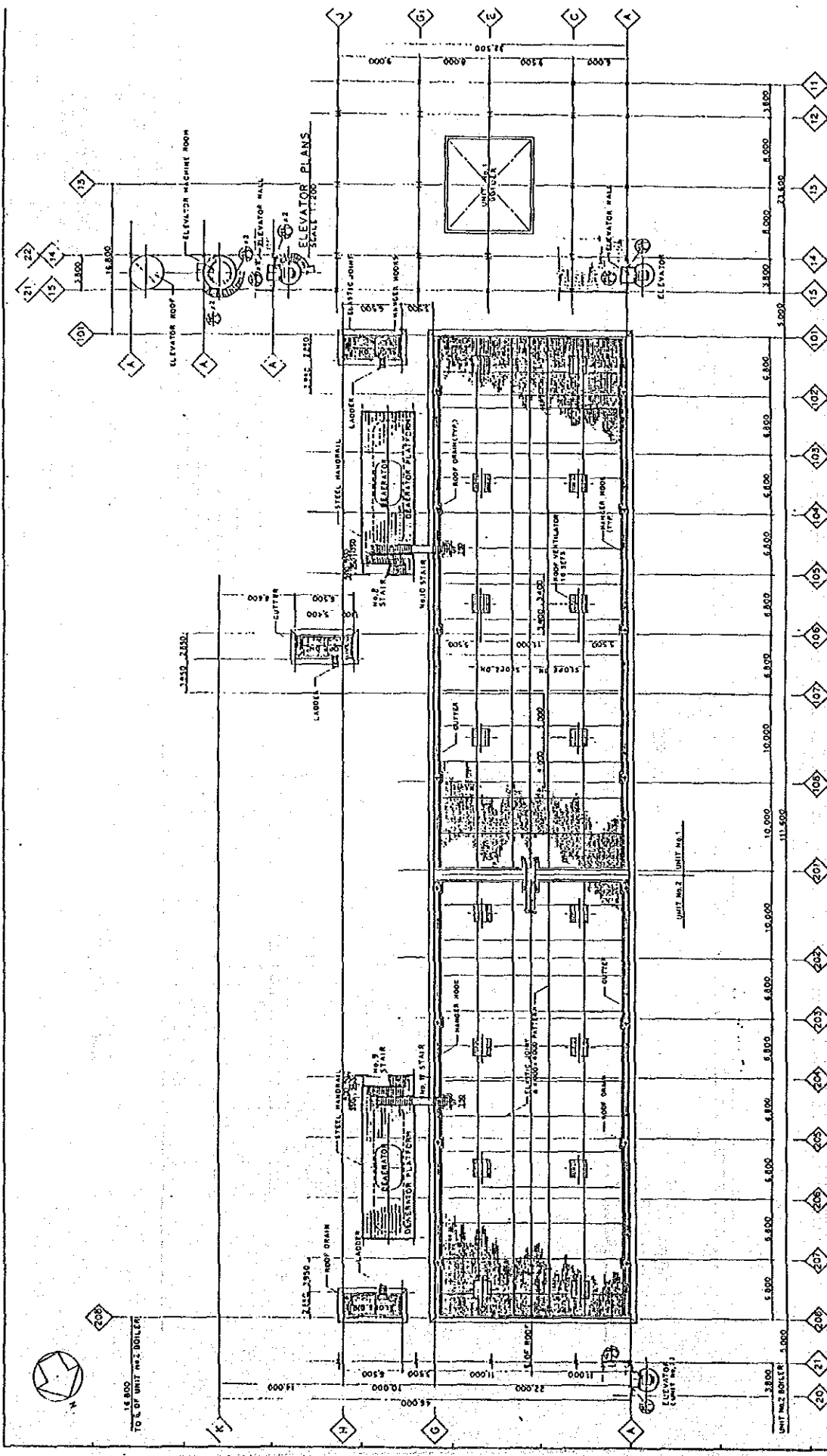
FORTH FLOOR PLAN (FL+21,000)
 SCALE 1:200



PAKISTAN
 KARACHI ELECTRIC SUPPLY CORPORATION
 WEST WHARF THERMAL POWER PLANT PROJECT
 UNITS NO.1 AND NO.2
 MAIN POWER HOUSE
 CRANE LEVEL & LOW ROOF PLAN
 JAPAN INTERNATIONAL COOPERATION AGENCY

GRAPHIC SCALE
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 SCALE 1:100

CRANE LEVEL (1/7 CRANE RAIL FL-21.500) & LOW ROOF (1/7 STEEL L.P. FL-21.000) PLAN
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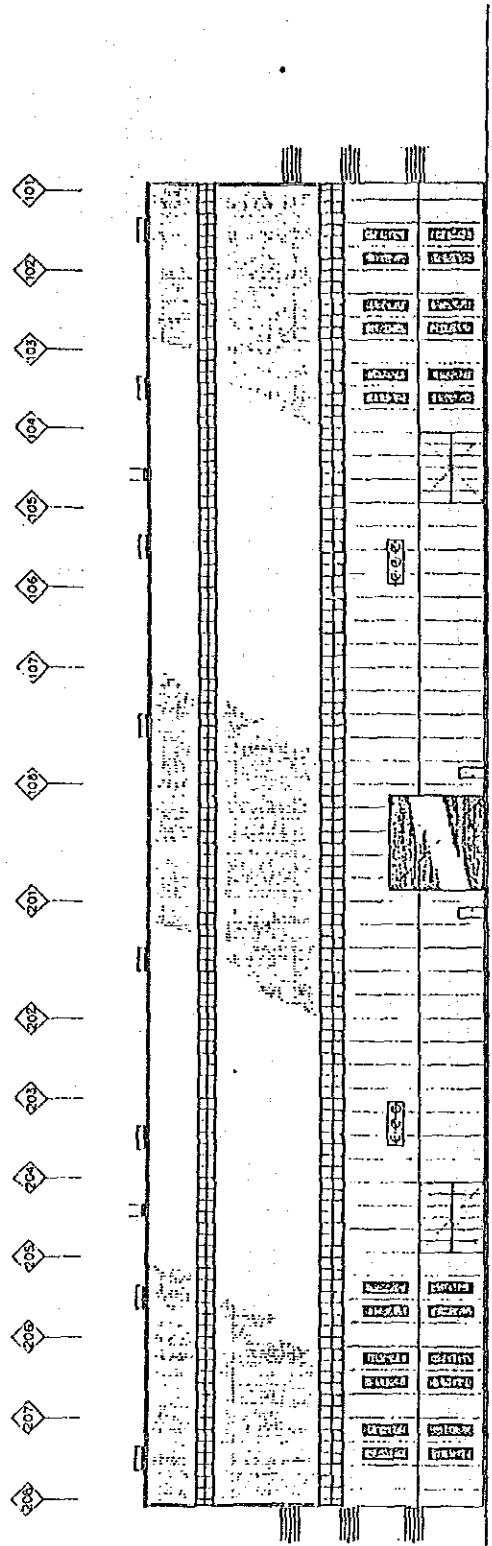


PAKISTAN
 KARACHI ELECTRIC SUPPLY CORPORATION
 WEST WHARF THERMAL POWER PLANT PROJECT
 UNITS NO. 1 AND NO. 2
 MAIN POWER HOUSE
 DEAERATOR PLATFORM & HIGH ROOF PLAN
 JAPAN INTERNATIONAL COOPERATION AGENCY

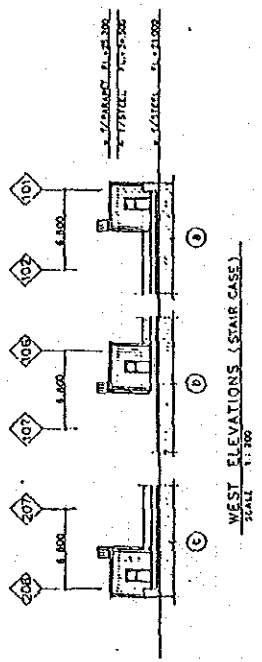
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DEAERATOR PLATFORM 6 HIGH ROOF PLAN (1/2 STEEL LP. P.L. x 27.100)
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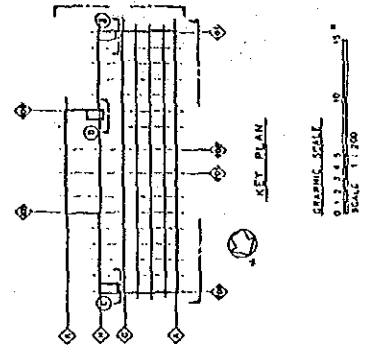
PAKISTAN
 KARACHI ELECTRIC SUPPLY CORPORATION
 WEST WHARF THERMAL POWER PLANT PROJECT
 UNITS NO. 1 AND NO. 2
 MAIN POWER HOUSE
 WEST & SOUTH ELEVATIONS
 JAPAN INTERNATIONAL COOPERATION AGENCY



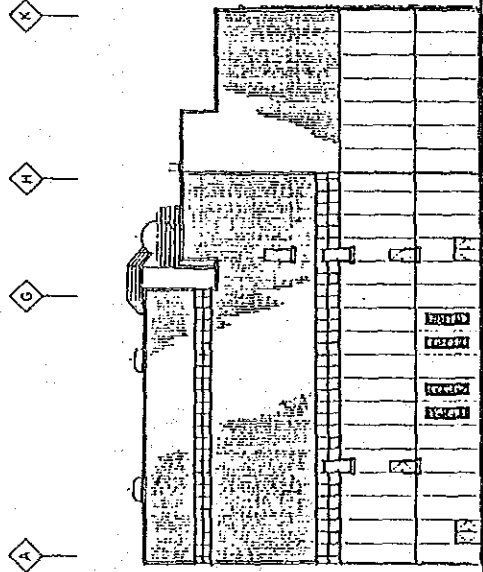
WEST ELEVATION
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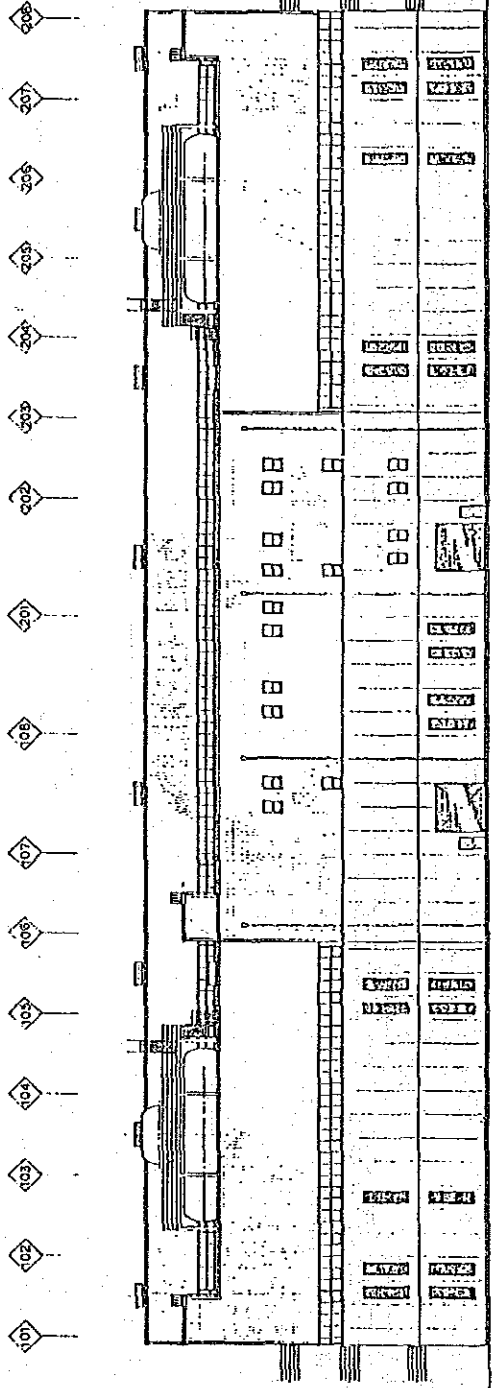


WEST ELEVATIONS (STAIR CASE)
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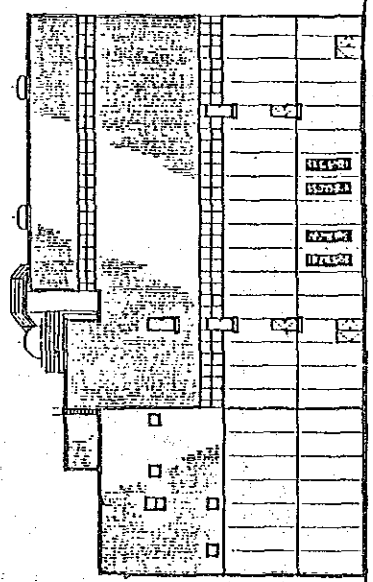


SOUTH ELEVATION
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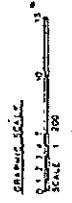
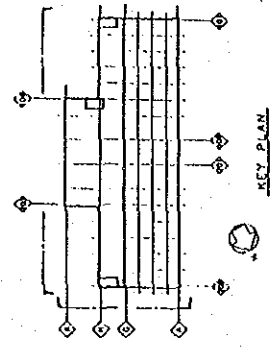




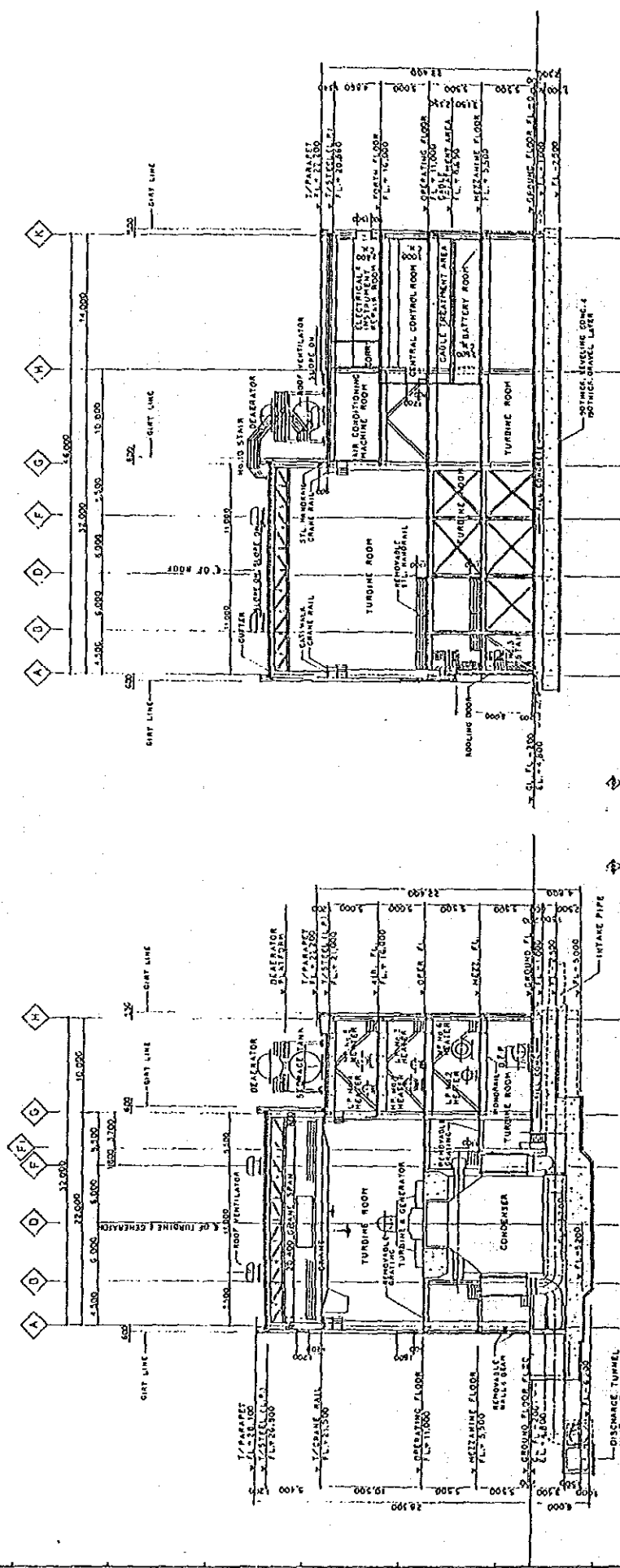
EAST ELEVATION
SCALE 1:200



NORTH ELEVATION
SCALE 1:200



PAKISTAN
KARACHI ELECTRIC SUPPLY CORPORATION
WEST WHARF THERMAL POWER PLANT PROJECT
UNITS NO.1 AND NO.2
MAIN POWER HOUSE
EAST 2 NORTH ELEVATIONS
JAPAN INTERNATIONAL COOPERATION AGENCY
Tokyo, Japan
PROJECT NO. 1411/80
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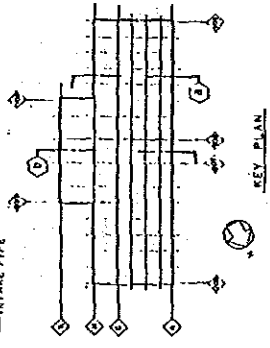


SECTION B SCALE 1:200

SECTION A SCALE 1:200

PARISTAR
KURARA ELECTRIC SUPPLY CORPORATION
WEST WHARF THERMAL POWER PLANT PROJECT
UNITS NO.1 AND NO.2
MAIN POWER HOUSE
SECTIONS
JAPAN INTERNATIONAL CORPORATION AGENT

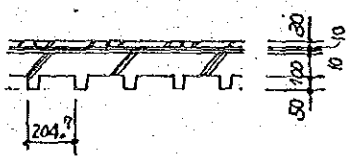
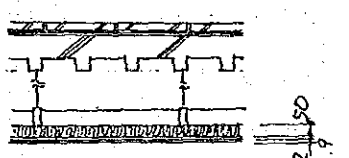
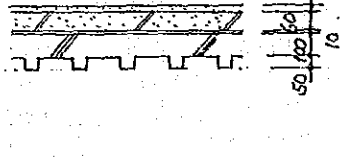
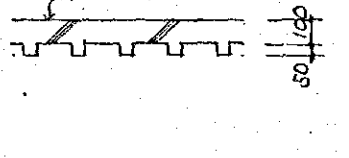
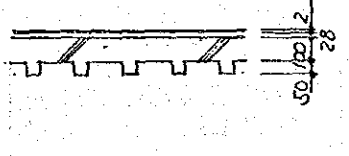
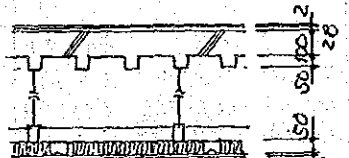
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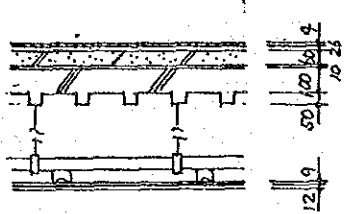
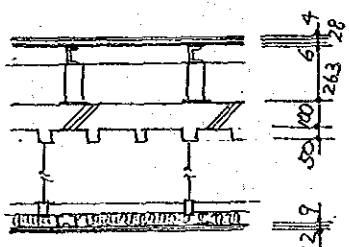
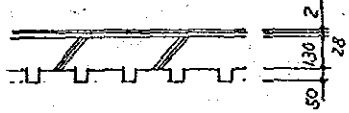
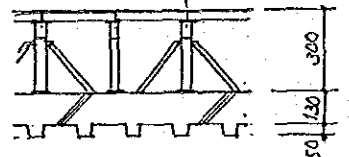
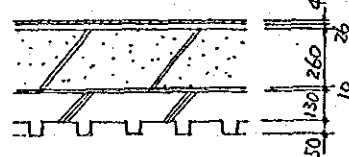
KEY PLAN

17. Design Load


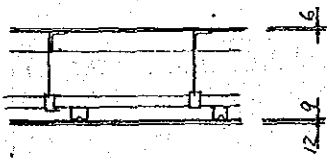
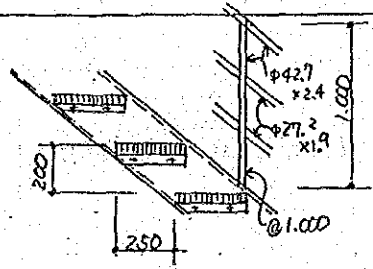
7.1 DEAD LOAD (1)
[固定荷重]

ROOM NAME OR LOCATION	FIGURE (mm)	MATERIALS (THICKNESS-mm)	WEIGHT (kg/m ²)	TOTAL (kg/m ²)
ROOF TURBINE ROOM A/C MACHINE ROOM		CONCRETE BLOCK (THK=30) SAND (t=20) ASPHALT ROOFING (t=10) CONCRETE SLAB (t=100) DECK PLATE V-50 (t=12)	60 20 15 275 13.9 383.5	→ 385
ROOF of ELECTORICAL & INST. REPAIR RM CONFERENCE ROOM		CONCRETE BLOCK SAND ASPHALT ROOFING CONCRETE SLAB DECK PLATE GLASS WOOL CEILING	383.5 2 25 410.5	→ 415
4TH. FL. A/C MACHINE ROOM		CEMENT MORTAL (t=30) CINDER CONCRETE (t=60) ASPHALT WATER PROOF (t=10) CONCRETE SLAB (t=100) DECK PLATE (t=12)	60 120 15 275 13.9 483.9	→ 485
4TH. FL. HP HEATER ROOM		CONCRETE SLAB (THK=100) DECK PLATE (t=12)	275 13.9 288.9	→ 290
LABORATORY ROOM		VINYL ASBESTOS TILE (THK=28) CEMENT MORTAL (t=28) CONCRETE SLAB (t=100) DECK PLATE (t=12)	4 56 275 13.9 348.9	→ 350
4TH. FL. ELECTORICAL & INST. REPAIR RM CORRIDOR		VINYL ASBESTOS TILE (THK=28) CEMENT MORTAL (t=28) CONCRETE SLAB (t=100) DECK PLATE (t=12) GLASS WOOL CEILING	348.9 2 25 375.9	→ 380

DEAD LOAD (2)
[固定荷重]

ROOM NAME OR LOCATION	FIGURE (mm)	MATERIALS (THICKNESS-mm)	WEIGHT (kg/m ²)	TOTAL (kg/m ²)
4TH. FL. LAVATORY		MOSAIC TILE (THK=4) CEMENT MORTAL (4=26) CINDER CONCRETE (4=60) ASPHALT WATER PROOF (4=10) CONCRETE SLAB (4=100) DECK PLATE (4=12) CEILING	8 52 120 15 275 13.9 25	508.9 → 510
LABORATORY ROOM PABX ROOM		VINYL ASBESTOS TILE (THK=2.9) CEMENT MORTAL (4=26) CONCRETE SLAB (4=100) DECK PLATE (4=12) GLASS WOOL CEILING STEEL PLATE (THK=1.0) STEEL FRAME FLOOR	375.9 47.1 40	463 → 465
OPE. FL. TURBINE RM.		VINYL ASBESTOS TILE (THK=2.0) CEMENT MORTAL (4=28) CONCRETE SLAB (4=130) DECK PLATE (4=12)	4 56 347 13.9	420.9 → 425
OPE. FL. CENTRAL CONTROL ROOM	Ditto			425
OPE. FL. COMPUTER ROOM		FREE FLOOR CONCRETE SLAB (THK=130) DECK PLATE (4=12)	60 347 13.9	420.9 → 425
OPE. FL. LAVATORY		MOSAIC TILE (THK=4) CEMENT MORTAL (4=26) CINDER CONCRETE (4=260) ASPHALT WATER PROOF (4=10) CONCRETE SLAB (4=130) DECK PLATE (4=12)	8 52 520 15 347 13.9	955.9 → 960 2/

DEAD LOAD (3)
[固定荷重]

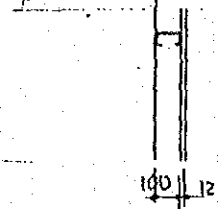

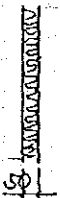
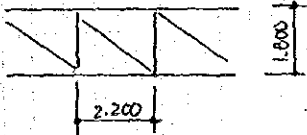
ROOM NAME OR LOCATION	FIGURE (mm)	MATERIALS (THICKNESS-mm)	WEIGHT (kg/m ²)	TOTAL (kg/m ²)
MEZ. FL. TURBINE RM	SAME AS OPE. FL. TURBINE FL.			425
MEZ. FL. CONTROL EQUIP. ROOM BATTERY ROOM LABORATORY ROOM	Ditto.			425
GRATING FLOOR		GRATING	46.4	→ 45
CHECKERED PLATE FLOOR		CHECKERED PLATE (THK=6) L-15 x 65 x 6 CEILING	48.8 20 25	93.8 → 95
STAIR		L-250 x 90 x 9 x 13 x 2 GRATING HAND RAIL φ42.7 (1.0 + 1.4) x 2 φ27.2 1.4 x 2 x 2	97.8 33 18.7 13.6	163.1 → 165 13/41

DEAD LOAD (4)
[固定荷重]

ROOM NAME OR LOCATION	FIGURE (mm)	MATERIALS (THICKNESS-mm)	WEIGHT (kg/m ²)	TOTAL (kg/m ²)
PARAPET		WEATHER PROOF METAL (THK=1.0) L=30x30x2...P.500 GIRT L=50x50x4...P.500 VERTICAL GIRT L=100x50...P.200 BEND. PLATE A=0.7 (THK=6.0) ASPHALT ROOFING (1"=50) WEATHER PROOF METAL (TH=1.0) CONCRETE BLOCK 150x120	5 3 6.1 4.7 0.2 7.5 7 43	110.5 → 120 kg/m
METAL SIDING		METAL SIDING (THK=1.0) FRAME (L=50x50x6, H=250)	18 25 43	→ 45
CONCRETE BLOCK WALL		CONCRETE BLOCK (THK=150)	300	→ 300
MORTAL FIN		MORTAL (THK=25)	50	→ 50
TILE FIN		MOSAIC TILE (THK=4) MORTAL (THK=25)	8 50 58	→ 60
PRECAST CONCRETE PANEL		PRECAST CONC. PANEL (THK=120)	288	→ 290

DEAD LOAD (5)

[固定荷重]

ROOM NAME OR LOCATION	FIGURE (mm)	MATERIALS (THICKNESS-mm)	WEIGHT (kg/m ²)	TOTAL (kg/m ²)
WALL (SINGLE SIDE)		FRAME... C-100 @ 450 PLASTER... BOAD (THK=12)	15 10.2 25.2	→ 26
WALL (DOUBLE SIDE)		FRAME... C-100 @ 450 PLASTER... BOAD (THK=12)	15 20.4 35.4	→ 36
GLASS WOOL		GLASS WOOL (THK=50)	2	→ 2
TRUSS		H-350 49.4 x 4.4 H-250 72.4 x 4.4 POST 26-130 215 57.6 x 1.8 x 2 BRACE 37.6 x 2 85 x 2	243.6	→ 250 kg/m
FENCE				→ 110 kg/m

NOTE: DL --- DEAD LOAD PHL --- PIPE HANGER LOAD
 LL --- LIVE LOAD TL --- TOTAL FLOOR LOAD

FLOOR LOAD
 [設計用床荷重]

Unit: kg/m²

FLOOR	ROOM NAME	SLAB			GIRDER			BEAM			COLUMN & FOUND.			SEISMIC		
		DL	LL	TL	DL	LL	PHL	TL	DL	LL	PHL	TL	DL	LL	PHL	TL
ROOF	T/G ROOM	385	90	475	535	60	595	535	60	595	535	60	595	535	60	535
5TH FL	COOLING TOWER ROOF	415	200	615	565	200	765	565	200	765	565	200	765	565	200	665
8-ROOF	A/C MACHINE ROOM ROOF	385	100	485	535	100	635	535	100	635	535	100	635	535	100	535
6L+210	DEAERATOR ROOF	385	500	885	535	500	1,285	535	500	1,285	535	500	1,285	535	500	690
4TH FL	CONFERENCE ROOM	380	300	680	530	180	710	530	180	710	530	180	710	530	180	610
6L+160	ELECTRICALS INS. REPAIR ROOM	380	500	880	530	500	1,030	530	500	1,030	530	500	880	530	500	880
	HP HEATER ROOM	290	1,000	1,290	440	1,000	1,690	440	1,000	1,690	440	1,000	1,290	440	1,000	665
	LAVATORY	510	130	640	660	130	790	660	130	790	660	130	790	660	130	720
	A/C MACHINE ROOM	485	500	985	635	500	1,135	635	500	1,135	635	500	985	635	500	985
01E FL	T/G ROOM (COVERHAUL)	425	2,000	2,425	575	2,000	2,825	575	2,000	2,825	575	2,000	2,225	575	2,000	800
6L+110	(OTHER)	425	1,000	1,425	575	1,000	1,825	575	1,000	1,825	575	1,000	1,425	575	1,000	1,350
	CENTRAL CONTROL ROOM	425	300	725	575	180	1,005	575	180	1,005	575	180	905	575	180	730
	COMPUTER ROOM	425	500	925	575	500	1,075	575	500	1,075	575	500	925	575	500	925
	LAVATORY	960	130	1,090	1,110	130	1,240	1,110	130	1,240	1,110	130	1,240	1,110	130	1,170
MEZ FL	T/G ROOM	425	800	1,225	575	800	1,625	575	800	1,625	575	800	1,225	575	800	1,150
6L+55	CONTROL EQUIPMENT ROOM	425	500	925	575	500	1,225	575	500	1,225	575	500	1,025	575	500	975
	BATTERY ROOM	425	500	925	575	500	1,225	575	500	1,225	575	500	1,025	575	500	975
	LABORATORY ROOM	425	300	725	575	180	905	575	180	905	575	180	855	575	180	705
COMMON	GRATING FLOOR	—	—	—	195	*130	*325	195	*130	*325	195	*130	*325	195	*130	*255
	STAIR	—	—	—	300	*130	*430	300	*130	*430	300	*130	*430	300	*130	*360
	CHECKERED PLATE FLOOR	95	100	195	95	100	195	95	100	195	95	100	195	95	100	195

7.3 Crane Load

1. Design Condition

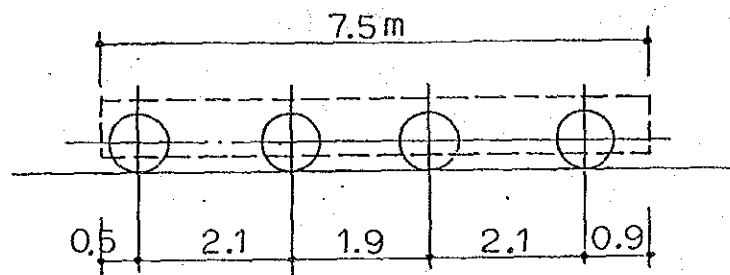
1.1 Overhead crane

Dead load : 45.0 ton (including 16.5 ton trolley)

Main hook : 60.0 ton

Auxiliary hook : 15.0 ton

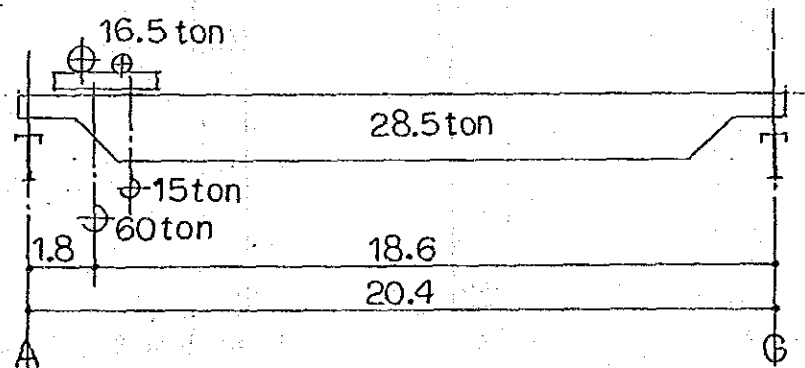
The wheel span is assumed to be as illustrated in the following diagram according to the experience.



1.2 The beam for the crane girder will be a simple beam each for 6.8m span and 10.0m span.

1.3 Maximum wheel load (P)

Crane span, $l = 20.4$ m



When

$$R_A = (60.0 + 16.5) \times \frac{18.6}{20.4} + \frac{1}{2} \times 28.5 = 84.0 \text{ ton}$$

$$R_B = (60.0 + 16.5) \times \frac{1.8}{20.4} + \frac{1}{2} \times 28.5 = 21.0 \text{ ton}$$

The maximum wheel load (A) per wheel becomes $84.0/4 = 21.0$ ton.

Since the impact factor is 120%, the design wheel load is

$$21 \times 1.2 = 25.2 \text{ ton / wheel.}$$

7.2 WIND LOAD

$$F_w = A \cdot C \cdot q$$

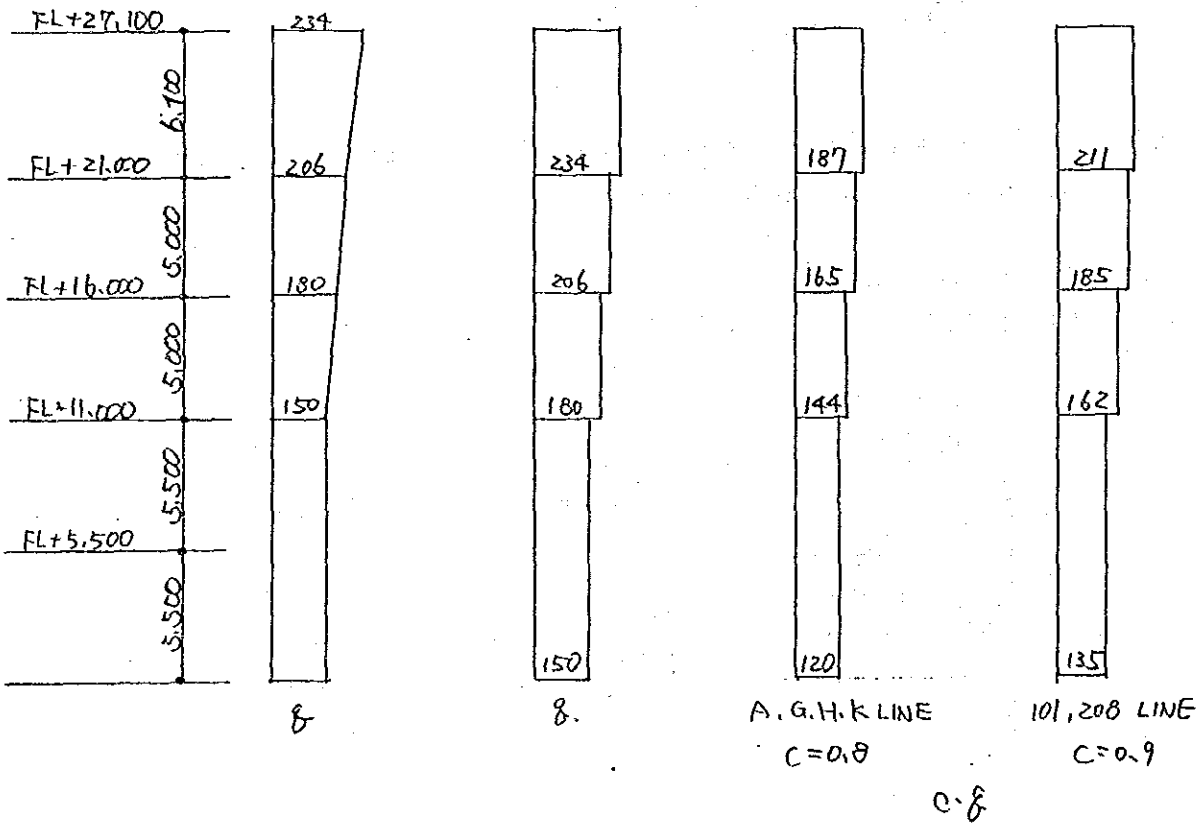
A: Projected area of structure (m²)

C: Shape factor

H: Height (m)

$$q = 150 \text{ kg/m}^2 \quad H \leq 10\text{m}$$

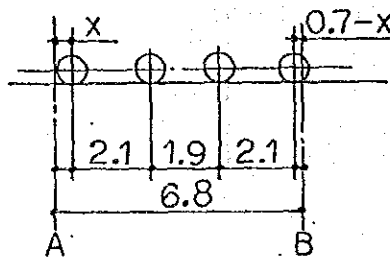
$$q = 45\sqrt{H} \quad H > 10\text{m}$$



2. Stress analysis

2.1 6.8m span

The stress becomes maximum in the case of the following diagram (four wheels are located on 6.8m span).



the stress of beam due to crane operation on simple beam "AB" becomes :

$$R_A = \frac{P}{6.8} (15.0 - 4x)$$

$$R_B = \frac{P}{6.8} (12.2 + 4x)$$

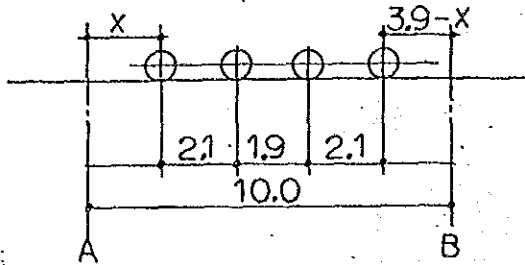
and the maximum bending moment becomes :

$$\begin{aligned} M_{\max} &= \left\{ \frac{15.0 - 4x}{6.8} (2.1 + x) - 2.1 \right\} P \\ &= -0.588 (x^2 - 0.97x - 4.31) P \end{aligned}$$

M becomes maximum when $x=0.485$ and P is 25.2 ton. Then, the maximum bending moment of beam becomes 67.3 t.m (vertical) and 5.6 t.m (horizontal), respectively.

2.2 10.0 m span

The stress becomes maximum in the case of the following diagram (four wheels are located on 10.0 m span).



The stress of beam due to crane operation on simple beam "AB" is:

$$R_A = \frac{P}{10} (27.8 - 4X) \quad , \quad R_B = \frac{P}{10} (12.2 + 4X)$$

$$M_{max} = \left\{ \frac{27.8 - 4X}{10.0} (2.1 + X) - 2.1 \right\} P$$

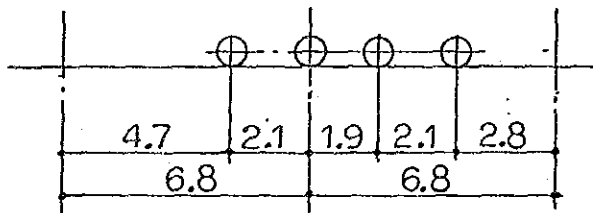
$$= -0.5 (X^2 - 2.24X - 12.76) P$$

Therefore, the bending moment becomes maximum when $X = 2.425$, and the maximum vertical moment becomes 155.1 t.m (Vertical) and 12.9 t.m (horizontal), respectively.

2.3 Maximum reaction against column due to wheel load

(1) In case of 6.8 m span

The reaction becomes maximum in the case of the following diagram:

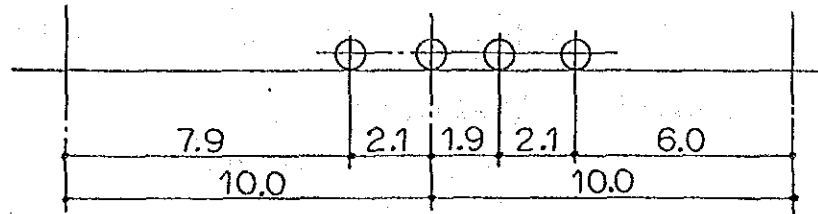


$$N = \frac{P}{6.8} \times (4.7 + 6.8 + 4.9 + 2.8)$$

$$= 2.824 P$$

(2) In case of 10.0m span

The reaction becomes maximum in the case of the following diagram:



$$N = \frac{P}{10.0} (7.9 + 10.0 + 8.1 + 6.0)$$

$$= 3.2 \times P$$

2.4 Reaction against column due to dead load

$$R_A = 16.5 \times \frac{18.6}{20.4} + \frac{1}{2} \times 28.5 = 29.3 \text{ ton}$$

$$R_B = 16.5 \times \frac{1.8}{20.4} + \frac{1}{2} \times 28.5 = 15.7 \text{ ton}$$

(1) In case of 6.8m span

Reaction for foundation design:

$$P_A = 2.824 \times \frac{29.3}{4} = 20.7 \text{ ton}, \quad P_B = 2.824 \times \frac{15.7}{4} = 11.1 \text{ ton}$$

Reaction for column design (vertical):

$$20.7 \times 1.2 = 24.8 \text{ ton}, \quad 11.1 \times 1.2 = 13.3 \text{ ton}$$

Reaction for column design (horizontal):

$$20.7 \times 0.1 = 2.1 \text{ ton}, \quad 11.1 \times 0.1 = 1.1 \text{ ton}$$

Force in travelling direction:

$$20.7 \times 0.15 = 3.1 \text{ ton}, \quad 11.1 \times 0.15 = 1.7 \text{ ton}$$

(2) In case of 10.0m span

Reaction for foundation design:

$$P_A = 3.2 \times \frac{29.3}{4} = 23.4 \text{ ton}, \quad P_B = 3.2 \times \frac{15.7}{4} = 12.6 \text{ ton}$$

Reaction for column design (vertical) :

$$23.4 \times 1.2 = 28.1 \text{ ton}, \quad 12.6 \times 1.2 = 15.1 \text{ ton}$$

Reaction for column design (horizontal) :

$$23.4 \times 0.1 = 2.3 \text{ ton}, \quad 12.6 \times 0.1 = 1.3 \text{ ton}$$

Force in travelling direction :

$$23.4 \times 0.15 = 3.5 \text{ ton}, \quad 12.6 \times 0.15 = 1.9 \text{ ton}$$

2.5 Reaction against column due to lifted load

(1) In case of 6.8m span

Reaction for foundation design :

$$P_A = 2.824 \times \frac{84.0}{4} = 59.3 \text{ ton}, \quad P_B = 2.824 \times \frac{21.0}{4} = 14.8 \text{ ton}$$

Reaction for column design (vertical) :

$$59.3 \times 1.2 = 71.2 \text{ ton}, \quad 14.8 \times 1.2 = 17.8 \text{ ton}$$

Reaction for column design (horizontal) :

$$59.3 \times 0.1 = 5.9 \text{ ton}, \quad 14.8 \times 0.1 = 1.5 \text{ ton}$$

Force in travelling direction :

$$59.3 \times 0.15 = 8.9 \text{ ton}, \quad 14.8 \times 0.15 = 2.2 \text{ ton}$$

(2) In case of 10.0m span

Reaction for foundation design :

$$P_A = 3.2 \times \frac{84.6}{4} = 67.2 \text{ ton}, \quad P_B = 3.2 \times \frac{21.0}{4} = 16.8 \text{ ton}$$

Reaction for column design (vertical) :

$$67.2 \times 1.2 = 80.6 \text{ ton}, \quad 16.8 \times 1.2 = 20.2 \text{ ton}$$

Reaction for column design (horizontal) :

$$67.2 \times 0.1 = 6.7 \text{ ton}, \quad 16.8 \times 0.1 = 1.7 \text{ ton}$$

Force in travelling direction :

$$67.2 \times 0.15 = 10.1 \text{ ton}, \quad 16.8 \times 0.15 = 2.5 \text{ ton}$$