EHV TRANSMISSION LINES CONSTRUCTION MANUAL

—A practical approach to construction practices and upgradation of technology.

Bangalore

May 1987

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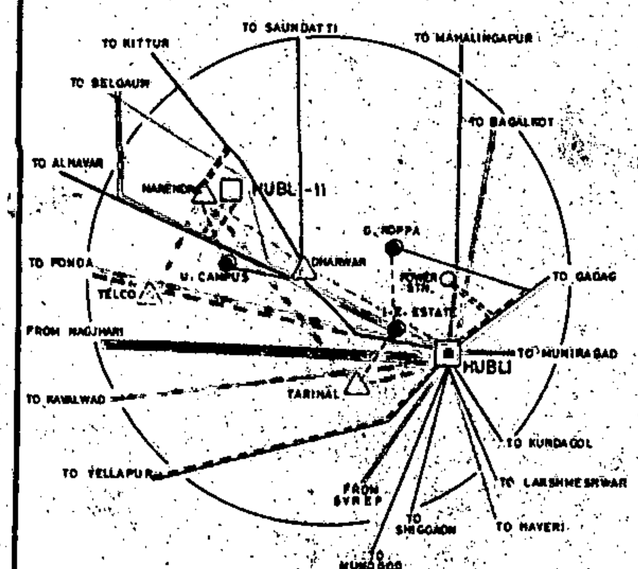
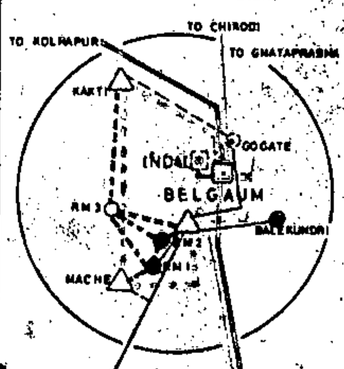
GRID MAP OF KARNATAKA

(AS ON 1st APR 1987)

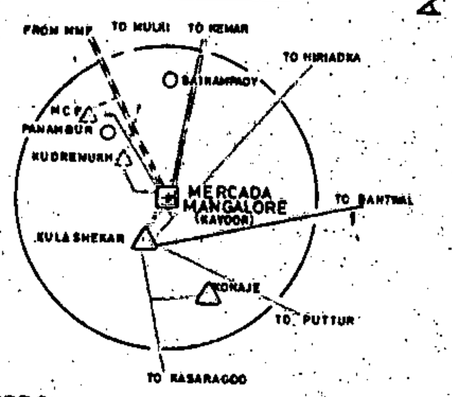
HUBLI DETAILS



BELGAUM DETAILS



MANGALORE DETAILS



NOTES:-

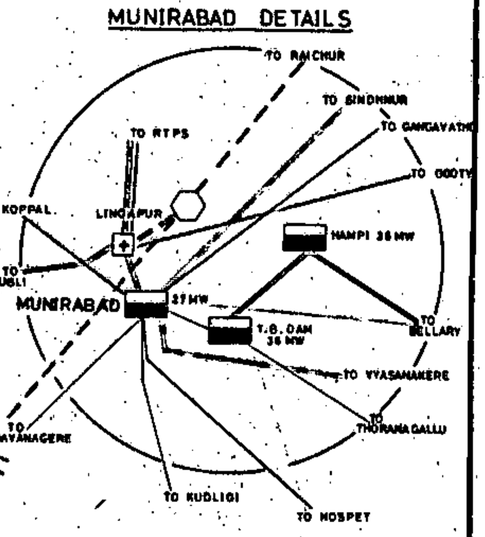
- ⊞ △ 220/110KV PROPOSED SWITCHING STATIONS
- ⊡ △ ▭ ◎ CONSUMER STATIONS

THE LINE BETWEEN MYSORE FTS AND SIVA WILL BE USED TO TRANSMIT POWER EITHER AT 78KV 25HZ OR 66KV 50 HZ.

LEGEND

SL NO.	PARTICULARS	EXISTING	PROPOSED
1	GENERATING STATION HYDEL		
2	GENERATING STATION THERMAL / GAS TURBINE / DIESEL		
3	GENERATING STATION NUCLEAR STATION		
4	400KV SUB STATION		
5	220KV SUB STATION		
6	110KV SUB STATION		
7	78KV SUB STATION		
8	66KV SUB STATION		
9	33KV SUB STATION		
10	400 KV TRANSMISSION LINES SC		
11	400KV TRANSMISSION LINE DC		
12	220KV TRANSMISSION LINE SC		
13	220KV TRANMISSION LINE DC		
14	220KV SC LINE STRUNG ON DC TOWERS		
15	110KV TRANSMISSION LINE SC		
16	110KV TRANSMISSION LINE DC		
17	110KV SC LINE STRUNG ON DC TOWERS		
18	78KV TRANSMISSION LINE SC		
19	66KV TRANSMISSION LINE SC		
20	66KV TRANSMISSION LINE DC		
21	33KV TRANSMISSION LINE SC		
22	33KV TRANSMISSION LINE DC		

MUNIRABAD DETAILS

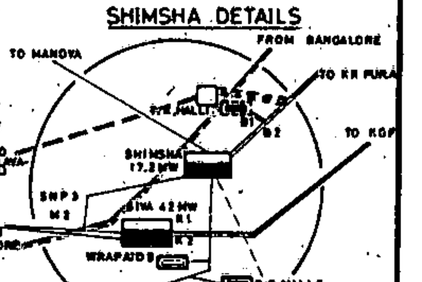


RINGMAINS AROUND BANGALORE

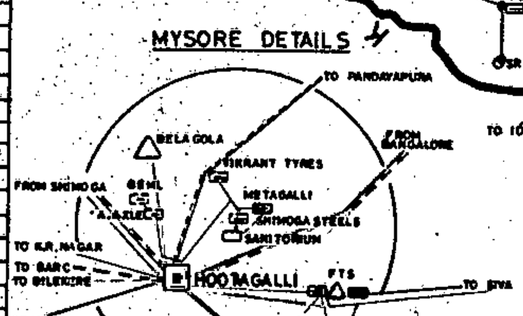
CONSUMER STATIONS

1. BANGALORE WIRE ROD MILLS	3. BHORUKA STEELS	19. CPRI.
3. KAP STEELS	4. ANDHRA STEELS	
5. GRAPHITE INDIA LTD	6. GRINDWEL ABRASIVES	
7. ESCORTS AND GOETZ	8. NMT	
9. BEL	10. ALEMBIC	
11. WHEEL AND AXLE	12. A D E	
13. HAL	14. BRINDAVAN ALLOYS	

SHIMSHA DETAILS



MYSORE DETAILS



CHIEF ENGINEER ELECTRICITY (GENERAL)
KARNATAKA ELECTRICITY BOARD.

DRAWN: B.G. SRIDHARA MURTHY

FOREWORD

The Board took a decision to initiate a training programme for the Engineers in the Major Works Circles, Divisions and Sub-divisions, who are actually engaged in the activity of the transmission line construction works. This, was following the occurrences of failures of transmission towers on important lines and analysis on the causes showing that the failures had been due to built-in weaknesses in foundations and such the like.

To assist the training programme and to serve the practising Engineers with a reference book, this Manual is being brought out, covering all aspects of transmission line construction, in a functional manner with due weightage for the practical aspects as against the purely theoretical.

The manual compiled with data drawn from several sources, is brought up-todate with the latest thinking, in Transmission line construction practices, Design criteria and reflecting the needs of the present time. A word of commendation is due to the painstaking effort put in by the technical staff particularly Sri Y. R. Nagaraja, Asst. Executive Engineer and his team comprising of Sri S. Muralidhar and Sri H. D. Srinagesh in collecting and compiling the data.

Transmission line construction covers the building of a system comprising of a large number of complex components like towers of various kinds (particular designs for particular locations), foundations, line hardware and actual construction modes like sags etc. There are no instruction manuals or manufacturer's technical literature like in the case of Circuit breakers or Power transformers which would adequately cover transmission lines, even though they play a very vital role, particularly so in the present-day context in the successful operation of a power system-considering the large blocks of power transfer and the fact that there is practically no redundancy in the transmission circuits.

The manual may need to be updated in the light of experience etc. and suggestions for additions to cover any inadvertant gaps are welcome.

Date : 23-4-1987

BANGALORE

R. SRIRAM
Chief Engineer, Electricity
(GENERAL)
Karnataka Electricity Board

CHAPTER 1

INTRODUCTION

1.00 SCOPE

The necessity of a comprehensive Manual is felt by all the practicing Engineers in the field of transmission line construction and this manual is prepared to cover all the relevent aspects pertaining to survey, tower spotting, foundations, erection of towers and stringing of ground wire and Power conductors, testing and commissioning of lines of all extra high voltage lines above 33 KV class, upto and including 400 KV class. However the scope is limited only to lattice type steel towers and do not cover all the lines with supports of any other form such as RCC, PCC structures etc,

The purpose of this manual is to present in one document sufficient details of various methods used to-day, materials and equipment to outline the basic conditions necessary to maintain safe and adequate control of towers, conductors etc. during erection and stringing operations.

CHAPTER 2

2.00 SURVEY

2.01 The survey of EHV lines has to be made as accurately as possible. A mistake in the field work or subsequent office work may pass on undetected to an advance stage in construction resulting in unnecessary delay in execution, increased expenditure and considerable inconvenience. It is very necessary that Engineers incharge of survey take all precautions in selecting the right corridor, taking out levels and plotting the route profiles, spotting the tower positions using appropriate Sag Templates etc. correctly as detailed in this chapter.

2.02 PRELIMINARY WALKOVER SURVEY :

The Govt of India Survey department has conducted detailed surveys of the entire country and has prepared Topo Sheets. These are very useful in deciding the route between two stations between which EHV lines are to be laid. These topo-sheets are confidential in nature and should not be copied by any means without the permission of the Survey of India Department. These Topo Sheets are to be kept under strict personal control and a certificate is to be furnished to the Government every year to that effect. These topo sheets are plotted in a scale of one inch to a mile.

After having marked the various feasible routes of the line on the Topo Sheets, a preliminary walkover survey should be carried out. It is essential that the "Right-of-way" is established before taking up detailed survey. The physical features not available on the Topo sheets shall be considered since the provisional route may be affected by the recent trend in fast development of buildings etc. Appropriate places for power line crossings, Railway and Road Crossings shall be located during the walkover survey. The following aspects require consideration.

(1) The line corridor selected is short and straight as far as practicable.

(2) From the point of view of ease in construction, the line should be close to a roadway.

(3) The number of angle towers should be minimum, and within these, the number of 60° towers shall be as small as possible.

(4) Good farming areas, uneven terrain, religious places, civil and defence installations aerodromes, ponds, tanks, lakes, gardens, likely water spread areas of proposed dams and tanks, should be avoided as far as is practicable.

(5) Cost of securing and clearing Right of Way, making access roads, and time required for, these works is minimum.

(6) The line should be as far away as possible from Telecommunication Lines and should not run parallel and close to these.

(7) Crossings with roads and railway lines should be minimum and preferably at right angles.

(8) Difficult and unsafe approaches should be avoided.

(9) The line should be away from buildings containing explosives, bulk storage oil tanks, oil and gas pipe lines.

(10) The line route should be suitable for catering to future load developments without major modifications.

On completion of the walkover survey, a route alignment should be prepared to a scale of 1:50,000. Route near towers will be shown in greater details to a scale of 1:10,000. Also a key. map be prepared showing the main sections to a scale of 1:200,000 in addition to the above. All the maps shall be made on sheets 297 x 1189 mm with 3 cm overlap shown on following sheet

2,03 DETAILED SURVEY

The detailed survey can be carried out by use of a Theodolite, Dumpy Level, Levelling Staff and Chain.

The procedure in setting out the line of route depends on whether the ground is flat, hilly. or has obstacles. The procedures can be generalised under the following heads.

(a) Where one angle position can be seen from the next.

(b) Where one angle position cannot be seen from the next but where both can be seen trom the intervening position, either way.

(c) Where one angle position cannot be seen from the next nor even from an intervening position.

(d) Where obstacles to sight intervene.

The procedure to be adopted for the above situtaions are as follows :-

(a) The laying of the route is simple where one angle position can be seen from the next. The theodolite is set over the peg at one position and directed to the flag at the next. Intervening hedges, if any, can be lopped to enable a clear view.

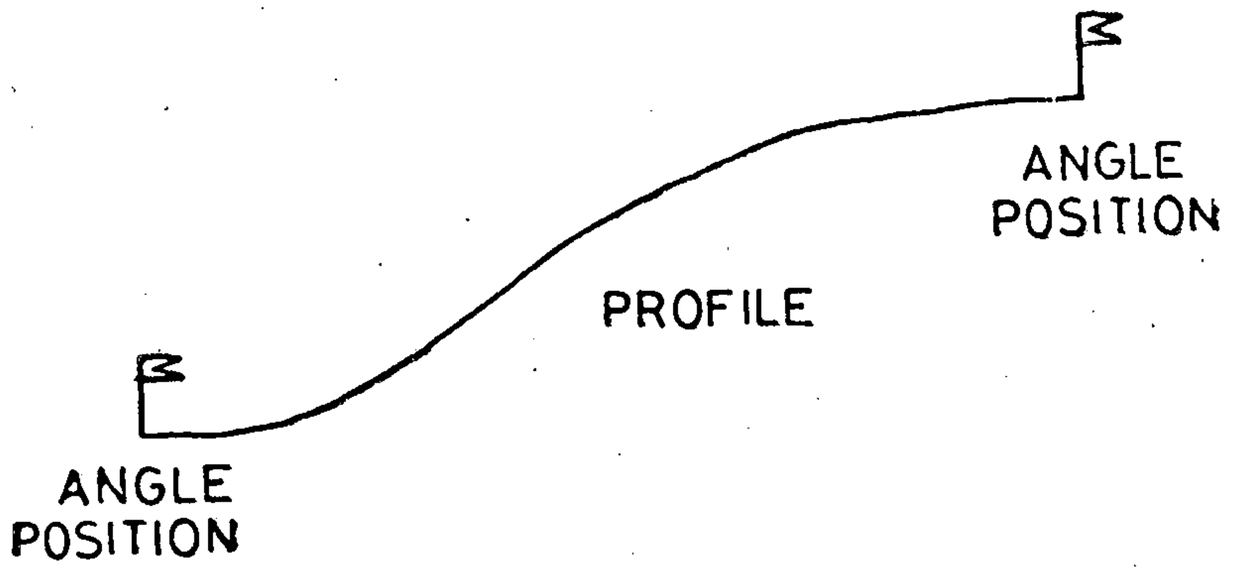


FIG-1 : WHERE ONE POSITION CAN BE SEEN FROM THE NEXT.

(b) The laying out of the line route is slightly more difficult in this case where one angle point cannot be seen from the next.

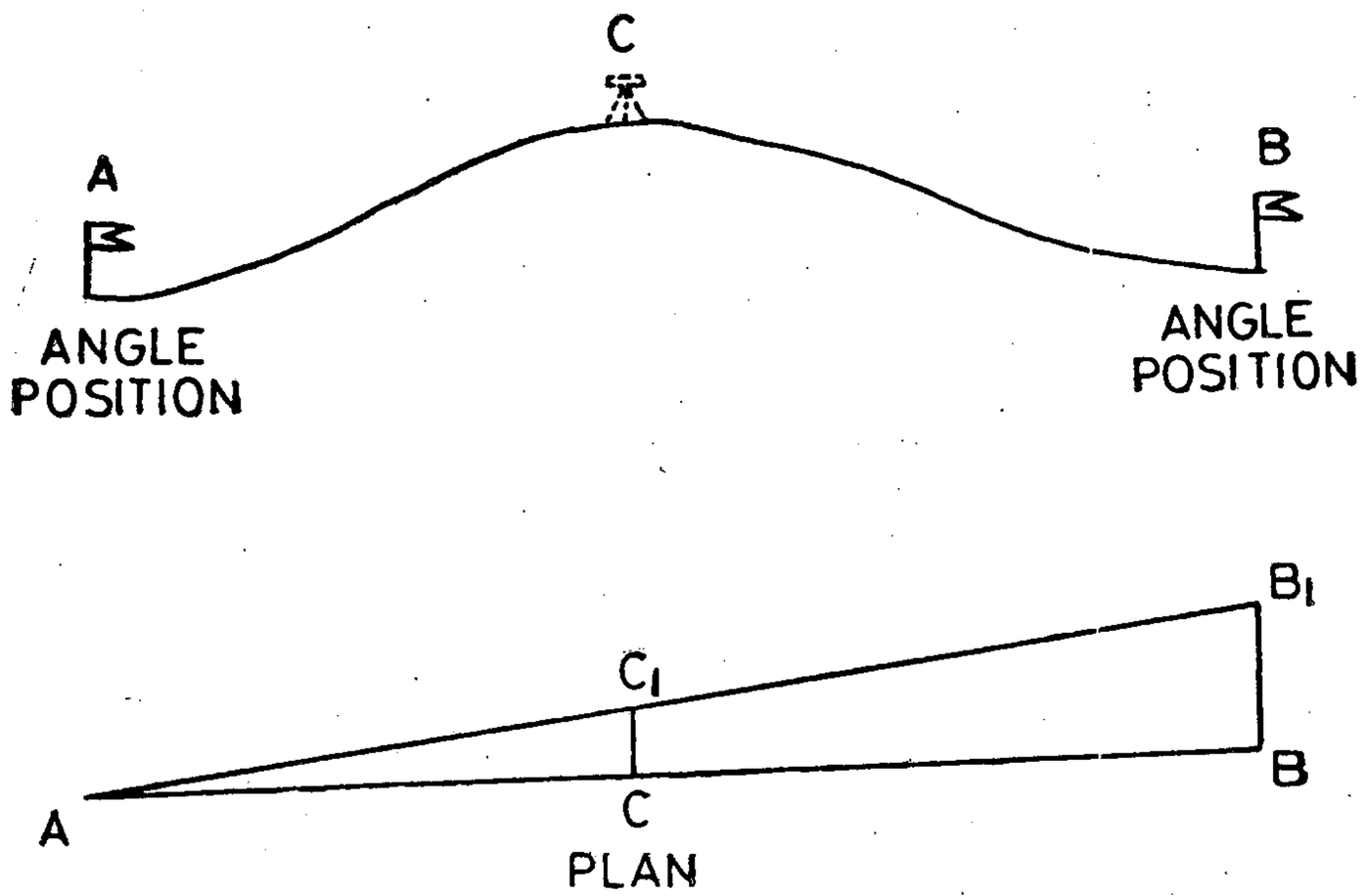


FIG-2: WHERE ONE ANGLE POSITION CANNOT BE SEEN FROM THE NEXT & THERE IS HIGH INTERVENING GROUND.

Flags are erected at angle positions A and B as in Fig. 2.

From the topo-sheet, scale off AC and CB where C is the point from which both A and B can be sighted. Hedges are lopped until the angle flags are visible. Set up the Theodolite at C1 and direct telescope to Flag A. Transit the instrument and line in the position of Transit near B. Turn the instrument horizontally through 180° and again direct the telescope to Flag A. Transit the instrument and again line in position of Transit near B. The mean of these positions is taken as the instrument transit B1. The distances of B1 from the Peg at B is measured perpendicular to the line. The distance that position C1 requires to be moved horizontally, so that the positions A, B and C are in a straight line when transitting can be calculated as follows :-

$$C_1C = \frac{AC}{AB} \times B_1B$$

Suppose $B_1B = 5$ mtr.

$AB = 3000$ mtr.

$AC = 1500$ mtr.

$$\text{Then } C_1C = \frac{1500}{3000} \times 5 = 2.5 \text{ mtr.}$$

The point C_1 is then moved horizontally by 2.5 mtr. and transitting carried out as before.

Practice in survey enables the first position C_1 to be located fairly accurately and often the horizontal travel of the self-centering device is sufficient to locate B without moving the instrument.

(c) Where one angle cannot be seen from the next, nor both from an intervening position, the method is just an extension of the method given in (b).

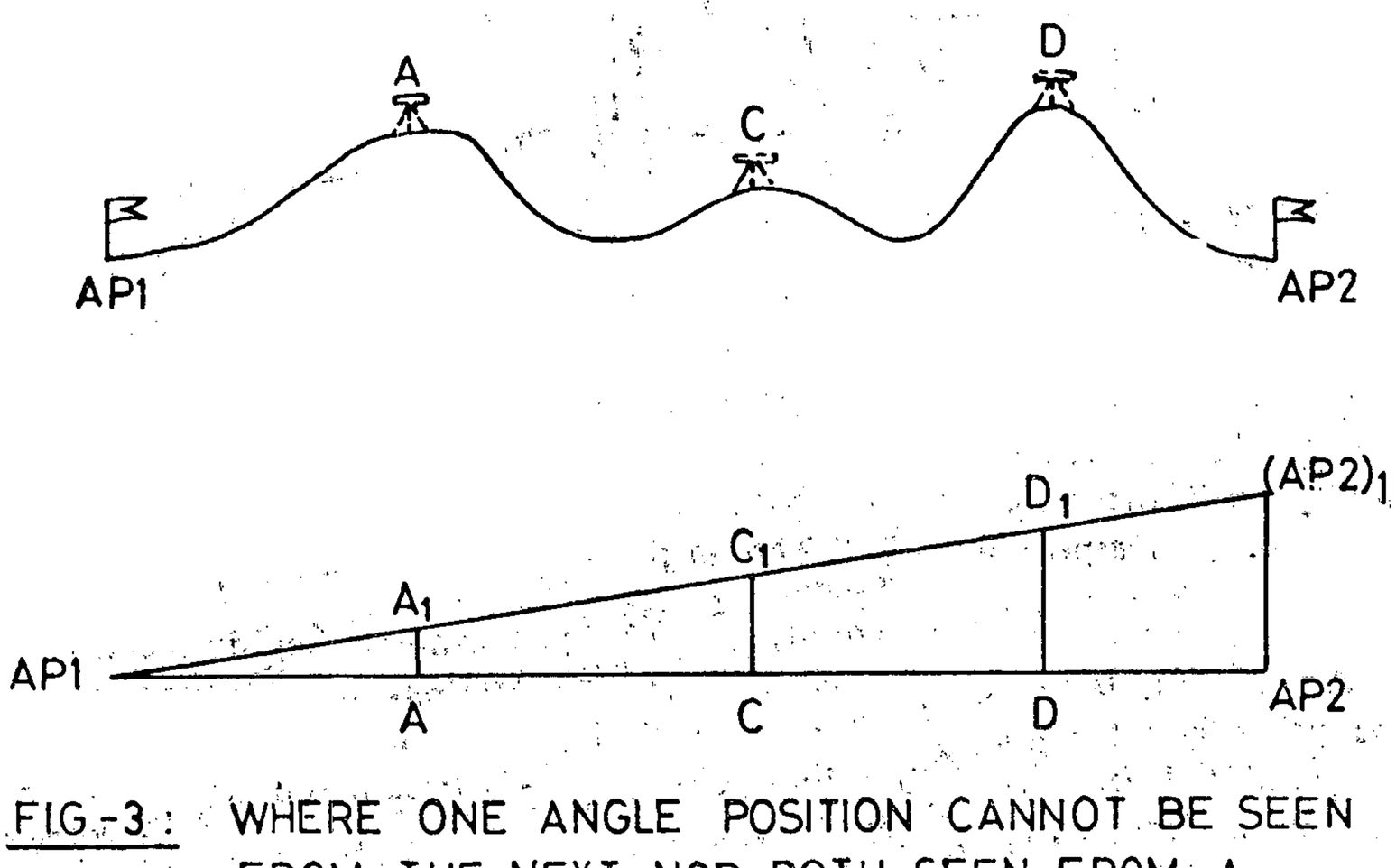


FIG-3 : WHERE ONE ANGLE POSITION CANNOT BE SEEN FROM THE NEXT, NOR BOTH SEEN FROM A CENTRAL POINT.

The approximate position of A_1, Figure-3, is scaled off from the topo-sheet and flags are erected at AP1 and AP2. The theodolite is set up at A_1 and directed to AP1, then transitted and position of C1 located. The instrument is turned horizontally through 180° and the procedure again repeated and the position C1 is the mean of the two transit readings. The instrument is then set up at C_1 and directed to A_1 and transitted as before to locate position D_1. The instrument is now set up at D_1 and directed to C_1 and transited to locate position (AP 2) 1. The horizontal distance which the instrument requires to be moved so that AP1, A, C, D and AP2 are in a straight line can be calculated by similar triangles as follows. :

$$\frac{A_1A}{AP_1A} = \frac{C_1C}{AP_1C} = \frac{D_1D}{AP_1D} = \frac{(AP2)_1 \quad (AP2)}{AP_2 \quad AP_1}$$

AP_1A, AP_1C, AP_1D and AP2 are all measured on toposheets, and $(AP2)_1$ is measured from the above survey.

Here again, an experienced engineer will be capable of scaling the position of A1 sufficiently accurately to enable the angle positions to be located by one movement of the instrument.

(d) Wherever obstacles such as buildings etc. impede the view, the right angle survey can be made going round the obstacle.

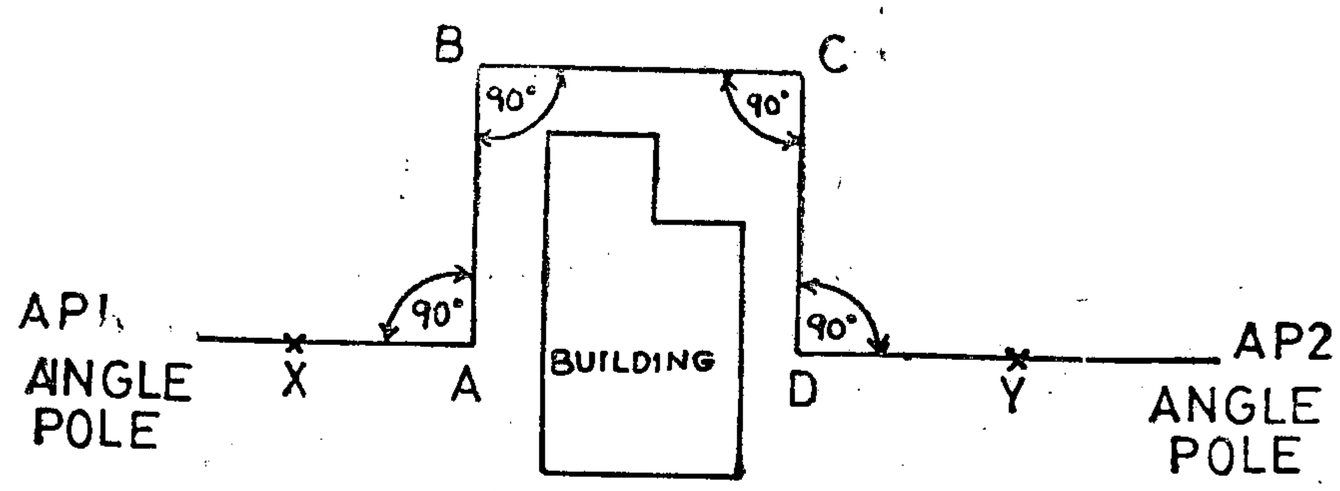


FIG-4

In running the trial line the approximate position of A can be located by measurement from the topo-sheet. The Theodolite is set up at A and makes a right angle AP1 $\hat{A}$ B. Points BCD are treated similarly until the position Y is located as before. Corrections are then made to the position and the process repeated until XY are in the required straight line.

Sometimes, wherever situations permit, it may be possible to simplify the above procedures as follows. A fairly long pole is erected with a flag on its top, at a point beyond the obstructions, such that the point is visible from the previous point; or it may even be possible to select a conspicuous and identifiable tree visible from the previous location and identified with a red flag fixed on to it and the further surveying continued.

In all the above cases it is good practice to repeat the process in the opposite direction, i.e. from angle position 2 to angle position 1 every time to avoid possible errors.

2.04 CHAINING AND LEVELLING OF THE LINE ROUTE :

The levelling and chaining shall be done at the same time. In chaining a route, it shall be remembered that all distances are measured horizontally and not on the slope. Flags are erected at each of the line positions which were instrument stations, since these are visible on the whole section and assist in keeping the chaining in the correct line route. The chaining party shall consist of a leader and follower, and the follower shall direct the leader in the correct direction. At the end of each measured length an arrow is inserted. The follower enters in his survey book

details of all distances with the positions of hedges, streams or other featurss which he thinks necessary.

Before commencing the levelling of the route. a bench mark is located and a level run from this to the starting peg. In levelling, accuracy must be observed and it is essential that the carrier of the staff holds it vertical when readings are taken. The leveller should balance the length of sights as much as possible and set up his instrument as near the line of route as practicable. The distance between level readings depends on the contour of the ground and incorporates all positions at which arrows have been left, recording chainage distances. This procedure of chaining and levelling is continued until the section between the locations of two adjascent angle towers is complete.

It is Important, that where there is considerable side slope on the ground, the levels should be taken on the high side as well as the centre of the route. Side levels should be taken at a horizontal distance equal to the distance of the outer conductor from the centre of the structure.

It should be remembered that the whole economics of the line will depend on the selection of positions relative to the profile.

The levelling figures are reduced so that every point on the profile wiil be corelated to the datum or to an assumed datum. Table-1 below gives a specimen level notes showing the method of reducing the levels by heignt of collimation method.

TABLE-1

B.S.	I.S.	F.S.	H.C.	R.L.	Remarks
0.3			480.6	480 3	Fields
	1.5			479.1	Fields
	3.2			477.4	Hedge
3.1		20.6		460.0	Field
	Check	20.3		20 3	

R.L. = Reduced Level

H.C. = Height of Collimation

F.S. = Fore Sight

I.S. = Intermediate Sight

B.S. = Back Sight.

R.L. + B.S. = H.C. 480.3 + 0 3 = 480.6

H.C. − I.S. = R.L. 480.6 − 1.5 = 479.1

Check : First R.L. − Last R.L. = F.S. − B.S.

480.3 − 460.0 = 20.6 − 0.3

20.3 = 20.3 O.K.

2.05 TACHEOMETRIC SURVEY :

A rather faster method of conducting survey without using chain and tape is by indirect measurement of distances by optical methods. This method eliminates the chaining of the route

and increases the speed of levelling. This is due to the fact that the Theodolite has a range of 1000 mtr. and readings can be taken with the telescope at any vertical angle. In the chain and tape method the level has to be truly horizontal and its range in the sloping ground is limited since levels at closer intervals have to be taken to compute the correct horizontal distance. The damage to the crops grown in fields is also minimum since the staff holder can walk between the crops to the required spot in the line of the route where readings are to be taken, eliminating the dragging of the chain in midst of crops.

Another important aspect of the Tacheometric Survey is that it is easier to maintain the line of the route since the Theodolite set over one peg always have the next peg in view.

2.05.01 All modern Theodolites are fitted with stadia diaphrams having two horizontal stadia, one on each side of the centre line. The readings of the staff intercepted by the upper and lower stadia lines are taken and let the difference between the readings is H. Then the distance between the instrument and the staff is = KH, where K is the co-efficient of the instrument. All the present day theodolites are internally focussed and fitted with stadia diaphrams. The constant K is usually 100. However, it is good practice to estimate the constant 'K' for a particular instrument by measuring a known distance in the beginning. The value of 'K' for a particular instrument is always constant and does not change. The readings of the centre hair on the staff is the figure required to find the " Reduced Level " for the profile.

2.05.02 In cases of the Theodolite where stadia diaphram is not internally focussed, in order to get the distance of the axis of the instrument, the distance G, the instrument constant, must be added to the equation as follows :

Distance of the staff from the axis of the instrument = KH + G.

2.06 INCLINED SIGHTS :

The above method works well when the collimation line of the telescope is horizontal. When the collimation line has to be inclined due to heavy raise or fall in levels, the staff shall be held perpendicular to the line of collimation and the actual horizontal and vertical distances are calculated as follows :

Horizontal Distance = $KH \cos^2 \phi$

Vertical Distance = $KH \cos \phi \sin \phi$

Where K = Instrumenf Co-efficient (usually 100) as described earlier.

H = Staff intercept readings, i.e. the difference in readings of staff intercept between upper and lower stadia lines.

ϕ = Angle of Inclination.

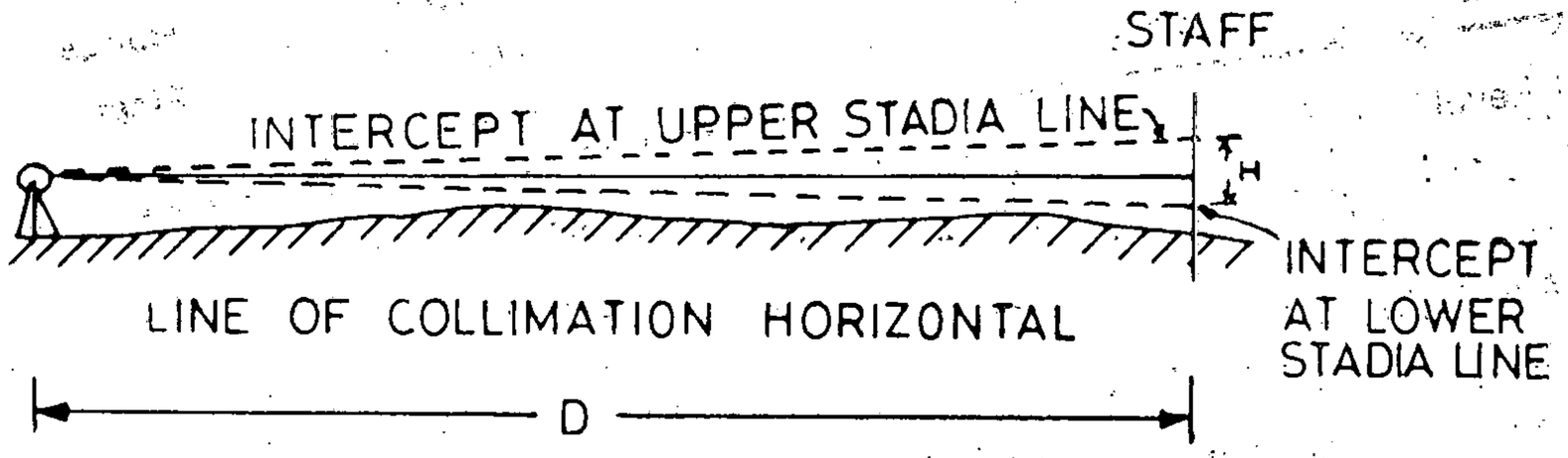


FIG - 5

The direct measurement of the horizontal distance between two points is not practicable in chain survey for the following locations :

1) On a hilly terrain where difference in level between the two points exists.

2) On undulated terrains.

This method is not only quicker than chain surveying but also accurate. Figure 6 on page 10 clearly illustrates the same.

The following example will illustrate the computations to be made after taking readings.

Eg : A Techeometer was set up at a station A and the readings on a vertically held staff at B were 2.255, 2.605 and 2.955, the line of sight being at an inclination of 8° 24.' Another, observation on the vertically held staff at B.M. gave the readings 1.640, 1.920 and 2.200, the inclination of the line of sight being 1° 6'. Calculate the horizontal distance between A and B and the elevation of B, if the R.L. of BM is 418.685 mtr. The constants of the instruments were 100 and 0.3

Solution :

a) Observation to BM

$V = KH \sin\phi \cos\phi + c \sin\phi$

$K=100,\ H=2.200-1.640=0.56$ m $\quad C=0.3$

$V=100\times0.560 \sin 1^{0}6' \cos 1^{0}6' + 0.3 \sin 1^{0}6'$

$V=1.081$

Elevation of collimation at the instrument

$=418.685+1.92-1.081$

$=419.524$ m

(b) Observation to B

$H=2.955-2.255=0.700$ mtr

$\phi=8°\ 24'$

$D=KH \cos^{2}\phi + C \cos\phi$

$=100\times0.7 \cos^{2} 8^{0}24' + 0.3 \cos 8^{0}24'$

$=68.81$ mtr

$V=KH \cos\phi \sin\phi + C \sin\phi$

$=100\times0.7\times \cos 8^{0}24' \sin 8^{0}24'$

$+0.3 \sin 8^{0}24'$

$=10.16$

R. L of B $=419.524+10.16-2.605$

$=427.079$ mtr.

In the above example, the distance 'C' the instrument constant, for the theodolite where stadia diaphram is not internally focussed is added to the equations.

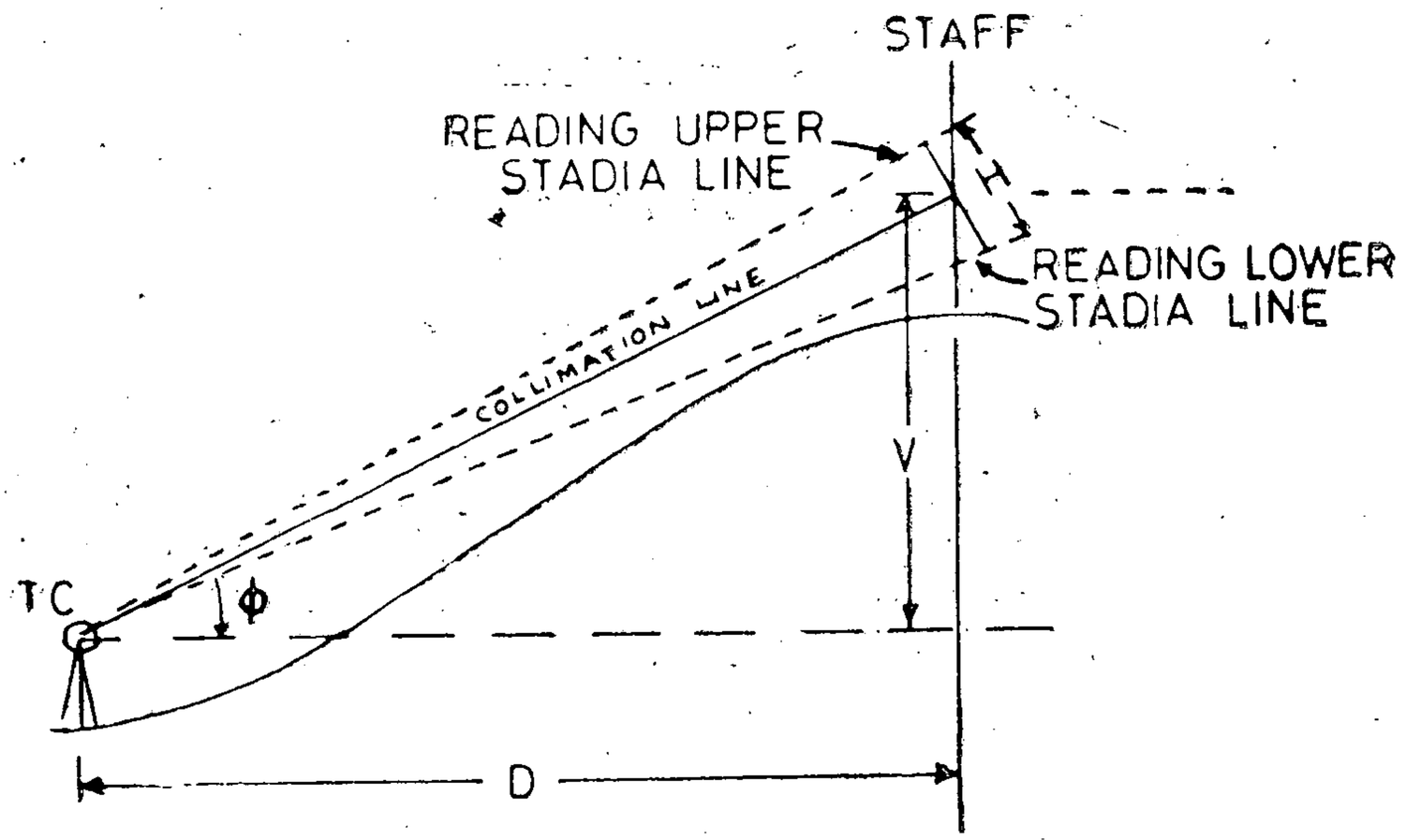


FIG - 6

Hoizontal Distance $D = KH \cos^2 \phi$

Vertical Distance $V = KH \cos \phi \sin \phi$

2.06.01 In cases of a Theodolite where stadia diaphram is not internally focussed (in order to get the distance of the axis of the instrument), the distance 'C', the instrument constant, must be added to the equations as follows :

Horizontal Distance $= KH \cos^2 \phi + C \cos \phi$

Vertical Distance $= KH \sin \phi \cos \phi + C \sin \phi$

2.06.02 To simplify the calculations, stadia tables are given in the Table-2. These tables give the value of multiplying constants for H and G for a value of K = 100. The following example illustrates the use of the tables.

H = 1.5 mtr. (difference in readings between upper and lower stadia hairs)

$\phi = 3^\circ\ 36'$ (angle of inclination to line of collimation)

C = 0.3 mtr. (instrument constant)

Horizontal distance = 99.61 × 1.5 + 0.3 = 149.71 mtr.

Vertical distance = 6.27 × 1.5 + 0.02 = 9.43 mtr.

2.07 REDUCING OF LEVELS :

In order to plot the profile it is necessary to find the reduced levels of all points at which readings were taken.

The procedure is as follows :

Let H.C = Height of Instrument axis.

RLS = Reduced level of staff.

BS = Back Sight as read on centre stadia hair.

FS = Fore Sight as read on centre stadia hair.

V = Vertical height calculated as above.

Angle of Elevation = + Ve

Angle of Depression = − Ve

When the level is started take a back sight before intermediate or foresight as the R.L. of initial staff readings are known either from a bench mark, or from the previous profiles and the new collimation line is obtained from this.

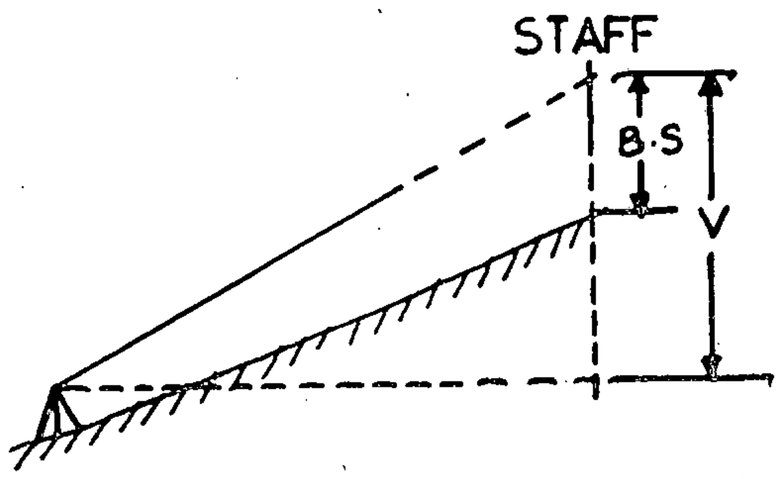


FIG-7: BACK SIGHT- ANGLE POSITIVE

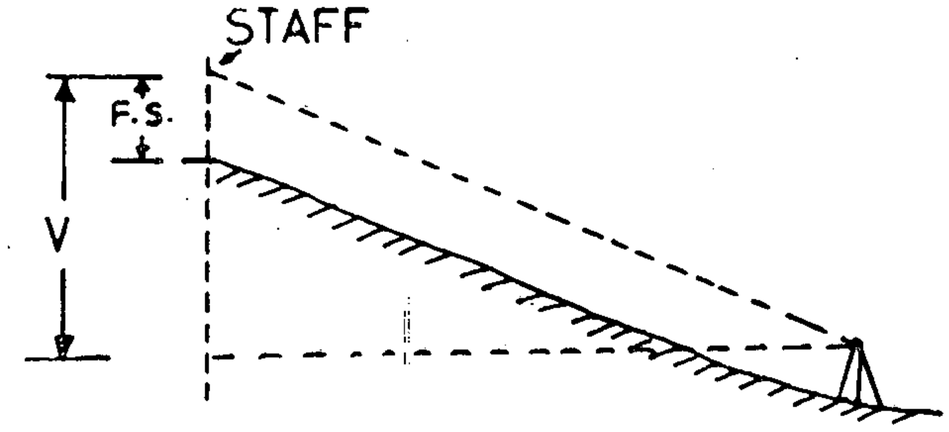


FIG-9 FORE SIGHT-ANGLE POSITIVE

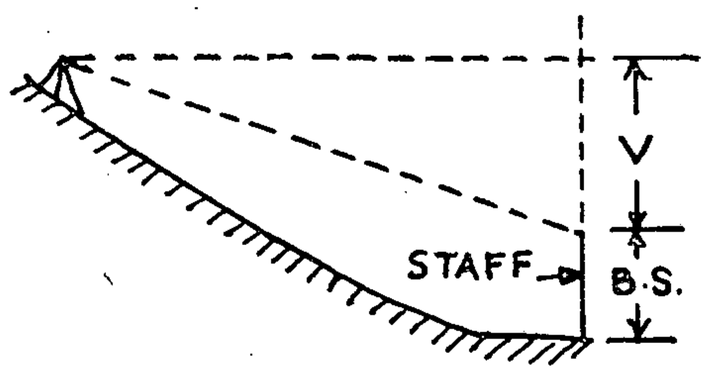


FIG-8 BACK SIGHT-ANGLE NEGATIVE

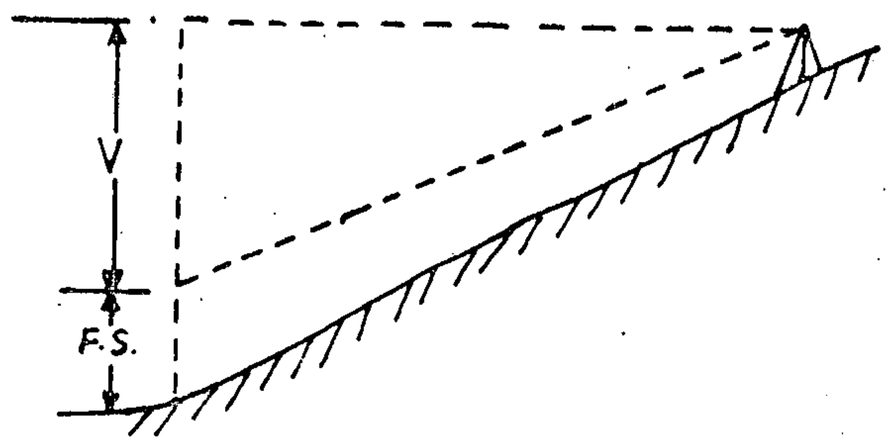


FIG-10 FORE SIGHT-ANGLE NEGATIVE

The procedure in reading levels become almost automatic if the following are observed :

Back Sight Angle	+ Ve	HC = RLS + BS − V
,,	− Ve	HC = RLS + BS + V
Fore Sight Angle	+ Ve	RLS = HC + V − FS
,,	− Ve	RLS = HC − V − FS

TABLE 2

STADIA REDUCTION TABLE: 1

Minutes	0°		1°		2°		3°	
	Hor. Dist.	Diff. Elev.	Hor. Dist	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Diff.	Diff. Elev.
0	100.00	0.00	99.97	1.74	99.88	3.49	99.73	5.23
2	100.00	0.06	99.97	1.80	99.87	3.55	99.72	5.28
4	100.00	0.12	99.97	1.86	99.87	3.60	99.71	5.34
6	100.00	0.17	99.96	1.92	99.87	3.66	99.71	5.40
8	100,00	0.23	99.96	1.98	99.86	3.72	99.70	5.46
10	100.00	0.29	99.96	2.04	99.86	3.78	99.69	5.52
12	100.00	0.35	99.96	2.09	99.85	3.84	99.69	5.57
14	100.00	0.41	99.95	2.15	99.85	3.89	99.68	5.63
16	100.00	0.47	99.95	2.21	99.84	3.95	99.68	5.69
18	100.00	0.52	99.95	2.27	99.84	4.01	99.67	5.75
20	100.00	0.58	99.95	2.33	99.83	4.07	99.66	5.80
22	100.00	0.64	99.94	2.38	99.83	4.13	99.66	5.86
24	100.00	0.70	99.94	2.44	99.82	4.18	99.65	5.92
26	99.99	0.76	99.94	2.50	99.82	4.24	99.64	5.98
28	99.99	0.81	99.93	2.56	99.81	4.30	99.63	6.04
30	99.99	0.87	99.93	2.62	99.81	4.36	99.63	6.09
32	99.99	0.93	99.93	2.67	99.80	4.42	99.62	6.15
34	99.99	0.99	99.93	2.73	99.80	4.47	99.61	6.21
36	99.99	1.05	99.92	2.79	99.79	4.53	99.61	6.27
38	99.99	1.11	99.92	2.85	99.79	4.59	99.60	6.32
40	99.99	1.16	99.92	2.91	99.78	4.65	99.59	6.38
42	99.99	1.22	99.91	2.97	99.78	4.71	99.58	6.44
44	99.98	1.28	99.91	3.02	99.77	4.76	99.58	6.50
46	99.98	1.34	99.90	3.08	99.77	4.82	99.57	6.56
48	99.98	1.40	99.90	3.14	99.76	4.88	99.56	6.61
50	99.98	1.45	99·90	3.20	99.76	4.94	99.55	6.67
52	99.98	1.51	99.89	3.26	99.75	4.99	99.55	6.78
54	99.98	1.57	99.89	3.31	99.74	5.05	99.54	6.79
56	99.97	1.63	99.89	3.37	99.74	5.11	99.53	6.84
58	99.97	1.69	99.88	3.48	99.73	5.17	99.52	6.90
60	99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96
c=0.2 m	0.20	0.00	0.20	0.01	0.20	0.01	0.20	0.01
c=0.3 m	0.30	0.00	0.30	0.01	0.30	0.01	0.30	0.02
c=0.4 m	0.40	0.00	0.40	0.01	0.40	0.02	0.40	0.02

Example. *Let* s = 1.5 *m* ; $\theta = 3^\circ 36'$; c = 0.3 *m.*
From table : 'Hori. Dist.' = 99.61 and 'Diff. Elev.' = 6.27 ;
Also corresponding to c = 0.3 m, 'Hori. Dist.' = 0.3 and Diff. Elev = 0_c02.

$\therefore$ D = (99.61 × 1.5) + 0.3 = **149.71 m**
V = (6.27 × 1.5) + 0.02 = **9.43 m**

TABLE 2

STADIA REDUCTION TABLE : 2

Minutes	4°		5°		6°		7°	
	Hor. Dist.	Diff. Elev.	Hor. Dist	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Diff.	Diff. Elev.
0	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10
2	99.51	7.02	99.23	8.74	98.90	10.45	98.50	12.15
4	99.50	7.07	99.22	8.80	98.88	10.51	98.49	12.21
6	99.49	7.13	99.21	8.85	98.87	10.57	98.47	12.27
8	99.48	7.19	99.20	8.91	98.86	10.62	98.46	12.32
10	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38
12	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43
14	99.46	7.36	99.17	9.08	98.82	10.79	98.41	12.49
16	99.45	7.42	99.16	9.14	98.81	10.95	98.40	12.55
18	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60
20	99.43	7.53	99.14	9.25	98.78	10.96	99.37	12.66
22	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72
24	92.41	7.65	99.11	9.37	98.76	11.08	98.84	12.77
26	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83
28	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88
30	99.38	7.82	99.08	9.54	93.72	11.25	98.30	12.94
32	99.38	7.88	99.07	9.60	98.71	11.30	99.28	13.00
34	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05
36	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11
38	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17
40	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22
42	99.33	8.17	98.01	9.88	98.64	11.59	98.20	13.28
44	99.32	8.22	98.00	9.94	98.63	11.64	98.19	13.33
46	99.31	8.28	91.99	10.00	98.61	11.70	9.817	13.39
48	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45
50	99.29	8.40	98·97	10.11	98.58	11.81	98.14	13.50
52	99.28	8.45	98.96	10.17	98.57	11.88	98.13	13.56
54	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61
56	99.26	8.57	98.93	10.28	98.54	11.98	98 10	13.67
58	99.25	8.63	98.92	10.34	98.53	12.04	98.08	13.71
60	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78
c=0.2 m	0.20	0.02	0.2	0.02	0.19	0.02	0.19	0.03
c=0.3 m	0.30	0.02	0.3	0.03	0.29	0.03	0.29	0.04
c=0.4 m	0.40	0.03	0.4	0.04	0.39	0.04	0.30	0.05

TABLE 2

STADIA REDUCTION TABLE: 3

Minutes	8°		9°		10°		11°	
	Hor. Dist.	Diff. Elev.	Hor. Dist	Diff. Elev:	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73
2	98.05	13.84	97.53	15.51	96.96	17.16	96.34	18.78
4	98.03	13.89	97.52	15.56	96.94	17.21	96.32	18.84
6	98.01	13.95	97.50	15.62	96.92	17.26	96.29	18.89
8	98.00	14.01	97.48	15.67	96.90	17.32	96.27	18.95
10	97.98	14.06	97.46	15.73	96.88	17.37	96.25	19.00
12	97.97	14.12	97.44	15.78	96.86	17.43	96.23	19.05
14	97.95	14.17	97.43	15.84	96.84	17.48	96.21	19.11
16	97.93	14.23	97.41	15.89	96.82	17.54	96.18	19.16
18	97.92	14.28	97.39	15.95	96.80	17.59	96.16	19.21
20	97.90	14.34	97.37	16.00	96.78	17.65	96.14	19.27
22	97.88	14.40	97.35	16.06	96.76	17.70	96.12	19.32
24	97.87	14.45	97.33	16.11	96.74	17.76	96.09	19.38
26	97.85	14.51	97.31	16.17	96.72	17.81	96.07	19.43
28	97.83	14.56	97.29	16.22	96.70	17.86	95.06	19.48
30	97.82	14.62	97.28	16.28	96.68	17.92	96.03	19.54
32	97.80	14.67	97.26	16.33	96.66	17.97	96.00	19.59
34	97.78	14.73	97.24	16.39	96.64	18.03	95.98	19.64
36	97.76	14.79	97.22	16.44	96.62	18.08	95.96	19.70
38	97.75	14.84	97.20	16.50	96.60	18.14	95.93	19.75
40	97.73	14.90	97.18	16.55	96.57	18.19	95.91	19.80
42	97.71	14.95	97.16	16.61	96.55	18.24	95.89	19.86
44	97.69	15.01	97.14	16.66	96.53	18.30	95.86	19.91
46	97.68	15.06	97.12	16.72	96.51	18.35	95.84	19.96
48	97.66	15.12	97.10	16.77	96.49	18.41	95.82	20.02
50	97.64	15.17	97.08	16.83	96.47	18.46	95.79	20.07
52	97.62	15.23	97.06	16.88	96.45	18.51	95.77	20.12
54	97.61	15.28	97.04	16.94	96.42	18.51	95.75	20.18
56	97.59	15.34	97.02	16.99	96.40	18.62	95.72	20.23
58	97.57	15.40	97.00	17.05	96.38	18.68	95.70	20.28
60	96.58	15.45	96.98	17.10	96.36	18.73	95.68	20.34
c=0.2 m	0.19	0.03	0.19	0.03	0.19	0.04	0.19	0.04
c=0.3 m	0.29	0.05	0.29	0.05	0.29	0.05	0.29	0.06
c=0.4 m	0.39	0.06	0.39	0.07	0.39	0.07	0.39	0.08

TABLE 2

STADIA REDUCTION TABLE: 4

Minutes	12°		13°		14°		15°	
	Hor. Dist.	Diff. Elev.	Hor. Dist	Diff. Elev.	Hor. Dist.	Diff. Elev:	Hor. Dist.	Diff. Elev.
0	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00
2	95.65	20.39	94.91	21.97	94.12	23.52	93.27	25.05
4	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8	95.58	20.55	94.84	22.13	94.04	23.65	93.18	25.20
10	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24	95.39	20.97	94.63	22.54	93.82	24.09	92.95	25.60
26	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75
32	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48	95.09	21.60	94 31	23.16	93.47	24.70	92.59	26.20
50	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45
60	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50
c=0.2 m	0.19	0.04	0.19	0.05	0.19	0.05	0.19	0.05
c=0.3 m	0.29	0.07	0.29	0.07	0.29	0.08	0.29	0.08
c=0.4 m	0.39	0.09	0.39	0.09	0.39	0.10	0.39	0.11

TABLE 2

STADIA REDUCTION TABLE: 5

Minutes	16°		17°		18°		19°	
	Hor. Dist.	Diff. Elev.	Hor. Dist	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78
2	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83
4	92.34	26.59	91.39	28.06	90.38	29.48	89.33	30.87
6	92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92
8	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97
10	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01
12	92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06
14	92.19	26.84	91.22	28.30	90.21	29.72	89.14	31.10
16	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15
18	92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19
20	92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24
22	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28
24	92.03	27.09	91.06	28.54	90.04	29.95	88.97	31.33
26	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38
28	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42
30	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47
32	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51
34	91.87	27.33	90.89	28.77	89.86	30.18	88.78	31.56
36	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60
38	91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65
40	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69
42	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74
44	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78
46	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83
48	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87
50	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92
52	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96
54	91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01
56	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05
58	91.48	27.91	90.49	29.34	89.44	30.74	88.34	32.09
60	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14
c=0.2 m	0.19	0.06	0.19	0.06	0.19	0.06	0.19	0.07
c=0.3 m	0.29	0.08	0.29	0.09	0.29	0.10	0.28	0.10
c=0.4 m	0.38	0.11	0.38	0.12	0.38	0.13	0.38	0.13

TABLE 2

STADIA REDUCTION TABLE: 6

Minutes	20°		21°		22°		23°	
	Hor. Dist.	Diff. Elev.	Hor. Dist	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	88.30	32.14	87.16	33.46	85.97	34.73	84.73	35.97
2	88.26	32.18	87.12	33.50	85.93	34.77	84.69	36.01
4	88.23	32.23	87.08	33.54	85.89	34.82	84.65	36.05
6	88.19	32.27	87.04	33.59	85.85	34.86	84.61	36.09
8	88.15	32.32	87.00	33.63	85.80	34.90	84.57	36.13
10	88.11	32.36	86.96	33.67	85.76	34.94	84.52	36.17
12	88.08	32.41	86.92	33.72	85.72	34.98	84.48	36.21
14	88.04	32.45	86.88	33.76	85.68	35.02	84.44	36.25
16	88.00	32.49	86.84	33.80	85.64	35.07	84.40	36.29
18	87.96	32.54	86.80	33.84	85.60	35.11	84.35	36.33
20	87.93	32.58	86.77	33.89	85.56	35.15	84.31	36.37
22	87.89	32.63	86.73	33.93	85 52	35.19	84.27	36.41
24	87.85	32.67	86.69	33.97	85.48	35.23	84.23	36.45
26	87.81	32.72	86.65	34.01	85.44	35.27	84.18	36.49
28	87.77	32.76	86.61	34.06	85.40	35.31	84.14	36.53
30	87.74	32:80	86.57	34.10	85.36	35.36	84.10	36.57
32	87.70	32.85	86.53	34.14	85.31	35.40	84.06	36.61
34	87.66	32.89	86.49	34.18	85.27	35.44	84.01	36.65
36	87.62	32.93	86.45	34.23	85.23	35.48	83 97	36.69
38	87.58	32.98	86.41	34.27	85.19	35.52	83.93	36.73
40	87.54	33.02	86.37	34.31	85.15	35.56	83.89	36.77
42	87.51	33.07	86 33	34.35	85:11	35:60	83.84	36.80
44	87.47	33.11	86.29	34.40	85.07	35.64	83.80	36.84
46	87.43	33.15	86.25	34.44	85.02	35.68	83.76	36.88
48	87.39	33.20	86.21	34.48	84.98	35.72	83.72	36.92
50	87.35	33.24	86.17	34.52	84.94	35.76	83.67	36.96
52	87.31	33.28	86.13	34.57	84.90	35.80	83.63	37.00
54	87.27	33.33	86.09	34.61	84.86	35.85	83.59	37.04
56	87.24	33.37	86.05	34.65	84.82	35.89	83.54	37.08
58	87.20	33.41	86.01	34.69	84.77	35.93	83.50	37.12
60	87.16	33.46	85.97	34.73	84.73	35.97	83.46	37.16
c=0.2 m	0.19	0.07	0.19	0.07	0.19	0.08	0.19	0.08
c=0.3 m	0.28	0.11	0.28	0.11	0.28	0.11	0.28	0.12
c=0.4 m	0.38	0.14	0.37	0.15	0.37	0.15	0.37	0.16

TABLE 2

STADIA REDUCTION TABLE: 7

Minutes	24°		25°		26°		27°	
	Hor. Dist.	Diff. Elev.	Hor. Dist	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45
2	83.41	37.20	82.09	38.34	80.74	39.44	79.34	40.49
4	83.37	37.23	82.05	38.38	80.69	39.47	79.30	40.52
6	83.33	37.27	82.01	38.41	80.65	39.51	79.25	40.55
8	83.28	37.31	81.96	38.45	80.60	39.54	79.20	40.59
10	83.24	37.35	81.92	38.49	80.55	39.58	79.15	40.62
12	83.20	37.39	81.87	38.53	80.51	30.61	79.11	40.66
14	83.15	37.43	81.83	38.56	80.46	39.65	79.06	40.69
16	83.11	37.47	81.78	38.60	80.41	39.69	79.01	40.72
18	83.07	37.51	81.74	38.64	80.37	39.72	78.96	40.76
20	83.02	37.54	81.69	38.67	80.32	39.76	78.92	40.79
22	82.98	37.58	81.65	38.71	80.28	39.79	78.87	40.82
24	82.93	37.62	81.60	38.75	80.23	39.83	78.82	40.86
26	82.89	37.66	81.56	38.78	80.18	39.86	78.77	40.89
28	82.85	37.70	81.51	38.82	80.14	39.90	78.73	40.92
30	82.80	37.74	81.47	38.86	80.09	39.93	78.68	40.96
32	82.76	37.77	81.42	38.89	80·04	39.97	78.63	40.99
34	82.72	37.81	81.38	38.93	80.00	40.00	78.58	41.02
36	82.67	37.85	81.33	38.97	79.95	40.04	78.54	41.06
38	82.63	37.89	81.28	39.00	79.90	40.07	78.49	41.09
40	82.58	37.93	81.24	39.04	79.86	40.11	78.44	41.12
42	82.54	37.96	81.19	39.08	79.81	40.14	78.39	41.16
44	82.49	38.00	81.15	39.11	79.76	40.18	78.34	41.19
46	82.45	38.04	81.10	39.15	79.72	40.21	78.30	41.22
48	82.41	38.08	81.06	39.18	79.67	40.24	78.25	41.26
50	82.36	38.11	81.01	39.22	79.62	40.28	78.20	41.29
52	82.32	38.15	80.97	39.26	79.58	40.31	78.15	41.32
54	82.27	38.19	80.92	39.29	79.53	40.35	78.10	41.35
56	82.23	38.23	80.87	39.33	79.48	40.38	78.06	41.39
58	82.18	38.26	80.83	39.36	79.44	40.42	78.01	41.42
60	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45
c=0.2 m	0.18	0.08	0.18	0.09	0.18	0.09	0.18	0.09
c=0.3 m	0.27	0.12	0.27	0.13	0.27	0.14	0.27	0.14
c=0.4 m	0.36	0.16	0.36	0.17	0.36	0.18	0.36	0.18

TABLE 2

STADIA REDUCTION TABLE: 8

Minutes	28°		29°		30°	
	Hor. Dist.	Diff. Elev.	Hor. Dist	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	77.96	41.45	76.50	42.40	75.00	43.30
2	77.91	41.48	76.45	42.43	74.95	43.33
4	77.86	41.52	76.40	42.46	74.90	43.36
6	77.81	41.55	76.35	42.49	74.85	43.39
8	77.77	41.58	76.30	42.53	74.80	43.42
10	77.72	41.61	76.25	42.56	74.75	43.45
12	77.67	41.65	76.20	42.59	74.70	43.47
14	77.62	41.68	76.15	42.62	74.65	43.50
16	77.57	41.71	76.10	42.65	74.60	43.53
18	77.52	41.74	76.05	42.68	74.55	43.56
20	77.48	41.77	76.00	42.71	74.49	43.59
22	77.42	41.81	75.95	42.74	74.44	43 62
24	77.38	41.84	75.90	42.77	74.39	43.65
26	77.33	41.87	75.85	42.80	74.34	43.67
28	77.28	41.90	75.80	42.80	74.29	43.70
30	77.23	41.93	75.75	42.86	74.24	43.73
32	77.18	41.97	75.70	42.89	74.19	43.76
34	77.13	42.00	75.65	42.92	74.14	43.79
36	77.09	42.03	75.60	42.95	74.09	43.82
38	77.04	42.06	75.55	42.98	74.04	43.84
40	76.99	42.09	75.50	43.01	73.99	43.87
42	76.94	42.12	75.45	43.04	73.93	43.90
44	76.89	42.15	75.40	43.07	73.88	43.93
46	76.87	42.19	75.35	43.10	73.83	43.95
48	76.79	42.22	75.30	43.13	73.78	43.98
50	76.74	42.25	75.25	43.16	73.73	44.01
52	76.69	42.28	75.20	43.18	73.68	44.04
54	76.64	42.31	75.15	43.21	73.63	44.07
56	76.59	42.34	75.10	43.24	73.58	44.09
58	76.55	42.37	75.05	43.27	73.52	44.12
60	76.50	42.40	75.00	43.30	73.47	44.15
c=0.2 m	0.17	0.10	0.17	0.10	0.17	0.10
c=0.3 m	0.26	0.14	0.26	0.15	0.25	0.15
c=0.4 m	0.35	0.19	0.35	0.20	0.34	0.20

TABLE-3

BOOKING FIELD NOTES

Name of Line :

Date :

Point No.	Angles		Reading of wires		Diffe-rence.	Hztl. distance	Reading of centre line		Diff. of level		Ht. of Col-limation	RL	Ht. of Instru-ment	Re-marks
	Hztl.	Vertical.	Top	Bottom.	H	KH $\cos^2\phi$	BS.	FS.	Raise	Fall	HC			

The readings shall be entered in field book as per the above table.

2.07.01 In fairly flat region, the levels should be measured at approximately every 20 mtr. horizontal distance. Levels at closer intervals have to be measured in hilly region and the intervals at which levels are to be measured is left to the discretion of the engineer incharge, depending on the steepness of the terrain. In addition, the level of ground at 8 mtr. from centre line on either side is also to be noted in hilly terrain, and marked in profiles so as to ensure required ground clearance underneath conductor and side clearances in swing conditions of conductor.

2.08 ADJUSTMENT OF SURVERY INSTRUMENTS :

The following adjustments are to be carried out on the instrument, before use :

THEODOLITE

(1) Testing and adjusting plate spirit levels :

(a) Clamp vertical axis of Theodolite,

(b) Unclamp the vernier plate so that the instrument is free to rotate.

(c) Turn telescope until it lies over a pair of screws in the case of four screw instrument, or parallel to a pair of screws in case of a three screw instrument.

(d) Bring the air bubble of each level to the centre of its run by means of the foot levelling screws.

(e) Turn the instrument through half a revolution to see if the air bubbles remain central. If not, the instrument is out of adjustment.

(f) Correct half the error by means of turning the capstain screws on the levels.

(g) Correct the other half of the error by the levelling foot screws. Turn the instrument through 180° and check if the bubble remains correct, if not repeat the adjustment.

The instruments are provided with locking devices, for the capstain screws and it is essential that the instrument is locked after adjustment.

(2) Testing and Adjusting of Collimation :

This is to ensure that the line of collimation is at right angles to the horizontal axis and parallel to the telescope.

(a) Leave the theodolite on fairly level and firm ground.

(b) Place a piece of white paper with a steel arrow 'X' pushed twice through it at approximately 125 mtr. from the theodolite as shown in Fig. 11.

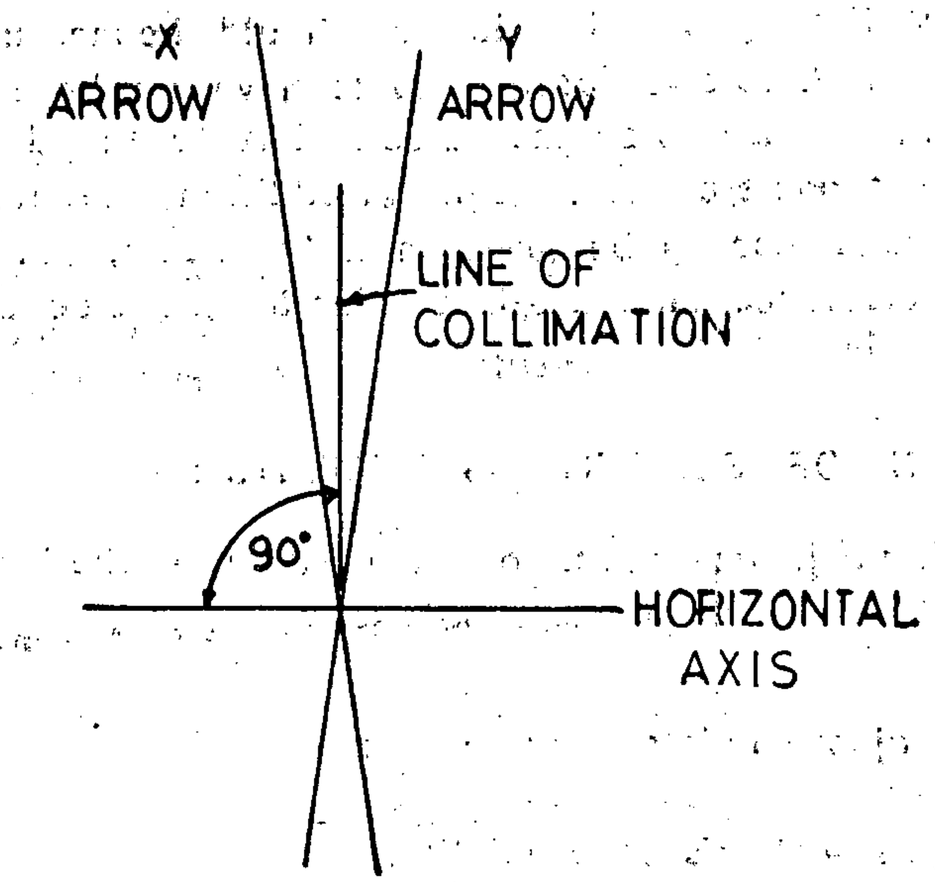


FIG-11 ADJUSTMENT OF LINE OF COLLIMATION

(c) Clamp upper or vernier plate with vernier A reading 360° and vernier B reading 180°.

(d) Direct the telescope to arrow 'X' until the vertical hair on the diaphram bisects arrow 'X' and clamp the vertical axis of this instrument in this position.

(e) Unclamp vernier or upper scale and turn the instrument through exactly 180° and clamp the instrument.

(f) Transit telescope and see if vertical hair on diaphram still curts arrow at 'X'. If it does not, the line of collimation is not at right angles to the horizontal axis and adjustment is necessary.

(g) The point where the line of collimation cuts the paper should be marked with another arrow 'Y'.

(h) Adjust half the error by the screws controlling the lateral movement of the diaphram.

(i) Adjust the other half of the error by means of the tangent screw of the vertical axis. Adjustment should be tested and repeated if necessary.

The difference between the first reading on arrow 'X' and the second on arrow 'Y' represents twice the collimation error.

(3) TESTING AND ADJUSTING HORIZONTAL ON TRUNNION AXIS :

This is to ensure that the horizontal axis is at right angles to the vertical axis.

(a) Level the instrument on firm ground.

(b) Direct the telescope to the top of a well defined object.

(c) Clamp vertical and upper plate axis and use the tangent screw of the vertical axis to set the intersection of the cross hairs exactly on the defined object.

(d) Depress the telesope to a point as far below the top of the defined object as possible and mark on a sheet of white paper fixed on the board the point 'X' as in Fig. 12.

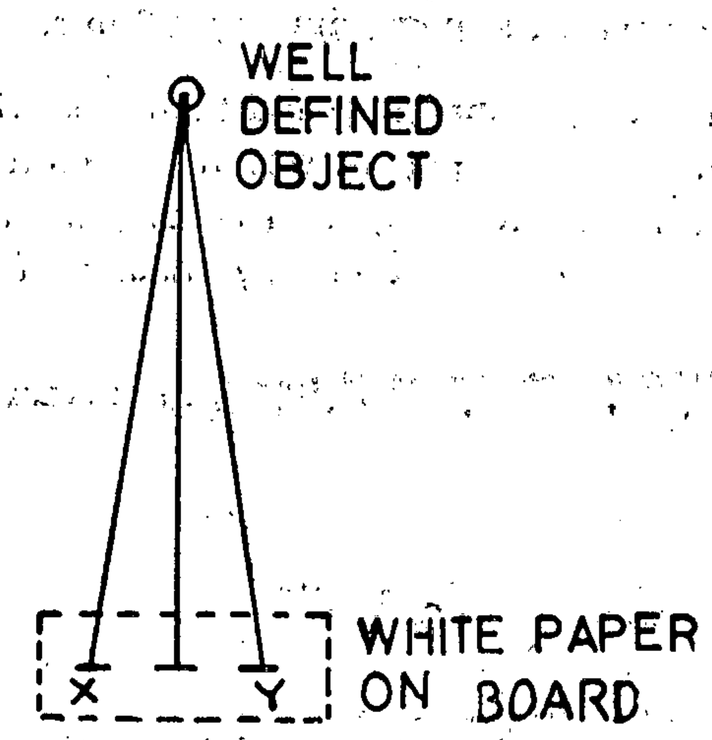


FIG-12: ADJUSTMENT OF HORIZONTAL AXIS

(e) Turn the instrument through 180° and again direct the telescope to the well defined object.

(f) Depress telescope and see if the intersection of the cross hairs coincides with point 'X' already on the paper. If not the horizontal axis is not at right angles to the vertical axis. The point 'Y' where the intersection of the cross hairs cuts the paper, should be marked.

(g) Correct half the error by means of capstain screws controlling the horizontal axis. Check and repeat if necessary.

The difference between points 'X' and 'Y' represents twice the actual error.

(4) TESTING AND ADJUSTING OF DUMPY LEVEL :

1. Testing and adjusting of spirit level perpendicular to the axis of rotation :

(a) Set up the instrument and turn the telescope over one pair of screws and bring the bubble to the centre of its run by levelling the foot screws.

(b) Turn telescope through 180° and observe if the bubble remains central, if not the instrument requires adjustment.

(c) Correct half the error by means of capstain screws which fix the tube to the telescope.

(d) correct other half by levelling the foot screws. Repeat for the telescope over the other pairs of screws and check.

2. Testing and adjusting spirit level and telescope to be parallel to the line of collimation :

(a) Drive two pegs 'A' and 'B' 100 mtrs. apart.

(b) Set up the level exactly between the pegs and level it.

(c) Take a staff reading on peg 'A'.

(d) Direct telescope to peg 'B' and take a staff reading. Adjust peg 'B' by raising or lowering until the reading is the same as that got on peg 'A'. The top of the pegs must then be in the same level plane.

(e) Set up level in line with the pegs, but say 12 mtr. behind one of them.

(f) Take a staff reading on the near peg and then a staff reading on the distant peg. If these are not the same, then the instrument is out of adjustment and the line of collimation is not parallel to the spirit level and telescope. The diaphram must be adjusted until the staff readings on both pegs are alike. This is done by means of the capstain screws holding the diaphram in position.

Example : Let the staff reading at Peg 'A' is 2 mtr. and that on peg 'B' is 1.5 mtr.

$$\text{Error per mtr.} = \frac{2 - 1.5}{100} = 0.005 \text{ mtr.}$$

At 12 mtr. from level, i.e. peg A, the error $= 12 \times 0.005 = 0.06$ mtr.

At 88 mtr. from level, i.e. peg B, the error $= 88 \times 0.005 = 0.440$ mtr.

The collimation dips from the instrument towards the far peg. The diaphram is then adjusted until the staff readings are similar and are :

Peg 'A' ; $2 - 0.067 = 1.94$ mtr.

Peg 'B' ; $1.5 + 0.44 = 1.94$ mtr.

2.09 The list of equipments required for survey are as follows :

(1) 1 No. Theodolite with stadia hairs.

(2) 6 Nos, ranging rods 2 mtr. fitted with ferrules so that they can be joined to make a long rod.

(3) 1 No. Dumpy level.

(4) 1 No. 30 mtr. Chain.

(5) 10 Nos. Arrows.

(6) 1 No. 2 Kg. Hammer.

(7) 1 No. 30 mtr. Tape.

(8) 1 No, Hedge cutter.

(9) 1 No. Optical square.

(10) 1 No. Levelling staff.

2.10 Each survey team shall consist of the following personnel.

(1) Two Engineers ; Two AEs and one AEE or three AEs.

(2) Six Helpers.

2.11 ELECTRONIC DISTANCE MEASURING INSTRUMENTS :

Battery operated electronic distance measuring instruments operating on the infra red micro processor principle can also be used by which the survey can be conducted more accurately with speed. Instruments which have a range of 1.4 KM to 2 KM are available by which the distances,

angles of inclinations etc can be measured to an accuracy of 5 mm. These instruments will be very helpful in measuring the distance, levels etc., at inaccessible places.

2.12 AERIAL SURVEY :

The technique employed for mapping the run of the line will depend both on the type of country across which the power line is to run, and the amount of previous industrial or residential development on the route. In underclosed country-mountain, forest or desert - for which good maps do not exist already, the first requirement will be for a block of photography to cover the country through which the projected line is to run; this small scale photography will be examined stereoscopicaily & the general route to be taken by the power line will be decided upon.

Horizontal control for mapping from these photographs may be established using one of the radar types of system for the measurement of distance. Vertical control elevation may be obtained 'by precise ground levelling and special photographic techniques. With practice many of the essential facts of the physical landscape may be perceived at a glance although a strictly analytical attack on the problem proves the most effective. For more exact location of the line to be taken, it is convenient to map & contour a band of country.

When a power line is to be carried across highly developed country, then contouring or peofiling will be to closer tolerances. This may be done in one of the two ways.

(1) The general route of the projected line is photographed from 2300 mtr. with 15 cm focal length lens. This produces a band of photography at 1/15,000 scale & just over three kilometers wide. From this photography contours at 1.5 mtr. verticals are added to the 1/2500 Ordnance survey map by photogrammetric means, and by examination of this contoured strip the final route of the power line is chosen.

(2) A different technique is to select a definite route and by photographic means produce a profile accurate to 0. 3mtr. For this result to be obtained, the aerial photography is run at 1/1600 scale, giving a band of cover about-1372 mtr & by photogrammetric means a profile of the chosen route at 1/240 vertical scale is produced. If the chosen route is not satisfactory, other routes with in the same band of photography can be profiled until a suitable line is found.

2.13 ROUTE MARKING :

At the starting point of the commencement of route survey, an angle iron spike made out of 65x65x6 mm M.S. angle 1 mtr. long shall be driven firmly into the ground to project 150 mm only above the ground level. A punch mark on the top of the section of the angle iron shall be made to indicate location of the survery instrument. Wooden pegs of atleast 50x50x650 mm size shall be driven at prominent places at intervals of not more than 750 mtr. along the transmission line to be surveyed upto the next Angle Point. Nails of 125 mm long should be fixed on the top of these pegs to show the location of instrument. The pegs shall be driven firmly into the ground to project only 100 mm. above ground level. At angle positions, concrete pillars with name of line and angle of deviation, direction of deviation marked on them shall be put up firmly on the ground for easy identification.

Eg.

RCHR - LNG
10° 23' Right

In case it is expected that considerable time will elapse between the finalisation of survey and actual execution, it is advisable to establish concrete blocks or dressed stones of at least half a meter in length, with due markings, along the route at appropriate places on the route within 500 to 750 mts. from each other.

2.14. The type of soil encountered in the route at regular intervals, viz., 'Dry', 'wet' 'Black cotton', 'partially submerged', 'fully submerged' etc shall be investigated at the time of survey itself, so that the advance information will be available for the Construction Engineer. These informations shall be included in the Tower schedule.

CHAPTER 3

PROFILE SHEETS AND TOWER SPOTTING :

3.01 PLOTTING OF PROFILES : Profile sheets shall be made on tracing paper, either squared transparent paper or plain transparent paper. The squared paper leads to greater accuracy and speed in profile plotting and subsequent application of sag template. The common practice is to use the blue prints of sag templates and hence a transparent paper for profile sheets is an absolute necessity. The sheet size shall be either 420 × 1189 mm or 594 × 1189 mm depending on whether the profile is for plains or hills respectively. Each section shall be started on a new sheet.

With plain tracing paper, it is necessary to fix the same carefully on the drawing board and use a 'T' square for horizontal guidance. Each point plotted must be drawn vertical relative to the 'T' square.

With squared tracing paper, the squares are a useful guidance for drawing either vertical or horizontal lines. It is advisible to use 1mm/5mm/1cm square paper for this purpose.

In commencing profile plotting, the level notes are examined to ascertain the range of levels so that the profiles can be suitably marked on the paper.

From the field book entries, the route plan and the level profile, commonly referred to as 'Profile sheet' or 'Survey chart' shall be plotted and prepared to scales of 1 : 2000 Horizontal and 1 : 200 Vertical.

The R.L. of the starting point is plotted and the various points at which the levels are taken are plotted. The profile is drawn through these points and any hedges, structures, etc. are shcwn.

3.02 DESIGN SPANS :

The following terms are used in the mechanical design of line spans.

NORMAL SPAN : The normal span is the maximum level span obtainable with a given structure height with a given conductor clearance above level ground. The usefulness of normal span is limited since the transmission line profile is seldom level and actual span will vary considerably with the normal span.

RULING SPAN : The ruling span is the span length in which the tension in the conductor under changes in temperature and loading will nearly agree with the average tension in a series of spans of varying lengths between dead ends. The Ruling Span for any section of transmission line having 'n' spans of length L_1, L_2, L_3 .... Ln between dead ends may be calculated from the following formula.

$$\text{Ruling Span} = \sqrt{\left(\frac{\sum_{o}^{n} L^3}{\sum_{o}^{n} L}\right)}$$

For eg., The following are the consecutive span in a section.

$L_1 = 300$ m
$L_2 = 320$ m
$L_3 = 350$ m
$L_4 = 310$ m
$L_5 = 250$ m
$L_6 = 300$ m

$$\text{Ruling Span} = \sqrt{\frac{(300)^3+(320)^3+(350)^3+(310)^3+(250)^3+(300)^3}{300+320+350+310+250+300}} = 309\text{mtr.}$$

WIND SPAN : The wind span is the span length used to calculate wind load on tower due to conductor wind, and is half of the sum of the two spans, adjascent to the support. The practice in K.E.B. is to provide a wind span of 1.1 times normal span.

WEIGHT SPAN : The weight span is the horizontal distance between the lowest point of conductors on the two spans adjascent to the tower. The lowest point is defined as the tangent to the sag curve, or the sag curve produced, is horizontal. The weight span adopted in tower designs is 1.5 times the normal span.

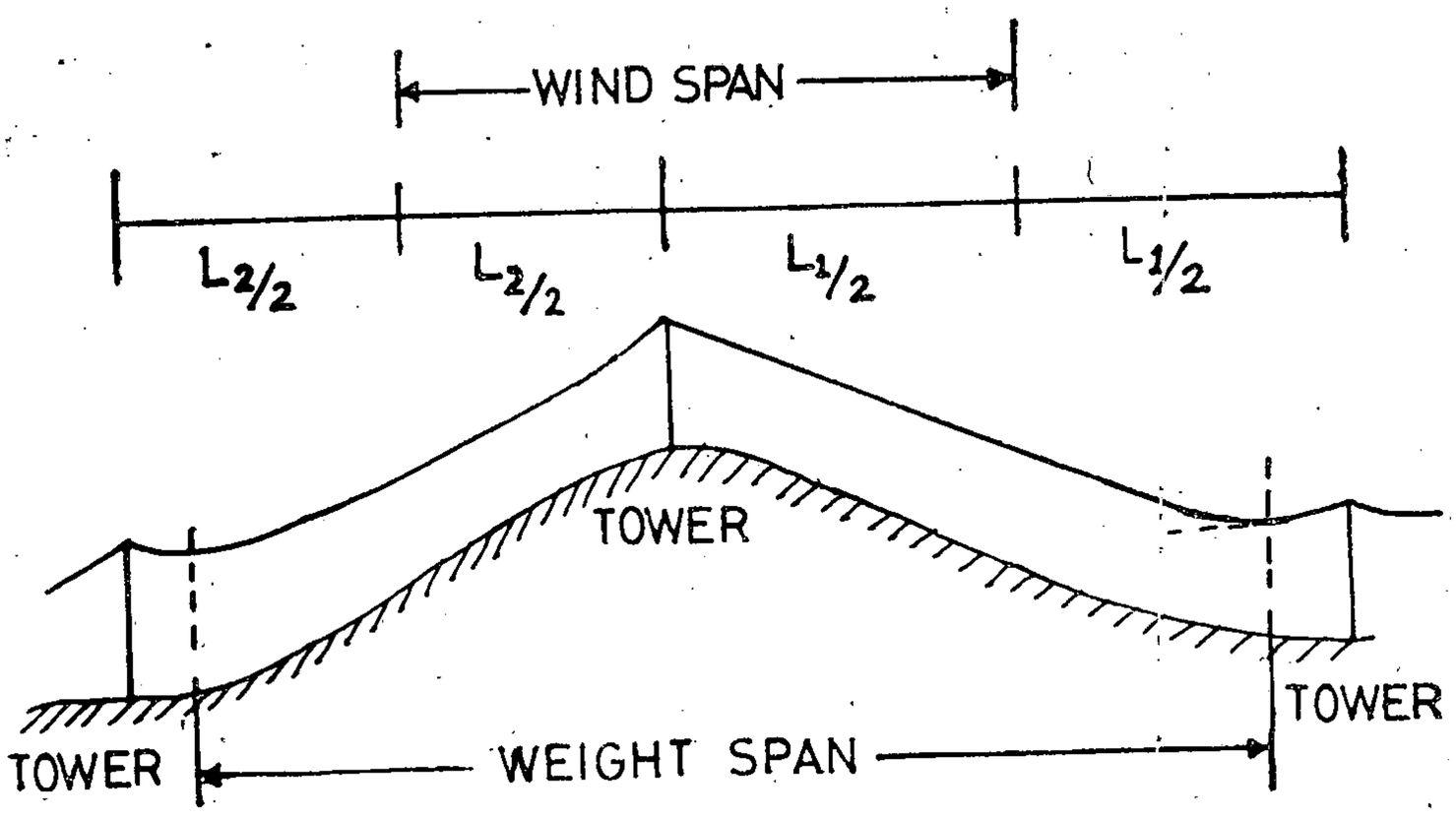


FIG-13

3.03 SAG TEMPLATE :

The tower designs are developed based on the minimum ground clearance considerations for a normal span on a flat terrain. The terrain on which the lines are constructed are seldom flat and hence a device is necessary to locate the tower, maintaining the required ground clearance on any terrain on profile sheet. For this purpose a sag template is developed.

The location of structure on the profile with Sag Template is essential for both correct design and economy. The Sag Template is made on transparent paper and blue prints of the template are used for tower spotting. The templates may also be made on card board, or on hard plastic sheet or on celluloid.

HOT TEMPLATE

GROUND CLEARANCE CURVE

TOWER FOOT CURVE

E.HTH. EARTH FOOT CURVE

G.H.T.E. EARTH FOOT CURVE

COLD TEMPLATE

NORMAL SPAN - 320 MTR

SAG = 7.509 MTR

1.4% TOLERANCE

A

B

C

D

E

DISTANCE

AB = 7.016 MTR

BC = 7.509 MTR

CD = 3 MTR

DE = 3 MTR

NOTE:

(1) CONDR SAG AT 15°C STILL AIR = 7.549 MTR

(2) TENSION AT 25°C STILL AIR = 2894 KG

(3) TENSION AT 18°C ½" WIND = 4416 KG

(4) TENSION AT 32°C NO WIND = 3344 KG

SCALE - 1CM = 20 MTR

ALL DIMS ARE IN MTRS

SAG TEMPLATE

EUBOEAN ELECTRICITY BOARD

APPROVED

CERAS

Tne Sag Template consists of the following curves :

(a) 'COLD TEMPLATE' OR 'UPLIFT' CURVE :

This corresponds to the vertical component of sag at the lowest conductor temperature.

(b) 'HOT TEMPLATE' OR 'MAXIMUM SAG' CURVE :

This corresponds to the sag at maximum conductor temperature - no wind - conditions.

(c) 'GROUND CLEARANCE CURVE'

This is drawn at a distance equal to the minimum specified ground clearance from the Hot templafe curve.

(d) 'TOWER FOOT CURVE'

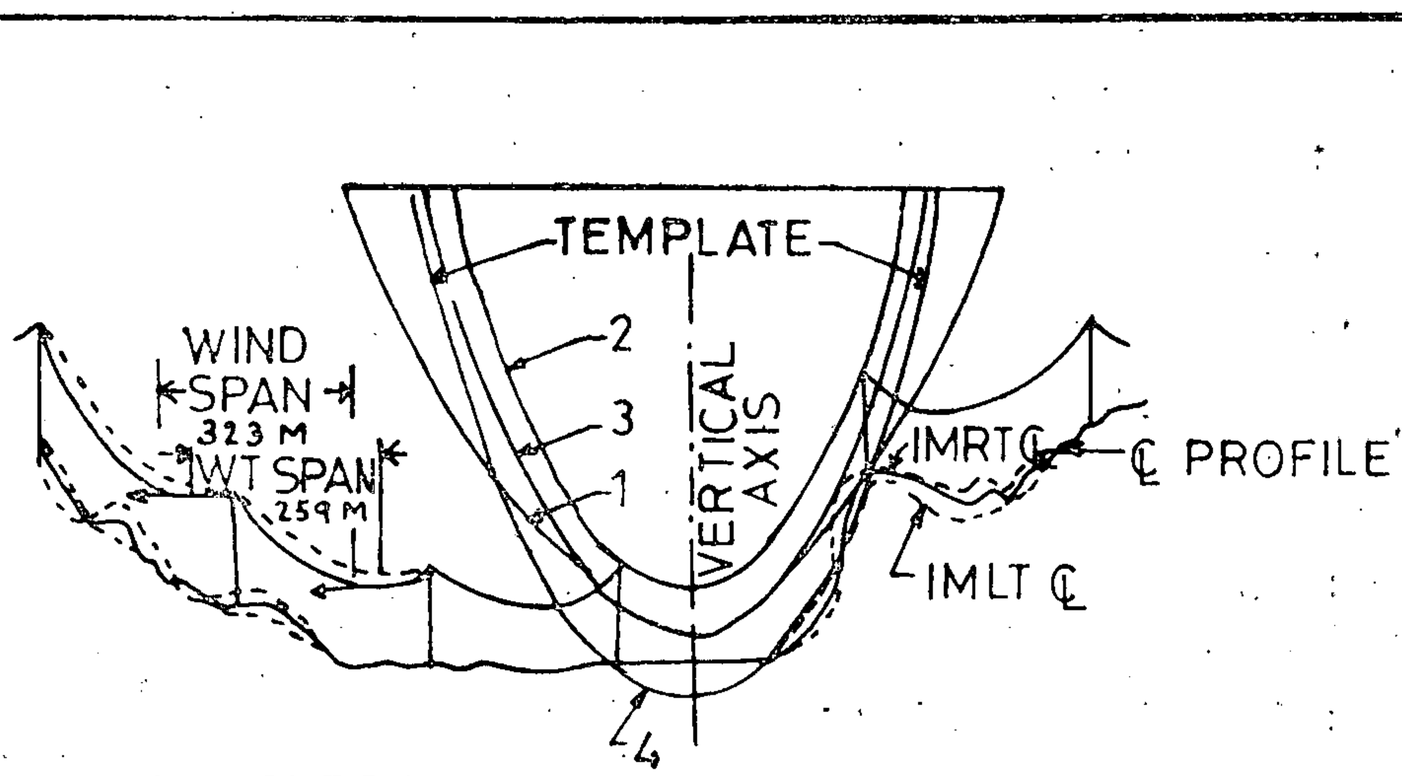
This is drawn at a distance equal to the bottom conductor height at tower from the Hot template curve. Separate tower foot curves are drawn for 3 mtr. and 6 mtr. extension towers.

The sag templates are prepared to the same scale as the profile sheet, that is 1 : 2000 for horizontal and 1 : 200 for vertical heights.

A typical Sag Template is shown in Fig. 14.

3.04 TOWER SPOTTING :

The method of application of the sag template is shown in Fig 15. The template is applied to the profile by moving the profile sheet horizontally, as shown in the figure and always keeping



1. REPRESENTS COLD TEMPLATE OR UPLIFT CURVE
2. REPRESENTS HOT TEMPLATE OR MAX. SAG CURVE
3. REPRESENTS GROUND CLEARENCE CURVE
4. REPRESENTS TOWER FOOT CURVE

IMLT CENTRAL LINE REPRESENTS LEFT OFFSET LEVEL

IMRT CENTRAL LINE REPRESENTS RIGHT OFFSET LEVEL

FIG - 15

the vertical axis and horizontal axis of both profile sheet and template strictly in line. The ground profile shall be moved strictly on support foot curve, and the hot template curve shall strictly be on the previous support marked on the profile sheet. The structure positions are marked where the support foot curve cuts the profile, while the ground clearance curve is just clear off and above the profile. The ground clearance curve shall not only clear the route line of the profile, but also the profile to the left and right of the centre line upto a distance equal to the maximum swing of conductor including cross arm spread on either side.

The 'Weight Span' on either side of the tower for all practical purposes is obtained by marking the low points of the sag in the two adjascent spans and scaling the same off.

Care should be taken that the weight span and wind spans of each location does not exceed the designed figures, viz. 1.5 times and 1.1 times the normal spans respectively, under the maximum permissable angle of deviation of the line at the tower, for which the tower is designed. However higher wind spans are permissable with lesser angles of deviation and the corresponding limits should be obtained from the technical section wherever necessary. On steep inclined spans the low point may fall beyond the lower support and this indicates the conductor in the uphill span exerts a negative or upward pull on the lower tower. The amount of this upward pull is equal to the weight of the conductor from the lower tower to the low point in the sag. When the upward pull is greater than the downward load in the next adjascent span, an 'UPLIFT' occurs and the conductor will swing clear off the tower upward during stringing. Hence, this location necessitates an Anchor Tower, also called 'Section Tower' even if there is no deviation. These positions shall also be checked for uplifts, with 3 mtr. or 6 mtr. extensions for tangent towers.

For an easy check whether a tower is under uplift or not the template is applied horizontally until the tops of alternative supports coincide with the cold template curve. If the curve is above the intermediate support, the support is under uplift and has to be extended till it touches the cold template and so culminates uplift. If 3 mtr. or 6 mtr. extensions do not satisfy the condition, section towers (anchor towers) designed for uplift shall be used.

The following type of towers are in use :

1) Type A : This is a suspension tower designed for a maximum deviation of 2°.

2) Type B : This is a section tower (anchor tower). Two types are in use. B-15 is designed for 15° line deviation. B-30 is designed for 30°. line deviation.

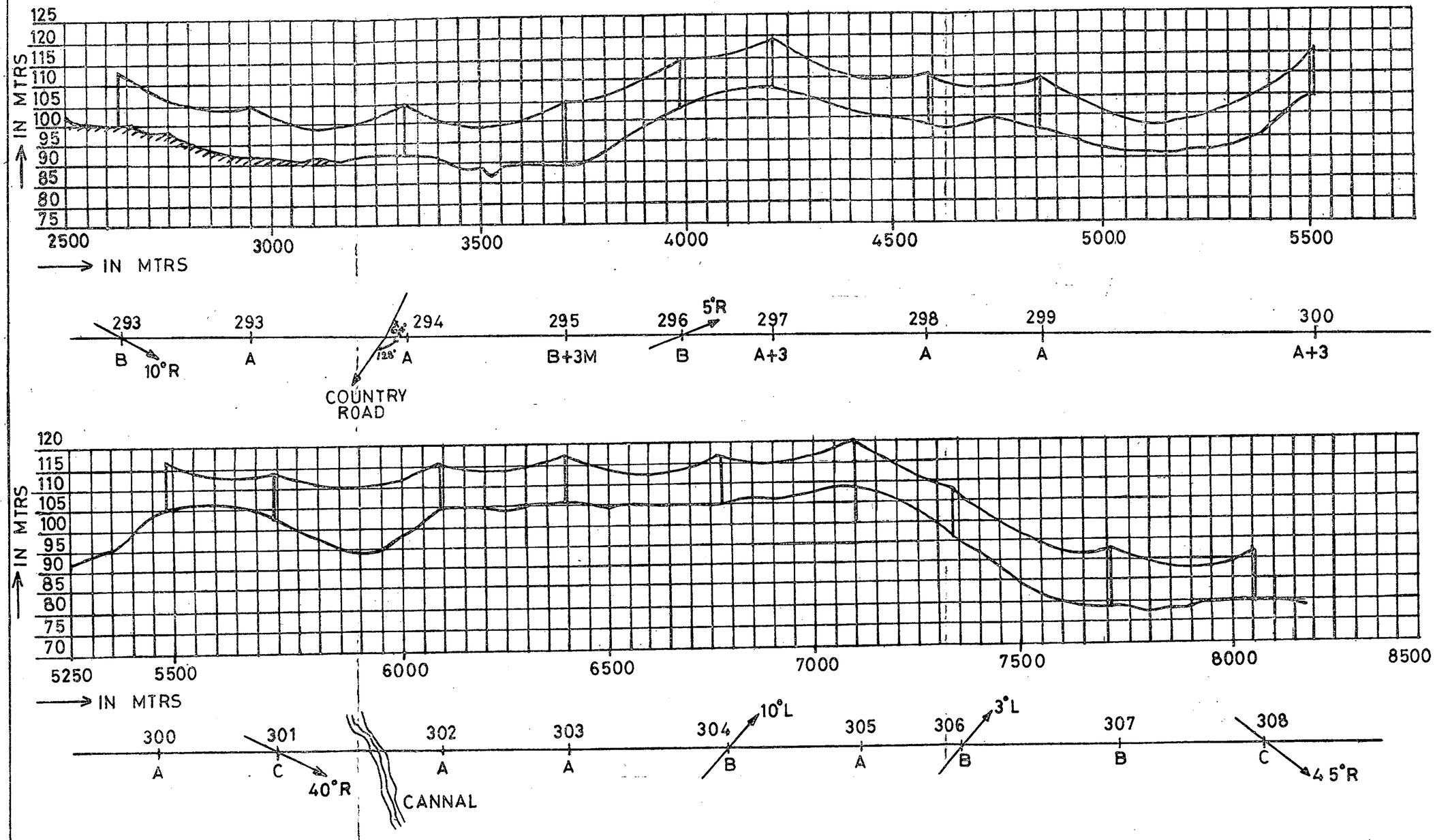
3) Type C : This is a Section Tower (Anchor Tower) designed for 60° deviation. In the normal course these towers are also suitable for dead ends with no angle of deviations and in such cases the same are called 'D' type towers. However special designs for D type towers are possible.

The above designations are adopted in K.E.B. so far. However to be in-line with the practice throughout the country the designations are being changed to A, B, C and D for 2°, 15°, 30° and 60° deviation towers respectively.

3 Mtr. and 6 Mtr. extensions can be used with all the above towers. These are standard towers. Apart from this special towers are used, in locations like river crossings, some of the power line crossings etc. and these towers are designed for specific locations only.

IS 5613 Part II Section 2 clause 5.5 permits the maximum length of section as follows :

FIG-16: A TYPICAL PROFILE SHEET



"Maximum length of section shall not exceed 15 spans or 5 Km in plain terrain and 10 spans or 3 KM in hilly terrain".

NOTE : A 'Section' means number of consecutive spans between two tension points. The individual spans within the sections are called 'intermediate' spans.

The angle points are decided at the time of survey itself and there is little scope to shift the same at the office.

Hence the following procedure is to be adopted for tower spotting.

(1) From the first angle point, plotting the locations of towers may be proceeded, till the next angle point is obtained.

(2) Check whether the last span, i.e. the span between the last tangent tower in the section to the second angle location is in the range of normal span.

(3) If this span is considerably less, find out the towers in the section which has the sum of adjascent spans less than twice the normal span. The tower plotting may be redone using suitable extension towers (either 3 mtr. or 6 mtr. extension pieces as the case may be), increasing the adjascent spans, duly maintaining the allowable limits of wind span and weight spans. Find out whether the last span can be reduced to Zero by this exercise.

(4) If it is found that the above is not possible, re-adjust all the spans in such a way that by introducing an additional tower all the spans are as nearly equal as possible. This will always provide higher ground clearance than necessary.

(5) In case, it is physically possible to shift the location of the second tension tower to such a position that all the spans are fairly equal, this will be a good proposition.

While performing the above exercise, care should be taken as follows :-

1) All the spans shall be as nearly as possible equal to the normal span.

2) Uplift on suspension towers are avoided. In case uplift is unavoidable it shall be examined whether the same can be overcome by adding standard 3 mtr. or 6 mtr. extensions, failing which tension towers (B-15, B-30 or C) shall be provided.

3) The total weight of structures between two angle points shall be minimum.

The final tower positions and the conductor profile shall be traced on the profile sheet. The type of tower, angle of deviation etc. shall be clearly marked. The type of soil found at the tower locations shall be indicated such as 'marshy'; 'black cotton', 'rock', 'laterite' etc.

The route plan of the line shall also be shown in the profile sheet duly indicating the important features such as road crossings, buildings or other objects the Engineer in-charge feels necessary.

A typical profile sheet is shown in Figure-16.

It shall be noted that applying of template is a job that must be carefully done and in case of tower lines the total cost of the line depends on the judicious application of template. Any wrong

assessment of a support height or any infringement in ground clearance will result in serious errors and remains undetected until the conductor erection.

3.05 The maximum number of consecutive spans between the section points shall be decided keeping the upper limit mentioned in clause 5.5 of IS. 5613 Part II Section 2 quoted above. However, it is preferable to limit the number of spans between sections as follows from the point of view of ease in erection.

(1)	400 kV lines	—	10 Spans.
(2)	220 kV lines	—	12 Spans.
(3)	110 kV lines	—	12 Spans.
(4)	66 kV lines	—	15 Spans.

A Section point shall be taken to comprise of either B–15, or B–30 or 'C' type of towers.

3.06 The individual spans should be as near to the normal span as possible. In case it becomes too short with normal tower due to undulations in profile 3 mtr. or 6 mtr. extensions shall be provided for one or both the supports as may be required.

3.07 ROAD CROSSINGS :

The spans at all important road crossings should be selected such that even under maximum conductor temperatures (Hot Template Curve), the required minimum ground clearance shall be available over the roads even in case of a broken wire condition in the adjascent spans.

At all National Highway crossings, tension towers with double tension strings shall be used on both sides of the crossing span and the crossing span shall not exceed 250 mtr. Wherever double tension strings are not provided, road guardings are required.

3.08 RIVER CROSSINGS :

In case of major river crossings, special towers, suspension type shall be used with double suspension strings and anchor towers (balancing towers) on either side shall be used. A typical arrangement is shown in Fig.17. Clearances required by the Navigation Authority shall be provided. For Non-navigable rivers, clearances shall be reckoned with respect to Highest flood level.

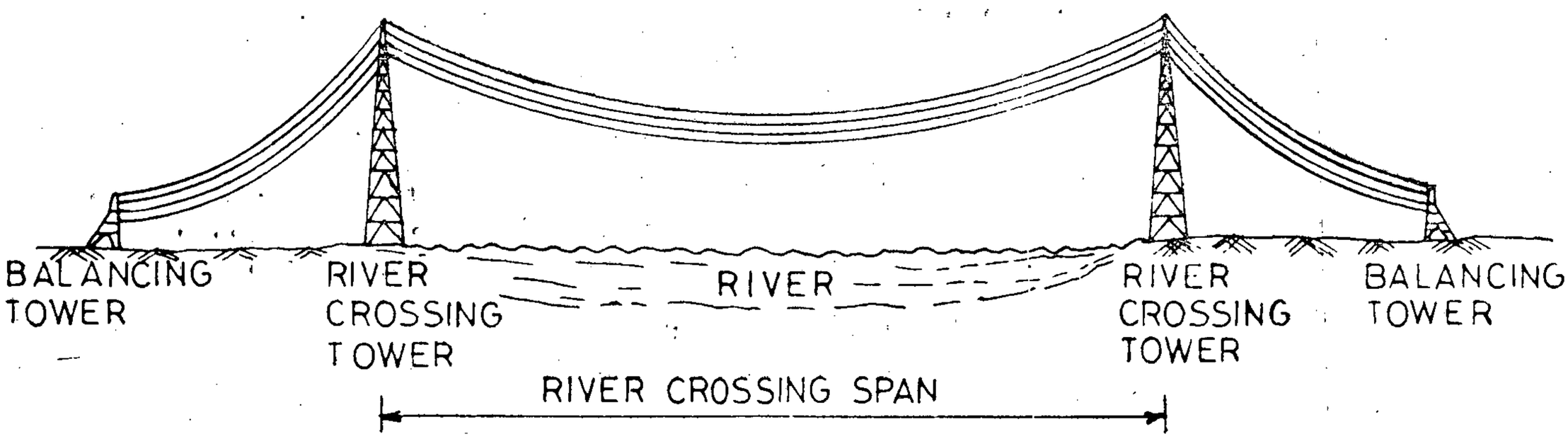


FIG – 17

3.09 RAILWAY CROSSINGS :

Railway crossings shall be provided with A, B or C type towers on either side with double suspension/tension strings, depending on the merits of each case and shall be constructed in conformity with the specifications laid down by the Railway Authorities vide Appendix-A

3.10 POWER LINE CROSSINGS :

Whenever the line has to cross a Power line of equal or lower voltage class, suspension towers with suitable extension shall be used. The clearances required are indicated in Appendix-B. It will be necessary to measure the height of ground wire and the top conductor of the line being crossed at the point of crossing. The angle of inclination of the wires from two points distant 'L' apart and at the same level perpendicular to the line shall be measured with a Theodolite and the height computed as follows.

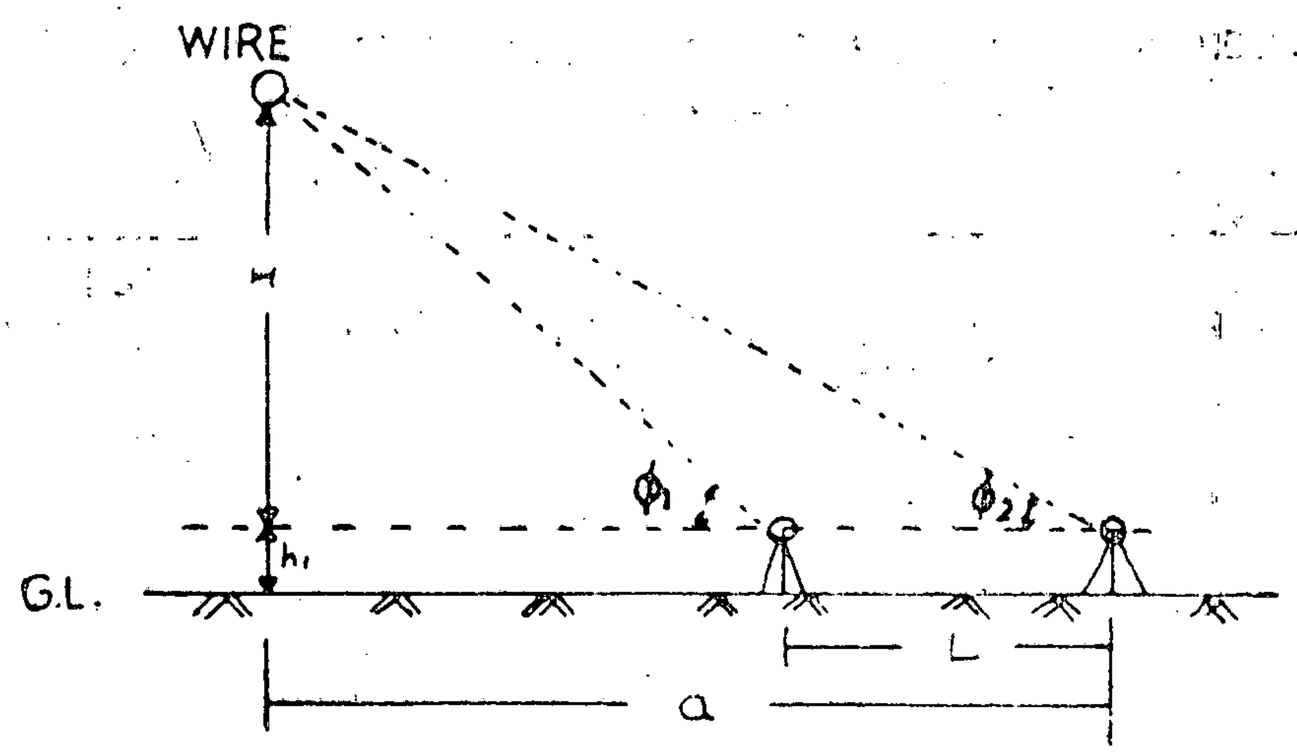


FIG-18

$$\text{Height } H = \frac{L.\ \text{Tan}\ \phi_1}{(\text{Tan}\phi_1).\ (\text{Cot}\ \phi_2)-1}$$

Height of wire above GL = H + h1 Where h1 is the difference between the ground at crossing point and the Theodolite station with the height of telescope added.

3.11 TELECOMMUNICATION LINE CROSSINGS :

The angle of crossing should be as near to 90° as possible. In exceptionally difficult situations, deviation to an extent of 30° may be permitted with the approval of Telecommunication Authorities. The power line supports should be as near to the telecom lines as possible to obtain increased vertical clearance between the wires.

3.12 PREPARATION OF TOWER SCHEDULE :

The Tower Schedule serves two important purposes.

(1) This will form the basis for the Material Management and purchase sections to order/ allot the required number of Towers, Insulators, Conductors and other hardware.

(2) This in conjuction with route plan and profile sheets shall be the guide for construction Sub-divisions for erection of line.

This will be the important link between the Office Organisations and the Construction Staff.

The tower schedules shall be prepared in the following format.

TABLE-4

TOWER SCHEDULE FOR (220/110/66) KV (DC/SC) LINE BETWEEN (STATION NAME) AND (STATION NAME).

CONDUCTOR : NORMAL SPAN :

Tower Location No. (1)	Type (2)	Angle of Deviation (3)	Insulator Type & No. of strings (4)	Span (5)	Soil encountered. (6)	Remarks (7)

Column (1) shall contain the location Nos. serially from the first station.

Column (2) shall contain the type of tower such as A, B15, B30, C, D, or special tower, and the extensions if required such as + 3 or + 6.

For eg : B15 + 3 extension means 15° deviation tower with 3 mtr. extension.

It may be noted that 'D' type towers are dead-end towers used only on both ends of the line. Angle of deviation towards the line shall be zero, i.e. the axis of tower joining the cross-arm tips shall be perpendicular to the line.

The dead end towers are preferably located within 50 to 75 mtr. from the line take off gauntry at station switchyard. However relaxation of this condition is possible with the consent of design office.

3.13 CO-ORDINATION OF SURVEY SUB-DIVISION, OFFICE AND CONSTRUCTION SUB-DIVISIONS :

The Survey sub-division after having completed all the above initial field works and the office works, shall pass on the essential information from office to the Construction Sub-divisions entrusted with the erection work.

A file shall be opened immediately after the profile sheets, route map and tower schedules are approved by the Competent Authority, as follows.

TABLE-5

.....SURVEY SUB DIVISION FILE NO.....

DATE OF SURVEY COMMENCED ON : DATE SENT :

COMPLETED ON :

NAME OF LINE : VOLTAGE : No. OF CIRCUITS :

Sl. No.	Particulars	No. of sheets	No. of copies	Date	Signature
1.	Route Map				
2.	Profile Sheets				
3.	Tower Schedule				
4.	Tree Schedule				
5.	Special Towers, foundations etc. required.				
6.	Detailed estimate of materials required.				
7.	Railway, Telephone, Road crossings.				
8.	Any other information.				

It is the responsibility of the Assistant Engineer and the Asst. Executive Engineers of Survey Sub-divisions engaged in the work to put up all the information pertaining to his section in the file with the date of entry and his initials.

When the file is complete, the work is ready to commence and sent to the Construction Sub-division for further action.

If any items are missing, a covering memo should be sent explaining the reason for such omission and giving information as to when the missing items will be sent, of if they are not required.

"THE SUCCESS OR FAILURE OF ANY
CONSTRUCTION JOB DEPENDS ENTIRELY ON
THIS. HUNDREDS OF MANHOURS CAN BE
WASTED IF INSUFFICIENT OR INADEQUATE
INFORMATION IS PASSED-ON TO
CONSTRUCTION SUB-DIVISIONS."

CHAPTER 4

TOWER FOUNDATIONS

4.01 COMPONENTS OF FOUNDATIONS AND THEIR FUNCTIONS :

The broad based lattice type of towers have independent foundations for each leg. The foundations are designed either with plain cement concrete or reinforced cement concrete as the circumstances require. The various components of foundation are shown in Fig. 19.

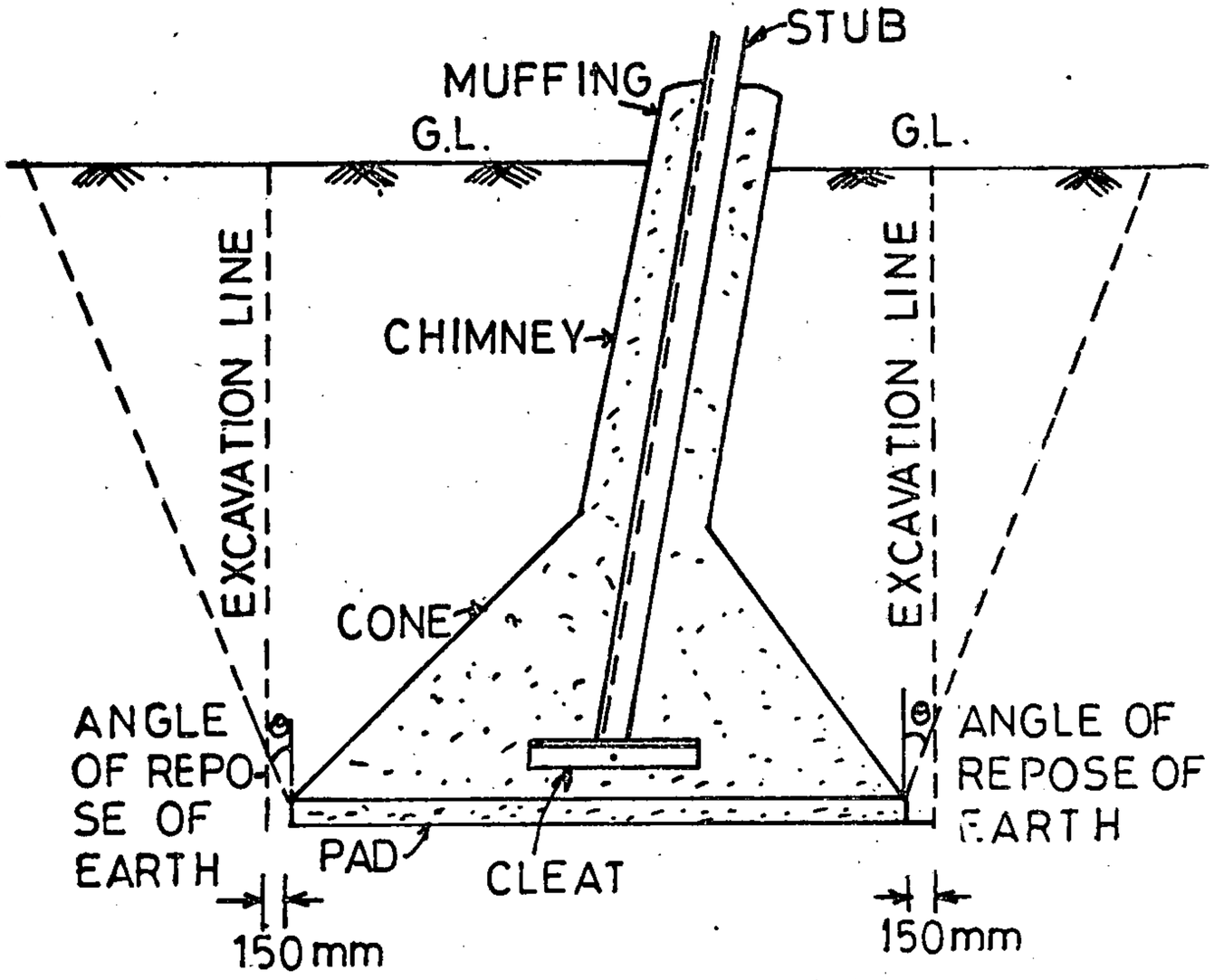
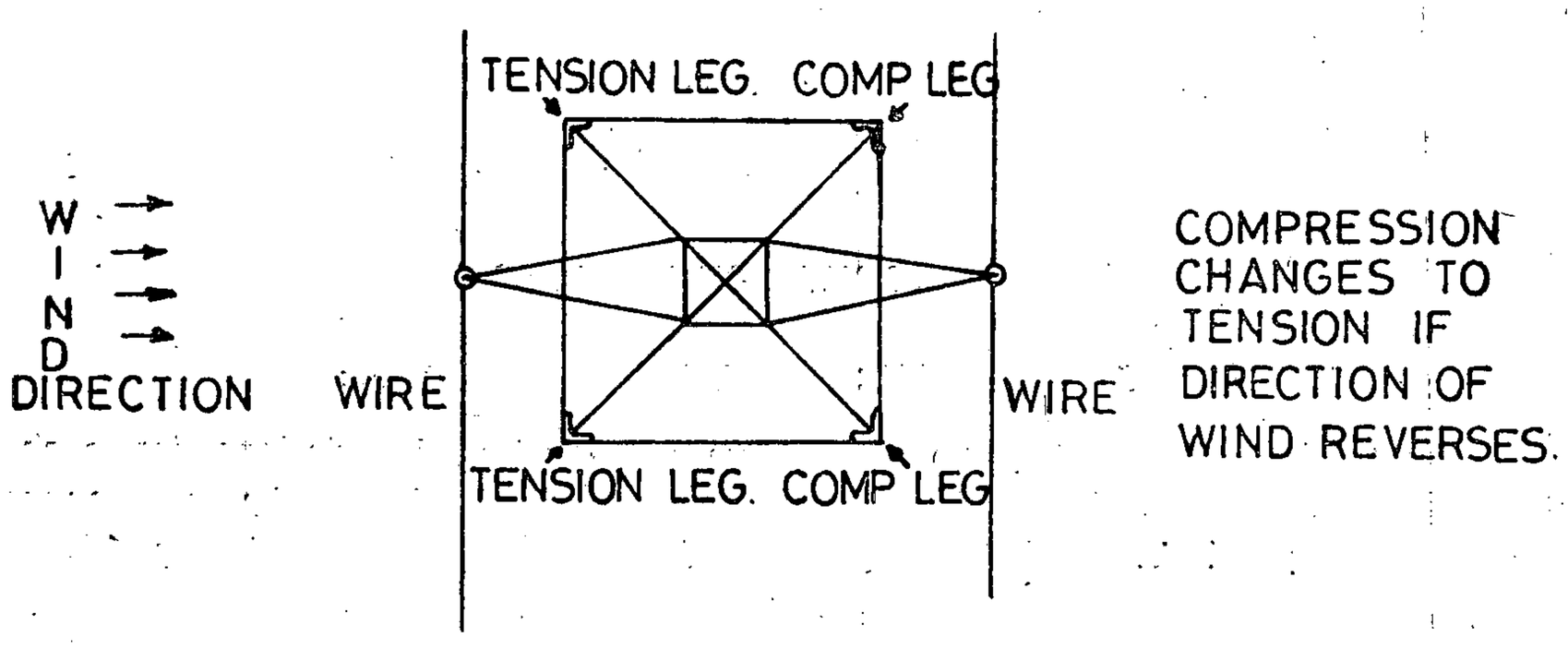


FIG -19 A TYPICAL DIAGRAM OF FOUNDATION

The Four legs of the Transmission line tower transfer the wind and other loads coming on the tower to the ground. The two legs of the tower coming towards the angle of the line in case of anchor towers as shown in the Figure 20, will have compressive force and the other two legs will carry tensile force. Similarly the two legs towards the line in a dead-end tower will carry Compressive force and the remaining two legs will carry tensile force. All the four legs of the suspension tower without any angle of deviation, and no-wind condition will carry compressive force. Depending on the direction of wind two of the legs will have tensile force and the compressive force on the other two legs increase. This is illustrated in Fig. 20.

TANGENT TOWER



ANCHOR TOWER (WITH ANGLE)

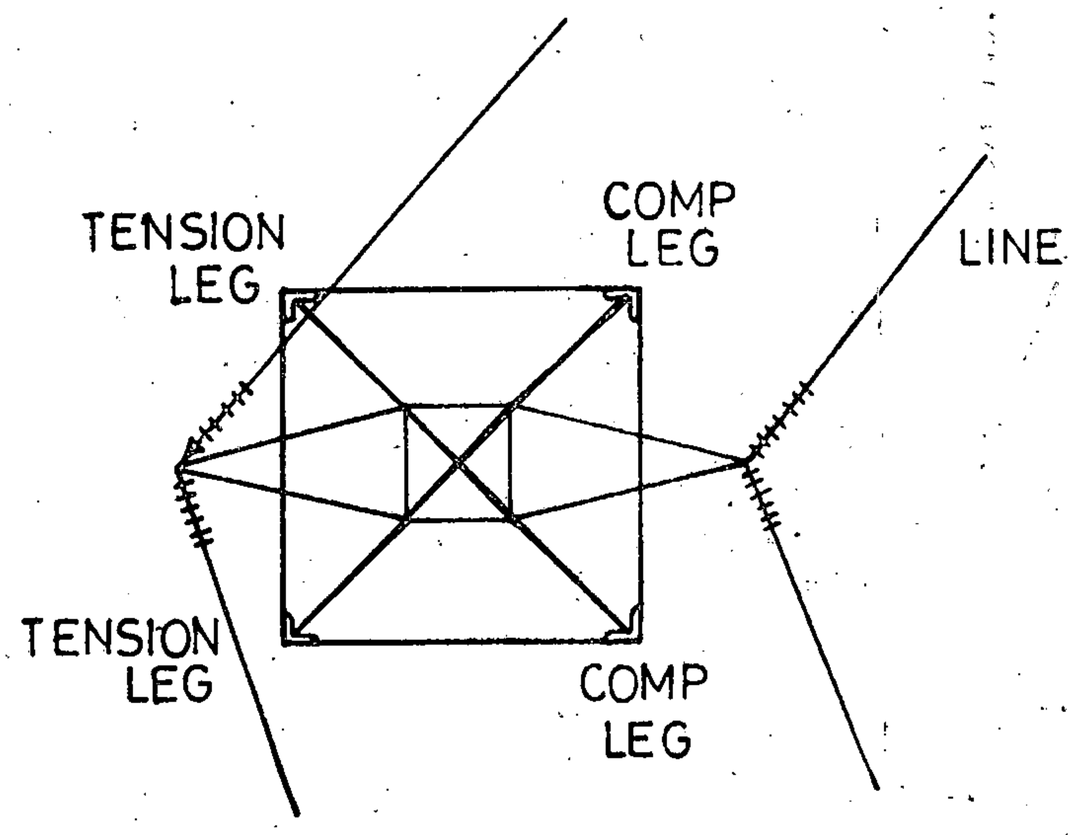


FIG – 20

The legs carrying compressive force induce thrust on the foundation. The effect of this is an attempt to sink the foundation. The soil in effect, produces a reaction to sustain the thrust. The capacity of the soil to sustain the thrust coming on it is termed as "SOIL BEARING CAPACITY".

The legs carrying Tensile force try to pull out of the foundation, up-rooting the tower. Sufficient counter-weight, exceeding the tensile force is necessary to hold the legs in position. This counter–weight is provided by the dead-weight of concrete and the weight of earth above it.

The various components of the foundation, viz., the pad, the cone (also called the pyramid), the Chimney, and the muffing are shown in the Fig. 19. The function of these components are as follcws :

1) THE PAD : This prepares the surface of soil to evenly take and distribute the load and the thrust uniformly. This is constructed to a minimum thickness of 50 mm with 1 : 3 : 6 concrete mix.

2) THE CONE : The thrust transferred from the leg-member through the stub on to the soil is to be distributed uniformly over the soil and the stress intensity on soil in the extreme loading condition should be well within the safe-bearing capacity of the soil. The cone provides this necessary area. In the process of transfer of thrust, the cone is subjected to bending stresses caused due to the reaction offered by the soil. This determines the thickness of the cone at various positions. Unless otherwise stated in the relevant drawings, the cone shall be of structural concrete of ratio 1 : 2 : 4. The cone also provides a counter–weight on the legs carrying tensile force, by its own weight and the weight of the soil above it. All the weight of the soil above the cone and the weight of the soil adjacent to the cone at an angle of repose depending on the nature of soil will counter the tensile force. The cone has to take the load of all the earth above it and is designed accordingly.

3) THE CHIMNEY :– The Chimney, together with the cone will aid distribution of forces from the leg-member through the stubs to the earth. The structural concrete of ratio 1 : 2 : 4 develops bondage with the stub and its safe value is usually more than 6 kg. per Sq cm. of the area of stub angle with adequate factor of safety insde concrete. The chimney and cone have to function as one unit and homogenity is an essentiality. In case of the presence of any shear plane between the two, the bond strength of stub inside cone will be insufficient and the chimney with stub will be pulled out from the earth due to the tensile forces.

4) MUFFING : The muffing provides the necessary strength to the stub, below the first panel which is subjected to both bending and dynamic loads ; and is designed accordingly. This will also be of 1 : 2 : 4 ratio cement concrete unless otherwise stated in the drawing.

All the components of the foundation have vital functions to perform and very important. None of them can be omitted or altered without weakening the design or strength of the tower which should be noted.

4.02 CLASSIFICATION OF FOUNDATIONS :

The foundation design shall depend on the type of soil, Sub soil water level and the of presence surface water in various locations, classified as follows :

1) Normal Dry : The foundation to be used in normal dry cohesive or non-cohesive soils.

2) Wet : The foundation to be used where subsoil water rises in the pit upto 1.5 mtr. below ground level ; or where there is water over the ground for long periods but does not penetrate beyond 1 mtr.. below ground such as paddy fields.

3) Partially submerged : The foundation to be used where water rises in the pit upto 0.75 m below ground level.

4) Submerged : The foundation to be used where sub-soil water rises in the pit within 0.75 mtr. below ground level.

5) Black Cotton Soil : The foundation to be used at locations where soil is clay type, not necessarily black in colour, which shrinks when dry and swells when wet, resulting in differential movement extending to a maximum depth of about 3.5 mtr. below ground level.

6) Soft Rock : The foundation to be used where decomposed or fissured rock, hard gravel, kankar, lime stone, or any other soil of similar nature is met.

7) Hard Rock : The foundation to be used at locations where chiselling, drilling and blasting are required.

8) Laterite : The foundation to be used at locations where hard laterite soil is encountered.

The correct foundation drawings approved for each type of above foundations shall be used in these locations.

4.03 The Engineer-in-charge of Construction work shall satisfy himself as to the correct type of foundation to be adopted for each location. In cases where difficulty arises with regard to the classification of soil for any particular location the properties of soil are to be got investigated in the nearest laboratory where facility is available.

APPENDIX 'C' gives the general guidelines required for soil investigation and testing.

4.04 CHECK SURVEY :

The Engineer-in-charge of construction should conduct a rough check on detailed survey and locate the peg mark and the tower positions on ground, conforming to approved profile sheets. In this process he shall mark the pit centres according to foundation drawings. The levels, up or down, of each pit centres with respect to the centre of tower location should be noted and recorded for determining the amount of pending or earth work required to meet the design requirement of foundation.. Fig. 21. shows a typical pit marking of tower.

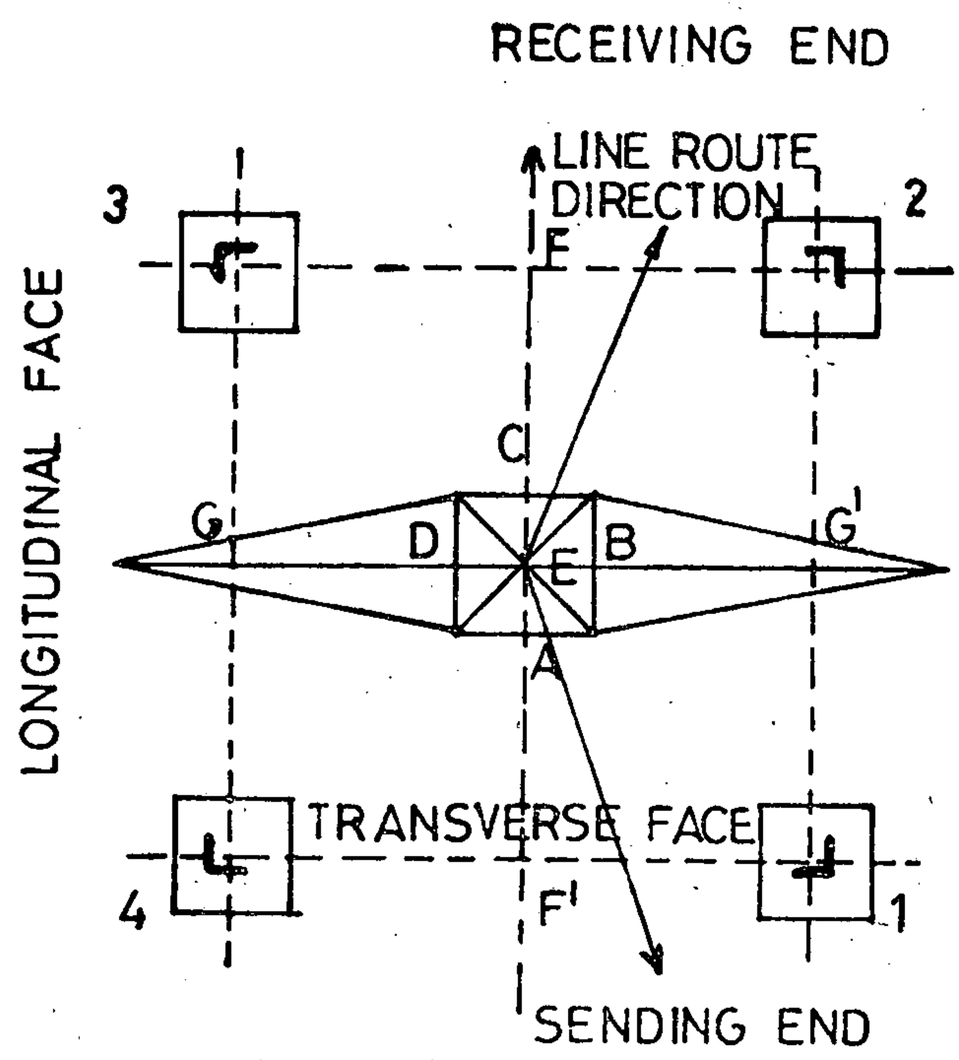


FIG - 21

1, 2, 3 & 4 represent legs or pit Nos. 1, 2, 3 & 4 respectively.

A & B represent nearside (NS) transverse and longitudinal faces.

C & D represent Far side (FS) transverse and longitudinal faces.

4.05 EXCAVATIONS :

Before any excavation is commenced for tower foundations, careful pegging must be carried out to avoid mistakes.

The following shall be carefully noted :

(a) The point at which a tower leg enters the ground is NOT the centre of excavation.

(b) The width between tower legs increases for 3 mtr. and 6 mtr. extension towers compared to Normal towers.

(c) The cross arms of B-15 B-30 and C type towers shall BISECT THE ANGLE BETWEEN THE ADJASCENT INTERMEDIATE SPANS.

(d) The cross arms of A type towers with angles up to 2° shall BISECT THE ANGLE BETWEEN ADJASCENT INTERMEDIATE SPANS.

(e) The cross arms of A type towers for straight run are placed at right angles to the line route.

The first operation is to check the centre and line pegs already put in during survey. The instrument is set over Peg 'E' and directed to the line Peg F.

With a square base tower, the telescope is turned through 45° to locate Peg 2. The distance E-2 from the foundation drawing is carefully set-off and the peg driven in. In a similar manner, pegs 3, 4 and 1 are located and pegged. These pegs are on the extreme corners of the excavations for tower legs. The actual sizes of the excavations are then marked off.

Similarly a number of methods can be devised to fix the pit markings. One of the other useful methods is to fix the theodolite at E. Two pegs F and F' are marked in line with the line alignment for suspension towers. Two pegs G and G' are marked at 90° to FF' with the help of theodolite making it a square of distance FF', the length being equal to the centre distance of foundation pit plus width of one foundation pit. The pegs E,F,F,' G and G' are the five pegs required at each location and these can be made out of iron rod, 300 mm long driven into the ground and fixed rigidly using cement concrete around them so that they will not be disturbed.

The actual sizes of excavations are then marked off.

It is important that these are taken to the correct size, and shape for foundations under construction. Excavations shall be generally picked and shoveled and the depths should be carefully checked.

4 05.01 Where rock is encountered it should be removed by explosives, and the work supervised by a competent person, fully conversant with the handling of the explosives.

The blasting of a rock support foundation consist of four separate operations as follows :

(a) Drilling of holes to hold explosive charge.

(b) Preparing explosive charge.

(c) Charging of drilled holes.

(d) Firing the charge.

The quantity of explosives usually required for transmission line construction is small. However if large quantities are required to be stored, adequate precautions should be taken as per clauses 116 to 128 of Chapter VI Part I of the explosive rules 1983.

a) DRILLING OF HOLES TO HOLD EXPLOSIVE CHARGE :

Since transportation of compressors and Pneumatic drilling is difficult at tower locations, hand drilling is recommended. The hand drilling equipment generally consists of a set of 'JUMPERS' which are usually made of 22mm dia hexagonal steel bars 3 to 4 feet long and suitably shaped. They must be tempered when sharpened to withstand the abrasion of the rock. The services of a local blacksmith may be obtained for the same. A 2-5 kg. hammer is used for striking the jumper, which is given a slight rotation after each blow.

(b) PREPARING EXPLOSIVE CHARGE :

The cartridges of suitable diameter are selected. The detonator shall be of low tension

class. Carefully open the paper at one end of the cartridge and make a little round hole in the explosive with a stick. Gently press the detonator into the hole untll it is completely embedded. Wrap the cartridge paper round the detonator leads and tie lightly with a piece of cord. This prevents the withdrawal of the detonator when charging the bore hole.

(c) CHARGING OF DRILLED HOLES :

Insert cartridges one at a time and press firmly home with a wooden stick called 'Tamping Rod', care being taken that no debris gets between the cartridges. When all the explosive charge has been put in the bore hole, insert the primer cartridge and press gently home with the Tamping Rod until it is in contact with the rest of the charge. Hold the detonator leads to one side so that they are not damaged in the subsequent operations. Put some loose earth or clay in the hole and press gently for the first few cm., then add parts of clay or earth and press home so that the hole is firmly packed.

(d) FIRING THE CHARGE :

The detonator leads are first connected to the exploder cable and a good connection is essential. The cable and detonator leads are bared for 6 to 7 cm, cleaned and joined, and the joint insulated. While this work is being done, all leads and the handle must be removed from the exploder which is located in a sheltered spot. To fire the shot, the exploder handle is turned at a high speed.

MISFIRED SHOTS :

(a) Never touch a misfired shot.

(b) Do not approach a misfired shot until 15 minutes have elapsed and all connections and handle removed from the exploder.

(c) Drill a second hole at a safe distance from the first and in such a direction as will keep the boring tool clear off the first hole.

(d) Charge this hole and fire the shot.

(e) Search the debris thoroughly for unexploded detonator and cartridges.

BLASTING NEAR BUILDINGS :

When blasting near buildings additional care should be taken to prevent debris from flying and destroying property. Holes should not be over-charged and drill shallow holes and take out the rock in two shifts. Before firing the shots, tree branches should be placed over the area of the shot hloes and bags of loose earth placed on top of these. This prevents the rock fragments from flying.

4.05,02 EXCAVATION IN SAND

Excavation in sand must be handled very carefully and timber shuttering should be started and continued down with the excavation.

4.06 STUB SETTING AND CONCRETING OF FOUNDATIONS :

The assembly of adjustable stub setting template and setting is a VERY IMPORTANT JOB and requires great care. Inaccuracies which creep in, in the dimensions and levels play havoc at the time of tower erection. Mismatch of members always occur due to inaccuracies and secondary stresses in members are created due to forced matching at the time of tower erection resulting in failure of towers when loaded. Hence the Assistant Engineer, in his own interest shall personally check the levels and dimensions at this stage. Erection of tower can also be made faster if stub setting is made accurately.

The Adjustable Stub Setting Template is assembled completely as per relevant drawings, put into position, packed up, and provisionally levelled with a spirit level. The diagonal dimensions are measured with strings and made equal. The stub angles and cleats, duly assembled, are bolted to the template and these bolts are fully tightened. The assembly is placed in position and suitable supports are given to the same. The template is then carefully centred to the strings from the line pegs and levelled up.

All the diagonal and side measurements marked on the template drawings shall be carefully made at this stage and levelling done with a dumpy level and staff and NOT a spirit level. Packing pieces are put in until the template is truly level when the levelling staff is placed at each corner. Correct alignment is carried out by 0.9 kg. plump bob, four in number, hung from the centre of horizontal bracing.

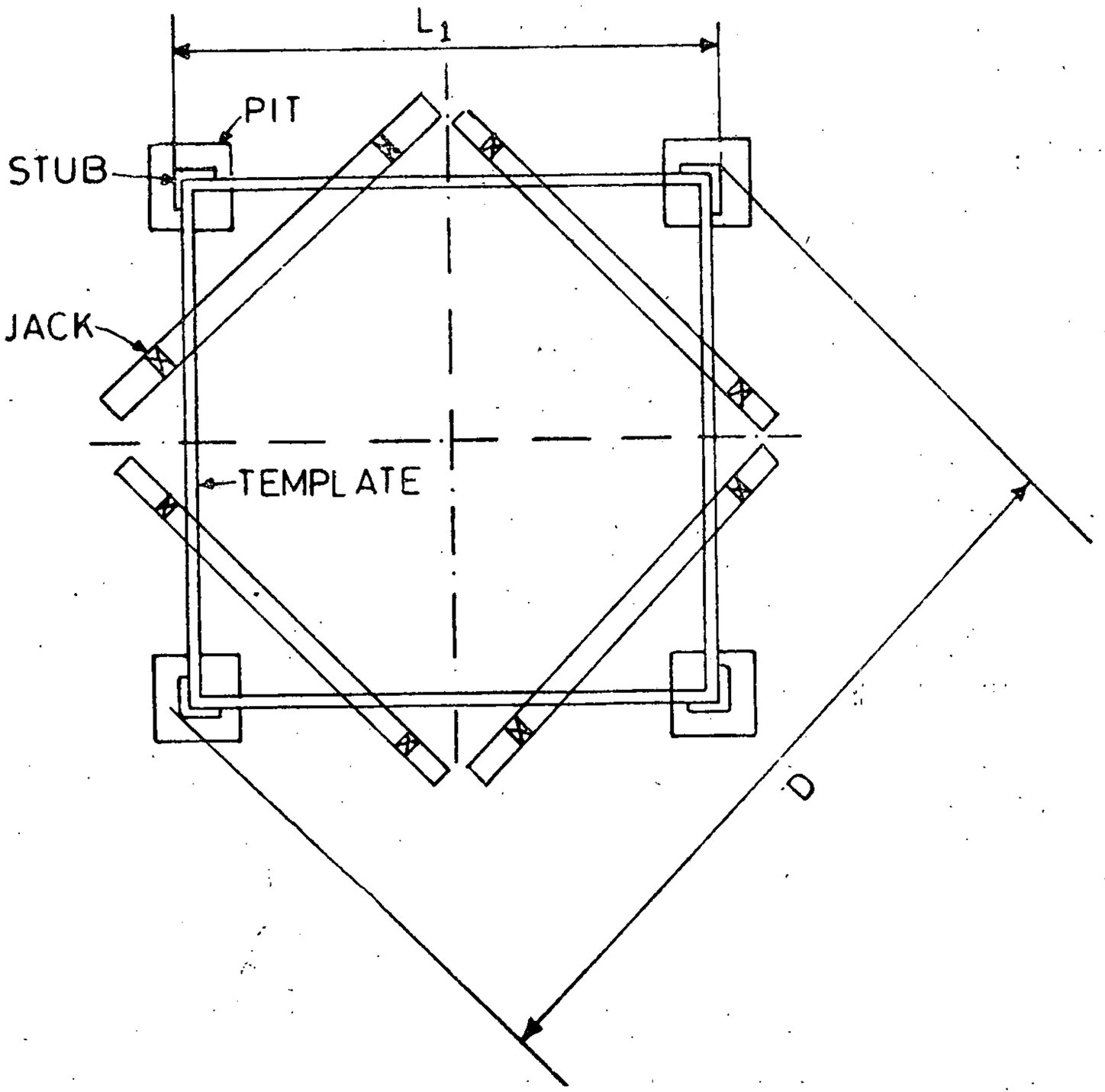


FIG-22:

Following is the step by step procedure for sub setting :

(1) Assemble the template as per the correct drawing.

(2) Set the template as per the drawing.

(3) Place it such that the corners are in the centre of the pits excavated.

(4) Place the stub setting jacks below the template. Jacks shall be placed as close to the pit edges as possible. Keep wooden logs on the jack so that the template rests on the logs.

(5) Align template, along with the line and centre it over the centre point of location.

(6) Fix the stub assembly to the template and with the help of a dumpy level, level the template corners to the required level.

(7) Ensure that all four stubs are at the same level.

(8) Check again the alignment and centering of the template.

(9) By placing on 4 to 8 screw jacks according to the length of template horizontal member with a level instrument and staff sighted and firm adjustment made by lift/lowering of the screw jack, the top bolt of the stub member can be perfectly levelled. This ensures 100 percent verticality. For ensuring all towers in one line and across arms at right angle to it, 4 plumb bobs should be dropped from the centre of the horizontal member of the template to correspond to the cross pegs and alignment pegs given during the alignment survey for tower centre.

4.07 It should be remembered that the templates are actually 'Adjustable Stub Setting Templates,, and a mere assembly of the same without a proper check of the dimensions is not allowed. Time spent on correct adjustments and alignment is not a waste since there will be considerable saving n time at the time of tower erection. Further the tower itself will be in danger if improper adjustments are made in the template.

Never attempt stub setting without a correct template. Some engineers prefer to erect the first stage of the tower itself before stub setting. This is very dangerous and never be resorted to.

4.08 ALLOWABLE TOLERANCES :

IS. 5613 Part II Section 2 allows the following tolerances in stub setting.

(1) Difference in elavation between identical parts of any two stub angles shall not exceed 1/1000 of the horizontal distance between the stubs, allowance being made for the difference if any, in the lengths of legs and extensions.

(2) The actual elevation of any stub angle shall not differ from the computed elevation by more than 1/100 of foundation depth.

(3) Stub angles shall be located horizontally so that each is within 6 mm. of its correct position, and the batter of the stub angle shall not differ from the correct batter by more than either by 1/100 of exposed stub length, or by the amount of play as offered by the clearance between-bolts and holes of the template.

(4) If actual elevation of stubs is beyond 6 cm. as found after casting the foundation and on the plus side (that is the foundation is raised) equivalent depth of earth work will be provided over the top of the foundation as per the design requirements with particular reference to such location.

By design requirements, it is meant, that earth required to resist uplift forces.

(5) The following tolerances shall be applicable in case of position of foundation as a whole with reference to the tower position as spotted on the profile sheet (Survey Chart).

TYPE OF TOWER	OUT OF ALIGN-MENT	FROM CL OF ROUTE	FROM TRANS CENTRE LINE
Suspension or intermediate.	0.5°	± 25 mm.	± 250 mm.
Section or Tension (Set at bisection of deviation angle).	0.5°	± 25 mm.	± 25 mm.

4.09 COLLAPSED PITS :

In case of collapsed pits, the template may not be fitted on jacks, the same shall be assembled with stubs resting over 1 : 2:4 plain cement concrete blocks in comparatively green condition cast at site with a 300 mm or 450 mm square base and a depth equal to the designed concrete cover under stub. The sides of the blocks shall be rough cast while the top shall be smooth, and for this purpose these may be cast in wetted pits made in ground. These blocks shall remain in position and shall form integral part ot foundation concrete. The templates shall remain in position for not less than 24 hours.

4.10 CONCRETING

Unless otherwise stated in the foundation drawings, the concrete mix shall be M 150 or 1 : 2 : 4 mix cement concrete. In case it is found that the pit excavation has been for more than the required depths, the extra depths thus excavated shall be concreted with M 100 or 1 : 3 : 6 concrete in addition to the concrete used for the foundations as per drawings. In no case the pyramid shall start from depths lower than the one shown in the drawings.

The correct form boxes conforming to shape, lines and dimensions shown on design drawings shall be used. These shall be rigid during placement of concrete and compacting and shall be sufficiently tight to prevent loss of liquid from concrete. It shall be of light design, easily removable without distortions and shall be of steel or hard wood. The inner suface coming in contact with concrete shall be free from projections. Window on one face shall be provided for pyramid forms to facilitate concreting in the lower parts which shall be fixed after concrete in the bottom part is placed. A Typical form box is shown in the Figure furnished at the end of this manual.

Skilled masons should be employed for concreting the pyramid using appropriate form boxes, and care should be taken by the engineer incharge to satisfy himself with the dimensions and shape of pyramid along with the quality of work.

All rubbish, particularly chippings, shavings, traces of concrete etc. if any shall be removed from the interior of form boxes before concrete is placed. The surface in contact with concrete shall be wetted and sprayed with fine sand.

The concrete shall be proportioned as follows :

(a) Prepare a wooden measuring box of 35 litre capacity (that is equal to 1 bag or 50 kg. of cement) with inside dimensions of (not exceeding) 30 × 30 × 30 cm or alternatively 34 cm dia and 39 cm. height. The mix quantities according to the measuring box shall be as follows.

	M.150 (1:2:4)	M.100 (1:3:6)
Cement	1 bag	1 bag
Sand	2 boxes	3 boxes
Jelly	4 boxes	6 boxes
Water	1 box less 3 litres	1 box less 1 litre

In the above, one bag of cement is taken to contain 50 kg or 35 litres of ordinary portland cement.

(b) Measurement of water shall be made with separate water tight drums of the above size or with 1 or 2 litre mugs. For concreting the bored foundations by displacing the drilling muds, 10 percent extra cement in mix is required.

The concrete after being mixed shall be placed and compacted before setting commences A concrete mixer will be very helpful. The concrete shall be laid in 150 mm layers and consolidated well so that the cement cream works upto the top and no honey combing is left in the concrete. The vibrator will be very helpful. However in case of the the non-availability of the vibrator, manual compaction should be made. After compacting the chimney and muffing portion, the top surface should be finished smooth with a slight slope towards the outer edge to drain off any rain water falling on the coping.

As a guide for compacting, 16mm. dia poking bars may be worked 100 times in an area of 200mm. square for 300 mm depth. Over compacting should be avoided since the same causes the liquid to flow out upward causing segrgation.

After the form box is removed, if the concrete surface is found to be defective, the damage shall be repaired with rich cement and sand mortar. The maximum tolerance on the dimensions shall be ±5 mm. This shall not be accumlative on height of various components of foundation.

Afrer concreting is done the contents shall be checked for hair line cracks as follows. Pour two to three buckets of water slowly on the top of concrete and observe for water seepage for about three to four hours. If seepage of water is observed. then concreting is to be redone.

CAUTION :- When stub setting is being carried out, avoid blasting of rock in the nearby location since the vibrations caused by the blasting may induce error in the stub setting.

4.11 PROCEDURE WHEN REMOVING FORM BOX :

Under fair weather conditions (generally where average daily temperature is 20° C or above) and where ordinary cement is used, form boxes may be removed after 24 hours of the placing of concrete. In dull weather (such as rainy periods) and very cold temperature the form boxes may be removed after 48 hours of placing of concrete.

4.12 The jelly used shall be 40 mm nominal size for slab/pyramid concrete and 20 mm nominal size for chimney concrete. The sand used shall be coarse variety with maximum particle size of 4.75 mm.

4.13 BACK FILLING AND CONSOLIDATION :

Following opening of form boxes and repairs to the foundation concrete if required, the back filling shall be started. Back filling shall be done with excavated soil. Care shall be taken that back filled earth is started from inner ends of the pits towards the outer ends. The adjustable stub setting templates shall be removed only after the pits have been back filled to half depth. All the surplus soil shall be deposited around each of the tower legs uniformly over the pits including the residual sand, jelly and concrete waste lying around if any. Any shortfall in back fill soil should be met with normal soil from suitable borrow pits.

The back filling materials should be clean and free from organic or other foreign materials. The earth shall be deposited in 200 mm layers, levelled had wetted and tamped properly before another layer is deposited.

Some engineers prefer to remove the adjustable stub setting template only after the back filling is complete. This is a very good practice.

The back filling and grading shall be carried to an elevation about 75 mm above the finished ground level to drain out water. After back filling, a 50 mm high earthen embankment (bandh) will be made along the sides of excavation pits and sufficient water will be poured in the back filled earth for atleast 24 hours.

4.14 CURING :

The concrete, after setting for 24 hours old shall be cured by keeping the concrete wet continuously for a period of 10 days after laying. The pit may be back filled with selected earth sprinkled with necessary amount of water and well consolidated in layers not exceeding 150 mm of consolidated thickness after a minimum period of 24 hours and thereafter both the back filled earth and muffing shall be kept wet for the remainder of the prescribed time of 10 days. The muffing shall be kept wet by providing empty cement bags dipped in water fully wrapped around the concrete for curing ensuring that the bags are kept wet by frequent pouring of water on them.

4.15 PROTECTION OF TOWER FOOTING :

Suitable measures, at the discretion of the Engineer incharge shall be taken to protect the foundations close to nallahs, riverbeds, etc. by providing revetments packed with boulders.

4.16 EARTHING :

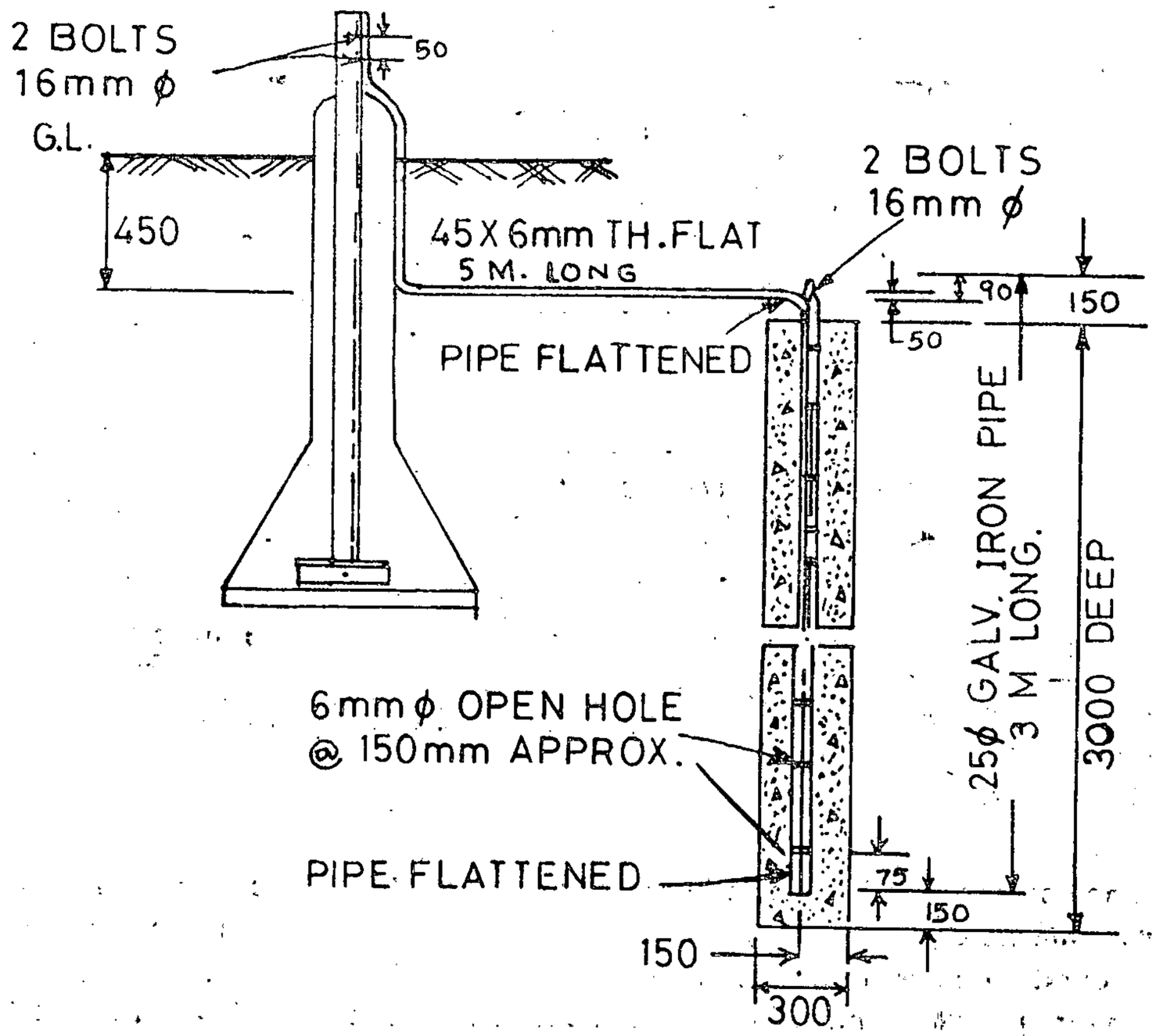


FIG-23: A TYPICAL EXAMPLE OF EARTHING EQUIPMENT

MATERIALS LIST

QUANTITY	DESCRIPTION	LENGTH mm	WEIGHT kg
1.	25mmϕ bore G.I. Pipe	3000	11·88
2.	45X6mm M.S. Flat	5000	15·50
3.	16mmϕ bolt with nuts	38	—
4.	16mmϕ bolt with nut	To suit stub	—
5.	Plain washer for 16 ϕ bolts	—	0·16

NOTE: (1) All ferrous parts are hot dip galvanised.
(2) In case of difficult location horizontal or slant laying of pipe and laying within the tower base or foundation pit shall be permissible.

The details of pipe type earthing and counterpoise earthing to be provided as necessary are shown in Fig. No. 23 and Fig. No. 24 reproduced from IS. 5613 Part II Section–2. Earth strips shall be fixed to the stub during concreting of the chimney and taken out horizontally below ground level. In normal circumstances the earth strip shall be provided on No. 1 stub leg, i.e. the leg with step bolts.

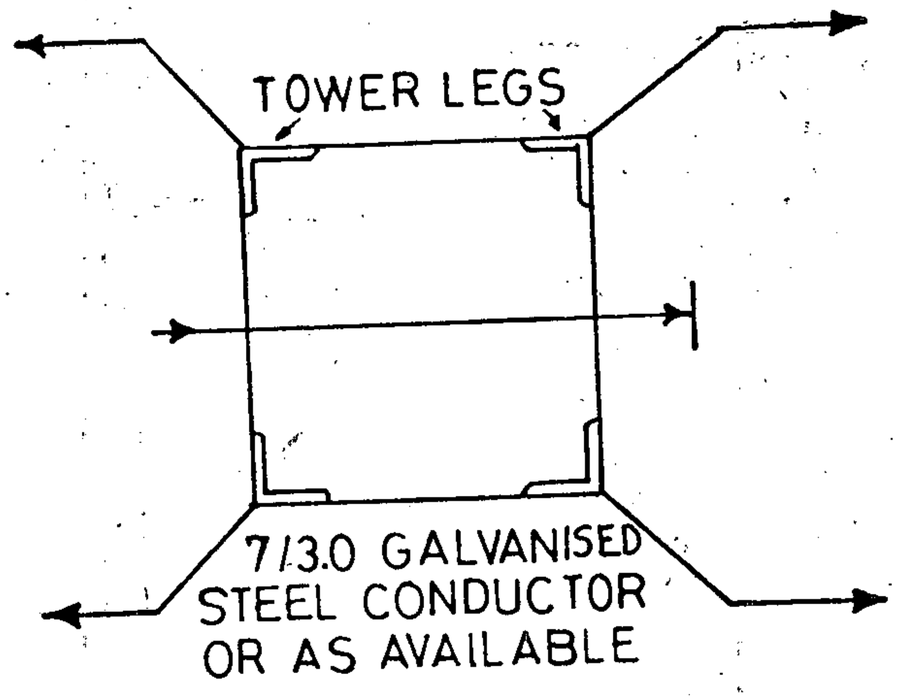


FIG-24 : TYPICAL EXAMPLE OF COUNTERPOISE TYPE OF EARTHING OF TOWER.

The resistance of the earth electrode shall not exceed 10 ohms. In case the resistance exceeds 10 ohms. multiple pipe earthing or counterpoise earthing shall be provided, without interfering the foundation concrete even through the earth strip/counterpoise lead remains exposed at the tower end. The connections in such case shall be made with existing lattice member holes on legs just above the chimney top.

The counterpoise earth consists of four lengths of galvanised steel stranded wires, each fitted with a lug for connection to the tower leg at one end. The wires are connected to each of the legs and taken radially away from the tower and embedded horizontally 450 mm below ground level. The length of each wire is limited to 15 mtr. but may be increased if resistance requirements are not met. The size of the galvanised steel standard wire shall be of the same sizee of earth conductor.

4.17 TOOLS AND TACKLE :

The following is the standard list of tools and tackle required for stub setting and foundations for each party.

1)	Adjustable stub setting template	....	1 Set.
2)	Required size spanners.	....	6 Nos each.
3)	Hammer - 0.9 Kg (2lb)	....	2 Nos.
4)	Sledge hammer 4.5 Kg (10 lb)	....	2 Nos.
5)	Crow bar 1.8 mtr. (6 ft.)	....	4 Nos.
6)	Brass plumb bob 0.45 Kg (1 lb)	....	6 Nos.
7)	Screw jack on wooden flat of size 20 cm × 5 cm × 3.75/5 cm.	....	8 Nos.
8)	Bucket	....	6 Nos.
9)	Cane basket.	....	12 Nos.
10)	Manilla Rope 3.8 cm.	....	150 Mtr.
11)	G.I. Plain sheet	....	12 Nos.
12)	Shovel	....	6 Nos.
13)	Pick axe	....	12 Nos.
14)	Kodali.	....	12 Nos.
15)	High carbon drilling bar for rocky locations	....	6 Nos.
16)	Rock blasting detonator, geliguli, cable etc.	....	6 Nos.
17)	Dewatering pipe, 7.6. cm. suction 5 cm. delivery 5 HP. engine driven pumpset for submerged/ partially submerged locations.	....	2 Nos.
18)	Diesel operated panel vibrator.	....	2 Nos.
19)	Concrete mixer—diesel engine driven. 0.08 to 0.14 Cu. mtr.	....	2 Nos.
20)	Water tank trailer.	....	1 No.

21)	Theodolite	....	1 No.
22)	Level and shaft	....	2 Nos.
23)	Survey umbrella	....	2 Nos.
24)	Steel rod ladder 3.7 mtr.	....	2 Nos.
25)	Engineers' spirit level	....	2 Nos.
26)	Steel piano wire	....	30 Mtr.
27)	Measuring boxes for concrete	....	2 Nos.

CHAPTER 5

TOWER ERECTION

5 01.01 TOWER CONFIGURATION :

The configuration of transmission towers are arrived based on the following conditions :

(1) Minimum ground clearance required for bottom conductor.

(2) Live metal clearance required for all conductors.

(3) Sheilding angle viz, the angle between the vertical from ground wire and the line joining the ground wire and power conductor, in vertical plane.

(4) Tower height considerations from ground level.

(5) Length of cross arms and phase spacings.

(6) Bracing pattern adopted.

(7) Mid span clearance between Ground wire and Top conductor. Several types of tower contigurations are in use, such as 'H' frame with two ground wires, Corset type towers with two Ground wires, Pylons with one or two ground wires, etc. Various conductor configurations such as Delta, Vertical, Horizontal, Right angle are in use. Each configuration has its own merits, for instance the H frame and corset type towers have more coverage for lightnings. The Delta formation of conductors have fairly equal impedences between phases.

5.01.02 ACCOUNTING OF TOWERS AND SORTING OF TOWER PARTS AT STORES AND RESPONSIBILITIES OF THE STORE KEEPER :

Tower sets are made up in steel sections. It is impracticable for the corner angles to be in one length. The code No. of each member is punched on the member. The same is also marked in indelible ink. The tower sets should be carefully checked when unloaded from the trucks and placed in a suitable position on the bay from where they can be picked up easily as a complete unit. The steel sections are usually delivered in bundles and checking is very important. It is not a good practice to lay the steel sections in members. It is always advisible to layout in towers, even though this is a little tedious. It should be remembered by the store keeper that considerable amount of time can be saved in sorting out and transporting to site if the sections are laid in towers. This will also facilitate the Store Keeper and others concerned to easily spot the shortages. All bolts, nuts, washers and other small parts like pack plates, hangers etc. should be in bags, marked with the number of the tower to which they are intended.

A word of warning regarding handling of long angles : These must be carefully transported or else they may get bent or twisted and it is a very difficult job to straighten without damaging the painting/galvanising.

The accounting of tower parts shall be made in code numbers and not in tonnages. A separate page shall be opened for each code number and the total No. of such parts required per tower shall be marked on the top of the page.

Many times, the tower parts will be despatched by the firm partwise. These have to be accounted in a register in relation to the bill of materials. The store keeper has to review the register everytime and with the bill of materials of each type of tower and identify the parts required to constitute complete towers and persue with the supplier for the supply of these parts. The store keeper shall issue all the tower parts required to make complete towers to the construction staff. The extention pieces shall be kept and issued separate from the main towers. Bolts and nuts, washers, required for each type of tower as per bill of materials shall be issued along with the towers.

The Store Keeper has a very vital role to play in the transmission line erection work. He should never hesitate to take pains to properly lay the towers at stores. Each bundle shall constitute one full tower. The speed of tower erection much depends on the store keeper in this regard and he plays a major role in the succes or failure of speediness in construction work. It is also not advisible to transport towers from one store to other which are distant apart unless in emergencies. Not only considerable amount of time and money are spent in such an exercise, but also results in untold difficulty in sorting out the towers and fabricate the missing parts. It is not uncommon that some of the parts are missed during this exercise due to difficulty in having checks at various places.

The tower fabricator should supply the required number of towers in lots of full towers to the nearest store. This cannot be monitored efficiently if proper accounting of each tower part is maintained individually. Care should be taken to fabricate the missing parts when required. The relevant dimensioned drawings shall be supplied by the fabricator well in advance for this purpose. The tower drawings shall be fully dimensioned, duly indicating the distances between holes of each members, edge cuttidg, flange cuts etc. A typical tower drawing is shown in Fig. No. 25.

5.02 ERECTION OF TOWER SUPERSTRUCTURE :

The towers shall be erected on the foundations, not less than 14 days after concreting, or till such time the concrete has acquired full strength. The towers shall be erected strictly as per erection drawings. Each tower member is marked with a code number corresponding to the number shown in the drawing to facilitate easy erection. Any damage to the steel or galvanising should be avoided. No member should be subjected to undue stresses during erection due to mis-fitting by force.

The erection of superstructure is an art by itself. Many accidents have taken place due to malhandling of tower material.

The misfit of tower parts may arise out of ;

1) Improper setting of stubs,

2) Improper numbering of members,

3) Fabrication errors.

The last one is not in the control of the erection engineers. Care should be taken at the fabrication shop to see that the towers are manufactured only as per approved prototypes.

Experienced staff can rectify the defect easily arising out of improper numbering.

No Attempt sould ever be made to somehow erect the tower if improper stub setting is detected. A fresh stub setting shall necessarily be made to avoid failures.

To some extent, fabrication errors can be rectified with difficulty if the magnitude of error is small. Otherwise these parts shall be totally rejected.

In the earlier tower designs, there was a little flexibility available due to higher margin of safety factor and higher assumptions of loadings on towers.

As the technology has advanced, more realistic estimation of loads has become possible and the workmanship of fabrication has improved to such an extent that the factor of safety on towers is safely reduced from 2.5 to 2 in Normal condition. The more realistic estimation of loads and the correct analysis of stresses in members using computers has resulted in further light towers. The following typical comparison indicates how tower design technology has advanced, resulting in economics.

220 kV D/C towers with Drake ACSR.	Year in which designs are developed.	Tower Weights.		
		A	B–30	C
Sharavathi–Shimoga–Bangalore line	1960	6 tons	11 tons	16 tons
Shimoga-Mysore line.	1982	3.83 tons	6.37 tons	8.9 tons

The advance in tower design technology over two decades can be seen from the above.

AN IMPORTANT POINT TO NOTE :

The strength of tower depends on how correctly the same is erected. The towers designed today, if they are correctly erected as per accepted practice, can be more stronger than an incorrctly errected tower of older design. Some of the towers of older design have not failed inspite of a number of missing/stolen members. This is because the ultimate designed loads of these towers have never appeared on the structures, the design assumptions being on the higher side than the actual loads to which they are subjected to in their present locations. By these observations the erection engineers should not become overconfident in erection of the present day towers since the towers designed in these days will very likely collapse under such circumstances.

5.03 For speedy erection of towers the following shall be adhered to ;

1) Way leave for a series of 6 to 7 towers are obtained in advance.
2) Picking up and transport of tower material along with accessories as per bill of materials to the location.
3) Detailed study of the structural drawing shall be made by all the concerned well in advance.
4) Atleast 25% of the labour employed shall be skilled.
5) The erection work should preferably start around sunrise.

There are four main methods for erection of steel transmission towers

(i) Built up method : applicable for heavy towers.
(ii) Section method : applicable for medium size towers.
(iii) Ground assembly method : applicable for lighter towers.
(iv) Helicopter method.

Among the above the fourth method has not yet made its advent in this country so far. The other three methods are described below.

(i) BUILT UP METHOD : The method is generally in practice everywhere. As the name implies the method consists of building the tower member by member The tower members are kept on ground serially according to erection sequence to avoid search or time loss. The erection progresses from the bottom upwards. The four main corner leg members of the first section of the tower are first erected and guyed off. Tne cross braces are then assembled on the ground and the assembly is raised as a unit and bolted to the already erected corner legs. The first section is thus built and horizontal struts if any are bolted in position. For assembling the second section of the tower, a light gin pole is placed on the top of one of the corner legs for raising parts of the second section of tower. The leg members and braces of this section are then hoisted and assembled. The gin pole is then shifted to the corner leg member on the top of the second section of the tower in position for assembly. Gin pole is thus moved up as the tower grows. This process is continued till the complete tower is erected.

Cross arms are assembled on ground and raised up and fixed to the main body of the tower. For heavier towers, a small boom is rigged on one of the tower legs for hoisting purposes. The members are handled by means of winches or double/trible pulley blocks operated from the ground. In order to maintain speed and efficiency, a party goes ahead of the main erection gang and its purpose is to assemble panels which can be raised as a complete unit and these parts are laid down on the ground in correct position in readiness for erection.

ii) SECTION METHOD : In this method major sections of the tower are assembled on the ground and the same are erected as units. Either a mobile crane or a gin pole fabricated out of steel pipes is used. The gin pole used is approximately 10 mtr. long and is held

in place by means of the guys by the side of the tower to be erected. The two opposite sides of the lower section of the tower are assembled on the ground. Each assembled. side is then lifted clear off the ground with gin or derrick and is lowered into position and bolted to stubs or anchor bolts. The two opposite sides are then laced together with cross member and diagonals. The assembled section is lined up, made square with the line and levelled. The proper elevation levelling are determined with a transit. After completing the first section, gin pole is set on the top of the first section. The foot of the gin rides on a look over a strut on the tower immediately below the leg joint. The gin pole then has to be properly raked and guyed into position. The first face of the second section is raised. To raise the second face of this section, it is necessary to slide the foot of the gin on the strut to opposite of the tower. After the two opposite faces are raised, the lacings on the other sides are bolted up. The last lift raises the top of the tower. After the tower top is placed and all lacings have been bolted up all the guys are thrown off except one which is to be used to lower the gin pole. In some cases the complete one face of the tower can be assembled on the ground, hoisted and supported in position. The opposite face is similarly assembled and hoisted, and then the bracing angles connecting the two faces are fitted.

iii) GROUND ASSEMBLY METHOD : This method is suitable for very light towers. The tower shall be assembled on the ground and erected as a complete unit. The complete tower is assembled in a horizontal position on the level ground at some distance from the tower footing. The tower shall be assembled in a line-wise position to allow the cross arm to be fitted. On sloping ground, however, elaborate packing of the low side is essential before assembly commences. After the assembly is complete, the tower is picked up from the ground with the help of a crane or a derrick and set on its foundation. This method is suitable for 33kV towers and similar smaller towers.

5.04 TIGHTENING OF NUTS AND PUNCHING OF THREADS :

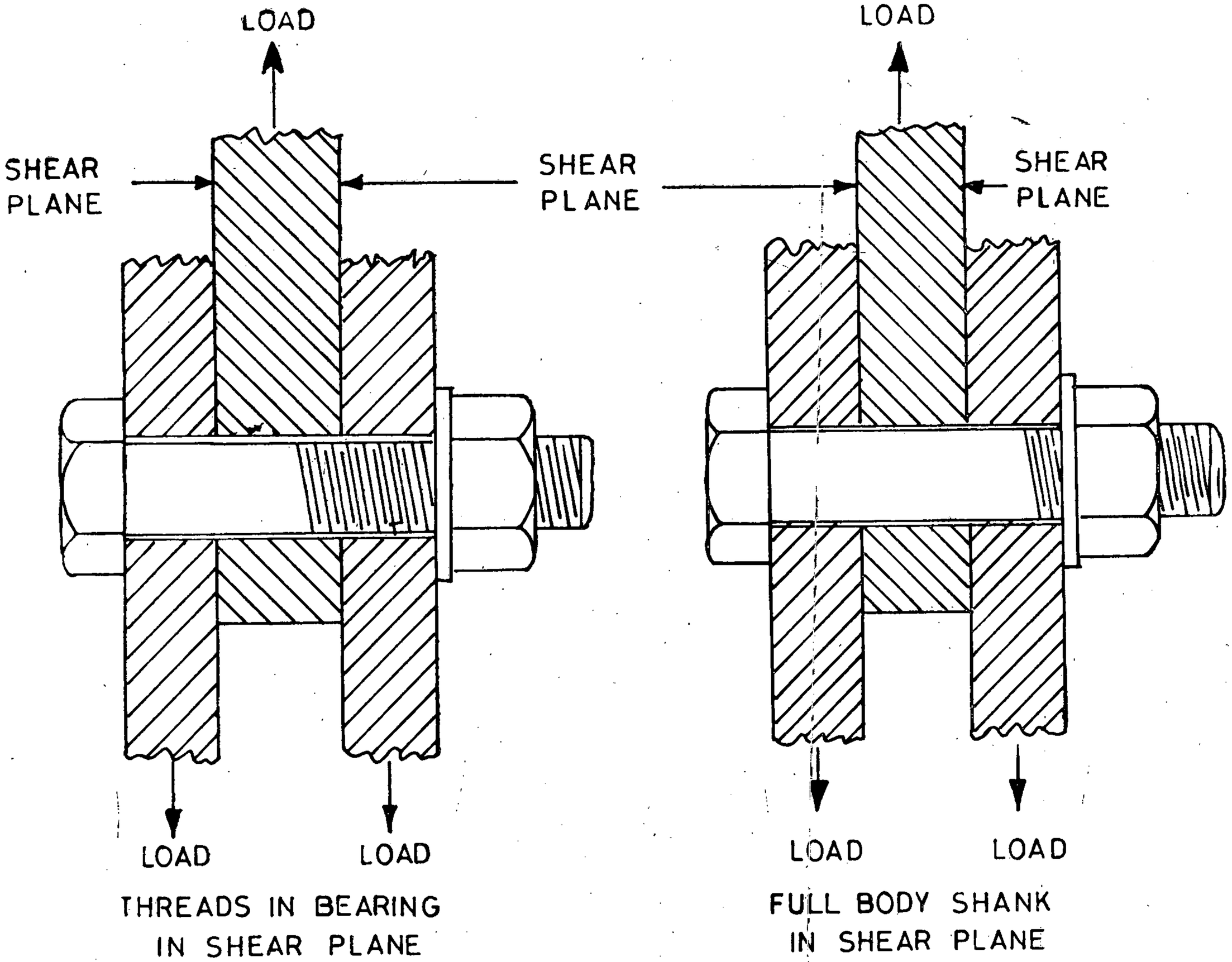
This is one of the most important items of tower construction and must be carefully and systematically carried out. All nuts should be tightened properly using correct size spanners. Before tightening, it should be ensured that filler washers and plates are placed in relevant gaps between members, bolts of proper size and length are inserted and one spring washer is inserted under each nut. It should be ensured that the threads do not fall on the members connected.

Four erectors, one on each leg shall be deployed. Each erector shall tighten the bolts and nuts on the leg for which he is deployed and in addition he will tighten all the bolts and nuts on the panel to the right of him. With an experienced gang this is usually well done, but with scratch gangs, bolts are often missed. To ensure that this does not occur, each erector should use a different coloured chalk and mark each bolt after tightening. This will enable to identify the bolts which have been missed.

In case of step bolts, spring washer shall be placed under the outer nut.

The tightening shall be progressively carried out from the top downwards, care being taken that all bolts at every level are tightened simultaneously.

The correct and incorrect methods of using bolts are shown as follows.



THREADS IN BEARING IN SHEAR PLANE (WRONG USAGE)

FULL BODY SHANK IN SHEAR PLANE (RIGHT USAGE)

EFFECT OF BOLT THREAD IN BEARING UNDER SHEAR JOINT LOADING

The threads of bolts projecting outside nut shall be punched at three positions on the diameter to ensure that nuts are not loosened in course of time. If during tightening a nut is found to be slipping or running over the bolt threads, the bolt, together with the nut shall be changed outright.

If the towers are not galvanised, the joints of all contact surfaces are generally cleaned and painted with a coat of aluminium or zinc—rich paint. For galvanised towers, this is not necessary except for lines in coastal regions. In addition the bolts and nuts in all joints upto 3 mtr. height above tower base shall be welded after final tightening. After welding, the same shall be painted with either aluminium or zinc—rich paints.

5.05 A NOTE OF WARNING :

(1) The tower is continuously subjected to dynamic vibrations of frequency varying from 1.5 to 3 HZ due to wind on tower and conductor vibrations. This has an adverse effect on the bolts and nuts which tend to loosen in course of time. The effect may be disasterous. Hence care should be taken to fully tighten the bolts and nuts. It is recommended that Torque—wrenches are used to apply the specified torque on bolts and nuts as recommended by the manufacturers of bolts and nuts. The G.K.W. has recommended the following tightening torques for bolting their bolts conforming to IS, 6639.

12 mm. dia bolts (M12)	.... 4.1 Kgf-mtr.
16 mm. dia bolts (M16)	.... 10 4 Kgf-mtr.
20 mm, dia bolts (M20)	.... 20.0 Kgf-mtr.

(2) Straining of members to bring them into position is not permitted. Tommy bars of not more than 450 mm long shall only be used to match the holes at joints.

(3) All plan bracings shall be fitted in position before the assembly of upper section starts.

(4) Blank holes, if any left, after complete erection of the tower, are to be filled up with bolts and nuts of correct size.

5 06 PAINTING : (in case of painted structures) :

The structurals are usually supplied duly painted with one coat of protective paints Another coat of red-oxide or any other primer shall be applied before the application of finishing coat. The specified number of finishing coats shall then be applied one after the other the later coat being applied only after the earlier coat completely dries up. Painting shall not be carried out damp or wet surfaces, early morning painting shall be avoided. Work shall preferably be carried out in dry and sufficiently warm weather, and shall progress from the top downwards. The brush shall be thoroughly worked into connections so that all gaps are filled in and sealed from the effect of weather.

5.07 MAXIMUM PERMISSIBLE TOLERANCES IN TOWER ERECTION :

IS. 5613 Part II Section-2 specifies the following maximum permissible tolerances in tower erection.

(1) No member of tower shall be out of straightness by more than 1 in 1000. Members

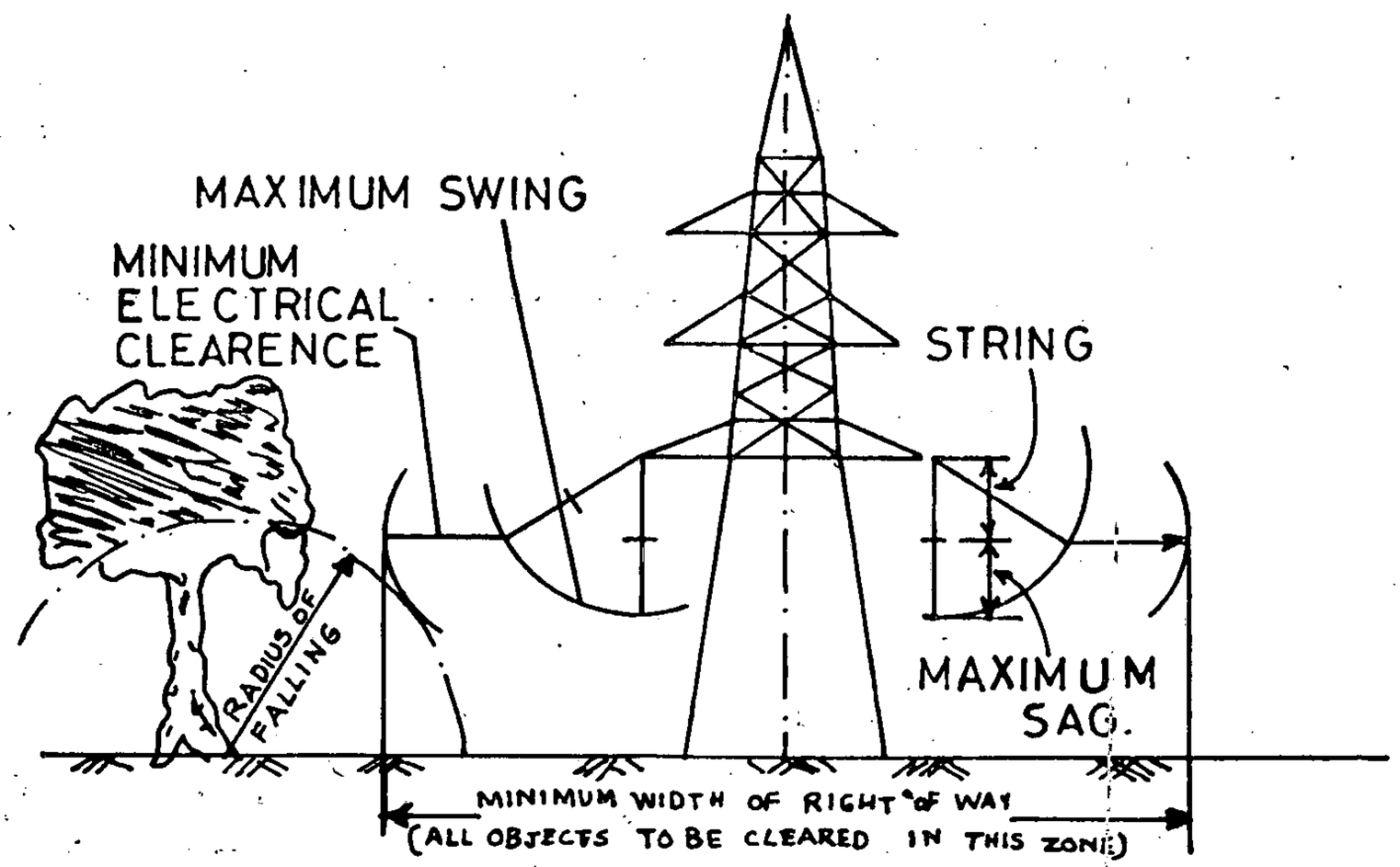
failing this requirement shall be straightened before erection in a manner that shall not damage their properties or the protective finish.

(2) The tower shall not be out of vertical by more than 1 in 360 before stringing is carried out.

5.08 LINE CORRIDOR : The width of the line corridor required for various transmission lines are indicated below.

Sl. No.	Voltage Class	Width of corridar (Right of Way) in Mtr.
1	66 kV	18 mtr,
2	110 kV	22 mtr.
3	220 kV	35 mtr.
4	400 kV	52 mtr.

Fig 26. shows the line clearance requirement for the construction of lines.



NOTE PORTION OF TREE FALLING WITHIN CLEARENCE TO BE LOOPED OR TRIMMED.

FIG-26: LINE CLEARENCE (RIGHT OF WAY) REQUIREMENT

5.09 TOOLS AND TACKLE :

The following are tools and tackle required for tower erection work.

a)	Gin Pole 8 5 to 9 mtr.	....	1 No.
b)	Manilla Rope 1.3 cm. dia. 50 mtr. long.	....	4 Nos.
c)	Manilla Rope 1.9 cm. dia. 30 mtr. long.	....	4 ,,
d)	Single sheave pulley block 102 cm. dia.	....	4 ,,
e)	Double sheave pulley block 10.2 cm. dia.	....	4 ,,
f)	'D' Shackle 7.6 cm.	....	6 ,,
g)	Tommy bars 300 to 450 mm. long.	....	2 Nos.
h)	Hexagonal box-spanner with fixed lever and end of the lever pointed to use as a hole bar.		6 Nos. of each required size.
i)	Bolt punches.	....	6 Nos.
j)	Hammers 5 kg.	....	2 Nos.
k)	Portable tool box	....	1 No.
l)	Tarpaulins.	....	2 Nos.
m)	Wooden sleepers.	....	24 Nos.
n)	Ground stays made from rails or T Sections and painted.	....	6 Nos.
o)	Paint pots and brushes.	....	6 Nos.
p)	Double end spanners of sizes.	....	6 Nos. of each size.
q)	Bolt cutters/Wire cutters	....	2 Nos.
r)	Steel wire with hemp core 18 mm dia.	....	100 mtr.

CHAPTER 6

Stringing of Power conductors and Earthwires (Groundwires)

6.01. Terminology : The terminology of various equipments and procedures associated with the installation of power conductors varies widely. The following terminology based on IEEE 524–1980 is followed throughout this manual. Whenever other terms carrying eqivalent meaning are also in use, the same has also been Included for guidance and corelation between the terms used in usage also.

Anchor—A device that serves as a reliable suport to hold an object firmly in place. The term anchor is normally associated with cone, plate, screw or concrete anchors, but the terms snub, deadman and anchor log are usually associated with pole stubs or logs set or buried in the ground to serve as temporary anchors. The latter are often used at pull and tension sites. Synonyms : anchor log, deadman, snub.

Angle—rool over-For tanget stringing, the sum of the vertical angles between the conductor and the horizontal on both sides of the traveler. Resultants of these angles must be considered when stringing through line angles. Under some stringing conditions, such as stringing large diameter conductor, excessive roll over angles can cause premature failure of a conductor splice if it is allowed to pass over the travelers.

Block—A device designed with one or more single sheaves, a wood or metal shell, and an attachment hook or shackle. When rope is reeved through two of these devices, the assembly is commonly referred to as a block and tackle. A set of 4s refers to a block and tackle arrangement utilizing two 4 inch double sheave blocks to obtain four load bearing lines. Similarly, a set of 5s or a set of 6s refers to the same number of load bearing lines obtained using two 5 inch or two 6 inch double sheave blocks, respectively. Synonyms : set of 4s, set of 5s, set of 6s.

Block, hold down.—A device designed with one or more single groove sheaves to be placed on the conductor and used as a means of holding it down. This device functions essentially as a traveler used in an inverted position. It is normally used in midspan to control conductor uplift caused by stringing tensions, or at splicing locations to control the conductor as it is allowed to rise after splicing is completed. Synonyms : hold down roller, hold down traveler, splice release block.

Block, snatch—A device normally designed with a single sheave, wood or metal shell and hook. One side of the shell usually opens to eliminate the need for threading of the line, Commonly used for lifting loads on a single line or as a device to control the position or direction. or both, of a fall line or pulling line.

Bonded—The mechanical interconnection of conductive parts to maintain a common electrical potential. Synonym : connected.

Bucket—A device designed to be attached to the boom tip of a line truck, crane or aerial lift and support workmen in an elevated working position. It is normally constructed of fiberglass to reduce its physical weight, maintain strength and obtain good dielectric characteristics. Synonym : basket.

Bullwheel—A wheel incorporated as an integral part of a bullwheel puller or tensioner to generate pulling or braking tension on conductors or puling lines, or both, through friction. A puller or tensioner normally has one or more pairs arranged in tandem incorporated in its design. The physical size of the wheels will vary for different designs, but 17 in (43 cm) face widths and diameters of 5ft. (150 cm) are common. The wheels are power driven or retarded and lined with single or multiple groove neoprene or urethane linings. Friction is accomplished by reeving the the pulling line or conductor around the groove of each pair.

Bundle—two conductor, three conductor, four conductor, multiconductor—A circuit phase consisting of more than one conductor. Each conductor of the phase is referred to as a subconductor. A two conductor bundle has two subconductors per phase. These may be arranged in a vertical or horizontal configuration. Similarly, a three conductor bundle has three subconductors per phase. These are usually arranged in a triangular configuration with the vertex of the triangle up or down. A four conductor bundle has four subconductors per phase. These are normally arranged in a square configuration. Although other configurations are possible, those listed are the most common. Synonyms : twin-bundle. tri-bundle, quadbundle.

Cable car—A seat or basket shaped device designed to be suspended by a framework and two or more sheaves arranged in tandem to enable a workman to ride a single conductor, wire or cable. Synonym : cable trolley.

clamp—cable—A device designed to clamp cables together. It consists of a U bolt threaded on both ends, two nuts and a base and is commonly used to make temporary bend back eyes on wire rope. Synonyms : clip, Crosby, Crosby clip.

Clamp—strand restraining. An adjustable circular clamp commonly used to keep the individual strands of a conductor in place and prevent them from spreading when the conductor is cut. Synonyms—Cable binding block, hose clamp, vise grip plier clamp.

Clearance—(1) The condition where a circuit has been deenergized to enable work to be performed more safely. A clearance is normally obtained on a circuit presenting a source of hazard prior to starting work. Synonyms : outage, permit, restriction.

(2) The minimum separation between two conductors, between conductors and supports or other objects, or between conductors and ground, or the clear space between any objects.

Clipping-in—The transferring of sagged conductors from the travelers to their permanent

suspension positions and the installing of the permanent suspension clamps. Synonyms : clamping–in, clipping.

Clipping offset—A calculated distance, measured along the conductor from the plumb mark to a point on the conductor at which the center of the suspension clamp is to be placed. When stringing in rough terrain, clipping offsets may be required to balance the horizontal forces on each suspension structure.

Conductor—A wire or combination of wires not insulated from one another, suitable for carrying an electric current. It may be, however, bare or insulated Synonyms : cable, wire.

Spacering Bicycle—A device designed to carry workmen and ride on sagged bundle conductors, thus enabling them to inspect the conductors for damage and install spacers and dampers where required. These devices may be manual or powered.

Crossing structure—A structure built of poles and, sometimes, rope nets. It is used when–ever conductors are being strung over roads, power lines, communications circuits, highways or railroads and normally constructed in such a way that it will prevent the conductor from falling onto or into any of these facilities in the event of equipment failure, broken pulling lines, loss of tension, etc. Synonyms : guard structure, H—frame, temporary structure, gauntry.

Deenergized—Free from any electric connection to a source of potential difference and from electric charge; not having a potential different from that of the ground. The term is used only with reference to current-carying parts that are sometimes alive (energized). To state that a circuit has been deenergized means that the circuit has been disconnected from all intended electrical sources. However, it could be electrically charged through induction from energized circuits in proximity to it, particularly if the circuits are parallel. Synonym : dead.

Dynamometer—A device designed to measure loads or tension on conductors. Various models of these devices are used to tension guys or sag conductors. Synonyms : load cell.

Energized—Electrically connected to a source of potential difference, or electrically charged so as to have a potential different from that of the ground. Synonyms : alive, current carrying hot, live.

Equipotential—An identical state of electrical potential for two or more items.

Explosives—Mixtures of solids, liquids or a combination of the two which, upon detonation transform almost instantaneously into other products which are mostly gaseous and which occupy much greater volume than the original mixtures. This transformation generates heat which rapidly expands the gases, causing them to exert enormous pressure. Dynamite and Primacord are explosives as manufactured. Explosives are commonly used to build construction roads, blast holes for anchors, structure footings, etc. Synonyms : dynamite, powder.

Grip, Conductor—A device designed to permit the pulling of conductor without splicing on fittings, eyes, etc. It permits the pulling of a continuous conductor where threading is not possible. The designs of these grips vary considerably. The design of the come-along incorporates a bail attached to the body of a clamp which folds to completely surround and envelope the conductor. Bolts are then used to close the clamp and obtain a grip. Synonyms : come–along.

Socks :—A device designed to permit the temporary joining or pulling of conductors without the need of special eyes, links or grips. Synonyms : wire mesh grip.

Grounded—Connected to earth or to some extended conducting body that serves instead of the earth, whether the connection is intentional or accidental.

Ground grid—A system of interconnected bare conductors arranged in a pattern over a specified area and on or buried below the surface of the earth. Normally, it is bonded to ground rods driven around and within its perimeter to increase its grounding capabilities and provide convenient connection points for grounding devices. The primary purpose of the grid is to provide safety for workmen by limiting potential differences within its perimeter to safe levels in case of high currents which could flow if the circuit being worked became energized for any reason or if an adjacent energized circuit faulted. Metallic surface mats and gratings are sometimes utilized for this same purpose. When used, these grids are employed at pull, tension and midspan splice sites. Synonyms : counterpoise, ground gradient mat, ground mat.

Ground, master—A portable device designed to short circuit and connect (bond) a deenergized circuit or piece of equipment, or both, to an electrical ground. Normally located remote from, and on both sides of, the immediate work site. Primarily used to provide safety for personnel during construction, reconstruction or maintenance operations. Synonyms : ground set, ground stick.

Ground, personal.—A portable device designed to connect (bond) a deenergized conductor or piece of equipment, or both, to an electrical ground. Distinguished from a master ground in that it is utilized at the immediate site when work is to be performed on a conductor or piece of equipment which could accidentally become energized. Synonyms : ground stick, red head, working ground.

Ground rod—A rod that is driven into the ground to serve as a ground terminal, such as a galvanized iron rod or galvanized iron pipe Synonym : ground electrode.

Ground, running—A portable device designed to connect a moving conductor or wire rope, or both, to an electrical ground. These devices are normally placed on the conductor or wire rope adjacent to the pulling and tensioning equipment located at either end of a sag section. Primarily used to provide safety for personnel during construction or reconstruction operations. synonyms : ground roller, moving ground, rolling ground, travelling ground.

Ground, structure base—A portable device designed to connect (bond) a metal structure to an electrical ground. Primarily used to provide safety for personnel during construction, reconstruction or maintenance operations. Synonyms : ground chain, structure ground, tower ground.

Ground, traveler—A portable device designed to connect a moving conductor or wire rope, or both, to an electrical ground. Primarily used to provide safety for personnel during construction or reconstruction operations. This device is placed on the traveler (sheave, block, etc) at a strategic location where an electrical ground is required. Synonyms : block-ground, rolling ground, sheave ground.

Hoist—An apparatus for moving a load by the application of a pulling force and not including a car or platform running in guides. These devices are normally designed using roller or link chain and built-in leverage to enable heavy loads to be lifted or pulled. They are often used to deadend a conductor during sagging and clipping in operations and when tensioning guys. Synonyms : chain hoist.

Hook, conductor lifting. A device resembling an open boxing glove designed to permit the lifting of conductors from a position above them. Normally used during clipping-in operations. Suspension clamps are sometimes used for this purpose.

Joint, compression—A tubular compression fitting designed and fabricated from aluminium, copper or steel to join conductors or overhead ground wires. It is usually applied through the use of hydraulic or mechanical presses. However, in some cases, automatic, wedge, and explosive type joints are utilized.

Jumper—(1) The conductor that connects the conductors on opposite sides of a deadend structure. Synonym : deadend loop.

(2) A conductor placed across the clear space between the ends of two conductors or metal pulling lines which are being spliced together. Its purpose then is to act as a shunt to prevent workmen from accidentally placing themselves in series between the two conductors.

Ladder, rope—A ladder having vertical synthetic or manila suspension members and wood, fiber glass or metal rungs. The ladder is suspended from the arm or bridge of a structure to enable workmen to work at the conductor level, hang travelers, perform clipping-in operations, etc.

Ladder, tower—A ladder complete with hooks and safety chains attached to one end of the side rails. These units are normally fabricated from fiberglass, wood or metal. The ladder is suspended from the arm or bridge of a structure to enable workmen to work at the conductor level to hang travellers, perform clipping-in operations, etc. In some cases, these ladders are also used as linemen's platforms. Synonym : hook ladder.

Leader cone—A tapered cone made of rubber, neoprene or polyurethane that is used to lead a conductor splice through the travelers, thus making a smooth transition from the smaller diameter conductor to the larger diameter splice. It is also used at the connection point of the pulling line and running board to assist in a smooth transition of the running board over the travelers, thus significantly reducing the shock loads. Synonyms : nose cone, tapered hose.

Lifter, insulator—A device designed to permit insulators to be lifted in a string to their intended position on a structure. Synonyms : insulator saddle, potty seat.

Line, bull—A high strength line, normally synthetic fiber rope, used for pulling and hoisting large loads.

Line, finger—A lightweight line, normally sisal, manila or synthetic fiber rope, which is placed over the traveller when it is hung. It usually extends from the ground, passes through the

traveler and back to the ground. It is used to thread the end of the pilot line or pulling line over the traveler and eliminates the need for workmen on the structure. These lines are not required if pilot lines are installed when the travelers are hung.

Line, pilot—A lightweight line, normally, synthetic fiber rope, used to pull heavier pulling lines which in turn are used to pull the conductor. Pilot lines may be installed with the aid of finger lines or by helicopter when the insulators and travelers are hung. Synonyms : lead line, leader, P–line, straw line.

Line, pulling—A high strength line, normally synthetic fiber rope or wire rope, used to pull the conduclor. However, on reconstruction jobs where a conductor is being replaced, the old conductor often serves as the pulling line for the new conductor. In such cases, the old condutor must be closely examined for any damage prior to the pulling operations. Synonyms : bull line, hard line, light line, sock line.

Line, safety line—A safety device normally constructed from synthetic fiber rope and designed to be connected between a fixed object and the body belt of a workman working in an elevated position when his regular safety strap cannot be utilized. Synonyms : life line, safety line, scare rope.

Line, tag—A control line, normally manila or synthetic fiber rope, attached to a suspended load to enable a workman to control its movement.

Line, threading—A light weight flexible line, normally manila or synthetic fiber rope, used to lead a conductor through the bullwheels of a tensioner or pulling line through a bullwheel puller. Synonym : bull line.

Link, connector—A rigid link designed to connect pulling lines and conductors together in series. It will not spin and relieve torsional forces. Synonyms : connector, link,

Link, swivel—A swivel device designed to connect pulling lines and conductors together in series or connect one pulling line to the drawbar of a pulling vehicle. The device will spin and help relieve the torsional forces which build in the line or conductor under tension. Synonym : swivel.

Load binder—A toggle device designed to secure loads in a desired position. Normally used to secure loads on mobile equipment. Synonyms : binder, chain binder.

Off road vehicle—A vehicle specifically designed and equipped to traverse sand, swamps, muddy tundra or rough mountainous terrain. Vehicles falling into this category are usually all wheel drive or tracked units. In some cases, units equipped with special air bag rollers having a soft footprint are utilized.

Overhead groundwire (lightning protection). Multiple grounded wire or wires placed above phase conductors for the purpose of intercepting direct strokes in order to protect the phase conductors from the direct strokes. Synonyms : earth wire, shield wire, skywire, static wire.

Platform, aerial—A device designed to be attached to the boom tip of a crane or aerial lift and support a workman in an elevated working position. Platforms may be constructed with

surrounding railings, fabricated from aluminum, steel or fiber reinforced plastic. Occasionally, a platform is suspended from the load line of a large crane. Synonyms : cage, platform.

Platform, lineman's—A device designed to be attached to a wood pole or metal structure, or both, to serve as a supporting surface for workmen engaged in deadending operations, clipping-in, insulator work, etc. The designs of these devices vary considerably. Some resemble short cantilever beams, other resemble swimming pool diving boards, and still others as long as 40 lt (12 m) are truss structures resembling bridges. Materials commonly used for fabrication are wood, fiberglass and metal.

Puller, bullwheel—A device designed to pull pulling lines and conductors during stringing operations. It normally incorporates one or more pairs of urethane or neoprene-lined, power driven, single or multiple groove bullwheels where each pair is arranged in tandem. Pulling is accomplished by friction generated against the pulling line which is reeved around the grooves of a pair of the bullwheels. The puller is usually equipped with its own engine which drives the bullwheels mechanically, hydraulically or through a combination of both. Some of these devices function as either a puller or tensioner. Synonym : puller.

Puller, drum—A device designed to pull a conductor during stringing operations. It is normally equipped with its own engine which drives the drum mechanically, hydraulically or through a combination of both. It may be equipped with synthetic fiber rope or wire rope to be used as the pulling line. The pulling line is payed out from the unit, pulled through the travelers in the sag section and attached to the conductor. The conductor is then pulled in by winding the pulling line back onto the drum. This unit is sometimes used with synthetic fiber rope acting as a pilot line to pull heavier pulling lines across canyons, rivers, etc. Synonyms : hoist, single drum hoist, single drum winch.

Puller two durm, three drum.—The definition and application for this unit is essentially the same as that for the drum puller previously described. It differs in that this unit is equipped with three drums and thus can pull one, two or three conductors individually or simultaneouslye. Synonyms : two drum winch, double drum hoist, double drum winch, three drum winch, triple drum hoist, triple drum winch, tugger.

Puller, reel.—A device designed to pull a conductor during stringing operation. It is normally equipped with its own engine which drives the supporting shaft for the reel mechanically, hydraulically or through a combination of both. The shaft, in turn, drives the reel. The application of this unit is essentially the same as that for the drum puller previously described. Some of these devices function as either a puller or tensioner.

Pulling vehicle—Any piece of mobile ground equipment capable of pulling pilot lines, pulling lines or conductors.

Reel stand—A device designed to support one or more reels and having the possibility of being skid, trailer or truck mounted. These devices may accommodate rope or conductor reels of varying sizes and are usually equipped with reel brakes to prevent the reels from turning when

pulling is stopped. They are used for either slack or tension stringing. The designation of reel trailer or reel truck implies that the trailer or tuck has been equipped with a reel stand (jacks) and may serve as a reel transport of payout unit, or both, for stringing operations. Depending upon the sizes of the reels to be carried, the transporting vehicles may range from single axle trailers to semitrucks with trailers having multiple axles. Synonyms : reel trailer, reel transporter, reel truck.

Ruling span—A calculated deadend span length which will have the same changes in conductor tension due to changes in conductor tension due to changes of temperature and conductor loading as will be found in a series of spans of varying lengths between deadends.

Running board—A pulling device designed to permit stringing more than one conductor simultaneously with a sigle pulling line. For distribution stringing, it is usually made of lightweight tubing with the forward end curved gently upward to provide smooth transition over pole crossarm rollers. For transmission stringing, the davice is either made of sections hinged transversely to the direction of pull or of a hard nose rigid design, both having a flexible pendulum tail suspended from the rear. This configuration stops the conductors from twisting together and permits smooth transition over the sheaves of bundle travelers.

Safety, conductor—A sling arranged in a vertical basket configuration, with both ends attached to the supporting structure and passed under the clipped-in conductor (s). These devices, when used, are normally utilized with bundled conductors to act as a safety device in case of insulator failure while workmen in conductor cars are installing spacers between the subconductors, or as an added safety measure when crossing energized eircuits. These devices may be fabricated from synthetic fiber rope or wire rope.

Sag section—The section of line between snub structures. More than one sag section may be required in order to sag properly the actual length of conductor which has been strung. Synonyms : pull, setting, stringing section.

Sag span—A span selected within a sag section and used as a control to determine the proper sag of the conductor, thus establishing the proper conductor level and tension. A minimum of two, but normally three. sag spans are required within a sag section in order to sag properly. In mountainous terrain or where span lengths vary radically, more than three sag spans could be requirued within a sag section. Synonym : control span.

Sheave—(1) The grooved wheel of a traveler or rigging block. Travellers are frequently referred to as sheaves. Synonyms : pulley, roller, wheel.

(2) A shaft-mounted wheel used to transmit power by means of a belt, chain, band, etc.

Site, pull—The location on the line where the puller, reel winder and anchors (snubs) are located. This site may also serve as the pull or tension site for the next sag section. Synonyms : reel setup, tugger setup.

Site, tension—The location on the line where the tensioner, reel stands and anchors

(snubs) are located. This site may also serve as the pull or tension site for the next sag section. Synonyms : conductor payout station, payout site, reel setup.

Step voltage—The potential difference between two points on the earth's surface separated by a distance of one pace (assumed to be 1 m) in the direction of maximum potential gradient. This potential difference could be dangerous when current flows through the earth or material upon which a workman is standing, particularly under fault conditions. Synonym : step potential.

Stringing—The pulling of pilot lines, pulling lines and conductors over travelers supported on structures of overhead transmission lines. Quite often, the entire job of stringing conductors is referred to as stringing operations, beginning with the planning phase and terminating after the conductors have been installed in the suspension clamps.

Stringing, slack—The method of stringing conductor slack without the use of a tensioner. The conductor is pulled off the reel by a pulling vehicle and dragged along the ground, or the reel is carried along the line on a vehicle and the conductor is deposited on the ground. As the conductor is dragged to, or past, each supporting structure, the conductor is placed in the travelers, normally with the aid of finger lines.

Stringing, tension—The use of pullers and tensioners to keep the conductor under tension and positive control during the stringing phase, thus keeping it clear of the earth and other obstacles which could cause damage.

Switching surge—A transient wave of overvoltage in an electrical circuit caused by a switching operation. When this occurs, a momentary voltage surge could be induced in a circuit adjacent and parallel to the switched circuit in excess of the voltage induced normally during steady state conditions. If the adjacent circuit is under construction, switching operations should be minimized to reduce the possibility of hazards to the workmen.

Target, sag—A device used as a reference point to sag conductors. It is placed on one structure of the sag span. The sagger, on the other structure of the sag span, can use it as his reference to determine the proper conductor sag. Synonyms : sag board, target.

Tensioner, bullwheel—A device designed to hold tension against a pulling line or conductor during the stringing phase. Normally, it consists of one or more pairs of urethane or neoprene-lined, power braked, single or multiple groove bullwheels where each pair is arranged in tandem. Tension is accomplished by friction generated against the conductor which is reeved around the grooves of a pair of the bullwheels. Some tensioners are equipped with their own engines which retard the bullwheels mechanically, hydraulically or through a combination of both. Some of these devices function as either a puller or tensioner. Other tensioners are only equipped with friction type retardation. Synonyms : retarder, tensioner.

Tensioner, reel—A device designed to generate tension against a pulling line or conductor during the stringing phase. Some are equipped with their own engines which retard the sup-

porting shaft for the reel mechanically, hydraulically or through a combination of both. The shaft, in turn, retards the reel. Some of these devices function as either a puller or tensioner. Other tensioners are only equipped with friction type retardation. Synonyms : retarder, tensioner.

Touch voltage—The potential difference between a grounded metallic structure and a point on the earth's surface separated by a distance equal to the normal maximum horizontal reach, approximately 1 m. This potential difference could be dangerous and could result from induction or fault conditions, or both. Synonym : touch potential.

Tractor, crawler—A tracked unit employed to pull pulling lines, sag conductor, level or clear pull and tension sites, and miscellaneous other work. It is also frequently used as a temporary anchor. Sagging winches on this unit are usually arranged in a vertical configuration.

Tractor, wheel—A wheeled unit employed to pull pulling lines, sag conductor, and miscellaneous other work. Sagging winches on this unit are usually arranged in horizontal configuration. It has some advantages over crawler tractor in that it has a softer footprint, travels faster, and is more maneuverable.

Traveler—A sheave complete with suspension arm or frame used separately or in groups and suspended from structures to permit the stringing of conductors. These devices are sometimes bundled with a center drum, or sheave and another traveler, and used to string more than one conductor simultaneously. For protection of conductors that should not be nicked or scratched, the sheaves are often lined with nonconductive or semiconductive neoprene or with nonconductive urethane. Any one of these materials acts as a padding or cushion for the conductor as it passes over the sheave. Traveler grounds must be used with lined travelers in order to establish an electrical ground. Synonyms : dolly, sheave, stringing block.

Traveler sling—A sling of wire rope, sometimes utilized in place of insulators, to support the traveler during stringing operations. Normally, it is used when insulators are not readily available or when adverse stringing conditions might impose severe downstrains and cause damage or complete failure of the insulators.

Uplift roller—A small single-grooved wheel designed to fit in or immediately above the throat of the traveler and keep the pulling line in the traveler groove when uplift occurs due to stringing tensions.

Winder, pilot line—A device designed to payout and rewind pilot lines during stringing operations. It is normally equipped with its own engine which drives a drum or a supporting shaft for a reel mechanically, hydraulically or through a combination of both. These units are usually equipped with multiple drums or reels, depending upon the number of pilot lines required. The pilot line is payed out from the drum or reel, pulled through the travelers in the sag section, and attached to the pulling line on the reel stand or drum puller. It is then rewound to pull the pulling line through the travelers.

Winder, reel—A device designed to serve as a recovery unit for a pulling line. It is normally equipped with its own engine which drives a supporting shaft for a reel mechanically, hydraulic-

ally or through a combination of both. The shaft, in turn, drives the reel. It is normally used to rewind a pulling line as it leaves the bullwheel puller during stringing operations. This unit is not intended to serve as a puller, but sometimes serves this function where only low tensions are involved. Synonym : takeup reel.

6.02 Stringing of power conductors and earth wire.

This is a very important part of transmission line construction. The appearance of the line and future security depends to a great extent on the proper erection of conductors and ground wires. This work SHALL NENER BE UNDERTAKEN WITHOUT PROPER EQUIPMENT, OTHERWISE THE SAFETY OF THE ERECTION PERSONNEL MAY BE IN DANGER.

6.03 DELIVERY OF POWER CONDUCTORS AND EARTH CONDUCTORS (GROUND WIRES) :

The conductors are usually delivered in standard lengths in wooden reels. The condition of the wooden reels are to be checked before they are transported to site. The damaged wooden planks etc., if any are to be rectified and the reels shall be in good condition since otherwise the same causes considerable inconvenience while paying out. The standard length contained in all the drums shall be noted down and the drums shall be batched in the following manner such that all the drums matched within a batch are of nearly equal lengths and the mid span. compression joints, where required to be made, fall preferably somewhere in the middle of the span in which they occur.

Type of line	No. of drums in a batch.
3 conductors 1 circuit....	3
3 conductors 2 circuits....	6
1 conductor 1 circuit....	2
1 conductor 2 circuits....	4

At every site two such batches shall be dumped. While deciding the place of dumping, due consideration shall be made of the particular standard length of batch, extra length consumed on account of sag, damaged ends of the conductor in the drum, inclined spans, etc.

The following points shall be borne in mind so that planning for dumping of the drums would not be disturbed, once it is finalised.

(a) No joint is placed within 15 mtr. of the conductor support.

(b) There should be no joints in important crossing spans, except where the spans are longer than the standard condnctor of the drum.

(c) There should not be more than one joint per conductor in a span.

All the drums in dilapidated conditions shall be discorded and the conductor shall be rewound on new drums before use. Suitable turn tables may be used holding the drums in vertical axis in case of drums with only laggings damaged.

6.04 CONDUCTOR STRINGING METHODS :

6.04.01 SLACK OR LAYOUT METHOD : This method is commonly used for construction of lines upto 220 kV where maintenance of Conductor surface condition is not critical to cause corona and radio interference and where terrain is easily accessible for pulling manually or with a pulling vehicle. The major equipment required to perform slack stringing includes reel stands and a 'Splicing Kit, for the conductor consisting of hydraulic compressor die sets etc.,

Using this method, the conductor is dragged along the ground by means of a pulling vehicle or the reel carried along the line on a vehicle and the conductor deposited on the ground. The conductor reels are positioned on reel stands or jacks, either placed on the ground or mounted on a transporting vehicle. These stands are designed to support the reel on an arbor, permitting it to turn as the conductor is pulled out. Usually a braking device is provided to prevent overrunning and backlash. When the conductor is dragged past a supporting structure, pulling is stopped and the conductor placed in travelers attached to the structure before proceeding to the next structure.

This method is chiefly applicable to the construction of lines upto 220 kV where maintenance of conductor surface condition is not critical and where terrain is easily accessible to a pulling vehicle.

Major equipment required to perform slack stringing includes reel stands, pulling vehicle(s) and a splicing cart.

6.04.02 RUNNING OUT OF POWER AND GROUND CONDUCTORS :

Two methods can be adopted for supporting the conductor drums during running out operations.

In the first method, heavy jacks are used with special drum carriages.

In the second method, holes are excavated in the ground, the length of the hole being 250mm longer than the diameter of the drum and the breadth 75 mm greater than the drum diameter and depth 150 mm greater than the drum radius. Two suitable wooden planks are placed on each side of the excavation to support the drum spindles. The drum with spindle in position is lowered to the planks and two pieces of wood of suitable size are nailed on each side of the spindle to prevent it from travelling along the plank. A wooden plank is used for braking the drums during running out operations.

The conductor should be run from the top of the drums to prevent damages. A tractor shall be used for pulling out the conductors. The conductors shall be pulled out evenly in preference to pulling out a complete section of one wire. Care should be taken to see that the conductors do not touch or rub against ground or other objects which would cause scratches or damages to the

strand. The conductor immediately after running out, shall be raised at the supports to a level as that of the clamp and placed into the running blocks or the aerial rollers.

The diameter of the running block shall not be less than the internal diameter of the drum. Alternatively, the blocks shall be provided with two small pulleys wnich shall enable the conductor to form a curve of minimum equivalent diameter. This is preferred to providing a single running block. The groove of the pulley shall be of such a design that the seat is semi circular and larger than the diameter of the conductor and it does not slip over or rub against the sides. The groove shall be lined with hard rubber or neoprene to avoid damage to conductor and shall be mounted on well oiled bearings.

The running blocks shall be suspended in a manner to suit the design of cross arms. All running blocks, especially those at the tensioning end shall be fitted on the cross arms with sacking wrapped over the steel work and under the slings, to avoid damage to the slings as well the protective surface of the steel work.

A NOTE OF WARNING :

The section towers (Tension Towers) used for termination of stringing operations shall be suitably guyed. The guy wires used shall be capable of taking the maximum tension of the conductor being pulled. Many accidents have happened due to failure of guys. Hence due care should be taken to inspect the condition of guy wires before use each time. Guys with damaged strands shall be discorded at once. The guys should be provided from the cross arms and shall be at an angle of not less than 30° to the vertical. Care should be taken to see that guy anchors are properly made to avoid failures. Some engineers prefer to have two guys at each cross arm at different angles. A responsible man shall be entrusted with a continuous watching of guys and their foundations during stringing operations. He shall have a loud sounding whistle with him to warn all the people at work at the time he notices any signs of failure of guy. The stringing operations should stop and the conductor de-tensioned immediately once this whistle is heard.

During stringing operations, there must be an efficient code of signals for the stringing party and these are usually given by whistles. The whistles used for the operations shall preferably differ in sound to that used by the man at the guy so that the latter can be clearly distinguished.

The drums shall be provided with a suitable braking device to avoid loose running out and to prevent kinking of the conductors. The conductors shall continuously be observed for loose or broken strands or any other damage. When approaching the end of a drum length, atleast three coils shall be left when the stringing operations are stopped. These coils shall be removed carefully and if another length is required to be run out a joint shall be made. The joints shall be so made that the same should not pass through the running blocks.

Crossing structures, such as temporary gauntries shall be used where roads, rivers, canals, telephone lines, overhead power lines, railways, fences or walls, are to be crossed during stringing operations. It should be ensured that normal services are not interrupted, or damage caused to property. Shutdowns shall be obtained when working at crossing of overhead power lines and railways (electrified or otherwise).

The sequence of running out shall be from top to downwards,i.e. the earth conductor shall be run out first, followed by top, middle and bottom conductors in succession. Unbalances in loads on towers shall be avoided as far as possible. It should be remembered that the section towers are not designed for all conductors broken condition resulting in unbalanced pulls of conductors. The single circuit anchor towers, either B or C type are designed for a factor of safety of 1.5 for one power conductor or earth conductor broken only. The double circuit B type towers are designed for a factor of safety of 1.5 for two couductors broken or one conductor and earth conductor broken only. Similarly the 'C' type double circuit towers are designed for a factor of safety of 1.5 for 3 power conductors or 2 power conductors and earth conductor broken condition only.

A tractor or a winch shall be used for pulling out the conductors. Suitable Bolted type or Automatic 'Come along' clamps shall be used for pulling the conductors. The latter is more advantageous since the grip increases with the tensoning.

6.04.03 TENSIONING AND SAGGING OF CONDUCTORS :

The Sag-tension charts supplied for the specific conductor and the line shall be used for determining the conductor tension at the rime of tensioning and clipping in. The tension corresponding to the atmospheric temperature at the time of stringing and the ruling span shall be read from these charts and the tension of the conductor shall be measured by a suitable dynamometer fitted at an appropriate place.

The tension insulator strings, complete with clamped conductors shall be hoisted at the ends remote from the tensioning points. The running blocks at the tensioning end shall be fitted on cross arms with sacking wrapped under slings.

The tension of the conductor at 32°C is also, marked on the sag templates for normal span. This will also provide a rough guidance for stringing tension.

It is preferable to check both sags and tensions though some engineers considered checking of sag only as sufficient. The 'Sag' should not be confused to 'ground clearance'. The level of the ground profile compared to the levels of the adjascent tower foots shall be considered to determine the sag wherever the ground clearances are measured.

A POINT TO NOTE : The conductor sag increases in course of time, during the life time of line. This is due to the fact that permanent elongation of conductor will be set-in,since the conductors are continuously stressed mechanically. This will result in decreased ground clearances in course of time. This phenomenon is called 'CREEP' and depends on the design of the conductor such as the aluminium-steel ratio. etc., The creep increases rapidly in the beginning period and attains a saturation in course of time. There are two ways of compensating the creep. The first method is pre-tensioning of the conductor before stringing. That is, the conductor by means of a weinch and come along clamp is pulled, before starting stringing, by a tension equal to 50% of ultimate tensile strength of the conductor and kept for two hours at this tension. This can also be done at the time of stringing. Either the tension of the conductor is mesaured, or the corresponding sag is measured.

Another method of compensating the creep is to give a tension to the conductor slightly in excess of the design tension for stringing.

The span chosen for measuring the sag of the conductor shall be the maximum span of the section.

One method of measuring the sag correctly is to clamp a Dumpy level to the tower leg so that the collimation line is at a point marked on the tower for the appropriate sag at the stringing temperature. The level is adjusted until the cross hairs are focussed on the similar sag mark on the next tower and the instrument can be rotated in this plane. The conductors are adjusted until the bottom of the sag is in line of sight.

By experience, many engineers measure the sag of only one conductor and judge the others by paralleling. It may be difficult many times to locate a position to view the conductors in anything like a favourable plane.

When sagging is completed, a mark is put on the conductor at a distance from the cross arms equal to the length of the complete insulator assembly. The clamp, in case of a bolted type tension clamp, can either be fitted on conductor under tension or on the ground on the slalkened out conductor. The latter is always preferred. In case of compression type dead end clamps, is however necessary to fix the same on ground on slackened out conductor. Due to its higher efficiency and dependability, it is always advisible to use compression type dead end clamps as far as possible. Before the insulator sets are raised to position, all nuts should be free, all Phospher Bronze 'W' clips or 'R' clips are in correct position and split pins opened. If the clamp are fitted under tension a pull-lift is necessary in the operation of connecting the clamp to ths insulator string. However clamps should never be fitted on conductors of higher sizes in tensione A come-along clamp is placed on the conductor beyond the conductor clamp and to this is attached the pull-lift. This is anchored on the support and the conductors are pulled in sufficiently to allow the insulator assembly to be fitted to the clamp. If the clamps are fitted on the ground then the tensioning gear will be used to pull the conductors again, and sufficiently pulled to allow the insulator set to be attached to the clamps. There is one point which requires attention. whoen the insulator stings are being raised to the horizontal. They should be supported at a centre position in addition to the end supports as otherwise the pins get bent and the insulators may get damaged.

The clamping of the conductors can then be carried out at intermediate supports on suspension insulator strings.

6.05 TENTION METHOD

6.05.01 This method is commonly used for all EHV and UHV lines where surface condition of the conductor is a critical factor from the point of view of radio interference and corona. Even this method is necessary where the terrain is mountain and not accessible for the layout method.

Using this method, the conductor is kept under tension during the stringing process. Normally, this method is used to keep the conductor clear of the ground and obstacles which might

cause conductor surface damage and clear of energised circuits. It requires the pulling of a light pilot line into the travellers, which in turn is used to pull in a heavier pulling line. The pulling line is then used to pull in the conductors from the reel stands using specially designed tensioners and pullers. For lighter conductors, a lightweight pulling line may be used in place of the pilot line to directly pull in the conductor. A ground vehicle can be used to pull or lay out a pilot line or pulling line. The tension method of stringing is applicable where it is desired to keep the conductor off the ground to minimise surface damage or in areas where frequent crossings are encountered. The amount of right of way travel by heavy equipment is also reduced. Usually, this method provides the most economical means of stringing conductor.

Major equipment required for tension stringing includes reel stands, tensioner, puller, reel winder, pilot line winder, splicing cart and pulling vehicle.

6.05.02 REEL STAND : The reel stands are designed to be used with tensioners to supply the necessary back pressure to the conductor.

The stand(s) are selected to accommodate the conductor (or groundwire) reel dimensions and gross weight.

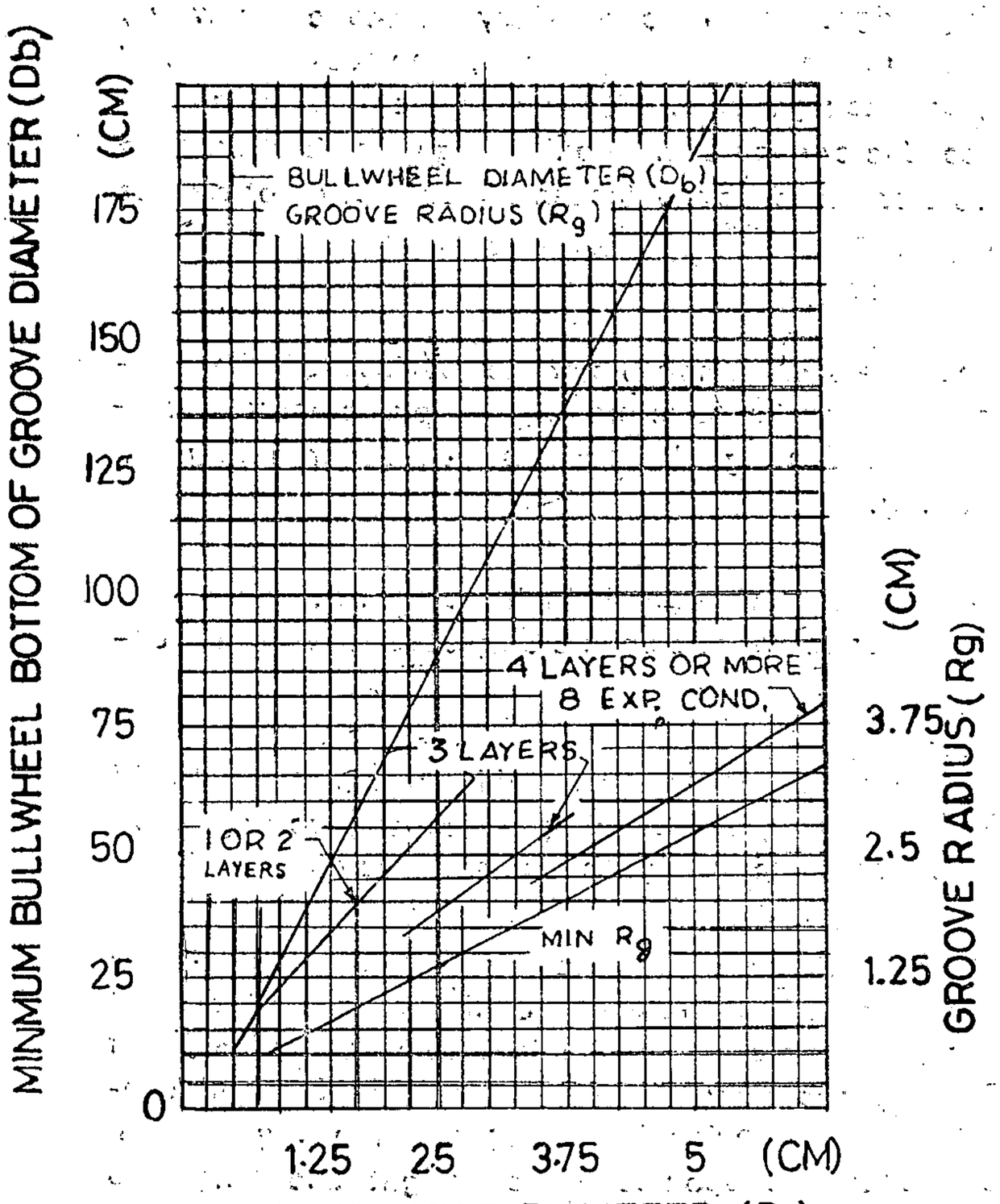
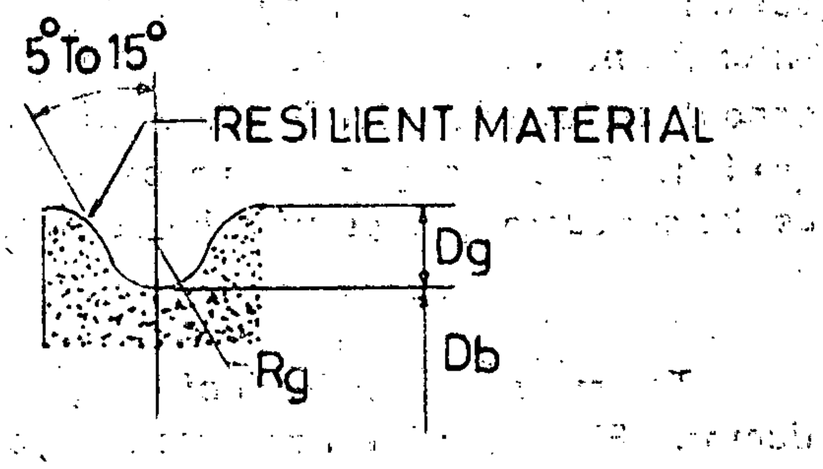


FIG-27: CONDUCTOR DIAMETER (Dc)



LEGEND

Db BULL WHEEL BOTTOM OF GROOVE DIAMETER
Dc CONDUCTOR DIAMETER
Dg GROOVE DEPTH
Rg GROOVE RADIUS

LAYERS OF ALUM WIRES	GROOVE MIN.	RADIUS MAX.
1,2	0.525 Dc	1.100 Dc
3	0.525 Dc	0.750 Dc
4 OR MORE 8 EXPANDED	0.525 Dc	0.625 Dc

THE 7 CENTRAL WIRES OF ALL ALUMINUM CONDUCTORS ARE CONSIDERED THE CORE

Some reels are not designed to withstand the forces developed by brarking during tension stringing operations. Direct tension stringing from the reel at transmission line stringing tensions should not be attempted.Conductor may be pulled directly from the reel stand when employing slack stringing methods.

If the reel stand is not self-loading, a crane, forklift or other suitable equipment is used to load the reel into the stand.

6.05.03 Conductor Bullwheel Characteristics. The depth (D_g) and flare of grooves in the bullwheels are not critical. Semicircular grooves with depths in the order of 0.5 or more times the conductor diameter and with flare angles the order of 5° to 15° from the vertical have generally been found to be satisfactory.

The rumber of grooves in the bullwheel must be sufficient to prevent the outer layer of wires of multilayer conductors from slipping over underlying layers. The minimum diameter of the bottom of the grooves (D_b) should be in accordance with Fig 27.

Tandem bullwheels should be so aligned that the offset will be approximately one-half the groove spacing. For normal conductors having a right hand direction of lay for the outer wires, bullwheels should be arranged so that when facing in the direction of pull, the conductor will enter the bullwheel on the left and pull off from the right side. For any conductors having a left hand direction of lay for the outer wires, the conductor should enter on the right and pull off from the left. This arrangement is necessary to avoid any tendency to loosen the outer layer of strands as the conductor passes over the bullwheels.

The material and finish of the grooves must be such as not to mar the surface of the conductor. Elastomer lined grooves are recommended for all conductors, but are particularly important for nonspecular conductors. Should a semiconducting elastomer be used for lining the grooves, it should not be relied upon for grounding.

Difficulties have been experienced with single u-groove type bullwheels on some multilayer and special construction conductors. These types of bullwheels should only be used with the concurrence of the conductor manufacturer.

6.05.04 Puller and Tensioner Operating Characteristics. The pulling and braking systems should operate smoothly and should not cause any sudden jerking or bouncing of the conductor. Each system should be readily controllable and capable of maintaining a constant tension.

Pullers and tensioners may be mounted separately, or in groups, for bundled conductor installation. Separately mounted tensioners for bundled conductors should have central control so as to maintain uniform conductor stress history. The controls should allow the independent adjustment of tension in each conductor. This is particularly vital when stringing bundled conductor. Pullers and tensioners should be equipped with tension indicating and limiting devices Capacity selection of the puller and tensioner is dependent upon conductor weight and length to be strung and the stringing tensions.

Tensioner bullwheels must be retarded so that conductor tension may be maintained at various pulling speeds. Positive braking systems are required for pullers and tensioners to maintain conductor tension when pulling is stopped. Failsafe type braking systems are recommended.

There are basically two types of pulling machines used in the construction of transmission lines being strung under tension. These are defined as bullwheel and drum or reel type pullers. Some drum or reel type pullers are available with level wind features to provide uniform winding of the line. Some drum type and all reel type pullers provide easy removal of the drum (or reel) and line to facilitate highway mobility. This feature also provides the advantage of interchangability of drums. The control of payout tension of the pulling line is a desirable feature of many pullers. Mobility of the pullers and tensioners is important to minimise down time between pulls. Also critical are the setup and leveling features of the units.

The overhead groundwise tensioner is normally a separate unit from the conductor tensioner, as the requirements are independent of each other.

6.05.05 Pilot Line Winder Operating Characteristics. Pilot line winders have operating characteristics similar to drum type pullers. They usually have multiple drums to provide pilot lines for several phase or groundwire positions, or both. These units normally have capability for high speed operation. Retardation of the drum(s) is desirable in order to provide controlled payout of the pilot lines. These units are frequently employed to directly pull in overhead groundwire.

6,05.06 PULLER AND TENSIONER OPERATING REQUIREMENTS

The pulling and tensioning (also known as breaking) systems must operate smoothly and during the process of stringing there should not be any jerks or bouncing of conductors.

Each system should be capable of controlling effectively and must maintain a constant tension throughout stringing.

Pullers and tensioners have been designed to handling conductors individually or in groups as in case of bundled conductors installation. In that case there should be proper controls for adjustment of tensions in each of the conductors.

Pullers and tensioners are also equipped with indicators which show the tension in the conductor under pulling and also must heve limiting devices.

The selection of the puller and tensioner must be given the following consideration.

(a) Weight of the conductor per unit length.

(b) No. of conductors per phase.

(c) Length of conductors to be strung.

(d) The working tensions.

(e) The terrain consideration and the time factor involved for completions.

(f) Cost factor for movement of equipments during stringing operations.

(g) Trained and experienced personnel for operation of the equipments.

ATTACHMENT OF CONDUCTOR FOR PULLING :

For the purposes of pulling and tensioning, conductors are attached to the pulling lines, Head Boards or Conductor to conductor by means of woven wire grips (also known by the name SOCK GRIPS) or pulling grips. These are mesh type grips made for holding different sizes of conductors. These multiple strength "Pulling Grips" are designed with gripping action for pulling conductors. The grips are made for different ranges of conductors with pulling strength varying from 2500 Kg. upto 18000 Kg. It is made with Triple, Double and Single weave grips and the tension is increased with increase in pulling.

The size of the grips should be seleceted depending on the diameter and tension to be adopted in pulling the conductor. The overall diameter of the grip should be small enough for its passage through the grooves of the running out blocks and its lining also should match with the size of the swivel joints. The open end of the grips should be properly wrapped with bands so that it may not strip out during the process of stringing.

6.05.07. PULLING SPEED OF CONDUCTORS :

While speed may be an important factor in completion of a line, subject to all the earlier squential operations are over, the "Speed of stringing" should be decided on "Experience" and based on the following considerations :

(a) Continuous lengths of sections available with tower erection complete without gaps.

(b) The complete availability of stringing materials like conductors. groundwire, insulators and hardware, conductor and earthwire accessories.

(c) Availabillty of all construction equipments.

(d) Availability of experienced construction personnel for all phases of working and all the equipment handling.

(e) Seasons of working and field conditions.

6.05.08. With due consideration of the above factors, if a Pulling speed of conductors could be maintained at about 5 to 6 Kilometers per hour and if all the operations preceding and following the pulling of conductors could be achieved without interruption, it can be considered a good average speed.

This speed of 5 to 6 Km per hour is considered good by experience also. Speed lower than this may cause the swinging of the Running-out blocks and the insulator assemblies and hardware thereof. Higher speeds are likely to damage the conductors due to the mal-functioning possibilities of the equipments.

The "Tension" to be adopted for stringing should be decided after considering the clearances required at the various points of crossing in the different sections of stringing. This calculated

tensions should be checked for clearances by actual observations during the process of pulling of conductors.

In general, a tension of about 50% of the "Sagging tension" of the conductor is considered good for working.

6.05.09 TRAVELLERS

Sheave Diameter–it is generally recognised that as diameters are made larger, the following advantages are gained.

(1) The radius of bending of the conductor is increased, so the amount of strain and the amount of relative movement between individual wires in the conductor are reduced. This, in turn, reduces the amount of energy required to bend and straighten the conductor as it passes through the travellers. The force and energy required for such bending and straightening retards the passage of the conductor in much the same way as friction in the bearings of the travellers.

(2) The bearing pressures between conductor strand layers are reduced, thus reducing potential conductor internal strand damage. This is commonly known as strand notching.

(3) The force required to overcome friction in the bearings is reduced because of the greater moment arm for turning.

(4) The number of rotations and speed of rotation is reduced, so wear on the bearings and grooves is alleviated.

(5) The obvious disadvantages of larger sheaves are cost and added weight.

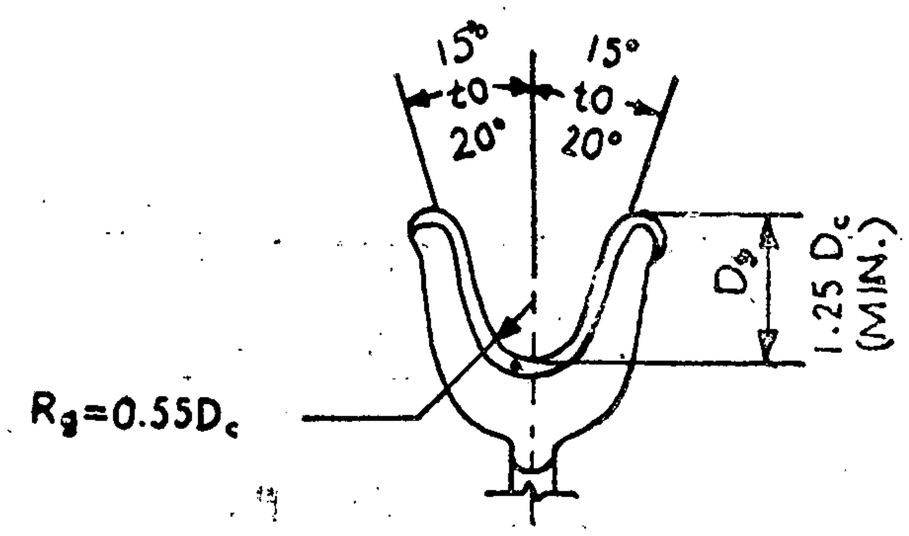
The minimum sheave diameter (D_s) at the bottom of the grove as shown in Fig 28 should be satisfactory for typical conductor stringing operations. However, for stringing conductors in excess of approximately 3 Km. or over substantially uneven terrain, the recommended minimum bottom groove diameter of sheaves is [$20D_c$—4] in ([$20D_c$ —10] cm) or larger, where D_c stands for conductor diameter. In exceptionally arduous circumstances. accurate sagging may sometimes be very difficult with sheaves having diameters of less than $19D_c$ or $20D_c$.

Configuration of Groove. The minimum radius at the base of the groove (R_g) is recommended to be 1.10 times the radius of the conductor as shown if Fig 28.

Sheaves having a groove radius as discussed above may, with limitations, be used with smaller conductors. The limitations relate to the number of layers of aluminium wires in the conductor. The more layers of aluminium wires, the more important it is to support the conductor with a well fitting groove.

The depth ot groove (D_g) should be a minimum of 25% greater than the diameter of the conductor. The sides of the groove should flare between 15° and 20° from the vertical to facilitate the passage of swivels. grips, etc, and to contain the conudctor within the groove, particulary at line angles.

Bearings—The bearings should preferably be ball or roller type with adequate provisions for lubrication and sealing out contaminants. The lubricant must be suitable for the temperature range involved, and where sealed bearings are not used, care should be taken to ensure subsequent lubrication with the same type of grease. Mixing of greases of different types (that is, lithium base and calcium base) many cause degradation of the lubricant and subsequent bearing failure. Bearings must have sufficient capacity to withstand running or static loads without damage. Proper maintenance is essential.



D_s (min)—20 D_c—8 inches or 20D_c–20 cm except D_s shall not be less than 12 D_e
D_s—Sheave diameter at base of groove
D_c—Conductor diameter
R_g—Sheave groove radius
D_g—Groove depth

FIG-28:

Number of Layers of Aluminum Wires*	R_g Minimum	R_g Maximum	D_g Minimum
1 or 2	0.55 D_c	1.1 D_c	1.25 D_c
3	0.55 D_c	0.75 D_c	1.25 D_c
4 or more & Expanded Conductors	0.55 D_c	0.625 D_c	1.25 D_c

A sheave designed for a conductor of a given diameter, in accordance with this figure, may be used for stringing conductors of smaller diameters using above table or as follows :

Number of Layers of Aluminum Wires*	Minimum Diameter Conductor That May Be Used in a Sheave Designed for a Conductor of a Larger Diameter in Percent of the Diameter of the Larger Conductor
1 or 2	50%
3	75%
4 or more & Expanded Conductors	87.5%

*The 7 central wires of all-aluminum conductors shall be considered as a core.

Example : A sheave, with a groove radius of 21 mm and a diameter at the bottom of groove of 560 mm, designed for use with a conductor 38 mm in diameter may be used for stringing a 2 layer conductor with a diameter as small as 19 mm.

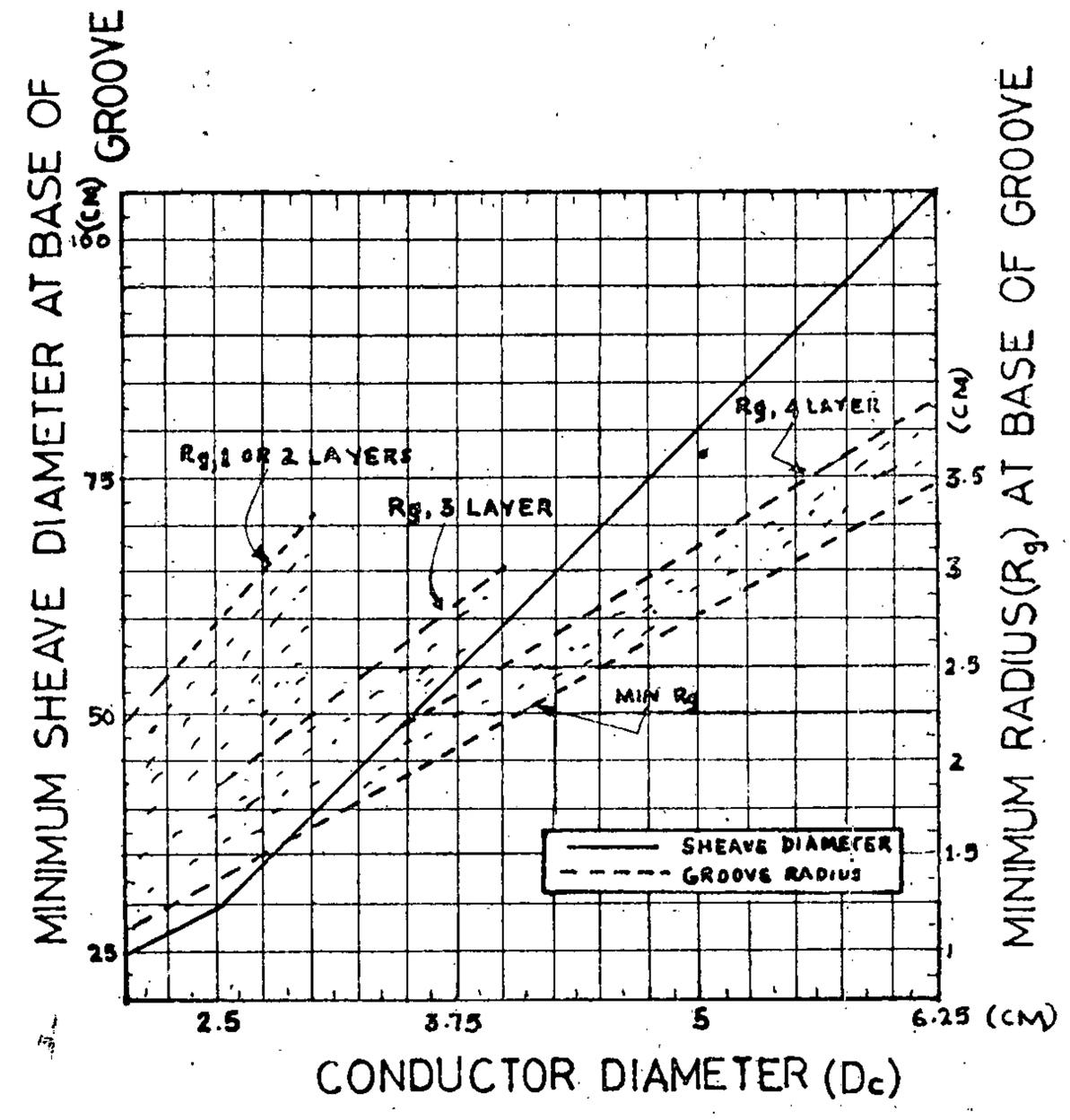


FIG-29: RECOMMENDED SHEAVE CONFIGURATION

Material and Constrcution. Travelers may be of any suitable material, with due consideration to weight. Unlined sheaves for stringing aluminium conductors should be made of aluminium or magnesium alloy and the grooves should have a smooth, polished finish. It is recommended that the manufacturers safe working load, or other identification to enable determination of such load, be permanently displayed on the traveler.

Lining—While grooves may be unlined or lined, lining with elastomer provides cushioning to increase bearing area and precludes damage to the conductor from scratched or marred groove surfaces. Steel pulling lines are likely to scratch or mar the surface of unlined grooves, so where such lines are to be used in the same groove as conductor, grooves definitely should be lined. It is generally recommended that all sheaves be lined.

The elastomer used for sheave linings should be capable of withstanding all anticipated temperatures without becoming brittle or developing semipermanent flat areas. It should be sufficiently hard to prevent the conductor from climbing up the side of the groove. Bearing pressure limits for sheave linings are further discussed in Appendix M.

Electrical Characteristics. Neither lined nor unlined travelers should be relied on for grounding the conductor being installed. Greased bearings do not provide necessary conductivity and may be damaged by relatively small currents passing from the sheave to the body of the traveller. Semiconductive linings, commonly referred to as conductive linings, tested to date are reported burned with currents as low as 20mA.

The induced electrical charges on conductor and pulling lines, particularly when stringing in the proximity of energized lines, must be drained off with traveller grounds which bypass the linings or greased bearings, or both. Traveller grounds provide a means to bypass electrically the sheaves and ground the conductor directly to a ground source.

Bundled Configurations. Bundle conductor type travellers for stringing two or more subconductors simultaneously require special considerations. When even numbers of conductors are strung, a symmetrical arrangement is used with an equal number of conductors on each side of the pulling line. An independent center sheave is provided only for the pulling line and must be of suitable material to withstand the abrasion of the pulling line.

When odd numbers of subconductors are strung, the center one could follow the pulling line in the center sheave. However, this is usully not desirable because of the material of the groove or because of contaminants deposited in this groove by the pulling line; or because of both. Offset type bundle conductor travellers are used which balance the load by properly spacing the even and odd number (s) of conductors on each side of the pulling force. These travellers are directional and should be color–coded, care should be taken to ensure their proper orientation.

When multiple conductors are strung in bundled conductor type travellers, reduced horizontal spacing between grooves can result in conductor oscillation, even in very light crosswind too severe to permit satisfactory sagging. (For example, groove spacing of 5.4 conductor diameters permitted sagging of conductors in a crosswind condition which repeatedly prevented sagging with a groove spacing of 2.7 conductor diameters because of very active couductor oscillation.)

When stringing muitiple conductors around line angles in excess of 5°, bundle conductor travellers are required until the running board passes through the traveller, but should be replaced prior to sagging with single type travellers to provide proper wire length in the clipped–in position.

conductor is lowered in whichever span it finally is to be joined (i.e., where the ends of the conductor is positioned). The lowering is to be done carefully and after proper anchoring and holdling the conductors on either side; the joint is made at the ends and the conductor hoisted up afterwards, for final sagging.

In the process of joining the conductors, there will be a number of places along the route where splicing will have to be carried out and at each location the lowering and hoisting back of the conductors will be required for which separate crew will be required.

In the Second method, the lengths of conductor are jointed at the tension site itself and pressed through the running out blocks during pulling. This has the advantage of making all the joints at one place and also the operation of lowering and lifting up the conductors back at different spans is avoided.

To adopt this method, a proper study of line is a pre-requisite to determine the tension with which the conductor is to be pulled, the angle points over which the joints have to pass and the deviations thereof and also to pre-determine the arrangements to be made for this purpose. It must also be ascertained, if the compressed joints are capable of withstanding the pull over the running out blocks. In this connection, it is desirable to have consultation with the manufacturers of jointing sleeves.

With all this, it would be necessary to take suitable precautions at the time of the passing over of the mid-span joints over the travellers (Running out blocks) on each tower by the use of "JOINT PROTECTORS".

6.10 JOINT PROTECTORS :—

These are devices used to protect the mid-span joints when passing through the stringing blocks, when the conductors are being pulled under constant tension. These devices are fixed on the mid-span joint when the pressing is complete and is detached as soon as it passes through the last stringing block in the span in which the joint will be permanently holding the conductor ends.

A joint protector comprises of two semi-circular steel plates which can accommodate the compressed joint of the conductor along with a protection lining of cloth or any other soft material to prevent scratching of the aluminium surface. The ends of the joint also are made of hard rubber split into two and both the steel and rubber sleeves and bound with a binding wire.

This arrangement will be quite light and easy to be fixed and removed when the purpose is over.

PROCEDURE FOR USING JOINT PROTECTOR :-

After the compression joint is made, it is wrapped with a cloth to fill up the gap between the steel protector and the compressed surface of the joint.

The protector is then bound by the binding wires on either ends at the specified positions

where the groove is provided for the purpose. Then the ends are covered with an adhesive tape which can be removed later.

The ends of the joint is also wrapped with rubber tape as well as adhesive tape to protect the conductor from any damage.

When the joint passes over the stringing blocks all care is to be taken to see that there is no jerk or any other mishap either to the running out block or to joint or the grooves of the pulleys of the stringing block This is done by reducing the speed of the conductor as it approaches the running out block and properly guiding the joint through the blocks until the passage is complete and then graduallly releasing the conductor.

The stresses created on the joint due to the vertical angle at the running out blocks on suspension towers should be minimum and the joint must be designed to withstand the same. In case of angle tower position, it may be necessary to use two rollers in order to reduce the horizontal angular pulling. In any case a concurrence in this regard is desirable both with the designers and manufacturers of conductor and mid-span joint.

6.11 STRINGING AND ROUGH TENSIONING::

With all the arrangements complete for a stringing section and also a pre-determined pulling tension, the conductor is spread from the tensioner site to the puller site. At the tensioner end structure the tension insulators and hardware assembly is attached through dead-ends.

The other end at the puller is transferred from the puller to the final sagging unit.

At the puller eud, the pilot wire is also to be recovered and when the pulling is complete. This function is done by the reel winder placed behind the puller at a suitable distance with an arrangement to wind the wires on drum reels, which are again transported to the next site for further utility.

6.12 FINAL TENSIONING OF CONDUCTORS :–

The finel tensioning of conductors is done on the principle of "BASIC" or "Equivalent Span" and "Constant Tension". This is done by applying one tension to any section and so a SAG — TENSION CHART is prepared for the appropriate line. Sag–Tension charts for ACSR 'Coyote' 'Lynx' and 'Drake' conductors corresponding to Basic spans of 275, 320 and 320 mtrs. are Provided at the end of the manual.

The basic span is determind for any section of a line as follows :-

Let L = Basic or Hypothetical span length

Let L_1, L_2, L_3, L_4 etc. = Individual span length in the Section of the line.

$$\text{Ruling Span} = \sqrt{\left(\frac{\sum_{o}^{n} L^3}{\sum_{o}^{n} L}\right)}$$

The basic formula for the parabola is

$$S = \frac{wl^2}{8\,T}$$

Where,

S = Sag of the conductor

W = Weight of the conductor.

L = Span length (measured horizontally)

T = Working tension in the conductor at any particular temperature all in identical units.

The tension applied on the conductor will be constant and uniform throught out the section and this constant tension will produce a difinite sag on a definite "ruling span" length at a given temperature.

Having determined the sags and tensions on the basic span at various temperatures, the sags on other spans (Actual) are corrected — the following way :

$$\text{Sag on any span } x = \left\{\frac{\text{Sag on ruling span } x}{(\text{Ruling span length})^2}\right. (\text{Actual span } x)^2$$

in terms of constant tension :

$$\text{Sag on span } x = \left\{\frac{(\text{span } x)^2 \times \text{Wt. of conductor/unit}}{8 \times \text{constant tension}}\right\}$$

Thus actual sag at the temperature of sagging and also the working tension at that temperature is calculated and the sag is measured on the span selected in the section at the time of final tensioning.

The selection of "Sagging span" is made on the following basis :

(i) The span should be on as level a ground between two towers as possible.

(ii) It should be as near to the Basic span as possible.

(iii) The span should be in the middle of the section of the different spans for sighting.

(iv) In case of longer lengths of spans to be strung (Say 8, 12 or more spans) it is desirable to select two spans for sagging purposes and so that they may be about 1/3 the distance of the section from either end of the tension towers to be strung.

6.13 TYPICAL PROCEDURES FOR STRINGING OPERATIONS

PULL, TENSION, ANCHOR AND SPLICING SITE :

Site Selection : The selection of pull tension, anchor and splicing sites must consider accessibility, location of deadends, length of conductor to be strung, available conductor and line lengths, puller capacity, snub structure loads, including placement of pullers, tensioner and conductor anchor location, placement or reel stands, pilot line winder(s), reel winder and the ability to provide an adequate grounding system.

Equipment Location. The location of the puller, tensioners and intermediate anchor sites must be selected so that the snub structures are not overloaded. Where possible, pulling line slope of three horizontal to one vertical from the traveler to the site is considered good practice. Refer to Appendix K for calculation of snub structure loads. It is also necessary that the puller be positioned so that the pulling line enters the machine at a minimum horizontal angle to minimize any possibility of damaging the line. When a bullwheel type puller is employed, the reel winder to recover the pulling line is located at the pulling site. The Pilot line winder is located at the tension site.

The arrangement of the tensioner and reel stands should be such that the lateral angle between the conductor as it approaches the bullwheel and the plane of rotation of the wheel is not great enough to cause the conductor to rub on the sides of the groove. As an example, birdcaging problems were eliminated with large conductors by using a maximum fleet angle of 1.5° from the plane normal to the conductor reel axis and a back tension of approximately 500 kg. Problems of birdcaging are normally more acute with large conductors of three or more aluminum layers.

Anchors. Anchors are normally required for holding equipment in place and snubbing conductors against tensions imposed. The type of anchor is dependent upon the soil conditions and sagging and stringing tensions. Portable equipment is often used for this purpose, as well as ground type anchors. Slack should be removed from all anchor lines prior to loading to minimize the possibility of equipment movement or impact loads to the anchors.

Equipment Grounding. Adequate grounding must be established at all sites. The methods required and equipment used will be determined by the degree of exposure to electrical hazards and the soil conditions at the site. All equipment, conductors, anchors and structures within the work area must be bonded together and to the ground source.

SECTION BETWEEN SNUB STRUCTURES

Crossing Structures. When crossing roads, highways, railroads, energized lines, etc, some type of supplemental crossing structure must be employed. This can be guard poles erected in football goalpost fashion of suitable height. In some cases, rope nets are strung between the poles to give more positive protection. A system of blocks can also be used to cradle the pulling lines and conductors. This is accomplished with support lines, space lines and load lines to properly locate the special cradle blocks to afford protection, should tension be lost during the stringing operation.

Terrain Problems. The terrain must be analysed to determine, if there are areas of impaired ground clearance under stringing tensions. If such areas exist, precautions must be taken to protect the conductor. Locations of conductor or pulling line uplift must also be identified in order that hold down blocks and uplift rollers may be provided. Other unusual terrain features may dictate special consideration.

Traveller Installation. Installation of travellers, including finger lines where used, requires consideration of traveler attachment methods and the need for and location of traveller grounds and uplift rollers. For single conductor vertical insulator assemblies, the travellers are normally connected directly to the insulators, and with vee string insulator assemblies, to the yoke plate. For most bundled conductor lines, the travellers are connected to the yoke plate. With post-type insulators, the travellers are connected to the end of the insulators. Where travellers are installed to string through deadend towers, the travellers are normally connected directly to the tower. If substantial line angles are involved, two travellers in tandem may de required to reduce the bending radius of the conductor or the load on each traveller, or both.

Where bundled conductor travellers are used at line angle locations of over 5°, it is advisable to change to individual single conductor travellers after the passage of the running board to facilitate accurate sagging.

When adequate quantities of travellers are available, it is common practice to install them at the same time the insulators are installed. Under some situations, travellers may be attached to slings or rods in place of the normal insulator assembly.

Need for traveller grounds and required locations must be based on the degree of exposure to electrical hazards. When such hazards exist, as a minimum, traveler grounds should be installed at the first and last tower between the tensioner and puller, When stringing in proximity to energized lines, additional grounds shall be installed as required, but at a maximum distance not exceeding three Km. Additionally, grounds shall be installed within a reasonable distance on each side of an energized crossing, preferably on the adjacent structures.

Travellers with grounds are usually sensitive to direction and care must be exercised in hanging the travellers. Usually the grounds are to the pulling end. Each traveller with grounds must be connected with temporary grounding sets to provide an electrical connection between the traveller and earth, or to some conductive medium that is at earth potential. Personnel should never be in series with a ground lead. Traveller grounds should have a suitable grounding stud located in an accessible position to enable placing and removing the ground clamps, with hot sticks when necessary. Travel grounds will also help protect the sheave linings.

At the time the travellers are hung, fixing lines, when used, should be installed and taken off at the base of the structure.

CONDUCTOR SPLICING

Normally, more than one conductor reel length will be required to obtain the total length of conductor to be strung at one time. Therefore the conductor lengths must be spliced together at tension site or midspan sites, or both. Regardless of the site, however, the required equipment and basic procedures are essentially the same and applicable to conductors, overhead groundwires and metal pulling lines.

EQUIPMENT. The major equipment required for splicing operations consists of splicing cart equipped with a hydraulic compressor, compression joints, strand restraining clamps, hold down blocks, rope, conductor grips, hoists, ground rods, personal ground bonding cables and clamp for a ground grid when it is to be installed. All equipment must have adequate mechanical or electrical capabilities, or both, for the work involved.

BONDING AND GROUNDING OF CONDUCTOR ENDS. It is extremely important that precautions be taken to prevent personnel from accidentally placing themselves in series between two conductors which are to be conneted together, or in series to ground with either conductor. Accidents of this type can be prevented by providing an equipotential work area, by grounding and placing a jumper across the opening between the ends of the two conductors to serve as a shunt or by a combination of both.

The following method is recommended when the line being strung might accidentally become energized, or when it is adjacent to parallel, or both, to an existing energized transmission line or when the possibility of high fault current exists and the work is to be performed at ground level by personnel in direct contact with the earth.

(1) Install a ground grid if the splice is to be made in midspan. Ground grids installed at the pull and tension sites will suffice for splices made at those locations.

(2) Bond the spling cart and all other mobile equipment, such as tractors, which may be holding the conductor ends, to the grid.

(3) Bond the two conductors to be spliced to a common ground using personal grounds connected within 10 ft. (3m) of each conductor end, then bond the conductor ends directly together using a jumper.

(4) Perform all splicing work within the grid perimeter.

In lieu of the ground grid, a metallic grounding mat may be used. The conductor ends and the mat should be bonded to a common ground. As before, a jumper must be installed directly between the conductor ends. If multiple ground rods are used, they should be bonded together. All splicing work should be performed on the mat.

If neither the grid nor the mat are used, all splicing work may be performed on an insulated platform. The conductor ends should be bonded to a common ground and directly together with a jumper as before. If multiple ground rods are used, they should be bonded together.

As a minimum, regardless of the level of exposure, a system of interconnected ground rods should be used, but the magnitude of potential electrical hazards must be thoroughly considered

COMPRESSION JOINT APPLICATION. The dies used to compress the compression joint must be of the correct size, and all PRESSES must be made in the proper sequence specified by the manufacturer of the joint. Joint compounds that aid electrical contact and prevention of corrosion must also be used as specified by the manufacturer. Failure to adhere to these requirements will result in defective splices which in turn may become potential hazards.

PASSING COMPRESSION JOINTS OVER TRAVELERS. The number of sites required for splicing conductors is dependent upon the number of conductor reel lengths required for the total length of conductor to be strung and the method used to join the conductor lengths as they are pulled out.

The most common stringing practice avoids pulling compression joints over the travellers. It consists of using woven wire grips to join the conductor lengths at the tension site until the total required length of conductor has been strung. The conductor is then lowered to the ground at each location of the woven wire grips, spliced, and later pulled up to sag.

Another stringing practice consists of splicing the conductor lengths together at the tension site with compression joints specifically designed to be pulled over travellers. It has an advantage in that all splicing is done at one location, thus reducing the total number of required operations when compared with the previous practice, particularly when ground grids are required. If this practice is to be employed a preliminary study of the line to be strung should be made to determine the maximum stringing tensions and roll over angles that would be encountered. Compression joint manufacturers shoald be consulted.

STRINGING PROCEDURES

INSTALLATION OF PULLING LINES. When finger lines are installed, they are used to pull the pilot line or pulling line through the travellers as it is pulled out. The pilot line, when used, is then pulled back by use of the pilot line winder behind it pulling line from a reel or drum puller, which can in turn be used to pull in the conductor. The initial pulling out of the pilot line or pulling line is usually done with any vehicle such as pickup truck or tractor, as appropriate.

INSTALLATION OF CONDUCTOR. Once the rope pulling lines have been installed and prior to pulling in any conductor or conductive type pulling lines, a running ground must be installed between the reel stand or tensioner for conductor, or puller for pulling line, and the first tower. This ground must be bonded to the ground previously established at the site.

Pulling lines are usually pulled in under tension. The pulling line is then connected to a single conductor through a swivel link, or to bundle conductors through swivel links and a running board.

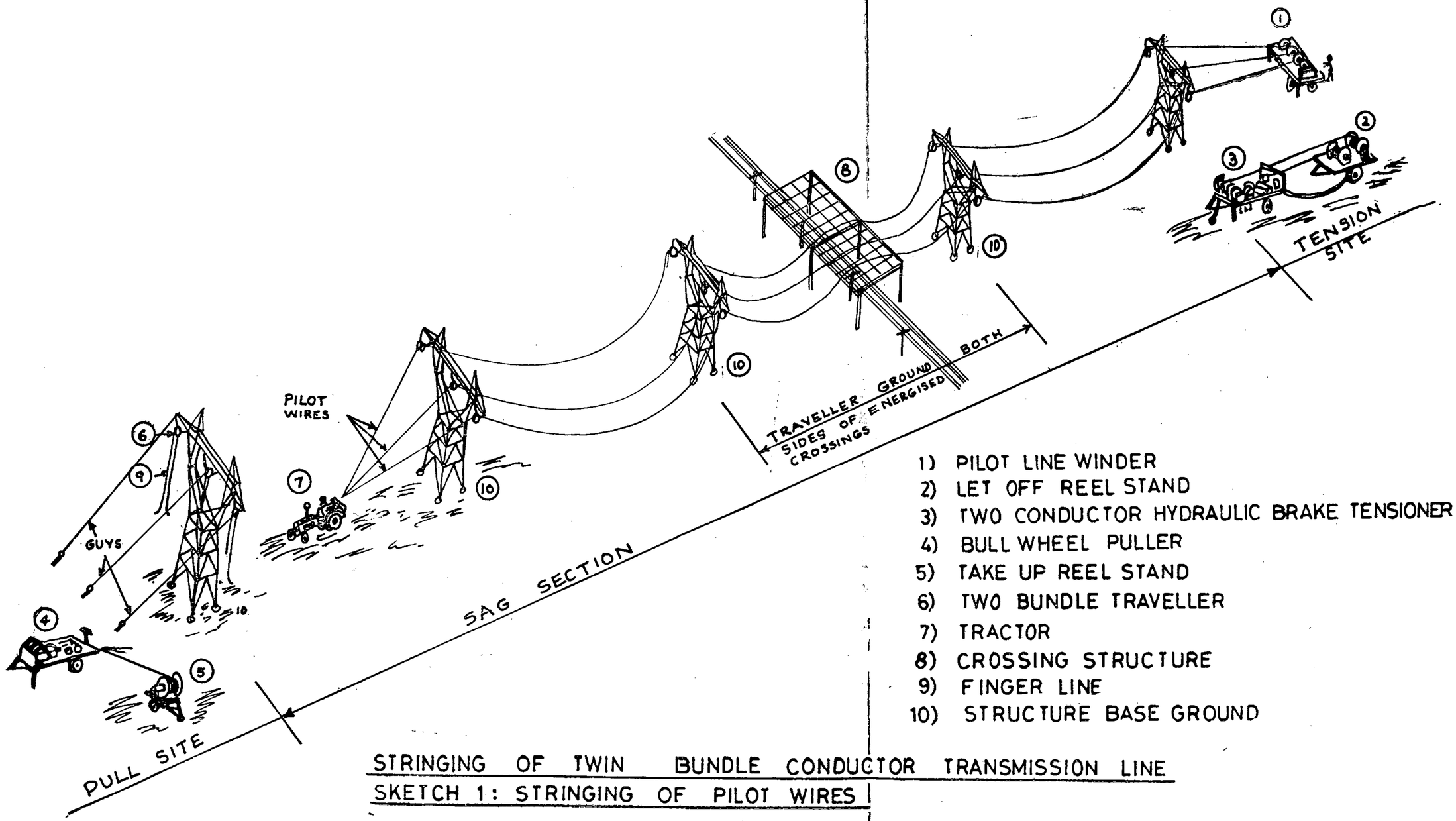
Swivel links should not be used on a three strand synthetic pulling line. Pulling lines may be synthetic fiber or wire rope. When wire rope is used, it is recommended that swaged type be used since it has less tendency to rotate under load, which minimises most spinning problems. Swaged rope also has a much smoother outer surface. This smoother surface, plus low rotation, minimises wear on traveller sheaves and bullwheel grooves on pullers. When synthetic pulling lines are used,a no torque rope is recommended to minimise the problems caused by kinking or twisting. This causes accelerated loss of strength of the pulling line, which results in a hazardous condition.

A ball bearing swivel link is usually used for the connections between conductors, pulling lines and running boards. Swivel links must be of sufficient rated working load to withstand loads placed on them during tension stringing. They should also be compatible with the travellers being used so they can pass through without spreading or damaging the sheaves. These special line stringing swivel links are clevis type and compatible with woven wire grips and swaged steel pulling lines. It is recommended that swivel links not be passed over bullwheels under significant tension since they may be weakend or damaged due to bending.

When reeving the bullwheels of a tensioner with the conductor entering and leaving the wheel from the top facing in the direction of pull, the conductor should enter from the left and leave from the right for right-hand lay (standard for aluminium conductor) and enter from the right and leave from the left for left-hand lay (standard for groundwire). This procedure will avoid the tendency to loosen the outer layer of strands as the conductor passes around the bullwheels.

It is recommended that conductor of-only one manufacturer be used in a given pull, and preferably in any given ruling span. Thls precaution will help avoid significantly different conductor sag characteristics.

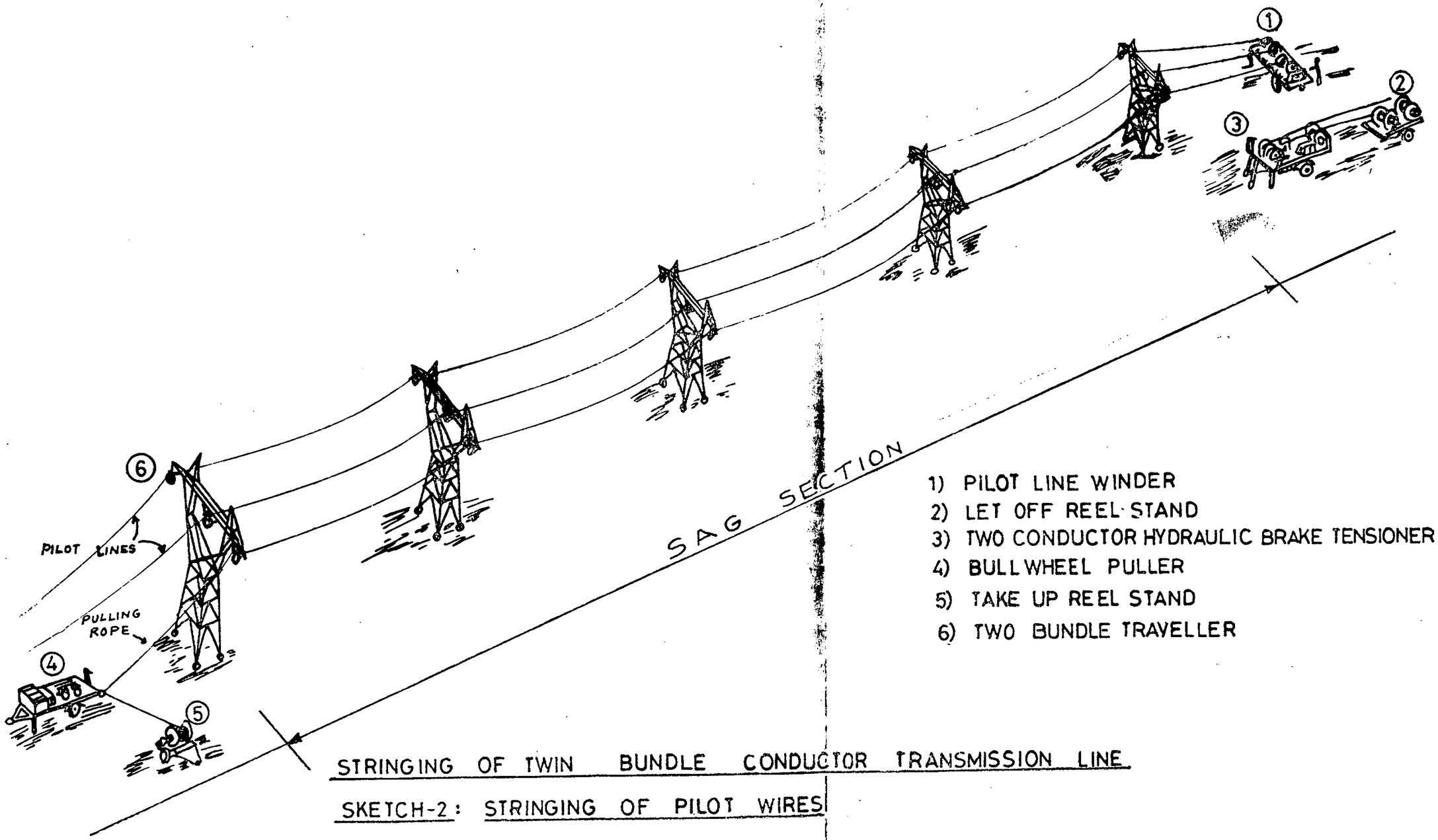
Attachment of the conductor to the pulling line, running board or to another reel of conductor to be pulled successively is accomplished by the use of woven wire grips. These grips should



1) PILOT LINE WINDER
2) LET OFF REEL STAND
3) TWO CONDUCTOR HYDRAULIC BRAKE TENSIONER
4) BULL WHEEL PULLER
5) TAKE UP REEL STAND
6) TWO BUNDLE TRAVELLER
7) TRACTOR
8) CROSSING STRUCTURE
9) FINGER LINE
10) STRUCTURE BASE GROUND

STRINGING OF TWIN BUNDLE CONDUCTOR TRANSMISSION LINE

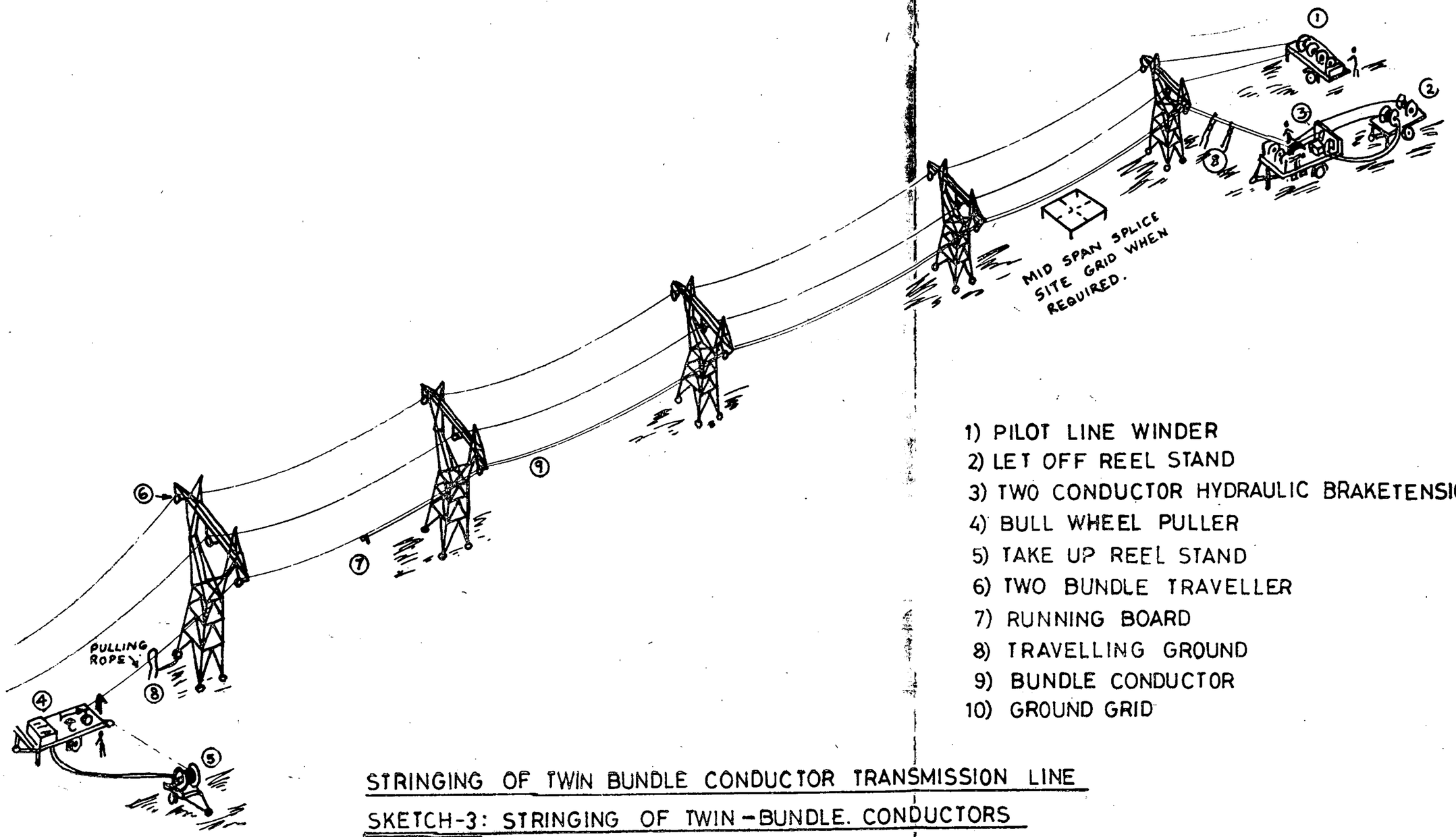
SKETCH 1: STRINGING OF PILOT WIRES



1) PILOT LINE WINDER
2) LET OFF REEL STAND
3) TWO CONDUCTOR HYDRAULIC BRAKE TENSIONER
4) BULL WHEEL PULLER
5) TAKE UP REEL STAND
6) TWO BUNDLE TRAVELLER

STRINGING OF TWIN BUNDLE CONDUCTOR TRANSMISSION LINE

SKETCH-2 : STRINGING OF PILOT WIRES



1) PILOT LINE WINDER
2) LET OFF REEL STAND
3) TWO CONDUCTOR HYDRAULIC BRAKETENSIONER
4) BULL WHEEL PULLER
5) TAKE UP REEL STAND
6) TWO BUNDLE TRAVELLER
7) RUNNING BOARD
8) TRAVELLING GROUND
9) BUNDLE CONDUCTOR
10) GROUND GRID

STRINGING OF TWIN BUNDLE CONDUCTOR TRANSMISSION LINE

SKETCH-3: STRINGING OF TWIN-BUNDLE. CONDUCTORS

be compatible strength-wise and sized as close as possible for the conductor or pullingnlie on which they are used. Overall diameter of the grip over the conductor or rope should be small enough to pass over the sheaves without damage to the sheave or lining and the grip must also be capable of matching with a proper size swivel link.

Metal bands should be installed over the grip to prevent it from accidentally coming or and dropping the conductor. The open end of the grip should be secured with two bands. This should then be wrapped with tape to prevent accidentally stripping the grip off the conductor if the end were to snag or catch. This is particularly important when these grips are used on pulling lines or between lengths of conductor when more than one reel is strung. The grips are then passing through the traveller backwards and if the ends are not banded and taped,they could be stripped off.

Experience has shown that pulling speed is an important factor in achieving a smoonth stringing operation. Speeds of 3-5 mi/h (5 km/h) usually provide a smooth passage of the runnig board or connecting hardware, or both over the traveller, whereas slower speeds may cause significant swinging of the traveller and insulator-hardware assemblies. Higher speeds create a potential Hazard of greater damage in case of a malfunction.

The maximum tension imposed on a conductor during stringing operations should not exceed that necessary to clear obstructions of the ground. This clearanced should be confirmed by observation. In general, stringing tension about half the sagging tension is a good criterion If greater tensions are required, cosideration must be given to any possible prestressing of conductors that may result, based on the tension and time involved. Cosideration must also be given to the fact that when long lengths of conductor are strung, the tension at the pulling end may exceed the tension at the tensioner by a significant amount. Differences in tension are caused by the length of conductor strung number and performance travellers, differences in elevation of supporting structures, etc. (See Appendix L, Efficiency of Travellers During Tension Stringing)

Light and steady back tension should be maintained on the conducror reels at all times sufficient to prevent over-run in case of a sudden stop.It must also be sufficient to cause the coductor to lie snugly in the first groove of the bullwheel and to prevent slack in the conductor between bullwhee-ls. It may be necessary periodically to loosen the brake on the reel stand as the conductor is payed off.

As the Reel empties, the moment arm available to over-come the brake drag is reduced, and the tension therefore rises. This may cause the conductor to wedge into the underlying layers on the reel.

The reel should be positioned so that it will rotate in the same direction as the bullwheels. Loosening of the stranding that often occurs between the reel and the bullwheels of the tensioner is caused to a great extent by coil memory in the conductor. As the conductor is unwound from the reel and straightens out, the outer strands become loose, a condition that is particularly noticeable in a large diameter conductor and can be best observed at the point at which it leaves the reel. As the conductor enters the bullwheel groove. the pressure of contact tends to push the loose outer strands back toward the reel where the looseness accumulates leading to the condition commonly known as birdcaging. If this condition is not controlled, the strands can become damaged to the extent that the damaged area of conductor must be removed.

This problem can be remedied by allowing enough distance between the reel and tensioner to permit the strand looseness to distribute along the intervening length of conductor and simultaneously maintaining enough back tension on the reel to stretch the core and inner strands to sufficiently tighten the outer strands.

The maximum time conductors may safely remain in the travelers depends on wind induced vibration or other motion of the conductors. Windblown sand can severely damage conductors in a few hours if clearance is less than about 10 ft (3m) over loose sand with little vegetation. Damage from vibration at sagging tensions is quite possible and, when required, dampers should be installed promptly. However, at lower tensions generally used for initial stringing, damage to conductors or sheave bearings, or both, is not likely to occur from vibration. Even for travellers having lined sheaves with root diameters 20 times the conductor diameter, it is important to complete conductor stringing, sagging, plumb marking, clipping, spacing and damping operations as soon as possible to prevent conductor damage from weather, particularly wind. Conductor should not be strung if adverse weather is predicted before the entire sequence can be completed.

Subconductor oscillation may occur in bundled conductor lines and tie-down methods, temporary spacers, or other means may be required to prevent conductor surface damage prior to installation of spacers. Temporarily positioning one subconductor above another to prevent conductor clashing is undesirable since different tension history will produce subconductor mismatch unless the tensions are low and duration short enough so that creep is not a factor Conductor clashing can mar the strands and produce slivers which can result in radio noise generation.

If a bullwheel type puller is utilised, the pulling line must be recovered during the pulling operation on a separate piece of equipment. This function is usually performed by a reel winder which is placed behind the puller in an arrangement similar to the reel stand at the tension site.

Once the conductor has been pulled into place, one end is normally attached to the structure through a deadend insulator-hardware assembly or to a previously sagged section of conductor, and the other end transferred from the puller or tensioner to the sagging unit. Attachment of the conductor to the sagging unit is accomplished by means of a properly designed conductor grip which must be capable of holding, without slipping, full sagging tension with appropriate safety factors. This must take into account possible impact loads which may be encountered as the pulling line wraps on the winch drum as well as over-tension if the conductor is accidentally pulled above desired sag.

Extreme caution must be exercised when transferring conductor from one holding device to another, or when connecting two conductors to ensure that the conductors are at all times adequately bonded together and to all equipment being used. This is essential to ensure that personnel connot get in series with two items at different potentials, or with a conductor which could conduct induced potential to a ground object.

Methods and procedures for the installation of overhead groundwires are the same as those indicated for conductors except that the loads and tensions involved are lighter. Groundwires are

commonly pulled with lightweight pulling lines which are installed directly without the use of a pilot line. The groundwire (s) are normally installed prior to pulling the conductors due to their higher location on the structures and to prevent damage to the more easily damaged conductors when pulling groundwires up through them.

6.14 MEASUREMET OF SAG :

Measurement of sag at the time of final tensioning of conductors is made by actual sightind of the sag at the selected "Sagging Span". The "Sag Boards" or "Sighting Boards" are use for this purpose. On the two towers of the "Sag Span" the Boards are tied at appropriate place corresponding to the measurement of the Sag for the span at the temperature of tensioning. These measurements are made from the point of suspension of the conductor and the sag boards are made of wooden battens with alternate colours of Red, White and Black for easy sighting purposes The sighting boards are tied facing each other. The sighting of sag is done by eye while standing behind one of the sag boards until the lowest point of the catenery coincides to the line of sight between the two sag boards of the sagging span. This measurement of sag is also checked with the reading of the dynamometer for the tension in the conductor at the particular temperature of sagging.

6.15 MEASUREMENT OF SAG WHERE THE SUPPORTS ARE AT DIFFERENT HEIGHTS :

In case of situations where the supports are at considerable elevation differences, the measurement of sag by sighting is impracticable by ordinary methods. In such cases the metod used is to depend on the dynamometer tor measurement of the tension in the conductor.

6.16 SHORT SPANS :

In case of very short spans and also short single spans of stringing, the method of sighting sag is impracticable and only tension readings of dynamometers is employed for final tensioning of conductors.

6.17 SAGGING PROCEDURES

1. SAGGING AND CLIPPING OFFSET THEORIES—Theoretically, conductor sagging is based upon hyperbolic functions describing a true catenary curve. In practice however. parabolic approximations of the catenary are often utilised.

The theory of clipping offsets is based upon the fact that, between snub structures, the total length of conductor at sag in the travellers is equal to the total length of conductor at sag in the suspension clamps.

Sags and clipping offests are interrelated since sag corrections required for computing sags are dependent upon clipping offset computations. The application of sags and clipping offsets computed in this manner will produce balanced horizontal forces which will be the same for each structure within the sag section.

Figures 30 through 34 depict a basic analysis for clipping offsets and typical parabolic methods and computations required for sagging conductors.

2. RECORDS AND FORMS—To assist in an accurate compilation of sag section data, a set of prepared forms should be devised to record accurately all field data, computations, drawing numbers, etc, as soon as they are obtained, Should questions arise while the work is in progress, or at a later date, the availability of such records might greatly assist in providing the answers.

DESIGN CRITERIA : A complete set of design criteria for the sag section should be available in the field. Included should be structure design data, stringing data, line profiles, conductor and pulling line sag templates, etc.

EQUIPMENT : Major equipment required for sagging includes transits (or similar viewing devices), portable radios, conductor thermometers, sagging platforms and targets, hand levels, stadia rods, measuring tapes and miscellaneous marking devices.

PULL SITE AND SNUB STRUCTURE RELATIONSHIP : A pull site should be adjacent to the snub structure whenever possible. However, if the snub structure is a deadend structure, it could be located several spans away. When this occurs, the conductor between the pull site and the snub structure must be slacked down as much as possible at sag completion to minimize prestressing of the conductor. It is not a desirable situation since the next sag section will include the prestressed conductor together with unstressed conductor. Such a situation should be avoided.

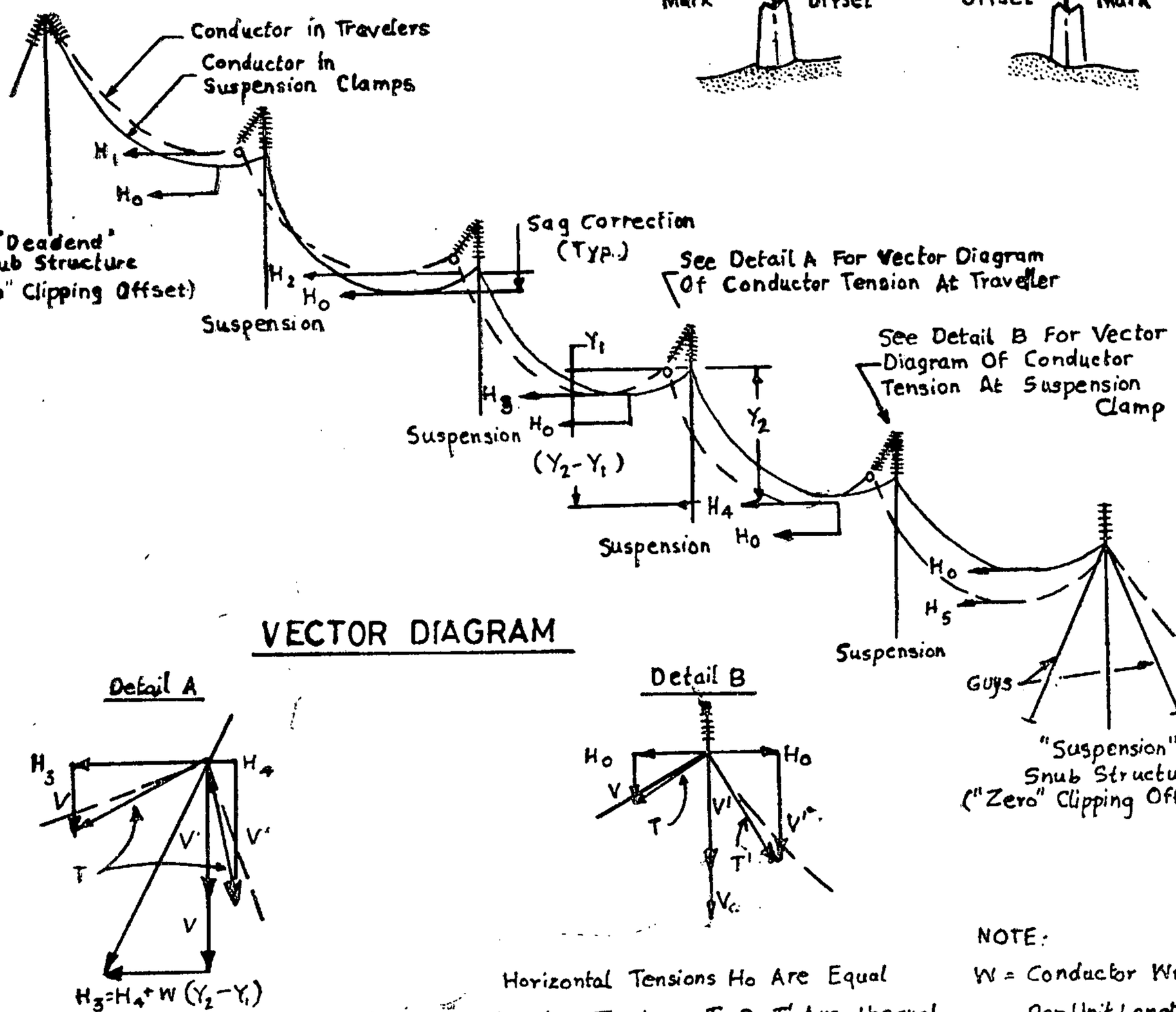
CONDUCTOR UPLIFT : Under certain conditions, conductor uplift within a sag section could occur at sag tension. Hold down blocks or uplift rollers, or both, will be required to hold the conductor in the travellers to compensate for this condition.

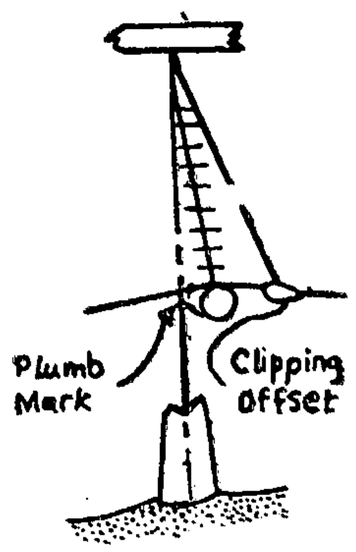
SAG SECTION LENGTH : A sag section should not exceed the limits mentioned in clause 3.05 Page 32. Exceptions do occur but should be avoided, particularly in hilly or mountainous terrain. Excessive sag section length will usually result in sagging difficulties.

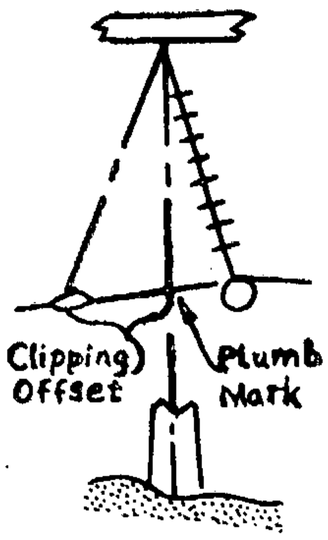
SAG SPAN LOCATIONS : Before sag spans are selected, a scale profile of the entire sag section should be reviewed to provide a complete, clear picture of the relationship between the terrain and the conductor. Such a profile is a valuable tool to be used in the selection of the sag spans and may emphasise locations of potential problems.

Sag spans should be at or near each end of the sag section. For sag sections over 3 KM long, additional sag span(s) near the center of the sag section should be utilised. Sag spans should be the longer, more level spans. If the sag span is not a level span, it is best if the transit is located at the lower structure since conductor control is increased. Sag spans should also be located on each side of line angles greater than 10 degrees.

TENSION CHANGES : Tension changes may occur at any point within a stringing section where a deadend structure is located. The most complicated situation occurs, however, when tension changes divide the stringing section into three or more separate parts, each of which must be sagged independently of the other. Under these conditions, two or more ruling spans, and hence two or more required tensions, exist within the stringing section. Although the conductor is continuous throughout the entire stringing section, the tension changes may be accomplished by







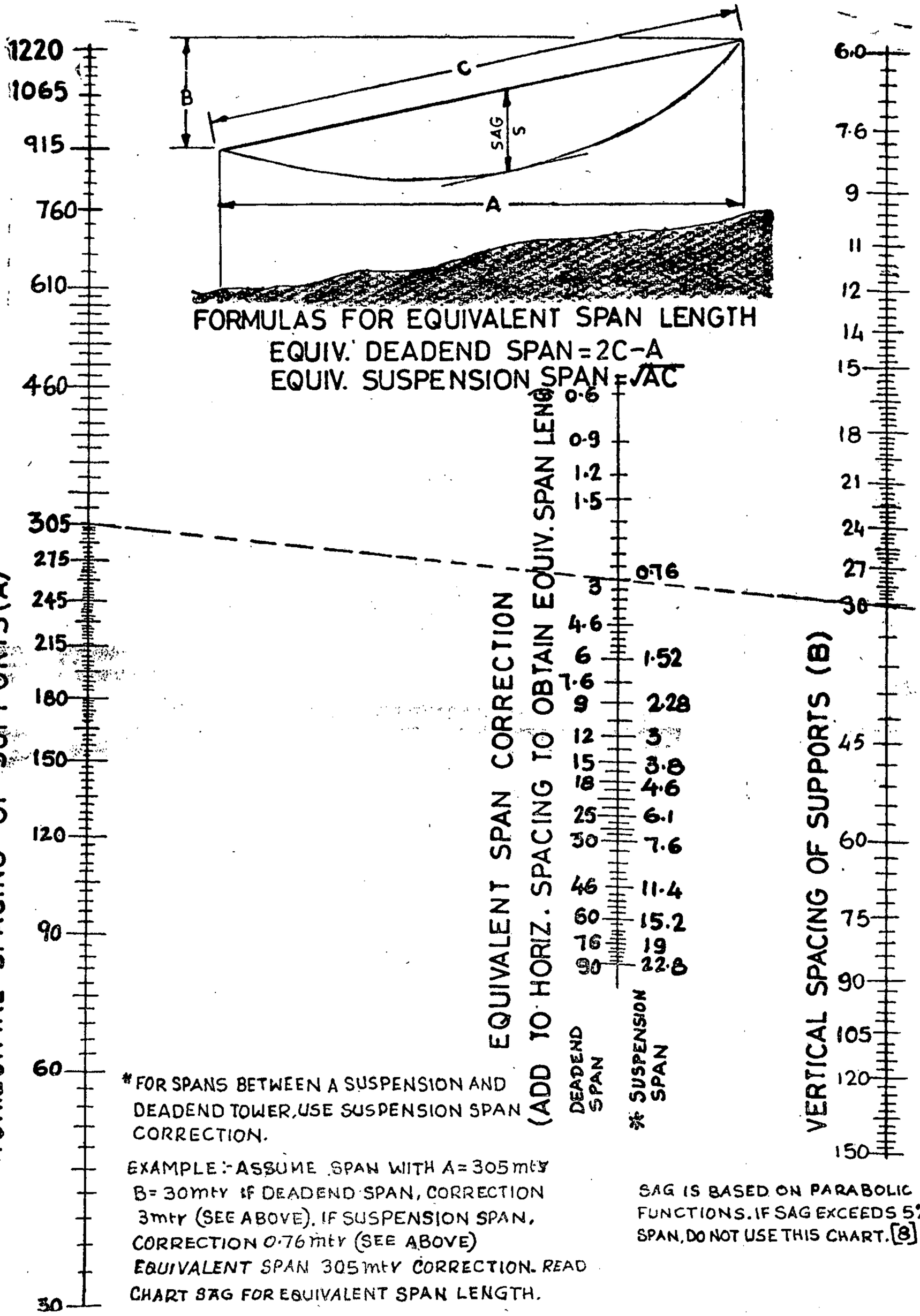
VECTOR DIAGRAM

NOTE:
W = Conductor Wt Per Unit Length

BASIC THEORY

$$\Sigma \text{ CONDUCTOR LENGTH IN TRAVELLERS} = \Sigma \text{CONDUCTOR LENGTH IN SUSPENSION CLAMPS}$$

FIG 30: EXAMPLE OF APPLICATION OF CLIPPING OFFSETS



* FOR SPANS BETWEEN A SUSPENSION AND DEADEND TOWER, USE SUSPENSION SPAN CORRECTION.

EXAMPLE :- ASSUME SPAN WITH A = 305 mtr B = 30 mtr IF DEADEND SPAN, CORRECTION 3 mtr (SEE ABOVE). IF SUSPENSION SPAN, CORRECTION 0·76 mtr (SEE ABOVE) EQUIVALENT SPAN 305 mtr CORRECTION. READ CHART SAG FOR EQUIVALENT SPAN LENGTH.

SAG IS BASED ON PARABOLIC FUNCTIONS. IF SAG EXCEEDS 5% OF SPAN, DO NOT USE THIS CHART. [8], [9]

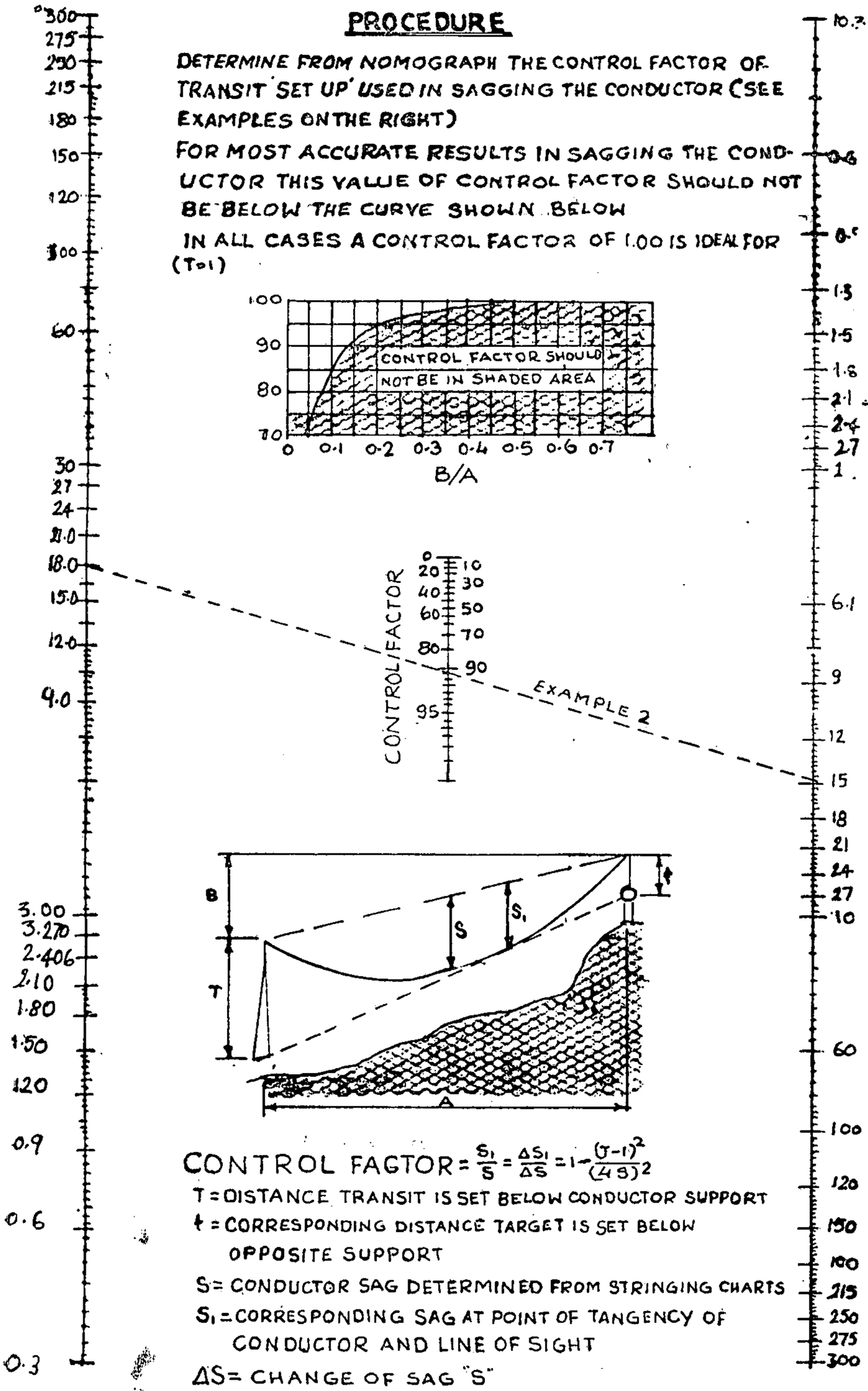
FIG-31: NOMOGRAPH FOR DETERMINING LEVEL SPAN EQUIVALENTS OF NONLEVEL SPANS

PROCEDURE

DETERMINE FROM NOMOGRAPH THE CONTROL FACTOR OF TRANSIT SET UP USED IN SAGGING THE CONDUCTOR (SEE EXAMPLES ON THE RIGHT)

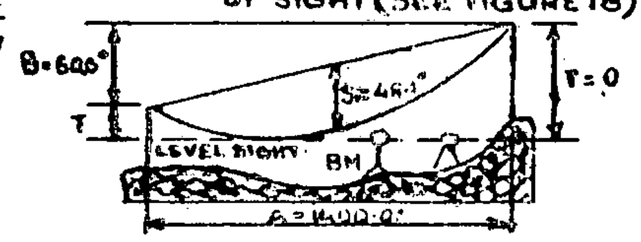
FOR MOST ACCURATE RESULTS IN SAGGING THE CONDUCTOR THIS VALUE OF CONTROL FACTOR SHOULD NOT BE BELOW THE CURVE SHOWN BELOW

IN ALL CASES A CONTROL FACTOR OF 1.00 IS IDEAL FOR (T=1)



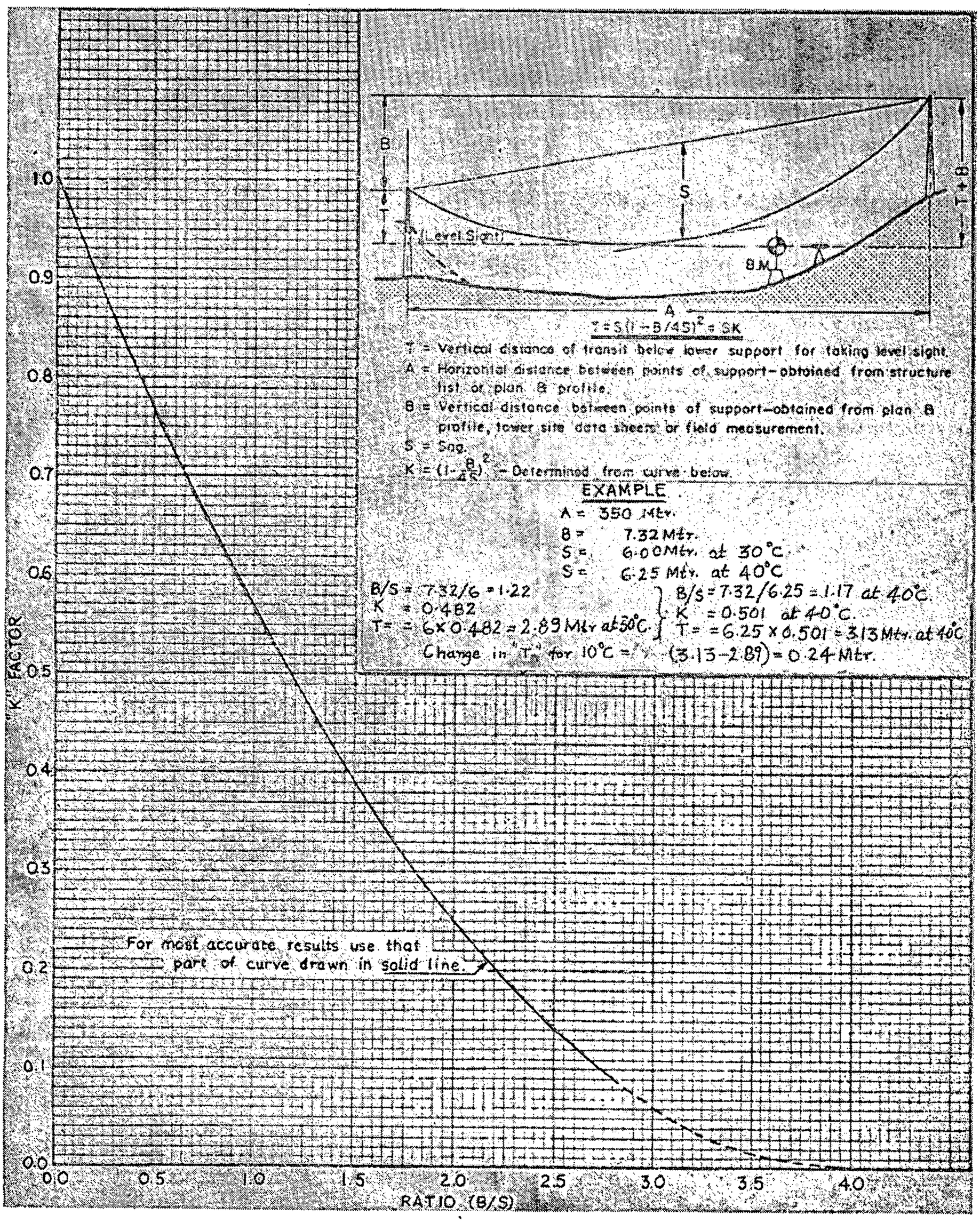
SAG IS BASED ON PARABOLIC FUNCTIONS.
IF SAG EXCEEDS 5% OF SPAN. DO NOT USE THIS CHART

EXAMPLE 2 – WHEN SAGGING BY HORIZANTAL LINE OF SIGHT (SEE FIGURE 18)



(T-t) = 'B' FOR HORIZANTAL LINE AT SIGHT = 6·00'
S = 49·1'
CONTROL FACTOR = 0·91 (FROM NOMOGRAPH)

FIG-32: NOMOGRAPH FOR DETERMINING CONTROL FACTOR FOR CONDUCTOR SAGGING.


B
T
S
(Level Sight)
B.M.
A
T + B
T = S (1 − B/4S)² = SK
T = Vertical distance of transit below lower support for taking level sight.
A = Horizontial distance between points of support – obtained from structure list or plan & profile.
B = Vertical distance between points of support – obtained from plan & profile, tower site data sheets or field measurement.
S = Sag.
K = (1 − B/2A)² – Determined from curve below.
EXAMPLE
A = 350 Mtr.
B = 7.32 Mtr.
S = 6.00 Mtr. at 30°C.
S = 6.25 Mtr. at 40°C
B/S = 7.32/6 = 1.22
K = 0.482
T = 6 × 0.482 = 2.89 Mtr at 30°C.
B/S = 7.32/6.25 = 1.17 at 40°C.
K = 0.501 at 40°C.
T = 6.25 × 0.501 = 3.13 Mtr. at 40°C
Change in "T" for 10°C = (3.13 − 2.89) = 0.24 Mtr.
"K" FACTOR
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
For most accurate results use that part of curve drawn in solid line.
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
RATIO (B/S)

deadending or the correct use of grips and hoists. Deadend structures will always exist at any point where conductor tension changes, but the mere existence of a deadend structure does not always imply a tension change.

CONTROL FACTORS : When choosing a sagging method, it should be kept in mind that the point of tangency of the line of sight from the transit to the conductor should fall in the middle third of the span. Reference to the profiles will usually give an indication of the best sagging method to use. For example, tall structures on flat terrian and short spans indicate that the methods shown in Figs 33 would probably provide the best control. Hills, long spans and large conductor sag should be studied separately Fig 32 depicts various nomographs and curves which may be used to ensure that the methods chosen to sag the conductor will provide adequate control. After the sag spans have been selected, they should be field checked for any potential difficulties which might occur during sagging. At the same time. sagging hubs should be established if required, and measurements required for sagging computations should be obtained. Although stopwatch sagging is sometimes used, accuracy restricts its application to smaller conductors and shorter spans than normally found in transmission work, Details of the stop watch method is furnished in Appendix 'O,

PREPARATATION PRIOR TO SAGGING : Preparations for performing the mechanics of conductor sagging should be completed well in advance of the actual sagging operation. Otherwise, excessive costs and delay can be incurred.

When required, sag span tranist hubs should be located and staked, transit height reference marks placed on the structures, and sagging platforms and transit mount brackets installed.

Sagging thermometers should be installed sufficiently prior to the actual sagging operation to allow temperature stabilisation and should be mounted far enough above the ground to avoid the effect of ground heat radiation. Thermometers should be inserted in'a container (sometimes a conductor section) to represent the temperature internal to the conductor. Two thermometers should be used and should be located in the sag spans which are near, or at the ends of the sag section.

The availability of sufficient portable radios should be ensured and, if necessary, transporta tion should be arranged.

All sagging personnel should ensure that they have the proper equipment and sagging data in their possesion. The person who controls the sagging should have in his possession a complete set of records pertaining to the entire saggin g operation.

Due to adverese terrain conditions, sagging personnel will not always be able to observe all spans of the sag section. A study of the sag section profile will normally reveal such a situation. If the condition exists, additional help will be required to ensure that the conductors are sagging evenly in the blind spans.

PERFORMANCE OF SAGGING OPERATION: After all preparations have been made and all personnel associated with the sagging opearaiton are in position, the person who controls the sag should relay all last minute details to the puller operator.

He should obtan last minute thermometer readings and use the average of the two readings-adjusted for an estimated increase or decrease in temperature at sag completion as the temperature

for sagging the conductor. This information should be relayed to all persons involved in the sagging.

Never sag a conductor to the level of a previously sagged conductor. Sag all conductors based on temperature design criteria only. At the time of sagging condctors, the sag of any given phase should be within 15 cm. of the theoretical value for the existing temperature conditions. The sag of all phases of a circuit should have similar tolerances and direction from theoritical sag. Subconductors within a phase should have tolerances between each other of not over two conductor diameters with a maximum of 5 cm. When checking sags at a time after original sagging, it must be remembered that creep will increase the sag and greater tolerance limits must be allowed for this and other unavoidable variations. Although it is desirable to check sags as soon as possible, it must be remembered that error may be introduced during the clipping and deadending processes.

Communications and co-operation between the personnel who are sagging and the pullee operator, and among the personnel themselves are essential. The personnel should keep the puller operator constantly informed of the conductor movement, and if bundled conductors are being sagged, they should also keep him advised of the state of evenness existing between the subconductors.

Conductor is sagged in progressive order from the tensioner end of the sag section to the puller end. Therefore, as the puller operator initiates conductor movement at the puller end, each person in a sag span, progressing from the puller end to the tensioner end should inform the person who is actually sagging, of the conductor movement as it moves through the sag section. Two benefits are derived by this method of communication. First, the person who is actually sagging knows when to expect conductor movement in his sag span, and second, the puller operator knows when he should slow down or stop pulling.

Actual conductor sagging is initiated by the person who controls the sag and is first performed by the person in the sag span farther from the puller working with persons who had spliced the conductor in the span containing the anchors for the previous sag. As the conductor is slowly released from the anchors, the person who is sagging should have the puller operator take the slack out of the conductor until it is slightly below sag. This condition should be maintained until the conductor is completely released from the hold down blocks. Once the conductor is completely released, it can be pulled to sag.

If the conductors being sagged are bundled conductors, they should be brought to sag as evenly as possible. Should one of the subconductors be inadvertently pulled above sag in the sag span, severe difficulties can develop. In this situation, an attempt to slack one subconductor of the bundle down to sag usually results in unevenness in all of the other spans. Should this situation occur after an attempt to slack one subconductor down to sag, the sag should be stopped and the entire bundle slacked down below sag and evened. Another attempt to sag the conductors can then be made. Once the first sag span has been brought to sag, the subconductors of the bundle should be checked for evenness, and then the next progressive sag span should be sagged. Unevenness in the sag spans in the middle or puller end of a sag section can usually be corrected by some manipulations of the conductors and under normal conditions will not result in starting the sag over again.

Attempts to sag conductor on excessively windy days should be avoided since serious errors can result due to conductor uplift caused by wind pressure on the conductor. Should severe wind

conditions occur after a sag is in progress, allowances must be made for conductor uplift or the sag must be stopped.

TECHNIQUES FOR CHECKING SATISFACTORY SAG PROGRESSION. There are various techniques which are employed to determine if a conductor is sagging correctly. As stated before, conductor is sagged progressively toward the puller end of a sag section. As the first sag span comes to sag, the second person to sag should find that the conductor in his sag span is too high. This is to be expected and is normal unless the conductor is excessively high. As the second person slacks his conductor down to sag, the third person should find the conductor too low in his sag span, and so on until the sag is completed. If any of the persons who are sagging do not have the required conditions when the conductor is brought to sag in the preceding sag span, the entire sagging operation should be halted until the trouble is located.

If the conditions above are met, satisfactory sag progression is indicated. However, if an attempt to sag any sag span results in serious movement of a previously sagged span, trouble is again indicated, and the sagging operation should be halted until the trouble is located.

When the sag is completed, a tension reading should be recorded if a dynamometer has been used. The reading should be very close to the nominal tensions expected. Should the reading deviate excessively from the nominal tensions expected, the trouble should be located and any corrections made before the completed sag is accepted.

CONDUCTOR REACTION TO SAGGING TENSIONS. The reaction of conductor to tensions applied during sagging operations is similar to the wave created by dropping a stone in water. Once the wave is initiated, it continues for some period of time. Similarly, when tensions are applied to the conductor at the puller end of a sag section, the movement of the conductor is initiated at that point, and although the tension may be held constant (puller stops), the movement of the conductor continues toward the other end at a decreasing rate. This movement must be dealt with when sagging conductor.

The travelers which are used to string conductor are not frictionless and, therefore, can cause problems during a sagging operation. If one or more of the travelers becomes jammed, sagging can become very difficult. A traveler which swings in the direction of the pull may be an indication of a defective traveller Should unexplainable sagging difficulties occur, the travellers should be checked. Tensions applied to the conductor to overcome sticky or jammed travellers can cause sudden, abrupt movement of the conductor in the sag spans and quickly cause loss of sag, particularly if the conductor is already very close to sag.

6.18 FINAL TENSIONING :

The conductors are sagged into the correct sags and tension by means of sagging units consisting of correct pulling grips and other equipments which hold the conductor to full sagging tension, without slipping and also having appropriate factor of safety. The strength of the equipment used must also take into consideration the possible impact loads during the course of working. Also extreme safety measures and caution must be exercised when transferring the conductor from one device to another.

6.19 GROUND WIRE (OVERHEAD) STRINGING :

The procedure for overhead ground wire stringing is similar to the process of conductor stringing except that the loads and the tensions involved are lighter. It is usual practice to string the groundwire first followed by the stringing of the conductors. Also ground wires could be installed directly without the use of pilot wires since they are normally lighter.

6.20 CLIPPING IN :

The next work is to plumb-mark the conductor or conductors resting on the running out blocks. This marking is done by means of a plumb bob or a plumb-marker made for the purpose so that marking on the conductor will be in plumb with the suspension insulator string assembly.

After the marking is done, the conductor is lifted by means of suitable hooks connected to a lifting tackle on the tower so that the load on the running block is released to enable the personnel to remove the running out block. The lifting hook will be of such a material as not to cause any damage to the conductor surfaces and also having enough strength to withstand the loadings imposed during lifting of the conductor. It shall also have a rubber or neoprene lining.

The lifting arrangement can be with a single hook in case of single conductor and with more hooks in case of bundled conductors and attached to a yoke.

Associated with the clipping-in of conductors is armouring of conductors and the fixing of vibration dampers wherever necessary.

Armouring can be of either tapered armour rod sets with ferrules on either side or preformed armour rods. The sizes and lengths depends on the size of the conductors

Fixing of vibration dampers also are to be done as per recommendation of manufacturers. The purpose of fixing vibration dampers on conductors is to minimise the vibration effects on the conductors and also to prevent the possible damage due to vibrations.

The vibration damper consists essentially of two hollow weights jointed together with a flexible wire of a certain distance. The centre of the flexible wire will have a bolted type attachment to fix the vibration damper to the conductor. Normally one damper is fixed on either side of the suspension clamp in a tower or on either side of the tension clamp as the case may be. The dampers are fixed at different distances measured from either the suspension clamp or the dead end assembly. This distance depends on the size of the conductor and the span on either side of a tower. In case of very long spans it will be necessary to use 2 or 3 dampers on each conductor.

6.20 INSTALLATION OF SPACERS :

Spacers are required to be provided only in case of bundled conductors. The purpose is to maintain the correct spacing of the sub-conductors and also to minimise the effect of osicillation on the sub-conductors. The fixing of spacers is done by persons with the use of a spacering-cycle for the purpose, which will facilitate their movement along the span.

The spacering-cycles can be either hand operated or power operated as per the requirement and the number of spacers to be fixed in a line. The load of the man, the spacer-cycle and

equipment should equally be distributed on the sub-conductors during the time of attachment of the spacers.

It is desirable that all the work of clipping-in, armouring and fixing of vibration dampers and spacer dampers are completed within 48 hours after the completion of final tensioning of conductors in any section. Further delay is likely to cause damage to the conductors due to wind and vibration loads.

DEAD ENDING PRECAUTIONS:

Electrical Hazards : The electrical hazards that exist where dead ending work is being performed are analogues to those that exist during splicing operations. Therefore precautions must be taken to prevent personnel from accidentally placing themselves in series with a potential electrical circuit.

TENSION AND PULL SITES : Continuity of grounding and bonding must be maintained when conductors or conductive pulling lines, or both, are transferred between pieces of equipment and anchors. In the majority of cases, it will be necessary to move an existing ground on a conductor or pulling line before it can be transferred. Before removing the existing ground, the person must install his own personal ground to ensure that he will not place himself in series to ground with the conductor or line being transferred.

DEADEND STRUCTURES : Prior to installing or removing deadend jumper on a metal structure, personal grounds must be installed on the conductors on both sides of the intended work area and connected to the structure. If the structure is wood, they must be connected to a common ground source. In some cases, after one end of the jumper has been permanently attached to one conductor, electrical induction may be so severe that a third personal ground will be required to bond the loose end of the jumper to the other conductor in order that the jumper can be permanently attached.

Clipping In. The clipping portion of the conductor stringing operation involves the work following sagging and plumb marking of the conductors. This entails removing the conductors from the travellers and placing them in their permanent suspension clamps attached to the insulator assemblies.

Clipping begins once the conductor has been brought to sag and is initiated by placing plumb marks on the conductor directly below the insulator attachment points on the structures with a plumb marker pole. This marking is done as soon as possible after reaching sag to minimise the effect of creep and possible movement of the conductor between spans. In rugged terrain, clipping offsets may be used whereby the suspension clamp, rather than being placed at the plumb marks, is offset a calculated distance from the mark to compensate for the unevenness of the terrain and to allow the insulator assemblies to hang vertically when all structures have been clipped in. When clipping is being done, care must be exercised to be certain that the conductosr

are grounded prior to clipping, despite the fact that the lines being clipped are not attached to any electrical source. This involves placing a personal ground upon the conductor at the location being worked.

After the conductors have been marked, personnel lift the weight of the conductors, allowing the travellers to be removed and the suspension clamps, and armuor rod if used, to be placed on the conductors. Lifting is normally done by use of a hoist suspended from the structure and a conductor lifting hook which is designed so as not to notch or severely bend the conductors. After placing the suspension clamps on the conductor, the hooks are lowered, thereby placing the weight of the conductor on the suspension clamp and completing the assembly. Where bundled conductors are used, the multiple conductors may be lifted simultaneously by the use of a yoke arrangement supporting the hooks and a single hoist or other lifting means.

DAMPER INSTALLATION : Dampers are normally placed on the conductors immediately following clipping to prevent any possible wind vibration damage to the conductors which at critical tensions and wind conditions can occur in a matter of a few hours.

Spacer Installation. Following the clipping sequence of operations for bundled conductor lines, spacers must usually be installed. This is done by placing personnel on the conductor with the use of a conductor car to ride from structure to structure. Depending on the amount of line to be spaced and the equipment available, cars may be hand powered' towed by persons on the ground or in adjacent structures with ropes, or powered by a small engine on the car itself. Care must be exercised to ensure that the concentrated load of the man car and equipment does not increase the sag sutficiently to cause a hazard from obstructions over which the car will pass. The installation of the spacers on the conductor varies with the type and manufacture of the spacer and is normally done in accordance with the manufacturer's recommendations.

The load of the man, car and equipment should be equally distributed to all subconductors of the phase. This is particularly impartant at the time each spacer is attached.

6.22 METHOD OF APPLYiNG TUBULAR COMPRESSION JOINTS :

(1) Clean the aluminium and steel stands. If any damages are observed, cut off the same.

(2) Slip the aluminium joint over the conductor and out of the way.

(3) With short lengths of wires serve the conductor ends. With a hacksaw cut off the aluminium wires from each conductor end and thus exposing the steel core for a distance equal to nalf the length of the steel compression joint after compression plus additional 3 mm. being careful not to nick the steel core. Serve the ends of the steel core with short lengths of wire.

(4) Loosen core servings and insert the two ends of the steel core into the steel compression joint taking care the ends are at the centre of the joint. Remove servings from steel core.

(5) Compress the steel joint, beginning at the centre and working first towards one end and then towards other end, making sure that the dies are fully closed and always overlap previous position. The distance between the end of the compressed steel joint and the end of the aluminium strands should not be more than about 6.5 mm.

(6) Using Emery paper clean the outer layer of the conductor over the compression length. Wherever filler compounds are used, the same shall be quoted liberally.

(7) Remove the servings from conductor and slip the aliminium joint over the steel joint, being careful that the steel joint is in the centre of the aluminium joint. This can be done easily by marking one conductor end with an adhesive tape at a distance from the centre of the steel joint equal to half the length of the aluminium joint.

(8) Wherever filler compound is used the same shall be injected with a chaulking gun. Aluminium plugs are inserted in the filler holes and hammered so that the same is completely locked in position.

(9) Compress the aluminium joint, starting with the die centre over one filler hole in the upright position and work towards the nearest end of the aluminium joint. Repeat this over the other portion of the joint also. Always make sure that the die overlaps the previous position.

6.23 METHOD OF APPLICATION OF COMPRESSION DEAD END CLAMP :

The methed is similar to that of compression joint. The only difference is steel sleeve be compressed from the barrel next to tbe grooved section working towards open end. Similarly the aluminium dead end should be compressed starting at the end nearest to the collar on steel dead end, and continued to the mouth of dead end. However it is not necessary to compress between the two circular markings over the portion of the compressed barrel of the steel dead end.

The aluminium jumper shall also be compresed in a similar way, with the jumper conductor, and bolted to the dead end.

6 24 REPAIR SLEEVES :

These shall be used wherever the damages to the aluminium strands of the conductors are observed. The repair sleeves are inserted in position and the keeper is placed in position. The sleeve is then compressed in a similar way to the aluminium sleeves of compression joint, starting from centre and working towards both ends.

6.25 PREFORMED ARMOUR RODS :

Take 2 or 3 rods with one hand on each side of the centre mark such that the hands will not be more than one or two pitch lengths away from the centre mark. With the centre mark of the rods located at the centre mark of the support begin applying the rods by rotating about conductor continuing from 1 or 2 pitch lengths on either side of the centre. Apply the remaining rods in groups of 3 or 4 as before. With a spiral motion of the hands continue applying rods untill their ends are, snapped into position.

6.26 VIBRATION DAMPERS :

The stock-bridge vibration dampers shall be provided in the positions shown in APPENDIX—D. These may be used only in the absence of manufacturer's instructions.

6.27 INSULATOR ASSEMBLY :

The No. of insulator discs to be used and the gradation of the distance between the gaps of arcing horns depends on the electrical design of the line, and instructions from the design office shall be strictly followed.

Appendix E gives the typical details of the string arrangement for various voltage class for general information.

Care should be taken to see at the time of erection that the arcing gaps are in line since otherwise the electrical characteristics are considerably alteled.

6.28 TOOLS AND TACKLE :

The following tools and tackle are required for conductor erection.

1) Manilla rope 1.9 cm. dia of suitable lengths.
2) Automatic come-along clamps of ground conductor and power conductors.
3) Pulley blocks of required sizes.
4) Spanners of required sizes.
5) Wooden sleepers.
6) Running blocks.
7) Tractor.
8) Pull lifts.
9) Hydraulic compressors & dies of sizes.
10) Ground rollers.
11) Dynamometers.
12) Dumpy level.
13) Stands for mounting conductor drums.
14) Tension stringing equipment for bundle conductors
15) Spacer fixing trolleys for bundled conductors.
16) Winches.
17) Aerial rollers.
18) Aerial trolleys.
19) Theromometers.
20) Measuring tape.
21) Whistles
22) Guy wires and Anchors.

CHAPTER 7

TESTING AND COMMISSIONING

Before the line is energised, Danger boards, number plates, phase plates, Anticlimbing devices etc. are to be fitted and a visual examination of the line shall be carried out to check that all the bolts and nuts are tight and insulators are in position at each support. The earths and earth connections shall also be checked. The insulators coming in heavily polluted area shall be cleaned and washed.

Before commissioning, the required clearances from Government Electrical Inspectorate, Railway and P & T authorities shall be obtained. PTCC approval alone is not sufficient for telephone and telegraph circuits and the approval of the local P & T authorities shall be obtained before tbe lines are energised.

The following pre-commissioning tests shall be carried out ;

(a) Conductor continuity test :- This is to verify that each conductor is properly connected electrically, that is the value of electrical resistance do not vary abnormally from that of a continuous conductor of the same size and length. The electrical resistance of the conductor shall be measured with a Wheat Stone bridge or other suitable eqipment.

(b) Insulation resistance test : The test shall be carried out with a 5KV motor operated megger.

ACKNOWLEDGEMENTS

Considerable assistance is derived from the following references in preparation o this manual.

1. IS 5613-Parts I and II-Section 1 & 2-"Code of practice for Design, Installation and main tenance of transmission lines upto 220 kv."
2. 'Overhead line practice' — John Mc Combe
3. 'Overhead Electric Power lines' — G. C. Gracy
4. 'Galvanised bolting for Transmission line towers' — Guest Keen Williams Publication.
5. IEEE Std. 524-1980-IEEE Guide to the installation of overhead Transmission line conductors
6. 'ALCAN' conductor and Accessories (Metric Edition)
   —Aluminium company of Canada Ltd, Publication.
7. N.G.K. Insulators — Catalogue No. 60.
8. Technical report No. 9. — Manual on Transmission line towers.
   — CBIP Publication.
9. Power Engineers' Hand Book — Edited & Published
   by Tamilnadu Electricity Board
   Engineers' Association
10. 'Surveying' — by B. C. Punmia

Our thanks are also due to Sri R.V. Murthy, who has furnished several valuable information egarding stringing of power conductor and grondwire.

APPENDIX A-1

REGULATIONS

Electrical Crossings of Railway Tracks

I. GENERAL

1. DEFINITION :

1.1 The following terms wherever occuring in these Regulations shall, unless excluded by or repugnant to the context, have the meaning attributed thereto as follows :

"Chief Electrical Engineer" means the officer designated as such by the Railway or a successor in office or on whom his duties devolve.

"Electrical crossing" means an electrical overhead or underground line placed across railway tracks for transmission and distribution of electrical energy. It is also referred to as a "crossing" in these Regulations.

"Electrical Inspector" means the officer appointed by the Government under Section 36 of the Indian Electricity Act, 1910, to exercise the powers and perform the functions under the said Act, in respect of the Railway.

"Owner" means the owner of an electrical crossing.

"Railway" means the railway administration in whose territorial jurisdiction the electrical crossing is located or proposed to be located and include the Chief Electrical Engineer and the Divisional Railway Manager (Electrical) concerned of the Railway adminstration.

'Writing' includes all matters written, typewritten or printed either in whole or in part.

2. SCOPE :

2 1 These Regulations apply to overhead electric transmission distribution lines or underground cables crossing railway tracks operated by the Indian Railways Rly. Companies and Port Commissioner's Railways, including assisted and private sidings on which rolling stock of Indian Railways may work, unless any special section or railway tracks is exempted from these Regulations by specific orders of the Electrical Inspector. They also cover the regulations for crossing of two overhead Power lines belonging to Railways or supply authorities, one or both of which would be supplying power to Railways.

Note : (i) If any existing or crossing infringes with these Regulations at the time of its issue the infringement/s shall be treated as permissible infringement/s

provided necessary relaxation is granted in respect of required clearances (See Clause–22.2) and Electrical Inspector's approval obtained.

(ii) These regulations do not cover/apply for crossing/s with railway track/s laid underground/inside tubes.

(iii) For crossings of 25 KV feeders and return conductors etc. which are part of the traction overhead equipment across railway tracks, the minimum clearance and other stipulations specified in these Regulations shall not apply as these conductors are essentialy traction conductors.

3. CLASSIFICATION OF CROSSINGS :

3.1 For the purpose of these Regulations, electric overhead line crossings are classified in accordance with the clearances required under the following categories :-

CATEGORY A : Tracks electrified on 1500 V dc. system in the Bombay area.

The existing overhead crossings will be retained as they are. In the case of new crossings, the clearances given under Clause-18.3(i) will apply.

CATEGORY B : Tracks already electrified or likely to be converted to or electrified on 25 KV ac system within the foreseeable future :

In these cases, the clearances as per Clause–18.3 (ii) shall apply.
The expression "foreseeable future" is intended to cover the track (s) where electification is expected to start within 10 to 15 years.

Note : On sections proposed to be electrified or to be converted to suit 25 KV ac, crossings existing at the time of proposed electrification/conversion shall be studied specially to avoid modifications to the maximum extent possible without jeopardising safety. Such modifications as are considered essential shall be carried out to improve clearances (See Clause–22.2).

CATEGORY C : Tracks not likely to be electrified in the foreseeable future (See Clause-18.3[i]).

4. APPROVAL OF WORKS BY THE RAILWAYS :

4.1 (i) Before commencing work on any crossing approval of the Railway and the Electrical Inspector in writing shall be obtained for the proposed location, detailed design and method of execution of crossing. For this purpose, data, designs, calculations and drawing/s (in duplicate) relating to the crossing shall be submitted by the Owner to the Railway and Electrical Inspector as per requirements indicated in Annexure—1.

The drawing/s shall show all relevant details including the information specified in Annexure—1. On receipt of approval from the Railway and the Electrical Inspector, the Owner shall execute an agreement in the Standard form (See Annexure—2) before commencing work on the crossing.

(ii) Construction : The crossings shall be constructed in accordance with approved designs and drawings, with good material and workmanship. Notice shall also be given before taking up construction, to the Railway in writing, whereupon the Electrical Inspector or his representative may inspect the crossing during construction, to ensure compliance with designs/drawings and Regulations etc.

(iii) Bringing crossing into use : The approval to bring the crossing into use will be given by the Railway only after compliance with the following requirements :

a) The Owner shall notify his intention to bring the crossing into use at least 15 days in advance to the Railways.

b) A certificate shall be submitted to the Railway indicating the works have been constructed in full compliance with these Regulations and in conformity with design/s and drawing/s approved by the Electrical Inspector and the Railway in the form given in Annexure—3.

5. COMPLIANCE WITH INDIAN ELECTRICITY ACT, 1910, AND INDIAN RAILWAYS ACT. 1980 AND RULES MADE THEREUNDER :

5.1 Except where otherwise stated in these Regulations, the relevant sections of the Indian Electricity Act, 1910, and Indian Railways Act, 1890, and rules made thereunder, including the relevant Schedules of Dimensions for broad, metre and narrow gauages together with latest amendment if any to the above rules, shall apply.

6. COMPLIANCE WITH STANDARD SPECIFICATIONS :

6.1 All material used in the construction of the crossings shall comply with the latest relevant Indian Standard Specifications and where these are not available, with the latest relevant British Standard Specifications.

7. WORKS TO BE EXECUTED BY THE RAILWAY :

7.1 The disturbance of any Rail road or ground or any attachment to any railway structure, which may be necessary in the placing, or maintenance of the crossing, shall be effected by or under the supervision of the Railway and any conduit, culvert, or similar work, passing under railway premises shall be constructed by the Railway in such a manner and of such materials as it may approve of and the cost of such work shall be borne by the owner of the crossing.

8. METHOD OF CROSSING, OVERHEAD OR UNDERGROUND :

i) For tracks already electrified or to be electrified in the foreseeable future. (Categories A and B) :

All low, medium and high voltage upto and including 11 KV crossings shall be by means of underground cables. For 22 and 33 KV high voltage crossings, the use of underground cable is recommended. For higher voltages, crossings may be overhead or underground, as, preferred by the Owner.

8.2 ii) For non-electrified tracks (Category C) :

All low, medium and high voltages (upto and including) 11 KV crossings shall be by means of underground cable. For higher voltages, crossings may be either overhead or underground as preferred by the owner.

9. PROTECTION OF COMMUNICATION LINES :

9.1 The crossing shall in no way interfere with or endanger railway communication lines, and approval given by the Railway to the placing or any crossing shall not be construed as affecting in any way the requirements of the Indian Posts and Telegraphs Department for the protection of communication lines.

9.2 The crossing shall also comply with the stipulations in the Code of Practice (1965) for the protection of Telecommunication lines at crossings with overhead power lines other than Electric Traction circuits issued by Power and Telecommunication co-ordination Committee (PTCC) Govt. of India and latest amendments thereof, if any.

10. MAINTENANCE OF CROSSINGS :

10.1 No work involving removal, alteration or maintenance of any crossing shall be under-taken without obtaining the consent in writing from the Railway and such works shall be carried out under the supervision of Railway's official.

10.2 The crossing shall be maintained in a state of good repair so as to reduce hazards to life and property. Each installation shall be inspected by the Owner periodically at intervals not exceeding 12 months, to determine its fitness for service. Defects noticed during such inspections or as pointed out by the Rly. shall be rectified by the Owner as soon as possible. The decision of the Railway in regard to defects and rectification/s called for, shall be final and binding on the Owner.

10.3 In overhead crossings, the crossing spans and the two adjoining spans shall be kep free by the Owner, from overhanging or decayed trees which might fall on the spans For EHT lines, all trees within 13 m on either side of the lines and all trees which on falling would foul with the line shall be cut by the Owner of such line. All bushes and wild vegetation up to 6 m on either side to be completely removed.

10.4 If steel poles or fabricated steel structures supporting the crossing span are not galvanised, they shall be painted periodically at intervals not exceeding five years.

10 5 The shifting of, or modification to, or dismantling of the crossing shall be carried out by the Owner. The cost of such works will be borne by the Railways except in those cases where the needs for such works on account of Railways anticipated development/requirements was foreseen and the Owner had agreed in writing prior to the construction of the crossing for meeting the cost of such works. Such works

shall be carried out on priority basis by the Owner within a fixed schedule, as mutually agreed upon between the Owner and the Railway; to the satisfaction of the Electrical Inspector. Railway shall have the right to claim the compensation for any loss/ inconvenience incurred by these delays.

11. MAJOR DEFECTS AND FAILURES :

11.1 (i) All major defects, failures, parting of conductors in the crossing span etc., shall be reported by the Owner to fhe Divisional Railway Manager/Divisional Electrical Engineer under advice to the Chief Electrical Engineer of the railway concerned and the Director (Transmission), Central Electricity Authority, R.K. Puram, New Delhi. Where a defect is likely to affect safe movement of traffic or affect safety of Railway property cr personnel, the defect shall be reported immediately by the Owner to tne Station Master of the nearest railway station on either side of the crossing.

ii) In the event of accident to Railway's tracks/rolling stock in the vicinity of the crossing, the Owner shall, if requested by the Railway or any official acting on behalf of Railway,expeditiously switch off the power line and connect the conductors to earth to enable Railway's cranes to work.

II. OVERHEAD CROSSINGS.

12. ANGLE OF CROSSING :

12.1 Normally any overhead crossing shall be effected at right angles to the railway track. However, in special cases a deviation to the extent of 30° may be permitted. Larger deviations may be specifically authorised by the Electrical Inspector.

13. STRUCTURES :

13.1 Steel poles, fabricatad steel structures or reinforced or pre-stressed concrete poles either of the selfsupporting or guyed type conforming in all respects to the latest Indian Electricity Rules and complying to the latest editions of Codes of Practice, IS : 800, IS : 875 and IS : 456 for Structural Steel, Loading Standards and Plain and Reinforced Concrete respectively, shall be used on either side of the track at the crosssing span. These structures may preferably be of the terminal type. For arriving at the crippling load, the wind loads as detailed in latest revision of IS : 802 (Part-I) shall be adopted. Steel structures should preferably be galvanised and shall comply generally to IS : 2629 for Recommended practice for hot-dip galvanizing of iron and steel.

13.2 The minimum distance of the supporting structures for crossing span from the centre of the nearest railway track shall be the following :-

For Categories A & C — Height of the structure above ground level plus 3 m.

For Category B — Height of the structure above ground level plus 6 m.

In special circumstances, individual cases may be examined by the Electricai Inspector and a lesser distance may be permitted.

13.3 The crossing span shall be restricted to 300 metres or to 80% of the normal span for which the structures are designed, whichever is less.

14. WIND PRESSURE :

14.1 The maximum wind pressure on the structure shall be determined as per the latest revision of IS : 802 (Part–I).

15. TEMPERATURE :

15.1 The maximum and minimum temperatures for the conductors and the ground wires shall be determined as per latest revision of IS : 802 (Part–I) (Clause-4) with necessary correction for conductor maximum temperature.

16. FACTOR OF SAFETY ETC.

16.1 The factor of safety of all conductors, guards, guys and ground wires used in the crossing shall be in accordance with Indian Electricity Rules 1956 (latest revision).

16.2 No conductor in the crossing span having a breaking strength less than 560 kg. shall be used.

16.3 All guard wires shall be of galvanised steel having a breaking strength of not less than 816 kg. and 372 kg. for bearer and cross wires respectively.

16.4 All guy wires shall be of galvanised steel and shall not be less than 7/2.95 mm. All guy wires shall be connected to the anchors above ground level.

16.5 No jointing shall be permited in the crossing span.

16.6 No tapping shall be permitted in the crossing span.

17. PROVISION FOR ICE LOADING :

Where provision has to be made for ice or snow loading these shall be determined in the light of local condition with the approval of the Railway.

18. MINIMUM CLEARANCE EETWEEN THE OVERHEAD LINE AND RAILWAY TRACK

18.1 Crossings over railway tracks already electrified shall normally be located at mid spans of overhead traction conductors, the distance between the outermost crossing conductor and the nearest traction mast under most adverse conditions shall not be less than 6 m

18.2 No. overhead transmission line crossing shall be located over Booster transformer, Switching station, Traction sub–station or a Track cabin location in an electrified area.

18.3 Vertical clearance : The minimum height above rail level of the lowest portion of any conductor of crossing, including guard wire, under conditions of maximum sag shall be as follows :-

(i) For category A (Sections electrified on 1500 V dc).

Voltage	Broad, Metre and Narrow gauges	
	Inside station limits (metres)	Outside station limits (metres)
Upto and including 11 KV	—ONLY BY CABLE—	
Above 11 KV and upto and including 33 KV.	13.28	11.28
Above 33 KV and upto and including 66 KV.	13.59	11.59
Above 66 KV and upto 110 KV	13.89	11.89
For 110 KV and 132 KV	14.20	12.20
For 220 KV	15.11	13.11
For 400 KV	16.63	14.63

Note : While calculating the above clearance, Railways high tension lines running over the 1500 V dc traction structure in some sections have not been taken into consideration.

(ii) For category B (Sections already elcctrified or likely to be converted to or electrified on 25 KV ac system within the foreseeable future).

Voltage	Broad, Metre and Narrow gauges	
	Inside station limits (metres)	Outside statoin Limits (metres)
Upto and including 11 KV	—ONLY BY CABLE—	
Above 11 KV and upto and including 33 KV	15 28	13.28
Above 33 KV and upto and including 66 KV	15.59	13.59
Above 66 KV and upto 110 KV	15.89	13.89
For 110 KV and 132 KV	16.20	14.20
For 220 KV	17.11	15.11
For 400 KV	18.63	16.63

(iii) For category C (Sections not likely to be electrified in the foreseeable future,

Voltage	Broad Gauge		Metre & Narrow Gauges	
	Inside station limlts (metres)	Outside station limits (metres)	Inside station limits (metres)	Outside station limits. (metres)
Upto and including 11 KV	—ONLY BY CABLE—			
Above 11 KV and upto and including 33 KV	10.06	7.62	8.84	6.40
Above 33 KV and upto and including 66 KV	10.36	7.92	9.15	6.71
Above 66 KV and upto 110 KV	10.67	8.23	9.45	7.01
For 110 KV and 132 KV	10.97	8.53	9.76	7.32
For 220 KV	11.89	9.45	10.67	8.23
For 400 KV	13.41	10.97	12.19	9.75

Note : If the crossing is located on a Metre gauge or a Narrow gauge, likely to be converted to Broad gauge, clearances applicable to broad gauge shall be adopted.

18.4 The words "station limits" mentioned in the above tables shall be taken to mean all tracks lying in the area between the outermost signals of a railway station.

19. Minimum vertical and horizontal clearances between any crossing conductor and any railway buildings and structures, other than traction support and overhead equipment under the most adverse conditions shall be in accordance with Rule 80 of the Indian Electricity Rules, 1956 (latest revision).

20. Minimum vertical crearances between power line crossings :

20.1 The minimum vertical clearances between any of the power line crossings at same or different voltages shall also be maintained as given below.:

a) Between 33 KV and below including (LT) and 33 KV. 3.66 m

b) Between 66 KV and below including (LT) and 66 KV. 3.97 m

c) Between 110 KV and below including (LT) and 110 KV. 4.27 m

d) Between 132 KV and below including (LT) and 132 KV. — 4.58 m

e) Between 220 KV and below including (LT) and 220 KV. — 5.49 m

f) Between 400 KV and below including (LT) and 400 KV. — 7.00 m

20.2 Separate guarding shall be provided above the lower power line in all cases except when the voltage of the higher line is above 33 KV. In this case the clearance from the guard wires to the lower power line shall be not less than 2m and to the upper power line not less than 1.5m.

21. CLEARANCES BETWEEN POWER LINE AND COMMUNICATION LINES :

21.1 The minimum clearance required to be provided between communication and power lines have been covered in the "Code of practice for protection of tele-communication lines at crossings with overhead power lines other than electrical traction circuits', (latest revision) issued by power and Telecommunication Co-ordination Committee (PTCC), which shall be adhered to.

22. RELAXATION BY THE RAILWAY :

22.1 In special cases, the Railway may permit reduction in the clearances specified under clause 18 subject to the following minimum clearance between the highest traction conductor and the lowest crossing conductor.

Voltage	Broad, Metre and Narrow Gauges	
	Inside station limits (metres) (Categories A&B)	Outside station limits (metres) (Categories A&B)
Upto and indluding 33 KV	5.66	3.66
Above 33KV and upto and including 66KV	5.97	3.97
Above 66KV and upto 110KV	6.27	4.27
For 110KV and 132KV	6.58	4.58
For 220KV	7.49	5.49
For 440KV	9.00	7.00

22.2 However, if the crossing is provided with a guarding, minimum clearance of 2m from the guard wire shall be provided.

22.3 The Railway may also, wherever possible, evolve special designs for traction overhead equipment return conductor, 25KV feeder or other power line on traction supports or structures consistent with economy and other requirements.

23. INSULATORS :

23.1 For categories A&B.: Double set strain insulator strings shall be used in the crossing

span in conjunction with a yoke plate where necessary as illustrated in the enclosed sketch 3. Each string of such strain insulators shall have one insulator disc more than that used in a normal span of the overhead line. The factor of safety of each string of strain insulators under worst conditions shall be not less than 2.

23.2 For category C : Double set strain insulators, suspension insulators or pin insulators shall be used. The factor of safety of each set of insulators under worst condtions shall be not less than 2. Arrangements adopted shall generally comply with those shown in sketches 1,2 3 (attached)

24 GUARDING :

24.1 All crossings upto and including 33KV shall be provided with guarding underneath. Guarding need not be provided for crossings of voltages above 33KV if the transmission line is protected by fast acting relay operated circuit breaker of modern design with a tripping time of the order of 0.20 sec, from the occurence of fault to its clearance. However, for EHV line 220KV and above, the tripping time shall not exceed 0.1 sec. Wherever guarding is adopted for the crossing, cradle guards shall also be provided.

24.2 The minimum height, above the rail level, to the lowest level of any cradle guard or guard wires under conditions of maximum sag shall not be less than the values specified in clause 18 but may be relaxed in accordance with clause 22.2 in special cases.

24.3 The minimum height between any guard wire and a live crossing conductor under the most adverse conditions shall not be less than 1.5m.

25. ANTI-CLIMBING DEVICES AND WARNING NOTICES :

25.1 Where the voltage exceeds 650V, the supporting structures on railway land shall be so provided with approved anticlimbing devices and warning notices shall be erected at all such structure locations, in such languages as may be considered necessary.

26. PROTECTION FROM MOVING ROAD VECHICLES :

26.1 Supporting structures including guys, adjacent to roadways shall be so located that the danger of being struck by moving road vehicles is avoided or reduced to the minimum. Wherever required guard rails, suitably pointed to make them conspicuous shall be provided for the purpose.

27. COMMUNICATION LINES :

27.1 The owners of communication crossings shall provide adequate safety devices so that no damage is caused in the event of parting of conductors. All communication lines crossing the railway tracks shall be protected and enclosed by an earthed cradle guard of approved design. In addition to those safety devices, the owner shall also provide

necessary surge absorbers in the system to guard against the effects of induction caused by surges during switching operations or system faults.

27.2 Overhead communication lines may also be permitted to be supported on crossing structures other than those for supporting the traction conductors and to cross the tracks. The factor of safety of conductors and insulators, clearances above rail level and the method of attachment of such crossings shall be the same as those specified for power conductors.

28. EARTHING :

28.1 (i) All supporting structures on either side of the crossing carrying the transmission/ distribution conductors shall be earthed effectively by two separate and distinct earth and connections. Separate earth electorde shall be provided for each earth connection.

(ii) All guard and stay wires shall be securely clamped to supports for connection to earth and shall maintain electrical continuity to earth.

(iii). Struts when provided shall also be effectively connected to the earth and maintain continuity with the main structure earthing.

(iv) where the tower/structure earth resistance is higher than 10 ohms, the owner shall take necessary steps to improve the earth resistance either by providing multiple earth electrodes or by treating artificially the soil surrounding the earth electrode or by resorting to the counterpoise earthing method. The method of earthing the transmission line structures in the crossing shall be of approved type.

(v) Earth shall be inspected and tested annually and test results furnished to the railways for verification and records.

(vi) The size of the earth conductor chosen for earthing system shall have adequate sectional area and capable of carrying short circuit current without damage, overheating or melting.

29. FIRE HAZARDS :

29.1 Supporting structures shall be so placed, guarded and maintained as to be exposed as little as possible to bush, grass, rubbish and building fires.

30. III. CABLE CROSSINGS

30.1 As far as possible cable crossings shall make use of any existing culverts, sub-ways etc. cable crossings under track already equipped for electric traction on 25 KV ac, system shall be provided at locations 5m. away from any traction switching stations or supports proposed or erected by the Railway for traction purposes in connection with the supply and distribution of power to the overhead equipment system. The exact locations of such switching stations or traction supports in any particular area will be obtained from the Railway.

31. TYPE OF CABLE :

31.1 The Owner shall specify the type of cable which shall preferably be armoured, to be used and obtain prior approval of the Railway. Where cables are suspended from supports and are not laid in a protective pipe, they shall be of the armoured and sheathed type.

32. CATHODIC PROTECTION :

32.1 Cathodic protection of the cables shall not be adopted without the specific approval of the Railway.

33. METHOD OF LAYING :

33.1 Where the cable is laid under railway tracks it shall be laid through cast iron pipes or spun concrete pipes of suitable diameter and strength. The specification for the pipes to be used shall be submitted to the Railway for approval. In the case of single core cables the pipe shall be large enough to accommodate all the three phases of power circuit. If it is intended to lay single core cables in individual pipe, such pipes shall be made of asbestos cement or spun concrete. The pipe shall be laid at not less than one metre below the surface of the formation level. It shall be possible to withdraw the cable/s for repairs or replacement without disturbing the railway track. Long lengths of pipe shall be laid with a gradient to facilitate drainage of water. Inside station limits, pipes shall be laid upto the point of the railways boundary or to a point to be decided by the Railways. Outside sation limits, pipes shall be laid upto a minimum distance of 3m from the centre of the nearest track on either side. The cable in the Railway lands shall be laid in accordance with IS : 1255 (latest revision) Code of Practice for Installation and Maintenance of Power Cables,.

34. WORKS CARRIED OUT UNDER OR NEAR RAILWAY TRACK :

34.1 Where the cable is to be laid under the railway tracks, the use of cast iron or spun concrete protective pipes for cable where they cross the tracks is obligatory and such cast iron or spun concrete pipes shall be laid only by the Railway (See Clause-7).

34.2 Armouring and sheathing of the underground cable laid across or near any electrified railway track shall be earthed by independent earths at the two sealing ends of the cable. No further earthing shall be done within 500 m. of any electrified track.

35. TERMINAL STRUCTURES OF CABLE CROSSINGS :

35.1 Where the ends of a cable of an underground crossing are terminated on structures for connecting them to overhead lines, the terminal structures shall comply with the regulations applicable to overhead crossings.

36. MARKING OF CROSSINGS :

36.1 Each cable crossing shall be indicated by two cast iron cable markers, one at each

end of the crossing. The cable markers shall be fixed at both ends of the underground crossing. The markers shall be of approved design, shall be painted in red and the following information shall be given therein :

ELECTRIC CABLE	—	Volts
NUMBER	—	Cables
DANGER	—	In English, Hindi and the vernacular of the District.
DEPTH OF CABLE	—	Below track level.
DEPTH OF CABLE	—	Below ground level between the toe of bank and railway fencing.

ANNEXURE—I

Data, Design Dand rawings to be furnished

The following data, design calculations, designs and drawings, in duplicate, together with six copies of the blue prints of the electrical crossing incorporating the following particulars, shall be submitted along with the supervision cum general charges as prescribed by the respective railways by the owner of the proposed overhead line or underground cable crossing, for approval by the Railway and the Electrical Inspector.

I. Overhead crossings :

a) Data and designs :

1. Location of the crossing, the names of railway stations either side nearest the crossing, the distance of the crossing from the nearest railway station, the painted numbers of telegrpah poles or traction masts between which the crossing will be located and the exact location in relation to such poles or masts.

   Note : Alignment of the crossing should be as far as possible at the mid point of the span between traction masts in the case of electrified tracks (Refer Clause–18.1 of the Regulations).

2. Particulars of the crossing overhead line, including voltage, frequency, number of phases and whether the neutral is earthed or not.

3. Wind pressure adopted.

4. Temperature data adopted.

5. Particulars of ice loading adopted, if any.

6. Factors of safety adopted in the designs for conductor, structures, guard wire/cross wires if provided, earth wire, stay wires etc.

7. Design calculations of structures and foundations proposed for the crossing spans communication lines or guarding, if any.

   Note : Even if the structures and foundations adopted are of a standard type used for the transmission line concerned, the full detailed design calculations shall be furnished.

8. Calculations leading to the minimum clearance under the worst conditions of the following

i) Vertical clearance between the lowest crossing conductor, guarding or communication lines and the different railway tracks in the crossing span.

ii) Vertical clearance between the lowest crossing conductor, guarding or communication lines, owners conductors and railway's conductors, traction conductors or otherwise.

iii) Horizontal clearance to Rly. structure/buildings, if any involved.

iv) Lateral clearance to the nearest Rly./traction structure, if involved.

Note : Full particulars of the number, size, materials and characteristics of various wires and conductors shall be furnished.

9. Partlculars of insulators, strandling, or bridling.

10. Details of guarding, size of guard & cross wires and their characteristics (Drawing showing the guarding arrangement when provided shall be attached)

11. Size and characteristics of guy wire if provided and the number of support.

12. Details of earthing indicating the method of connection to the support. size of earth-strip, earth electrode, and the metod of artificial soil treatment if proposed.If counter-poise earthing is cotemplated, details shall be furnished.

13. Details of protection against moving road vehicles.

14. Particulars of anti-climbing devices and notice boards proposed,

15. Full details of scheme of protection for the transmission line including relay particulars, opererating time etc.

b) DRAWINGS :

1. Layout and site plan of the crossing indicating railway boundaries.

2. Longitudinal elevation of the crossing. The drawing shall include full particulars of a span on either side of the crossing span, various clearances with respect to the track. The drawings shall show the cross-section of the railway formation and tracks.

3. Warning notice drawing.

NOTE : All drawings shall be to any one of the following preferred scales :

1:1, 1:20, 1:50, 1:100, 1:200, 1:500. The drawings shall be in standard sizes, as-prescribed in IS;696.

II. UNDERGROUND CABLES :

a) Data and designs :

1. Location of the cable crossing, the names of the railway stations on either side nearest to the crossing from the nearest railway station, the painted numbers of telegraph poles or traction masts between which the crossing will be located in relation to such poles or masts.

2. Supply system particulars, particulars of cable/s their number, size of cores, voltage, type of insulation, armouring, if any etc.

3. Full particulars of the en-casing pipe for the crossing.

4. Method of earthing of the cable armouring, if any.

5. Method of marking the crossing.

6. Design calculations of terminal masts for the cable/s, if any if the terminal masts would foul with railway tracks in the event of failure.

b) DRAWINGS :

1. Layout and site plan including route, location of the terminal structures and railways boundaries, if any.

NOTE : Earths in the vicinity of the crossing shall be indicated :

2. Detailed cross-section drawing showing the lengths and position of encasing pipe of the cable/s, including details of terminal masts, if any.

NOTE : In the case of crossing through a railway culvert or under a bridge, detailed drawings of the attachment of cable to any part of the culvert or bridge shall be furnished.

3. Crossing marker drawing.

NOTE : All drawings shall be to any one of the following preferred scales :
1:1, 1:20, 1:50, 1:100, 1:200, 1:500.

ANNEXURE-2

FORM OF AGREEMENT

(i) For Overhead crossings

AN AGREEMENT made this.....day of.....one thousand nine hundred and.....BETWEEN THE PRESIDENT OF INDIA, acting through the Divisional Superintendent/Chief Electrical Engineer of the.....Railway Administration (hereinafter called 'the Railway') of the one part and .....

.....

(hereinafter referred to as 'the owner') of the other part. WHEREAS the Owner wishes to erect an electric overhead line and carry out the works connected there with. For transmission or distribution of electrical energy over and across the railway tracks and/or land at kilometrage .....in the section...../at.....railway station, of the railway, the said overhead line where it crosses the railway tracks and/or land works connected therewith hereinafter referred to as the 'crossing' NOW IT IS HEREBY AGREED as follows : —

1. General.—The railway will permit the Owner as from the.....day of..... 19,....to lay the crossing as per Drg No.....approved by tne railway,hereunto attached as Annexure 1, and in compliance with Regulations for Elecrtical crossings of Railway Tracks, hereunto attached as Annexure 2 hereinafter referred to as the Regulations, for the purposes hereinbe fore mentioned, subject to the terms and conditions hereinafter contained.

2. Permission to lay and maintain the crossing —The railway will subject to the provisions of Clause 3 hereinafter contained permit the Owner to erect, keep and maintain in accordance with the Regulations the crossing over and across the railway tracks and/or land at the place/s shown on the said drawing and to execute all repairs in connection with the same when necessary from time to time and all such work shall be carried out and executed at the cost of the Owner and at such times as may be permitted and to the satisfaction of the Railway in all respects.

3. Railway to carry out protection works.—In the event of it being necessary in the opinion of the Railway to support or protect the railway tracks and/or land or works during the erection of the crossing or during the execution of any repairs thereto or during any removal thereof the work of supporting or protecting the railway tracks or land and restoring the tracks and/or land to its original condition or such part of the said work as the Railway shall deem fit may be carried out by the the Railway at the cost of the Owner in all respects and the amount of such costs thereof shall be determined by the Railway in its absolute discretion and be paid by the Owner to the Railway on demand. The Owner will if so required deposit with the Railway prior to the carrying out of the said work such a sum as may be estimated by the Railway to be the cost of the work

required to be done and the amount of the said deposit will be set off against the said cost to be determined as aforesaid and the balance paid as aforesaid.

4. Cost or supervision of works.—All works in connection with the matters referred to in Clauses 2, 3, 6 and 11 will be subject to such supervision by the Railway as may be considered necessary by the Railway and the Owner will pay to the Railway on demand all costs of such supervision including the cost of the staff required to look after the safety of the railway tracks and/or land while all or any of such works are in progress. The amount of such supervising and other costs as aforesaid shall be determined by the Railway in its absolute discretion.

5. Access.—Neither the Owner nor his employees shall at any time enter upon the railway land and for any purpose whatsoever in connection with the crossing as aforesaid without the consent in writing of the railway.

6. Modification, Shifting or removal of crossing.—If for convenience of operation unsatisfactory maintenance or for any reason whatsoever the Railway desires special maintenance, repairs, modification, shifting or removal of the crossing the Owner will subject to the provisions of Clause 3 hereof carry out such works or such portion thereof as the Railway shall not under the provisions of Clause 3 hereof propose to carry out to the satisfaction of the Railway within a reasonable period determined by the Railway in its absolute discretion from the date of a notice to that effect of the Railway and if he so desires may re-erect the same at his own expense but to the satisfaction of the Railway in all respects on such other land or track of the Railway as it may in its absolute discretion consider suitable and available for the purpose and in the event of the crossing being so re-erected the land on which the same is re-erected will be used and occupied upon the terms of the Agreement Mutatis mutandis as if the same has originally been subject to this Agreement.

7. Termination of Agreement by the Railway.—The Railway shall at anytime and from time to time be at liberty in its absolute discretion to suspend temporarily and/or to terminate this Agreement and all or any of the privileges hereby granted upon the expiration of three months' notice in writing of its intention to do so being left at or sent by registered office of the Owner/and not withstanding that the Owner may have executed any work of a permanent or temporary character and incurred expenses in the execution thereof and the Owner shall not be entitled to any damages or compensation by the reason of such termination or suspension.

8. Subject as otherwise provided in this contract, all notices to be given on behalf of the President of India and all other action to be taken on his behalf may be given or taken on his behalf by the Divisional Superintendent/Chief Electrical Engineer of the Railway.

9. Termination of Agreement by the Owner.—The Owner may on giving to the Railway one month's notice in writing terminate this Agrreement and such notice shall be sufficiently served if sent by registered post to the Divisional Superintendent/Chief Electrical Engineer of the Railway or left at his office.

10. Termination of Agreement for default.—In the event of the Railway giving notice under Clause 7 hereof for special maintenance, shifting or removal of fhe crossing and the Owner failing within the time stipulated to carry out the said works except such portion thereof as the Railway may propose to carry out under the provisions of Clause 3 hereof or in the event of the Owner committing any other breach of this Agreement or any part thereof, the

Railway shall be entitled in its absolute discretion (notwithstanding the provisions of Clause 8 hereof) to terminate this Agreement and all and any of the privileges thereby granted upon the expiration of six months' notice in writing of its intention to do so being given in the manner provided by Clause 7.

11. Removal of crossing.—Prior to the termination of this Agreement and subject to the provisions of Clause 3 hereof the Owner shall at his own cost take up and remove the crossing from the property of the Railway and shall restore the land to its original condition to the satisfaction of the Railway in all respects. In the event of the Owner failing to take up and remove the said crossing as aforesaid and to restore the land to its orginal condition in manner herinbefore provided the Railway shall be entitled at its option immediately after the termination of this Agreement to carry out such work of removal and restoration without being responsible for any loss or damage whatsoever done to the said crossing as aforesaid or any part thereof and in such event the owner shall pay to the Railway on demand all costs incurred by the Railway in connection with such work including supervision charges the amount of such cost to be determined by the Railway in its absolute discretion. The said crossing and the materials used in connection therewith and belonging to the Owner shall be and remain the property of the Owner but the Railway shall be entitled to retain the same without any liability therefor until the amount of such cost as aforesaid shall have been paid by the Owner to the Railway.

12. Indemnity.—The said crossing shall be used at the sole risk and on the responsibility os the Owner and if at any time owing directly or indirectly to such user or to the existence of the said crossing or to the carrying out of the work of erection and/or repair and/or removal of the said crossing and restoring the land to its original condition or to the exercise by the Owner of any privileges hereby granted or to any other cause arising out of the operation of this Agreement any damage shall be caused to the Railway or to the Permanent way and works, rolling stock or any property of the Railway or if in consequence of any of the matters aforesaid or of any default in performing the conditions of this Agreement or of any negligence on the part of the Owner or any person connected with him any claim or damage or loss be substantiated by any person or persont against the Railway the Owner shall forthwith upon demand pay and make good the same and shall also make good to the Railway all costs and expenses which it may incur in regard to any such damage or claim as aforesaid. In the event of there being any question or dispute as to whaf specific loss and/or damage has been caused by reason of any of the matters aforesaid such question or dispute shall be preferred to the Chief Electrical Engineer of the Railway, whose decision thereon shall be final and binding.

13. Railway accidents.—The Railway shall not be responsible for any damage to the crossing, and property of the Owner due to an accident in working traffic over the Railway or to any cause whatsoever.

14. Sub-letting : The owner shall not sub-let, transfer or assign this Agreement or any of the priviliges hereby granted without the previous consent in writing of the Railway.

15. Limitation of rights : Nothing herein contained shall be construed as conferring upon the Owner or his permitted assignee any rights over the property of the Railway.

16. Cost of Agreement :—All cost and expenses of an incidental nature to the preparation and completion of these presents including stamp duty shall be borne and paid by the Owner.

In witness whereof the parties have hereunto set and subscribed their respective hands and/or seals the day and year respectively mentioned against their respective signatures.

(Seal of the Owner)

(signature)

Signed at.....by Shri.....for and on behalf of the Owner in the presence of :

1. Name
   Address .....
   (Signature of witness)

2. Name
   Address .....
   (Signature of witness)

[Signature]

Signed at..... by Shri..... for and on behalf of the Presiden of India, in the presence of :

1. Name
   Address .....
   (Signature of witness)

2. Name
   Address .....
   (Signature of witness)

NOTE—1. In the case of Railway Companies or Port Commissoner's Railways, the term Chief Electrical Engineer wherever occuring in this Agreement may be replaced by the designation of the officer on whom the duties of the Chief Electrical Engineer devolve.

2. Para 16 will not apply in case one or both the parties are Government Departments.

3. The agreements should be signed by and on behalf of the President of India by an officer duly authorised under Article 299(1)of the Constitution of India.

ANNEXURE—II

FORM OF AGREEMENT

(II) For underground crossings

AN AGREEMENT made this .....day of.....one thousand nine hundred and .....BETWEEN THE PRESIDENT OF INDIA, acting through the Divisional Superintendent/Chief Electrical Engineer of the.....Railway Administration (hereinafter called "the Railway") of the one part and..... .....(hereinafter reffered to as "the owner")of the other part WHEREAS the Owner wishes to lay an underground cable and carry out works connected therewith for transmission or distribution of electrical energy across and under the railway tracks and/or land at kilometrage .....in the section.....at.....railway station, of the railway, the said cable and works connected therewith hereinfter referred to the "crossing" NOW IT IS HEREBY AGREED as follows :-

1. General.—The railway will permit the Owner as from the ..... day of.....19 , to lay the crossings as per Drg. No..... ..... approved by the railway, hereunto attached as Annexure 1 and in compliance with Regulations for Electrical Crossings of Railway Tracks, hereunto attached as Annexure 2 hereinafeter referred to as the Regulations, for the purposes hereinbefore mentioned, subject ro the terms and conditions hereinafter contained.

2. Permission to lay and maintain the crossing.—The Railway will, subject to the provisions of Clause 3 hereinafter contained, permit the Owner to lay keep and maintain in accordance with the Regulations the crossing under the railway tracks and/or land at the place (s) shown on the said drawing and to execute all repairs in connection with the same when necessary from time to time and all such work shall be carried out and executed at the cost of the Owner and at such time as may be permitted and to the satisfaction of the Railway in all respects.

3. Railway to carry out protection work.—In the event of it being necessary in the opinion of the Railway to support or protect the railway tracks and/or land or works during the crossing or during the execution of any repairs thereto or during any removal thereof the work of supporting or protecting the railway tracks or land and/or laying or removing the encasing protective pipe to carry the crossing cable and restoring the tracks and/or land to its original condition or such part of the said work as the Railway shall deem fit may be carried out by the Railway at the cost of the Owner in all respects and the amount of such costs thereof shall be determined by the

Railway in its absolute discretion and be paid by the Owner to the Railway on demand. The Owner will if so required deposit with the Rallway prior to the carrying out of the said work such a sum as may be estimated by the Raliway to be the cost of the work required to be done and the amount of the said deposit wlll be set off agalnst the said cost to be determined as aforesaid and the balance paid as aforesaid.

4. Method of laying.—The cables shall be laid as indicated in the said drawing and shall be carred through an encasing pipe in such manner that the cable can be laid withdrawn and/or maintained without interfering with or endangering the railway tracks and/or land the cost of providing and laying pipe shall be borne by the Owner as aforesaid.

5. Cost of supervision of work.—All works in connection with the matters referred to in Clauses, 2,3,4,7, and 12 will be subject to such supervsion by the Railway as may be considered necessary by the Railway and the Owner will pay to the Raiiway on demand all costs of such supervision including the cost of the staff required to look after the safety of the railway tracks and/or land while all or any of such worke are in progress. The amount of such supervising and other costs as aforesiad shall be determined by the Railway in its absolute discretion.

5. Access—Neither the Owner nor his employees shall at any time enter upon the railway land for any purpose whatsoever in connection with the crossing as aforesaid without the consent in writing of the railway.

7. Modification, shifting or removal of crossing—If for convenience of operation unsatis-actory maintenance or for any reason whatsoever the Railway desires special maintenance, repairs modification, shifting or removal of the crossing the Owner will subject to the provisions of Clause 3 thereof carry out such works or such portion thereof of the Railway shall not under the provisions of Clause 3 thereof propose to carry out to the satisfation of the Railway with in a reasonable period determined by the Railway in its absolute discretion from the date of a notice to that effect from the Railway and if he so desires may re-lay the same at his own expense but to the satisfaction of the Railway in all respects on such other land or track of the Railway as it may in its absolute discretion consider suitable and available for the purpose and in the event of the crossing being so re-erected the land the land on which the same is re-erected will be used and occupied upon the terms of the Agreement mutatis mutandis as if the same has originally been subject to this Agreement,

8. Termination of Agreement by the Railway—The Railway shall at any time and from time to time be at liberty in its absolute discretion to suspend temporarily and or to terminate this Agreement and all or any of the privileges hereby granted upon the expiration of three month's notice in writing of its intentiou so to do being left at or sent by registered office of the Owner and notwithstanding that the Owner may have executed any work of a permanent or temporary character and incurred expenses in the execution thereof and the Owner shall not be entiled to any damages or compensation by the reason of such termination or suspension.

9. Subject as otherwise provided in this contact, all notices to be given on behalf of the President of India and all other action to be taken on his behalf may be given or taken on his behalf by the Divisional Superintendent/Chief Electrical Engineer of the Railway.

10. Termination of Agreement by the Owner—The Owner may on giving to the Railway one month's notice in writing terminate this Agreement and such notice shall be sufficiently served if sent by registered post to the Divisional Superintendent/Chief Electrical Engineer of the Railway or left at his office.

11. Termination of Agreement for default—In the event of the Railway giving notice under Clause 8 hereof for special maintenance, repairs, modification, shifting or removal of the crossing and the Owner failing within the time stipulated to carry out the said works except such portion thereof as the Railway may propose to carry out under the provisions of Clause 3 thereof or in the event of the Owner committing any other breach of this Agreement or any part hereof, the Railway shall be entitled in its absolute discretion (Notwithstanding the provisions of Clause 9 hereof) to terminate this Agreement and all and any of the privileges hereby granted upon the expiration of six month's notice in writing of its intentions so to do being given in the manner provided by Clause 8

12. Removal of crossing—Prior to the termination of this Agreement and subject to the provisions of Clause 3 hereof the Owner shall at his own cost take up and remove the crossing from the property of the Railway and shall restore the land to its original condition to the satisfaction of the Railway in all respects. In the event of the Owner failing to take up and remove the said crossing as aforesaid and to restore the land to its original condition in manner hereinbefore provided the Railway shall be entitled at its option immediately after the termination of this Agreement to carry out such work of removal and restoration without being responsible for any loss or damage whatsoever done to the said crossing as aforesaid or any part thereof and in such event the owner shall pay to the Railway on demand all costs incurred by the Railway in connection with such work including supervision charges the amount of such costs to be determined by the Railway in its absolute discretion. The said crossing and the materials used in connection therewith and belonging to the Owner shall be and remain the property of the Owner but the Railway shall be entitled to retain the same out without any liability therefor until the amount of such cost as aforesaid shall have been paid by the Owner to the Railway.

13. Indemnity.—The said crossing shall be used at the sole risk and on the responsiblity of the Owner and if at any time owing directly or indirectly to such uses or to the existence of the said crossing or to the carrying out of the work of erection and/or repair and/ or removal of the said crossing and restoring the land to its original condition or the exercise by the Owner of any privileges hereby granted or to any other cause arising out of the operation of this Agreement any damage shall be caused to the Railway or to the permanent way and works, rolling stock or any property of the Railway or if in consequence of any of the matters aforesaid or of any default in performing the conditions of this Agreement or of any negligence on the part of the Owner or any person connected with him any claim or damage or loss be substantiated by any person or persons against the Railway the Owner shall forthwith upon demand pay and make good the same and shall also make good to the Railway all costs and expenses which it may incur in regard to any such damage or claim as aforesaid. In the event of there being any question or dispute as to what specific loss and/or damage has been caused by reason of any of the matters aforesaid such question or dispute shall be preferred to the Chief Electrical Engineer of the Railway, whose decision thereon shall be final and binding.

14. Railway accidents.—The Railway shall not be responsible for any damage to the

crossing, and property of the Owner due to an accident in working traffic over the Railway or to any cause whatsoever.

15. Sub-letting.—The Owner shall not sub-let, transfer or assign this Agreement or any of the privileges hereby granted without the previous consent in writing of the Railway.

16. Limitation of rights.—Nothing herein contained shall be construed as conferring upon the Owner or his permitted assigns any rights over the property of the Railway.

17. Costs of Agreement.—All the costs and expenses of an incidental nature to the preparation and completion of these presents including stamp duty shall be borne and paid by the Owner.

In witness whereof the parties have hereunto set and subscribed their respective hands and/or seals the day and year respectively mentioned against their respective signatures.

(Seal of the Owner)

(Signature)

Signed at ..... by Shri ..... for and on behalf of the Owner in the presence of :

1. Name
   Address

   (Signature of witness)

2. Name
   Address

   (Signature of witness)

(Signature)

Signed at _____ by Shri _____ for and on behalf of the President of India, in the presence of :

1. Name _____

   Address

   (Signature of witness)

2. Name _____

   Address

   (Siguature of witness)

Note :- 1. In the case of Railway Companies or Port Commissioner's Railways, the term Chief Electrical Engineer wherever occurring in this Agreement may be replaced by designation of the officer on whom the duties of the Chief Electrical Engineer devolve.

2. Para. 17 will not apply in case one of or both the parties are Government Departments.

3. The Agreement should be signed by and on behalf of the President of India by an officer duly authorised under Article 299 (1) of the Constitution of India.

ANNEXURE—3

Form for Certificate of Compliance

It is hereby certified that the electrical overhead/underground crossing No..... at km.....on the section .....of the .....Division of the .....Railway has been constructed in full compliance with Indian Electricity Act, 1910, and Indian Railways Act, 1890, and the rules made thereunder and the Regulations for Electrical Crossings of Railway Tracks 1963. The crossing has been constructed in accordance with drawings approved by the.....Railway, and the Electrical Inspector of the .....railway references of which are given below :

Drawing No.	Title	Reference under which drawing is approved	Approving authority
1.			
2.			
3.			

A reproduction print of the "as erected" drawings of the crossing is/are enclosed.

.....

(Signature of the Owner)

APPENDIX-A

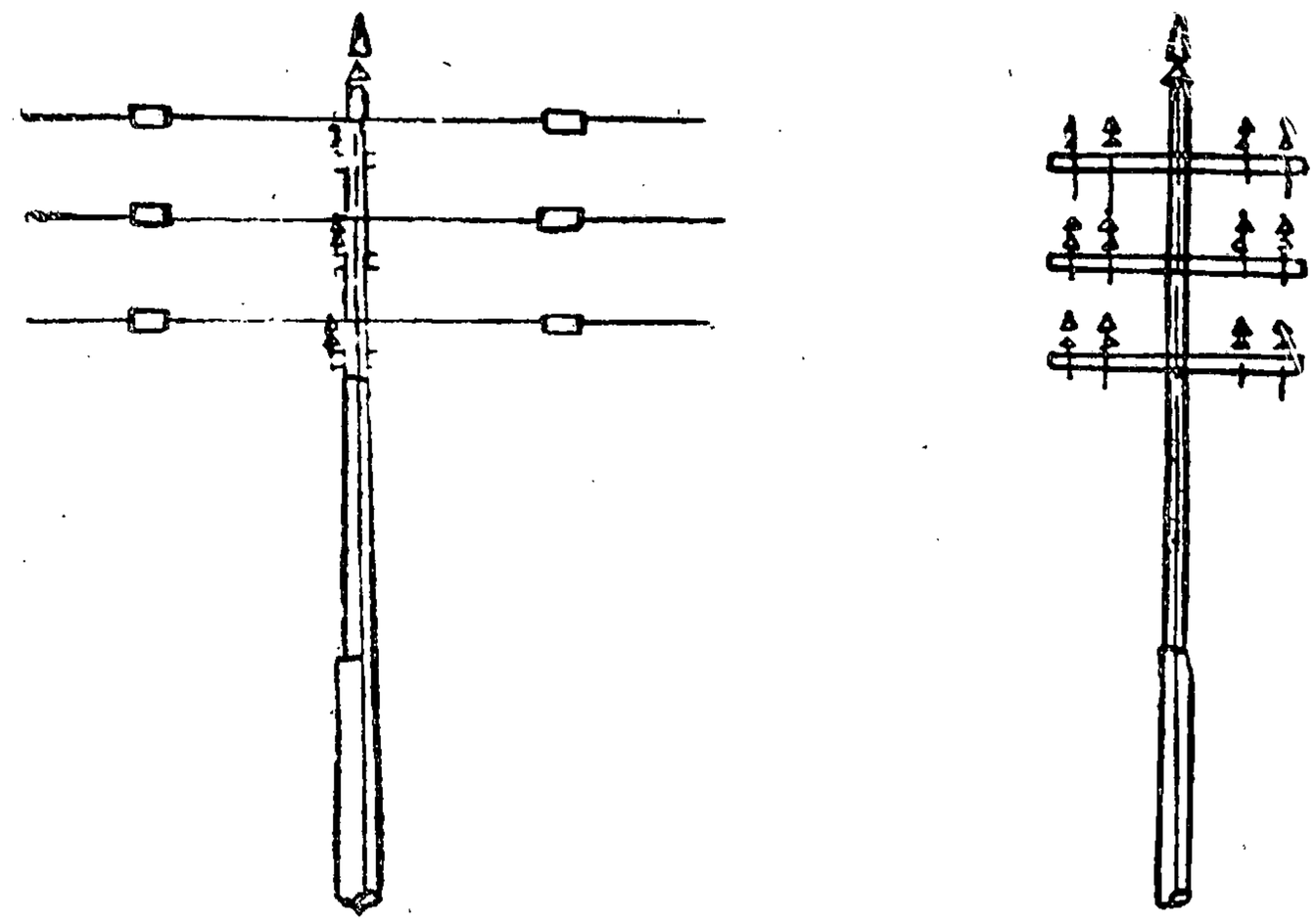


FIG-1 FOR LIGHT CONDUCTORS

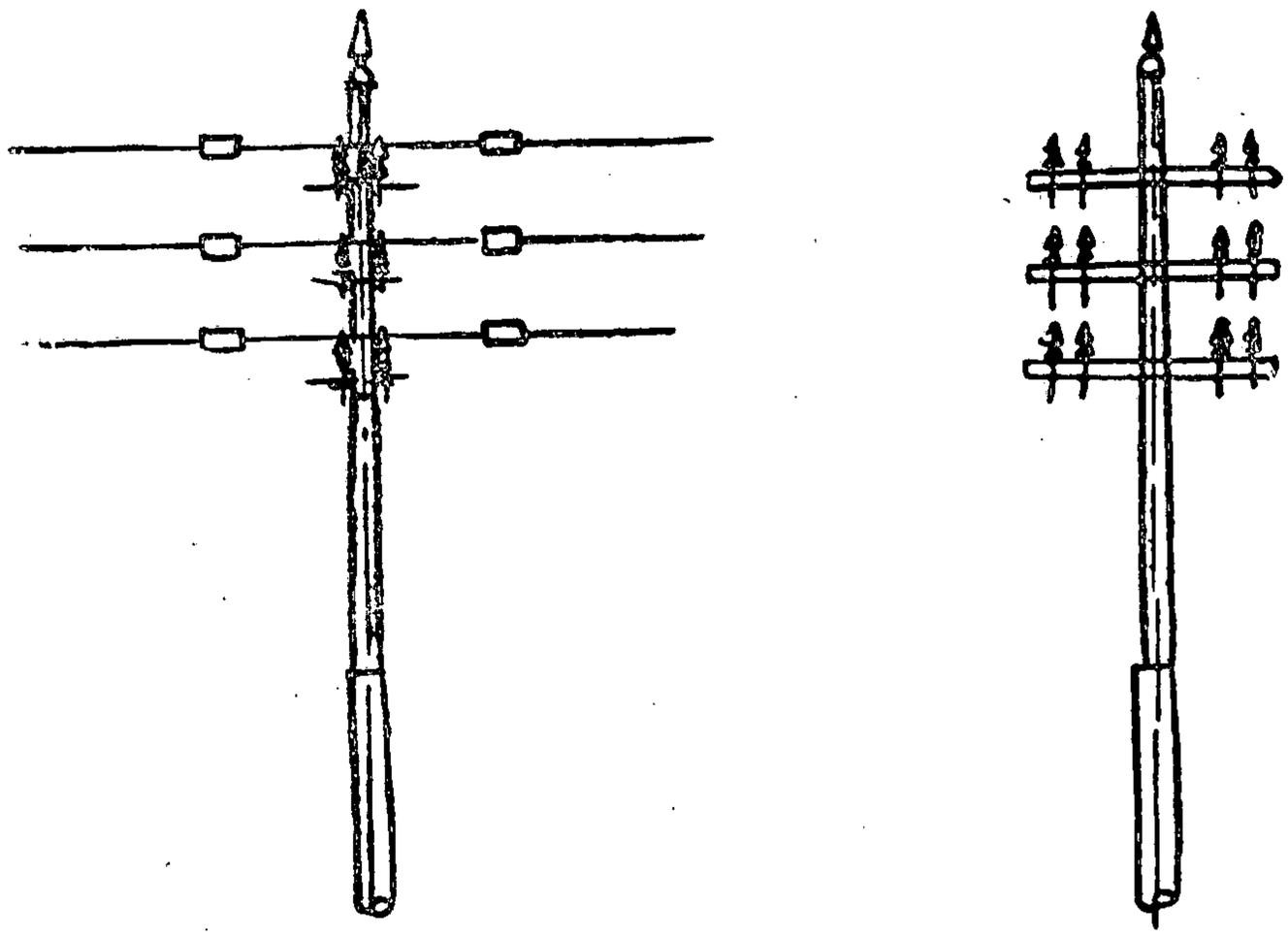
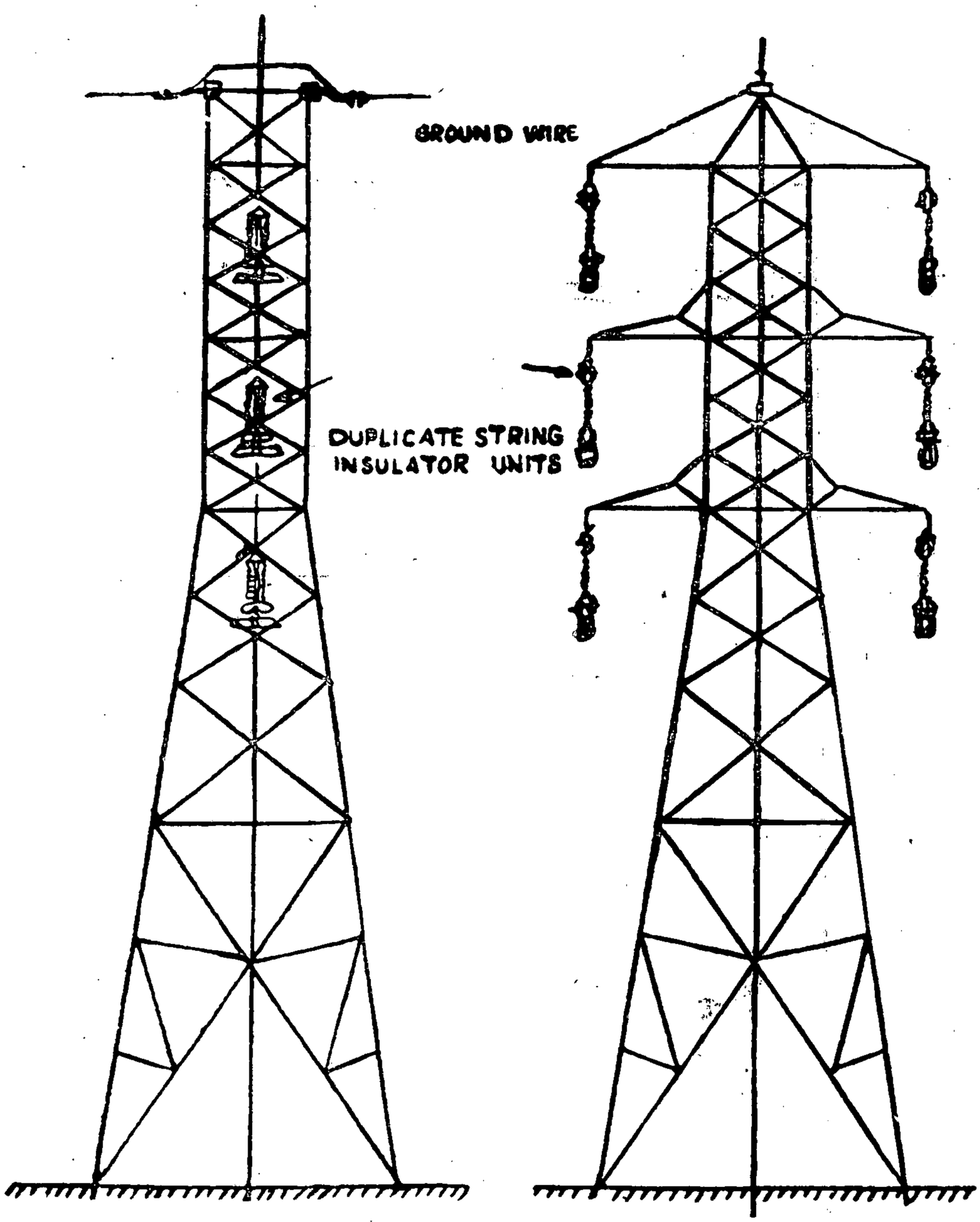


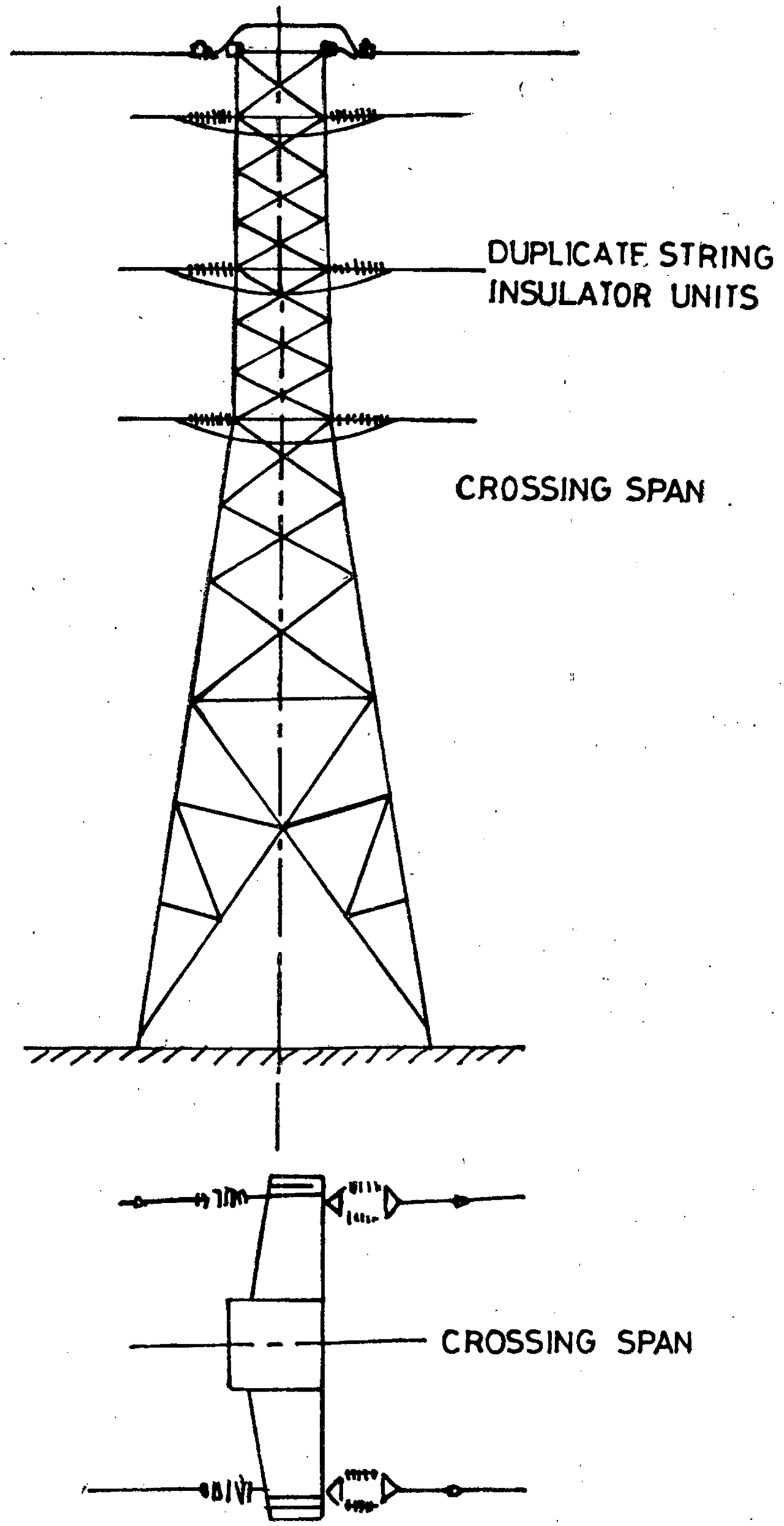
FIG-2 FOR HEAVY CONDUCTORS

OVERHEAD CROSSING WITH PIN INSULATORS SKETCH-9



HIGH TENSION CROSSING WITH SUSPENSION INSULATORS

SKETCH 2



HIGH TENSION CROSSING WITH TERMINAL STRAIN INSULATORS

SKETCH-3

APPENDIX A—2

PROCEDURE FOR CLEARANCE OF PTCC CASES OF POWER AND TELECOM LINES

I. POWER LINES EXCEEDING 132 KV.

1. In the case of power lines of 220 KV and, above the application for clearance of the route is processed by the Central PTCC. The application for PTCC clearance is to be accompanied by the following documents :

   a) Questionnaire No. 1, as per specimen form attached, duly filled in with all relevant details.

   b) A route map of the proposed power line (with terminal stations prominently marked) drawn to a scale of 1" to 1 mile or 1 cm to 0.5 km. The route map should depict all topographical details including railway lines, rivers, canals and important roads and other landmarks like towns, villages with names etc. on either side of the proposed power line upto 8 km.

   c) Where there is close parallelism, the scale of the route map should be larger in order to compute the mutual coupling between the two lines seperately.

   d) Statement showing the soil resistivity in the area covered by the line measured by the four–electrode method with an inter–electrode spacing of 50 metres, measurements being taken at every 2 or 3 km. along the length of the line.

   e) Single-line diagram of the electrical layout of the relevant portion of the power system with details as in the questionnaire.

   f) In the case of tap or spur lines, distances of the tap point from either of the end sub–stations should be clearly marked.

   g) The State Electricity Boards will keep a liaison with the P & T/Railways to ensure that the protective measures are provided in time.

2. Copies of all the documents are to be sent to :

   i) Jt. Scretary (Power), PTCC, CEA. R.K. Puram, New Delhi–110022.

   ii) Concerned DET (PTCC) of the P & T Dept. as per addresses given below (with 2 additional copies of route map)

   DET (PTCC), Southern Region, 100/101, Wallajah Road, Madras-600 002.

3. Copies of route map are also to be sent to :

i) The local DET of the P&T Dept. with a request to mark the telecom lines involved and forward the same to the DET (PTCC) concerned — Two copies ; if more that one DE (T) is involved, copy to be sent to other DEs (T) concerned.

ii) The AE (PTCC) C. O. G. M. (Telecom) of the P&T Circle concerned - One copy.

iii) G. M. (S&T) of the Railways concerned (four copies) with a request to mark their telecom lines involved and forward one copy thereof to the JS (P), PTCC and one copy to the concerned DET (PTCC).

iv) G. M. (Projects) and G. M. (Maintenance).... 2 copies each.

4. The final PTCC clearance would be issued by the DET (PTCC) concerned after receipt of the I. V. computations and Reilways recommendations.

II. POWER LINES OF 33 KV D/C AND ABOVE UPTO 132 KV D/C :

1. In these cases, the application for clearance of the route is to be processed by the State Electricity Board concerned which is to designate a suitable officer and the DET (PTCC) as per I [2], ii]. The application for PTCC clearance is to be accompanied by the documents mentioned in I [1]. The route map is to cover 8 Km on either side of power line for 66 KV and above and 5 Km for 33 KV lines.

2. Copies are to be sent to the officers as in I [2] except that instead of JS [P], PTCC CEA mentioned therein, the officer designated in the Electricity Board, is to be contacted.

3. Copies of the route map are to be sent to the officers mentioned I (3).

4. The final PTCC clearance would be issued by the DET (PTCC), concerned.

QUESTIONNAIRE—1

GOVERNMENT OF INDIA

POWER TELECOMMUNICATIONS CO-ORDINATION COMMITTEE

QUESTIONNAIRE

(To be answered by the authorities in charge of Power Systems while applying for route approvals)

Please supply data of the Power System as per details below :

1.1 Key diagram (single line) of the electrical layout of the relevant portions of the power system, indicating the number, voltage ratings, capacities, etc. of the various power apparatus. Indicate also by dotted lines the extensions proposed ultimately o through the current Five Year Plan.

*NOTE : By relevant is meant all the power stations which under normal operating conditions will feed into a fault occurring within or outside the parallelism section as well as all lines on which such fault current would flow.

1.2 Data on the characteristics of equipment, viz. generators, transformers, reactors, synchronous condensers, earthing transformers etc, installed in the system as per enclosed appendix (transient reactance figures should be given for all rotating machines).

1.3 Please state if the neutral points of the power systems are [i] insulated, or [ii] earthed. If the latter, please indicate the type of earthing, e.g. solidly earthed, earthed through Peterson coils, earthed through resistance or reactance. Give also full particulars.

2. Please supply the following data in respect of the particular power line for which approval is sought.

2.1.1 Name.

2.1.2 Operating voltage and number of circuits.

2.1.3 a) Length

b) Conductor/Earthwire size and material.

2.1.4. If it is a tap or spur line, the length of tap and the distance of the tapping point from the end sub-stations should be clearly indicated.

2.1.5. Is the power line bussed at any intermediate Sub-stations ? If so, please give details.

2.1 6. Will the power line initially be charged at some lower voltage ? If so at what voltage?

2.1.7. Probable date of commencing tne construction.

2.1.8, Probable date of commissioning.

2.1.9. Date by which approval is desired,

2.2.1 Please supply a route map showing the proposed alignment of the power line and the paralleling telecommunication lines in the area, drawn to a scale of 1cm=0.5 km (1" = 1 mile). All topographical details including all railway lines, rivers, canals and important roads upto 8 Km. on eitherside of the proposed power line may also be drawn to the scale. The railway stations should be located on the map and named.

NOTE : 1) If the proposed line is an extension of the existing line which had not been referred to the Committee previously a similar route map of the existing line should also be supplied along with the route map of the proposed line.

2) A copy of the route map with telecom circuits marked be also sent to local P&T authorities and railway authorities, requesting them to confirm the telecom. Circuits and also indicate the points of discontinuity in the telecom circuits to both the Joint Secretaries of the Committee.

2.2.2. Number and date of the route map showing the proposed alignment.

2.3. Sketch or sketches of supports showing the conductor and ground wire arrangements of the transmission line together with an indication of the sizes and materials of the various wires.

2.4 Please indicate the protective device adopted ior the line. In respect of lines protected by circuit breakers, please furnish also the type of the line and relaying proposed and the total time [Breaker and Relay] for clearance of ground faults on the line with normal relay settings.

2.5 Please indicate the soil resistivity in the area covered by the line. The soil resistivity should be measured by the four-electrode method using an inter-electrode spacing of 50 metres [150 ft]. The measurements may be made at every 2 or 3 Km along the length of the line.

2.6 Please indicate the number of crossings between the proposed alignment and the telecommunication lines involved and state if the crossing arrangements will be provided in accordance with the Code of Practice for Crossings issued by the Power Telecommunications Co-ordination Committee.

3. While applying for route approvals of the Committee, the above particulars should be furnisl.ed to —

i) Joint Secretary (Power),
Power Telecommunication Co-ordination
Committee, Central Electricity Authority,
B-6-7/19, Safdarjung enclave,
New Delhi — 110-029.

ii) D.E.T, [PTCC] Concerned.

Place :

Date :

Signature :

Name :

Designation :

N. B : For computing the interference current from the Power line on the single-wire earth return telegraph circuits, indicate the maximum load for which the power line has been designed.

Appendix vide para 1.2

Please furnish the characteristics of the various power apparatus as under :

1. Synchronous machines (Generators, Synchronous condensers).

Sl. No.	Name of the Power Stn. or Sub–Stn.	Rating KVA.	Transient reactance (percentage reactance on its own base).
1.			
2.			

2. Transformers.

Sl. No.	Name of power Station or Sub-station.	High voltage Winding KV Connec-tions	Medium voltage Winding KV Connec-tions	Low or tertiary Winding KV Connec–tions	Percentage reactance HV/ MV	MV/ LV or tertiary.	HV/LV or tertiary.
1.							
2.							

* 1) In the case of star connections, please state clearly/whether the neutral is effectively grounded.

2) In the case of windings connected delta, please indicate whether it would be operated with isolated neutral or grounded through earthing transformers.

** 3) The MVA base to which these values relate should be clearly specified.

3. Reactors.

Sl. No.	Name of the Power house or Sub-Stn.	Rating	Percentage reactance (on its own base)
1.			
2.			
Etc.			

4. Earthing Transformers.

Sl. No.	Name of the Power House or Sub-Station	Current rating (Short-time)	Voltage rating	Percentage reactance (on the short–time rating)
1.				
2.				
Etc				

APPENDIX—B

(Power Line Crossing — Clearances)

The minimum vertical clearances between any of the Power line crossings at same or different voltages shall be maintained as below :

		Minimum clearance between conductors at crossing points.
a) For 33 KV lines crossing power lines of 33 KV and other lower voltages (including LT.)	:	3.66M
b) For 66 KV lines crossing power lines of 66 KV and other lower voltages (including LT)	:	3.97M
c) For 110 KV lines crossing Power lines of 110 KV and other lower voltages (including LT)	:	4.27M
d) For 132 KV lines Crossing Power lines of 132 KV and other lower voltages (including LT)	:	4.58M
e) For 220 KV lines crossing power lines of 220 KV and other lower voltages (including LT)	:	5.49M
f) For 400 KV lines crossing power lines of 400 KV and other lower voltages (including LT,)	:	7.00M

NOTE :

1) Separate guarding shall be provided above the lower power line in all cases except when the voltage of the higher line is above 33 KV. In this case, the clearance from the guard lines to the lower power line shall be not less than 2 mtr. and the upper power line not less than 1.5 mtr.

APPENDIX—C

SOIL TESTING FOR FOUNDATIO IS

From the point of view of standardising the foundation drawings, the following classes of soils are taken into consideration.

Type of soil	Minimum ultimate bearing capacity	Angle of repose
1) Normal dry soil.	21870 Kg/Mtr²	30°
2) Partially submerged normal soil.	10935 Kg/Mtr² to the extent of submergence.	15° to the extent of submergence.
3) Fully submerged normal soil.	10935 Kg/Mtr²	0°
4) Black Cotton soil.	10935 Kg/Mtr²	15°

Whenever difficulty is experienced in classification of soil visually the same shall be got tested in the nearest laboratory for the above properties.

For this purpose one bore-hole of 150mm dia. shall be drilled at the centre point of the tower foundation. Standard penetration test [SPT] shall be carried out at 1.5 mtr. interval of change of strata upto a depth of 7 mtr. below ground level, or to refusal whichever occurs earlier. By 'refusal' it shall mean that a standard penetration blow count [N] of 100 is recorded for 30 cm. penetration.

Details of water table upto 7 Mtr. below ground level shall be ascertained.
Based on the above SPT and other details the type of soil shall be classified.
If the soil is 'sand' the Bearing capacity and Angle of repose shall be evaluated seperately and furnished to design office.

If the soil is 'Mixed soil' or 'Clay soil' the following tests shall be carried.

a) Detailed bore log with IS classification of soil and its properties such as Specific-gravity and bulk unit weight, moisture content, etc.

b) Collect undisturbed samples of 100/75 mm dia 450 mm long from the bore-holes at 1.5 mtr. interval, or change of starta starting from 3 mtr. and upto 7 mtr. below ground level.

c) Laboratory tests shall be carried out and the following properties are evaluted on the above undisturbed samples.

i) Type of soil and gradation (as per IS Classification).

ii) Attenberg limit (liquid and plastic limit only)

iii) Triaxial tests to determine shear parameters such as cohesion (c) and angle of internal friction (ϕ)

iv) Natural moisture content, specific gravity and bulk unit weight.

v) Consolidation Test.

vi) Unconfirmed compression test.

vii) Unconsolidated undrained test.

viii) Chemical tests on soils and water to determine the carborates, sulphates nitrates and organic matter and any other chemicals harmful to the concrete foundation.

ix) The bearing capacity of the soil at different levels from 3 mtr. to 7 mtr. below ground level. These shall be calculated considering a base width of foundation as 2.0 mtr.

While carrying out the SPT, if the blow count (N) of 100 is recorded for 30 Cm. penetration the soil shall be classified as rocky soil.

In case of rock the bore drilling shall be confirmed for 3 mtr. further to ascertain its sufficient thickness. Core recovery and crushing strength of rock shall also be carried out.

Reference Indian Standards for the above Tests.

1) IS 2131—1983 For standard penetration test.

2) IS 2720

Part III 1973	For grain size analysis,
Part IV 1975	moisture content,
Part V 1970	specific gravity,
Part XI 1971	liquid limit, plastic limit
Part XV 1965	Triaxial compression test. Consolidation test.

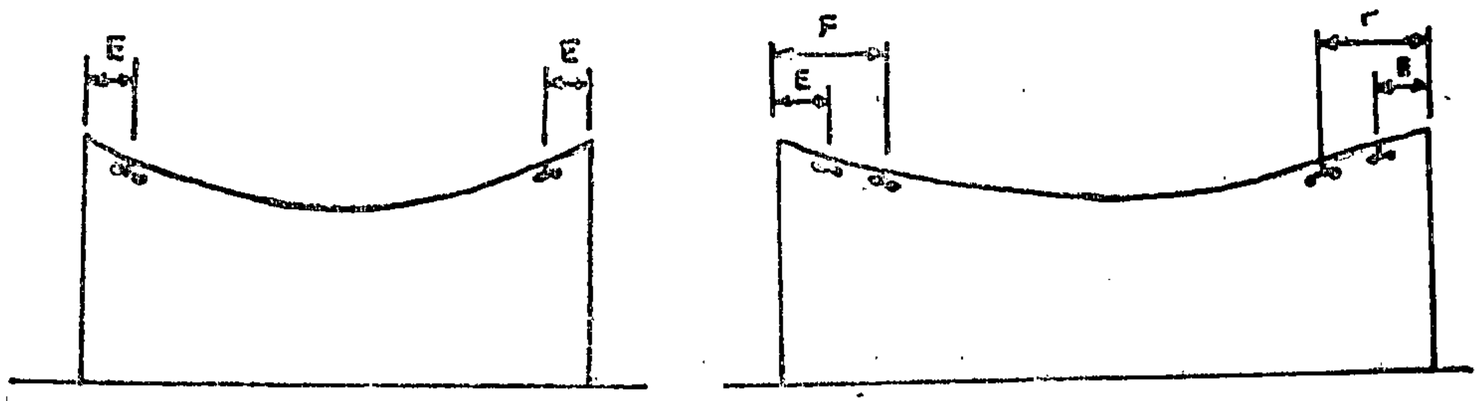
APPENDIX—'D'

RECOMMENDED DAMPER SPACINGS

The maximum efficiency of vibration dampers depend on the design of the Damper, Average wind velocity, conductor diameter, direction of wind etc. The spacings of Dampers for individual lines shall be obtained from the design office for each individual line.

However, in the absence of such information, the following spacings may be adopted :

ACSR CONDUCTOR	DAMPER SPACINGS IN MTR.	
	E	F
RABBIT	0.53	1.07
COYOTE	0.91	1.83
PARTRIDGE	0.99	1.98
PANTHER	1.14	2.29
LYNX	1.14	2.29
DRAKE	1.45	2.89
DEER	1.52	3.05
MOOSE	1.60	3.20



(a) FOR SPAN UP TO 366 MTR WITH ONE DAMPER AT EACH END OF SPAN

(b) FOR SPAN OVER 366 MTR & UP TO 671 MTR WITH TWO DAMPERS AT EACH END OF SPAN.

FIG-35: SPACING OF VIBRATION DAMPERS

1. Spans upto 366 Mtr. require one damper at each end of span spaced at a distance from point of support equal to dimension 'E' as given in the table.
2. Spans over 366 Mtr. and upto 671 mtr. require two dampers at each end of span spaced at distances from point of support equal to dimensions 'E' & 'F' as given in the table.
3. Spacings of Damper on suspension lines are measured from the C.L. of clamp.
4. Spacings of Dampers on dead-ends are measured from mouth of dead-end clamp.

APPENDIX—'E'

DETAILS OF INSULATOR STRINGS

I. NO. OF DISCS FOR EACH VOLTAGE CLASS :

SL No.	Voltage Class	Suspension string.			Tension string		
			No. of discs	Ems strength Kg.		No. of discs	Ems Strength Kg.
1.	66KV	S/S	4	7000	S/T	5	7000
		D/S	2×4	7000	D/T	2×5	7000
2.	110KV	S/S	7	7000	S/T	8	9000
		D/S	2×7	7000	D/T	2×8	9000
3.	220KV	S/S	14	9000	S/T	16	11500
		D/S	2×14	9000	D/T	2×16	11500
4.	400KV	S/S	23	11500	DT	2×24	16500
		D/S	2×23	11500			

S/S Single Suspension String.
D/S Double Suspension String.
D/T Double Tension String.
S/T Single Tension String.

II. The gap distance to be maintained for the adjustable type arcing horns for the first three approach spans at the sub-station shall be obtained from the Design Office.

In the absence of information the following gap distance should be mantained.

	Arcing horn gap distance at first dead end tower.	Arcing horn gap distance for the subsequent 3 towers
For 220 KV lines.	1118mm	1118mm
For 110 KV lines	597mm	622mm
For 66 KV lines	330mm	356mm

The above gap settings are to be followed upto 300 mtrs. altitude above mean sea level. The rod gaps shall be increased by the following percentages for other altitudes.

ALTITUDE :

300 mtr	7 %
600 mtr	12 %
900 mtr	16 %
1200 mtr	21 %
1500 mtr	26 %

APPENDIX—'F'

MEASUREMENT OF SOIL RESISTIVITY AND GROUND RESISTANCE

1. SOIL RESISTIVITY :

Four spikes are driven in a straight line into the ground at equal intervals. The depth of insertion of spikes into the ground shall not exceed 1/20th of the spacing. The two extreme spikes are connected to the instrument terminals C1 and C2. The two inner spikes should be connected to the terminals P1 and P2 as shown in the sketch below :

4 POINT METHOD:

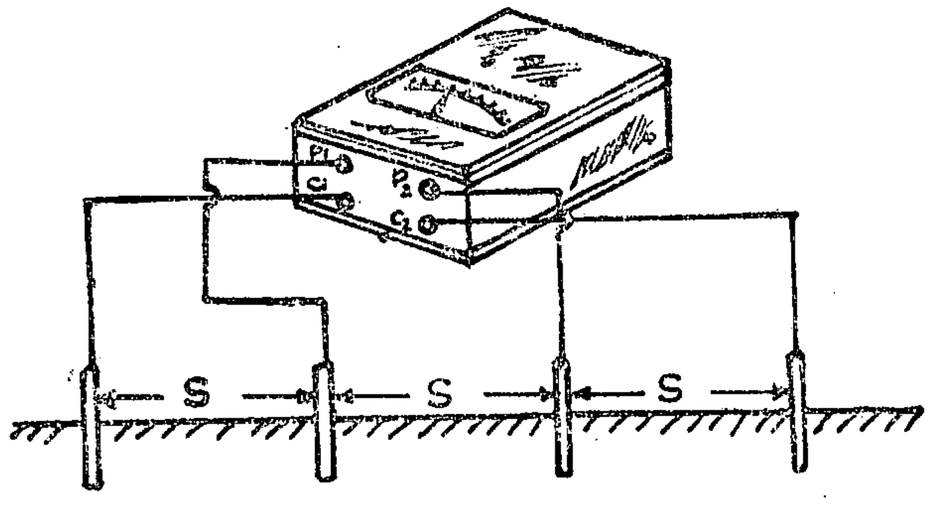


FIG-36: CONNECTION FOR MEASUREMENT OF SOIL RESISTIVITY

The megger handle is rotated steadily for one minute till the readings are stablized. The readings are then recorded.

The process is repeated varying the spacings from 3 mtr. to 15 mtr. at regular intervals of atleast 2 mtr, The soil resistivity P in ohm-mtr. is calculated from the following formula.

$$P = 2\pi SR$$

Where S = spacing between electrodes in mtr.

R = the instrument reading in ohms.

2. GROUND RESISTANCE :

The terminals, P1 and C1 of the Earth megger are strapped together and connected to the earth electrode under test. The terminals P2 and C2 are connected to two spikes driven in a line at spacings say 10 mtr. and 20 mtr from the earth electrode under test. The farther spike should be connected to terminal C2 and the intermediate spike should be connected to terminal P2. The handle of the earth-megger should be rotated steadily for at least one minute till the readings stabilise. The steady readings should be noted. The process is repeated by increasing the spacings further and the readings are once again noted. This process should be repeated till constant readings are obtained. The constant instrument readings thus obtained is the resistance of the earth electrode under test.

APPENDIX— 'G'

APPROXIMATE WEIGHT OF TOWERS

The following table gives the approximate weight of towers as per the current design practice.

These weights are to be used only for estimation purposes.

LINE VOLTAGE	No. of Ckts.	Type of Tower	WEIGHTS OF TOWER IN M T.		
			Normal Tower.	3 Mtr. Extn.	6 Mtr. Extn.
1	2	3	4	5	6
1. 400 KV ACSR TWIN "MOOSE" 2 GROUND WIRES	S.C.	A	6.38	1.18	2.04
		B-15	9.05	1.58	2.52
		B-30	10.73	1.91	3 18
		C	13 50	2 03	3.41
2 400 KV. ACSR TWIN "MOOSE" 2 GROUND WIRES	D.C.	A	11.85	2.19	3.79
		B-15	17.50	3.06	4 87
		B-30	24.00	4.27	7.11
		C	29.51	4.43	7.45
3. 220 KV. ACSR "DRAKE" SINGLE GROUND WIRE.	S.C.	A	2.77	0.45	1.02
		B-15	3.41	0.85	1.50
		B-30	3.94	0.98	1.65
		C	4.81	1.10	1.83
4. 220 KV ACSR "DRAKE" SINGLE GROUND WIRE	D.C.	A	3.83	0.60	1.10
		B-15	5.50	0.92	1.65
		B-30	6.36	1.06	1.3
		C	8.89	1.60	3.2
5. 110 KV ACSR "LYNX" SINGLE GROUND WIRE	S.C.	A	1.73	0.36	0.73
		B-15	2.08	0.46	1.04
		B-30	2.40	0.53	1.14
		C	2.86	0.59	1.41

1	2	3	4	5	6
6. 110 KV	D.C.	A	2.31	0,43	0.88
ACSR "LYNX"		B-15	3.37	0.62	1.31
SINGLE GROUND WIRE		B-30	3.89	0.71	1.44
		C	4.60	0.89	1.88
7. 66 KV	S.C.	A	1.17	0.33	0.68
ACSR "COYOTE"		B 30	1.78	0.37	0.78
SINGLE GROUND WIRE		C	1.97	0.58	1.26
8. 66 KV	D.C.	A	1.80	0.40	0.82
ACSR "COYOTE"		B-30	2.30	0.56	0.15
SINGLE GROUND WIRE		C	3.20	0.75	1·60
9. 66 KV	D.C.	A	2.39	0.44	0.89
ACSR "DRAKE"		B-30	4.38	0.66	0.33
SINGLE GROUND WIRE		C	5.62	1.05	2.15
—10. 66 KV		A	2.50	0.45	—
QUADRUPLE CIRCUIT	Q.C.	B-30	4.25	0.80	—
ACSR "COYOTE"		C	5.00	1.10	—

APPENDIX—'H'

MINIMUM CLEARANCES

Sl No	Voltage category	High Voltage		Extra High Voltage.			
		22 KV	33 KV	36 KV	110 KV	220 KV	400 KV
	Clearance :			Minimum value in Metres :			
i)	Clearance to ground:						
a)	Across Street	6.1	6.1	6.1	6.1	7.0	8.84
b)	Along street	5.8	5.8	6.1	6.1	7.0	8.84
c)	Other areas	5.2	5.2	5.5	6.1	7.0	8.84
ii)	Clearance to Buildings:						
a)	Vertical from highest object.	3.66	3.66	3.97	4.58	4.59	—
b)	Horizontal From nearest point.	1.83	1.83	2.14	2.75	3.66	—

APPENDIX—I

FOUNDATIONS

The following table gives the approximate quantity of earth excavation and concreting required for the towers purely for estimation purposes, to be used in absence of design data. These values are only typical and in no way to be used for construction purposes. Only the foundation drawings issued from design office shall be used for construction.

(All quantities are in cubicmeters)

VOLTAGE CLASS AND TOWER TYPE		TYPE OF SOIL							
		Normal Dry		Partially Submerged		Fully Submerged		Black cotton	
		Earth Excavation	Concreting.	Earth Excavation	Concreting.	Earth Excavation	Concreting.	Earth Excavation	Concreting.
1		2	3	4	5	6	7	8	9
1. 220 KV S.C.									
	A	18.6	3.0	59.7	9.60	80.20	15.0	42.5	6.3
DRAKE	B	29.1	4.1	95.5	16.5	122.4	24.1	65.0	9.6
	C	41.3	5.5	128.9	20.5	162.5	29.3	85.7	11.6
2. 220 KV D.C.									
	A	22.6	3.4	61.3	9.6	94.2	18.7	48.5	7.3
DRAKE	B	50.3	6.5	134.5	22.8	186.4	38.80	100.0	15.5
	C	60.5	7.8	146.1	24.8	196.0	39.9	107.5	16.6
3. 110 KV S.C.									
	A	13.3	2.4	39.0	6.7	58.1	11.3	30.3	4.4
LYNX	B	24.0	3.5	43.8	15.9	83.0	20.9	46.7	7.0
	C	31.9	4.3	84.1	18.7	111.3	28.5	61.4	8.8
4. 110 KV D.C.									
	A	18.8	2.9	49.1	8.1	69.4	12.8	39.2	5.5
LYNX	B	43.2	5.7	115.5	28.6	145.2	40.5	81.7	12.2
	C	53.6	6.6	144.5	33.80	194.9	53.5	101.0	14.9

1		2	3	4	5	6	7	8	9
5. 66 KV S.C.									
	A	13.3	2.44	36.5	7.38	48·0	10.0	40.0	8.0
COYOTE	B	14.85	2.56	48.6	8.85	60.0	12.0	50.0	9.1
	C	23 00	3.14	60.0	9.50	75.0	15.0	65 0	10.1
6. 66 KV D.C.									
	A	21.3	3 52	42.0	8.5	54.0	12.0	43.2	8.8
COYOTE	B	28.3	4.34	52.0	10.0	70.0	14.5	54.3	10.8
	C	43.0	5 93	68.0	13.0	95.0	20.0	69.9	13.2
7. 66 KV D.C.									
	A	28.9	4.10	70.0	10.2	100.0	19.5	72.0	11.2
DRAKE (Narrow based]	B	80.0	9.20	150.0	25.0	190.0	42.0	160 0	27.0
	C	110.0	13 60	165 00	27.0	210.0	45.0	170.0	28.5
8. 66 KV Q.C.									
	A	28.0	4.0	65.0	9.5	95.0	18.0	70.0	10.5
COYOTE (Narrow based)	B	78.0	9.0	140.0	23.0	180.0	40.0	150.0	25 0
	C	108.0	13.50	160.0	26.0	200.0	43.0	165.0	27.5

APPENDIX—'J'

DETAILS TO BE FURNISHED ALONG WITH LINE ESTIMATE :

The following information shall accompany each estimate :

1) Tower schedule.

2) The following details of special structures such as River crossing, Power line crossing etc, if any required.

i) EL of Tower.

ii) Angle of deviation of the line incident on the tower.

iii) Required height of bottom conductor.

iv) Type of soil for foundation.

v) Adjascent Span

9) Route Map

APPENDIX—K

TRAVELLERS OR SNUB STRUCTURE LOAD CALCULATION

The following is a method for calculating the actual load on travellers and snub structures when tension stringing. If structures are at the same elevation and there are no angles in the line, only the first and last travellers need to be considered. However, in rough terrain and when angles are encountered, the load at these points should also be calculated. For snub structure loading the weight of insulator assemblies and travellers must also be considered.

A = distance of tensioner or puller from structure

B = height of structure arm from elevation of tensioner or puller

D = sag during stringing operation

E = difference in elevation between points of attacement

F° = angle of conductor from tensioner or puller to horizontal

G° = angle tangent to conductor and horizontal

K° = azimuth angle of departure in line

L = length of span

R_h = horizontal load on traveller

R_v = vertical load on traveller

R_{max} = total load on traveller

T = line tension

EXAMPLE : Stringing tension is 2500 kg [T] and you locate your tensioner 100 mtr [A] from the first structure. Height from the point of attachment of the traveller to the elevation of the tensioner is 30 mtr [B]. The first span is 320 mtr [L] and sag during stringing is to be 15 mtr[D]. Angle of departure frcm the lead-in from the tensioner is 16° [K]. The difference in elevation from the first to the second structure is 25 mtr [E]. The resultant load on the traveller is calculated as follows.

A=100 mtr L=320 mtr.

B=30 mtr D=15 mtr

E=25 mtr

$$\text{Tan } F = \frac{B}{A} \qquad \text{Tan } G = \frac{E+4D}{L}$$

$$T = \frac{30}{100} \qquad \text{Tan } G = \frac{25+4\times15}{320} = \frac{85}{320}$$

$$F = 16\ 69^\circ \qquad G = 14.87^\circ$$

The lead-in angle is 16.69° from horizontal and the lead-out angle is 14.87°. The traveller will bisect the total angle of 31.56°, actually giving a 15.78° angle on either side

$$T = 2500 \text{ kg} \qquad K = 16^\circ$$

To solve for R_v :

$$R_v = 2\ T \sin \frac{F^\circ + G^\circ}{2}$$

$$R_v = 2\times2500\times\sin 15.78$$

$$R_v = 1360 \text{ kg}$$

To solve for R_h :

$$R_h = 2\ T \sin \frac{K^\circ}{2}$$

$$R_h = 2\times2500\times\sin 8^\circ$$

$$R_h = 696$$

To solve for R_{max} :

$$R_{max} = \sqrt{1360^2+696^2}$$

$$R_{max} = 1528 \text{ kg}$$

Therefore, the total load on the traveller is 1528 kg. This value is approximate as the above formulae are based on parabolic rather than catenary equations and sag is disregarded between the tensioner and first traveller. However, this method gives slightly less than actual load.

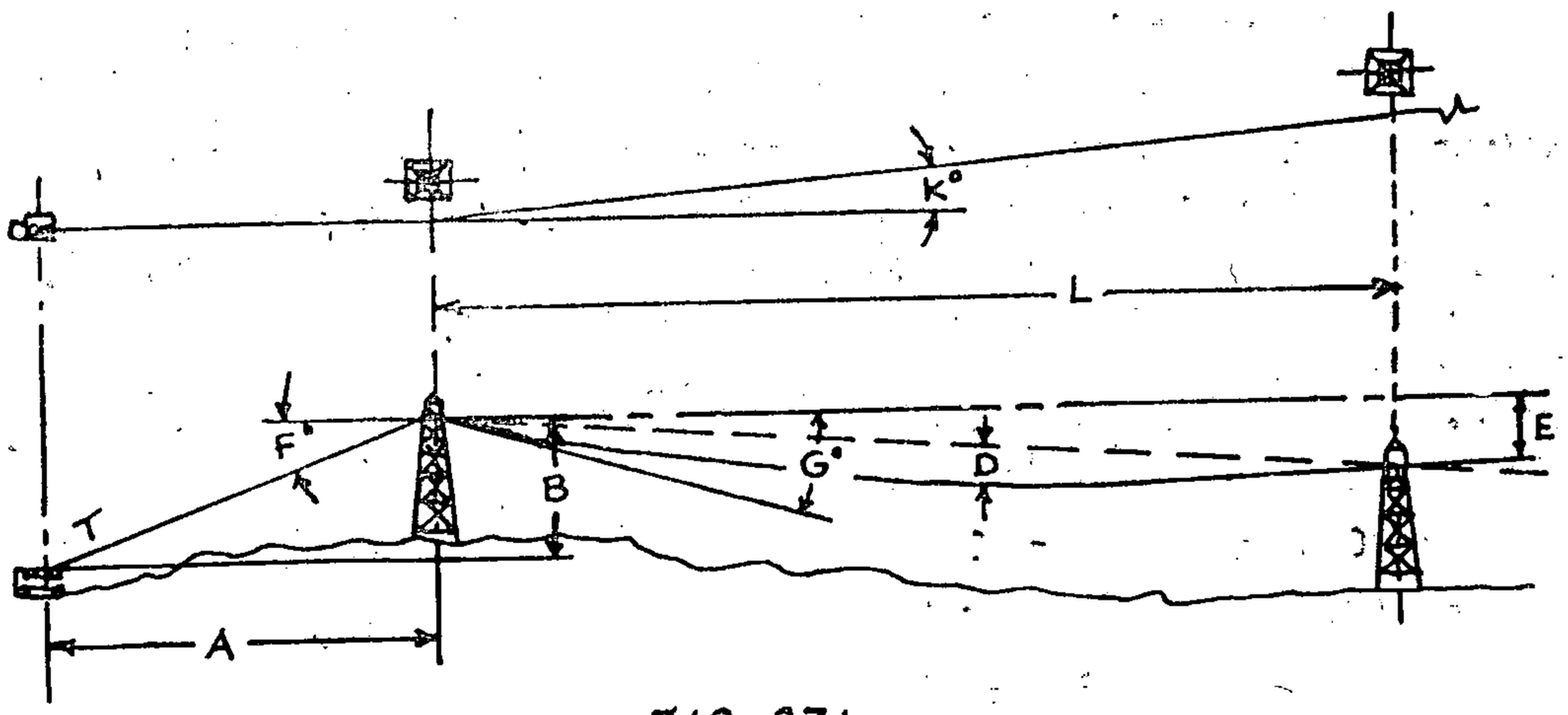


FIG-37:

APPENDIX—L

EFFICIENCY OF TRAVELLERS DURING TENSION STRINGING

The question of the efficiency of travellers often arises when planning overhead line construction jobs. Before this can be determined, the amount of force, holding power or tension just to support the wire in the span must be calculated. For a level span this can easily be done with the following formula.

$$T_1 = \frac{WL^2}{8D}$$

W = weight per unit length of conductor

D = sag (sag during stringing, not final sag)

L = span length

T_1 = tension to support wire in span (static condition)

Knowing the tension required to support the wire in a static condition, the next consideration is the amount of tension needed to pull the wire across the supports, which in this case are the travellers. The additional tension required here is primarily the work to bend the wire, not to overcome the friction on the bearings of the travellers.

If a solid round metal bar is bent around a radius, the metal on the inside of the bend must compress and the metal on the outside of the bend must stretch. It takes a considerable amount of force acting through an appreciable distance to bend such a rigid bar. Force acting through a distance is called work.

Wire rope, strand or conductors is made much more flexible than a solid bar by taking round wires and forming them into a helix. The greater flexibility of such a structure is due to the fact that the wire at any point on the inside of the bend does not have to compress, or on the outside of the bend, stretch. Instead, the wire simply slips around the helix so as to adjust for the shortening on the inside and the lengthening on the outside of the bend.

However these wires are pressed together with considerable pressure. The pressure is due to and is proportional to the tension in the cable (the pull on the cable). Thus the slipping of the wire around the helix when the cable is bent is accompanied by considerable friction. Therefore while it takes a great deal less work to bend a cable than it does to bend a solid bar still it does involve an appreciable amount of work. Friction is proportional to the tension in the cable, Thus, the higher the tension, the more work is required to bend the cable around a radius.

At each point of support as the cable or conductor is being pulled, it must bend to the sheave radius of the traveller at the entering side and then must be straightened out again at the leaving side. Thus an appreciable amount of work [or resistance to pull] is developed at each sheave. The amount of work [resistance to pull] is proportional to the tension and is inversely proportional to the diameter of the sheave because it obviously takes more to bend around a smaller arc than around a larger arc.

From this it is apparent that the tension becomes greater as each traveller is passed since this tension builds up progressively at each support.

If we assume 2% loss at each block, then the efficiency is 98% at each support. To solve for the total loss or rhe total efficiency, the number of travellers must be an exponent of the efficiency. The efficiency will vary depending on the size of the wire, size of the block, and other factors discussed above. Efficiency at 98% is used as representative under normal conditions encountered.

From this, if the initial tension before entering the fist sheave = T_1, and the final tenosin after passing over N mumber of supports = T_{max}, then :

$$T_{max} = \frac{T_1}{0.98^n}$$

where

T_1 =tension to support first span

0.98 =the efficiency at each traveller

n =number of supports

EXAMPLE

D =15.24 Mt [Sag in mt during stringing]

W =2 kg [Wt of conductor per mt]

L =305 Mt [span length in Mt]

T_1 =tension to support first span

n =8 [Number of supports]

0.98 =Assumed efficiency of each traveller

T max =Tension to pull conducror

$$T_1 = \frac{WL^2}{8D} = \frac{2 \times (305)^2}{8 \times 15.24} = 1526 \text{ kg.}$$

$$\text{Then } T_{max} = \frac{T_1}{(0.98)^n} = \frac{1526}{(0.98)^8} = 1794 \text{ kg.}$$

This formula, explantion and example are published in this form as a guide. Many factors affect the value being sought. This is an acceptable figure in most instances. In the case of actual varying field conditions encountered, an allowance should be considred.

Many variables will affect the assumed 98% efficiency of the travellers. Should very small sheaves be used, the efficiency of the travellers will be much less. On the other hand, cases of large sheaves, over 20 times conductor diameter at bottom of groove, have resulted in efficiency of over 99%. This is important as it must be considered in the selection of pulling and tensioning equipment and pulling lines.

$T = 5443$ kg for pulling line.

$T = 2722$ kg for each conductor.

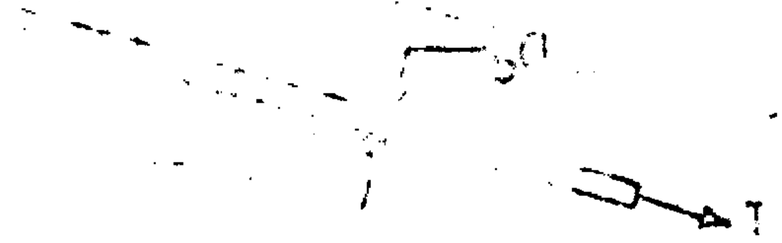
$D_s = 61$ CM (71 CM SHEAVE, 24 CM in bottom of groove diameter)

$D_c = 1.587$ CM (diameter of pulling line)

$D_c = 3.822$ CM (diameter of conductor)

$$P = \frac{3T}{D_s\ D_c} = \frac{2 \times 5443}{61 \times 1.587} = 169 \text{ Kg/Cm}^2$$ representing the unit bearing pressure for the 1.587 cm in OD pulling line)

$$P = \frac{3 \times 2722}{61 \times 3.822} = 35 \text{ kg/CM}^2$$ (representing the unit bearing pressure for the 3.822 cm in OD conductor)



APPENDIX—M

RECOMMENDED BEARING PRESSURE ON SHEAVE LININGS

Considering bearing pressure between conductors and stringing sheaves, it is to be noted that the pressure per unit of length between the conductor and sheave groove is a function of the tension [T] in the conductor and the diameter of the sheave to the bottom of the groove [D_s] and the diameter of the conductor [D_c]. The pressure is independent of the angle of radial contact around the sheave and the resulting load on the traveller. The bearing pressure is therefore expressed by the following equation :

$$P = \frac{3T}{D_s D_c}$$

P = bearing pressure

T = conductor tension

D_s = diamater of sheave to bottom of groove

D_c = diameter of conductor or pulling line

Limits or guidelines for conductors have been 500-700 for lined sheaves, less for unlined ones. To obtain reasonable wear on sheave linings maximum allowable unit bearing pressures for steel pulling lines is 2000 for Neoprene, 3500 for Urethane.

Examples :

T = 5000 kg for pulling line

T = 2500 kg for each conductor

D_s = 61 cm (71 cm sheave, 61 cm bottom of groove diameter)

D_c = 1.60 cm (diameter of pulling line)

D_c = 3.82 cm (diameter of conductor)

$$P = \frac{3 \times 5000}{61 \times 1.60}$$

P = 154 representing unit bearing pressure for the 16 mm OD pulling line

$$P = \frac{3 \times 2500}{61 \times 3.82} = 32$$ representing unit bearing pressure for the 38.2 mm OD conductor.

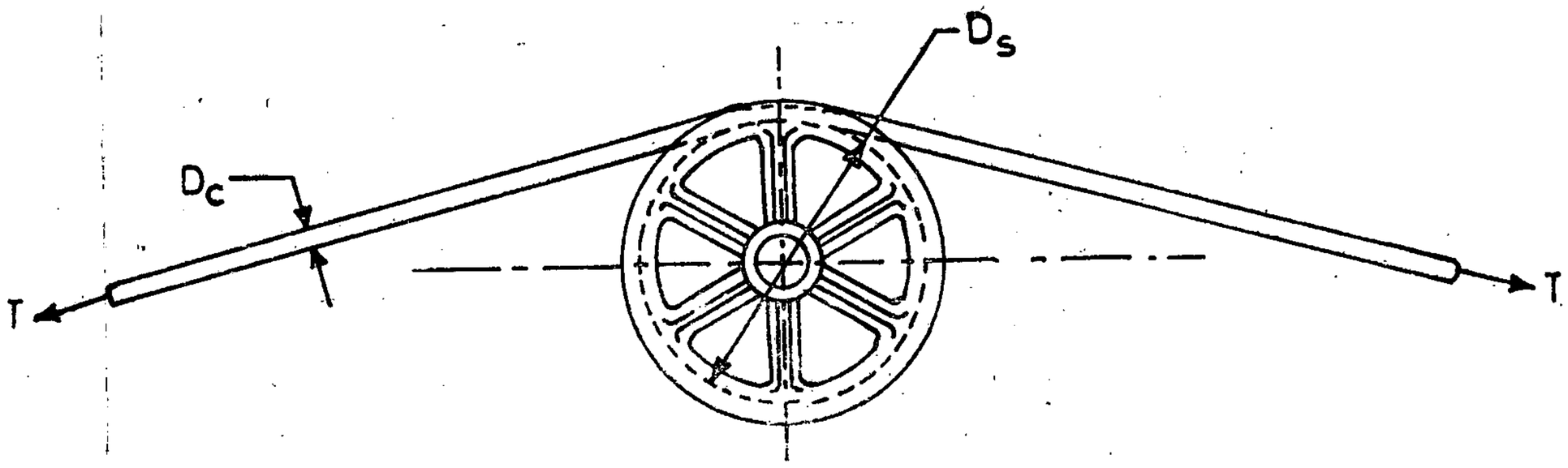


FIG-38:

APPENDIX—N

DRUM OR REEL WINDING

Stranded members should be wound on a drum or reel according to the lay and the direction of travel.

Note the convenient thumb rule. Clench the hand into a fist, but with the thumb and index finger protruding. Use the right hand for right lay and the left hand for left lay. The clenched fingers represent the barrel and the index finger the direction of pull-off. The thumb points to the proper attachment site.

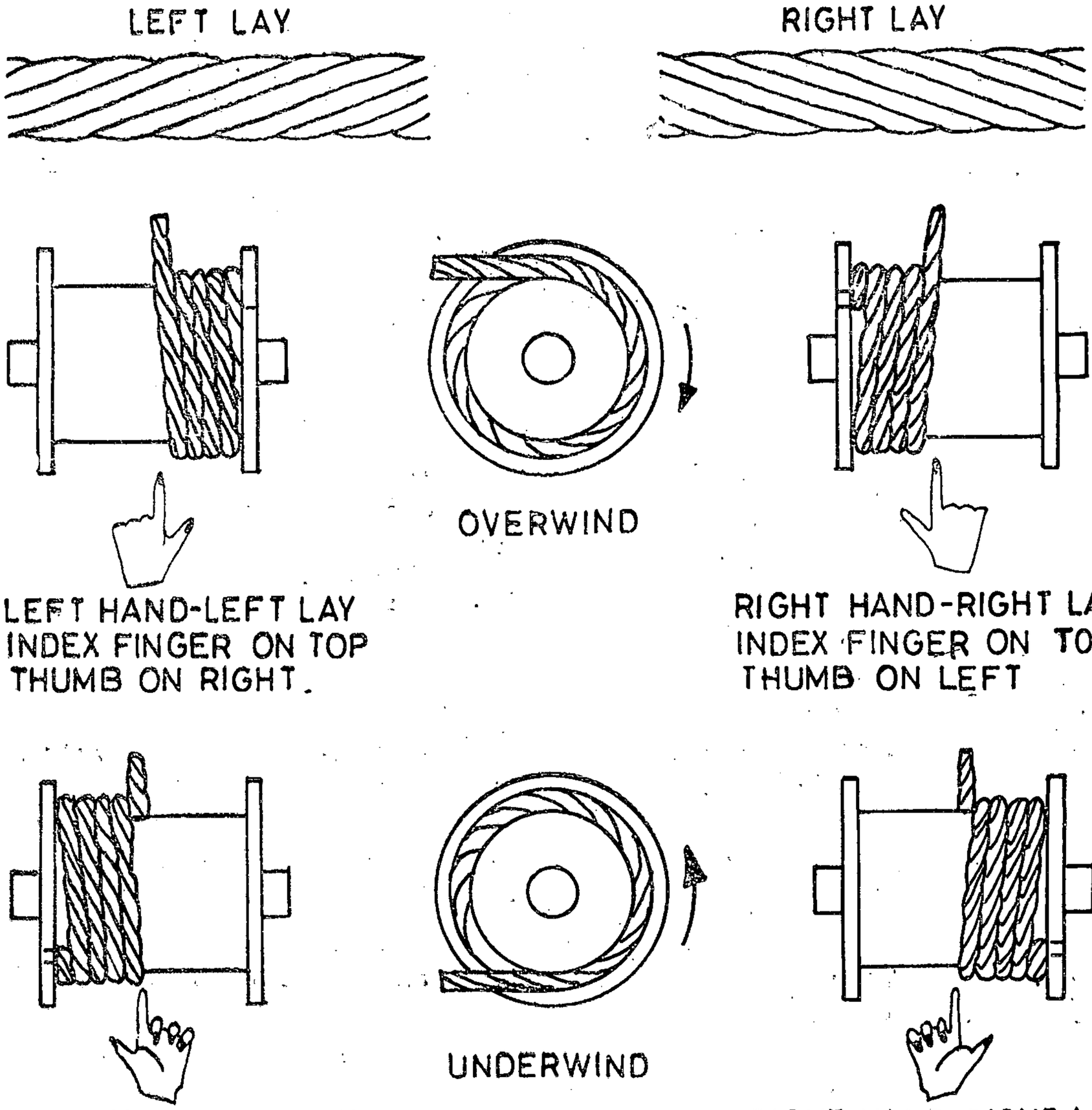


FIG-39

APPENDIX—O

STOP WATCH OR RETURN WAVE METHOD

In this method a Sharp blow near the Tower is given to the conductor. This will cause a wave to travel to the other tower from where the wave is again reflected back. This wave will travel back and forth until it finally dies out by absorption of energy by the conductor.

There exist a definite relation between the time in seconds taken by the wave to return to the first support and the amount of sag. For convenience and to reduce the errors in the recording time, it is advisable to note the time for the tenth return of the wave instead of the first return, However some times the time for the fifth and third return waves are also taken into account.

The relations which give the sag in the lines are

(i) For tenth return wave

$$D = 0.00306\ t^2 \text{ mtr}$$

(ii) For fifth return wave

$$D = 0.0123\ t^2 \text{ mtr}$$

(Iii) For third return wave

$$D = 0.0341\ t^2 \text{ mtr}$$

Where D is in mtr and t is in Seconds.

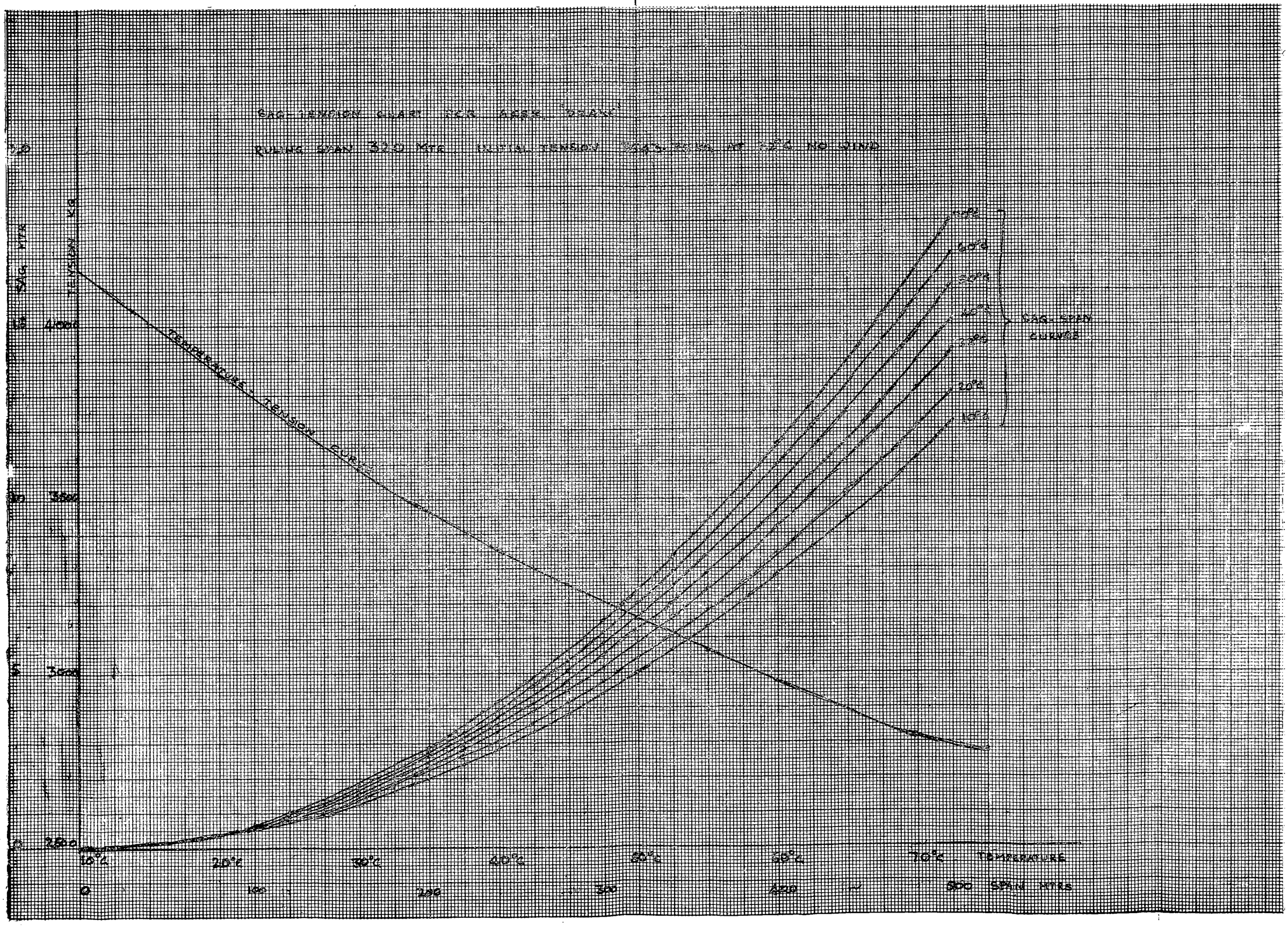
The return wave can be felt by a man on the first tower to throw a light and dry chord rope on the conductor at about 1.5 metre away from the first support. This chord is held by a man standing on the ground. The chord can also be used for giving the initial blow. The counting should not be started when the initial impulse is given. Start counting one on the return of first wave.

To obtain satisfactory results by this method, any other disturbance to the line during this process should be avoided.

Sag in Mtr.	Time in Seconds for 10th return wave	Sag in Mtr.	Time in Seconds for 10th return wave
4.0	36	6.8	47.1
4.2	37	6.9	47.5
4.4	38	7.0	47.8
4.6	38.7	7.1	48.2
4.8	39.6	7.2	48.5
5.0	40.4	7.3	48.8
5.1	40.8	7.4	49.1
5.2	41.2	7.5	49.5
5.3	41.6	7.6	49.8
5.4	42.0	7.7	50.2
5.5	42.4	7.8	50.5
5.6	42.8	7.9	50.8
5.7	43.2	8.0	51.1
5 8	43 5	8.1	51.4
5.9	43.9	8.2	51.8
6.0	44.2	8.3	52.0
6.1	44.6	8.4	52.4
6.2	45.0	8.5	52.7
6.3	45.4	8.6	53.0
6.4	45.7	8.7	53.3
6.5	46.0	8.8	53.6
6.6	46.4	8.9	53.9
6.7	46.8	9.0	54.2

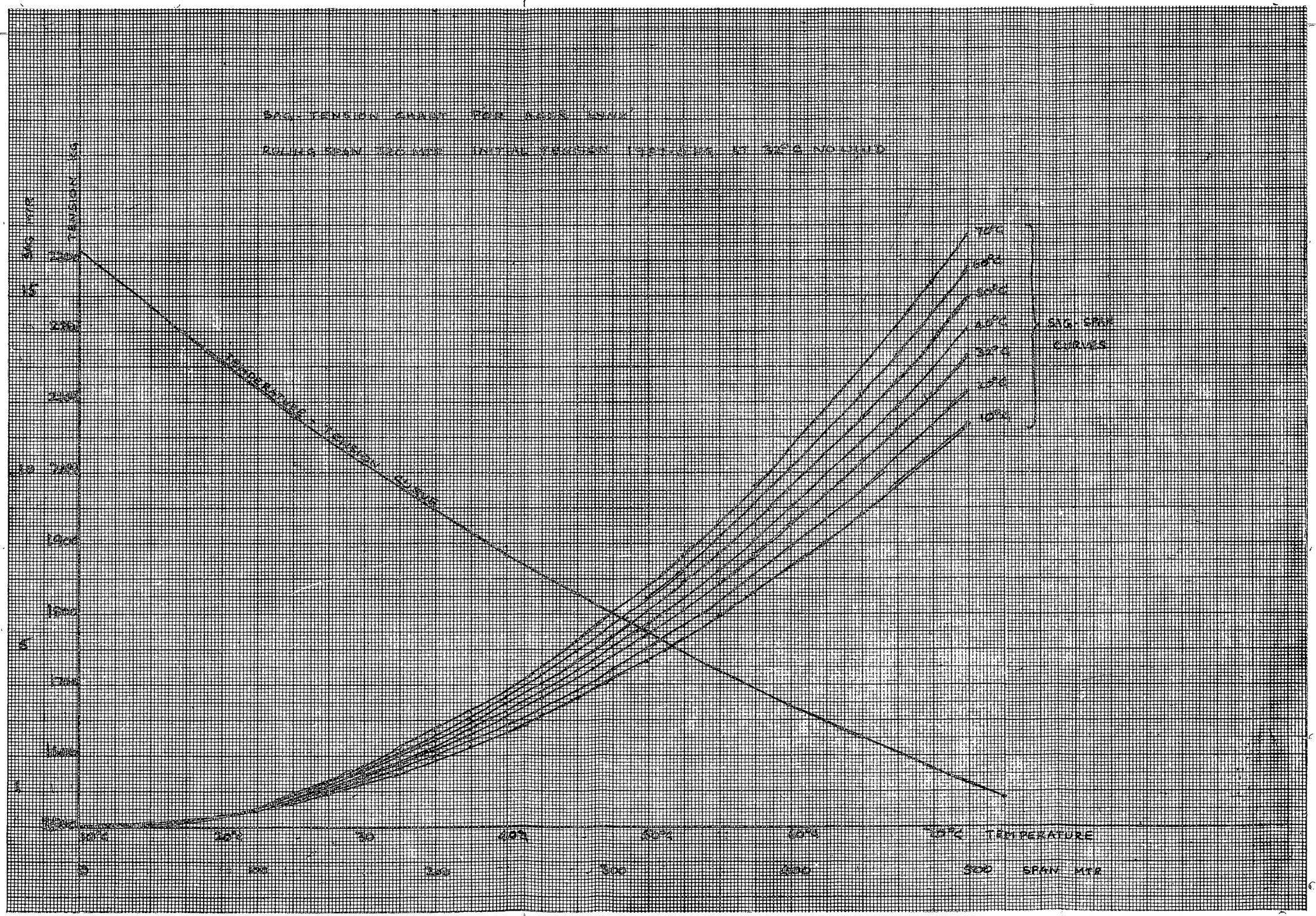
SAG-TENSION CHART FOR ACSR "DRAKE"

SD RULING SPAN 320 MTS INITIAL TENSION 7545 KGS. AT 32°C NO WIND



SAG - TENSION CHART PER ACSR 'LYNX'

RULING SPAN 320 MTR INITIAL TENSION 1582.5 KG AT 32°C NO WIND



SAG-TENSION CHART FOR ACSR GROSBEAK

ROLLING SPAN 275 MTR INITIAL TENSION 1559.5 KG AT 32°C

SAG MTR

TENSION KGS

15

10

5

0

1500

1300

1200

1100

1000

900

800

700

TEMPERATURE-TENSION CURVE

10°C

20

30°C

40°C

50°C

60°C

70°C

TEMPERATURE

SAG-SPAN CURVES

0

100

200

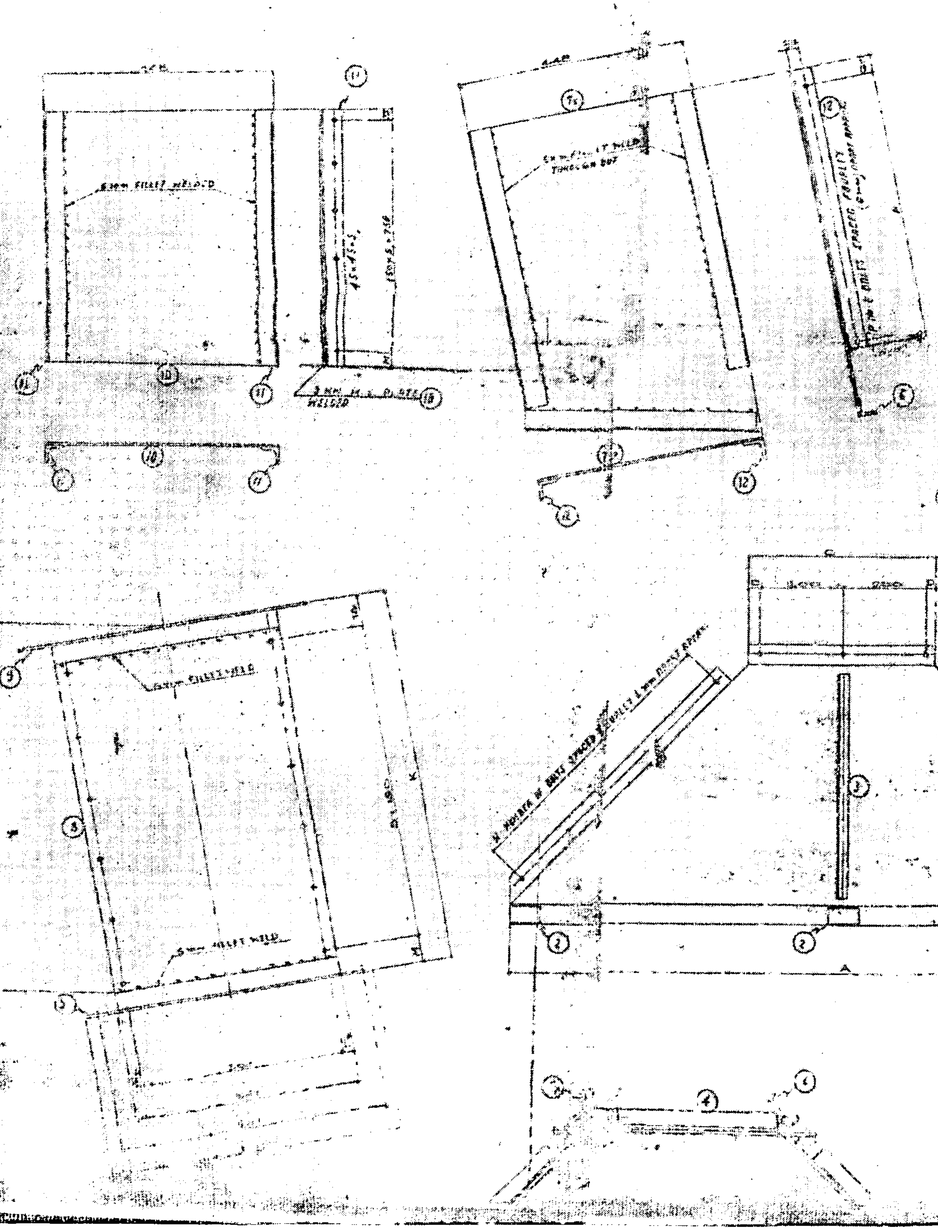
300

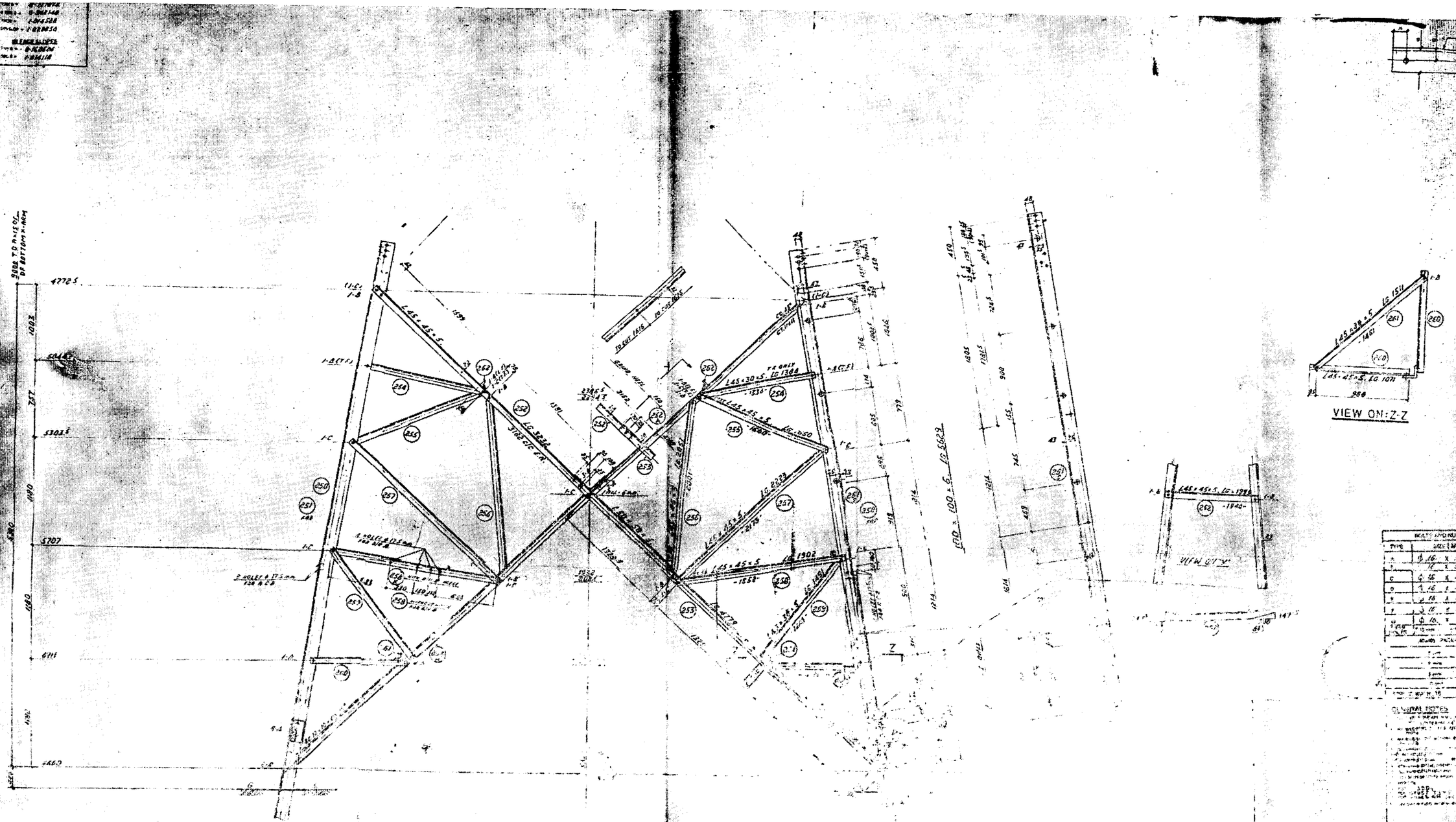
400

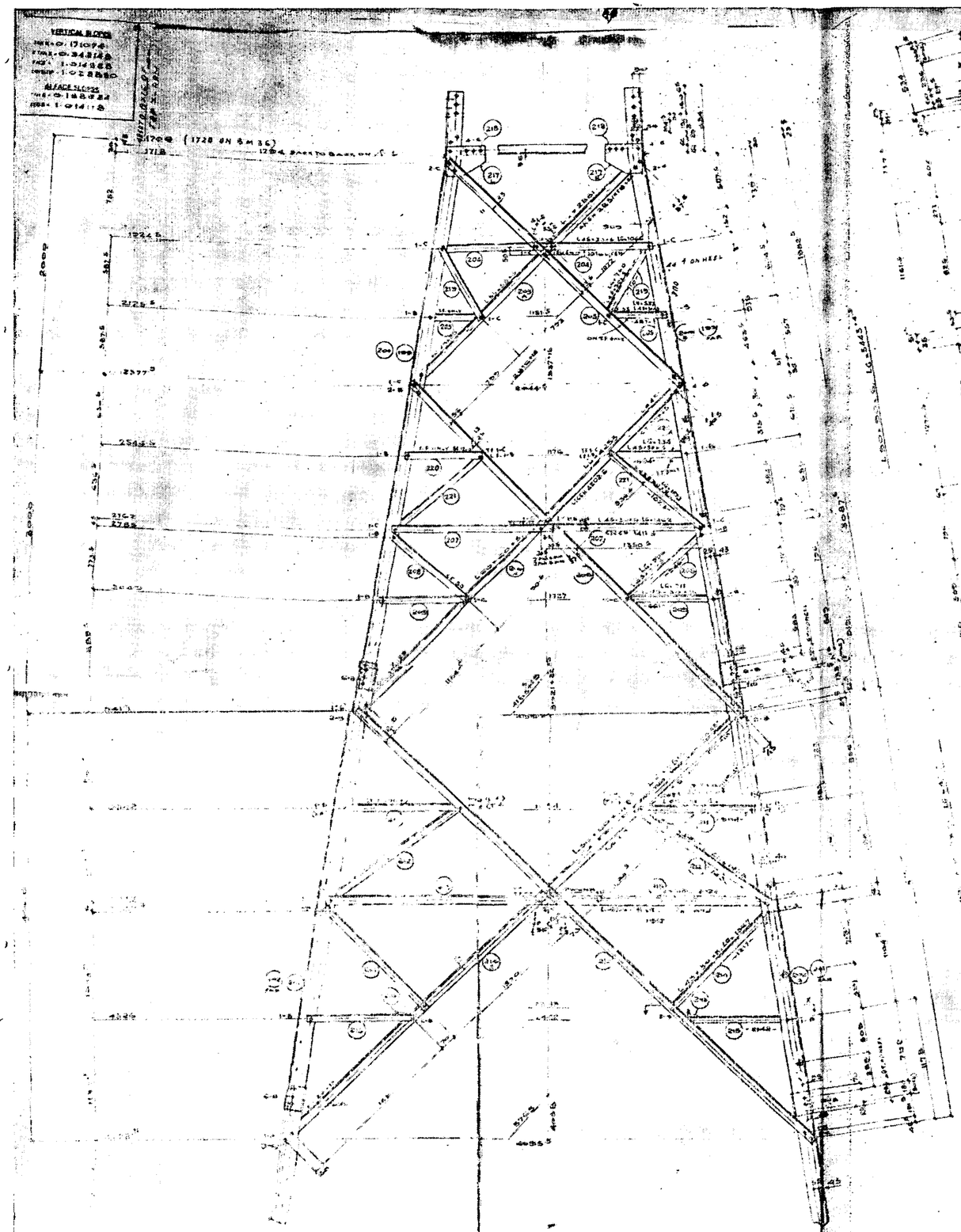
500

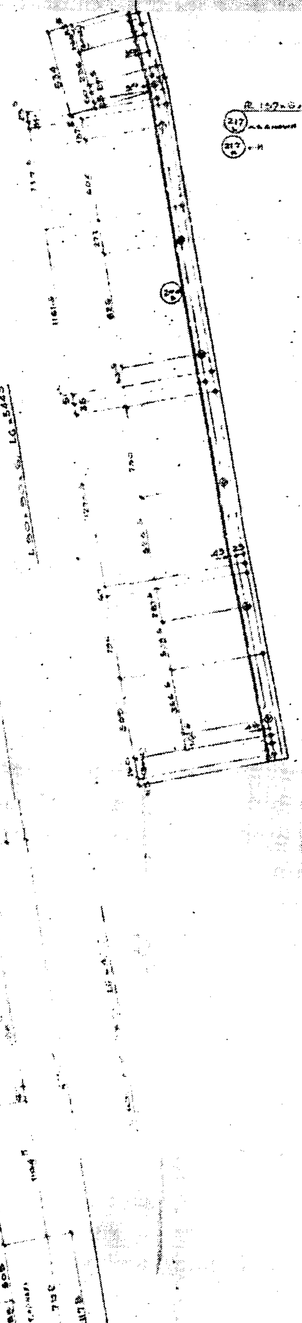
SPAN MTR

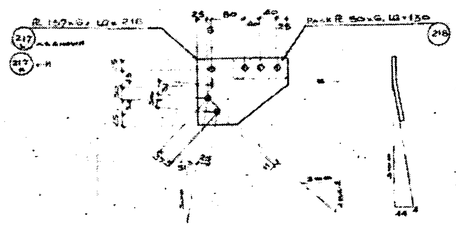
TOWER SECTION	A	B	B1	C	D	E	F	G	H	J	K	L	M	N	P	Q	R
BODY	800	200	600	432	25	1094		107	850	448	224	224	64	32	32	32	16
LEG				432	25												
LEG				432	25												
LEG	2	200	400	432	25												

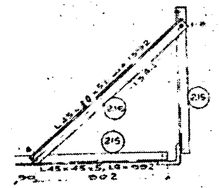

6 mm FILLET WELDED
6 mm FILLET WELDED
6 mm FILLET WELDED

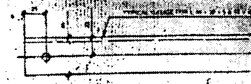

VIEW ON Z-Z
VIEW ON Y-Y
220 KV S/C
TOWER (TYPICAL)
FIG NO ST-1

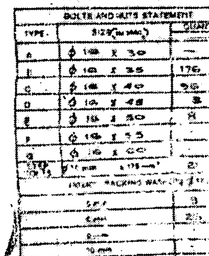

VERTICAL SLOPES
SURFACE SLOPES

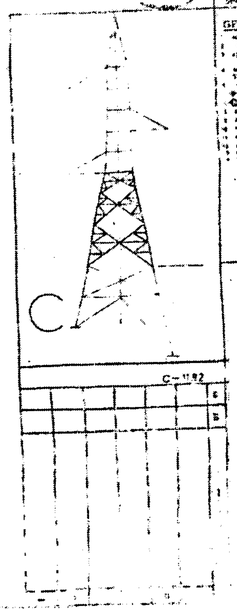


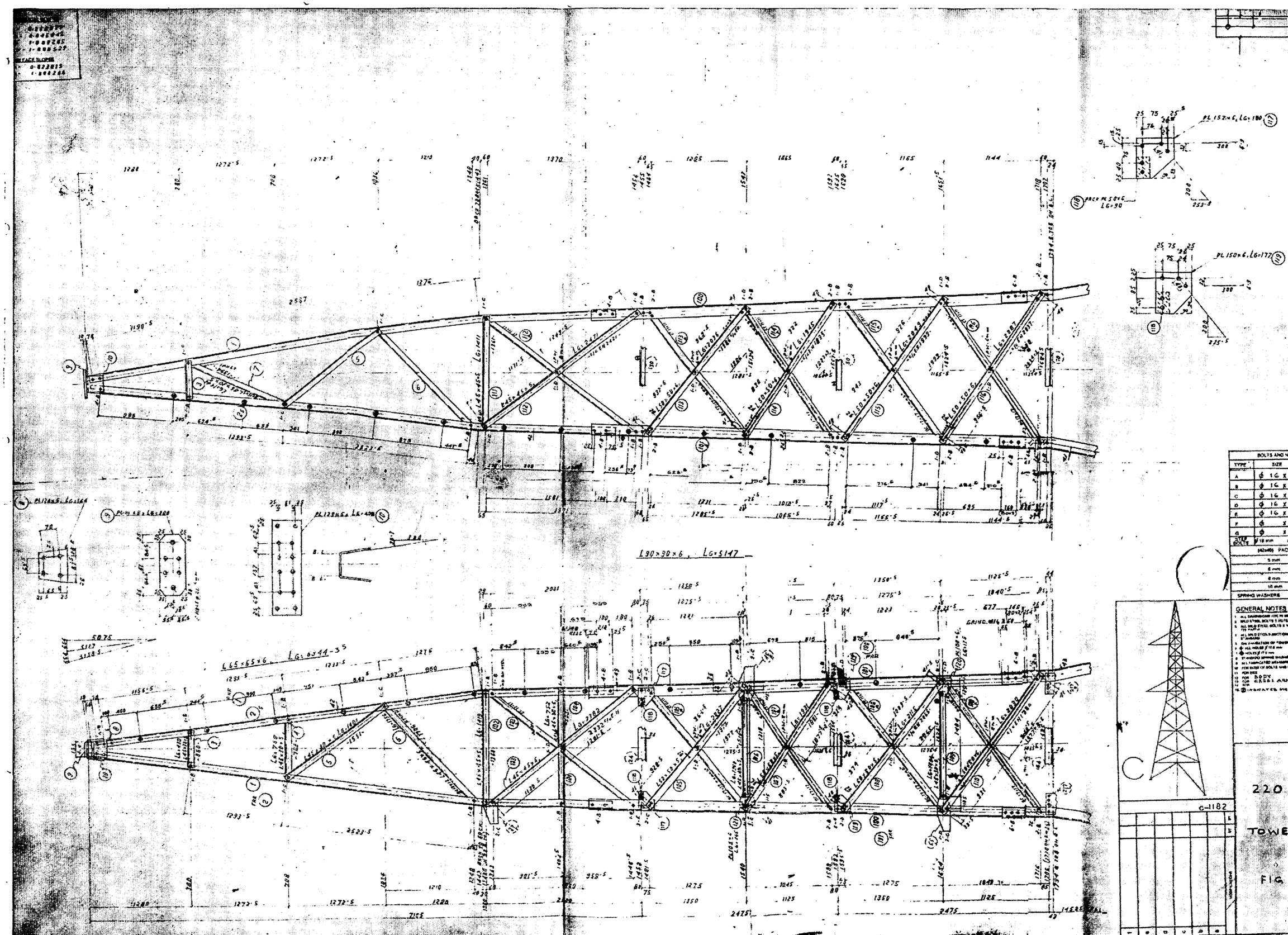



VIEW IN XX




BOLTS AND NUTS STATEMENT
GENERAL NOTES


220 KV.
TOWER



BOLTS AND NUTS STATEMENT		
TYPE	SIZE	QUA
A	ϕ 16 X 30	
B	ϕ 16 X 35	178
C	ϕ 16 X 40	52
D	ϕ 16 X 45	42
E	ϕ 16 X 50	12
F	ϕ X	
G	ϕ X	
SPLIT BOLTS	ϕ 18 mm x 178 mm	24
(M24HR) PACKING WASHERS @ 11		
5 mm		
6 mm		16
8 mm		6
10 mm		
SPRING WASHERS		276

GENERAL NOTES:

6-1182

220 K.V.

TOWER (T

FIG NO

CON

TOP CROSS ARM

BOTTOM CROSS ARM

MIDDLE CROSS ARM

BOLTS AND NUTS REQUIREMENT		
TYPE	SIZE	QUANTITY
A	ϕ 16 X 30	
B	ϕ 16 X 35	65
C	ϕ 16 X 40	12
D	ϕ 16 X 45	24
E	ϕ 16 X 50	
F	ϕ 16 X 55	
G	ϕ 16 X 60	
ETC	ϕ 16 mm X 175 mm	

SPRING WASHERS	
16 mm	
20 mm	
22 mm	
24 mm	
30 mm	

GENERAL NOTES

220 KV

TOWER

DRG NO

C-1182