THE EFFECT OF BLAST LOADING ON A GUY CABLE

by

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III. LIST OF SYMBOLS

P	cable tension, lb.
P_0	initial cable tension, lb.
ρ	cable mass per unit volume, slugs/ft^3
A	cross-section area of cable, ft^2
L	cable length, ft.
$q(t)$	dynamic pressure, lb/in^2, as function of time
q	maximum dynamic pressure, lb/in^2
t_+	duration of positive phase of blast wave
K	shape factor (drag coefficient)
d	cable diameter, ft.
t	time
t_r	rise time (time for dynamic pressure to reach its maximum)
I	impulse, lb-sec
$q(x,t)$	effective force per unit length of cable
ξ	dummy variable
α	angle cable makes with horizontal
W	bomb yield in kilotons
X_n	function of x only
T_n	function of t only
T_n	function of t only
X_n''	$\frac{d^2X_n}{dx^2}$

$\ddot{T}_n$ $\frac{dT_n}{dt^2}$

A_n, B_n, C_n, D_n ordered constants resulting from solution of differential equations.

H_n, d_n, f_n, h_n ordered constants resulting from integration of Duhamel's integral.

m_n ordered, dimensionless parameter

δ elongation of the cable

$p(t)$ overpressure, lb/in^2, as a function of time

p_m maximum overpressure, lb/in^2

IV. LIST OF TABLES AND FIGURES

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V. INTRODUCTION

The purpose of this thesis is to find some effects, such as tension and deflection, of a guy cable under an air blast loading resulting from a nuclear explosion. The document "The Effects of Nuclear Weapons", (ENW)(1) prepared by the Department of Defense and published by the Atomic Energy Commission, covers in considerable detail air blast and ground shock and constitutes a main source of information for this thesis.

In 1963, Mr. Donald Arthur Ball who was a graduate student in Engineering Mechanics, Virginia Polytechnic Institute, wrote a thesis entitled "Effects of Nuclear Blasts on Guy Cables"(2) for his master's degree in Engineering Mechanics. In his thesis, he dealt with the cables of a TV Tower under a nuclear blast. Due to the fact that he considered the tension in the cables to be always constant, the result which he obtained under that assumption did not appear reasonable. Now, this thesis just follows all the data which he used, but considers the tension to be variable. By so doing, the author hopes to obtain a better and more reasonable result than that obtained by Mr. D. A. Ball.

In the past few years, increased emphasis has been placed on the design of structures to resist blast loading. It would be highly desirable that certain types of structures be able to withstand the effects of a nuclear blast, among these being guyed television and radio towers. There are two main destructive phenomena associated with a nuclear blast; the first being an overpressure, or an increase in the ambient atmospheric pressure, and the second being a dynamic pressure, or drag force, caused by the mass flow of air behind the shock front. Structures such as buildings with little or no window area would be particularly susceptible to overpressures, since a large pressure differential would develop between the inside and outside of its walls. Conversely, guyed cables would hardly be affected by a moderate overpressure, but would definitely be affected by the drag force. Hence, only the effects of the dynamic pressure will be considered in this analysis.

VI. REVIEW OF LITERATURE

All data concerning the blast loading and nuclear blast effects was extracted from "The Effects of Nuclear Weapons", published by the United States Atomic Energy Commission[1], "Blast Loading on Structures", an ASCE paper by H. L. Murphy[3], and "Blast Phenomena From a Nuclear Burst", an ASCE paper by Ferd E. Anderson, Jr.[4].

The cable specifications were obtained from the design drawing of a 1,500 feet tower prepared by the Dresser-Ideco Company[5]. This tower was designed in accordance with ETA-RS-222 specifications[6].

Some example data considering tension in the cable to be constant was obtained from "Effects of Nuclear Blasts on Guy Cables" by Donald Arthur Ball[2].

VII. BLAST LOADING

As stated previously in the introduction, the only blast loading which will be considered in this analysis is that of the dynamic pressure. The dynamic pressure will rise almost instantaneously to its maximum value when the shock front arrives, and then it will decay, as shown in Figure 1. after the shock front has passed. The empirical equation used to describe the decay should give fair accuracy for dynamic pressures of less than 20 psi.

In order to get a fair representation of the loading caused by the dynamic pressure, an impulse, $I = qt_r =$ constant as $t_r \rightarrow 0$, will be superimposed on the function shown in Figure 1. This impulse is shown in Figure 2. The feasibility of using this impulse is exemplified by the fact that for a 1 megaton bomb the rise time, t_r, is 30 to 50 micro-seconds[4], while the duration of the positive phase of the blast, t_+, is 3 to 7 seconds.

The values of q and t_+ will depend on many parameters, such as height of burst, bomb yield, and distance from ground zero. Values of these quantities are given in Figures 5. and 6. for a 1 kiloton bomb. These values are sufficient for any bomb yield since all parameters are expected to scale as the cube root of the yield.

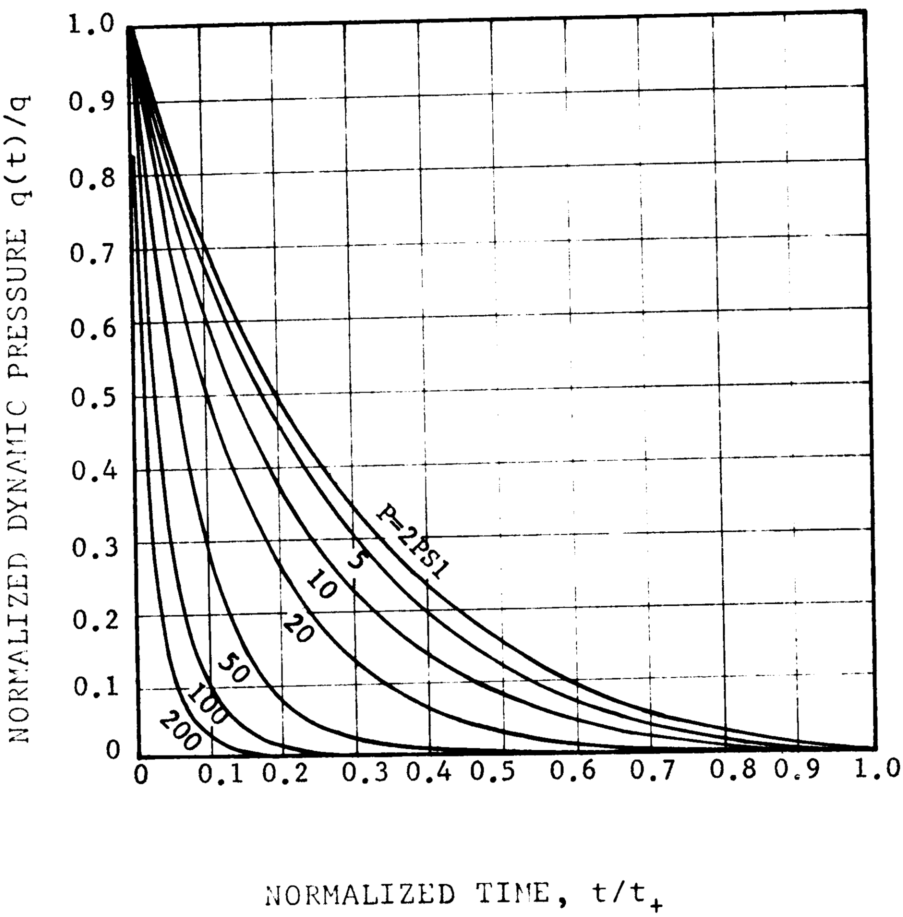

Figure 1. (Page 126, ENW) Rate of decay of dynamic pressure with time for various values of the peak overpressure.

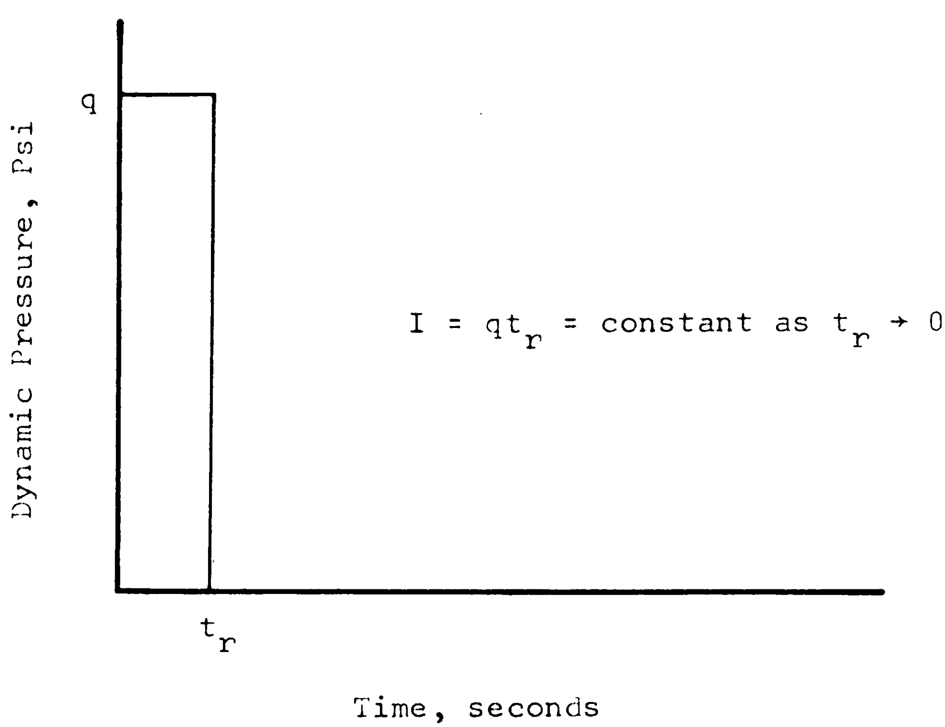

Figure 2. Square impulse used to represent almost instantaneous rise to maximum dynamic pressure.

VIII. DERIVATION OF GOVERNING EQUATION

Consider a parabolic cable of length L, making an angle α with the horizontal, and attached to a tower as shown in Figure 3. The dynamic pressure, q(t), approaching from the left is travelling at about the speed of sound, hence it will be assumed that it reaches the entire length of the cable simultaneously.

Choosing axes as shown in Figure 3., and considering an elemental length as shown in Figure 4., the differential equation for motion in the transverse direction is obtained as follows.

Assumptions:

1. constant density, ρ
2. constant cross-section, A
3. cable weight small compared to initial tension P_0
4. perfectly flexible

$$\Sigma F_x = 0$$

$$P \cos\theta - (P + dP)\cos(\theta + d\theta) = 0$$

or

$$\frac{\partial}{\partial x}(P \cos\theta) = 0 \quad \text{------------------------------} \quad (1)$$

Since

$$P = P(x,y,t)$$

so

$$P \cos\theta = f(y,t) + C$$

$$= F(y,t) \quad \text{------------------------------} \quad (2)$$

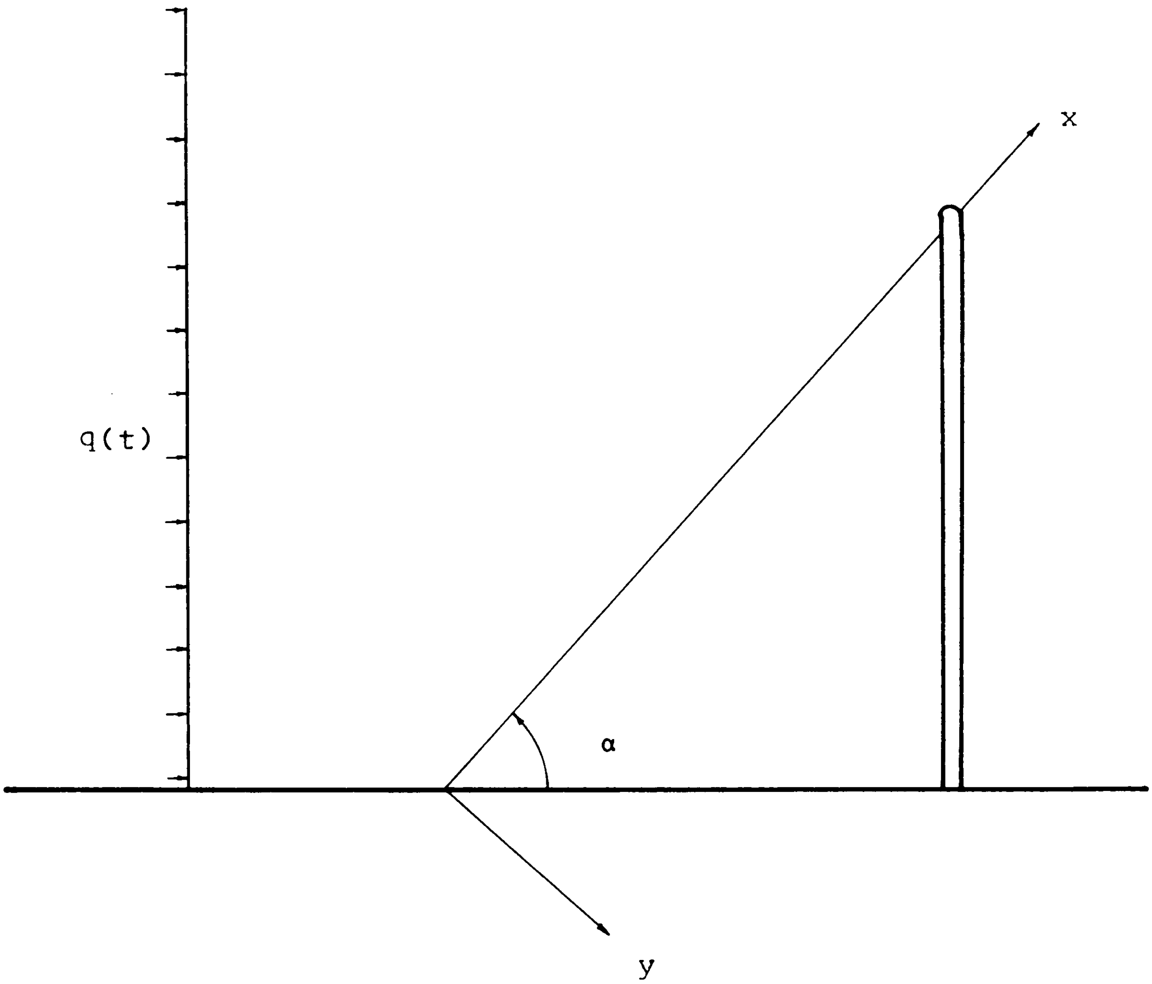

Figure 3. Sketch showing tower, cable, and approaching dynamic pressure.

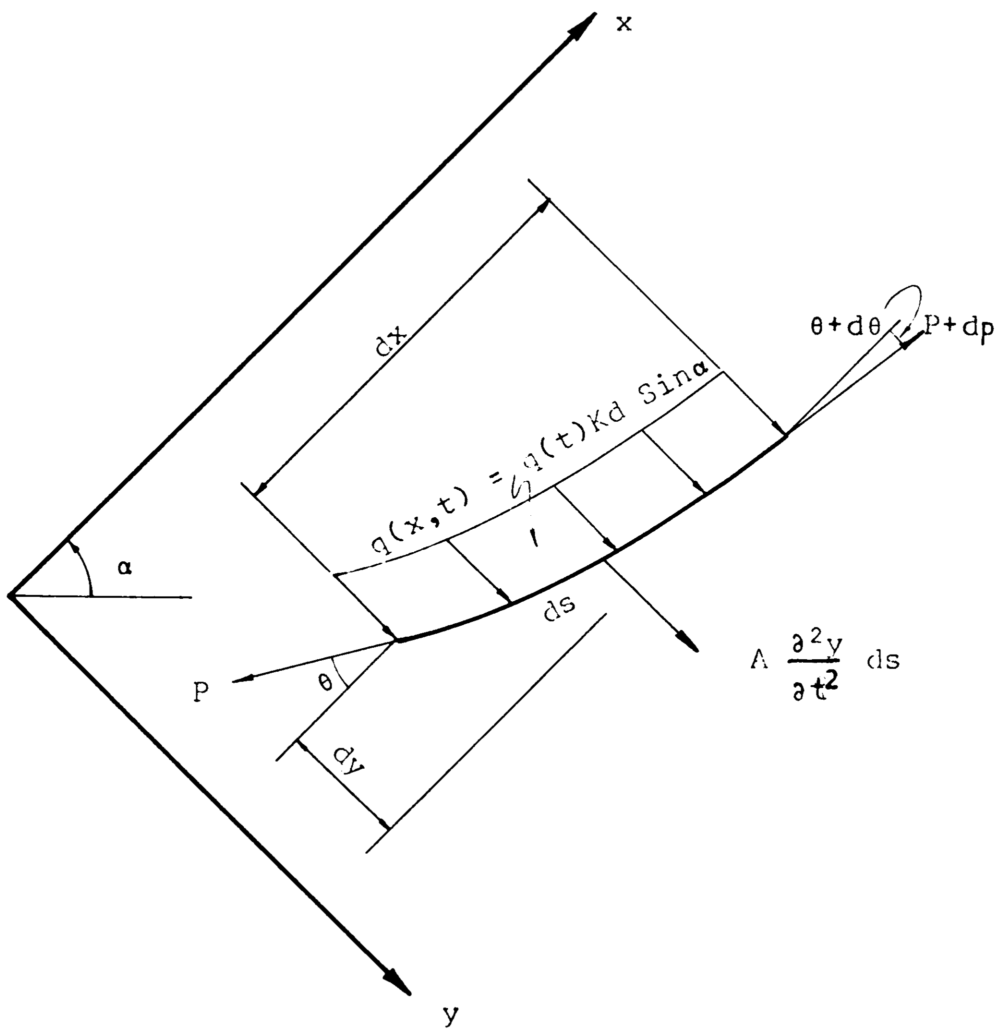

Figure 4. Elemental cable length showing forces acting in the transverse direction.

$$\Sigma F_y = ma_y$$

$$(P+dP)\text{Sin}(\theta+d\theta) - P\ \text{Sin}\theta + q(t)Kd\ \text{Sin}\alpha\ dx = \rho A \frac{\partial^2 y}{\partial t^2} ds$$

where K is an aerodynamic shape factor, or

$$\frac{\partial}{\partial x}(P\ \text{Sin}\theta) + q(x,t) = \rho A \frac{\partial^2 y}{\partial t^2}\frac{ds}{dx}$$

or

$$\frac{\partial}{\partial x}(P\ \text{Cos}\theta\ \tan\theta) + q(x,t) = \rho A \frac{\partial^2 y}{\partial t^2}\frac{ds}{dx} \quad \text{--------} \quad (3)$$

substituting eq. (2) into eq. (3), results in the following,

$$F(y,t)\frac{\partial^2 y}{\partial x^2} + q(x,t) = \rho A \frac{\partial^2 y}{\partial t^2}\frac{ds}{dx} \quad \text{--------------} \quad (4)$$

But

$$d\delta = ds - dx = \frac{P-P_0}{AE} dx$$

or

$$P = AE\left(\frac{ds}{dx} - 1\right) + P_0 \quad \text{--------------------------} \quad (5)$$

substituting eq. (5) into eq. (2), the following results,

$$F(y,t) = AE\left(1 - \frac{dx}{ds}\right) + P_0\frac{dx}{ds} \quad \text{------------------} \quad (6)$$

substituting eq. (6) into eq. (4),

$$(P_0 - AE)\frac{\partial^2 y}{\partial x^2}\left(\frac{dx}{ds}\right)^2 + \left[AE\frac{\partial^2 y}{\partial x^2} + q(x,t)\right]\left(\frac{dx}{ds}\right) = \rho A \frac{\partial^2 y}{\partial t^2}$$

$$\text{------------------} \quad (7)$$

writing in the series form,

$$\frac{dx}{ds} = [1 + (\frac{dy}{dx})^2]^{-1/2}$$

$$= 1 - \frac{1}{2}(\frac{dy}{dx})^2 + \frac{3}{8}(\frac{dy}{dx})^4 - \frac{5}{16}(\frac{dy}{dx})^6 + \text{-------------}$$

$$(\frac{dx}{ds})^2 = [1 + (\frac{dy}{dx})^2]^{-1}$$

$$= 1 - (\frac{dy}{dx})^2 + (\frac{dy}{dx})^4 - (\frac{dy}{dx})^6 + \text{-------------}$$

Since $(\frac{dy}{dx})^2$ is small, substituting the first and second terms of $\frac{dx}{ds}$ and $(\frac{dx}{ds})^2$ back into eq. (7), the following is obtained,

$$P_0 \frac{\partial^2 y}{\partial x^2} - [(P_0 - \frac{1}{2}AE)\frac{\partial^2 y}{\partial x^2} + \frac{1}{2}q(x,t)](\frac{\partial y}{\partial x})^2 + q(x,t)$$

$$= \rho A \frac{\partial^2 y}{\partial t^2} \text{ ------------------------------ } (8)$$

Equation (8) is the governing equation for this problem, but this non-linear partial differential equation is very difficult to solve.

Comparing the above equation with that obtained by D. A. Ball[2], i.e.,

$$P \frac{\partial^2 y}{\partial x^2} + q(x,t) = \rho A \frac{\partial^2 y}{\partial t^2} \text{ -------------------- } (10)$$

it is seen that equation (10) is the result of assuming $(dy/dx)^2$ in equation (8) to be negligible.

Equation (10) can only be used directly to detect cable deflections for small dynamic effects. Equation (8) could be used for large dynamic effects including a variable cable tension. However, the solution of this equation is not directly available. In this work, equation (10) will be used with a step variation in cable tension, examining the cable movement for small time increments. It will be assumed that the angle α between the cable and velocity vector remains unchanged.

IX. SOLUTION TO DIFFERENTIAL EQUATION (10)

A. General Solution

Assume:

$$y(x,t) = \sum_{n=1}^{\infty} X_n(x)\ T_n(t)$$

$$q(x,t) = \sum_{n=1}^{\infty} X_n(x)\ T_n(t)$$

Substituting above into equation (10) and dividing by $\rho A T_n X_n$

$$\frac{P}{\rho A}\frac{X_n''}{X_n} + \frac{T_n}{\rho A T_n} - \frac{\ddot{T}_n}{T_n} = 0$$

and since the variables are separated, the equation can be written as

$$\frac{P}{\rho A}\frac{X_n''}{X_n} = \frac{\ddot{T}_n}{T_n} - \frac{T_n}{\rho A T_n} = -P_n^2$$

where P_n is an ordered constant. The resulting two ordinary differential equations are:

$$X_n'' + \frac{\rho A}{P} P_n^2 X_n = 0 \qquad \text{(11)}$$

and

$$\ddot{T}_n + P_n^2 T_n = \frac{T_n}{\rho A} \qquad \text{(12)}$$

The solution to equation (11) is

$$X_n = A_n \operatorname{Cos} \frac{m_n}{L}x + B_n \operatorname{Sin} \frac{m_n}{L}x \qquad \text{(13)}$$

where

$$\frac{\rho A}{P} P_n^2 = \frac{m_n^2}{L^2}$$

The solution to equation (12) can be obtained by the use of Laplace transforms or by the use of step functions. The complete solution of T_n is

$$T_n = C_n \operatorname{Sin} P_n t + D_n \operatorname{Cos} P_n t$$

$$+ \frac{1}{P_n \rho A} \int_0^t \operatorname{Sin} P_n(t - \xi) T_n(\xi) d\xi \quad \text{-----} \quad (14)$$

The third term in equation (14) is known as Duhamel's integral.

The function T_n is obtained from the theory of Fourier expansion. Hence, for normal modes,

$$T_n = \frac{\int_0^L q(x,t)\, X_n(x)\, dx}{\int_0^L [X_n(x)]^2\, dx} \quad \text{------------------} \quad (15)$$

B. Particular Solution

This solution will be obtained by assuming that the cable is simply supported at both ends. This gives rise to the following boundary conditions,

$$y(0,t) = y(L,t) = 0$$

which implies

$$X_n(0) = X_n(L) = 0$$

Applying the first condition to equation (13)

$$X_n(0) = A_n = 0$$

and from the second condition

$$X_n(L) = B_n \operatorname{Sin} m_n = 0$$

which gives rise to the frequency equation

$$m_n = n\pi$$

The eigenfunctions will be

$$X_n = B_n \operatorname{Sin} \frac{n\pi x}{L} \qquad n = 1,2,3 \ldots$$

from equation (15),

$$T_n = \frac{\int_0^L q(x,t) \operatorname{Sin} \frac{n\pi x}{L} dx}{\int_0^L \operatorname{Sin}^2 \frac{n\pi x}{L} dx} \cdot \frac{1}{B_n}$$

$$= \frac{4q(x,t)}{n\pi} \cdot \frac{1}{B_n} \qquad n = 1,3,5 \ldots$$

The overpressure, p(t), behind the wave front at any time, t, can be expressed by the simple empirical equation in terms of the peak overpressure p_m and the time duration of the positive phase t_+, i.e.,

$$p(t) = p_m(1 - \frac{t}{t_+})e^{-t/t_+} \quad \text{------------------ (16)}$$

A similar empirical expression for the variation of the dynamic pressure with time behind the shock front is

$$q(t) = q(1 - \frac{t}{t_+})^2 e^{-2t/t_+} \quad \text{---------------- (17)}$$

where q(t) is the value of the dynamic pressure at any time, t, after the arrival of the shock front, and q is the peak dynamic pressure.

Equations (16) and (17) are plotted on non-dimensional axes in Figure 5.

An important blast damage parameter is the impulse which takes into account the duration of the positive phase and the variation of the dynamic pressure during that time. Impulse may be defined as the total area under the dynamic pressure-time curve, such as that shown in Figure 5, at a given location. The positive phase dynamic pressure impulse, I, (per unit area) may then be represented mathematically by

$$I = \int_0^{t_+} q(t)\, dt$$

$$= \int_0^{t_+} q\left(1 - \frac{t}{t_+}\right)^2 e^{-2t/t_+}\, dt$$

The positive phase overpressure impulse can be defined by a similar expression in which p(t) replaces q(t).

The function T_n will be the sum of Duhamel's integral from the impulse, T_n', and Duhamel's integral from the exponential function, T_n''.

$$T_n' = C_n \text{ Sin } P_n t + D_n \text{ Cos } P_n t$$

$$+ \lim_{t_r \to 0} \frac{4IKd \text{ Sin}\alpha}{B_n \rho A P_n n \pi t_r} \int_0^{t_r} \text{Sin}P_n(t-\xi)d\xi \quad (t \geq 0)$$

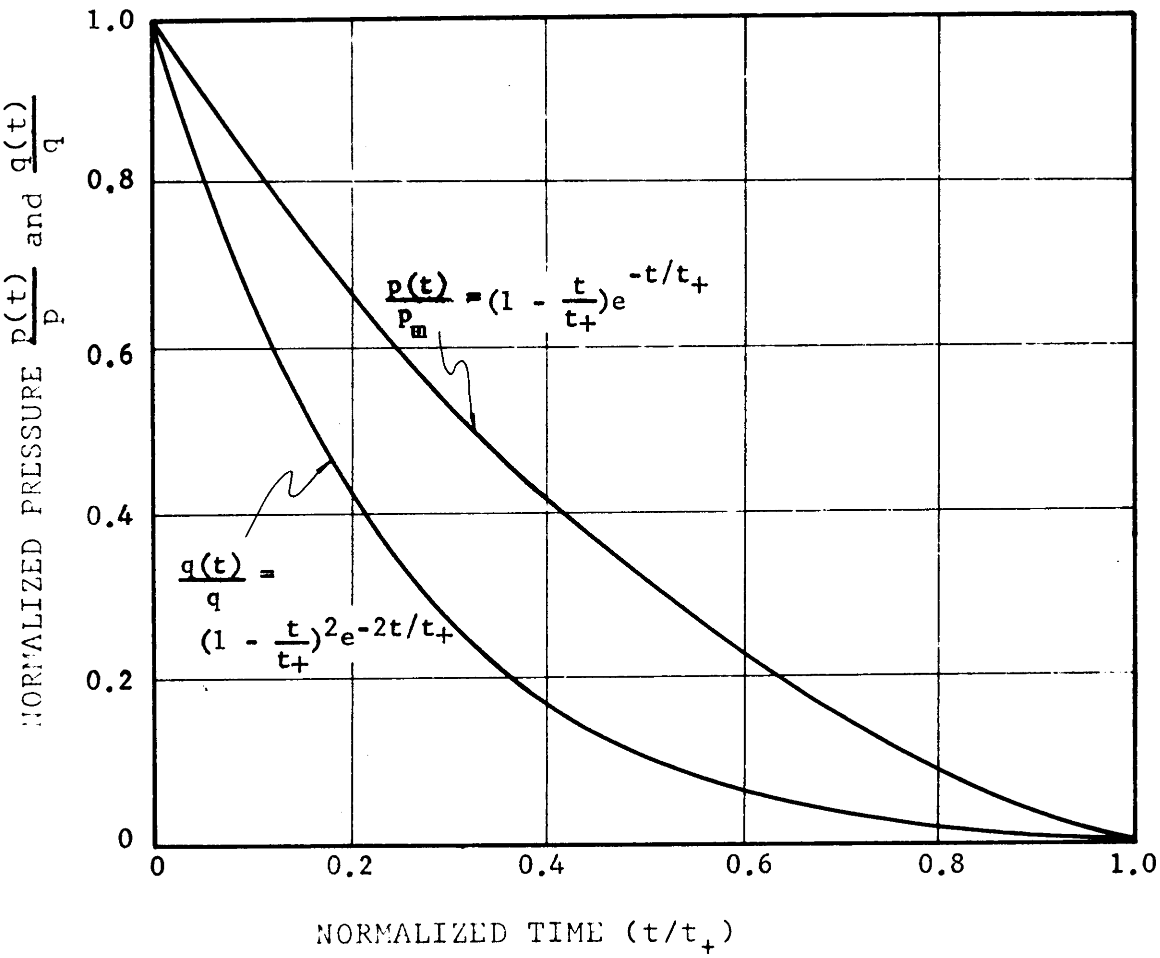

Figure 5. Normalized overpressure and dynamic pressure versus normalized time.

Integrating the expression for T_n' it results,

$$T_n' = C_n \operatorname{Sin} P_n t + D_n \operatorname{Cos} P_n t + \frac{4qt_r K d \operatorname{Sin}\alpha}{B_n \rho A n \pi P_n} \operatorname{Sin} P_n t \quad (t \geq 0)$$

When $T_n'(0) = \dot{T}_n'(0) = 0$ the constants C_n and D_n are zero, and only the third term which is left contributes something in the first time interval. In the example used later, the value of this term is very small, so it is neglected. The most important effect is T_n'', i.e.,

$$T_n'' = C_n \operatorname{Sin} P_n \xi + D_n \operatorname{Cos} P_n \xi$$

$$+ \frac{4qKd \operatorname{Sin}\alpha}{B_n \rho A P_n n\pi} \int_0^{\xi} \left(1 - \frac{\tau + t_i}{t_+}\right)^2 e^{-2(\tau+t_i)/t_+} \operatorname{Sin} P_n(\xi - \tau) d\tau$$

$$(t_+ > t_i + \xi > 0)$$

Integrating the expression for T_n'' results,

$$T_n'' = C_n \operatorname{Sin} P_n \xi + D_n \operatorname{Cos} P_n \xi + \frac{4qKd \operatorname{Sin}\alpha}{B_n \rho A \pi} \frac{H_n^3}{P_n n} e^{-2t_i/t_+}$$

$$\cdot \left\{ e^{-2\xi/t_+} P_n \left[h_n - t_i g_n + t_i^2 f_n - \xi\left(\frac{P_n^4 t_+^2}{4} + P_n^2 - 2t_i f_n\right) \right.\right.$$

$$\left. + \xi^2 f_n \right] - P_n \operatorname{Cos} P_n \xi \left[h_n - t_i g_n + t_i^2 f_n \right]$$

$$\left. + \operatorname{Sin} P_n \xi \left[d_n - P_n^2 t_i \left(\frac{P_n^2 t_+}{2} + \frac{2}{t_+} \right) \right] \right\} \quad (t_+ > t_i + \xi > 0)$$

where

$$H_n = \frac{\frac{2}{t_+}}{(\frac{2}{t_+})^2 + P_n^2}$$

$$h_n = \frac{P_n^4 t_+^2}{8} - \frac{P_n^2 t_+}{4} + \frac{1}{t_+}$$

$$g_n = \frac{P_n^4 t_+^2}{4} + P_n^2$$

$$f_n = \frac{P_n^4 t_+}{8} + \frac{P_n^2}{t_+} + \frac{2}{t_+^3}$$

$$d_n = \frac{P_n^4 t_+^2}{2} + \frac{P_n^2}{2} + \frac{2}{t_+^2}$$

$i = 0, 1, 2, 3 \ldots$

$t_0 = 0,\ t_1 = \xi,\ t_2 = 2\xi \quad \ldots$

In the equation for T_n'', t_i represents the time from $t = 0$ to the actual time at the beginning of any interval. The interval time is taken from zero to any arbitrary value of ξ. Thus the equation is actually written for a new time origin for each interval. The use of t_i as time from the beginning of the action is necessary to define the dynamic pressure variation during the arbitrary intervals.

The time interval t is divided into many small segments of value ξ. Starting from zero to ξ, C_n and D_n both are zero for the initial interval. The values of T''_n and $\dot{T}''_n$ at the end of first time interval and the beginning of the second time interval should be equal. By equating the two expressions the values of C_n and D_n at the beginning of second time interval are found. Then for the second step, the origin is shifted to the $t_1 = \xi$. From this new origin and with the values of C_n and D_n at this point the same method as applied in the first time interval is followed step by step, and the successive values of C_n and D_n at each time interval will be found. In other words, for each special time interval, a new equation for T''_n is also obtained. Combining T''_n with X_n will result in the following equation for the particular solution.

$$y(x,t_i+\xi) = \sum_{n=1,3\ldots}^{\infty} B_n \mathrm{Sin}\,\frac{n\pi x}{L}[C_n \mathrm{Sin}P_n\xi + D_n \mathrm{Cos}P_n\xi$$

$$+ \frac{4qKd\mathrm{Sin}\alpha}{B_n\rho A\pi}\,\frac{H_n^3}{P_n n}\, e^{-2t_i/t_+}\{e^{-2\xi/t_+}\, P_n[h_n - t_i g_n$$

$$+ t_i^2 f_n - \xi(\frac{P_n^4 t_+^2}{4} + P_n^2 - 2t_i f_n) + \xi^2 f_n]$$

$$-P_n \mathrm{Cos}P_n\xi[h_n - t_i g_n + t_i^2 f_n] + \mathrm{Sin}P_n\xi[d_n - P_n^2 t_i$$

$$.(\frac{P_n^2 t_+}{2} + \frac{2}{t_+})]\} \qquad (t_+ > t_i + \xi > 0)$$

In the first interval, the initial tension P_0 is used in the above expression and a center displacement

y_1 is obtained. The length of cable, L, required to fit the deflection curve for the first mode is found. Using

$$d\delta = ds - dx$$

and

$$ds = dx \sqrt{1 + (\frac{dy}{dx})^2} \quad ,$$

$$\delta = \int_0^L \{[1 + (\frac{dy}{dx})^2]^{1/2} - 1\} dx$$

Putting the integrand in series form,

$$\delta = \int_0^L [\frac{1}{2}(\frac{dy}{dx})^2 - \frac{1}{8}(\frac{dy}{dx})^4 + \dots] dx$$

Substituting $\frac{dy}{dx} = A_1 \frac{\pi}{L} \text{Cos} \frac{\pi x}{L}$ into the above equation, the change in length, δ_1 is obtained. (A_1 is the value of amplitude of the first mode.)

Now, by substituting the change in length into the equation $\delta = \frac{\Delta PL}{AE}$, there is found one additional new tension in the cable, say ΔP_1, and then the cable is acted on by the total tension $P_0 + \Delta P_1$.

Using this value of tension instead of P_0 in the next interval t_1 to t_2, y_2 and ΔP_2 are obtained. Using $P_0 + \Delta P_2$ the third displacement, y_3, is found.

The procedure is repeated for successive time intervals in order to obtain an approximate solution for the displacement-time and tension-time relations. The approximation gives results on the conservative side of the correct result.

X. ILLUSTRATIVE EXAMPLE

The following will serve to illustrate the numerical use of the solution.

Consider a tower located 14,000 feet from a surface burst of 1 megaton. The scaling factor will be $W^{1/3}$ = $(1,000)^{1/3}$ = 10. From Figure 6., multiplying the values on abscissa by scaling factor 10, the point 14,000 feet above the ground zero is obtained, from that point draw a vertical line to peak dynamic pressure line then goes horizontally, as shown by dotted line, the peak dynamic pressure is found to be 0.7 lb/in^2 or 101 lb/ft^2. From Figure 7., in the same way, the positive phase duration on the ground of dynamic pressure for 1-kiloton burst is found to be 3.9 seconds, i.e., t_+ = 3.9 seconds. t_r = 40 m. sec[4].

The tower under consideration is a 1,500 feet TV tower located in Springfield, Missouri. The guy cables used on this tower range from a 1 3/8" x 1963' cable attached to the top of the tower (guy #6) to 1 3/16" x 1963' cable attached to a point 231' from the ground (guy #1).

The pertinent data on guy #6, which will be used in this example, is

d = 0.115 ft.

ρ = 15.6 $slugs/ft^3$

A = 0.00792 ft^2

α = 53°

$L = 1,960$ ft.

$P_0 = 29,000$ lb.

$E = 24 \times 10^6$ lb/in^2

The shape factor will be 1.25[6].

Using the above data, all constant coefficients are obtained using the time t_+ as 3.9 seconds. By applying the procedures stated previously, displacements and cable tensions are obtained for every value of t, as listed in Table 1.

Examination of the values in Table 1. show that for $x = \frac{L}{2}$, the maximum displacement resulting from the first two modes (n = 1 and n = 3) will be 20.954 ft, and the corresponding maximum tension in the cable is 43,855 lb. These occur at t = 2.1 seconds. The solution appears to converge rapidly enough so that the addition of the third mode (n = 5) would at most change the third significant figure of the cable deflection by one integer. Therefore the effect of the third mode, and all successive modes, is neglected in this example.

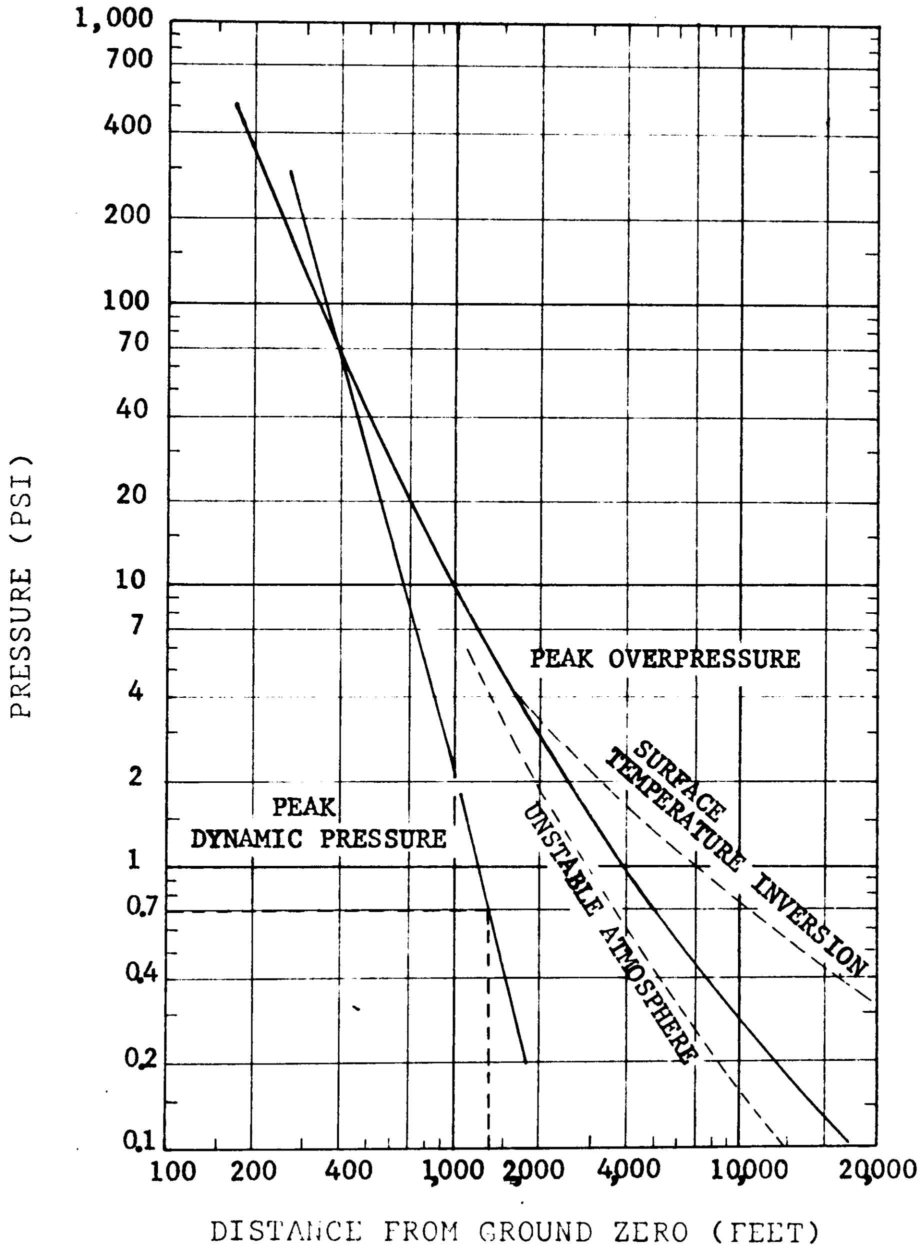

Figure 6. (Page 135, ENW) Peak overpressure and peak dynamic pressure for 1-kiloton surface burst.

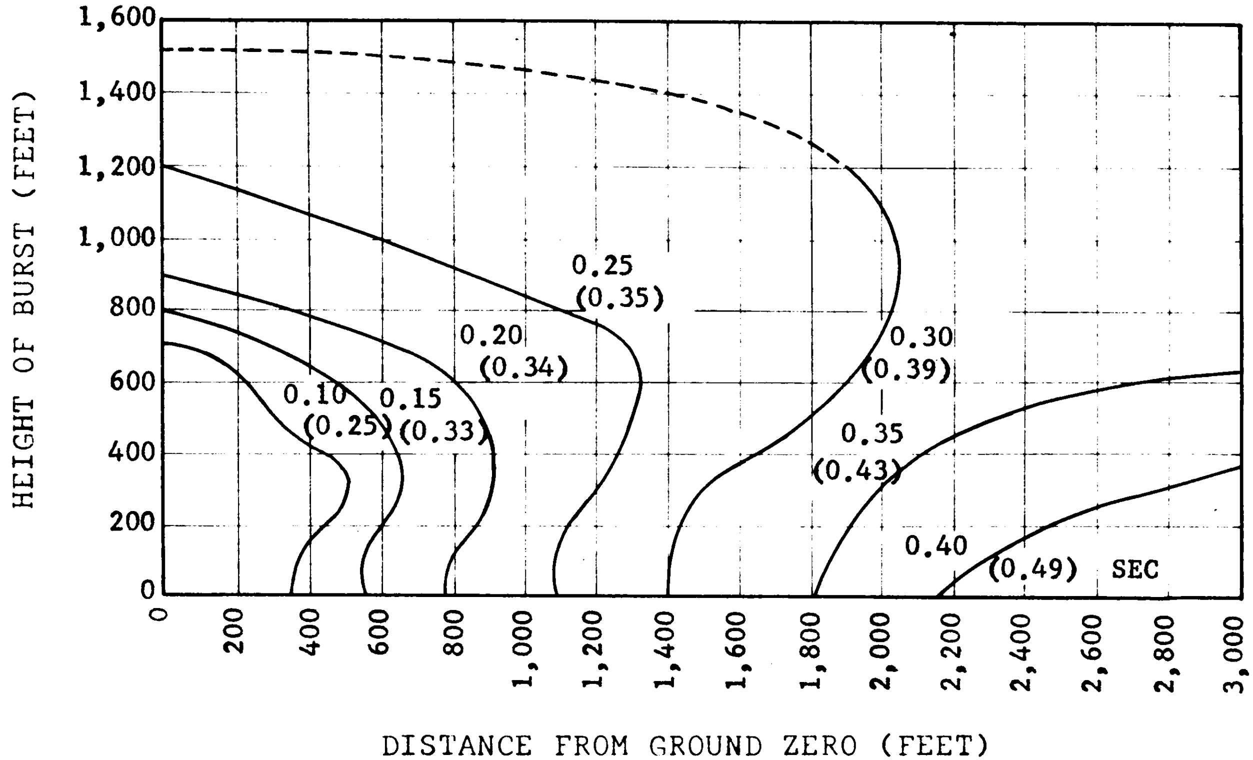

Figure 7. (Page 143, ENW) Positive phase duration on the ground of overpressure and dynamic pressure (in parentheses) for 1-kiloton burst.

TABLE 1

Values of the displacement and cable tension for n = 1 and n = 3 mode with each indicated time

L = 1,960 ft. ρ = 15.6 slugs/ft^3

q = 0.7 psi d = 0.114 ft.

Time t (sec)	Displacement y (ft)	Tension p (lb)
0.0	0.000	29,000
0.5	9.260	31,835
1.0	17.450	37,930
1.5	22.470	43,580
2.0	25.358	47,950
2.4	26.545	49,700
2.5	26.585	49,800
2.6	26.575	49,770
3.0	25.574	48,800
3.5	22.617	45,700
3.9	19.450	41,580

TABLE 2

(Reference (2), Page 24) Values of the coefficient of $\sin \frac{n\pi x}{L}$, for n = 1 and n = 3, and displacement at $\frac{L}{2}$.

L = 1,960 ft. ρ = 15.6 slugs/ft^3

q = 0.7 psi d = 0.114 ft.

Time t (sec)	Coeff. of $\sin \frac{\pi x}{L}$ (ft)	Coeff. of $\sin \frac{3\pi x}{L}$ (ft)	Displacement at $\frac{L}{2}$ y (ft)
0.5	3.80	4.91	-1.11
1.0	30.50	13.20	17.30
1.5	64.10	19.00	45.10
2.0	95.00	18.70	76.30
2.5	115.00	11.40	103.60
2.7	119.00	7.10	111.90
2.8	120.00	4.80	115.20
2.9	120.00	2.30	117.70
3.0	118.00	-0.60	118.60
3.1	118.00	-2.40	120.40
3.2	116.00	-4.60	120.60
3.3	113.00	-6.90	119.90
3.4	110.00	-9.30	119.30
3.5	107.00	-10.80	117.80
3.6	101.00	-12.70	113.70
3.9	84.50	-16.20	100.70

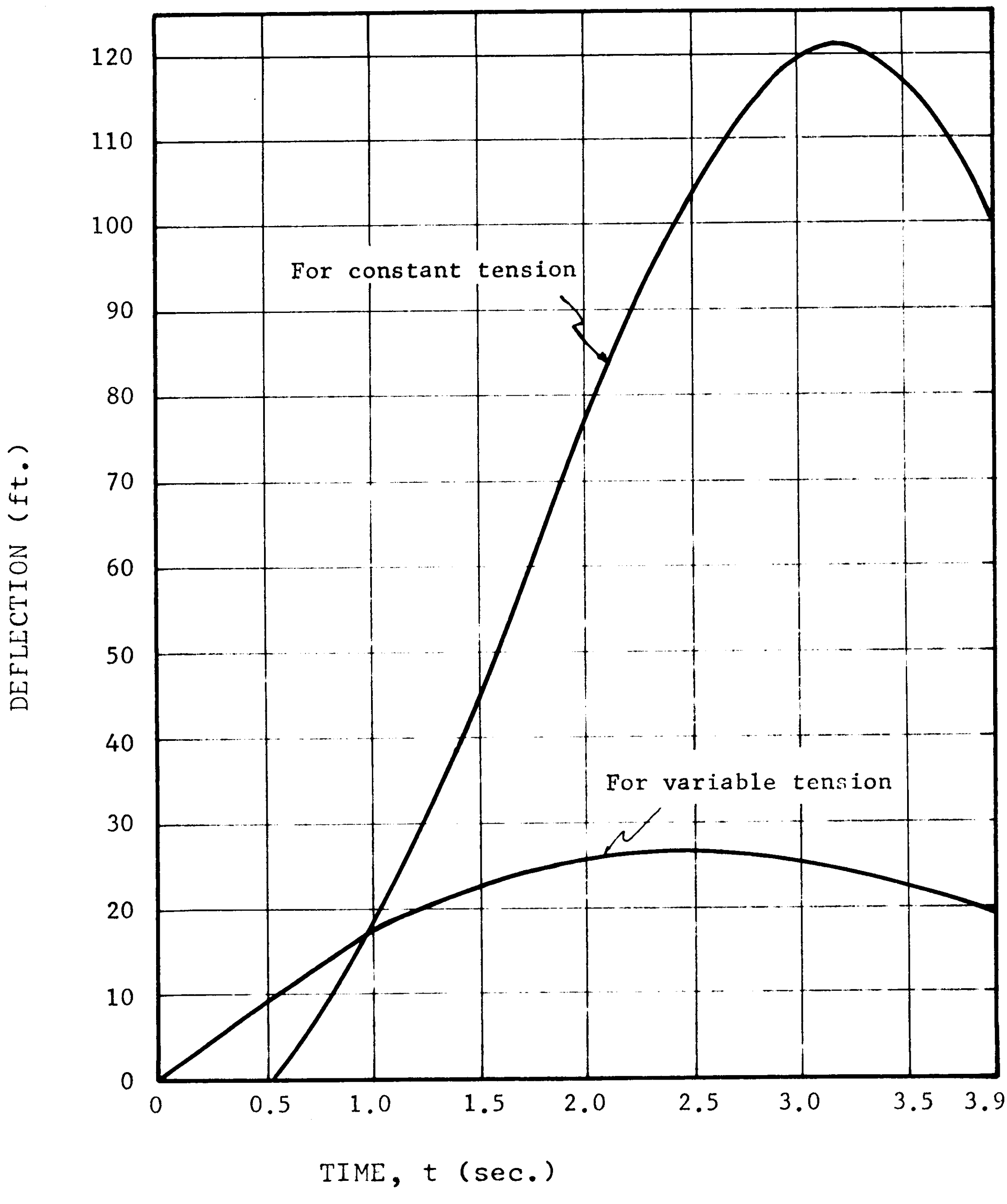

Figure 8. Deflection curves at L/2 for constant tension and variable tension with respect to time.

XI. DISCUSSION OF RESULTS

Comparing Table 1. with Table 2. from the thesis by Mr. D. A. Ball[2], it is found that there are significant differences between them. The curves of displacement at the center of cable with respect to time are plotted in Figure 8. It has been shown that the maximum deflection in this analysis is 26.585 ft. and the maximum tension is 49,800 lb. But the maximum deflection and tension found in reference (2) are 120.6 ft. and 283,000 lb. which are about between five and six times these new values. Therefore, analysis of this problem using a constant tension assumption is not a valid approach.

The angle α between the cable and velocity vector was assumed constant in this thesis. But actually, during the action of blast loading, the cable deformed and did not stay at original position. From the previous investigation, the maximum deflection at the center of cable was found to be 26.585 ft. Since

$$\tan\alpha = \frac{dy}{dx} = A \cdot \frac{\pi}{L} \cos \frac{\pi x}{L}$$

Since α is small, then $\tan\alpha \approx \alpha$, and at the center of cable

$$\alpha = A \frac{\pi}{L} = \frac{26.585\pi}{1960} = 0.0429 \text{ radius} = 2.46°$$

$$\frac{\sin 55.46° - \sin 53°}{\sin 53°} \times \frac{100}{100} = 3.13\%$$

From equation (18), it shows the change of angle α will affect the solution by 3.13 per-cent. This effect is very small and can not contribute a great change in the result. So it can be neglected.

XII. CONCLUSIONS

From the comparison of the results of this thesis with those in reference (2), the variable tension is found to have a great influence on this analysis. It reduces the maximum cable tension to less than one sixth of that obtained under the constant tension assumption. So the variable tension plays a very important role in this problem and can not be neglected. From Figure 9., the relation between the variable tension and time can be seen.

In the above investigation the maximum tension reaches values less than twice the value of the initial tension. In reference (2), the initial tension assumed in the example problem was one-eighth the cable breaking strength. Doubling or tripling the tension should not cause failure as long as the tower and cable anchors could stand it. So no dangerous situation will occur. If the time intervals are taken much smaller, then a more exact result can be obtained, since the stiffening effect of the cable is not considered as continuous, but as varying in steps.

The analysis assumed that the cable supports are fixed in space. The same general approach might be applied to other situations by adjusting boundary or continuity and initial conditions to suit the particular case. In this way, the analysis might be applied to telephone and transmission lines.

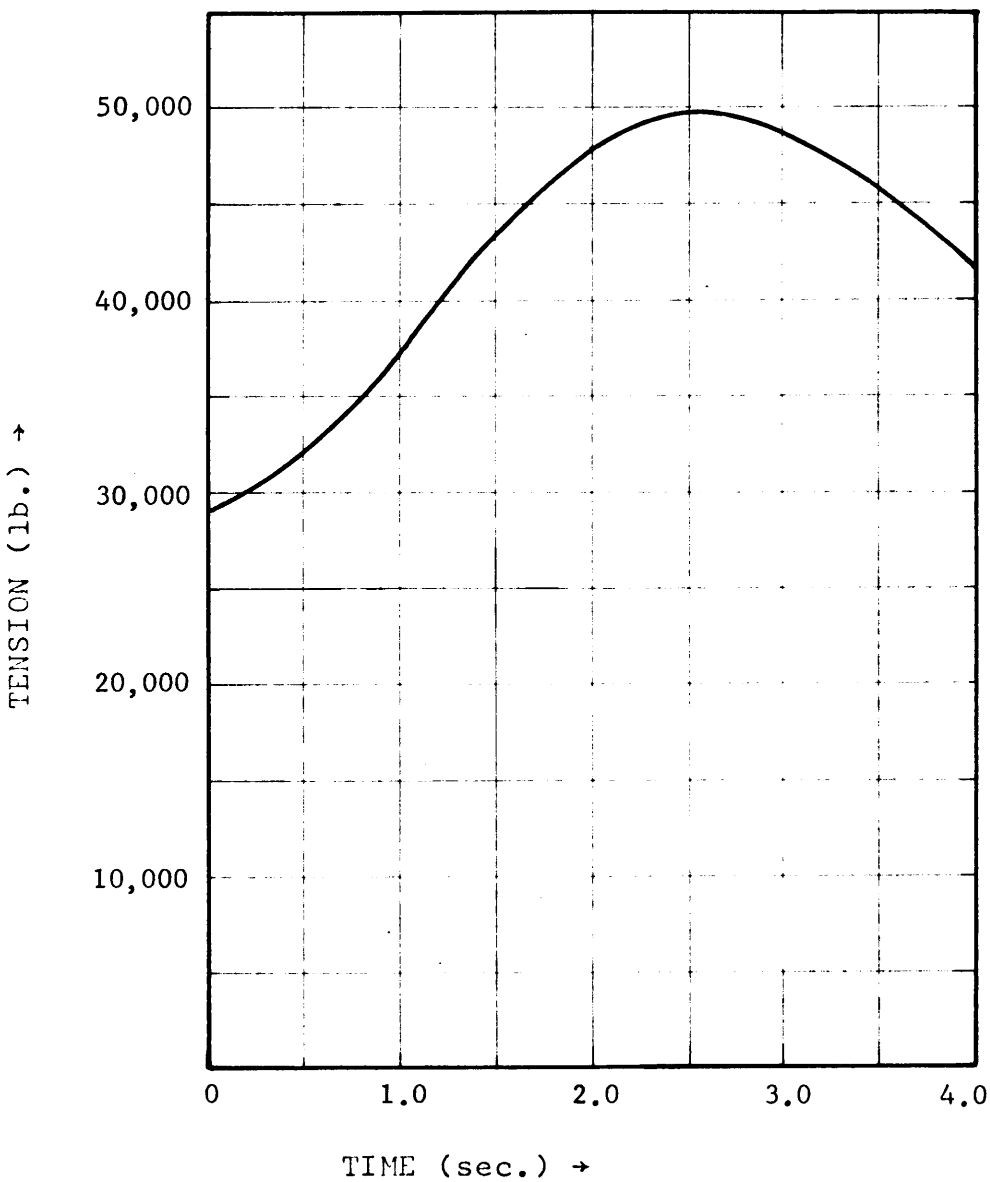

Figure 9. Relation between the variable tension and time.

XIII. ACKNOWLEDGEMENTS

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The author also expresses his appreciation to his parents who are largely responsible for whatever accomplishments he may have obtained.

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THE EFFECT OF BLAST LOADING ON A GUY CABLE

by

Tzu-Ti Kuo

ABSTRACT

The blast loading on a structure is a function of the incident blast wave characteristics, that is, overpressure and dynamic pressure. But the most damaging effects to the guy cable from a nuclear explosion would be the dynamic pressure caused by the high winds which follow the shock front. This dynamic pressure reaches its maximum value very rapidly, almost zero time after the passage of the shock front, and then decays exponentially as shown by equation (17).

The work of this thesis has been the investigation of a guy cable under blast loading by correcting the tension during each small time interval. The results from this procedure are considerably smaller than those in the analytical work of Mr. D. A. Ball. From this point of view, we know that the tension of the cable in such a problem can not be considered as constant.