WIND LOAD DURING THE LIFE OF A STRUCTURE IN BANGKOK

by

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INTRODUCTION

As the number of tall buildings is increasing very rapidly in Bangkok, the wind loading effect is gaining importance and significance. This is due to the greater wind velocity at the higher level and the force varying in direct proportion with the square of the velocity. Thailand is highly centralised at Bangkok where most activities occur. The population density is getting higher everyday. This introduces land insufficiency and many high-rise buildings have to arise. These buildings are relatively slender and very sensitive to the wind load whose effect has to be seriously taken into account in the design of structures. In fact the more accurate consideration is required. This can be done through the structural dynamic analysis which will include the dynamic effect of the wind. In the analysis short time records are required and lack of these has led us to the simulation of the wind (PANNACHET,- 1975). However, in usual practice only static wind load is applied to the structures to avoid complication. In order to simplify the problem the pressure, according to the available codes of practice on wind forces, is assumed to be statically applied and acts normally to the surface.

The Bangkok Municipality Bylaw specifies that the wind pressures to be used on buildings in the analysis of structures are 100 kg/m^2 for the first two stories and 150 kg/m^2 for the above stories. This was introduced in 1940 and should be improved as technology has progressed through the years. It is, thus, the intention of the author to show a useful means of obtaining the design wind velocity from the available past extreme velocity record. The emphasis is on the return period of design velocity. This return period can always be converted from the design life of structure. Statistical analysis is introduced in the study to make it feasible.

PAST STUDY

The only existing study was made by PRAPAITRAKUL (1972). He obtained the available annual extreme velocity records of Don Muang Station and Sukhumvit Station and corrected them according to the terrains when the data were collected. Assuming the distribution of the corrected wind velocity data follow the normal distribution the velocity profiles were obtained with certain risks for the city and the outskirt area. The reference heights used were those of the anemometers at both stations. He selected 15 percents of the probability of occurrence for the calculation of the wind pressure adopting the formula recommended by Davenport (PRAPAITRAKUL, 1972). The results applied for the simple box type buildings only. These are shown in Fig. 1.

Though his means of obtaining the design wind velocity seems to be reasonable the results are not very realistic. Firstly, the correction of the velocity data according to the terrain was not systematically made and thus may introduce unrealistic results in some unknown ways. Secondly the probability of occurrence that he used applies only for one year and leads to unsafe results for the longer periods. It is, therefore, recommended that they should not be adopted in the structural analysis.

PROPOSED METHOD

Before proceeding some important theories should be discussed. These are the power-law and the extreme value theory. The procedure then follows.

Power-law

Wind velocity is known as varying with height above the ground. This variation is affected by many factors, such as pressure gradient, eddy viscosity, mass density of air, etc. but the most important factor is found to be the surface roughness of the ground. The height above which the surface frictional effect becomes negligible is called the gradient height. It varies according to the topography of the ground with a commonly accepted value of about 1000 feet.

Many formulas to relate the wind veloclty with the height above the ground have becn derived but the most efficient and simplest one is called the power-law. It was discovered by Archibald in 1885 as

$$\frac{V_1}{V_2} = \left(\frac{H_1}{H_2}\right)^p \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where V_1 = velocity at height H_1; V_2 = velocity at height H_2; and p = a parameter depending on topography, surrounding structures, temperature gradient, etc. However, the influence of the surface rounghness on the parameter is greatest and the values suggested by DAVENPORT (1960) are given in Table l. In this table the gradient height, H_G, is considered at the reference height and is related to p as in Fig. 2. Thus the above formula becomes

$$\frac{V}{V_G} = \left(\frac{H}{H_G}\right)^p \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

This equation is very useful in changing velocity at a height to the other at a different height. It also provides a very efficient method in correcting the velocity variation due to the changing terrain in the past since it is known that H_G and p vary with the terrain. Therefore the velocity on one terrain may be obtained from the record on the other terrain at the same location.

Extreme Value Theory

It has been established that the statistical distribution of the annual extreme wind velocities recorded over a number of years at a particular station can be represented by the following probability distribution function (DAVENPORT, 1960)

$$P(V) = e^{-e^{-y}} \qquad \ldots\ldots(3)$$

where $y = C(V-U)$; C = scale factor for the data (measuring its dispersion); and U = mode of the extreme value data.

The probability distribution function, $P(V)$, denotes the probability that the extreme velocity in any one year is less than V.

Eq. (3) can be rewritten in another form as

$$V = U - \frac{1}{C} \log_e(-\log_e P(V) \qquad \ldots\ldots(4)$$

THOM (1954) showed an easy way of finding $P(V)$ for each V by rearranging the set of n V's in ascending order and assigning, in that order, the value from 1 to n. Then, for the j^{th} velocity the corresponding $P(V)$ is

$$P(V) = j/(h+1) \qquad \ldots\ldots(5)$$

A straight line may, then, be fitted by the least square curve-fitting method and mode, U, and scale factor inverse ,1/C; are found

DAVENPORT (1961) expressed Eq. (4) in terms of return period, r, when r is large (r = 10 years) as

$$V = U + \frac{1}{C} \log_e(r) \qquad \text{...(6)}$$

Thus the velocity for any given return period may be easily obtained.

Also, DAVENPORT (1960) showed that if q is the risk we want to take within the life-time T of a structure, the return period can be related to q and T by

$$r = \frac{T}{q} \quad \text{when q is small} \qquad \text{................................(7)}$$

For instance, if T = 30 years and q = 15%

then r = 30/.15 = 200 years.

Procedure

A set of annual extreme velocity data has to be obtained for Bangkok. Since there are two meteorological stations, namely, Sukhumvit Road Station and Don Muang Airport Station, the better records Should be selected in case disagreement occurs. The heights of the anemometers are 18.8 m (61.7 feet) and 23 4 m (76.7) for Don Muang and Sukhumvit respectively. It was discovered by PANNACHET (1975) that both stations provided very similar records but if the annual extreme hourly velocity is used to judge for the betterment the Don Muang one should be adopted However, there is not much differencre here since the two extreme records agree very well. The annual extreme wind velocities at Don Muang (1959-1970) and Sukhumuit (1952-1971) are shown in Table 2, each with the corresponding p and H_G anticipated for correction according to the terrain when the reading was taken.

These annual extreme velocities are raised to the gradient height by employing the power–law with appropriate parameters. Having obtained the gradient velocities the extreme value theory is applied and this yields the gradient velocity for any desired return period. The power–law is then again used to convert this velocity to that at the required height with the power-law parameters for the required terrain. This final value is therefore the extreme velocity for a given return period at a given height on a given terrain.

Pressure - Velocity Relationship

There are several recommendations for determining the wind pressure. Most are based on conditions of open terrain, level country as a standard of reference. The influence or shielding, or of deflections and channelling due to the unusual topography or large obstructions shall be evaluated for each individual case.

PRAPAITRAKUL (1972) suggested the formula recommended by Davenport as the most suitable one to use with the available data the pressure on the surface of a structure is

$$q = C_g.C_s.C_a \quad 1/2\ \rho V^2 \quad \text{.......................}(8)$$

where C_g = gust coefficient depending on the size of the building; C_s = shape coefficient; C_a = amplification factor due to possible orographic or funnelling effects; ρ = air density; V = velocity.

For gust coeffcients, the values suggested by KHAN (1970) will be used in this study and these are given in Table 3. the values of shape coefficients given in the Swiss Code which are recommended by Davenport will be used. Again only sharp - edge structure is considered here and the appropriate shape coefficient is 1. 5 which is the value for extreme case of simple box type building. The standard air of 0.07651 lb/ou. ft., corresponding to 15°C at 760 mm. of mercury will be used in this study and the amplification coefficient will be neglected due to the fact that Bangkok Metropoliton Area is located on a very flat terrain.

For standard air and velocity expressed mile/hr, Eq. (7) can be rewritten as

$$q = 0.00256 \quad C_g.C_s.C_a \quad V^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Applying the values of C_s and C_a reads to

$$q = 0.00384 \quad C_g. \quad V^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots(10)$$

and

$$q = 0.00148 \quad C_g. \quad V^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

if V is in km/hr.

Eq. (11) can then be readily used to compute the wind Pressure on structures when velocity is known.

RESULTS, DISCUSSION, AND CONCLUSION

The gradient velocity-return period relationship is shown as the straight lines in Fig. 3. It can be clearly seen that the Don Muang result and the Sukhumvit result almost coincide and on significant difference occur at any stage. However only the Don Muang one is used in developing the pressure-height relationship for various common terrains and return periods.

Fig. 4.1 to Fig. 4.4 represesent the obtained final results for the four terrains between p = 1/3.5 and p = 1/6.5. The design pressure-height relationship can always be adopted in the static analysis of wind load on simple box type buildings. Each figure contains the four common return periods (100 to 400 years) which can be converted to the design life of structures for any desired risks by Eq. (7). Any other terrains with any other return periods can always be similarly attained.

Steps of constant pressure may be adopted according to engineeas' judgment.

It is considered that these design pressure-height relationships lead to conservative results since it is true that the terrain at one location changes from time to time, usually to a rougher one. If one can predict how the terrain will change during the life of a structure it may be useful to include a reduction factor. Otherwise it may be concluded that a safety factor has already been taken into account.

Refefences

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TABLE 1. TYPES OF TERRAIN GROUPED ACCORDING TO THEIR AERODYNAMIC ROUGHNESS (DAVENPORT, 1960)

Category	Description	P	H_G
1	Very smooth surfaces: e.g. large expanses of open water; low unsheltered islands; tidal flats; low-lands verging on the sea	$\frac{1}{8.5}$	800
2	Level surfaces with only low, surface obstructions: e.g. prairic grassland; desert; arctic tundra	$\frac{1}{7.5}$	900
3	Level, or slightly rolling surfaces, with slightly larger surface obstruction; e.g. farmland with very scattered trees and buildings, without hedgerows or other barriers; wasteland with low brush or surface vegetation; moorland	$\frac{1}{6.5}$	1,000
4	Gently rolling, or level country with low obstruction and barriers; e.g. open fields with walls and hedges scattered trees and buildings	$\frac{1}{5.5}$	1,100
5	Rolling or level surface broken by more numerous obstructions of various sizes; e.g. farmland, with small fields and dense gedges or barriers; scattered windbreaks of trees, scattered two-story buildings	$\frac{1}{4.5}$	1,200
6	Rolling or level surface uniformly covered with numerous large obstructions; c.g. forest, scrub trecs, parkland	$\frac{1}{3.5}$	1,350
7	Very broken surface with large obstructions: e.g. towns; suburbs; outskirts of large cities; farmland with numerous woods and copses and large windbreaks of tall trees	$\frac{1}{3}$	1,500
8	Surfacs broken by extremely large obstructions: e.g. center of large city	$\frac{1}{2.5}$ $\frac{1}{1.5}$	1,800

Table 2 - Annual Extreme Wind Velocity Data

Year	Don. Muang			Sukhumvit		
	Extreme Vel.(km/hr)	P	H_G (feet)	Extreme Vel.(km/hr)	P	H_G (feet)
1952	—	—	—	102.4	.145	955
53	—	—	—	82.4	.148	970
54	—	—	—	74.2	.151	985
55	—	—	—	80.0	.155	1000
56	—	—	—	84.0	.158	1015
57	—	—	—	94.0	.162	1030
58	—	—	—	81.0	.166	1045
59	96.2	.155	1002	95.7	.170	1060
60	68.5	.157	1009	74.2	.175	1075
61	88.8	.159	1016	88.5	.180	1090
62	96.2	.161	1023	96.4	.185	1105
63	75.9	.163	1030	77.8	.190	1120
64	79.6	.165	1037	74.1	.195	1135
65	81.4	.166	1044	76.0	.200	1150
66	85.1	.168	1051	74.1	.205	1165
67	83.3	.170	1058	77.8	.211	1180
68	79.6	.173	1065	68.6	.217	1195
69	83.3	.175	1072	65.9	.223	1210
70	85.1	.177	1079	76.1	.229	1225
71	—	—	—	60.8	.235	1240

TABLE 3 – Gust Coefficients at Different Height

Elvation (feet)	C_g
30	1.69
60	1.59
90	1.55
120	1.51
180	1.46
240	1.42
300	1.38

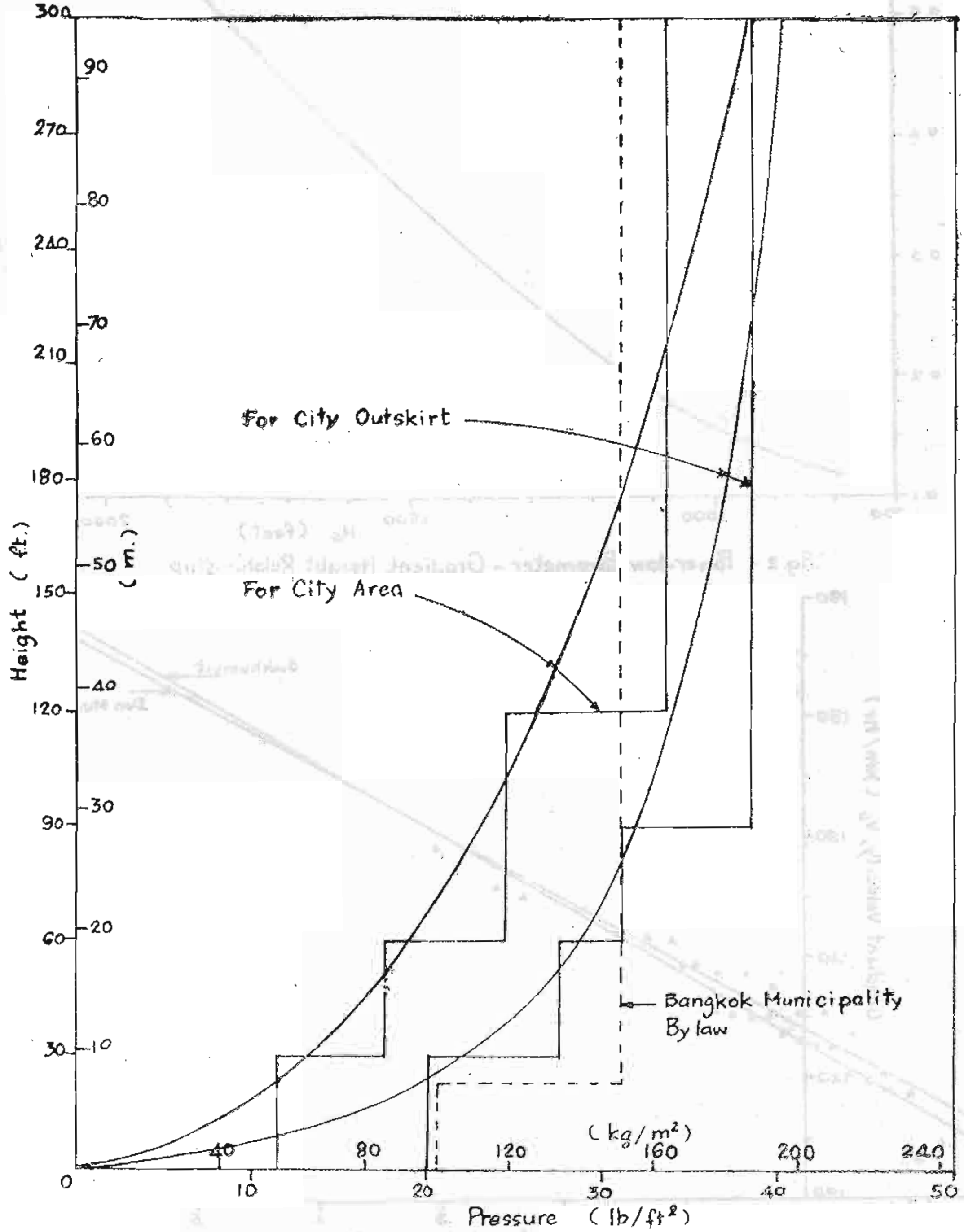

Fig. 1 - Recommended Wind Pressure for Design of Buildings in Bangkok Metropolitan Area (PRAPAITRAKUL, 1972)

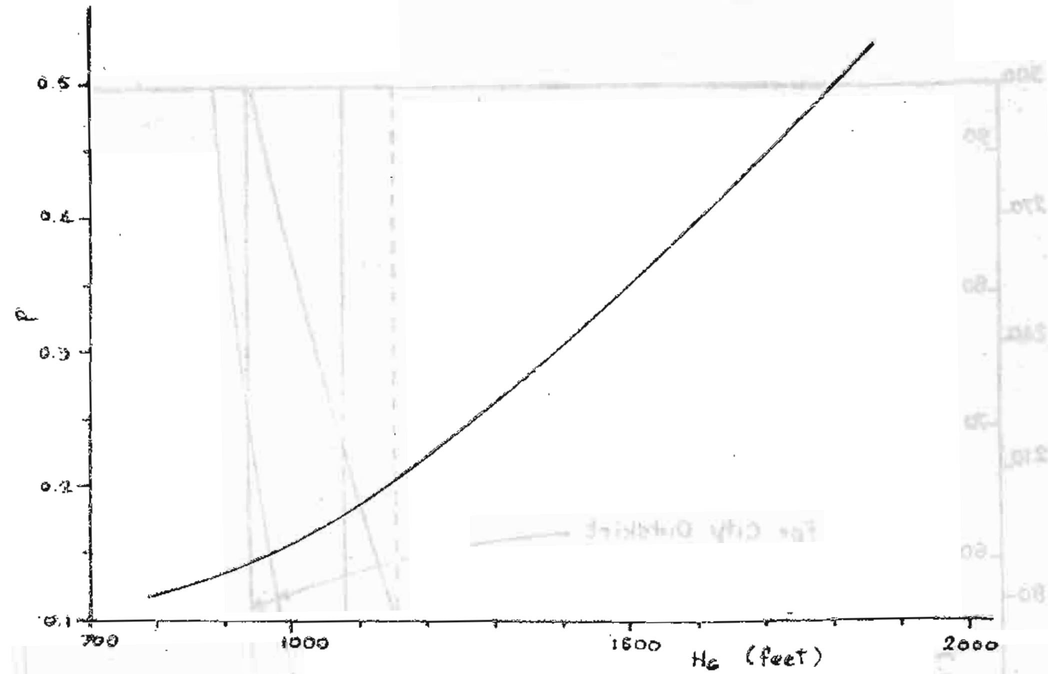

Fig. 2 - Power-law Parameter - Gradient Height Relationship

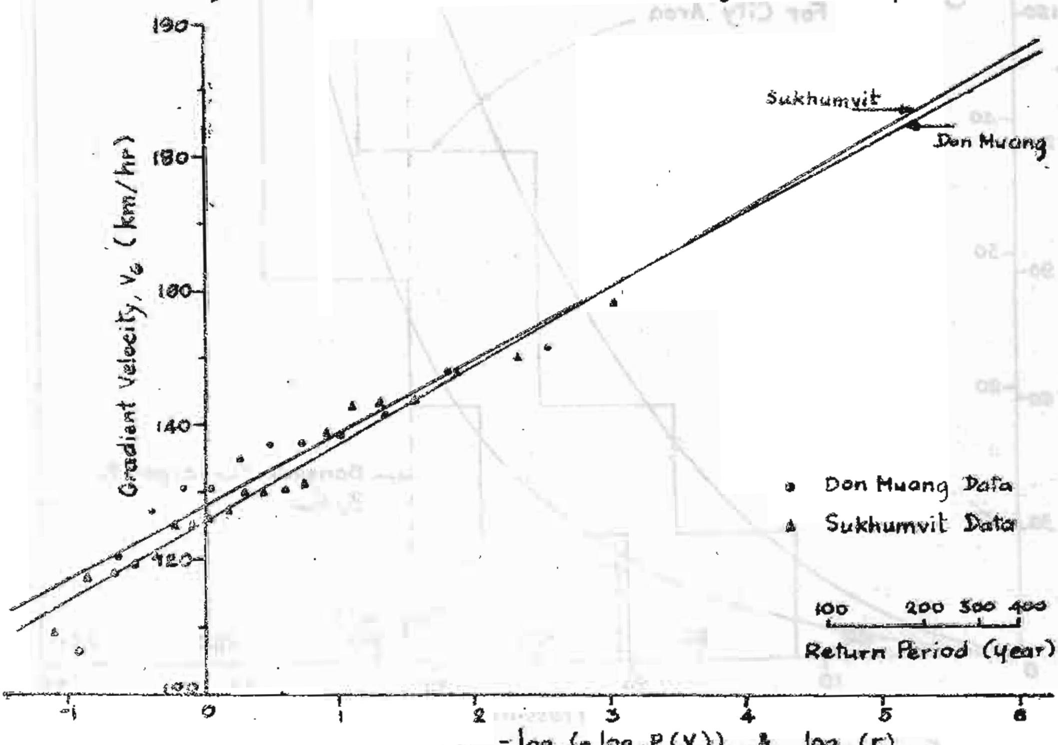

Fig. 3 - Equation $V_G = U - \frac{1}{C}\log_e(-\log_e P(V))$ and $V_G = U + \frac{1}{C}\log_e(r)$

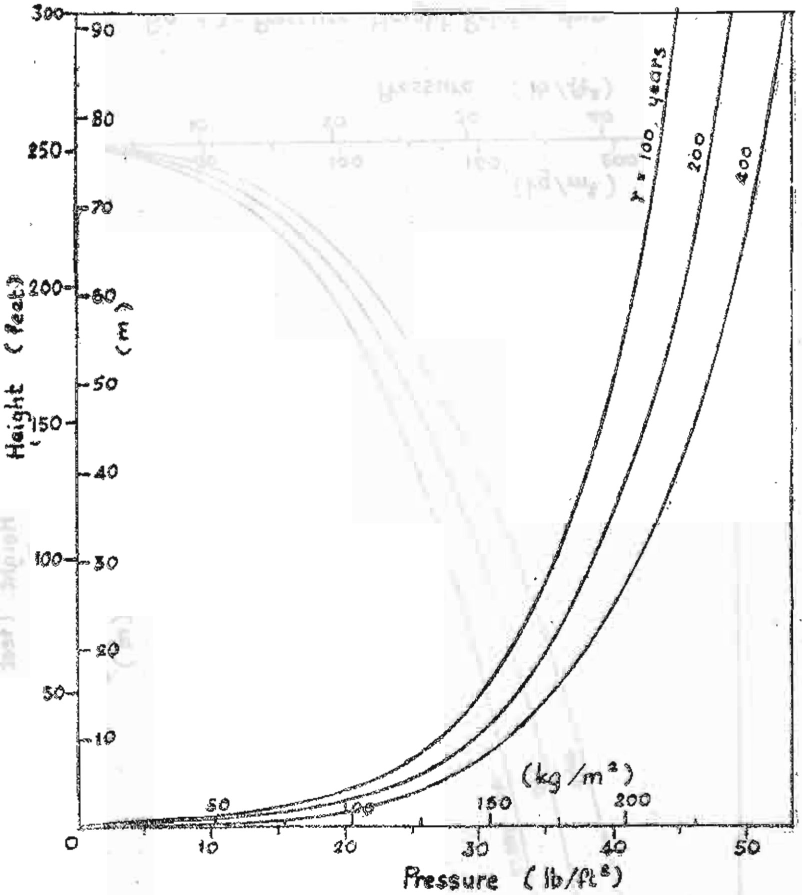

Fig. 4.1 - Pressure-Height Relationship
(p = 1/6.5 , H_G = 1000 ft.)

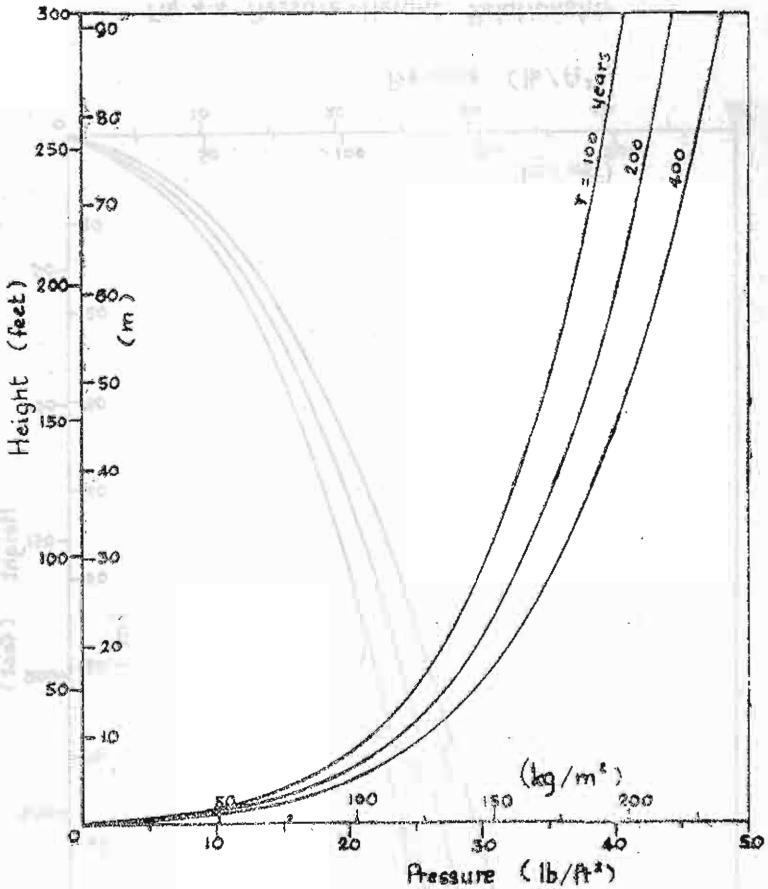

Fig. 4.2 - Pressure - Height Relationship
(p = 1/5.5 , H_G = 1100 ft.)

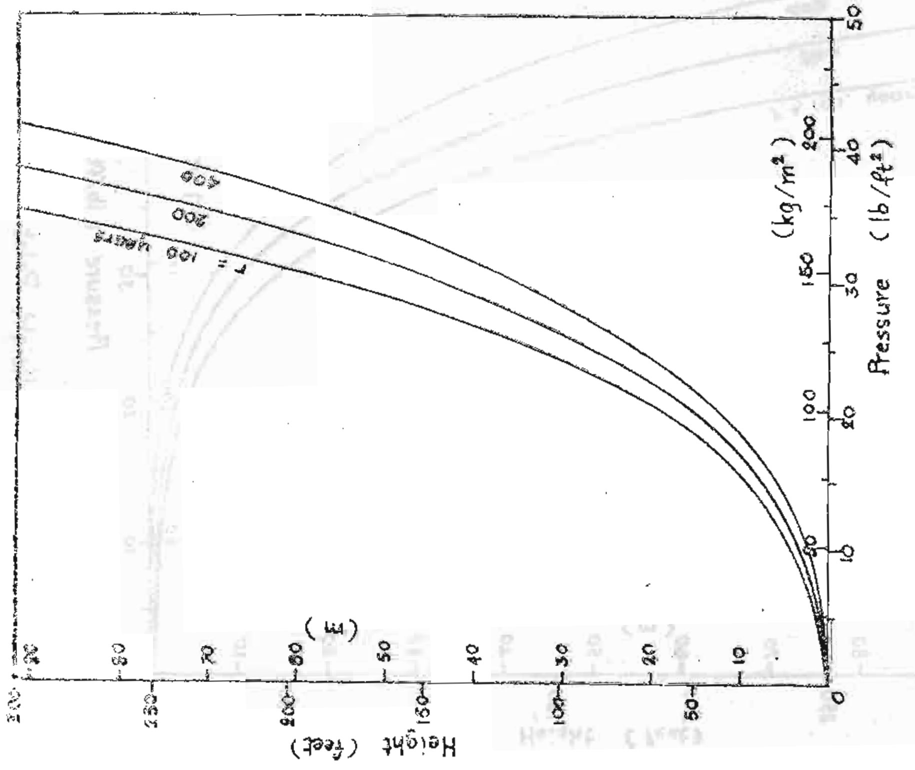

Fig 4.3 – Pressure - Height Relationship

($p = 1/4.5$, $H_G = 1200$ ft.)

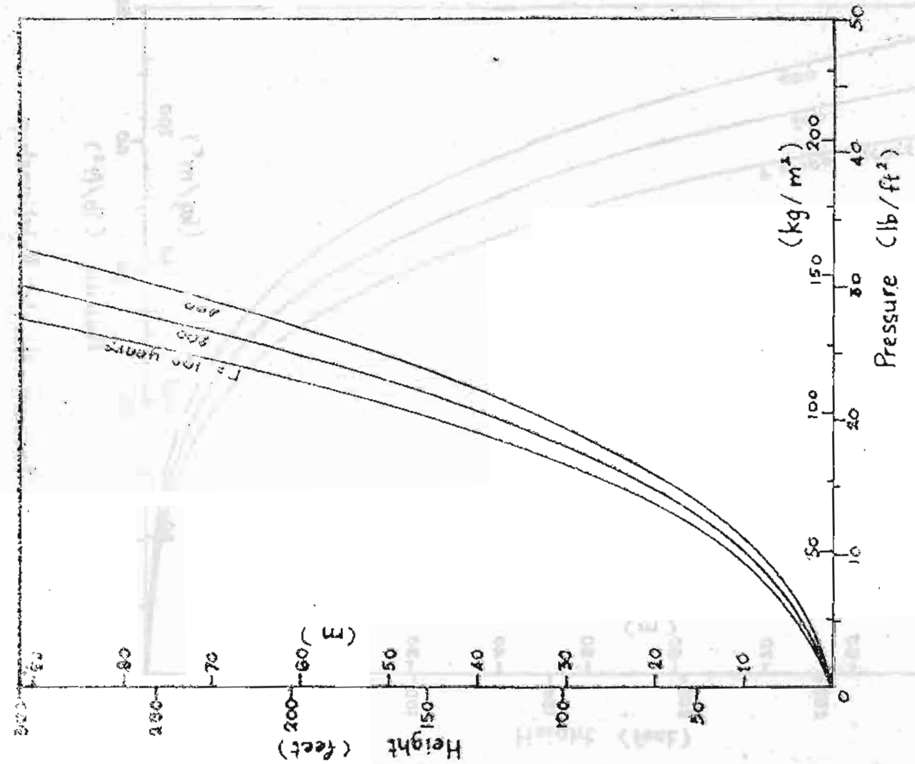

Fig. 4.4 – Pressure - Height Relationship

($p = 1/3.6$, $H_G = 1350$ ft.)