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MULTIFLUE CHIMNEYS IN INDIA

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INTRODUCTION

The installed capacity of thermal power generation in India has increased by about 14000 MW in the last decade. With the current trend of putting up large size thermal power plants, several large diameter multiflue chimneys, height ranging from 160 m to 225 m, have already been built in the country. Barring a few chimneys with steel liners, most of these chimneys consist of an outer wind-shield in reinforced concrete supporting internal brick flues, usually two or three in numbers, on platforms spaced at intervals along the chimney height. This paper deals with one such multiflue chimney recently completed at Kota (India), with particular relevance to aero-dynamic aspects of design and remedial measure to suppress vortex excitation.

STRUCTURE

The chimney is 180 m high to serve the 2 x 210 MW units of the Kota Thermal Power Project, Stage II, for Rajasthan State Electricity Board. (Project Consultant: Desein (New Delhi) Pvt. Ltd., New Delhi, Engineer & Contractor: Gammon India Limited, Bombay). It consists of an outer shell in reinforced concrete with an external diameter of 16.6 m at the top tapering to 23.7 m at the base (Fig. 1). The shell thickness varies along its height from 300 mm at the top to 850 mm at the base. The internal flues, 3 in number, consist of 115 mm thick refractory brick lining with a 4.9 m internal diameter, and wrapped around with 50 mm thick mineral-wool insulation to resist thermal effects due to flue gas temperature of 182^{o} C. The flues are supported on reinforced concrete floors spaced at 10 m centres. Construction of the outer shell was completed in February 1986 using slip-form technique, while that of the internal floors has been completed in the meantime.

DESIGN

Wind force forms the major external applied loading in the design of the chimney. The basis for calculation of wind pressures acting on the structure is the Indian Standard Code of Practice IS:875-1964 (Ref. 1). The chimney is designed for a basic wind pressure of 1.5 kN/sq.m up to 30 m height, and there above increasing in value with height, with a maximum value of 2.14 kN/sq.m at the top. Along-wind moments on the shell are calculated by deterministic approach considering a drag coefficient of 0.7 (Fig. 2).

The chimney being a tall structure with low inherent structural damping, an investigation of cross-wind response due to vortex shedding was necessary. In circular chimneys, aero-dynamic problems arise from fluctuating distribution on the shell due to alternate shedding of vortices from airflow at opposite sides of the chimney. Several analytical methods have been developed over the years to analyse cross-wind response of structures. However, a reliable prediction of the response is still not possible in view of uncertainties in the value of some of the parameters adopted in design. The natural frequency of the chimney in the fundamental mode is 0.51 Hz (Fig. 3), and the critical wind speed at this frequency, at one-third height from the top, is 45 m/sec. As this critical speed is lower than the design wind speed of 50 m/sec at the corresponding level, resonance in the fundamental mode is expected to take place, but resonance at higher modes is not likely to occur since the critical wind speed in these cases is more than the design wind speed. For the analysis of this chimney, cross-wind moments are calculated by deterministic method as given by Rumman (Ref. 2), considering a Strouhal number of 0.2, and ratio of Lift Coefficient to Fraction of Critical Damping equal to 16. However, a check on these moments was made later by the probablistic approach given in ACI 307-84 draft (Ref. 3) and found that the cross-wind moments calculated by this approach are comparatively lower than the values calculated by the earlier method, but still it is higher than the along-wind moments (Fig. 2).

The Mass Damping Parameter (Scruton number) $K_s = \frac{2m}{\rho D^2}$ by which the probability of aero=dynamic stability is assessed, works out to 15.24 for the chimney by considering a Logarithmic Decrement of Damping equal to 0.03, and this K_s value is lower than the usual accepted figure of 20 for cylindrical chimneys and 25 for tapered chimneys as found by Scruton by model studies. If the K_s value were to be increased to say 20, it means providing an additional mass of 10500 kN (= 420 cu.m of concrete) as a mass-tuned damper at the top level of the chimney which is not practicable. The cross-wind moments as seen in Fig. 2, are very high as compared to along-wind moments, and if these are considered in design, it would obviously lead to very thick and uneconomical shell sections. Hence, means of suppressing the vortex excitation was considered necessary.

SUPPRESSION OF VORTEX SHEDDING

A large number of remedial measures to suppress or alleviate the effects of periodic vortex excitation have been developed. For practical considerations, only Scruton's continuous strakes on steel chimneys have found widest use. More than thirty single/multiflue reinforced concrete chimneys in India have been mounted with discrete helical strakes at the advice of the Indian Institute of Science, Bangalore, following their extensive testing of models in wind tunnel. For this chimney, a total number of 39 discrete strakes of size 1.8 m wide x 2.25 m high are provided above 92 m level along three start helices at a vertical spacing of 6.75 m, and displayed by 30^{o} in azimuth along each helix (Fig. 4). Each strake is designed for an enhanced wind pressure of 8 kN/sq.m which is equal to three times the design wind pressure at the maximum elevation. The strakes are in mild steel amounting to 32 t of fabrication, and are hot-dip galvanised and further treated with epoxy paint for durability against acid corrosion. In view of increased cross-sectional area presented to the wind by mounting strakes, the drag coefficient considered earlier in the along-wind calculation is enhanced by 25%, and this increase in wind pressure did not pose much of a problem in the design of the shell. Although strakes increase the wind moments in shell, there is very little doubt about their economical advantages over the thick sections resulting from designing for high values of cross-wind moments, particularly in large diameter chimneys as this chimney is.

AERO-DYNAMIC INTERFERENCE

The use of discrete helical strakes on chimneys is extended in situations where there is aero-dynamic interference. In large power stations, it is a common practice to locate two or more chimneys in a line, and modal studies (Ref. 4) have shown that vortex-induced lateral movements in such a case increase in the upstream chimney due to very strong interference effect on the downstream chimneys. The maximum increase in amplitude over that of an isolated chimney is when spacing of the chimneys is 5 times the chimney diameter, and the magnitude of this increase in amplitude is as much as 10 for 1 in 50 taper chimney, and about 5 for 1 in 40 taper (Fig. 5). The interference effect becomes negligible at spacings greater than 20 times the diameter. These studies which are carried out in a smooth flow at low Reynolds number of about 10^5, no doubt indicate an upper limit of lateral movements, but these movements would be relatively less in the transcritical Reynolds number greater than 10^6 realised in practice for most R.C. chimneys. For the given spacing and taper of identical chimneys, and for the magnification of the oscillatory load as found in Fig. 5, the area of each discrete strake can be worked out from the following Table (Ref. 5).

TABLE 1

Magnification of load as found in Fig. 5	Minimum area of one strake $\frac{\pi D_e^2}{4}$	Additional equivalent drag coefficient over the region of strakes
1.5	0.005	0.05
1.5 - 2.5	0.010	0.10
2.5 - 5	0.020	0.20
5 - 7.5	0.025	0.25

D_e = Chimney diameter at 5/6 height.

Fig. 6 shows two closely-spaced chimneys, 100 m high, at the Indian Petro-Chemicals Limited, Jawaharnagar (India), (Engineers: Engineers India Limited, Contractor : Gammon India Limited), where discrete helical strakes in mild steel are mounted on the reinforced concrete shell at top elevation to suppress vortex shedding due to aero-dynamic interference.

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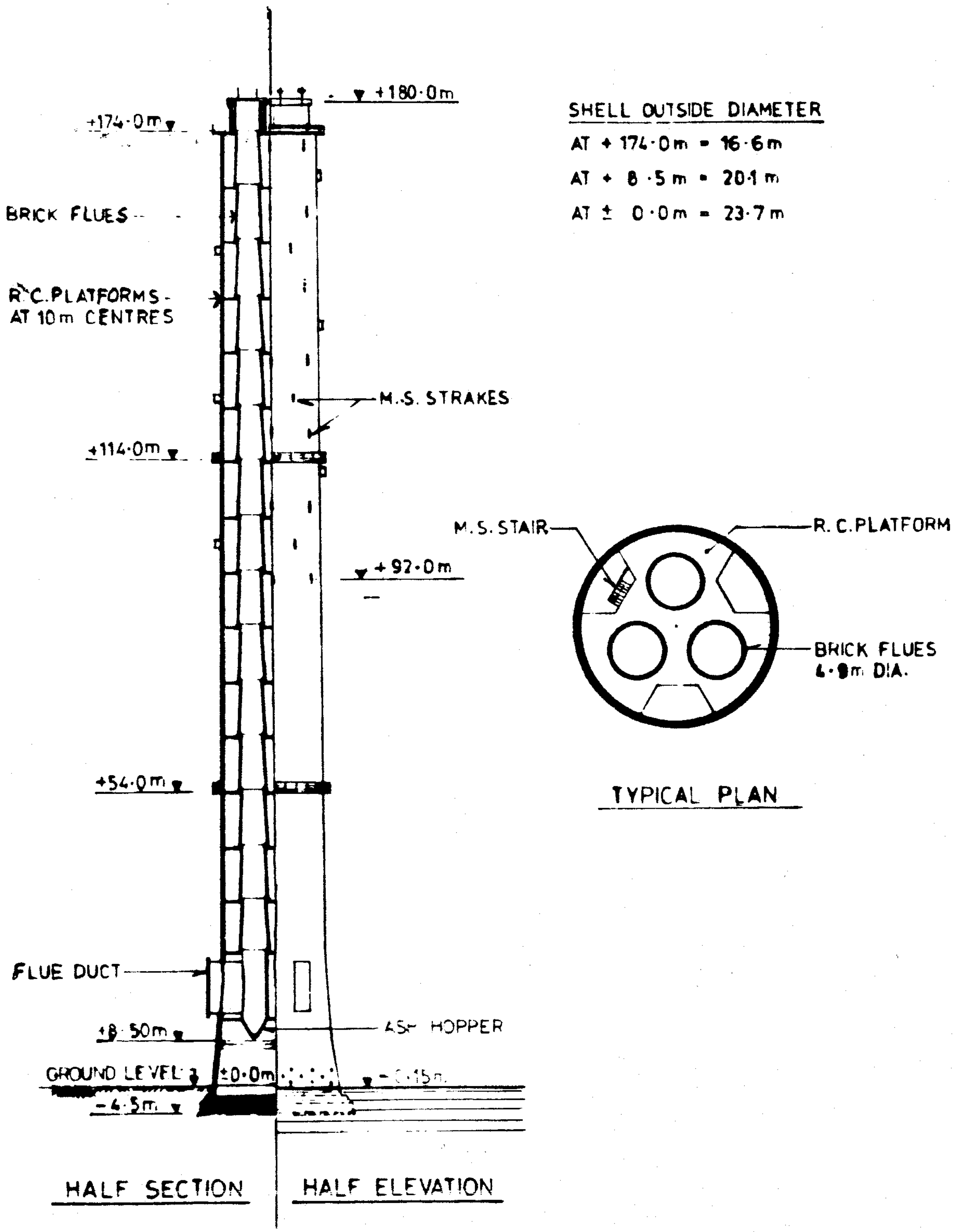

FIG. 1 : GENERAL ARRANGEMENT

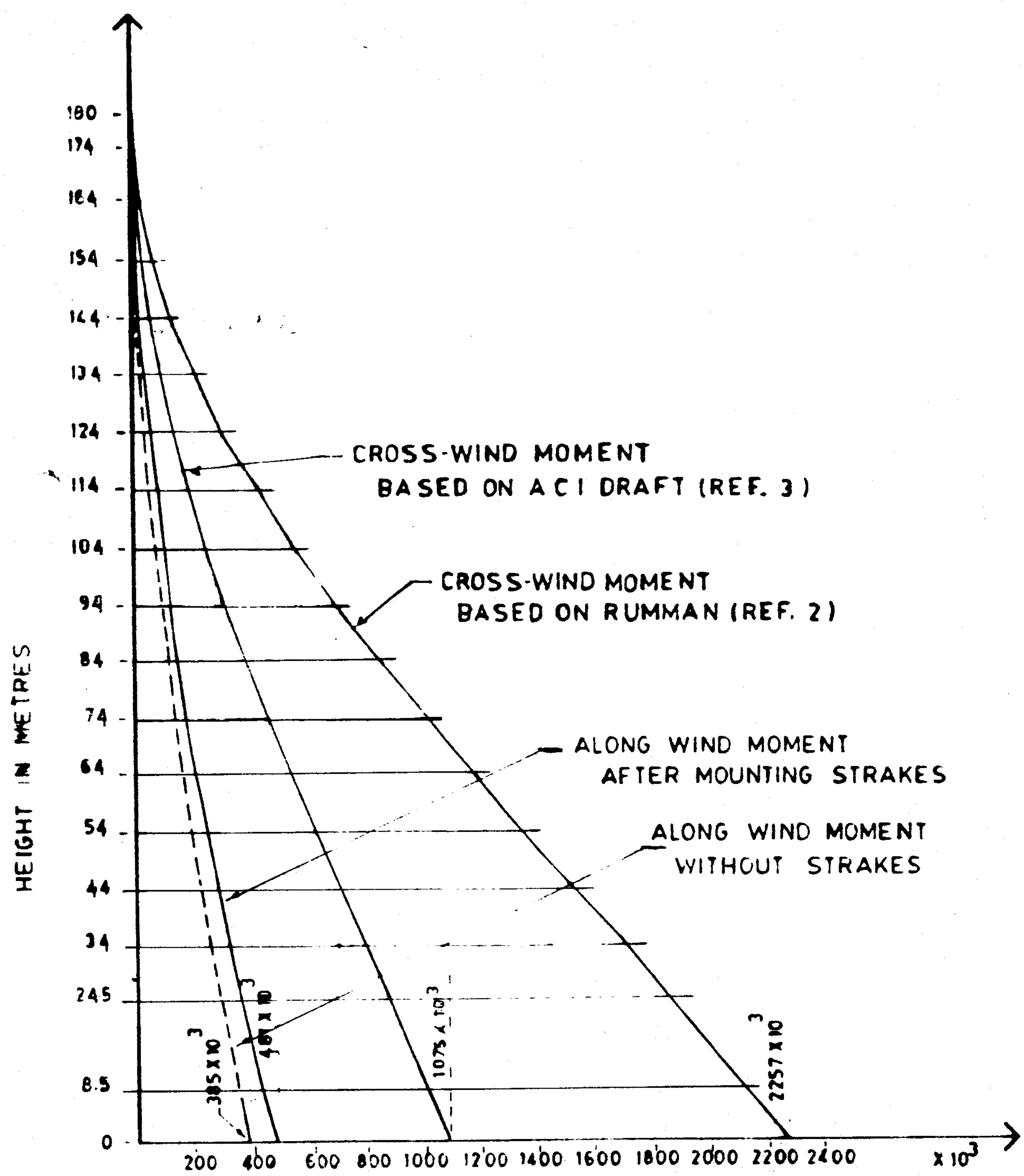

FIG 2 : BENDING MOMENT IN SHELL IN kNM

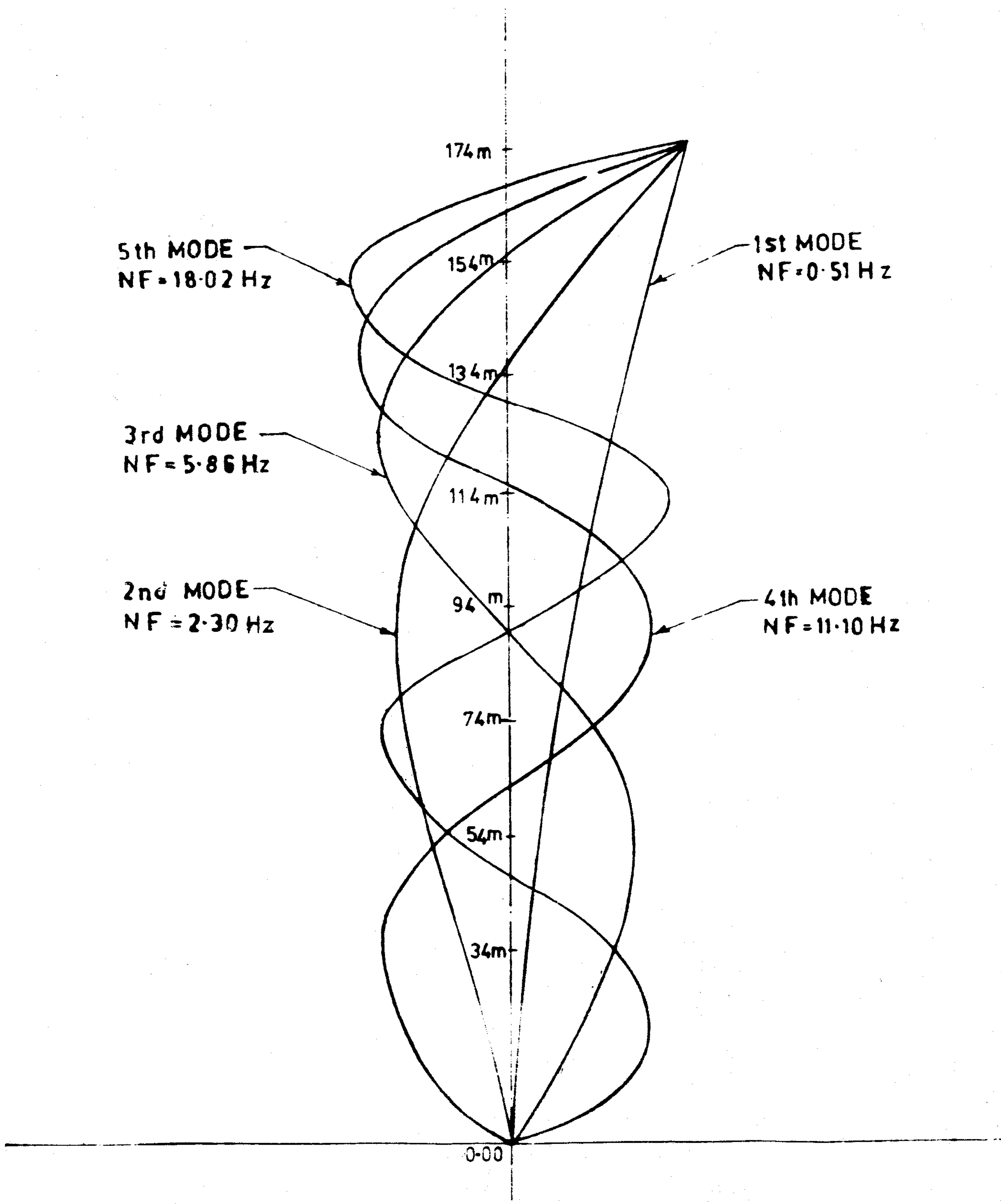

FIG. 3. MODE SHAPE AND NATURAL FREQUENCY

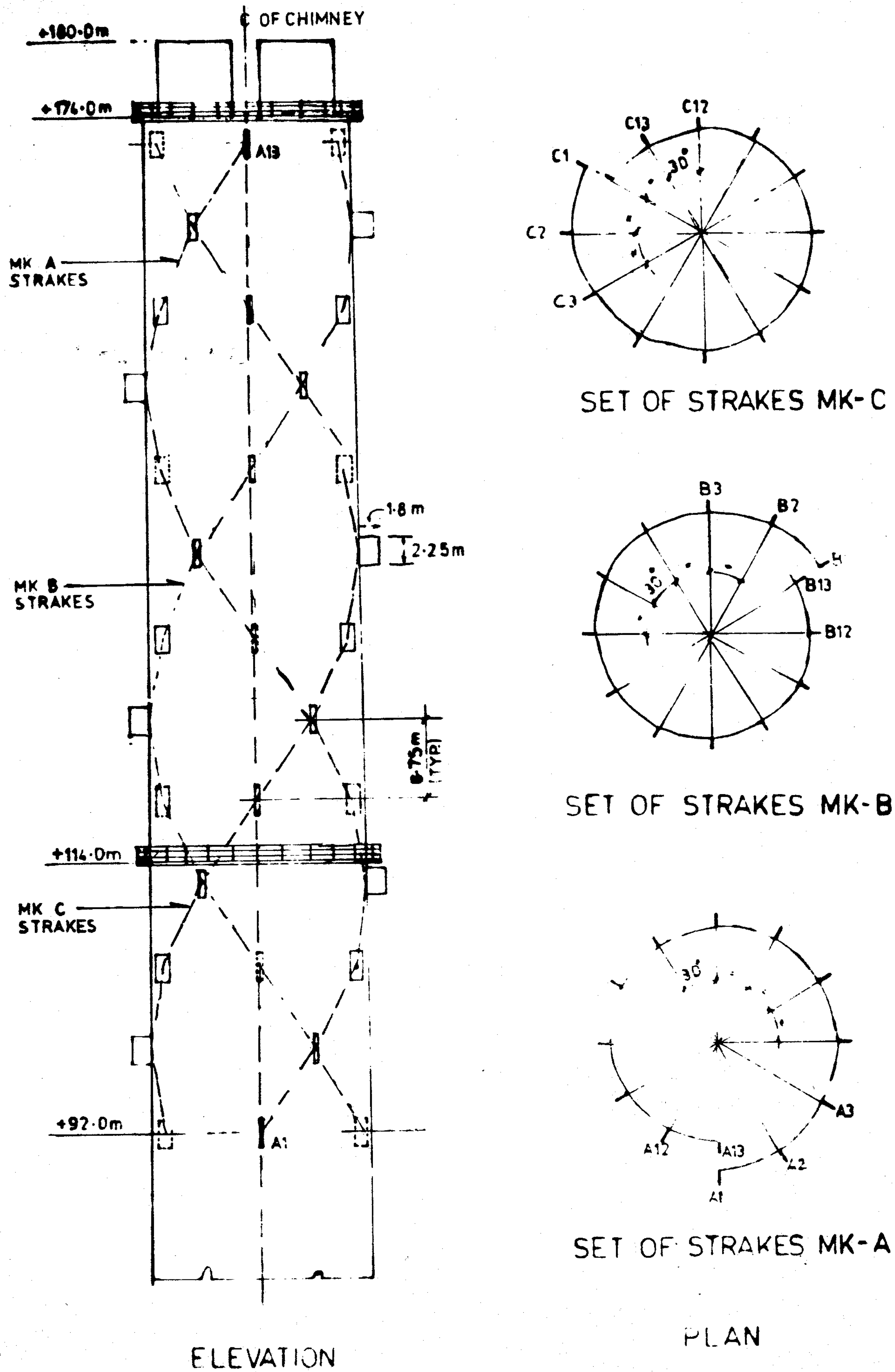

FIG. 4 : STRAKES ARRANGEMENT

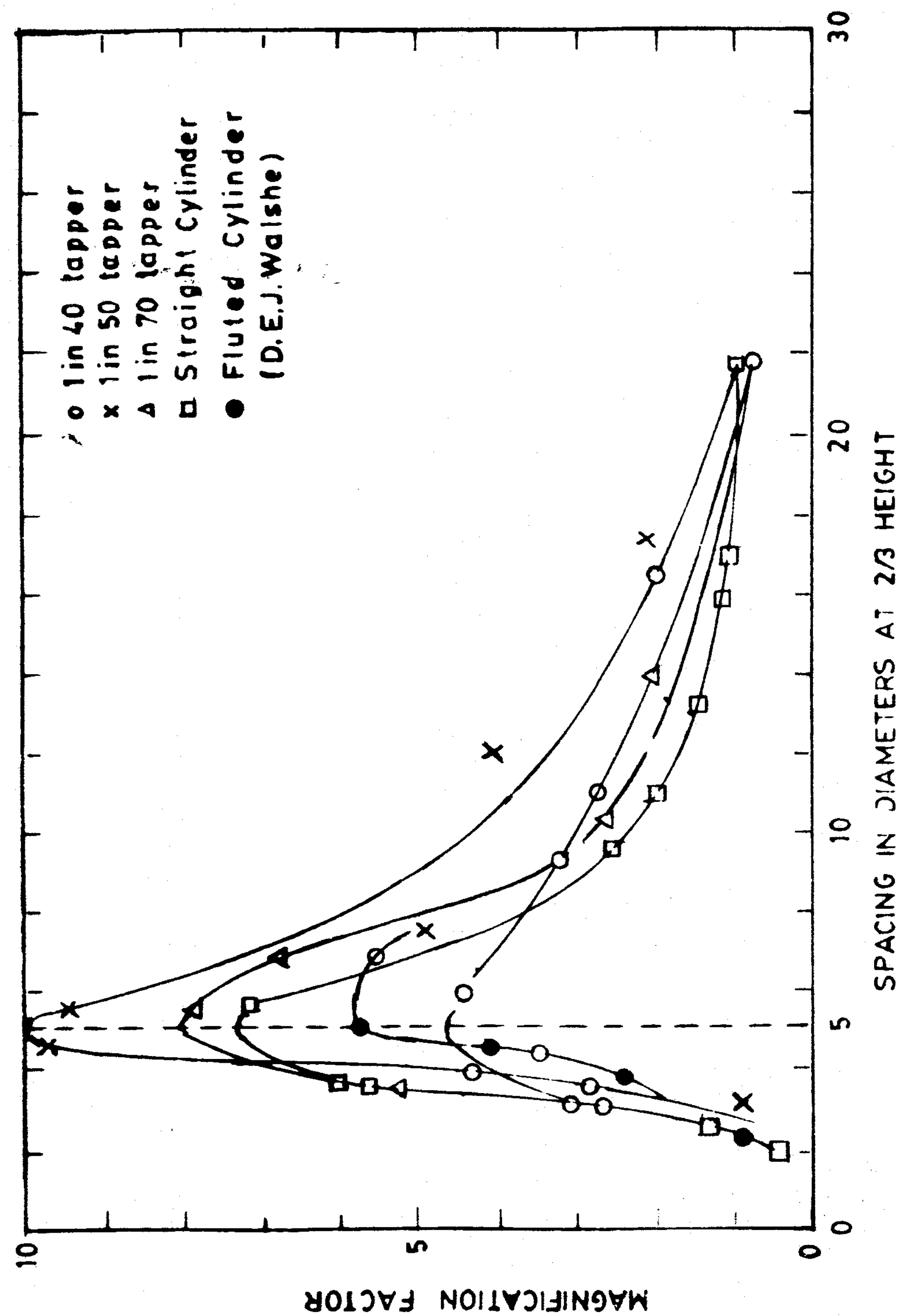

FIG.5: MAGNIFICATION FACTOR (REF. 4)

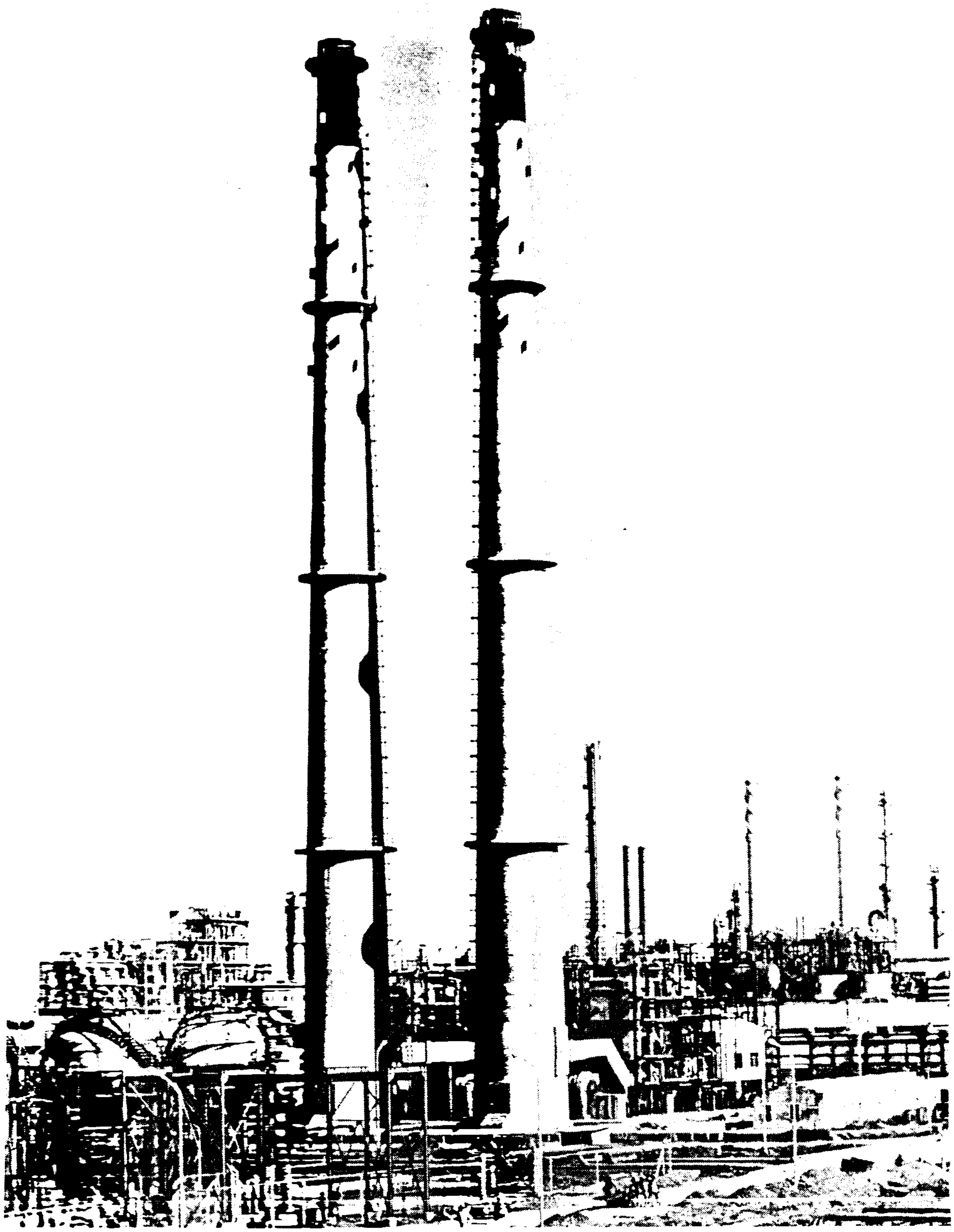

FIG. 6 : JAWAHARNAGAR CHIMNEYS