Table 5-19 Corona Noise Level for Various Conductors and Bundles

Phase Voltage (kV)		$230/\sqrt{3}$	$550/\sqrt{3}$						
Conductor		CONDOR	CONDOR			Dipper		Bluebird	Thrasher
Number of Subconductor		1	2	3	4	3	4	2	2
G_{max} (kV/cm)		15.5	23.3	18.3	15.2	15.0	12.5	15.7	15.7
$N_1 + 3$ (dB)		49.8	78.6	60.1	48.7	52.0	42.8	58.8	58.1
N'_1 (dB)	R=1 (mm/H)	65.9	88.4	76.4	62.9	67.9	53.2	70.3	69.3
	2 "	68.2	87.7	77.8	65.4	70.3	56.3	72.9	72.0
	4 "	70.2	87.4	78.8	67.5	72.5	59.3	75.0	74.1
	6 "	71.0	87.3	79.2	68.5	73.4	60.7	75.8	75.0
Radio of N'_1 for 230 kV CONDORx1	R=1 (mm/H)	1	1.34	1.16	0.95	1.03	0.81	1.07	1.05
	2 "	1	1.29	1.14	0.96	1.03	0.83	1.07	1.06
	4 "	1	1.25	1.12	0.96	1.03	0.84	1.07	1.06
	6 "	1	1.23	1.12	0.96	1.03	0.85	1.07	1.06

Table 5-20 Corona Loss for Various Conductors and Bundles

Conductor	G_{max} (kV/cm)	Corona loss (kW/KM.1φ)			Annual corona power less	
		Fair weather	High humidity	1mm/H Rain	MWH/kM.1φ	MWH/KM.2 cct
CONDOR x 2	23.3	6.11	12.22	61.13	211.7	1269.9
" x 3	18.3	0.68	1.36	6.81	23.6	141.5
" x 4	15.2	0.18	0.36	1.81	6.3	37.6
DIPPER x 3	15.0	0.20	0.39	1.97	6.8	41.0
DIPPER x 4	12.5	0.07	0.14	0.72	2.5	14.9
BLUEBIRD x 2	15.7	0.31	0.61	3.06	10.6	63.6
THRASHER x 2	15.4	0.27	0.54	2.74	9.5	56.9

Conditions : Fair weather 3,540 hour [(365-140)x 24 + 140x12)] x 0.5

High humidity 3,540 hour

Annual rainfall 2,400 mm

Table 5-21 <u>Tentative Estimate for EHV Tower Weights</u>

Maximum tension (kg)	5,100	4,900	4,700	4,500
Sag (120°C,no wind, 400m) (m)	12.42	12.97	13.56	14.20
Difference	0	+0.6	+1.2	+1.8
Type of tower (ton)				
E D Q	45.6	46.0	46.5	46.9
E D R_1	56.0	56.1	56.1	56.2
E D R_2	50.1	50.1	50.1	50.1
E D S	57.7	57.1	56.6	56.2
E D T	70.5	69.6	68.8	67.8
Average weight per Kilometer (ton)	129.5	129.7	130.0	130.1

percentage of each tower type EDQ 60%

EDR$_1$ 10

EDR$_2$ 5

EDS 10

EDT 15

average span length 400m

average body extension 18m

tower weight : based on Fig. 5-38

Table 5-22 Examples of Tower Design Conditions on Existing 230 kV Lines in Philippines

bundles of "CONDOR"	Type	DQ Suspension	DR Suspension strain	DS Suspension strain	DR Strain D.E.
795MCM x 1	Angle	0°	0°~15°	0°~15°	0°~30°A 0°~30°D.E.
	Max.span				
	Wind span	400m	400m	400m	500^{m}A 250^{m}D.E.
	Weight span C	600m	900m	1200m	1200m
	G	800m	1300m	1800m	1800m
795MCM x 2	Angle	1°... 5°	5°... 0°	15°..7.5°..0°	0°~30°A ↗ 0°~45/2°D.E.
	Max.span	510^{m}.... 510^{m}	680^{m}.... 680^{m}	850^{m}..850^{m}..850^{m}	850^{m} 850^{m}
	Wind span	340^{m}.... 380^{m}	340^{m}.... 540^{m}	340^{m}..640^{m}..940^{m}	430^{m} 215^{m}
	Weight span C	510^{m}.... 510^{m}	765^{m}.... 765^{m}	1020^{m}.1020^{m}.1020^{m}	1020^{m} 1020^{m}
	G	680^{m}.... 680^{m}	1105^{m}... 1105^{m}	1530^{m}.1530^{m}.1530^{m}	1530^{m} 1530^{m}
795MCM x 4	Angle	1°... 0°	5° ... 0°	10°.. 5° .. 0°	0°~30°A ↗ 0°~45/2°D.E.
	Max.span	400^{m} .... 400^{m}	550^{m} .... 550^{m}	700^{m}..700^{m}..700^{m}	700^{m} 700^{m}
	wind span	270^{m} .... 310^{m}	270^{m} .... 470^{m}	270^{m}..470^{m}..670^{m}	340^{m} 270^{m}
	Weight span C	405^{m} .... 405^{m}	608^{m} .... 608^{m}	810^{m}..810^{m}..810^{m}	810^{m} 810^{m}
	G	540^{m} .... 540^{m}	878^{m} .... 878^{m}	1215^{m}.1215^{m}.1215^{m}	1215^{m} 1215^{m}

C : Conductor G : Ground wire

Table 5-23 Calculation of Required Horizontal Separation

Span length (m)	300	400	500	600	700	800
ditto (ft) A	984	1312	1640	1969	2297	2625
60°F final Sag (m)	5.75	10.98	17.80	26.17	36.08	47.52
ditto (ft) B	18.86	36.02	58.40	85.86	118.38	155.91
% Sag B/A x 100	1.92	2.75	3.56	4.36	5.15	5.94
A (ft)	0.025 (550) = 13.75					
L/2 (ft)	4.9m/0.304794/2 = 8.04					
Horizontal separation (ft)	23.02	25.45	26.54	27.61	28.66	29.72
ditto (m)	7.02	7.76	8.09	8.42	8.74	9.06

Horizontal separation = C.D/W.(% Sag)+A+L/2

where C : Experience factor larger than 1.25

D : Diameter of conductor (in) "CONDOR" = 1.093

W : Weight of bare conductor (lbs/ft) "CODOR" = 1.024

(% Sag) = (60°F final sag in ft)/(Span length in ft) x 100

A : 0.025 x (Voltage between phases in kV)

L : Length of insulator strings (ft)

Table 5-24 Dimensions for Tower Clearance Diagram

		Suspension EDQ (1°)	Suspension EDR_1 (5°)	Strain
Insulation distance (mm)	a	1300 (1300)		
	b	3600 (3600)		
Swinging angle of insulator strings (°)	θ_1	21 (21)	39 (39)	15 (15)
	θ_2	67* (70)	74 (74)	60 (60)
Length of swinging Hanger		– (–)	800 (–)	– (–)
Length of insulator strings (mm)		4,900 (6,700)	4,900 (6,700)	4,900 (6,000)

( ) Contamination design

a : Minimum insulation clearance for commercial frequency voltage

b : Standard insulation clearance for lightning impulse

θ_1 : Swinging angle of insulator strings in ordinary condition

θ_2 : Swinging angle of insulator strings in worst condition

* : Calculation results is 70 degrees but is limited up to 67 degrees not to install swinging hanger

Table 5-25 Application Standard for EHV Tower Foundation

Type (bearing capacity)	Typical land	Soil condition	Remarks
I ($>30\ t/m^2$)	Mountainous land Hill Forest Farm	Hard soil	
II ($20\sim30\ t/m^2$)	Rice field Farm near the river or close to the rice field	Medium soil with low underground water level	
III ($10\sim20\ t/m^2$) IV ($<10\ t/m^2$)	Rice field near the river Marshy ground	Soft soil with high underground water level or submerged condition	This type can be applied for the standard penetration value not less than around 5. For angle towers piles should be applied.

The details of such expressions are possible only after the precise survey of the tower position is finished and appropriate soil survey results are obtained.

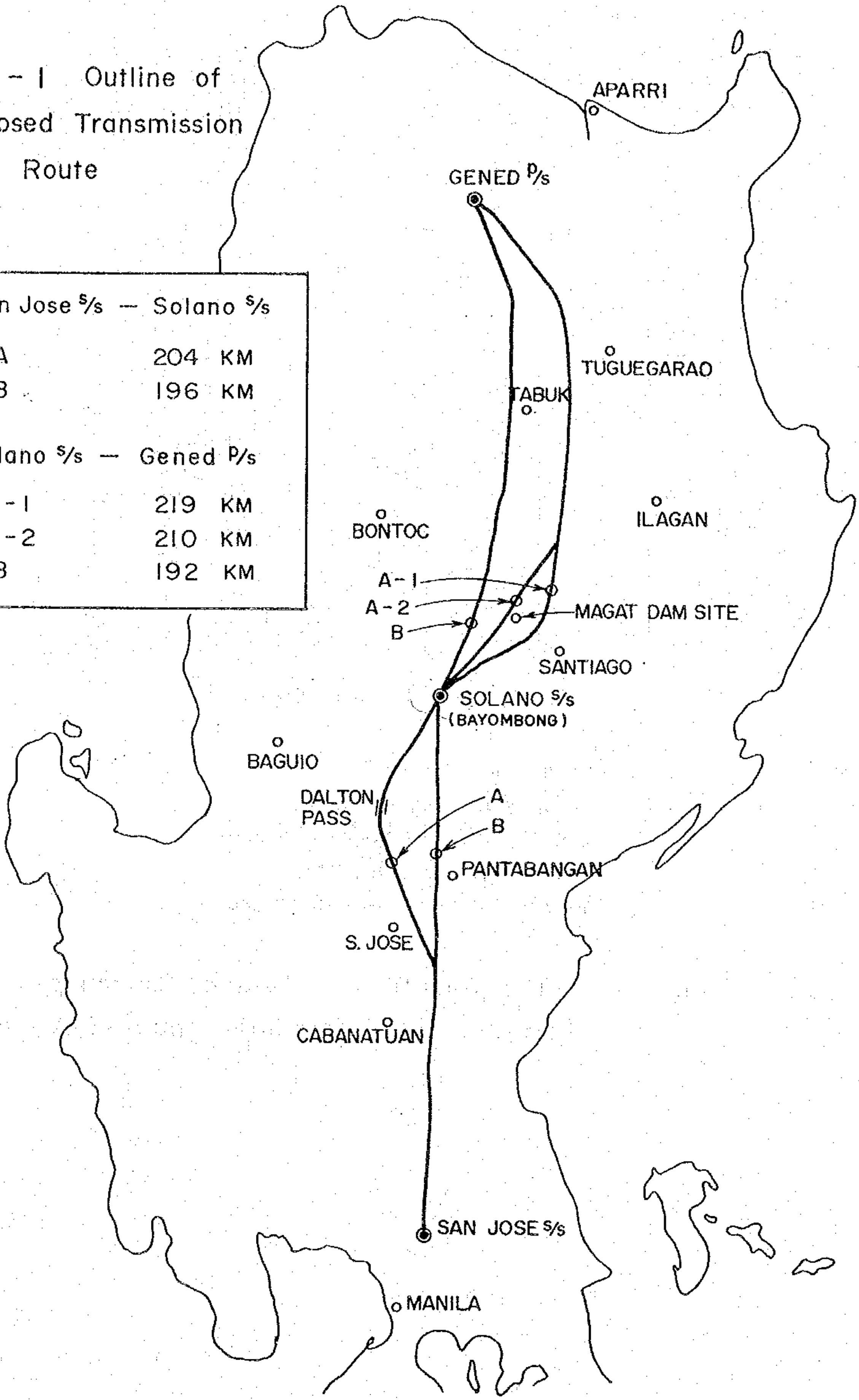
Table 5-26

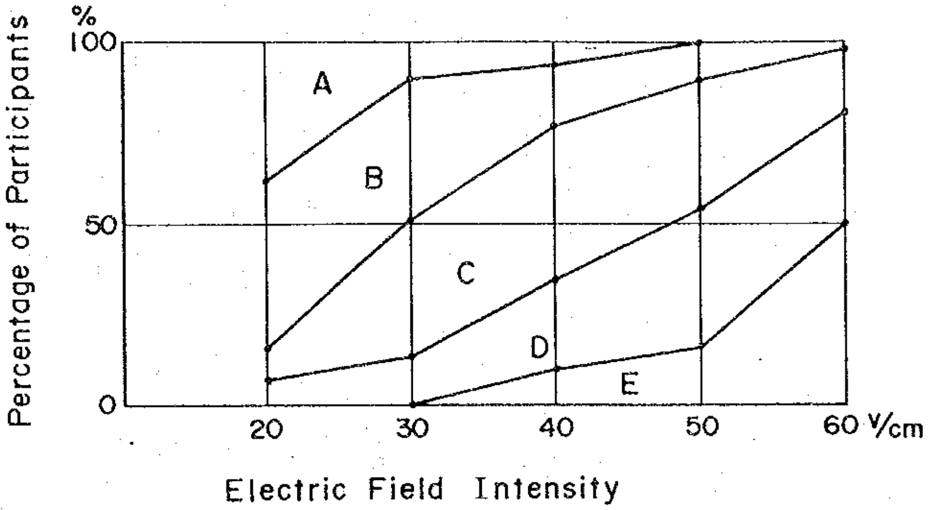
List of Stringing Tools and Equipment for EHV Line Construction

Description	Q'ty Unit
Engine puller 5t. double capstan	2
Tensioner for conductor	4
Tensioner for wire	4
Wire reel (empty)	20
Reel winder	4
Stringing block for bundle conductors	200
Stringing sheave for conductor	50
Stringing sheave for ground wire	50
Running board	4
Running board for wire	4
Gondola for bundle 4 conductors	8
Engine compressor for joint 100t.	4
Dise for joint compression work	12
Cutter for stranded aluminum conductor	5
Joint protector	40
Engine winch	4
Come along for conductor	45
Come along for ground wire	15
Wire rope 16mm dia.	60 KM
Wire rope 12mm dia.	3 KM
Wire rope 10mm dia.	25 KM
Cable clamp for pulling conductors	20
Wire net	10
Swivel	6
Shackle for wire joint	60
Wire pulling clamp	20
U-clevis	50
Turn backle	20
Ladder for stringing work	6
Complession type wire cutter	6
Exchanger for 320mm insulators	1
Exchanger for 280mm insulators	1
Others	1

Fig. 5 - 1 Outline of Proposed Transmission Line Route

San Jose S/s — Solano S/s	
A	204 KM
B	196 KM
Solano S/s — Gened P/s	
A - 1	219 KM
A - 2	210 KM
B	192 KM





A. no shock
B. shock scarecely perceived
C. slight shock but not unpleasant
D. unpleasant but torelable
E. hateful to tolerate manytimes

Fig. 5-2 Test Results of Influence Caused by Electric Field Intensity under EHV Line

Fig. 5-3 Relations between Conductor Height and Electric Field Intensity under EHV Transmission Line

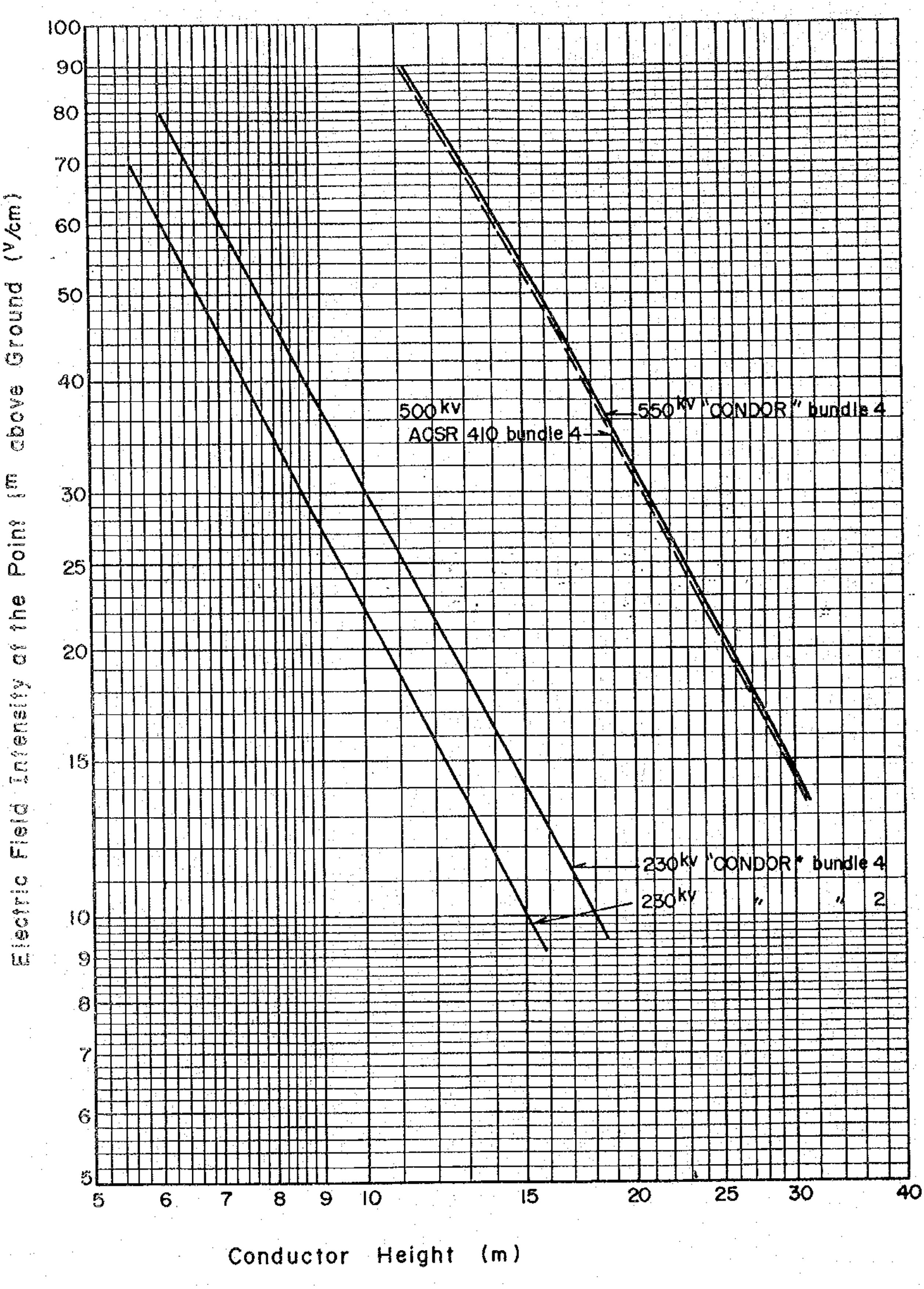
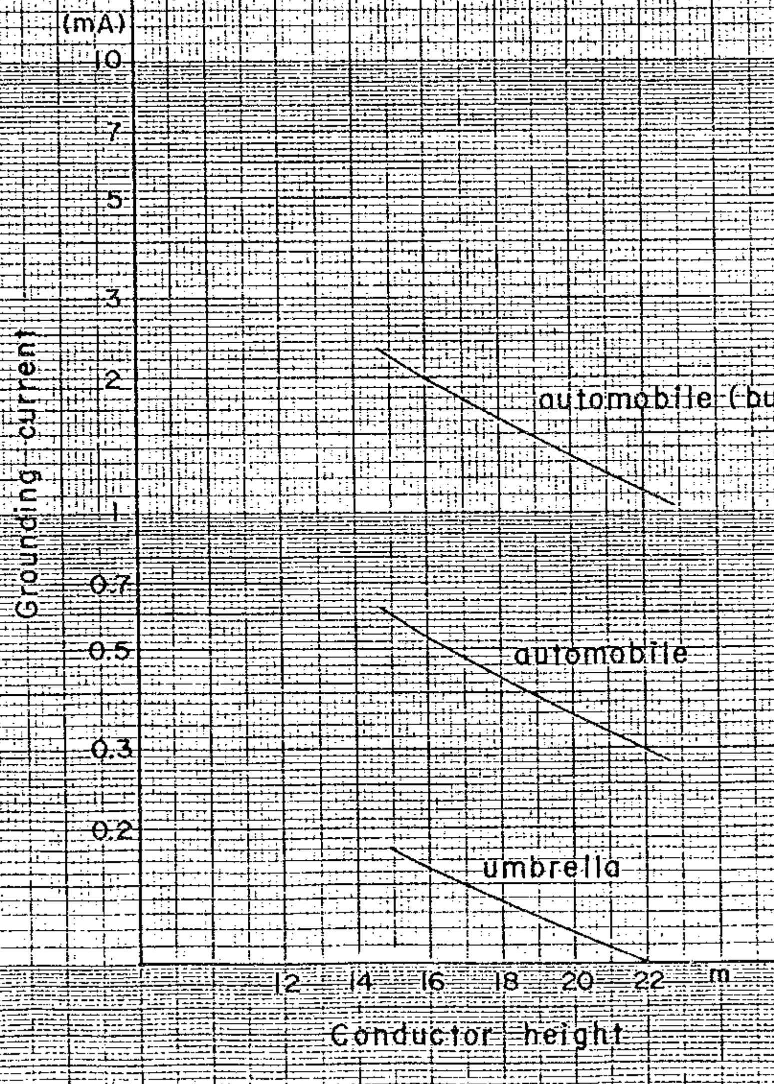
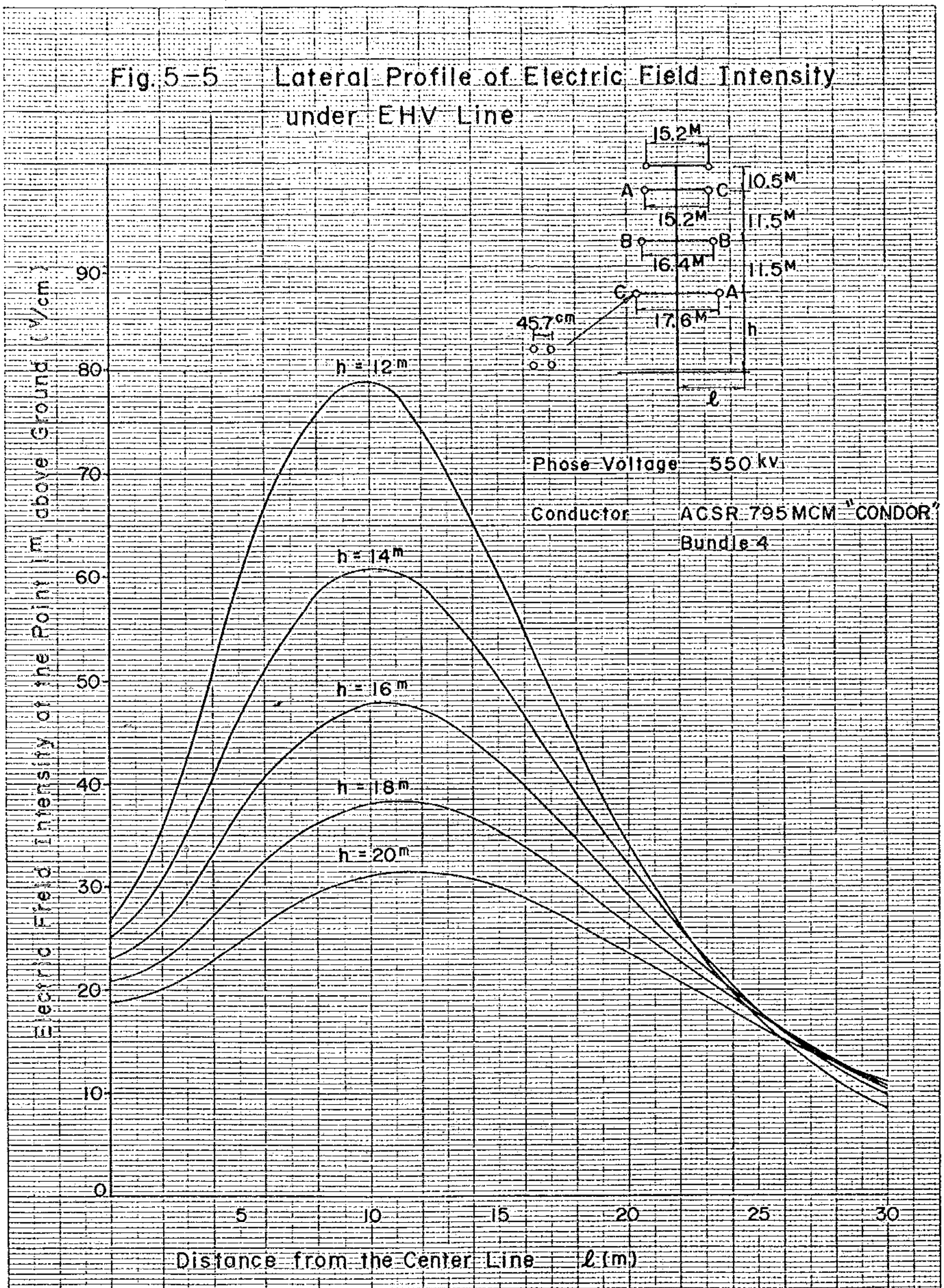


Fig. 5-4 Relations between Grounding Current and Conductor Height for EHV Lines





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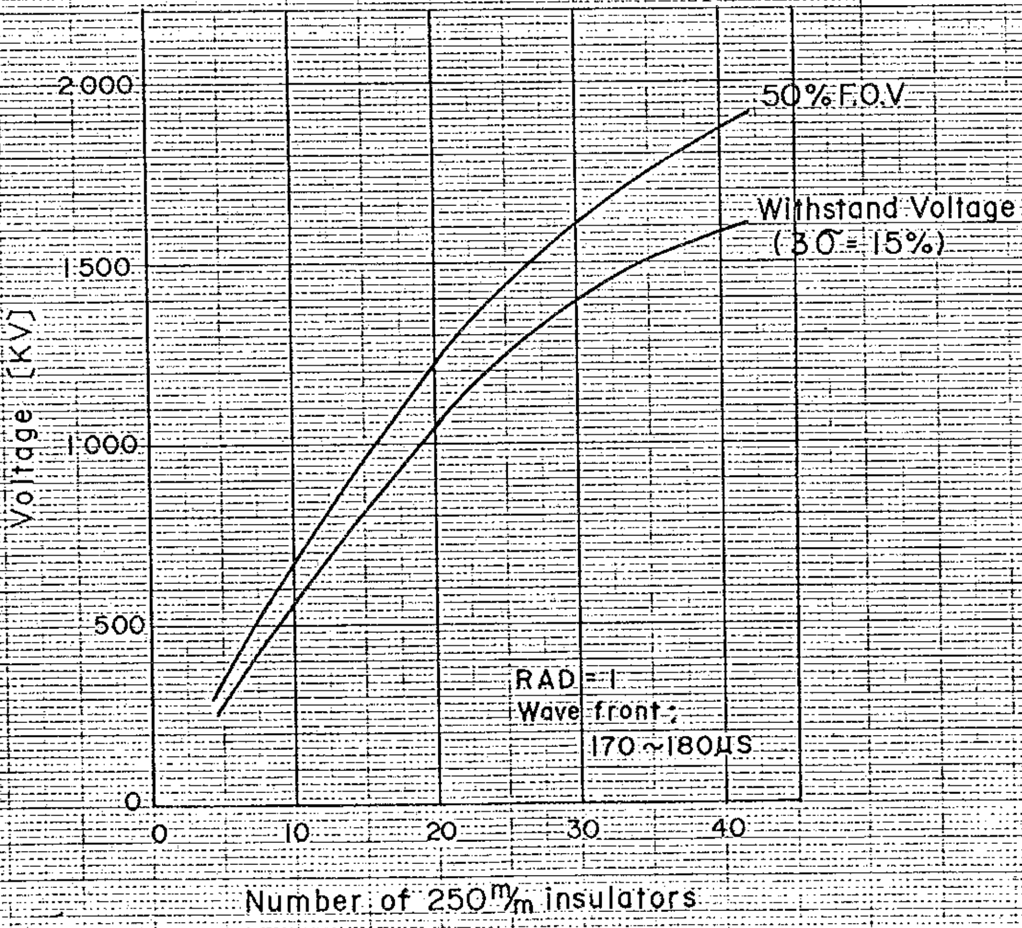


Fig. 5-6 Switching Surge 50% F.O.V and Withstand Voltage of 250 m/m Insulators

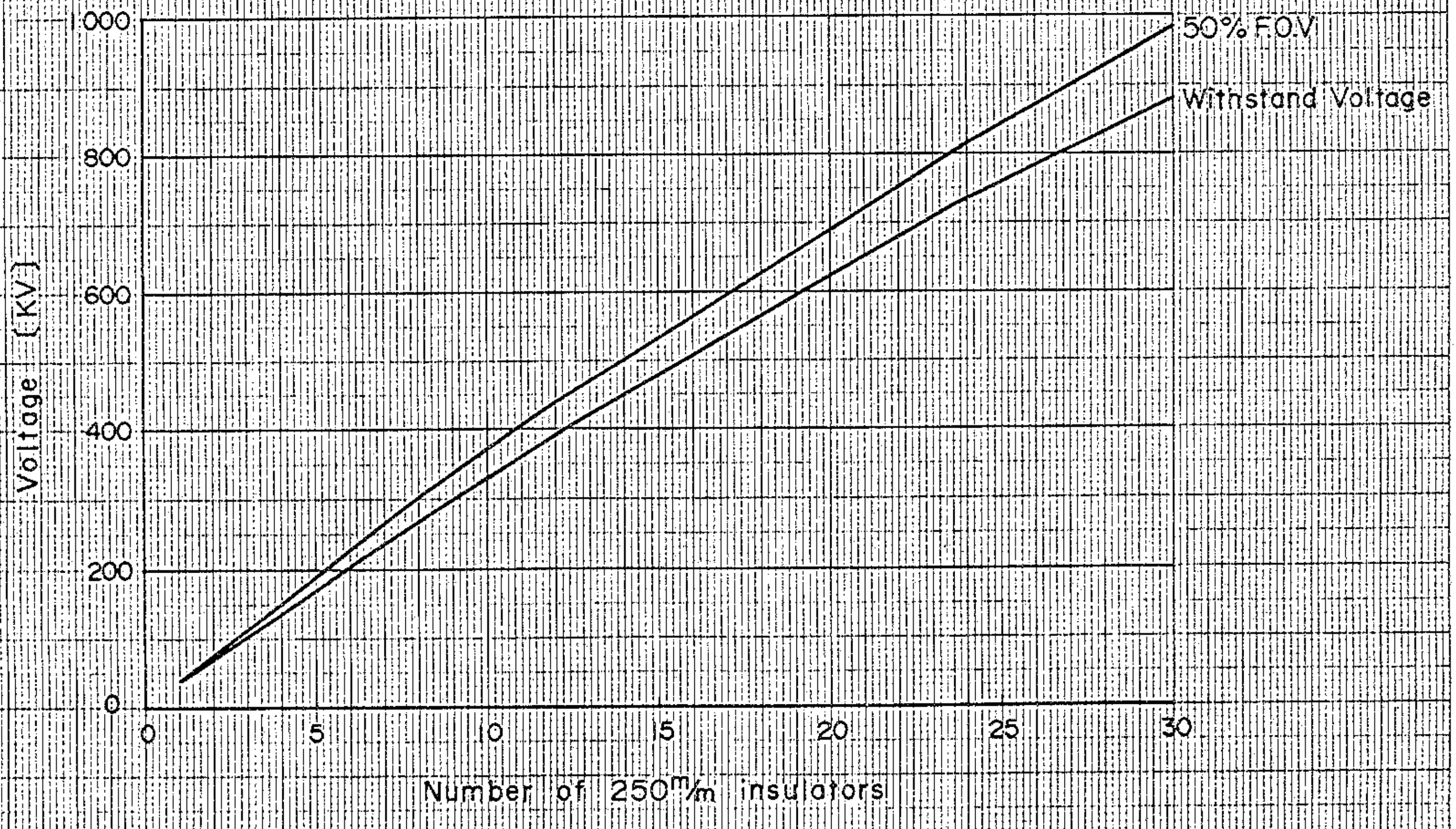


Fig.5-7 Power Frequency 50% F.O.V and Withstand Voltage of 250m/m Insulators (Wet)

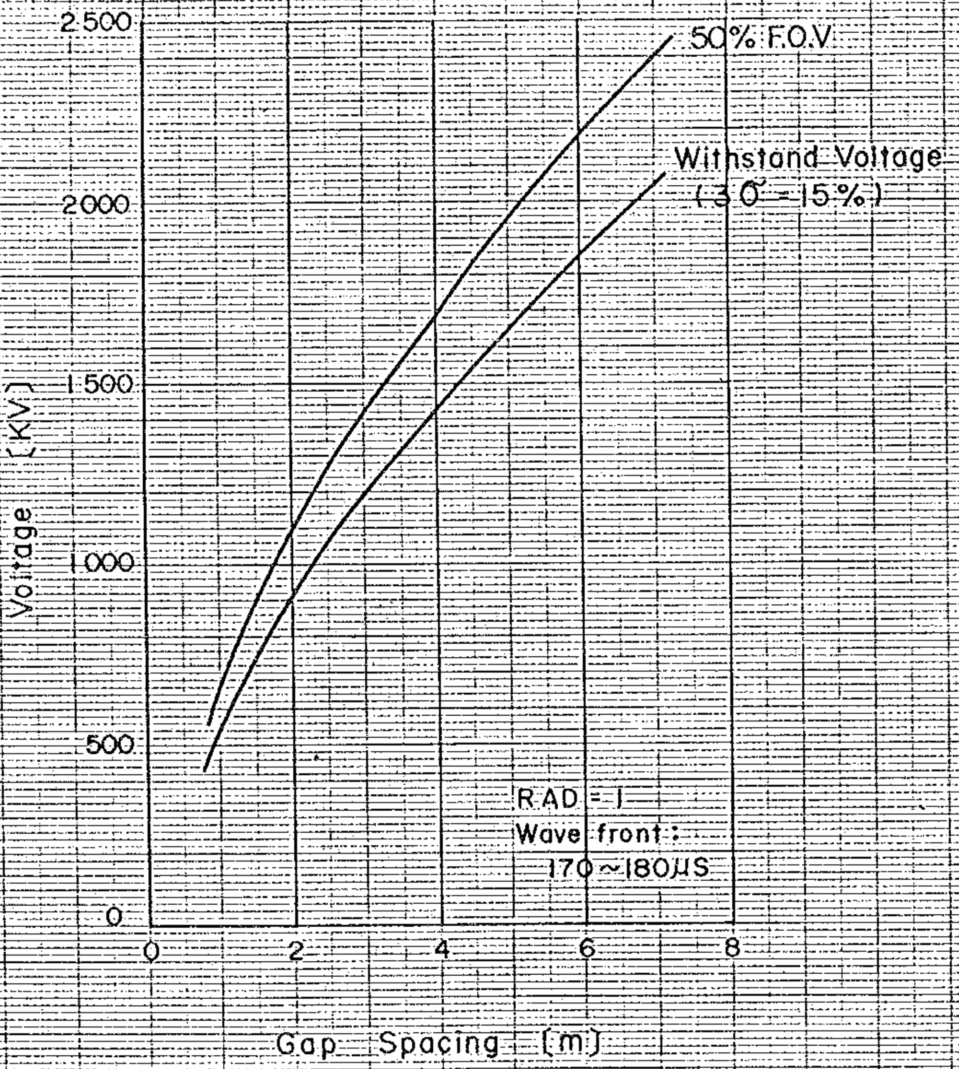


Fig. 5-8 Switching Surge 50% F.O.V and Withstand Voltage of Rod - Rod (Positive polarity, Dry)

JIS A4 180×250㎜ SEKIREI NO. 401 C

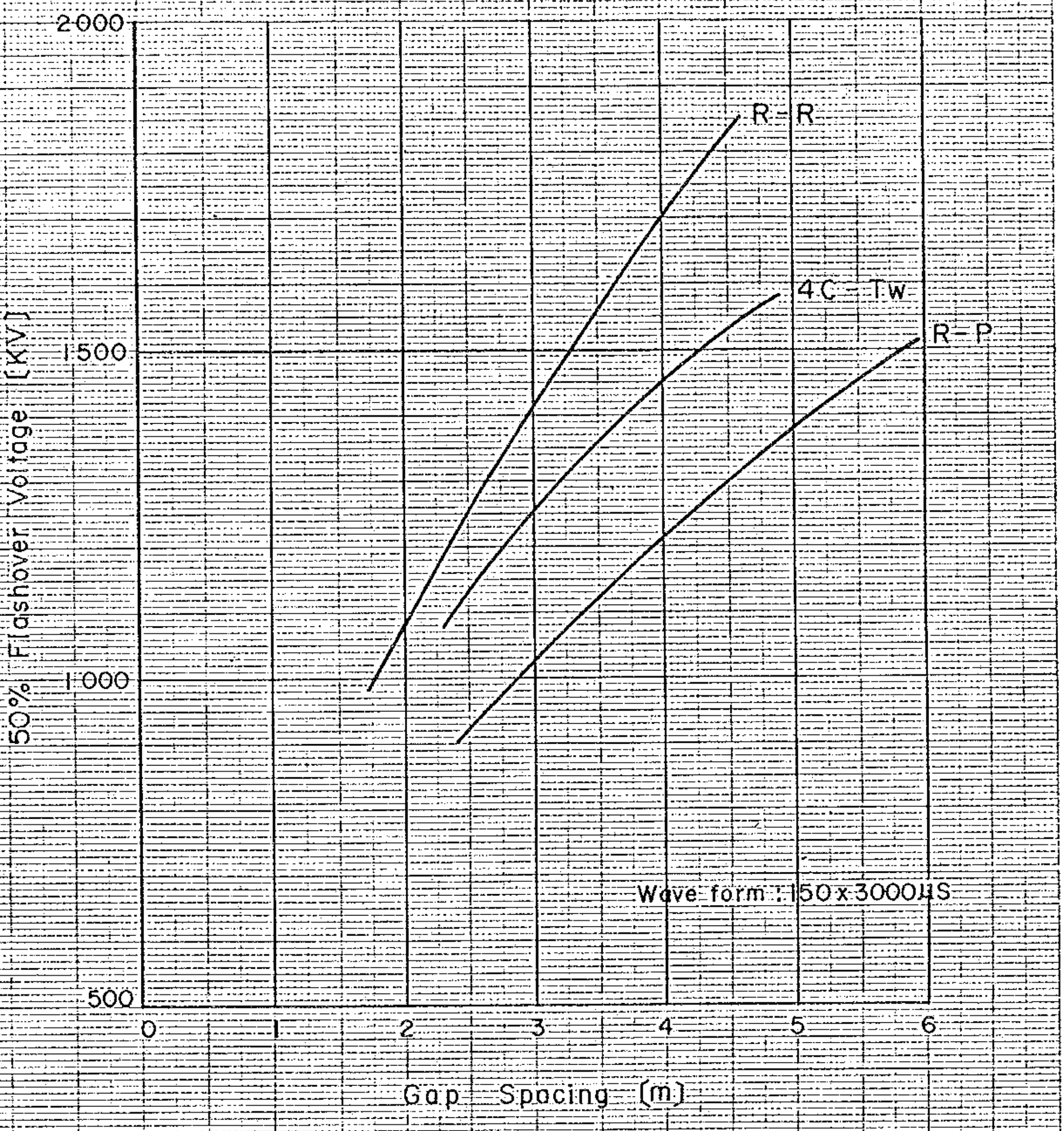


Fig.5-9 Switching Surge 50% F.O.V of Rod-Rod, Rod-Plane and 4 Conductor-Tower (Positive polarity, Dry)

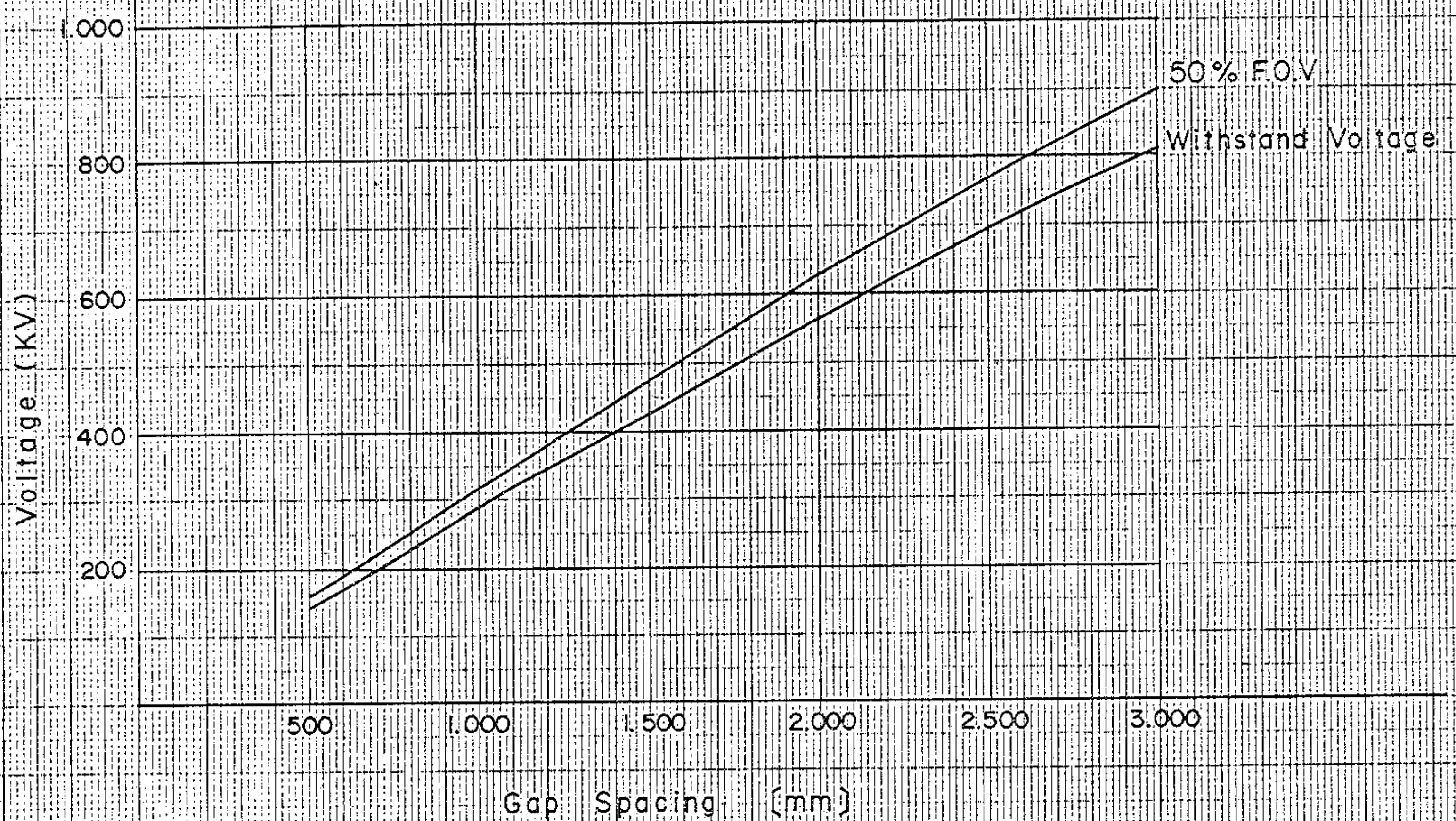


Fig.5-10 Power Frequency 50% F.O.V and Withstand Voltage of Rod-Rod (Wet)

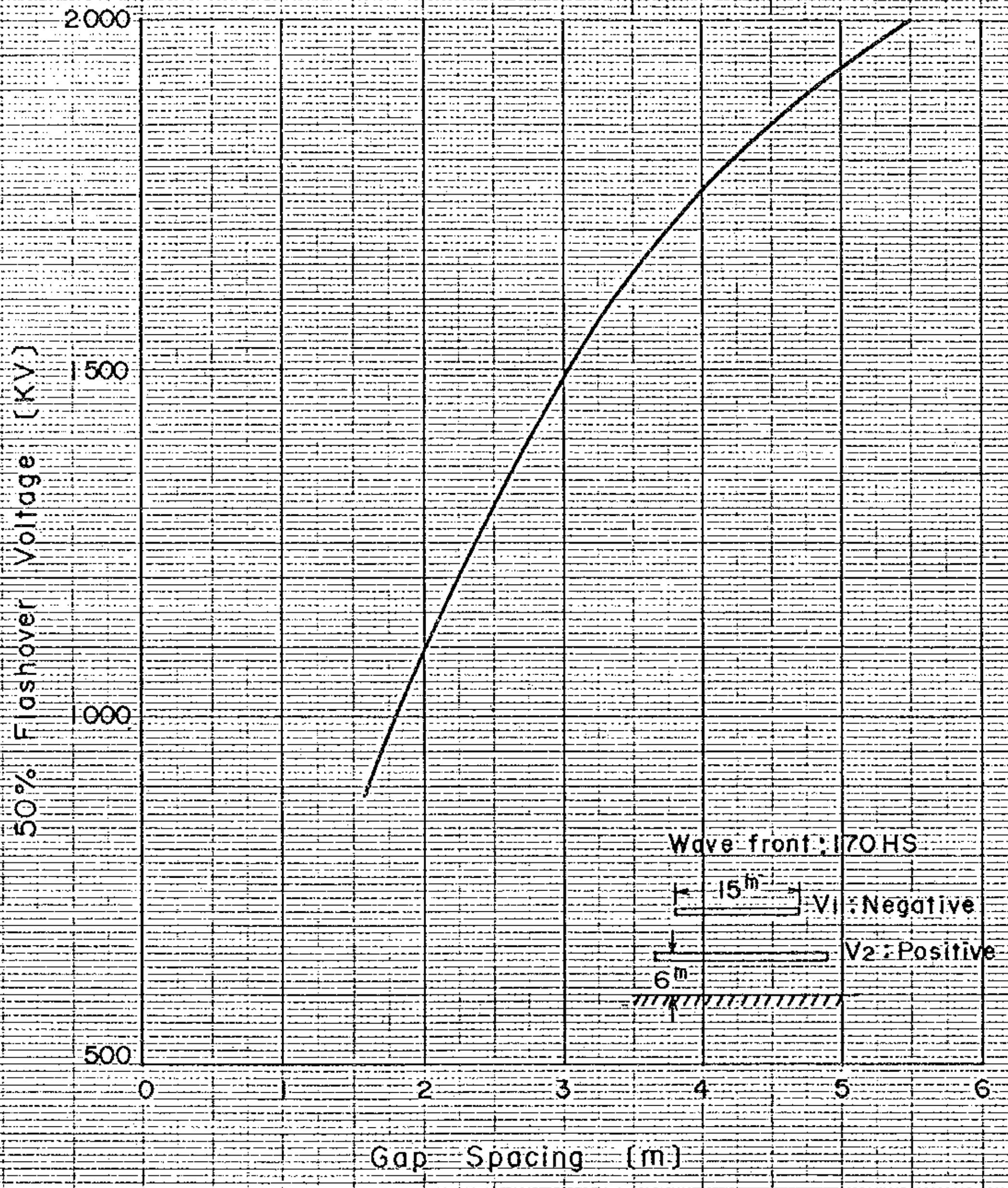


Fig. 5-11 Switching Surge 50% F.O.V of Parallel Conductors

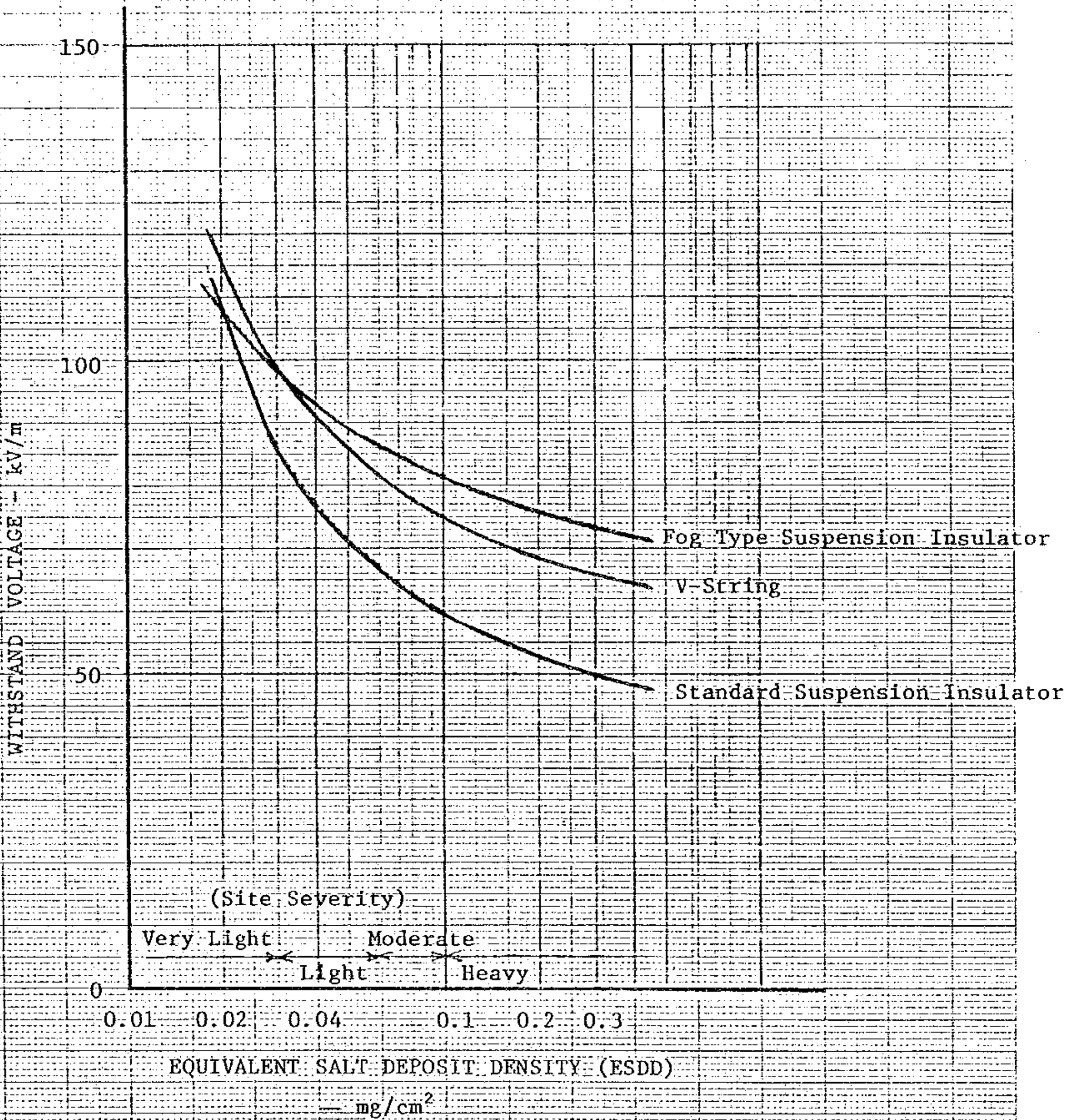


Fig. 5-12 Power Frequency Withstand Voltage of Contaminated Suspension Insulators in Fog.

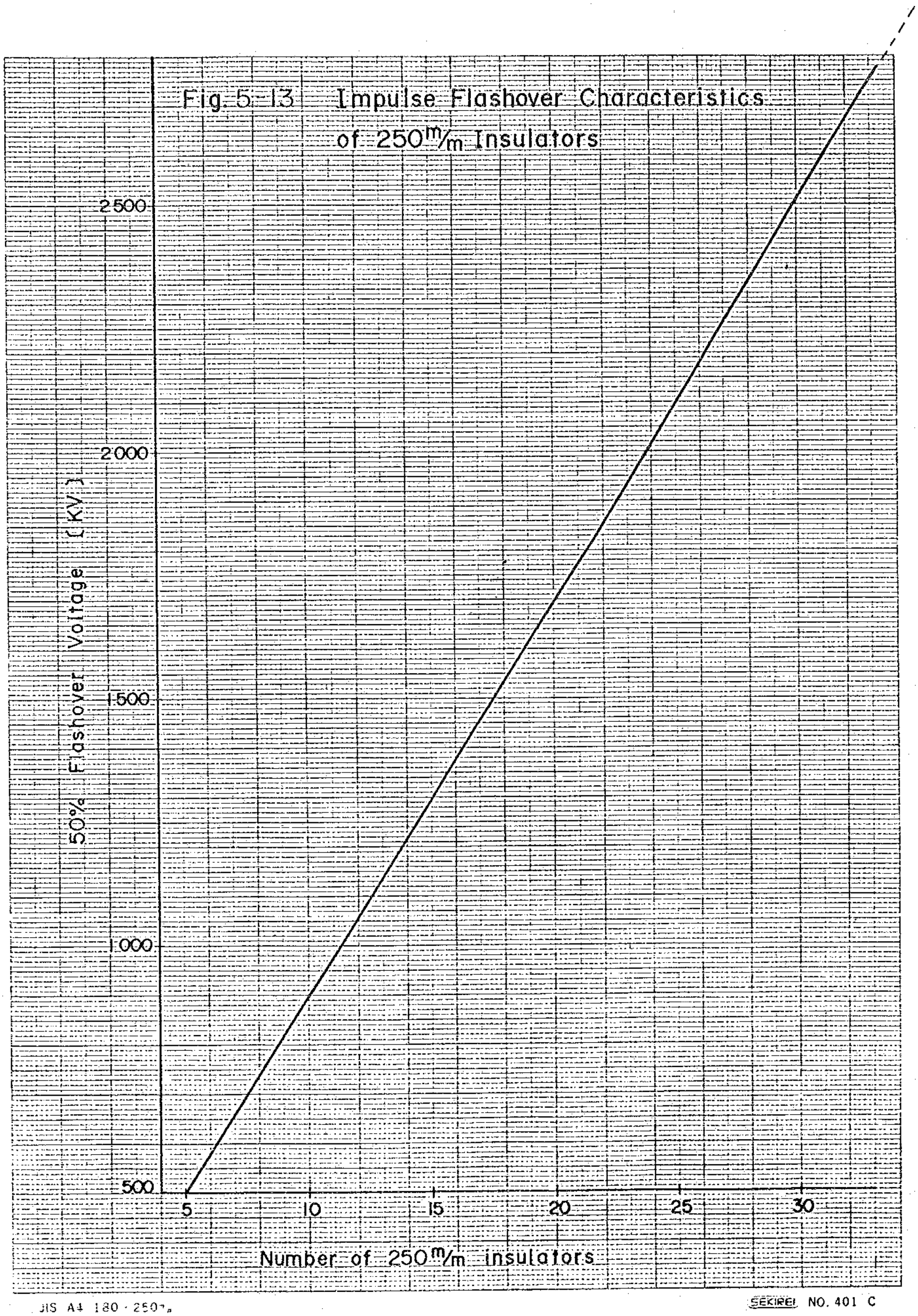


Fig. 5-13 Impulse Flashover Characteristics
of 250m/m Insulators
2500
2000
1500
1000
500
50% Flashover Voltage (KV)
5
10
15
20
25
30
Number of 250m/m insulators

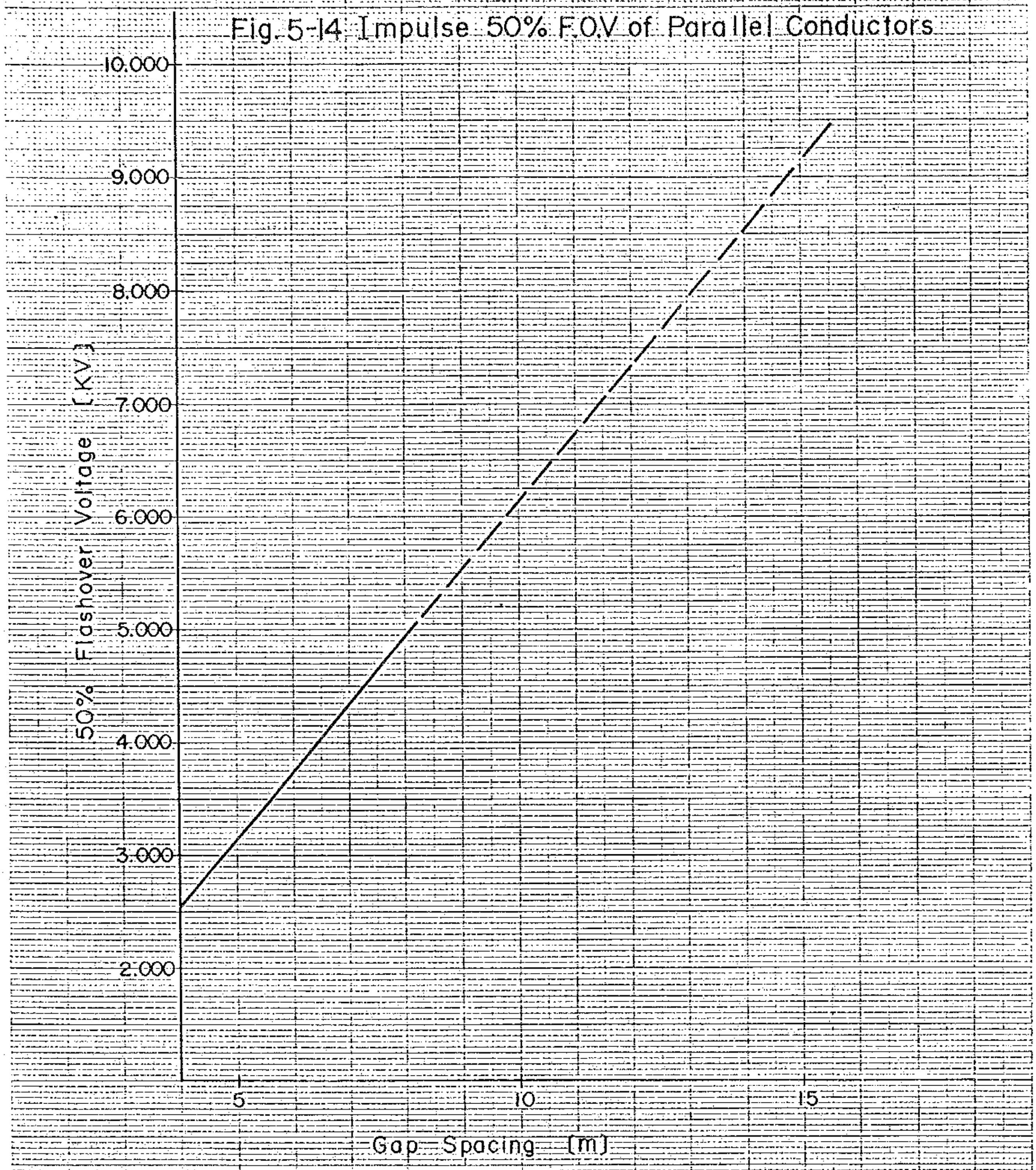
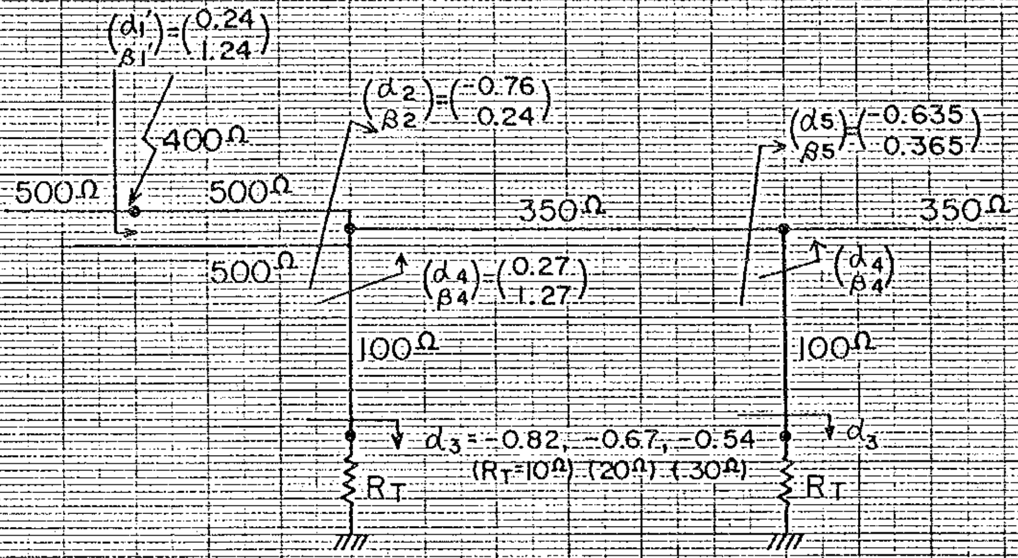


Fig. 5-14 Impulse 50% F.O.V of Parallel Conductors
10.000
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
50% Flashover Voltage [KV]
5
10
15
Gap Spacing [m]

Fig. 5-15 Illustration of Calculation Conditions for Impedance Rise Caused by Lightning



Reflection coefficient $\alpha = (Z_2 - Z_1)/(Z_1 + Z_2)$

Transmission coefficient $\beta = 1 + \alpha$

$\alpha' = \alpha + \beta$, $\beta' = 1 + \alpha$

Calculation conditions

Impedance of lightning pass	400 Ω
Surge impedance of g.w.	500 Ω (1 line), 350 Ω (2 line)
Surge velocity	300 m/μs (g.w.), 210 m/μs (tower)
Damping constant	0.85 (g.w.), 0.9 (tower)
Duration of wave	4 μs
Initial impedance at midspan	$Z_m = 1/(1/400 + 1/500 + 1/500)$
	= 154 Ω

Fig.5-16(1) Illustration of Grid Diagram Calculation for Lightning Surge Caused by Lightning Stroke at Midspan

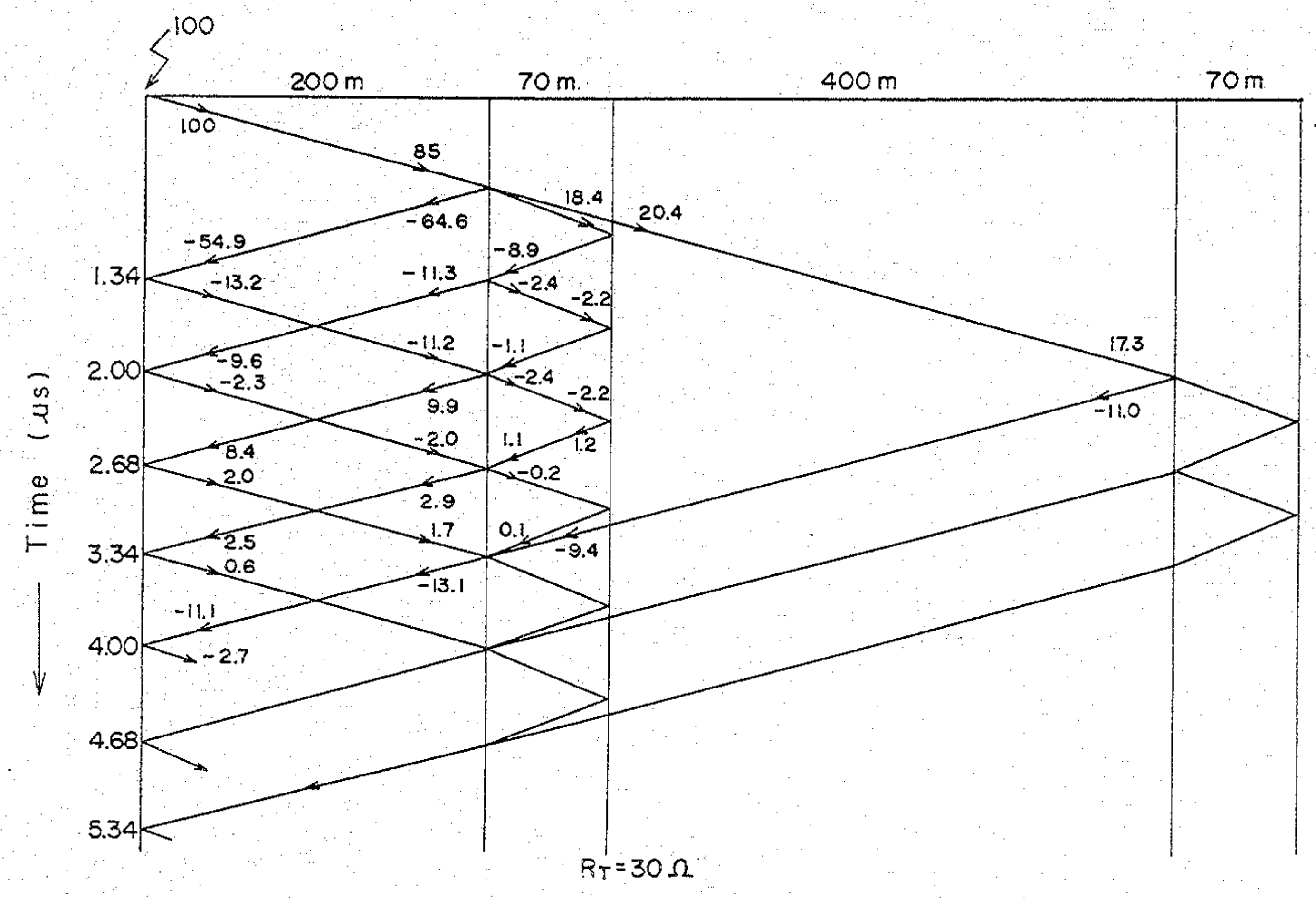


Fig.5-16(2) Illustration of Grid Diagram Calculation for Impedance Rise on Tower Top

Time		Impedance
0 μs	100	154 Ω
1.34	- 68.1	-105
2.00	- 11.9	- 18
2.68	10.1	16
3.34	3.1	5
4.00	- 8.4	- 13

R_T = 30 Ω

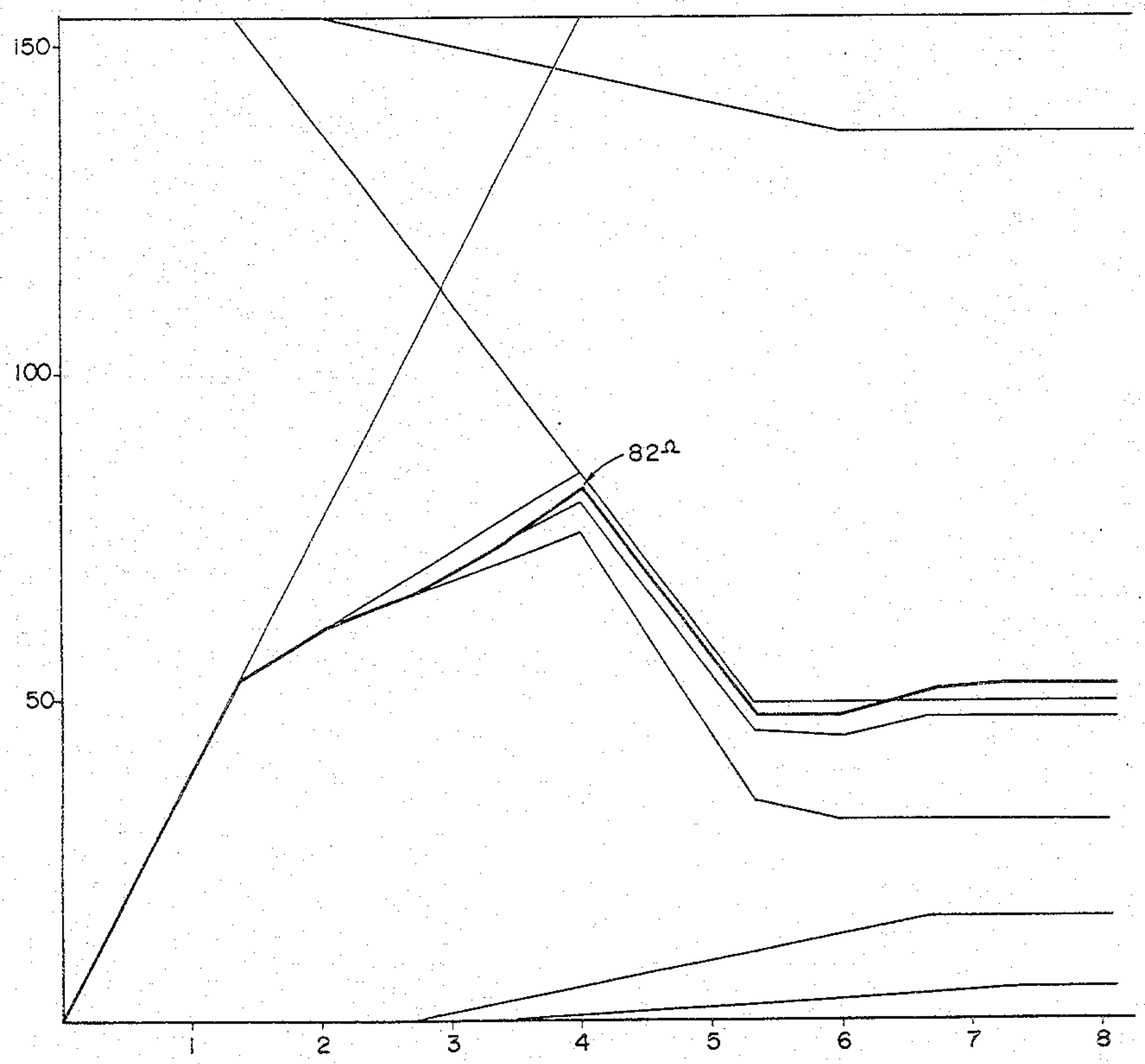
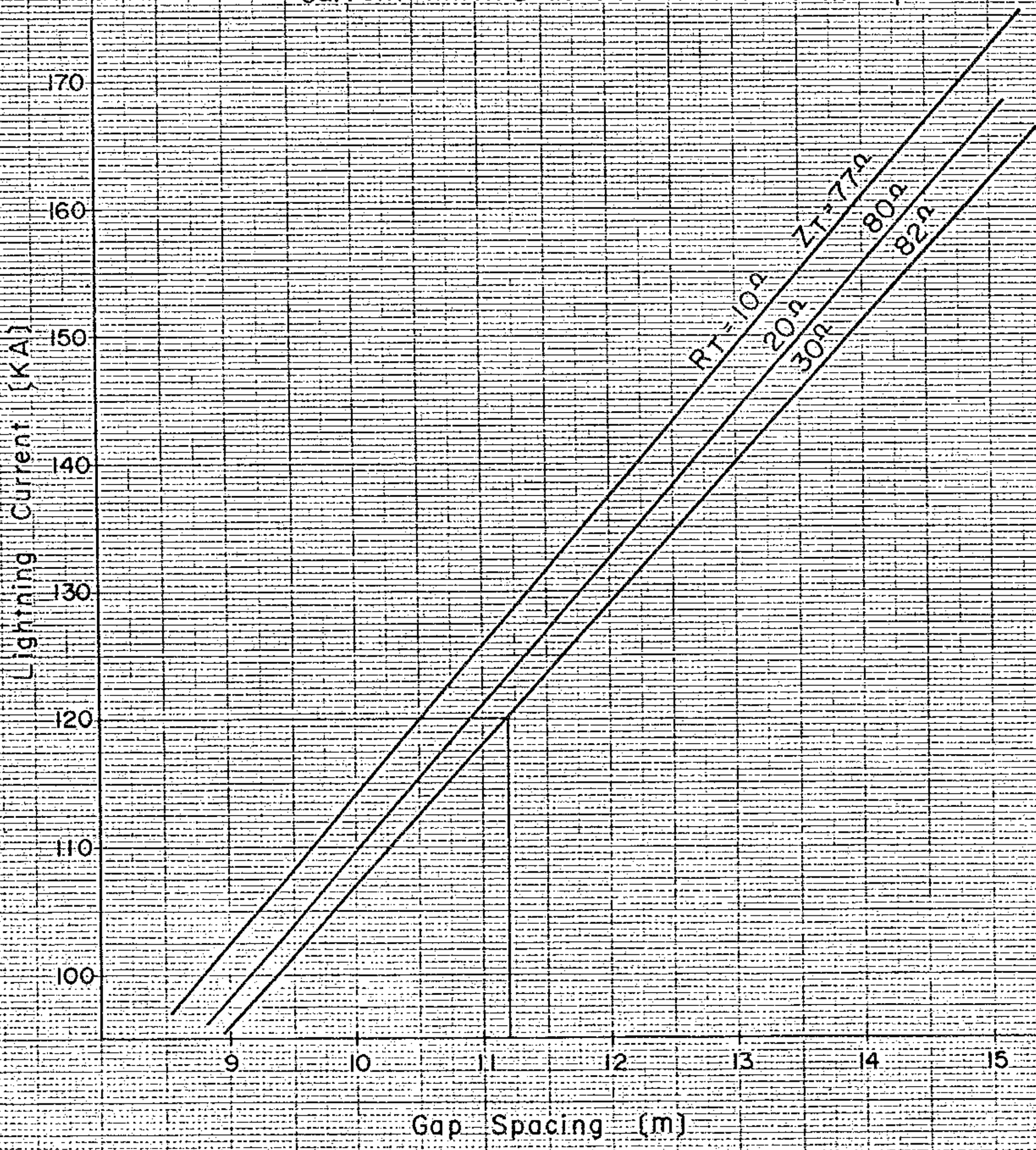


Fig. 5-17 Relations between Gap Spacing and Lightning Current which Causes Flashover at Midspan



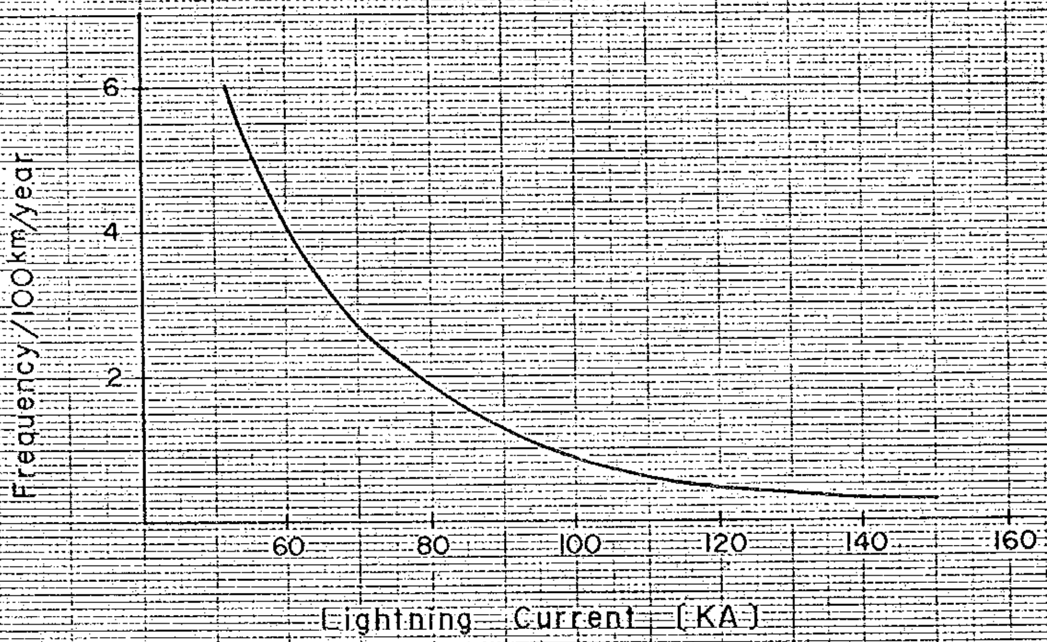


Fig.5-18 Lightning Current Frequency Curve

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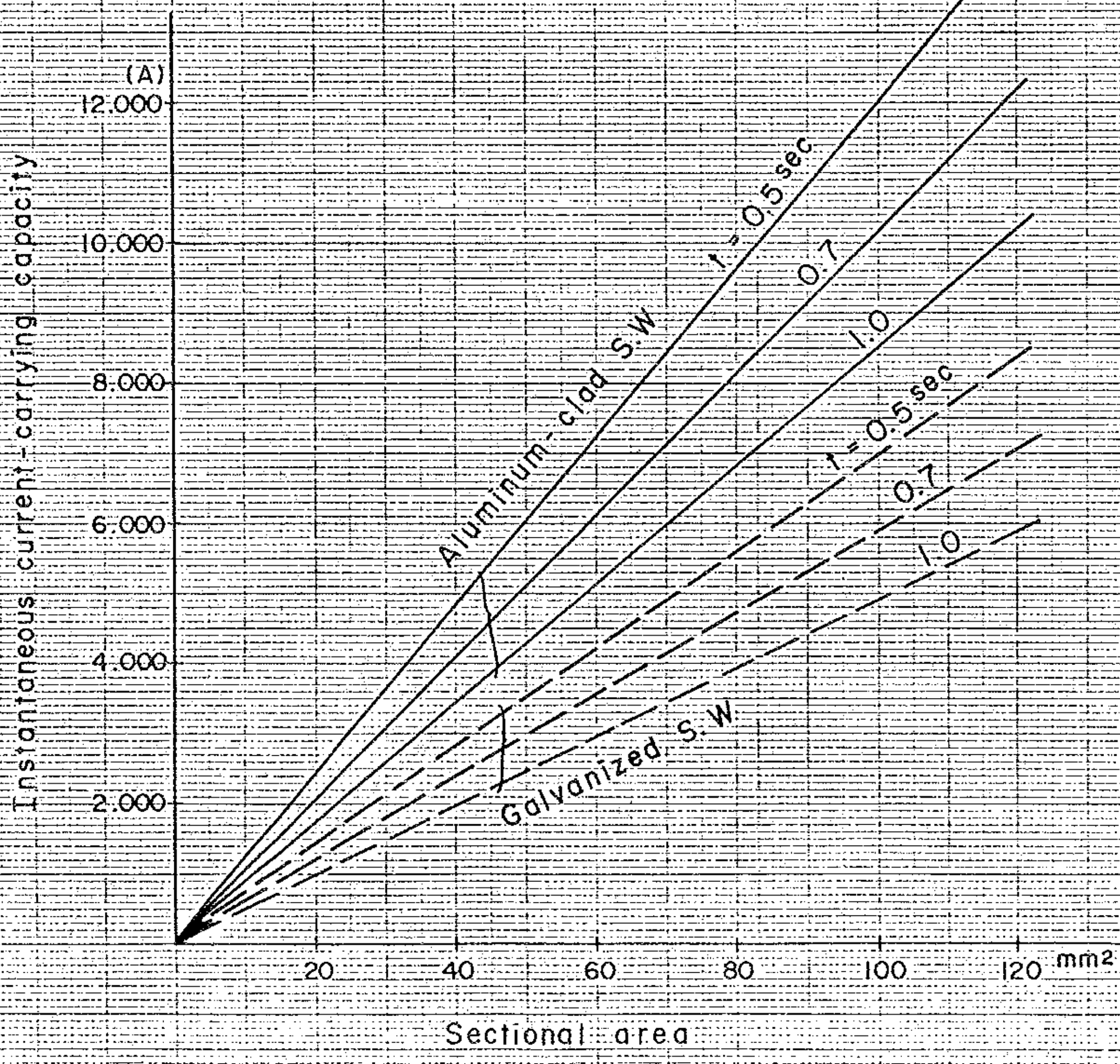


Fig. 5-19 Instantaneous Current-Carrying Capacity of Ground Wire

Fig.5-20 Relations Between Footing Resistance and Impedance Rise

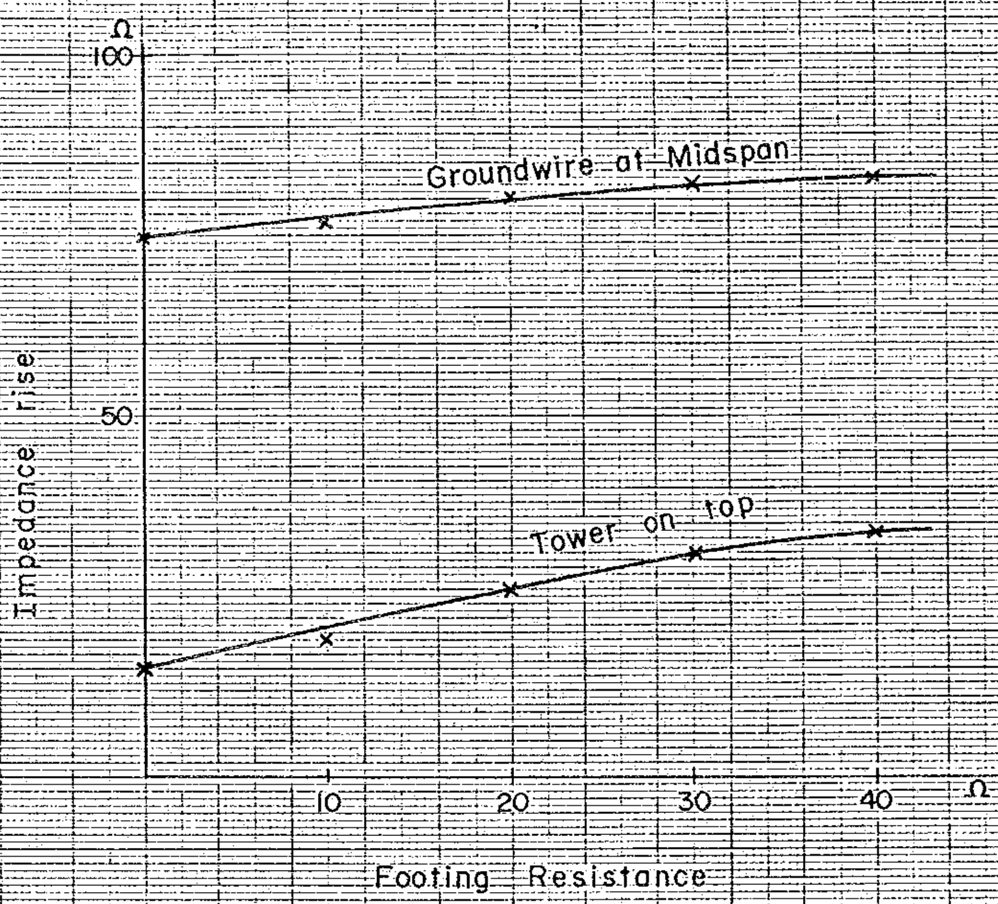


Fig. 5-21 Relation between Outage Rate and Footing Resistance in Luzon

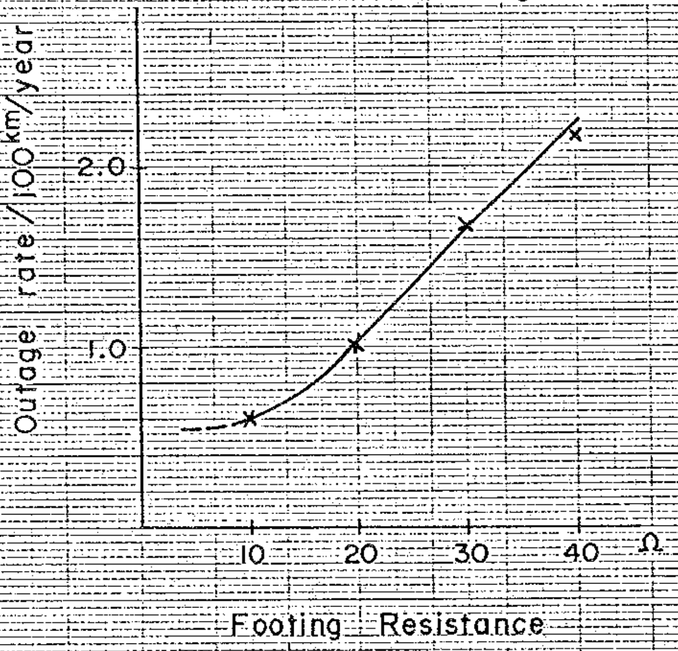
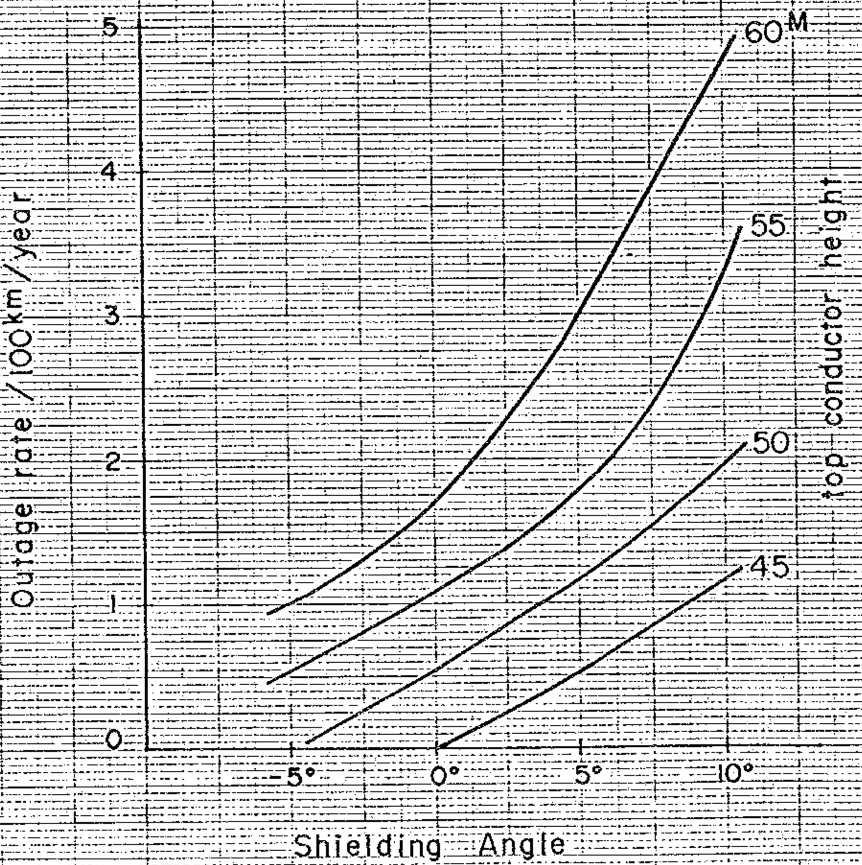


Fig. 5-22 Outage Rate Caused by Shielding Failure



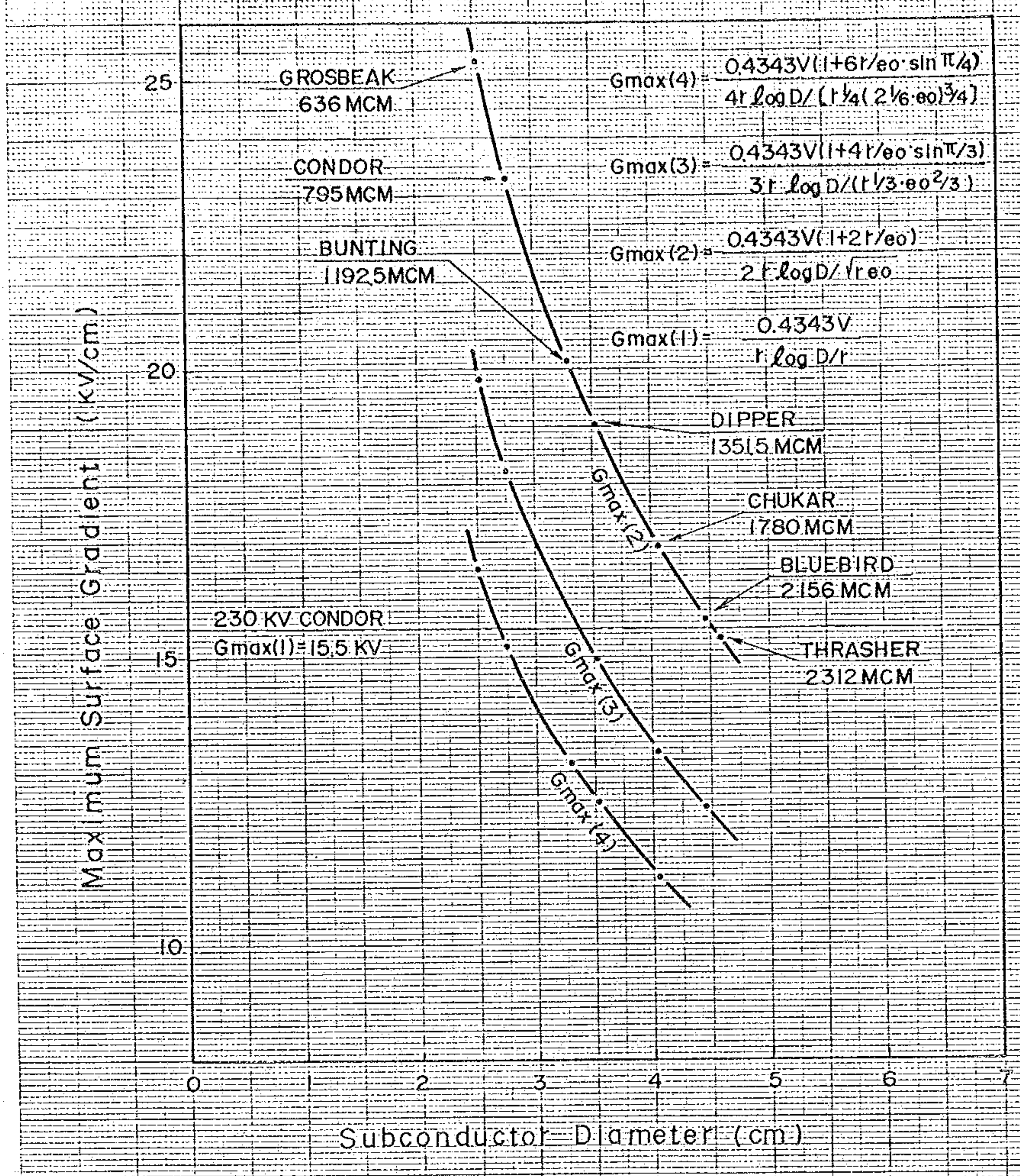


Fig.5-23 Maximum Conductor Surface Gradient versus Subconductor Diameter

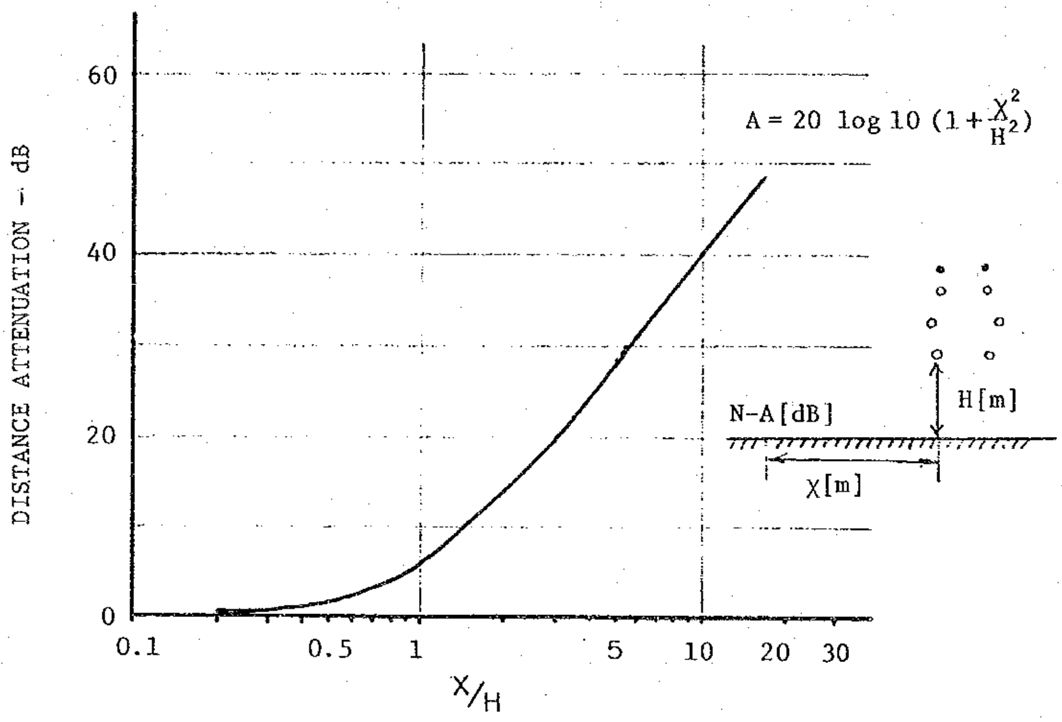
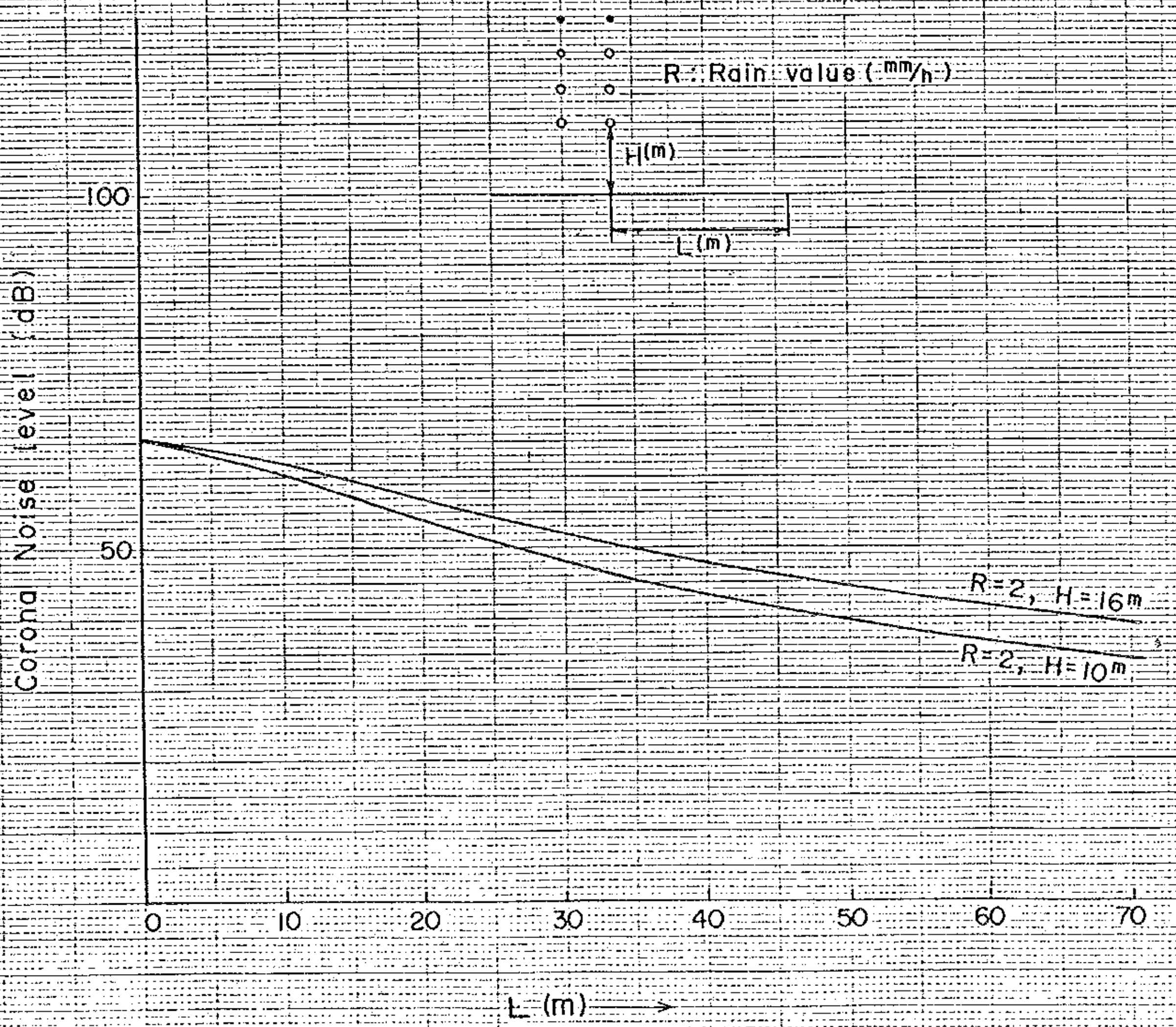


Fig. 5-24 Distance Attenuation of Corona Noise Level

Fig.5-25 Corona Noise Level under EHV Line



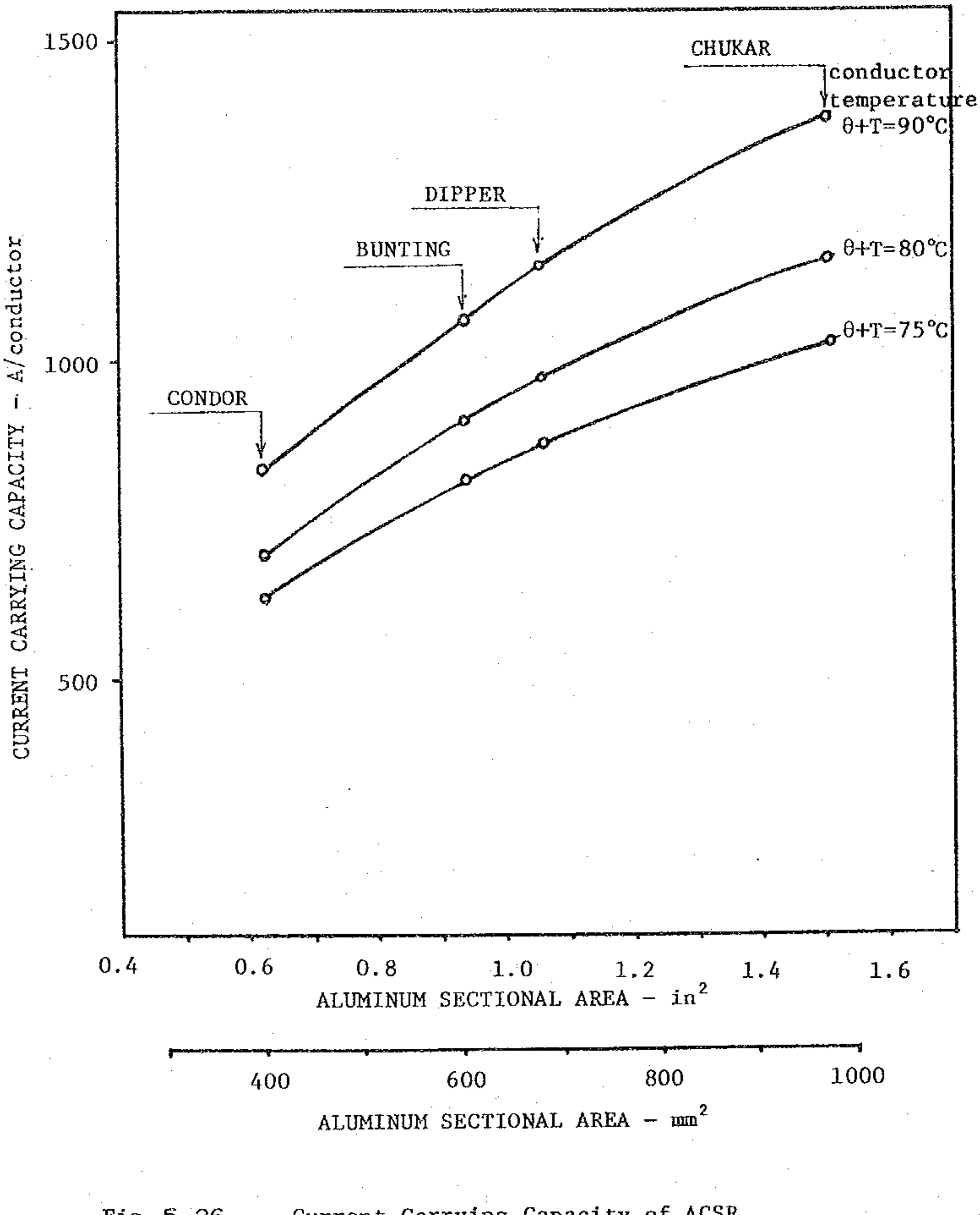


Fig. 5-26 Current Carrying Capacity of ACSR with Various Conductor Temperature

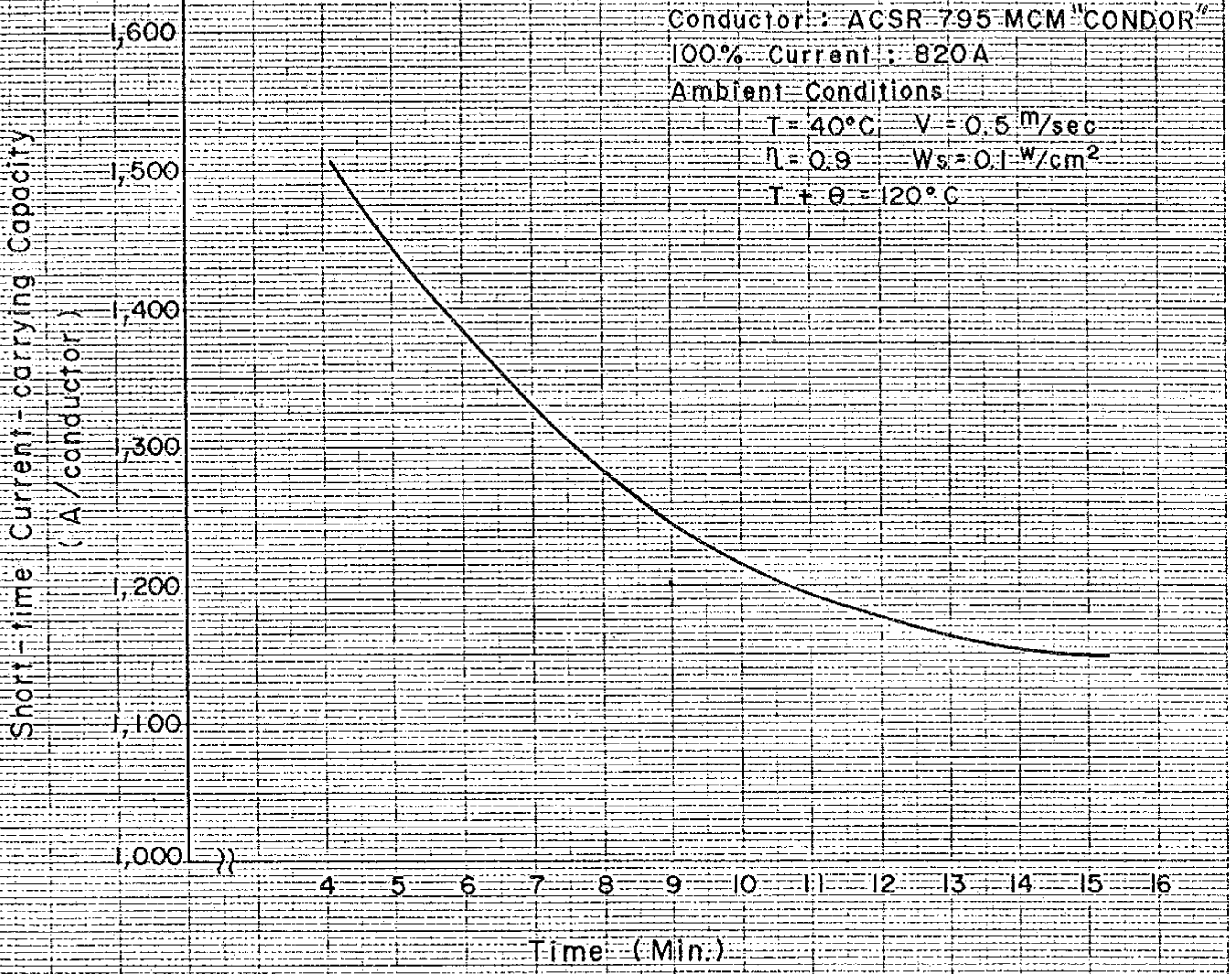


Fig. 5-27 Short-Time Current-Carrying Capacity

(ACSR 795 MCM "CONDOR")

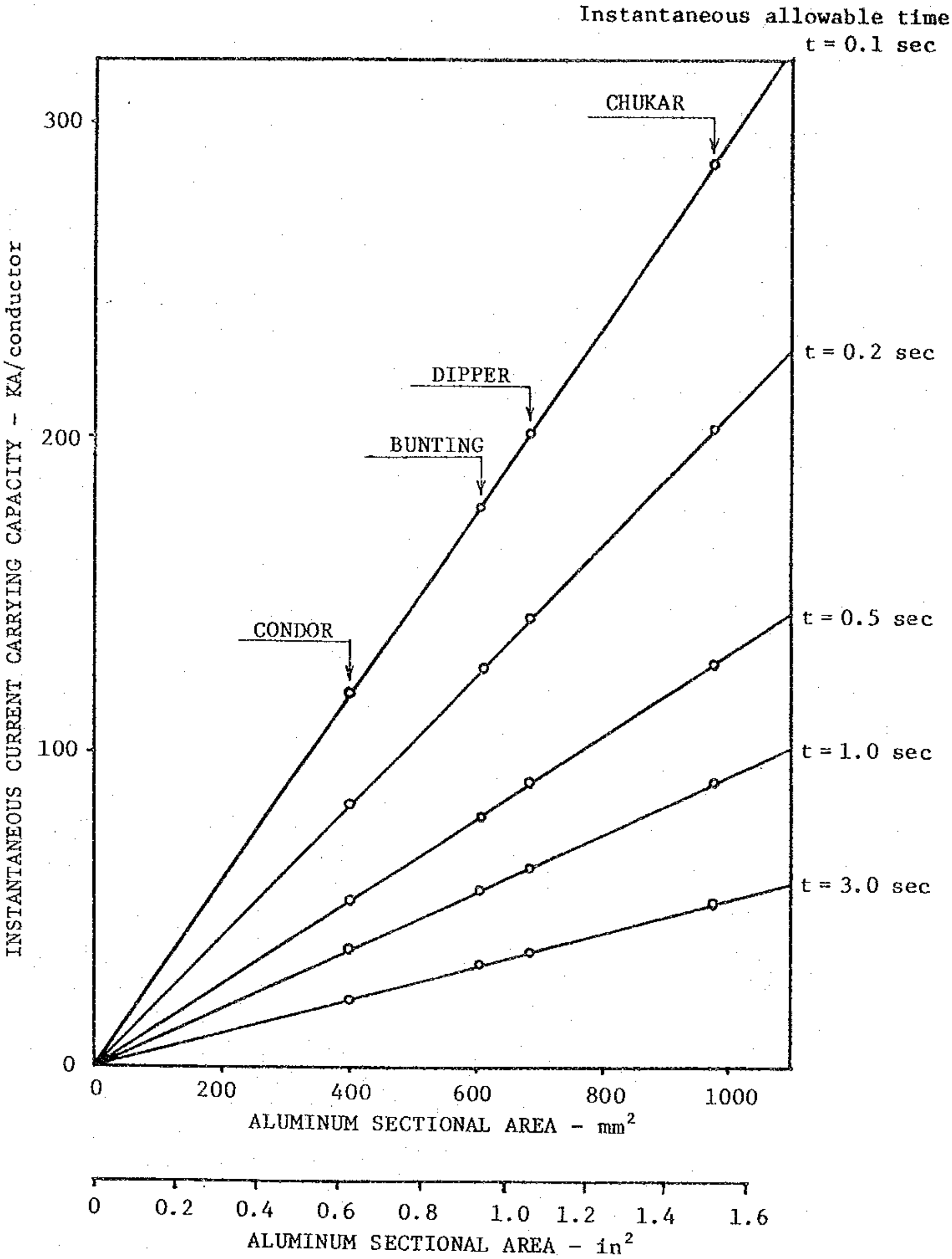


Fig. 5-28 Instantaneous Current Carrying Capacity of ACSR with Various Instantaneous Allowable Time

Fig.5-29 Strength Diagram for Suspension Insulator Strings

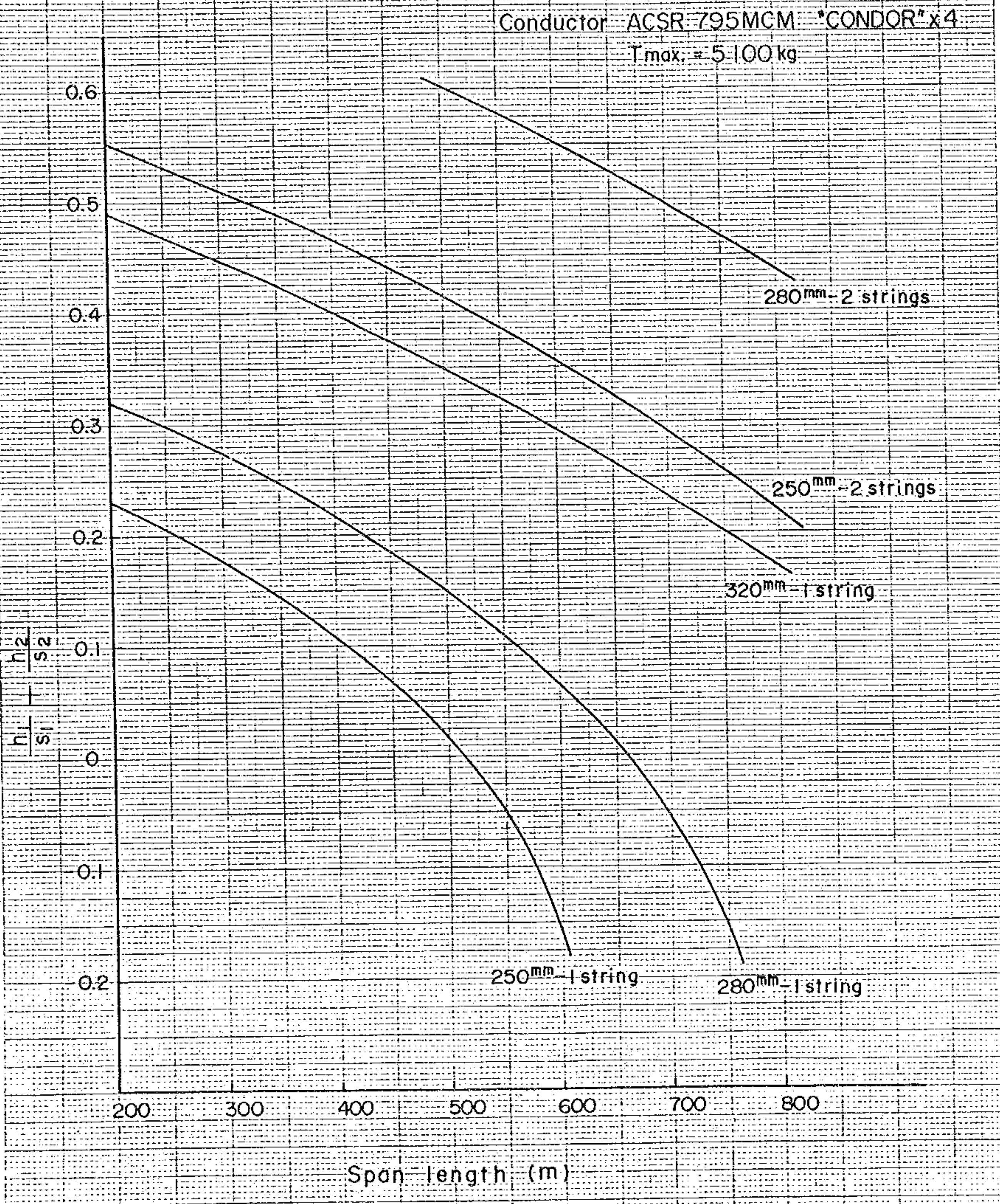


Fig.5-30 Comparison of Suspension Insulator Strings in Price