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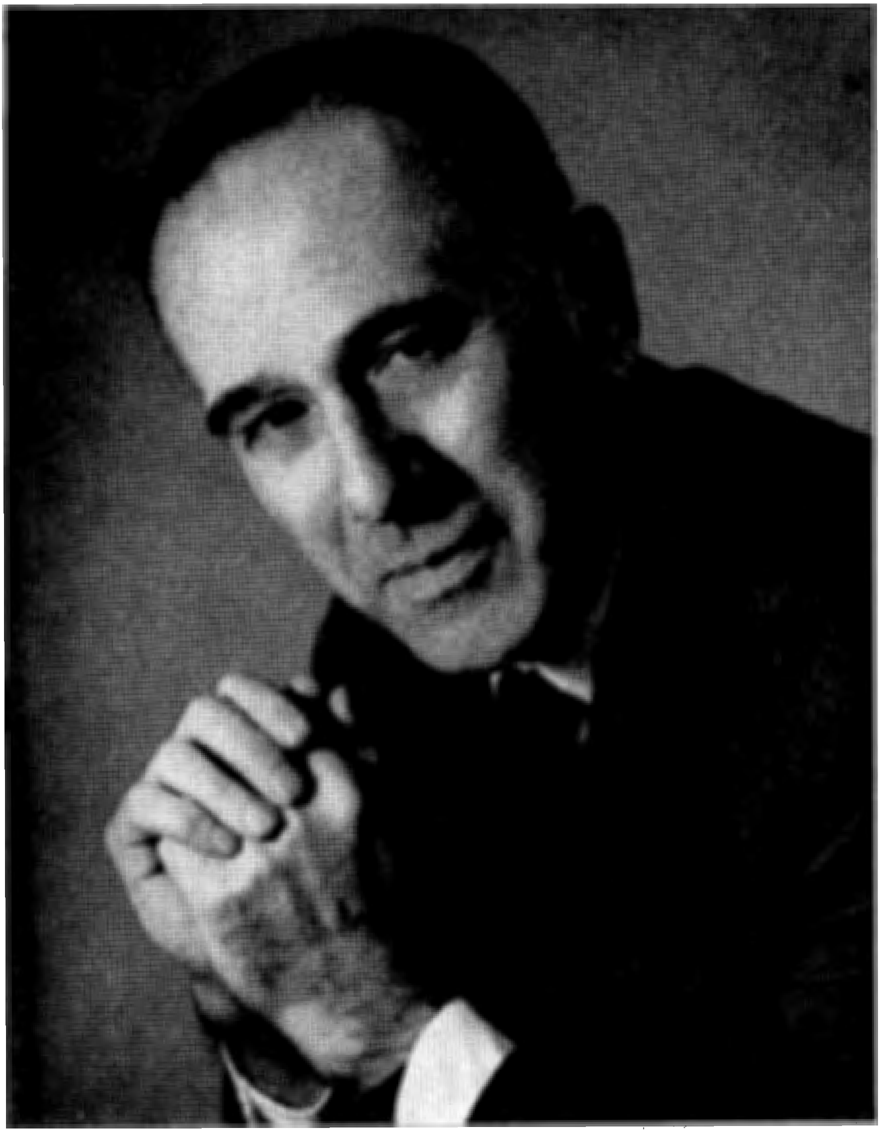

LESLIE J. HOOPER

President, Boston Society of Civil Engineers, 1965-66

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume 52 APRIL, 1965 Number 2

WHITHER THE BOSTON SOCIETY OF CIVIL ENGINEERS?

PRESIDENTIAL ADDRESS BY WILLIAM A. HENDERSON

(Presented at Annual Meeting of Boston Society of Civil Engineers, March 18, 1965)

The one hundred-seventeenth year in the life of the Boston Society of Civil Engineers has now drawn to a close. Those years have been replete with accomplishments and with service to the engineering profession. The roster of Past Presidents, some fortunately still with us, and others now only a legend from out of the past, reads like a list of eminent engineers of their day. Truly the Society has given much to the development of engineers and engineering during its lifetime.

Let us review, for a moment, the current work of the Society. It and its various sections hold some two dozen meetings each year in which talks are presented on various phases of engineering or related subjects. The meetings are open, of course, to members and non-members alike. The speakers are generally well known in their fields and the subjects technical and most informative. Unfortunately, and possibly because of the general apathy that seems to have prevailed in engineering as well as in other areas, the attendance at these meetings is often discouragingly small. The excellence of the talks is such that those engineers who fail to attend are missing one of the chief advantages of their membership.

Another accomplishment in which the Society has been able over the years to take pride is publication of the Journal. Until recently the papers contained therein were required first to have been presented before the Society or one of its Sections, but other papers on technical subjects are now acceptable. It is not generally appreciated that, in insisting on a high degree of excellence of papers for the Journal, the Society rejects many that superficially appear good. The Journal is currently sent to subscribers in many countries around the world. Indeed, if one looks up bibliographies on engineering subjects he will be surprised at the number of references made to our Journal—certainly an indication of the esteem in which it is held by the scientific world.

A third activity most worthy of mention is the series of lecture courses on various phases of engineering. Several of these series have been given and more are planned. The speakers have generally been well known and excellent and the talks well organized. Enthusiasm for these courses has been great and the attendance more than satisfactory. Some twenty or thirty years ago objection might have been raised to such courses on the ground that they were in competition with the colleges and technical schools, but now with the emphasis on advanced degrees, such objection is no longer raised. In any case the extent of response of the engineering profession to the lectures has been most surprising. Many of the lectures are being published as articles in the Journal. Orders for reprints have been received sometimes in large numbers from corporations, universities, the Federal Government and others. In all this the Society is offering truly professional services.

Nevertheless, during my term as President this past year, I have often stopped to wonder whether we are presently giving and doing up to the limit of our capacity, and I have not been thoroughly satisfied with my own answers. Such doubt as to the extent of the Society's service is in no way a reflection on those who have helped run the Society during the past twelve months. Rather, I feel, it is a reflection on my own accomplishments, or lack thereof, as nominal leader and so, rather than talk to you on some technical subject, I shall bring to your attention some thoughts I have had concerning the functions of the Society.

To begin with, what are the privileges and the responsibilities of the Society? An examination of the Act of Incorporation and the applicable statutes gives little definite information to the layman. We are forbidden elsewhere by law to use our funds for certain purposes such as lobbying, and here we may conclude we are on definite ground. But then, what is lobbying? Presumably the hiring of an individual to represent us before the legislature or one of its committees comes under that category and is therefore proscribed. But is it acceptable for one of our officers, for instance, to so represent and speak for the Society? Here opinions differ. It could very well be worth our while to obtain legal advice on the matter. We have, it is true, an excellent and active Legislative Committee which follows the various items of proposed legislation that are of interest to the Society and reports its recommendations to the Board of Government. Surely when such items affecting the welfare of engineers or of the profession are proposed, the Society should throw its full weight in support of or in opposition to the measure. Should we not find out just how far we may legally proceed?

One who reads the daily papers will no doubt recollect having seen many an article or letter submitted by an official group of the medical or legal profession. For some reason engineers are much more reticent, and it is rarely indeed that one will find any communication from one of their groups; yet it would appear that the medical and legal professions have influence and stature partly because they keep themselves constantly in the public eye and the public press. They have sold themselves. It is true that our own Society has not met with much success in having the papers report on our meetings. Nevertheless it is felt that they would more readily welcome articles or letters expressing the official opinions and recommendations of a recognized engineering group, such as ours, on engineering matters affecting the public. The general public would be glad to know of those recommendations and would come to recognize the stature of our Society. Might we not therefore profitably consider more extensive use of the press in the interests of the engineering profession?

We have recently deplored the dearth of students choosing to enter the engineering field. There seem to be several reasons for this. First, of course, there is the influx of many of the so-called glamor industries that lure prospective students away. Then, too, the need for specialization in this age and the difficulty of finding one's proper slot discourages others. Personal contact with, and advice and guidance of, the student in his secondary school days are prerequisite if he is to be influenced toward engineering as a career. This work is already being carried forth on a large scale by more than one organization. Several of our members are already doing their share in interviewing and guiding secondary school students, but so far the Society has not officially taken part. In view of the crying need for more rather than fewer engineers, should not the Society consider active participation in the program, possibly in concert with others? It is here suggested that the prestige of the Society might go a long way toward influencing prospective engineers.

In past years there was a certain amount of co-ordination between the various engineering groups. Recently, however, with a large increase in the number of societies and associations, the co-ordination has for the most part disappeared. Sometimes the various groups seem to be competitors and rivals rather than engineering groups with much the same goals. Often too, lack of proper inter-communications prevent a united backing for some items of general interest. If genuine co-ordination is to be obtained in the future one of two steps must be taken. Either the original coordinating unit must be restored to its earlier status or a completely new method of general liaison must be found. Neither of the steps is a one-society project, but certainly one engineering group, such as our own, must take the lead in furthering necessary coordination. One can find no reason why this cannot be obtained while still remaining short of actual amalgamation. Should our own Society not be the leader in restoring this coordination?

It should be noted that the various suggestions herein are expensive both in time and in money. The question then arises whether the Society, providing in the first place it agrees that some parts of the program are desirable, feels it can find the necessary funds, the necessary number of member participants. There is almost no limit to the services an association of engineers can render, but there is definitely a practical limit of expense and of manpower. What those limits may be should be a subject of most careful study.

Having considered the foregoing suggestions, an engineer might be tempted to say: "The out-going President has been in office for a year and now comes up with various suggestions that he should have covered during his own term." But the thoughts presented have been accumulating during the year and are herein set down as suggestions only, which later Boards of Government may or may not care to follow.

Many an American youth, on listening in on the World Series, has imagined himself out on the pitcher's mound firing strikes past the bewildered opposing batters. But even while he pitches he can somehow detach himself and sit in the stands and watch himself at work as he becomes a national hero. And every so often we in the Society must look at our own work with complete detachment and ask ourselves if it has been good. Only by so doing can we hope to improve on our work and ensure that our Society is living up to its complete capabilities.

The question necessarily arises to one who has the best interests of the Society at heart: has the time yet arrived when we should carefully examine its organization and procedures so that this Boston Society of Civil Engineers may gain still more in stature and influence while giving even more in service?

DIFFUSION AND MIXING

By William E. Dobbins*, *Member*

(Presented as one of the John R. Freeman Lectures on Fundamental Hydraulic Processes in Water Resources Engineering, Boston Society of Civil Engineers, November 5, 1963)

Diffusion

Diffusion is the movement of a substance within another, the diffusing phase being in solution or suspension within the dispersing phase. The term Diffusion is also applied to the migration of some property of a substance such as its temperature. Diffusion is one of the most basic of all the processes in nature, being one of the essential processes of life itself. The living cell obtains its food and eliminates its waste products by diffusion through the cell wall.

Diffusion takes place whenever there is a gradient of the concentration of the dispersed phase or intensity of the property which migrates. The dispersing phase may be in the solid, liquid or gaseous state. If it is in the solid state, the diffusion takes place as a result of molecular motion; if it is in the fluid state, diffusion can take place as a result of either the molecular movements alone or the combined effect of molecular motion and the movements of macroscopic masses of the fluid. In a turbulent flow regime, the diffusion which results from the macroscopic turbulent movements is very much greater than that due to the molecular motions. Since most of the problems of concern to hydraulic engineers deal with turbulent flow, turbulent diffusion is generally of more importance than molecular diffusion. However, there are some situations in which both processes play an important role, an example of which will be presented later.

Basic Laws of Diffusion

The basic equations of diffusion were first given by the physiologist, Fick, and have become known as Fick's Laws of Diffusion. Fick's first law is given by the equation

$$\frac{1}{A}\frac{dm}{dt} = -D\frac{dc}{dx} \tag{1}$$

* Professor of Civil Engineering, New York University.

in which $\frac{dm}{dt}$ is the rate of mass transfer by diffusion in the direction of x across an area, A, normal to x, $\frac{dc}{dx}$ is the gradient of the concentration of the diffusing substance and D is a proportionality constant. Fick's second law is given by

$$\frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial x^2} \qquad (2)$$

where $\frac{\partial c}{\partial t}$ is the rate of change of concentration at a point where the concentration gradient is $\frac{\partial c}{\partial x}$. Equation (1) is intuitively acceptable, and equation (2) is readily derived from equation (1). Considering a stream tube of cross section A, and length dx, the rate of increase of the mass of diffusing substance within this element would be equal to the rate of diffusion into the element at x less the rate of diffusion out of the element at x + dx, or

$$\frac{dm}{dt} = -AD \frac{\partial c}{\partial x} - \left[-AD \left(\frac{\partial c}{\partial x} + \frac{\partial}{\partial x} \left(\frac{\partial c}{\partial x} \right) dx \right) \right]$$
$$= AD \frac{\partial^2 c}{\partial x^2} dx$$

From this it follows that

$$\frac{\partial c}{\partial t} = \frac{dm}{A\, dx\, dt} = D \frac{\partial^2 c}{\partial x^2}$$

These equations may be applied to both molecular diffusion and turbulent diffusion, by use of the appropriate values of D. For molecular diffusion, D is known as the "Diffusivity" or the "Coefficient of Molecular Diffusion"; in the turbulent case, D is commonly known as the "Coefficient of Turbulent Diffusion." The values of the Diffusivity vary with the substances involved and with the temperature. For the diffusion of substances dissolved in water at ordinary temperatures, the molecular Diffusivity is of the order of magnitude of 10^{-5} cm^2/sec. The turbulent Diffusion Coefficient varies with the scale and intensity of the turbulence and is many orders of magnitude larger than the molecular Diffusivity.

Equation 2 can be applied to the flow of heat in a solid when C is taken as the temperature, and D as the Thermal Conductivity divided by the product of density and the specific heat of the substance. The constant, D, in this case, was called by Kelvin the "Diffusivity" of the substance.

Equation (2) is for the case of one dimensional diffusion with a constant value of D. For the more general three dimensional case, with variable values of D, the equation is

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}\left(Dx\frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(Dy\frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial z}\left(Dz\frac{\partial c}{\partial z}\right) \tag{3}$$

In many practical cases, the three components of D will be constants and the equation will be

$$\frac{\partial c}{\partial t} = D_x\frac{\partial^2 c}{\partial x^2} + D_y\frac{\partial^2 c}{\partial y^2} + D_z\frac{\partial^2 c}{\partial z^2} \tag{3a}$$

Diffusion and Convection

In most cases of interest, the movement of a dispersed substance with reference to a fixed coordinate system will be the combined result of the diffusion of the substance within the fluid and the movement of the fluid itself. The rate of transfer of a dispersed substance with concentration, c, by the movement of the fluid across an area, A, is equal to cA multiplied by the component of the fluid velocity normal to A. With U, V and W representing the three components of the average velocity of the fluid, the equation for the rate of change of concentration at a fixed point due to the combined effect of diffusion and convection will be given by

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}\left(D_x\frac{\partial c}{\partial x} - Uc\right) + \frac{\partial}{\partial y}\left(D_y\frac{\partial c}{\partial y} - Vc\right) + \frac{\partial}{\partial z}\left(D_z\frac{\partial c}{\partial z} - Wc\right) \tag{4}$$

In many cases, each of the velocity components and the components of the diffusion coefficient are constants. Equation (4) then reduces to

$$\frac{\partial c}{\partial t} = D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} + D_z \frac{\partial^2 c}{\partial z^2} - U \frac{\partial c}{\partial x} - V \frac{\partial c}{\partial y} - W \frac{\partial c}{\partial z} \quad (4a)$$

Equation 4 is the basic differential equation for the movement of a conservative substance.

Movement of Non-Conservative Substances

In many cases of practical interest, notably problems dealing with the dispersal of pollutants in water or in the atmosphere, the substance is non-conservative, i.e. its concentration decreases with time in accordance with some known law. Examples are the natural decay of radioactivity, the removal of a substance by sedimentation, the removal of organic matter by biological oxidation and the removal, by death, of bacteria. Most of these removal rates are simple first order reaction rates, in which the rate of removal is proportional to the amount present. This is fortunate, since it makes it possible to obtain many solutions which would be impossible with more complicated removal mechanisms.

It is also possible to have various sources or sinks which supply or remove the substance under variously defined conditions. Examples of the latter are the addition of pollutants along the path of flow of a stream, the addition of oxygen by reaeration at the surface of a stream, and the removal of oxygen by plant respiration. In general, these sources or sinks will supply or remove the substance along some axis or surface in accordance with some definable function of time. From these considerations, the general equation for the rate of change of concentration at a point can be written as

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}\left(D_x \frac{\partial c}{\partial x} - Uc\right) + \frac{\partial}{\partial y}\left(D_y \frac{\partial c}{\partial y} - Vc\right) + \frac{\partial}{\partial z}\left(D_z \frac{\partial c}{\partial z} - Wc\right) - \phi(c) + \psi(t) \quad (5)$$

and in the case of constant components of velocity and diffusion coefficient as

$$\frac{\partial c}{\partial t} = D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} + D_z \frac{\partial^2 c}{\partial z^2} - U \frac{\partial c}{\partial x} - V \frac{\partial c}{\partial y} - W \frac{\partial c}{\partial z} - \phi(c) + \psi(t) \quad (5a)$$

In equations (5) and (5a), $\phi(c)$ represents the rate of removal of the substance at some decay rate which is a function of c and $\psi(t)$ represents the net rate of increase of c due to sources and sinks. In many practical cases $\phi(c)$ can be taken as Kc, K being a constant and $\psi(t)$ can be taken as a constant along some line or plane.

Solutions for Cases of Practical Interest

The differential equation for any particular case must be solved subject to particular boundary conditions. In most cases the general equation (5) can be greatly simplified because many of the terms vanish. One and two dimensional cases are of great practical interest, but use of the general three dimensional equation is only rarely necessary. Solutions to a great many problems can be found in treatises dealing with heat conduction. The book, "Conduction of Heat in Solids," by Carslaw and Jaeger (1) is a catalogue of solutions for particular boundary conditions. Solutions to some of the most important cases are given below:

I(a) *One Dimensional Diffusion*—No convection—Instantaneous release at time $t = 0$ and $x = 0$, of a conservative substance in an amount, m, per unit cross-sectional area.

Differential equation: $\dfrac{\partial c}{\partial t} = D_x \dfrac{\partial^2 c}{\partial x^2}$

$$\text{Solution:} \quad c = \frac{m}{\sqrt{4 \pi D_x t}} \exp\left(-\frac{x^2}{4 D_x t}\right) \quad (6)$$

This condition would be approximated by the release of a slug of tracer in a long narrow, completely mixed, estuary of uniform cross-section in which the fresh water inflow is so low as to make U negligible. The concentration at any time, t, would be spread out as a Gaussian curve with its center at the point of release. As time went on, the concentration would approach zero at all values of x.

I(b) *One Dimensional Diffusion*—Convection along x axis—Instantaneous release as in I(a).

Differential equation: $$\frac{\partial c}{\partial t} = D_x \frac{\partial^2 c}{\partial x^2} - U \frac{\partial c}{\partial x}$$

Solution: $$c = \frac{m}{\sqrt{4 \pi D_x t}} \exp\left[- \frac{(x - Ut)^2}{4 D_x t} \right] \qquad (7)$$

This would represent a completely mixed narrow estuary in which the seaward velocity is U. The distribution will be Gaussian as in I(a), with the center moving downstream at velocity, U.

I(c) *One Dimensional Diffusion*—No convection—Continuous release of conservative tracer at $t = 0$ and $x = 0$ at rate m per unit cross-sectional area per unit time.

Differential equation: same as in I(a)

Solution: $$c = \frac{m t^{1/2}}{\sqrt{\pi D_x}} \exp\left[- \frac{x^2}{4 D_x t} \right] - \frac{m x}{2 D_x} \operatorname{erfc}\left(\frac{x}{2\sqrt{D_x t}} \right) \qquad (8)$$

This would represent the continuous release of a tracer, or pollutant, into a long narrow, completely mixed, estuary. The equation implies that the concentration would continue to increase indefinitely at all values of x. Physically, this result would have no meaning since the volume of the tracer fluid would increase the volume of the dispersing fluid and would continue to build up until a net outflow developed at a rate equal to the inflow. The concentration of any particular substance would then reach an equilibrium, as is indicated by the next case, I(d).

I(d) *One Dimensional Diffusion*—Convection along x axis—Continuous release as in I(c).

Differential equation: same as in I(b)

Solution: $$c = \frac{m}{\sqrt{4 \pi D_x}} \int_0^t \frac{1}{\sqrt{t - t'}} \exp\left[\frac{-[x - U(t - t')]^2}{4 D_x (t - t')} \right] dt' \qquad (9)$$

For the steady state $c = m/U$ for all values of $x > 0$
$(t = \infty)$ (downstream)

$$\text{and} \quad c = \frac{m}{U} \exp\left[\frac{Ux}{D_x}\right] \text{ for } x < 0$$

(upstream)

II(a) *Two Dimensional Diffusion*—No convection—Instantaneous release of a conservative tracer in amount m per unit depth.

Differential equation: $$\frac{\partial c}{\partial t} = D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2}$$

Solution: $$c = \frac{m}{4\pi \sqrt{D_x D_y}\, t} \exp\left[-\frac{x^2}{4 D_x t} - \frac{y^2}{4 D_y t}\right] \tag{10}$$

The distributions along the x and y axes would be Gaussian and the iso-concentration lines would be ellipses. The maximum concentration would be centered around the point of release and would gradually decrease to zero. If D_x and D_y were equal, the equation would be

$$c = \frac{m}{4\pi D t} \exp\left[-\frac{r^2}{4 D t}\right] \tag{10a}$$

where $r^2 = x^2 + y^2$

This condition represents, approximately, the dispersal of a slug of tracer released in a large body of water like the ocean. However, as will be discussed later, this condition is not too well represented by equation (10a) since the value of D will actually be a function of r.

II(b) *Two Dimensional Diffusion*—Convection along x axis—Instantaneous release as in II(a).

Differential equation: $$\frac{\partial c}{\partial t} = D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} - U \frac{\partial c}{\partial x}$$

Solution $$c = \frac{m}{4\pi \sqrt{D_x D_y}\, t} \exp\left[-\frac{(x - Ut)^2}{4 D_x t} - \frac{y^2}{4 D_y t}\right] \tag{11}$$

This would represent the movement and spread of a substance in a large body of water with a current velocity U. As in case II(a), the solution is only approximate since D_x and D_y would increase with the extent of the spread of the substance.

II(c) *Two Dimensional Diffusion*—No convection—Continuous release of conservative substance at t = 0 and x = 0, at rate m per unit depth per unit time.

Differential equation: same as in II(a)

$$\text{Solution:} \quad c = \frac{m}{4\pi D}\int_{\frac{r^2}{4Dt}}^{\infty} \frac{e^{-\theta}}{\theta}\, d\theta \tag{12}$$

This solution is for the symmetrical case in which $D_x = D_y = D$.

Equation (11) indicates a concentration which would increase indefinitely. As in the case of I(c), this result could not take place physically since the release of the tracer fluid would ultimately result in a radial outflow from the point of release. The maximum concentration would obviously be the actual concentration of the tracer substance, itself, in its carrier fluid.

II(d) *Two Dimensional Diffusion*—Convection along x axis—Continuous release of conservative substance as in II(c).

Differential equation: same as in II(b)
Solution: The steady state concentration for the case where $D_x = D_y = D$ is given by

$$c = \frac{m}{2\pi D}\exp\left[-\frac{Ux}{2D}\right]K_o\left(\frac{Ur}{2D}\right) \tag{13}$$

where Ko is the modified Bessel Function of the second kind of order zero.

Dispersion of Non-Conservative Substances—The cases considered above show that the continuous release of a fluid containing a highly concentrated conservative tracer substance into a turbulent field with no convection would result in the gradual build up of the tracer substance to a very high concentration. However, if the substance is non-conservative and decays at a rate proportional to Kc, the concentrations in all cases will be less than the values given by the previous equations. For the instantaneous releases, the concentrations will be as given by the previous equations, multiplied by e^{-Kt}. For the continuous releases, the solutions are more complicated. The effect of natural decay of the diffusing substance has been discussed by Diachisian (2), who concluded that a steady state condition would be reached, even in those cases of continuous release into a turbulent field with no convection.

Coefficient of Longitudinal Dispersion—In case I(b) the assumption is that the velocity, U, is uniform across the section of flow. Under these conditions D_x is the true coefficient of turbulent diffusion, which results from the turbulent fluctuations of velocity. In the turbulent shear flow which occurs in conduits and channels, there is a variation in U across the section which results in an apparent value of D_x which is much larger than the value due to the velocity fluctuations alone. This apparent value is referred to as the longitudinal dispersion coefficient, D_L. Taylor (3) has analyzed this problem and derived the equation for D_L in a circular pipe as

$$D_L = 10.1\, r\, U_* \tag{14}$$

where r is the pipe radius and U_* is the friction velocity $\sqrt{\tau_0/\rho}$. Elder (4) considered this for channel flow and presented the equation

$$D_L = 20.2\, R \sqrt{R\, S\, g} \tag{15}$$

where R is the hydraulic radius and S is the slope of the energy gradient. If the Manning equation is used for S, equation (14) becomes

$$D_L = 77\, R^{5/6}\, n\, U \tag{15a}$$

The vertical component of the eddy diffusion coefficient for a channel is given by

$$D_y = 0.0667\, R \sqrt{R\, S\, g} \tag{16}$$

and D_x is thought to be of the same order of magnitude. From this, it follows that D_L is several hundred times as large as D_x. Equation (7) is still applicable for turbulent shear flow, but D_x must be replaced by D_L and U is to be taken as the average velocity. In many natural channels, the effective value of D_L will be greater than that given by equation (15) because of the influence of bends, obstructions, etc. Methods of computing D_L from measured dispersion curves have been discussed by Parker (5), Krenkel and Orlob (6), Diachisian (2) and others.

Effect of Scale on the Value of the Diffusion Coefficients—Many observers have noted that the value of the turbulent diffusion coefficient increases with the scale of the phenomenon. This was first reported by Richardson (7), who suggested that the diffusion coefficient in the atmosphere is proportional to $L^{4/3}$, where L is some measure of the scale of the system. Although there is no simple way of defining L in all cases, for ocean diffusion it can be taken as the size of the patch of the diffusing substance. That the "four-thirds law" seems to be valid is shown by Fig. 1, which was compiled by Pearson (8).

That the effective diffusion coefficient should increase with the size

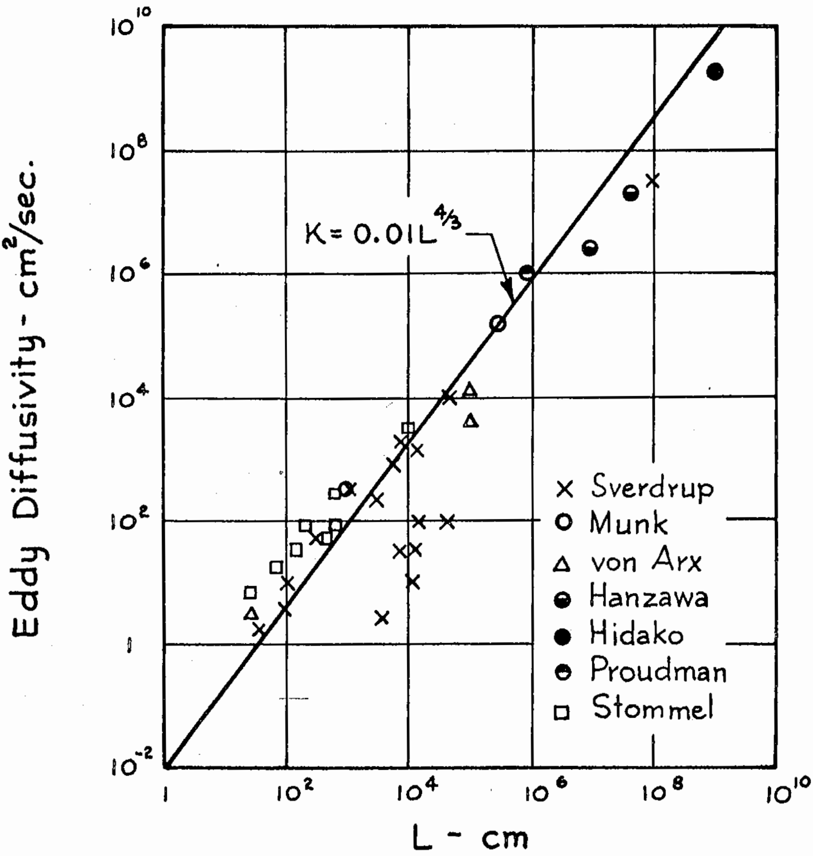

FIG. 1 VARIATION OF EDDY DIFFUSIVITY WITH SCALE (AFTER PEARSON)

of the patch is readily understood when one considers the nature of the structure of turbulence. Turbulence is considered to be the superposition of eddies of all sizes varying from the largest ones which are of the order of the size of the system to the smallest ones in which the dissipation of the kinetic energy into heat takes place.

It is obvious that the effect of the largest eddy would be convection which would move the whole patch without having any effect on its shape or size. The diffusion within the patch is influenced only by those eddies of the scale equal to or less than the size of the patch itself. As the patch grows the influence of still larger eddies increases the effective value of the diffusion coefficient. It is noted from Fig. 1 that the four-thirds law seems to be applicable over a very wide range of L from less than one foot to over several hundred miles.

Since the diffusion coefficient should be influenced by the turbulent energy as well as the scale of the phenomenon, it could be considered as being proportional to some power of E multiplied by $L^{4/3}$. By dimensional considerations, this leads to

$$D = \alpha E^{1/3} L^{4/3} \tag{17}$$

where E is the rate of dissipation of turbulent energy per unit mass of fluid. Orlob (9) found a value of 0.0136 for α in a laboratory channel. Values in the same order of magnitude have been reported for lateral diffusion in the oceans. Orlob (9) and Okubo (10) have discussed this subject in detail.

Because of the variation of D with the scale of the phenomenon, the Fickian solutions, based on constant values of D, are not strictly applicable. A number of investigators have proposed alternate solutions for the diffusion of substances in the ocean. Okubo (10) presented a detailed review and analysis of these alternate solutions.

Sediment Transport

The transport of suspended sediment in rivers is of very great interest to hydraulic engineers and a great deal of research has been done in this area. Most of the work has been done on the equilibrium distribution of sediment across the section of flow. The one dimensional diffusion—convection equation can be applied to the transient condition, in the form

$$\frac{\partial c}{\partial t} = D_x \frac{\partial c^2}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} + \left(w + \frac{\partial D_y}{\partial y} - U \right) \frac{\partial c}{\partial y} \qquad (18)$$

where D_x, the longitudinal component of the diffusion coefficient, is assumed to be constant; the vertical component, D_y, is assumed to be a function of y and where w is the settling velocity of the sediment particles. An analytical solution to a certain simplified case of equation (18) has been obtained by the writer and the application of this solution to estimating the removal of grit in a channel has been discussed by Camp (11).

Analysis of River and Estuary Pollution

For the rate of change of concentration of an organic pollutant at some cross section of a river or estuary, the diffusion-convection equation would take the form

$$\frac{\partial L}{\partial t} = D_L \frac{\partial^2 L}{\partial x^2} - U \frac{\partial L}{\partial x} - (K_1 + K_3)L + L_a \qquad (19)$$

in which L is the first stage BOD, K_1 is the rate constant for the removal of BOD by biochemical oxidation, K_3 is the rate constant for removal of BOD by sedimentation or adsorption and L_a is the rate of addition of BOD by the local runoff or by the resuspension of organic matter from a bottom sludge deposit. For the steady state condition in which the BOD is changing only with x, the equation would be

$$D_L \frac{d^2 L}{dx^2} - U \frac{dL}{dx} - (K_1 + K_3)L + L_a = 0 \qquad (19a)$$

Applied to a stretch of a stream in which U, K_1, K_3 and L_a can be taken as constants and in which the BOD at the upper end is L_A, the equation (19a) can be integrated to give the variation of L along the stretch, as

$$L = L_A \exp(mx) + \frac{L_a}{K_1 + K_3}(1 - \exp(mx)) \qquad (20)$$

where

$$m = \frac{U - \sqrt{U^2 + 4(K_1 + K_3)D_L}}{2\, D_L}$$

The differential equation for the oxygen profile for the steady state condition is given by

$$D_L \frac{d^2c}{dx^2} - U \frac{dc}{dx} - K_1L + K_2(C_S - C) - D_B = 0 \qquad (21)$$

where C represents the concentration of dissolved oxygen, C_S is the saturation concentration, K_2 is the reaeration constant and D_B represents the net rate of removal of oxygen by all processes other than the oxidation of the flowing BOD load. D_B could be positive if the predominant processes were the removal of oxygen by plant respiration and the oxygen demand of the bottom sludge; it could be negative if the addition of oxygen by photosynthesis predominated.

Equation (21) can be integrated by using the expression for L as given in equation (20) and taking $C = C_O$ at the beginning of the stretch, to give

$$D = \frac{K_1\left(L_A - \frac{L_a}{K_1 + K_3}\right)\left(\exp(mx) - \exp(rx)\right)}{K_2 - (K_1 + K_3)} + D_O \exp(rx)$$
$$+ \left(\frac{D_B}{K_2} + \frac{K_1 L_a}{K_2(K_1 + K_3)}\right)\left(1 - \exp(rx)\right) \qquad (22)$$

in which the concentration, C, has been replaced by the saturation deficit, $D = C_S - C$, and in which

$$r = \frac{U - \sqrt{U^2 + 4 K_2 D_L}}{2 D_L}$$

A simplified version of equation (22), which omitted the factors, K_3, L_a and D_B, was presented by O'Connor (12). A detailed discussion of the application of equation (22) in stream pollution analysis has been presented elsewhere (13).

Reaeration in Streams—The absorption of atmospheric oxygen by a natural stream is a process that is controlled by both molecular diffusion and turbulent mixing. The principal resistance to the absorption process is due to the existence of a laminar film at the surface of the water, through which the oxygen must pass by molecular diffusion. Beneath the film the gas is so rapidly dispersed by the turbulent mixing that the concentration of gas in solution is essentially uniform throughout the depth.

The rate of mass transfer of oxygen across a surface area, A_S, can be expressed by the general equation

$$\frac{dm}{dt} = K_L A_S (C_S - C) \tag{23}$$

and the rate of change of concentration within the body of water by

$$\frac{dc}{dt} = K_L \frac{A_S}{V} (C_S - C) \tag{23a}$$

where V is the volume and K_L is variously known as the "absorption coefficient," the "transfer coefficient" or the "liquid film coefficient." For a river, the interfacial area is commonly taken as the horizontal projection, A_O, although the actual interfacial area will be greater in most cases. In these notes the interfacial area will be defined as

$$A_S = C_A A_O \tag{24}$$

where C_A is a coefficient whose value will depend upon the flow characteristics and the magnitude of any surface disturbances created by wind, etc. In the absence of wind or other disturbances, the value of C_A will probably be related to the Froude No., $U/\sqrt{gH}$. As applied to a river, the absorption equation becomes

$$\frac{dc}{dt} = \frac{K_L C_A A_O}{V} (C_S - C) = \frac{K_L C_A D}{H} = \frac{K_L' D}{H} = K_2 D \tag{25}$$

where K_2 is the reaeration constant previously referred to. Equation (25) emphasizes that the reaeration constant, K_2, is equal to the apparent absorption coefficient, K_L', divided by the depth and that K_L' is equal to the true absorption coefficient, K_L, multiplied by the factor, C_A.

If the liquid film were considered to be stagnant, the value of K_L would be equal to the molecular diffusivity, D_M, divided by the film thickness, L. This follows directly from equation (1). Such a concept was first proposed by Whitman (14). This theory has now been largely abandoned because of the fact that the film cannot be considered stagnant. Danckwerts (15) proposed that the film concept should be abandoned and introduced a different physical model of the process. By Danckwerts' model, the liquid is assumed to remain quiescent for a period of time, t′, during which the gas penetrates the liquid by molecular diffusion and the entire depth of liquid is then instantaneously mixed, this sequence being repeated indefinitely. To take into account the stochastic nature of the mixing process, Danckwerts proposed that the mixing should not be considered to be taking place at the same time over the entire surface but that there would be a random distribution of ages over the surface area, the age at each point representing the time elapsed since the previous mixing at that point. Danckwerts' age distribution function is given by the expression

$$\psi(t) = r \exp(-rt) \tag{26}$$

where $\psi(t)\,dt$ would represent that portion of the interface that had ages between t and t + dt, and r would be the average rate of surface exchange, $1\sqrt{t'}$. From these considerations, and assuming that the liquid depth was infinite, Danckwerts derived the expression for K_L as

$$K_L = \sqrt{D_M\, r} \tag{27}$$

Danckwerts' development was intended for application to industrial process equipment, such as absorption towers, in which the liquid flows in layers over various types of packings. In such applications, the flow might well be entirely laminar and the abandonment of the film concept be, thereby, justified. However, for a natural stream, the film concept must be closer to the actual physical conditions. The film can maintain its existence in the statistical sense, i.e. it is always present but the liquid content is being continuously exchanged for liquid from the main body. Kanwisher (15) has reported on experiments in which the surface film at the interface between the atmosphere and a turbulent mass of water has been observed and actually sampled.

Using the Danckwerts age distribution function, but applying it to a film of finite thickness, L, with uniform concentration below the film, the writer (16) obtained the equation

$$K_L = \sqrt{D_M\, r}\,\coth\left(\sqrt{\frac{rL^2}{D_M}}\right) \tag{28}$$

Fig. 2 shows how the rate of absorption of oxygen would vary with time at some particular point at the surface in accordance with the film replacement model. With reference to Fig. 2, the time, t = 0, represents some instant at which the film at the point had just been replaced.

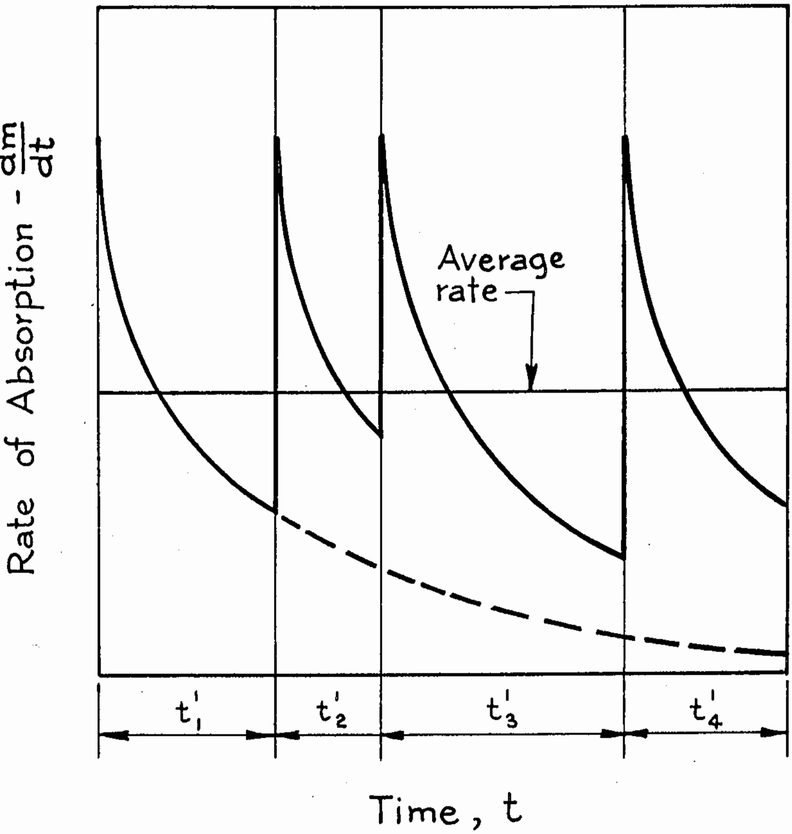

FIG. 2 RATE OF ABSORPTION OF OXYGEN AT A FIXED POINT ON THE SURFACE (BY FILM REPLACEMENT MODEL)

The concentration of dissolved oxygen at that instant would be uniform across the film and equal to the concentration in the main body of water. The concentration would immediately become that of saturation at the very interface and the process of absorption would commence at an infinite initial rate and decline with time as indicated by the curve. At time, t′, replacement would occur and the process would start all over again. Such a process would continue indefinitely, with the period between replacements being a random variable. The average rate of absorption would be given by equation (23) with K_L as in equation (28). The acceptability of equation (28) has been demonstrated by experiments conducted at New York University using various gases, principally helium and nitrogen (17). These experiments indicate that the effective values of r and L depend upon the intensity of the surface turbulence and that a given value of r is always accompanied by the same value of L, thus demonstrating that they are both controlled by the same conditions.

A proposed theory which relates r and L to the stream flow parameters and the liquid properties has been given in detail elsewhere (13) and will be presented very briefly here. It was reasoned that the effective film thickness, L, would be related to the smallest of the turbulent eddies, in which the forces are predominantly molecular and in which most of the dissipation of kinetic energy into heat takes place. The size of these eddies was given by Kolmogoroff as $(\nu^3/E)^{1/4}$, where ν is the kinematic viscosity and E is the rate of loss of energy per unit mass of fluid. The molecular forces which are responsible for surface tension act to oppose the surface overturn and energy must be expended in opposition to these forces in order to break the surface. It was reasoned that the rate of expenditure of energy required to oppose the surface tension must be proportional to the product of the frequency, r, the surface tension, σ, and the square of some length factor, L, which is related to the eddy size. The rate of expenditure of energy per unit mass of fluid would then be given by the expression

$$\frac{r\,\sigma\,L^2}{\rho\,L^3} = \frac{r\,\sigma}{\rho\,L}$$

This energy would have to be supplied by the turbulence and was assumed to be equal to C_1E_S, where E_S is the turbulent energy per unit mass in the vicinity of the surface and C_1 is a proportionality constant. E_S was in turn assumed to be equal to C_2E where E is the energy per unit mass for the flow as a whole and C_2 is a factor whose value depends upon the dynamics of the system. These considerations lead to the following expressions for r and L and their interrelationships.

$$L = C_3\left(\frac{\nu^3}{E_S}\right)^{1/4} = \frac{C_3}{(C_2)^{1/4}}\left(\frac{\nu^3}{E}\right)^{1/4} = C_4\left(\frac{\nu^3}{E}\right)^{1/4} \qquad (29)$$

$$r = C_1(C_2)^{3/4} C_3 \frac{\rho(\nu E)^{3/4}}{\sigma} = \frac{C_5}{(C_4)^3} \frac{\rho(\nu E)^{3/4}}{\sigma} \tag{30}$$

$$rL^3 = C_1(C_3)^4 \frac{\rho\nu^3}{\sigma} = C_5 \frac{\rho\nu^3}{\sigma} \tag{31}$$

Equation (31) indicates that rL^3 should be independent of the system dynamics and should depend only upon the properties of the liquid. This was quite closely complied with in the results of the laboratory experiments and a value of 6.70 was obtained for C_5.

In order to apply the proposed theory to stream flow conditions it was necessary to establish the relationships between the various stream flow parameters and the factors C_A and C_4. Based purely on judgment, C_A was taken as

$$C_A = 1.0 + 0.3\ F^2 \tag{32}$$

where F is the Froude Number. For the purpose of evaluating C_4, the equations were assembled in the form

$$\frac{K_L'(C_4)^{3/2}}{C_A\sqrt{C_5 D_M \theta}} = \coth\left(\sqrt{\frac{C_5 \psi}{C_4 D_M}}\right)$$

in which

$$\theta = \frac{\rho(\nu E)^{3/4}}{\sigma}$$

and

$$\psi = \frac{\rho\nu^{9/4} E^{1/4}}{\sigma}$$

In these expressions, ρ, ν, σ and D_M are functions of the temperature of the water. E is equal to SUg, where S is the slope of the energy gradient, U is the mean velocity and g is the gravitational constant. With C_5 taken as 6.70, C_A computed from equation (32) and K_L' computed from the logarithmic absorption equation or the oxygen sag equation, C_4 is the only unknown. Although it cannot be expressed as an explicit function of the other variables, the value of C_4 was readily computed for a number of reported stream flow conditions by a process of iteration using a digital computer. Fig. 3 shows the computed values of C_4 plotted against the ratio of $(\nu^3/E)^{1/4}$ to the depth H. The laboratory channel data were reported by Krenkel and Orlob (18),

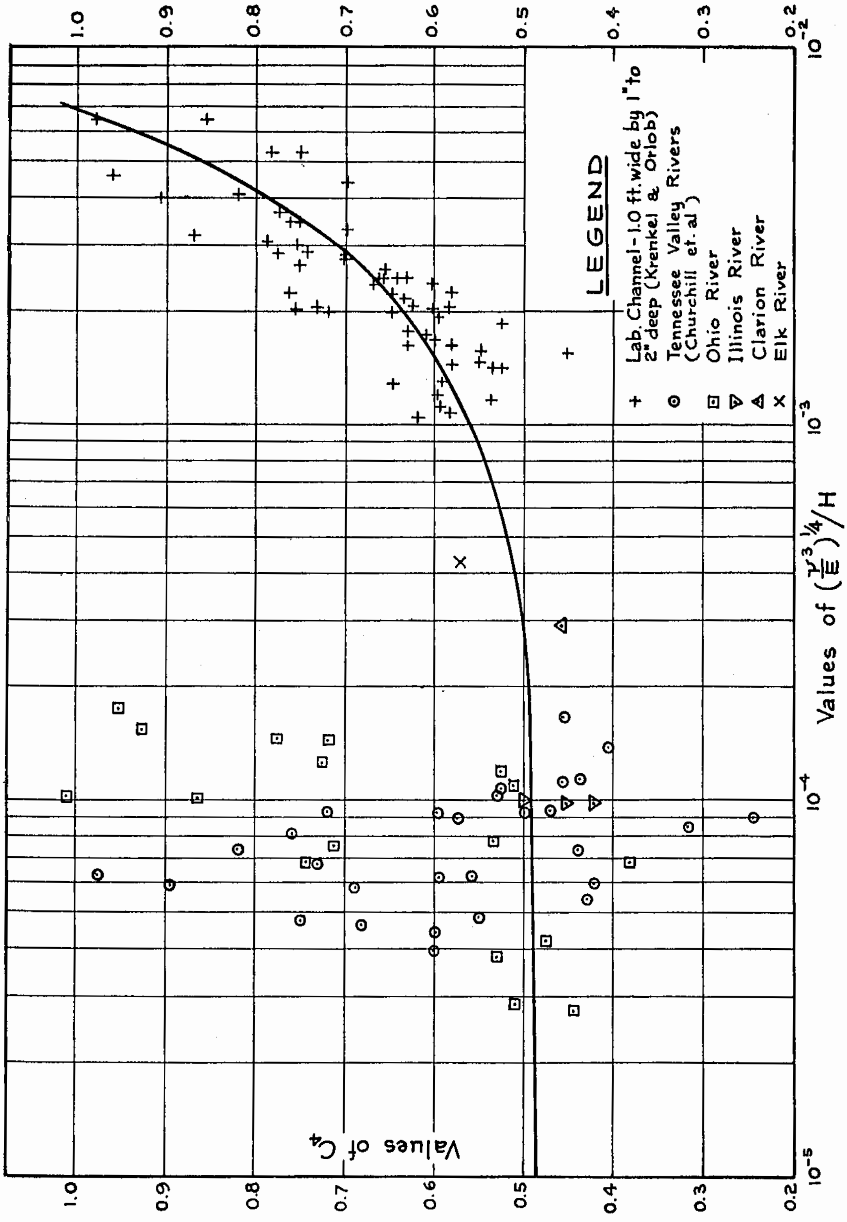
LEGEND
+ Lab. Channel-1.0 ft. wide by 1" to 2" deep (Krenkel & Orlob)
⊙ Tennessee Valley Rivers (Churchill et. al)
⊡ Ohio River
▽ Illinois River
△ Clarion River
× Elk River
Values of C_4
Values of $\left(\frac{\nu^3}{E}\right)^{1/4}/H$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
10^{-2}
10^{-3}
10^{-4}
10^{-5}

FIGURE 3

the data on the Tennessee rivers by Churchill, Elmore and Buckingham (19), and the data for the Ohio and other rivers were previously assembled by O'Connor and Dobbins (20). The curve which is drawn on Fig. 3 can be represented by the equation,

$$C_4 = 0.485 + 75 \frac{(\nu^3/E)^{1/4}}{H} \tag{33}$$

This is actually a linear relationship although it appears as a curve on the semi-logarithmic plot. With C_A from equation (32) and C_4 from

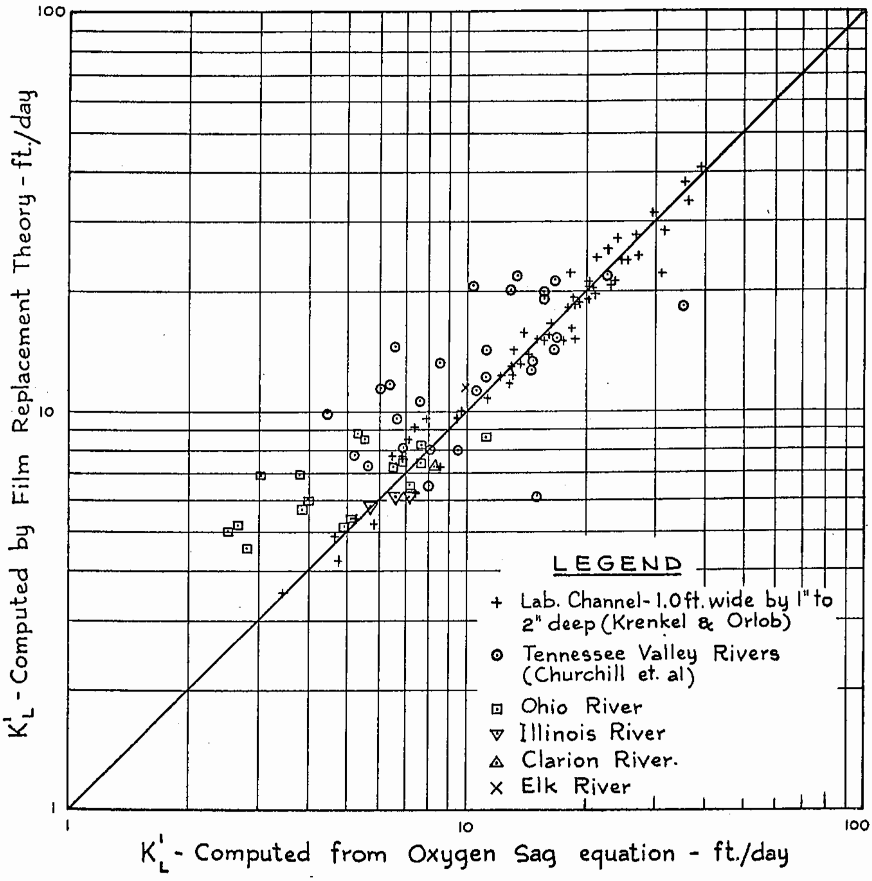

FIG. 4 . OXYGEN ABSORPTION COEFFICIENTS

equation (33) the theoretical values of K_L' were then computed and compared to the reported values, the results being shown by Fig. 4. It is seen that there is excellent agreement between the computed and reported values for the small channel and for the majority of the rivers. For some of the rivers, the predicted values are somewhat greater than the reported values, a fact which can be attributed to the presence of pollutants which are known to reduce the oxygen transfer or to the effect of various conditions which were not taken into account in the field evaluations.

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RELATIONSHIP BETWEEN *ESCHERICHIA COLI*, TYPE I, COLIFORM AND ENTEROCOCCI IN WATER

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(Presented at a meeting of the Sanitary Section, B.S.C.E., on March 3, 1965.)

Introduction

Various methods have been used to evaluate the bacteriological condition of a stream. Total plate counts on gelatin or nutrient agar media will indicate a change in condition in the stream, but do not determine whether this change is a result of fecal contamination. Further, the total plate count does not differentiate between harmless and potentially dangerous bacteria. Another method of evaluation which could be utilized would be to test for pathogens. This would be the most direct method, but suffers from serious drawbacks. The number of different analyses required to test for various pathogens would be sizeable and the test difficult. Secondly, it is still possible that some pathogens may be missed even with a large number of tests. In addition, it is extremely dangerous for relatively untrained personnel to work with pathogenic bacteria.

The most satisfactory method for bacterial evaluation of a water, to date, is through the use of an indicator organism. Ideally, indicator bacteria should be harmless to man, simple to identify, not present in natural water, found only in fecal material, and have a greater survival time in water than enteric pathogens. According to Mallman and Litsky (1), 1951, only two groups of bacteria found in fecal material are suitable as indicators, namely the coliform and the enterococci groups.

At the present time, the coliform group of microorganisms is used as the standard indicator of fecal contamination in this country. In particular, this group has proved satisfactory in the evaluation of potable water. While the coliform group possesses most of the advantages of an "ideal" indicator, it suffers from two serious dis-

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advantages which influence its use in stream pollution work. Members of the coliform group are ubiquitous in nature and may be found naturally on plants and may also be found in the soil. As a result, the presence of the coliform group in water does not necessarily indicate fecal contamination. Secondly, under certain conditions, members of the coliform group may multiply in water.

For many years the enterococci group has been periodically investigated as an indicator of fecal contamination, but until recently, was not thought to be of importance because of difficulty in testing, and their comparatively small numbers in sewage. Recent work, using sodium azide as an inhibitor, has developed a simple test for the enterococci. The results of these studies indicate the group is present in sewage in numbers approaching the coliform organisms. It has also been demonstrated recently that the enterococci do not multiply in water and have a more predictable death rate than the coliform group. At the 61st Annual Meeting of the Society of American Bacteriologists, Heukelekian and Rosenberg (2) stated:

"Until a more specific analysis for *E. coli* is perfected, the enterococcus count appears to be the most easily performed and reliable method for determination of fecal pollution."

Recently, a practical method was developed for rapid determination of the number of *E. coli*, Type I, bacteria present in water (3). As a result of this finding, attention has been focused on the use of *E. coli* as an indicator of fecal contamination.

The purpose of this paper is twofold. First, to establish if a definite relationship exists between these indicator bacteria, and secondly, if these relationships can be used to determine if the source of indicator bacteria is human fecal material.

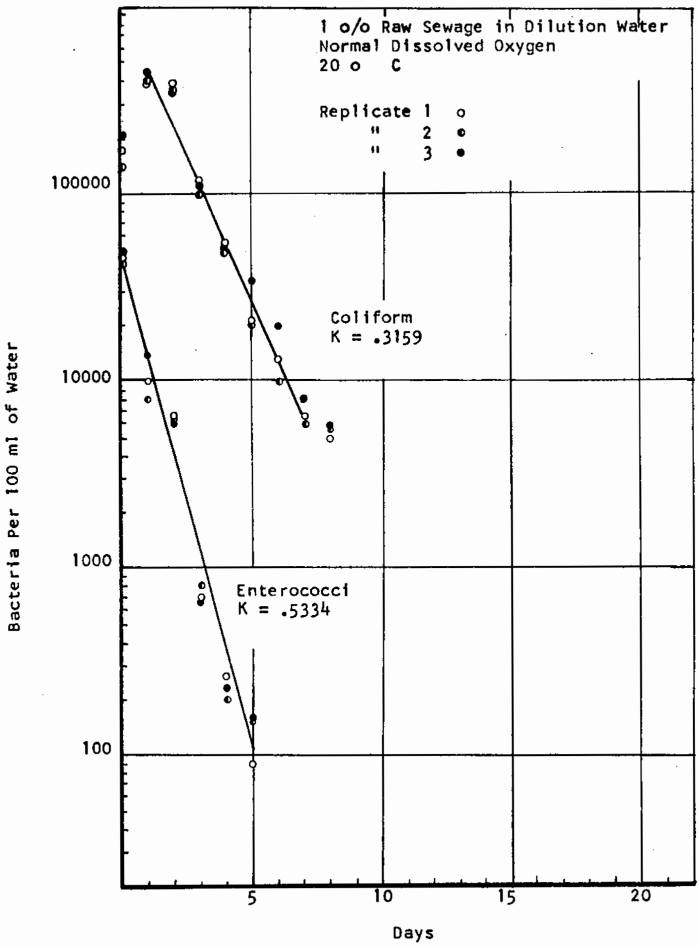
Relationship Between Indicator Bacteria

In the past, several attempts have been made to establish a relationship between the number of *Escherichia coli* in water and the number of enterococci. Of these studies, only two went into the problem with any depth. The first was by Lattanzi and Mood in 1951 (4) where they reported that a straight line relationship exists between *E. coli* and enterococci on coordinate paper. The samples were collected from ten stations in the New Haven, Connecticut, Harbor. A positive correlation of +.70 between these data and the straight line was reported.

The second study was by Litsky, et al., 1955 (5), and reported that a straight line relationship existed between *E. coli* and enterococci on log-log paper. His data showed a positive correlation of +.84. These samples were collected from fourteen stations on the Connecticut River over a period of two years. As a result of these two reports, the question arises which relationship, coordinate or log-log, provides the greater degree of accuracy.

If a point source of indicator bacteria is assumed in a river, which

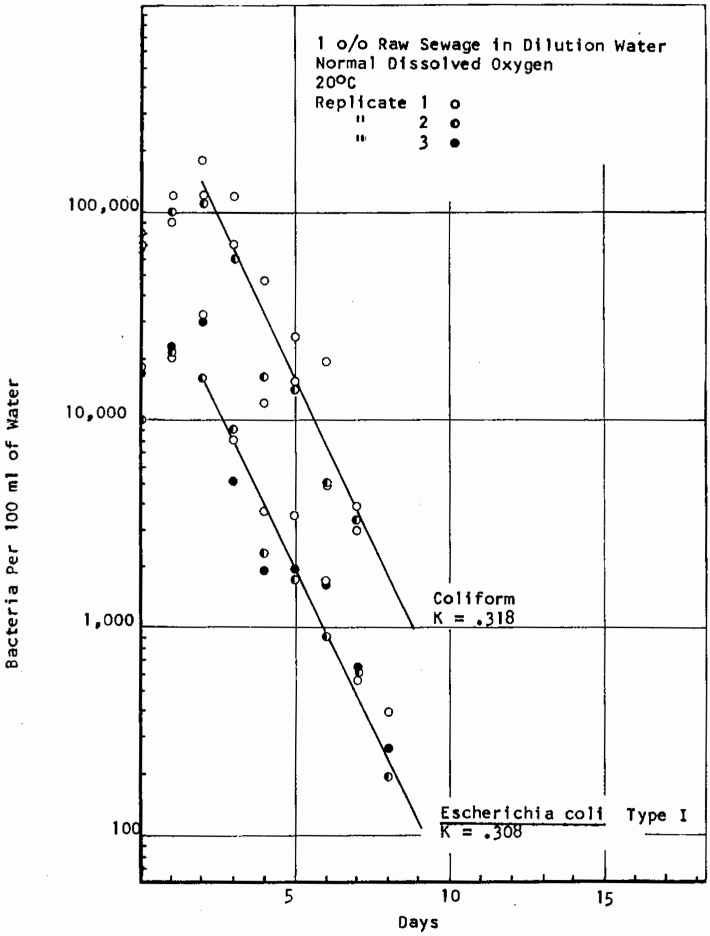
FIGURE I



could be the case, a laboratory study of survival of these bacteria in water would show which relationship would be the most likely to be correct.

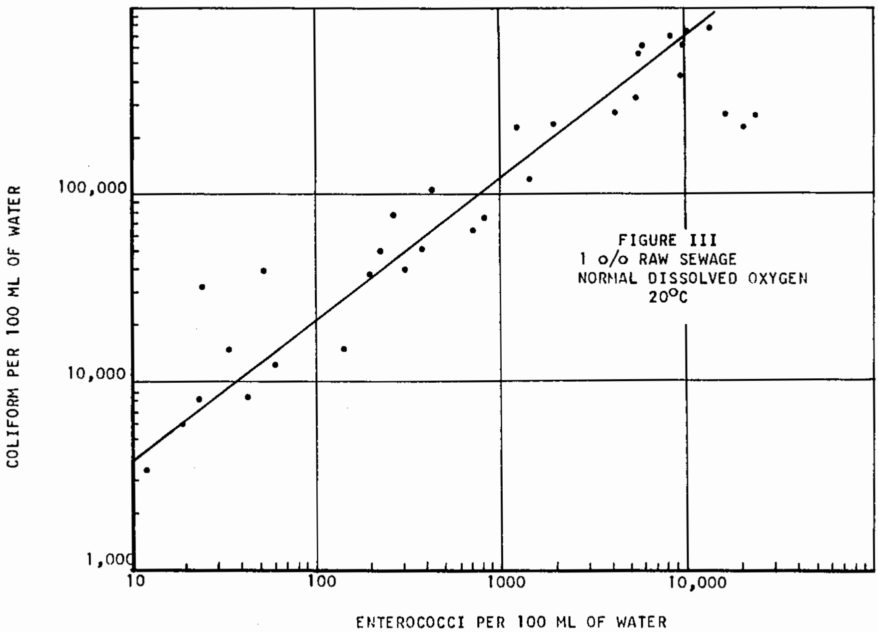
The results of a study of this type by Hanes et al., 1964 (6) indicated that under laboratory conditions the coliform group experiences a period of growth before they go into a death phase while no such period of growth is evident for the enterococci. Also, a well defined logarithmic death phase was demonstrated for both groups of

FIGURE II



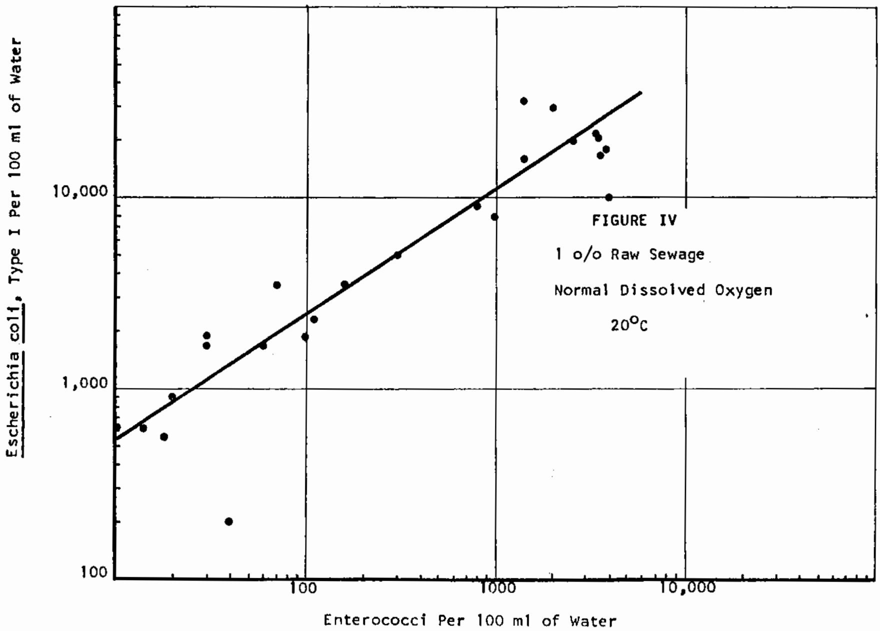
indicator bacteria (Fig. 1). It has since been demonstrated by O'Leary, 1965 (7), that *Escherichia coli*, Type I, demonstrates a survival curve in water that is very similar to that of the coliform group (Fig. 2).

It can be shown, theoretically, that if both the enterococci and the coliform or *E. coli*, Type I, exercise only logarithmic death, that is, their numbers decrease as a straight line on semilog paper, then



when either coliform or *E. coli*, Type I, are plotted against the enterococci on log-log paper, the mathematical relationship would always be lineal. This would not be true when the data is plotted on coordinate paper except for one special case which occurs when the slope of the log-log plot is unity. The data presented in Figs. 1 and 2 have been replotted on log-log paper (Figs. 3, 4) and it can be seen that straight line relationships do exist between the coliform and the enterococci and the *E. coli*, Type I, and the enterococci except during the short period of growth by the coliform and the *E. coli*, Type I. A positive correlation of +.95 was established for the coliform and +.94 for the *E. coli*, Type I, relative to the enterococci.

When Lattanzi and Mood's (4) data is replotted on log-log paper, a straight line may be fitted, under these conditions, by the method of least squares. The correlation coefficient was computed for this plot and it was found to be +.76. This represents a 20 per cent improvement of the estimation over the coordinate plot. This improvement indicates that Lattanzi and Mood's data best fits a straight line on a log-log plot.



It is noted that the positive correlation of the data for both field studies was less than that obtained in the laboratory when plotted on log-log paper. The reason is that under the field conditions studied it is doubtful if a point source of bacteria was present in either study but rather bacteria were entering the river from several sources. As a result, the bacteria from each source were at different points on the survival curves, some being in growth and some in death, giving a greater scatter to the points.

Determination if Source of Indicator Bacteria is Human Feces

Many authors have concluded that the presence of either enterococci or *E. coli*, Type I in water indicates fecal contamination. This may be true, but it must be pointed out that both enterococci and *E. coli*, Type I are present in the feces of many animals whose natural habitats are the drainage basins of our streams. In other words, the mere presence of these indicator bacteria will not tell if a dangerous condition exists from a public health standpoint. For example, Delaney (8) collected some unusual bacteriological samples from Hubbard Brook (Table I). This stream, which drains into the Pemigewasset River, is located near Woodstock, New Hampshire. Stations 1 through 5 are located on the upper reaches of the stream. The watershed in this area is thickly forested and no homes, farms, or summer camps are permitted. A sanitary survey has been made of this area and there are no possible sources of human fecal contamination. If these data for stations 1 through 5, however, are examined in light of the present Massachusetts Bacteriological Standards, stations 1 and 2 could be questioned as a satisfactory bathing area (coliform counts greater than 2400 per 100 ml) and all stations would be questioned as being satisfactory for the taking of market shellfish (coliform counts greater than 70 per 100 ml). Also, in all cases, both enterococci and *E. coli*, Type I were present. From these data it is apparent that counts of these three indicator bacteria alone are not adequate to evaluate a water from a public health standpoint.

Goldreich et al., 1964, (9) reported that a difference in the ratio between fecal coliform and fecal streptococci occurred, depending on the source of the fecal material. He further indicated that when ratios are greater than 2:1, usually this indicates that the pollution was primarily derived from domestic sewage, whereas ratios less than 1:1 indicate the major quantity of pollution was primarily derived from wastes from warm blooded animals other than man, such as stockyard and dairy animals. This study was concerned with bacterial densities in various sewages including a prison dairy.

It is realized that in stream water the ratio between *E. coli*, Type I and enterococci may not remain constant at all times because of the possibility of different death rates for these indicator bacteria. For this reason, it was felt that a more general approach than a ratio was needed to differentiate between human fecal contamination and fecal contamination from other warm blooded animals in water. It seemed reasonable to assume if a water was contaminated with sewage or other fecal material with different *E. coli*, Type I to enterococci ratios, then the linear relationship on log-log paper between these indicator bacteria from the different sources should also be markedly different. This was evaluated by comparing log-log plots of *E. coli*, Type I and enterococci in two streams, one containing no human wastes (Hub-

TABLE I
HUBBARD BROOK BACTERIOLOGICAL DATA
SUMMER 1964

Station	August 12, 1964 Coliform per 100 ml	August 12, 1964 Enterococci per 100 ml	August 12, 1964 *E. coli*, Type I per 100 ml	August 17, 1964 Coliform per 100 ml	August 17, 1964 Enterococci per 100 ml	August 17, 1964 *E. coli*, Type I per 100 ml
1	3,480	1,830	56	290	100	5
2	710	3,360	150	307	110	17
3	1,000	1,530	100	157	57	30
4	2,810	1,130	110	287	173	23
5				347	103	10
6				747	557	316
7	170	450	6	150	30	4

NOTE: The August 12, 1964 samples were collected during a period of increasing stream level following a long drought.

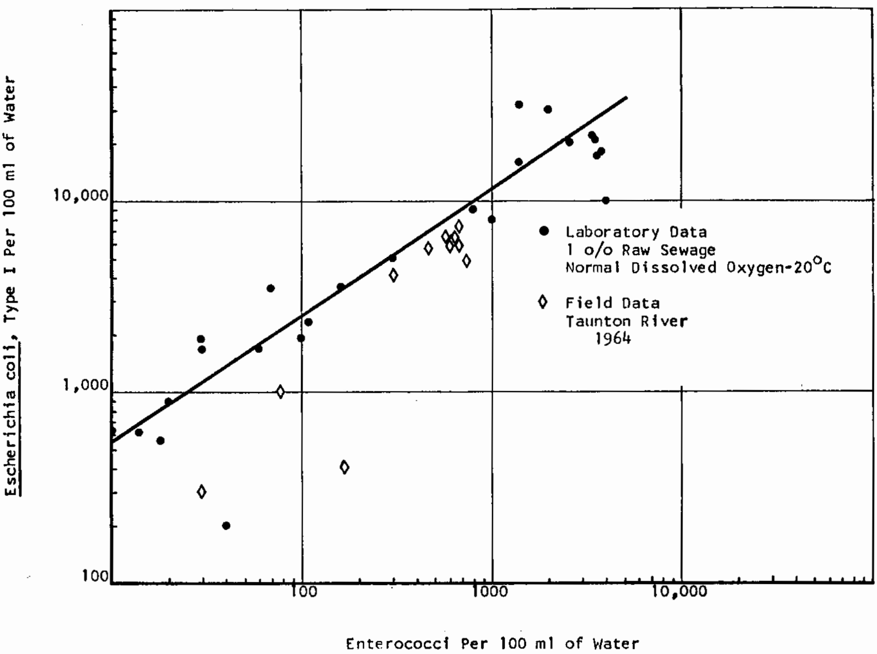
bard Brook) and the other which contained a large amount of domestic sewage (Taunton River). The Taunton River is located in the southeastern part of Massachusetts. At the time the samples were collected (Table II) the Taunton River was receiving a large amount of untreated sewage from the city of Brockton, Massachusetts.

TABLE II
TAUNTON RIVER BACTERIOLOGICAL DATA
February 8, 1964

Station	Coliform per 100 ml	Enterococci per 100 ml	*E. coli*, Type I per 100 ml
1	1,100	30	300
2	2,000	60	
3	1,000	170	400
3a	48,000	750	4,900
4	56,000	650	6,400
5	45,000	690	5,800
6	39,000	680	7,400
7	48,000	580	6,400
7a	4,000	80	1,000
8	36,000	600	6,200
9	36,000	470	5,700
10	28,000	310	4,100

A check was made to determine if the log-log relationship between *E. coli*, Type I and enterococci in the Taunton River represented human fecal contamination. This was done by comparing this relationship to one obtained in the laboratory when biochemical oxygen demand (B.O.D.) dilution water was seeded with domestic sewage. A one per cent dilution was used and bacteriological samples were obtained daily for eight days. It can be seen from Fig. 5 that the Taunton River field data compared closely to the laboratory data, indicating that the indicator bacteria present in the Taunton River were primarily of human origin. A graphical comparison of the relationship between *E. coli*, Type I and enterococci for Hubbard Brook and the Taunton River is presented in Fig. 6. The line labeled "no domestic sewage" passes through the data points from Hubbard Brook. The line labeled "domestic sewage" passes through the data from the Taunton River. Several data points have been plotted between these lines. These points represent waters that receive fecal contamination from both man and other warm blooded animals. Most of them were collected on the Beverly-Salem, Massachusetts Watershed which received a small amount of treated septic tank effluent and one was collected below a boys' camp which has a septic tank on lower Hubbard Brook. It can be seen from Fig. 6, depending on the lineal relationship, that it may be possible to determine if indi-

FIGURE V



cator bacteria found in streams are of human origin and hence whether the water is potentially dangerous to public health or if the indicator bacteria are the result of the natural habitat of the drainage basin. Further studies are underway to confirm these initial findings.

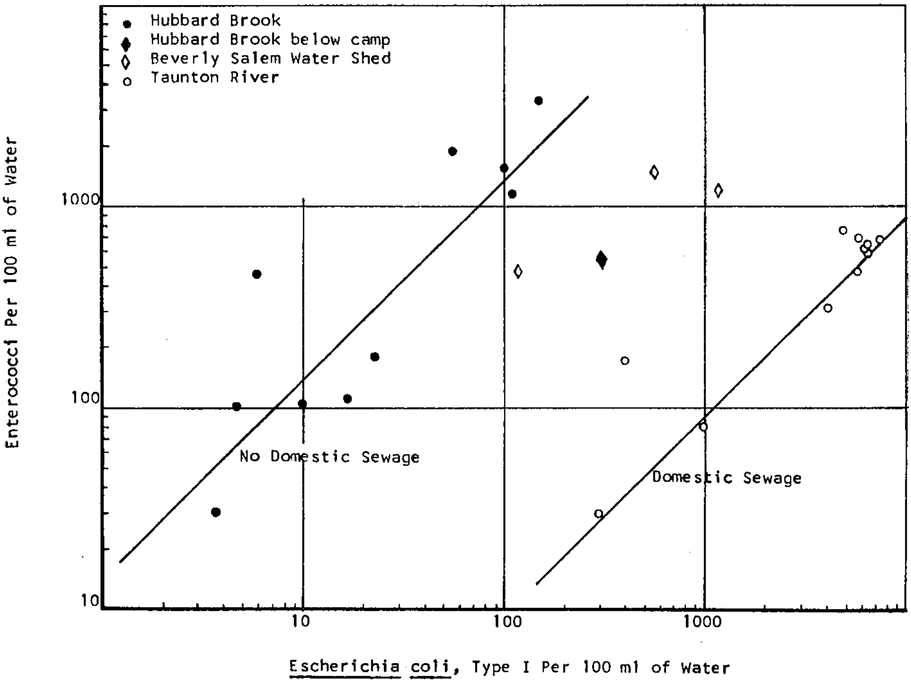
Conclusions

1. The best relationship between enterococci and the coliform group or *E. coli*, Type I will be developed on a log-log plot.
2. A definite equation cannot be developed for the relationship

between enterococci and the coliform group or *E. coli,* Type I because the relationship will vary with the source of contamination.

3. A graphical relationship, such as Fig. 6, between *E. coli,* Type I and enterococci may be used to differentiate between human fecal contamination and fecal contamination from other warm blooded animals in stream water.

FIGURE VI



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SAN FRANCISCO BAY AREA RAPID TRANSIT

BY W. S. DOUGLAS*

(Presented at the Engineers Week Luncheon in Boston, February 24, 1965.)

The San Francisco Bay metropolitan complex covers an area of 7,000 square miles and is the home of 4,250,000 people. In 25 years, its population is expected to grow to 7,000,000 as it expands to fulfill its role of a major port for international commerce and as the regional center of the whole of northern California. The Bay Area is characterized by rugged topography bordering on, and separated by, salt water. On both sides of San Francisco Bay, the major part of the population lives in long and relatively narrow corridors between precipitous hills and the water. These corridors are served by an excellent network of limited access highways which are being extended and improved. Those highways and the city streets, and parking facilities of their terminal areas in San Francisco, Berkeley, and Oakland, are seriously congested with motor vehicles during the morning and evening commuting hours. It has long been apparent to the Bay Area citizens that land does not exist in its narrow corridors for additional limited access highways, nor in its center city cores for massive increases in parking and access facilities sufficient to relieve congestion.

The San Francisco Bay Area Rapid Transit project is conceived of as a bold attack on that congestion. It will provide a regional express mass transportation system which will offer for those travelling to destinations near its stations, speed, comfort, and convenience comparable to that of a private automobile. It is to be integrated with the highway transportation system by generous parking facilities at stations, and by proper facilities for transfer from surface buses and from chauffeur-driven private automobiles. We use the word "chauffeur" in a broad sense to include those devoted ladies who will drive their husbands to and from the stations. The principal role of the transit system will be to serve the intense travel peaks during commuting hours. The initial project, which is now under design and construction, is to serve three counties—San Francisco, Alameda, and Contra Costa. Ultimately, it may be extended to serve all nine counties of the San

* Partner, Parsons, Brinckerhoff, Quade & Douglas, Joint Venturers for Engineering and Construction Management, San Francisco Bay Area Rapid Transit District.

Francisco Bay Area. It is not to be an urban rapid transit system such as we are accustomed to in the east. Its service will be more comparable to that of the commuting railroad. It will traverse, however, the center city cores and give distribution in series of station stops so that the vast majority of its patrons will disembark within short walking distances of their places of employment. The cost of the project is estimated to be $1 billion. Of this amount, authorization for $792 million in general obligation bonds was approved by the voters in November, 1962. The significance of this favorable vote can best be realized when it is understood that the owner of a $16,000 home will have his taxes increased by twenty-six dollars per year. $135 million will be provided by a revenue bond issue backed by the income from tolls of the San Francisco-Oakland Bay Bridge. This amount is allocated to the cost of construction of a Transbay rapid transit tunnel. The two together, the existing Transbay Bridge and the Transbay rapid transit service, will provide, at a cost substantially less than that for a new bridge, a superior service for Transbay travellers. The cost of rapid transit equipment will be met by the proceeds of a revenue bond issue backed by the gross revenues of the rapid transit system. The many hurdles that are interposed during the development of massive public works projects have now been crossed. The public has pledged its endorsement and made adequate funds available, construction of the first elements has already begun, and design of the balance of the system is underway. I shall not, therefore, dwell further today on the history of how this project came about. Rather, I shall speak of the technology which is now mobilized behind it and of the prospects for route and station developments, equipment and operations which the application of that technology will bring about. The thrust of this technology is in many directions.

Its potential for rapid transit progress is being immensely reinforced by a ten million dollar program of test and development which is currently under way and which has been made possible by a very substantial grant of the Housing and Home Finance Agency of the Federal Government. The program is directed toward eight main areas of investigation including train vehicle stability, sound and vibration abatement, propulsion equipment and power supply, transit vehicle trucks, automatic train control, automatic fare collections, and track construction. The first four and one-half miles of the rapid transit project is now under construction and will be completed this spring.

Three laboratory cars are already completed and are being mounted and equipped with the various components and systems proposed by manufacturers. Tests will begin this spring and will in the aggregate comprise a partnership effort of the Federal Government, the Rapid Transit District, we, their engineers, and industry to advance the state of art of rapid transit.

Of first importance in the design of the project has been the mobilization of modern concepts and tools for the creation of segregated and grade-separated rights of way. In downtown areas of the center cities, such rights of way will be in subways. This is not because structures for modern rail transit cannot be made as attractive as those for highways or those proposed for monorail, for instance. It is important to understand that the immense costs of rapid transit of any kind are justified only when there is the need for the movement of large volumes of people. This in turn necessitates trains from 500 to 700 feet in length. The accommodation of such trains requires stations of equal length. Such stations, if elevated, will not be esthetically acceptable over city streets in the narrow canyons that characterize the center city cores. They must be in subways. I do not affirm this in an academic way for we have had considerable experience with public officials, city fathers and property owners and know their uniform convictions in this regard. We agree with them.

In 1900, the founder of my firm, General William Barclay Parsons, was Chief Engineer of the first New York City subway. In the preparation for that undertaking, he visited cities abroad, particularly London, whose subways then were the most modern. They had been constructed at a deep level to avoid conflict with building foundations and utilities. Access and egress from the London stations was generally by elevators or otherwise by very long flights of stairs. General Parsons concluded that the vertical circulation from such a deep subway would throttle its otherwise great inherent capacity. He proposed, therefore, to construct subways near the surface of the ground by the method we have come to know over the years as cut-and-cover. In his day, there were some utilities to cope with and numerous horse-drawn carriages and trolleys to keep moving. Since his day, cut-and-cover has remained the usual method for subway construction, despite the fact that the maintenance of traffic and the handling of utilities has become immensely more complex and costly. Today, a subway could be constructed in an open field unhindered by utilities or traffic for $5 million a mile, and probably less. The construction of the same facility under a city street costs $20 million a mile. This puts the matter in proper perspective. It costs four times the inherent value of a subway simply to build it at a point where contractors must cope with modern traffic and utilities. General Parsons, despite calamitous predictions of many of his time, successfully pioneered cut-and-cover construction. We, his heirs, are with equal vigor, seeking to avoid it. Instead, we propose tunnels. Rapid advances are being made these days in tunnelling techniques in terms of modern shields and tunnelling machines, efficient mucking methods, and economical tunnel linings. We have, for instance, under way in the Bay Area now a test of precast prestressed concrete segmental tunnel linings which give some promise of cost reduction if they prove structurally adequate and watertight. There have been advances in the techniques for cast-iron segmental tunnel linings; prefabricated steel segmental linings may challenge precast concrete in cost.

In the light of the state of the art today, however, we see no alternative to cut-and-cover construction at stations, and have adopted that method for the subway stations of the San Francisco Project Nevertheless, the state of the art is advancing rapidly. Much is being done these days with chemical soil solidification, although current costs of $5 per cubic foot make its wide application impractical. I, for one, am more optimistic about the potential of ground freezing. It is quite likely that in the relatively near future, we shall be able to drive tunnels under city streets economically and create stations by freezing the ground surrounding the tunnels and mining out the necessary space with minimum disturbance to the street and utilities above.

I do not wish to intimate that a tunnel subway system can be constructed as close to the surface as a cut-and-cover system, although with modern methods, it is not necessary to construct them as deep as those in London. There is available today, however, a tool, in the form of the modern escalator, which effectively neutralizes the traditional disadvantage of vertical circulation. Thus, a subway ten to twenty feet deeper than one constructed by cut-and-cover methods can be accepted with equanimity.

The cost of subway construction underneath city streets is disproportionate to the value of adjoining land and buildings, except in the center city cores. Outside of these cores, other means of creating a grade-separated right-of-way must be adopted. One very desirable development is the location of rapid transit in the median strip of freeways where both facilities are serving the same corridor. We have had great cooperation in such planning from the Department of Public Works of the State of California with the result that approximately 13.6 miles, or about one-sixth of the San Francisco system will be located on common rights-of-way with the freeways. Agreements have been worked out so that the Rapid Transit District will reimburse the Department of Public Works for the incremental cost of providing right-of-way for rapid transit. The District will, of course, then pay for the cost of rails and stations, and other transit facilities. The net result is a very effective and economical solution for the Bay Area community.

Along other routes of the project, rapid transit will be elevated. The elevated structure will be simple prestressed concrete box girders or steel box girders supported by center column piers. A great deal of architectural and engineering effort has been expended to insure that the elevated structures will be esthetically pleasing.

Elevated construction is economical, and has been adopted for 31.2 route miles of the San Francisco project. In my opinion, it has an important role in the future. The question is only one of suitable environments. These include industrial areas, alongside railroad tracks, and otherwise in locations where there is at least 100 feet, and preferably 150 feet, between building lines. In the latter case, where such widths are available, elevated construction can be placed in center malls with appropriate landscaping. In such locations, provisions for it should be esthetically acceptable, and as a result of developments I shall describe later, noise will not be objectionable.

I have dwelt at some length on the development of a segregated and grade-separated right-of-way for the rapid transit project because although less dramatic than the equipment, its creation will pre-empt almost three-fourths of the rapid transit capital cost dollar. An important result of the very high costs of such rights-of-way is the financial impracticality of providing more than two tracks along any single route in the San Francisco area. Thus, there cannot be express and local tracks that generally characterize commuting railroads and such major rapid transit systems as, for instance, that of New York City. Without at least three tracks, there cannot be non-stop service, though some trains may skip some stops. The only way to compensate for the necessity of making many station stops is to minimize the length of time required for each and to achieve high speeds in between. This is being done on the San Francisco project by providing sufficient power to accelerate the trains at approximately 3 miles per hour per second, which is about as high as passengers will comfortably tolerate, and to assure balancing speeds of up to eighty miles per hour. By these means, the average rate of progress of the San Francisco rapid transit trains will be between 45 and 50 miles per hour, including time for station stops. These average speeds we consider adequate for reasonable competition with the private automobile.

Rapid acceleration requires high power for propulsion which in turn will result in high system demand during peak travel hours. Unfortunately, in the evening especially, rapid transit peak demand may coincide with the peak hours of public utilities. To minimize power demand, every effort is being made to reduce the weight of the rapid transit cars. The weight of New York City rapid transit cars is 1300 pounds per foot. Recently, new cars for Philadelphia have been so designed as to reduce weight to 890 pounds per foot. The San Francisco rapid transit cars will be approximately 800 to 850 pounds per foot and perhaps a little less. The major opportunity to reduce weight is in the rapid transit trucks.

The laboratory cars of our test program are now being mounted on rapid transit trucks of new designs proposed by several manufacturers, including the Budd Company, the Westinghouse Air Brake Company, the Pullman Standard Company, the General Steel Industries Company, and LFM Manufacturing Company. After extensive testing in actual operation, final specifications will be drawn. It is already clear, however, that a substantial advance will be made in the state of the art of rapid transit truck design.

I would emphasize that we do not seek lightweight for lightweight's sake, nor do we ask you to believe that a Volkswagen is as comfortable as a Cadillac. Our objective is to reduce mass in order to reduce power requirements to accelerate trains at a rapid rate, and in order to reduce wear and tear caused by decelerating trains from high speeds.

The reduction of weight to the level which I have just described brought an unexpected problem—the stability of rapid transit cars due to wind loads and other dynamic conditions. A contract was let to Stanford Research Institute of Palo Alto, California, to investigate these phenomena. They have done so in the wind tunnel of the Lockheed Aircraft Company. Their conclusion is that for safety and stability, the cars we propose must have wider than ordinary gauge. Their original recommendation was for a gauge of six feet. In reaching a final decision, many other factors came into play. The gauge adopted is 5½ feet which will insure safety and stability, and a better ride for the passengers. It should be kept in mind that the San Francisco project involves a completely new system and does not need to be compatible with any existing rails.

Stanford Research Institute has also assisted in a vigorous search for methods to reduce noise. Their conclusion is that the best way to reduce noise is to prevent it at its source. They have worked intimately with the car builders. Many of the recommendations have concentrated on the mounting of the various elements making up a rapid transit truck. The trucks which will be tested this spring include a variety of rubber mounting to an extent not heretofore used. (See Fig. 1.)

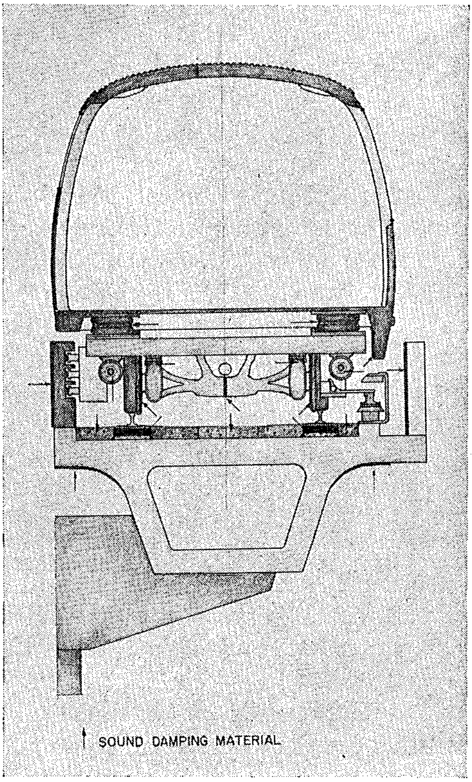

FIG. 1

Strategic locations for sound damping material are indicated in this sketch—one of the many considerations in the design of car and rails.

Attention is also being given to the reduction of noise originating at the wheel rail contact point. Our program includes the installation of elastomeric rail pads, the possible use of acoustical concrete on the roadbed, absorption material on parapets installed along the side of the cars, and suitable material under aerial structures to reduce the transmission of noise from that particular path. At subway stations, a curtain wall between the station passenger and the rapid transit cars is under very active consideration. Such a barrier wall, if it proves practical, will have many advantages. It will insulate the passenger from the noise of approaching trains; it will protect the passenger from being pushed off the station platform; it will improve circulation along the platform because of that protection; it will make possible better control of temperature and humidity in the stations; and it will prevent the accumulation of trash on tracks. The concept of a barrier wall in subway stations, however, introduces various problems, including the accurate positioning of trains in stations so that rapid transit car doors and doors in the barrier wall will match. This and other related problems can only be evaluated on the test track.

Truck performance and noise control depend not only on equipment design but on track and structure also. For the test tracks, rails will generally be mounted on wood ties on ballast. Certain parts of the test track will be on prestressed concrete ties and one part on a continuous concrete slab. Certain of the bridges of the test track are being constructed of prestressed concrete box girders, and others of welded steel box girders similar to those to be adopted for aerial construction. These will be instrumented to measure both noise and stress levels.

The test program has also become of the essence in designing the power system. It is interesting to know that power input will approximate 1,000 k.w. per 70 foot long car during acceleration and 150 k.w. per car at 75 miles per hour. The use of an overhead catenary is not practical for the San Francisco system due to the close clearances in the subway tunnels and the Transbay Tube, and otherwise because of its awkward appearance on elevated structure or at grade. The investigation of power systems has accordingly been confined to third rail. The initial investigations for power included three-phase and single-phase alternating current systems from 600 volts to 4,160 volts, and direct current systems from the traditional 600 volts to 3,000 volts. Of these, the two that show most promise are the three-phase 4,160 alternating current system and the 1,000 volt direct current system.

Both are to be installed on the test track and both exhaustively tested. Little need be said about the potential utilization of direct current. The utilization of three-phase alternating current would be a major innovation in rapid transit power supply. Contracts for the development of both alternating current and direct current propulsion systems of the size and performance required have been let. The alternating current systems require investigations in many areas. The incentives to undertake such investigations are the possibility of lower distribution cost, the possible use of regenerative braking, the reduction of cathodic protection requirements, and the reduction of propulsion equipment weight and the improved propulsion controls needed for automatic train control.

Perhaps that facet of our design test program which is eliciting most interest is the development of a train control and communication system. It is essential that a control system be highly refined and fully integrated for the San Francisco Bay Area Rapid Transit system. This system will provide all aspects of control and operation which heretofore had been considered separate operations in a rapid transit system. Their integration into a single system may be one of the more significant developments of this rapid transit system. The system will provide several inter-related functions. It will provide in the first place for train protection and will function to prevent collision and derailment. It will maintain safe operation for trains running on the same track. Trains will be protected from overspeeding downgrades and around curves of short radius.

In its second function, the train control system will provide for line supervision and will automatically dispatch trains at terminals of origin and along the lines. In its third function, the train control system will provide for automatic train operation and will function to move trains automatically without an operating crew under all normal conditions. Automatic train operation will achieve selective rates of acceleration, deceleration, and maximum speed in accordance with a proposed speed limit. Trains will make station stops and will operate their doors automatically. There will be an operator at the head of each train to override the automatic controls in the event of his observation of any interference on the track ahead and for such other duties as experience on the test track may indicate.

A communications system will provide for voice communication between the central dispatcher and the trains, for the announcement of train arrivals and departures, and on the station platforms for public address by the central dispatcher. Contracts have been awarded to the General Electric Company, the General Railway Signal Company, the Union Switch and Signal Division of Westinghouse Air Brake Company, and the Westinghouse Electric Company for the demonstration on the test track of systems which they propose to fulfill these purposes. Each company is confident that the system which it will install and test will fulfill the requirements I have just noted.

The purposes of automatic train control should be fully understood. It is not fundamentally a labor-saving program, although reduction in the cost of transit operation will be necessary for its survival or revival. What is more important is that such controls will be necessary for maximum safety, taking into account the high speeds and short headways at which the system will ultimately operate.

I would conclude this review of the technical aspects of the San Francisco project by telling you of the plans and program for the automated fare collection. I cannot over-emphasize the importance of this phase of our program. One of the real handicaps in mass transit has been the single level fare which brings to the transit operator the same reward for short trips as for long trips. The single level fare discourages operations to reach out beyond the thickly populated areas and is the cause of many transit deficits. The proper economic functioning of the San Francisco system will require separate station-to-station fares, the collection of which is simply not practical by traditional methods of fare collection. In studying this problem, our findings to date indicate that it will be possible to install a fare collection system around advanced electronic mechanical concepts and meet system requirements for station-to-station fares. No special difficulties are visualized for those travellers who will want to pay in cash for a single trip. Such passengers would purchase a minimum fare ticket through an automatic vending machine, and use it to activate a turnstile for admission to the system and relinquish it at the exit gate of the station of discharge. Electronic instrumentation in the exit gate would check every ticket, reading the station of origin and almost simultaneously determining if the fare paid were sufficient. If in order, the ticket would trigger the release mechanism. If not, it would activate a device advising the rider what to do. Both the entry and exit gates would operate rapidly, processing and returning the ticket faster than the hand could move from insert slot to recovery slot. There will, however, be many passengers who will want to pay for a number of trips in advance. One concept is that such a traveller will purchase a plastic wallet-size card, on which will be a magnetic coding of stored fare of up to $20, depending upon the purchaser's outlay. After each trip, the value of the ticket will be reduced, in both the machine-readable encoding on the back and in a visible imprinting on the front. This accounting would be accomplished by the gates at both entry and exit. The entry gate would read the value of the ticket and record the name of the station entered and the time of entry. The exit gate would compute the cost of the completed trip, erase the old value and imprint the new residual value. The gates processing such a ticket will have to prove highly flexible and completely reliable. The electronic computer mechanisms required may be located in each of the gates or at central locations in the stations. At the present time, contracts have been let to several companies for the development of alternative hardware for the various components of such a fare collection system. After a final selection is adopted, a trial installation will be made in the Cleveland Transit System in Cleveland, Ohio.

A final word may be of interest concerning the design and functioning of the body of the rapid transit car itself. A contract has been let to a joint venture of Sundberg-Ferar industrial designers, and the St. Louis Car Company to develop the design beginning with sketches of all possible ideas, progressing through models at various scales for the most promising configurations. Ultimately, a full-scale mockup of one half a car will be constructed. Many presentations at the different points in the design process have been made to the members and staff of the Rapid Transit District and to interested car builders. The District has approved a design for a final full-scale mock up. Car widths will be about 10½ feet. Fenestration has been carefully worked. Interiors will be bright, clean, comfortable, and easy to maintain. Plans for air conditioning involving the introduction of conditioned air under the windows have been worked out for us by a Los Angeles firm who are well known for their designs for air conditioning for airplanes.

The objectives of the San Francisco project are clear. They are simply to provide comfortable, high-speed, public transportation serving the principal corridors of the region which will deliver a major proportion of home-to-work travellers, and others also, to within convenient walking distances of their destinations, with comfort and at speeds comparable to that available by private automobile.

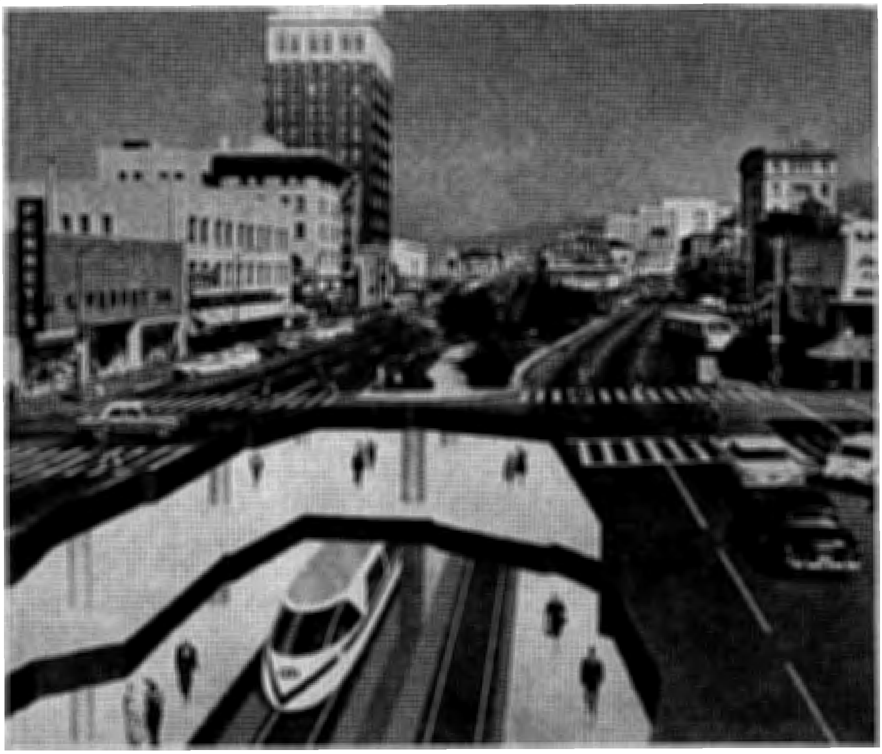

FIG. 2.
The proposed Bay Area Rapid Transit system will provide for a subway beneath Shattuck Avenue in Berkeley, with a station located just south of University Avenue. As depicted in the above photo-rendering, the two-level subway station will provide direct delivery to downtown Berkeley and the University of California, with feeder bus lines, as shown, also making a direct station connection. Assured peak-hour rapid transit travel times to and from the downtown Berkeley station include Richmond, 10 minutes; Broadway and 19th, Oakland, 7 minutes; 77th Avenue, Oakland, 15 minutes; San Leandro, 18 minutes.

Bay Area Rapid Transit Photograph

The engineering goes forward in an orderly, and yet to us, an exciting way. Because of the long lead construction time of major physical features, and the availability of funds, the design engineering is being supplemented by the comprehensive test and development program which permits designers to work on the frontiers of today's technology without gambling on the untried.

The human relations aspect of the project goes forward apace and in point of fact, is more exciting than the engineering. We are playing for keeps now. Routes and station locations, architectural design, landscaping, all have their impact on the welfare and lives of thousands and thousands of people. Having come to understand it, their ambitions are being pressed upon the Rapid Transit District with skill and persistence by their various political and other representatives. The reconciliation of such ambitions with each other, where they conflict, and with the project itself where cost control must be exerted, is a major job in public relations, skillfully conducted by the members of the District, their President, Mr. Adrien Falk, and their General Manager, Mr. William B. Stokes. As their engineers, we are bound to be projected into the thick of the fray; our head is bloody, but unbowed.

So, as I conclude this afternoon, let me invite you all to come out to the test track this summer in the hopes that perhaps you may witness in progress significant advances in the technology of public transportation.

EMIL A. GRAMSTORFF

EMIL ANTON GRAMSTORFF
1892-1964

"No bubble is so iridescent or floats longer than that blown by a successful teacher." Sir William Osler.

Emil Anton Gramstorff was born in Everett, Massachusetts on April 23, 1892, and received his early education in the Everett Public Schools and later at the Chauncy Hall School in Boston. He earned the Bachelor of Science degree in Architectural Engineering at the Massachusetts Institute of Technology in 1917 and later received the M.S. in Civil Engineering from the same institution.

During World War I Grammy saw service as a Lieutenant in the United States Naval Reserve. Following discharge, he was superintendent of construction for a private engineering firm in Boston.

He accepted an appointment to the faculty of Northeastern University as an instructor in civil engineering in September 1921 and thus began a long career of distinguished teaching. No bland personality, Professor Gramstorff generated many emotions among his students but never indifference. He knew what he knew and deeply wanted his students to want to know. He sternly demanded a great deal from his students and expected them to rise to his level. Woe to the student who didn't respond, for Grammy had many ingenious ways to prod a reluctant student to begin to climb. Along with this, he had the gift of wisdom in counselling and an infinite capacity for friendship.

Professor Gramstorff served with distinction as Chairman of Department from 1939 to 1954 when he was made Dean of the Graduate Division of the College of Engineering. Under his direction the division expanded its offerings, flourished and reached its present position of influence in the community. With his retirement in 1962, he ended more than forty years of dedicated service to the University.

He served his profession admirably as president of the Boston Society of Civil Engineers and through chairmanship and membership in innumerable committees of the American Society of Civil Engineers, the American Society for Engineering Education and the American Society for Testing and Materials.

He served his community unstintingly as a member of the City of Boston Planning Board, the Massachusetts Scientific Advisory Committee on Selective Service, in Civil Defense, and many other areas.

On September 1, 1964, he closed a long life of duty, devotion and dedication.

He leaves his wife, Pauline (Manning) Gramstorff; three daughters, Mrs. Howard (Catherine) Munday of Topsfield, Mrs. Clinton (Jane) Gove of Northfield, and Mrs. E. Henry (Ann) Anderson of Andover; and nine grandchildren.

The quality of a man is not to be judged by a chronological list of events, or honors, or distinguished posts or outstanding deeds. The quality of a man is best judged by his impact on society and, if he happens to be a teacher, by his impact on eternity. Gram will be remembered as he would have wanted, as a loving husband, a devoted father and an inspiring, dedicated teacher.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

JANUARY 27, 1965:—A Joint Meeting of the Boston Society of Civil Engineers with the Metropolitan Chapter, Society of Professional Engineers and the Massachusetts Section of the American Society of Civil Engineers was held this evening at Arthur D. Little Company, Cambridge, Mass., and was called to order at 8:40 P.M., by President John J. Cusack, Metropolitan Chapter, Society of Professional Engineers.

President Cusack called upon Past President John F. Flaherty to conduct any necessary business for the Boston Society of Civil Engineers at this time.

Past President Flaherty stated that the reading of the Minutes of the previous meeting held December 16, 1964 would be published in a forthcoming issue of the Journal and that the reading of those Minutes would be waived unless there was objection.

Past President Flaherty called upon the Secretary to announce names of applicants for membership in the Boston Society of Civil Engineers.

Past President Flaherty requested the Secretary to present a recommendation of the Board of Government to the Society for action. He stated that this matter was before the Society in accordance with the provisions of the By-Laws, and that notice of such action was published in the ESNE Journal dated January 18, 1965.

Secretary Charles O. Baird, Jr., presented the following recommendation of the Board of Government to the Society for action to be taken at this meeting.

MOTION "to recommend to the Society that the Board of Government be authorized to transfer an amount not to exceed $6,000 from the Principal of the Permanent Fund to the Current Fund for Current Expenditures."

On MOTION duly made and seconded it was VOTED "that the Board of Government be authorized to transfer an amount not to exceed $6,000 from the Principal of the Permanent Fund to the Current Fund for Current Expenditures."

Past President Flaherty stated that this was the final action on this matter and turned the meeting back to John J. Cusack, President, Metropolitan Chapter, Society of Professional Engineers, who introduced the guest speaker of the evening, Floyd E. Dominy, Comm. Bureau of Reclamation, Department of the Interior, who gave a most interesting talk on "Glen Canyon."

One hundred ninety members and guests attended the dinner preceding the meeting and 250 members and guests attended the meeting.

The meeting adjourned at 10:15 P.M.

CHARLES O. BAIRD, JR., *Secretary*

FEBRUARY 17, 1965:—A Joint Meeting of the Boston Society of Civil Engineers with the Transportation Section was held this evening at the Society Rooms, 47 Winter Street, Boston, Mass., and was called to order at 7:00 P.M., by President William A. Henderson.

President Henderson stated that the Minutes of the previous meeting January 27, 1965 would be published in a forthcoming issue of the Journal and that the reading of those Minutes would be waived unless there was objection.

President Henderson announced the death of the following member:

David M. Brown, elected a member May 20, 1942, who died January 26, 1965.

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership February 17, 1965:

Grade of Member—Robert H. Burrage, Jr., William S. Franz, David B. Goldstein, John P. Hartman,* Ralph A. Kohl, Domenic V. Tutela*
Grade of Junior—Stanley I. Bornstein, Walter W. Massie

President Henderson stated that this was a Joint Meeting with the Transportation Section and turned the meeting over to Ernest A. Herzog, Chairman of that Section to conduct any necessary business of the Transportation Section.

Chairman Herzog introduced the speaker of the evening, Oscar Bakke, Director, Eastern Region, Federal Aviation Authority, who gave a most interesting talk on "Coordinated Transportation."

A discussion period followed the talk.

* Transfer from Junior.

39 members and guests attended the meeting.

Meeting adjourned at 8:50 P.M.

CHARLES O. BAIRD, JR., *Secretary*

MARCH 18, 1965:—The 117th Annual Meeting of the Boston Society of Civil Engineers was held today at the Hotel Vendome, 160 Commonwealth Avenue, Boston, Mass., and was called to order at 4:00 P.M., by President William A. Henderson.

President Henderson announced that the reading of the Minutes of Society meetings had been omitted during the year. The Minutes of the January and February meetings will be published in a forthcoming issue of the Journal. The Minutes of the April, May, Oct., Nov., and December meetings to be declared approved as published.

It was VOTED "to approve the Minutes as published."

The Secretary announced the names of applicants for membership and that the following had been elected to membership March 16, 1965:

Grade of Member—Francis M. Knight, William R. Langrill, Paul D. Guertin.*

The Annual Reports of the Board of Government, Treasurer, Secretary and Auditors were presented. Reports were also made by the following committees:—Hospitality, Library, John R. Freeman, Subsoils of Boston, Membership, Joint Legislative Committee, Education Committee.

It was VOTED "that these reports be placed on file."

The Annual Report of the various Sections were read and it was VOTED "that the Annual Reports of the various Sections be placed on file."

* Transfer from Junior.

President Henderson stated that all foregoing reports would be published in the April, 1965, issue of the Journal.

The Report of the Tellers of Election, Charles A. Parthum and Max D. Sorota was presented and in accordance therewith the President declared the following had been elected Officers for the ensuing year.

President,	Leslie J. Hooper
V-President,	Harry L. Kinsel
Secretary,	Charles O. Baird, Jr.
Treasurer,	Paul A. Dunkerley
Directors	Robert H. Culver
	Myle J. Holley, Jr.
Nominating Committee,	Percival S. Rice
	Marcello J. Guarino
	James P. Archibald

The retiring President William A. Henderson then gave his address entitled "Whither the Boston Society of Civil Engineers?"

Sixty members and guests attended the business meeting.

The meeting adjourned at 5:20 P.M., to re-assemble at 7:00 P.M., The Social Hour and Annual Dinner being held during the interim.

President Henderson called the meeting to order at 7:00 P.M.

Following general remarks and the introduction of the newly elected President, Leslie J. Hooper, and other guests at the head table, President Henderson announced that Honorary Membership in the Society has been conferred on four of the Society's distinguished members, in accordance with the vote of the Board of Government on February 1, 1965.

The Secretary announced the names of the newly elected Honorary Members and asked them to come forward:

Arthur Casagrande, Harry P. Burden, Ralph W. Horne, Frederic N. Weaver.

President Henderson presented the newly elected Honorary Members with certificates of Honorary Membership which read as follows:

"Author, Lecturer, Professor, World Wide Consultant, he has contributed unsparingly of his time and effort to place before the Engineering Profession the Theory and the Practice of Soil Mechanics. In recognition of his service as an Engineer and as Past President of this Society

ARTHUR CASAGRANDE
has been duly elected an
Honorary Member
By direction of the Board of Government
February 1, 1965"

WILLIAM A. HENDERSON, *President*
CHARLES O. BAIRD, JR., *Secretary*

"As Professor and Dean, he has had a long and distinguished career in the art of formative Education in the field of Sanitary Engineering. For his untiring devotion as a Student Adviser and as Past President of this Society

HARRY POOLE BURDEN
has been duly elected an
Honorary Member
By direction of the Board of Government
February 1, 1965"

WILLIAM A. HENDERSON, *President*
CHARLES O. BAIRD, JR., *Secretary*

"He has attained outstanding achievements in the Field of Sanitary Engineering as a practicing Consultant, and has set an example for young engineers to follow. He has given freely of his talents to Philanthropic and Governmental Agencies and to this Society as Past President

RALPH WARREN HORNE
has been duly elected an
Honorary Member
By direction of the Board of Government
February 1, 1965"

WILLIAM A. HENDERSON, *President*
CHARLES O. BAIRD, JR., *Secretary*

"An Engineer's Engineer, a Teacher's Teacher, but most revered as a Student's Professor he has given devoted and untiring service to the Profession and to this Society as Past President

FREDERIC NIXON WEAVER
has been duly elected an
Honorary Member
By direction of the Board of Government
February 1, 1965"

WILLIAM A. HENDERSON, *President*
CHARLES O. BAIRD, JR., *Secretary*

President Henderson announced that in June, 1964, the Society received $3,000 from the Directors of Fay, Spofford & Thorndike, Inc., to create a Fund to be called the "Ralph W. Horne Fund," the income from which shall be devoted in part to a prize or certificate to be awarded annually to a Member of BSCE selected by a committee, as having been outstanding in unpaid public service in Municipal, State, or Federal elective or appointive posts; or in Philanthropic activity in the public interest.

On recommendation of the Special Ralph W. Horne Fund Committee the Board of Government voted to approve recommendation of the committee, namely, that Charles O. Baird, Jr., be the first recipient to receive this Award. President Henderson presented the certificate which read as follows:

"RALPH W. HORNE FUND
AWARD
BOSTON SOCIETY OF
CIVIL ENGINEERS

CHARLES O. BAIRD, JR.

Engineering educator who has given unstintingly of his time and wisdom in unpaid public service and in philanthropic activity, has been selected by the Boston Society of Civil Engineers, by unanimous action of its Board of Government, as the first recipient of the Ralph W. Horne Fund Award, and this certificate is proudly presented to him."

March 18, 1965
William A. Henderson, *President*

President Henderson stated that a number of prizes were awarded annually for worthy papers presented at the Society and Section meetings and also Scholarship Awards. The Secretary read the names of recipients and asked them to come forward and President Henderson presented the following awards and Scholarships (see p. 161):

President Henderson then introduced the guest speaker of the evening, Father Daniel Linehan, S.J., Director of Weston Observatory, who gave a most interesting illustrated talk on "Ancient Civilization of the Incas in Peru and Adjacent Areas."

At the conclusion of the talk, President Henderson turned the meeting over to President-elect, Leslie J. Hooper.

President Hooper presented retiring

Award	*Recipient*	*Paper*
Letter of Commendation	Karl R. Kennison	"The Wanderings of the Center of Gravity"
Desmond FitzGerald Medal	Keistutis P. Devenis	"Proposed Dam, Navigation Locks, and Flood Control Pumping Station for the Mystic River Basin"
Clemens Herschel Award	Harry M. Horn	"The Analysis and Design of Antenna Tower Foundations"
Sanitary Section Award	Paul W. Prendiville	"Proposed Pollution Control for the Merrimack River"
Hydraulics Section Award	Ronald T. McLaughlin Lawrence C. Neale	"Prototype Simulation" "Flow Measurements"
Desmond FitzGerald Scholarship	Richard A. Easler of Northeastern University	
William P. Morse Scholarship	Allen B. Potvin of Tufts University	

President William A. Henderson with a certificate of appreciation for services rendered.

Two hundred twenty-seven members and guests attended the dinner and meeting.

The meeting adjourned at 10:00 P.M.

CHARLES O. BAIRD, JR., *Secretary*

CONSTRUCTION SECTION

JANUARY 6, 1965:—A regular meeting of the Construction Section was held this date at the Society Rooms.

The meeting was called to order at 7:15 P.M., by Chairman Leonard Tucker. The Section business included only the election of officers for the upcoming year as follows:

Chairman,	Herman G. Protze
Vice-Chairman,	Robert J. Van Epps
Clerk,	William E. Wiley

The speaker of the evening was Mr. Christopher J. Murray, Jr., Supt., George A. Fuller Co., Inc. who talked on the subject of "Construction of the Behavioral Science Building at Harvard University." The talk was excellently illustrated by a multitude of color slides. The building structure essentially comprised exposed quartz aggregate concrete and exposed prestressed concrete. The only poured-in-place concrete above ground is in the structural columns inside the exposed aggregate column liners, made tight with mortar.

A432 reinforcement was employed and was made continuous by butt-welding. Welding consumed 180 hours per floor for reinforcement and 100 hours per floor for structural steel. Scheduling of welding with CPM controlled.

Foundations were placed at a rate of 165 cu. yds. per hr. whereas the top story concrete was deposited at the rate of 2 cu. yds. per hr.

The derrick was 220 ft. high, and a crane was used as a supplement. Cost of derrick was $700 per day. Safety was maintained via dual telephone lines to operator.

The construction utilized a phenomenal amount of scheduling to have the precast, prestressed and poured-in-place concrete at the correct place at the right time. The column concrete comprised 4500 psi H.E.S. mixture + 1½% calcium chloride. Staging was cantilevered out from floors below to avoid need of scaffolding the entire building. Only 2 broken stones occurred on the entire job.

The excellent paper was enthusiastically received. The meeting adjourned at 8:30 P.M. Forty-three members and guests were present.

William E. Wiley, *Clerk*

March 24, 1965:—A regular meeting of the Construction Section was held on this date at the Society Rooms.

The meeting was called to order at 8:05 P.M. by Chairman Herman Protze.

The report on the previous meeting was accepted as read.

The speaker of the evening was Mr. Herbert M. Priluck, Construction Planning Consultant, who spoke on "Critical Path Scheduling in Building Construction."

It was first observed that the critical path method is not a panacea but can be a powerful tool when thoughtfully used to plan, schedule, and control the development and construction of a building project. He then illustrated the basic mechanics of CPM by scheduling a simple drainage structure on the blackboard. Based on his observations in applying CPM on building projects as a consultant to New England contractors and engineers, he discussed some of the concepts and misconceptions involved in the use and possible abuse of the critical path. A brief exhibit and explanation of networks and computer outputs actually used on several jobs concluded the talk.

The meeting was adjourned at 11:00 P.M.

Sixty-nine members and guests were present.

William E. Wiley, *Clerk*

HYDRAULICS SECTION

February 19, 1965:—The Annual Meeting of the Hydraulics Section of the Boston Society of Civil Engineers was held in the Society Rooms, 47 Winter Street, Boston, Massachusetts and was called to order at 7:15 P.M. by Chairman Keistutis P. Devenis.

The reading of the minutes of the previous meeting was dispensed with and the report of the Nominating Committee was read by the Chairman, Richard F. Dutting. The motion carried to close the nominations and the Clerk was ordered to cast a unanimous ballot for the slate. The following officers were elected to serve for the coming year:

Chairman, Peter S. Eagleson
Vice-Chairman, Nicholas Lally
Clerk, Allan Grieve
Executive Committee,
Anthanasios A. Vulgaropulos
Ronald T. McLaughlin
Stephen E. Dore

Mr. Devenis introduced the speaker of the evening, Mr. Lyle E. Branagan, Hydraulic Engineer, Chas. T. Main, Inc. Mr. Branagan spoke on "Vortex Investigations of a Submerged Intake at Cornwall Pumped Storage Plant." His remarks were confined primarily to the results of model testing conducted at the Alden Hydraulic Laboratory to determine a design that would prevent the drawdown of air into the submerged intake at the upper pool. His conclusions were that a satisfactory empirical design has been developed, however, there is still much to learn about the causes and actions of vortexes.

The meeting had an attendance of 20 members and adjourned at 8:45 P.M.

NICHOLAS LALLY, *Clerk*

SANITARY SECTION

MARCH 3, 1965:—The annual meeting of the Sanitary Section was held on this date in the Society rooms, following a dinner at the Smorgasbord. The officers elected for the coming year are as follows:

Chairman, William C. Traquair
Vice Chairman, Robert L. Meserve
Clerk, Walter M. Newman
Executive Committee,
Charles A. Parthum
Allison C. Hayes
David Duncan

Speaker for the meeting was Dr. N. Bruce Hanes, Assistant Professor of Civil Engineering, Tufts University, who presented an interesting illustrated paper entitled "Relationship Between *Escherichia coli,* Type I, Coliform, and Enterococci in Water." Dr. Hanes was accompanied by graduate students C. O'Leary and G. P. Delaney who assisted in the preparation of the paper. Attended by 35 members and guests, the presentation was well received and actively discussed. It will be published in a forthcoming issue of the Journal.

ROBERT L. MESERVE, *Clerk*

STRUCTURAL SECTION

JANUARY 13, 1965:—A regular meeting of the Structural Section was held on this date in the Society rooms and was called to order by the Chairman, Max D. Sorota, at 7:00 P.M.

A Nominating Committee was elected composed of the following:

Myle J. Holley, Chairman
Percival Rice
Harl Aldrich

The Chairman introduced the speaker of the evening, Dr. Howard Simpson, of Simpson, Gumpertz & Heger, Inc., who spoke on "The Computer Analysis of Complex Structures."

Dr. Simpson described how computers were used in the analysis of complex structures such as the vertical assembly building at Cape Kennedy, the Haystack antenna, the space environment chamber in Houston, and a large antenna in Australia. Slides were shown depicting the structures and to illustrate how the computer was programmed to analyze complex structures.

After an extensive question and answer period, the meeting was adjourned at 8:30 P.M.

Attendance was 62.

ROBERT L. FULLER, *Clerk*

FEBRUARY 10, 1965:—The annual meeting of the Structural Section was held on this date in the Society rooms and was called to order by the Chairman, Max D. Sorota, at 7:00 P.M.

The election of officers was held. Those elected were:

Chairman, Donald T. Goldberg
Vice-Chairman, Robert L. Fuller
Clerk, Charles C. Ladd
Executive Committee,
Fritz F. Hampe
Richard C. Jasper
Albert B. Rich

The Chairman introduced the speaker of the evening, Dr. Joaquim L. Serafim, Visiting Professor at M.I.T. and Consulting Civil Engineer in Lisbon, Madrid and Rio de Janeiro, who spoke on "Foundations of Concrete Dams."

Dr. Serafim showed slides of dam sites in Portugal, Spain, Africa, and South America, describing the investigations undertaken to determine the properties of the foundation materials and the steps that were taken to improve these properties and control deflection of the rock.

After an extensive question and answer period, the meeting was adjourned at 8:30 P.M.

Attendance was 62.

ROBERT L. FULLER, *Clerk*

MARCH 10, 1965:—A regular meeting of the Structural Section was held on this date in the Society rooms and was called to order by the Chairman, Donald T. Goldberg, at 7:20 P.M.

The Chairman introduced the speaker of the evening, Mr. William A. Milek, Jr. of the American Institute of Steel Construction, who spoke on "Practical Aspects of Buckling in Structural Steel Design."

The speaker started with a history of columns and buckling loads on various shaped columns. Considerable time was spent on problems connected with the locating of splices when using the plastic method to design continuous beams.

After an extensive question and answer period, the meeting was adjourned at 8:40 P.M.

Attendance was 54.

ROBERT L. FULLER, *Acting Clerk*

ANNUAL REPORTS

REPORT OF THE BOARD OF GOVERNMENT FOR YEAR 1964-1965

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

Pursuant to the requirements of the By-Laws the Board of Government presents its report for the year ending March 18, 1965.

The following is a statement of the status of membership in the Society:

Honorary	11
Members	1032
Associates	5
Juniors	43
Students	8
Total	1099
Student Chapters	2

Summary of Additions

New Members	19
New Juniors	12
New Students	5

Reinstatements

Members	2

Summary of Transfers

Junior to Member	3

Summary of Loss of Members

Deaths	12	
Resignations	7	
Dropped for non-payment of dues	14	
Dropped for failure to transfer	5	
Life Members		107
Members becoming eligible today for Life Membership		11
Applications pending on March 18, 1965		4

Honorary Membership is as follows:

Arthur Casagrande, elected February 1, 1965
Harry P. Burden, elected February 1, 1965

Thomas R. Camp, elected February 3, 1964
E. Sherman Chase, elected February 3, 1964
Gordon M. Fair, elected February 3, 1964
Frank M. Gunby, elected February 15, 1950
Ralph W. Horne, elected February 1, 1965
Karl R. Kennison, elected February 7, 1951
Frank A. Marston, elected February 15, 1960
Howard M. Turner, elected February 18, 1952
Frederic N. Weaver, elected February 1, 1965

The following members have been lost through death:

James F. Brittain, April 11, 1964
Burtis S. Brown, May, 1964
David M. Brown, Jan. 26, 1965
Porter W. Dorr, Dec. 18, 1964
Clyde M. Durgin, Jan., 1964
Arthur L. Ford, 1964
Emil A. Gramstorff, Sept. 1, 1964
J. Henry Leon, May 2, 1964
Edwin A. Taylor, 1963
Laurence E. Weeks, July 11, 1964
Francis S. Wells, Dec. 10, 1964
Thomas H. Wiggin, Jan. 17, 1964

Meetings of the Society

March 16, 1964. Address of the retiring President John F. Flaherty. "The Civil Engineer in Municipal Service."

April 15, 1964. Joint Meeting with Massachusetts Section, American Society of Civil Engineers. Charles L. Miller. "Civil Engineering at M.I.T."

May 13, 1964. Joint Meeting with Structural Section. William J. LeMessurier. "Structural Design of Tall Buildings."

October 21, 1964. Joint Meeting with Massachusetts Section, American Society of Civil Engineers (Student Night). Robert C. Copeland, Meteorologist at WBZ-TV. "Latest Innovation in Weather Observations."

November 18, 1964. Joint Meeting with Structural Section. Robert E. White, Vice-President, Spencer, White and Prentis. "Slurry Trench Walls."

December 16, 1964. Frank L. Heaney, Associate, Camp, Dresser & McKee. "Registration and Professionalism."

January 27, 1965. Joint Meeting with Society of Professional Engineers, Metropolitan Chapter, and Massachusetts Section, American Society of Civil Engineers. Floyd E. Dominy, Comm. Bureau of Reclamation, Department of the Interior. "Glen Canyon."

February 17, 1965. Joint Meeting with Transportation Section. Oscar Bakke, Director, Eastern Region, Federal Aviation Authority. "Coordinated Transportation."

Attendance at Meetings

Date	*Place*	*Meeting*	*Dinner*
March 16, 1964	M.I.T. Faculty Club	191	191
April 15, 1964	M.I.T. Faculty Club	56	56
May 13, 1964	Society Rooms	85	
October 21, 1964	Tufts University	152	152
November 18, 1964	Smith House	79	49
December 16, 1964	Society Rooms	33	
January 27, 1965	Arthur D. Little Co.	250	190
February 17, 1965	Society Rooms	39	

Section Meetings

Twenty meetings were held by the Sections of the Society during the year. These meetings of the Sections, offering opportunity for more detailed discussions, continue to demonstrate their value to their members and to the Society. A wide variety of subjects were presented. The Annual Reports of the various Sections will be presented at the Annual Meeting and will be published in the Journal.

*Funds of the Society**

Permanent Fund. The Permanent Fund of the Society has a present value of $76,112.32. The Board of Government authorized the use of as much as necessary of the current income of this fund in payment of current expenses. By vote of the Society (as prescribed by the By-Laws) at the December 16, 1964, and January 27, 1965, meetings, the Board of Government was authorized to transfer an amount not to exceed $6,000 from the Principal of the Permanent Fund for current expenditures. The amount necessary to transfer from the Principal of the Permanent Fund for current expenditures was $3,973.25.

John R. Freeman Fund. In 1925 the late John R. Freeman, a Past President and Honorary Member of the Society, made a gift to the Society of securities which was established as the John R. Freeman Fund. The income from this fund is to be particularly devoted to the encouragement of young engineers. Mr. Freeman suggested several uses, such as the payment of expenses for experiments and compilations to be reported before the Society; for underwriting meritorious books or publications pertaining to hydraulic science or art; or a portion to be devoted to a yearly prize for the most useful paper relating to hydraulics contributed to this Society; or establishing a traveling scholarship every third year open to members of the Society for visiting engineering works, a report of which would be presented to the Society.

Edmund K. Turner Fund. In 1916 the Society received a bequest of $1,000 from Edmund K. Turner, a former member of the Society, "the income of which is to be used for Library Purposes." The Board voted to use $75 of the income of this fund for the purchase of books for the Library. The expenditure from this fund during the year was $75.00.

* Details regarding the values and income of these funds are given in the Treasurer's Report.

Alexis H. French Fund. The Alexis H. French Fund, a bequest of $1,000, was received in 1931 from the late Alexis H. French of Brookline, a former Past President of the Society. The income of this fund is "to be devoted to the Library of the Society." The Board voted to use $75 of the income of this fund for the purchase of books for the Library. The expenditure from this fund during the year was $77.32.

Tinkham Memorial Fund. The "Samuel E. Tinkham Fund," established in 1921 at Massachusetts Institute of Technology by the Society, "to assist some worthy student of high standing to continue his studies in Civil Engineering," had a value of $2,922.70 on June 30, 1964. James Joel Bauman, a student in Civil Engineering, class of 1965, was awarded this Scholarship of $100 for year 1964-65.

Desmond FitzGerald Fund. The Desmond FitzGerald Fund, established in 1910 on a bequest from the late Desmond FitzGerald, a Past President and Honorary Member of the Society, provided that the income from this fund shall "be used for charitable and educational purposes." The Board voted April 18, 1963, "to appropriate from the income of this fund the sum of $100, to be known as the Boston Society of Civil Engineers Scholarship in Memory of Desmond FitzGerald, and be given to a Civil Engineering Student at Northeastern University. It was voted on February 17, 1964 "to adopt the recommendation of the Committee at Northeastern University, namely, that a $100 Scholarship be given to Nils-Frederik Braathen. Presentation was made at the Annual Meeting of the Society, March 16, 1964.

Clemens Herschel Fund. This fund was established in 1931, by a bequest of $1,000 from the late Clemens Herschel, a former Past President and Honorary Member of the Society. The income from this fund is "to be used for presentation of prizes for papers which have been particularly useful and commendable and worthy of grateful acknowledgment." The Board of Government voted on April 13, 1964, "that payment of prize Awards be appropriated from the income of this fund." The expenditure made during the year from this fund was $170.65.

Edward W. Howe Fund. This fund, a bequest of $1,000, was received December 2, 1933, from the late Edward W. Howe, a former Past President of the Society. No restrictions were placed upon the use of this money, but the recommendations of the Board of Government were "that the fund be kept intact, and that the income be used "for the benefit of the Society or its members." No expenditures were made from this fund during the year.

William P. Morse Fund. This fund, a bequest of $2,000, was received in 1949, from the late William P. Morse, a former member of the Society. No restrictions were placed on the use of this money, but the recommendations of the Board of Government were "that this fund be kept intact and that the income be used for the benefit of the Society or its members." Upon recommendation of the Committee appointed by the President, the Board voted on April 5, 1954, "to appropriate from the income of this fund the sum of $100, to be known as the Boston Society of Civil Engineers Scholarship in Memory of William P. Morse, and be given to a Civil Engineering Student at Tufts University." It was voted on February 17, 1964 "to adopt the recommendation of the committee at Tufts, namely, that a $100

Scholarship be given to Linfield C. Brown. Presentation was made at the Annual Meeting of the Society, March 16, 1964.

Frank B. Walker Fund. This fund, a bequest of $1,000 was received in 1961, from Mary H. Walker, wife of Frank B. Walker, a former Past President of the Society. No restrictions were placed on the use of this money, but the recommendations of the Board of Government were "that this fund be kept intact and that the income be used for the benefit of the Society or its members." No expenditure was made from this fund during the year.

Ralph W. Horne Fund. This fund, a bequest of $3,000, was received June 29, 1964, from the Directors of Fay, Spofford & Thorndike, Inc., the income from which shall be devoted to a prize or certificate to be awarded annually to a member designated by the Board of Government as having been outstanding in unpaid public service in Municipal, State, or Federal elective or appointive posts; or in philanthropic activity in the public interest. Members of BSCE only are eligible for the award. The Board of Government voted January 27, 1965 "to approve recommendation of the Ralph W. Horne Fund Award Committee, namely, that Charles O. Baird, Jr., be the first recipient to receive the Ralph W. Horne Fund Award." Presentation was made at the Annual Meeting of the Society, March 18, 1965.

Prizes

Award	*Recipient*	*Paper*
Desmond FitzGerald Medal	Keistutis P. Devenis	"Proposed Dam, Navigation Locks, and Flood Control Pumping Station for the Mystic River Basin"
Clemens Herschel Award	Harry M. Horn	"The Analysis and Design of Antenna Tower Foundations"
Sanitary Section Award	Paul W. Prendiville	"Merrimack River Pollution Abatement Study"
Hydraulics Section Award	Ronald T. McLaughlin Lawrence C. Neale	"Prototype Simulation" "Flow Measurement"
Letter of Commendation	Karl R. Kennison	"The Wanderings of the Center of Gravity"

Library

The report of the Library Committee contains a complete account of the Library Committee activities during the past year.

Committees

The usual special committees dealing with the activities and conduct of the Society were appointed. The membership of these committees is published in the Journal and the reports of the Committees will be presented at the Annual Meeting.

Your Board, in conclusion, wishes to express its appreciation of the excellent work done by the Officers of the Sections and by the Committees of the Society.

WILLIAM A. HENDERSON, *President*

REPORT OF THE SECRETARY

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

The following is a statement of cash received by the Secretary and of the expenditures approved by the President in accordance with the Budget adopted by the Board of Government.

FOR THE YEAR ENDING MARCH 18, 1965

	Expenditures	Receipts
Office		
Secretary's Salary & Expense	$ 900.00	
Treasurer's Honorarium	500.00	
Stationery, Printing & Postage	667.16	
Incidentals and Petty Cash	120.22	
Insurance & Treasurer's Bond	501.74	
Quarters, Rent, Tel. & Light	5,356.51	
Office Secretary	5,992.11	
Social Security	252.00	
Meetings		
Rent of Halls, etc.	—	
Stationery, Printing & Postage	34.00	
Hospitality Committee	639.72	$ 545.71
Reporting & Projection	16.40	
Annual Meeting, March 1964	1,043.70	710.00
Special Fund for Speakers	50.00	
Sections		
Sanitary Section	27.50	
Structural Section	40.19	
Transportation Section	32.50	
Hydraulics Section	57.19	
Construction Section	9.00	
Forward	$16,239.94	$1,255.71

REPORT OF THE SECRETARY (Continued)

	Expenditures	Receipts
Brought Forward	$16,239.94	$1,255.71
Journal		
Editor's Salary & Expense	750.00	
Printing & Postage	6,968.83	
Advertisements		1,597.98
Sale of Journals		2,607.84
Reprints	434.05	343.16
Copyright	16.00	
Library		
Periodicals	94.30	
Binding	64.30	
Miscellaneous		
Binding Journals for Members	8.50	8.50
Badges		5.00
Bank Charges	7.45	
Miscellaneous	150.26	157.97
Engineering Societies Dues and Charge for Journal Space	1,186.25	
Public Relations Committee	53.00	
Dues from B.S.C.E. Members		11,864.50
Trans. Income Perm. Fund		4,158.97
Trans. Prin.		3,973.25
	$25,972.88	$25,972.88

Entrance Fees to Permanent Fund $280.00

19 New Members; 12 New Junior Members; 3 Juniors transferred to Member; 5 New Student Members.

The above receipts have been paid to the Treasurer whose receipt the Secretary holds. The Secretary holds cash amounting to $30 included as payment under item 26 (Petty Cash) to be used as a fixed fund or cash on hand. $273.15 withholding Tax and $97.00 Social Security which is payable to Collector of Internal Revenue and State of Massachusetts in April, 1965, is not included in the above tabulation.

CHARLES O. BAIRD, JR., *Secretary*

REPORT OF THE TREASURER

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

This report covers the period beginning March 1, 1964 to the close of business March 1, 1965.

The Boston Safe Deposit and Trust Company holds the Society investment securities and serves as custodian and advisor. All security transactions are made by the custodian upon a vote of approval of the Board of Government. In accordance with the terms of the agreement, the custodian furnished the Treasurer of the Boston Society of Civil Engineers with a certified audit of the account. This audit, the receipts from the Secretary, the bills paid by the Treasurer, and the Savings Bank Passbook have all been reviewed by the Auditors of the Society and the information checked in this report.

The financial standing of the Society as of March 1, 1965 is summarized in seven of the tables accompanying this report. These tables are as follows:

Table	I	Distribution of Funds
Table	II	Distribution of Funds—Receipts and Expenditures
Table	III	Record of Investments—Bonds
Table	IV	Record of Investments—Stocks
Table	V	Record of Investments—Savings Bank
Table	VI	Comparison of Book and Market Values of Stocks, Bonds, Savings Bank, and Investment Cash
Table	VII	Comparison of Book and Market Values of Funds

The custodian reviews our portfolio twice a year. Theirs is a conservative policy and in recent years the recommendations have resulted in a reduction of our holdings in certain stocks with a subsequent reinvestment in more stable stocks or more generally in bonds.

Three additional tables have been prepared to show the comparison of the Book Values, Market Values and earnings from the Society assets during the last five years. These tables are as follows:

Table	VIII	Comparison of Book Values During Last Five Years
Table	IX	Comparison of Market Values During Last Five Years
Table	X	Comparison of Earnings from Invested Funds During Last Five Years

Approximately one half of the income is applied to the Permanent Fund and can, therefore, be transferred to the Current Fund to meet current expenses.

Mr. Karl R. Kennison reported in a letter to the Treasurer on the status of the irrevocable trust fund established by him for the Society. Two trusts are involved both holding shares of Massachusetts Life Fund. The following summarizes his report:

	January 1, 1964	Increase	January 1, 1965
Trust #4305	178.32	178.330	356.650
Trust #4444	183.74	190.968	374.708
Totals	362.06	369.298	731.358 Shares

On January 1, 1965, the bid price was $12.31 per share making the total value of the two funds $9,003.02.

The following is a record of the security changes accomplished by the custodian during the fiscal year:

Monsanto Chemical Co. (Monsanto Co.)
Bought 100 shares
Received in stock dividend 2 shares

Union Carbide Corp.
Sold 100 shares

U.S.A. Treasury Bonds
Bought $5,000 par value

American Telephone and Telegraph Co.
Bought 3 shares using 60 rights
Sold 97 rights
Received in stock split 160 shares

U.S.A. Treasury Notes Ser. A
Delivered for exchange $2,000 par value

U.S.A. Treasury Bonds
Received in exchange $2,000 par value

Pacific Gas and Electric Co.
Sold 315 rights

Consolidated Edison Co. of New York, Inc.
Sold 50 shares

Standard Oil of New Jersey
Sold 25 shares

Texaco Inc.
Sold 25 shares
Received in stock dividend 11 5/20 shares
Sold 5/20 shares

Jewel Tea Co., Inc.
Bought 63 shares

Marine Midland Corporation Deb. Bonds
Bought $5,000 par value

Radio Corporation of America Cum 1st Preferred
Sold 20 shares

New England Electric System
Bought 10 shares using 200 rights

Receipts from the Secretary including membership dues, advertisements in the Journal, sale of Journals and similar items amounted to $17,840.66. The sum of $280.00 in Entrance Fees was received and credited to the Permanent Fund. The sale of notes from the series of lectures sponsored by the Hydraulics Section amounted to $258.50 and was credited to the John R. Freeman Fund.

The following tabulates the receipts and credits from the sale of other Society publications:

Sanitary Lectures	$ 15.75
Soil Mechanics	775.07
Boring Data	60.00

In June 1964, the Secretary received and delivered to the Treasurer a check in the amount of $3000.00 from the firm of Fay, Spofford and Thorndike, Inc. The letter accompanying the check stated in part "the Directors of Fay, Spofford and Thorndike, Inc., herewith present to the Society a check in the amount of $3000.00 to create a fund to be called the Ralph W. Horne Fund, the income from which shall be devoted in part to a prize or certificate to be awarded annually to a member selected by the Board of Government, or a committee thereof, for notable public service in unpaid positions, either elective or appointive." This fund and its value as of March 1, 1965 is shown in Tables II and VII.

Expenditures from the Current Fund are tabulated in detail in the report of the Secretary and the membership is referred to this report for further information. Some expenditures are made from out of the Funds and are not listed in the report of the Secretary. The details of these expenditures follows:

John R. Freeman Fund

In the spring of 1963 the Freeman Fund Committee awarded a graduate school scholarship to Edward R. Holley Jr. of Arlington, Massachusetts.

Expenditures during 1963 Fiscal Year	$3,775.00
Scholarship during 1964 Fiscal Year	4,000.00
Total Expenditure	$7,775.00

Structural Lectures Fund

In the spring of 1964 the Structural and Construction Sections sponsored a series of nine lectures on Prestressed Concrete Design. Expenditures for this fiscal year for this series of lectures amounted to $1,141.97. Major contributions to the support of the series were made by the Portland Cement Association and Prestressed Producers of New England.

Desmond FitzGerald Fund

A scholarship prize of $100 from the Desmond FitzGerald Fund was presented to Nils-Frederik Braathen of Northeastern University at the Annual Meeting in March, 1964.

William P. Morse Fund

A scholarship prize of $100 from the William P. Morse Fund was presented to Linfield C. Brown of Tufts University at the Annual Meeting in March, 1964.

Edmund K. Turner Fund

The sum of $75.00 was expended during the fiscal year from the income to the Edmund K. Turner Fund for the purchase of books for the Library.

Alexis H. French Fund

The sum of $77.32 was expended during the fiscal year from the income to the Alexis H. French Fund for the purchase of books for the Library.

Clemens Herschel Fund

The sum of $170.65 was expended during the fiscal year from the income to the Clemens Herschel Fund for books awarded for the Herschel Prize Award and Section Prize Awards during the previous fiscal year.

Journal of the Boston Society of Civil Engineers

Expenditures necessary to publish the Journal are made from the Current Fund.

Printing, Postage, and Copyright	$6,984.83
Receipts from Advertisements	1,597.98
Net Expenditures	$5,386.85

Permanent Fund

The income to the Permanent Fund from interest and dividends less the expenses charged to the Fund was $4,158.97. In order to meet the expenses for the fiscal year, it became necessary to transfer $8,132.22 from the Permanent Fund to the Current Fund. Of this amount, $4,158.97 was transferred from income to the Fund and $3,973.25 was transferred from the principal of the Permanent Fund.

Withholding Tax and Social Security

Of the cash on hand as indicated in the accompanying tables, $370.15 is held in escrow for Federal Withholding Tax, Massachusetts Income Tax, and Social Security payments.

PAUL A. DUNKERLEY, *Treasurer*

TABLE I

DISTRIBUTION OF FUNDS

	Book Value Mar. 2, 1964	Interest and Dividends		Net Profit or Loss at Sale or Maturity		Transfer of Funds		Book Value Mar. 1, 1965
		Cash	Credit	+	—	Purchased +	Sold —	
	1	2	3	4	5	6	7	8
Bonds	62,293.77	2,710.00			—22.81	11,928.13	2,022.81	72,199.09
Savings Bank	5,015.44		216.00					5,231.44
Stocks	58,293.09	5,344.67		14,939.68		11,277.42	7,757.14	61,813.37
Available for Investment	4,638.38						866.17	3,772.21
	130,240.68	8,054.67	216.00	14,939.68	—22.81	23,205.55	10,646.12	143,016.11

Columns 1 + 3 + 6 — 7 = 8

TABLE II

DISTRIBUTION OF FUNDS—RECEIPTS AND EXPENDITURES
March 1, 1964 to March 1, 1965

Funds	Book Value Mar. 1, 1964	Allocation of Income-Profit and Loss: Income Col. 2 & 3	Allocation of Income-Profit and Loss: Net Profit Col. 4 & 5	Received	Expended	Book Value Mar. 1, 1965
Permanent	71,499.40	4,646.31	+8,306.17	280.00	8,619.56	76,112.32
John R. Freeman	41,283.47	2,518.66	4,623.98	258.50	4,341.66	44,342.95
Edmund K. Turner	1,628.56	105.69	189.09		86.09	1,837.25
Desmond FitzGerald	3,148.11	199.45	361.16		120.81	3,587.91
Alexis H. French	1,613.47	104.05	186.48		88.25	1,815.75
Clemens Herschel	1,337.57	78.48	147.86		178.70	1,385.21
Edward W. Howe	1,708.94	110.91	198.42		11.63	2,006.64
William P. Morse	3,279.03	207.94	376.37		121.70	3,741.64
Frank B. Walker	1,413.60	91.73	164.13		9.63	1,659.83
Ralph W. Horne	0.00	103.63	129.70	3,000.00	9.55	3,223.78
Surveying Lectures	537.61	34.62	62.07		11.64	622.66
Transportation Lectures	336.40	21.84	39.06		2.29	395.01
Structural Lectures	1,569.64	47.36	132.38		1,147.59	601.79
Boring Data	210.50			60.00	0.00	270.50
Soil Mechanics	2,826.00			775.07	52.33	3,548.74
Sanitary Lectures	−2,151.62			15.75	0.00	−2,135.87
Subtotal	130,240.68	8,270.67	14,916.87	4,389.32	14,801.43	143,016.11
Current	1,500.00	4,158.97		21,813.91	25,972.88	1,500.00
Totals	131,740.68	12,429.64	14,916.87	26,203.23	40,774.31	144,516.11

Secretary's change fund of $30.00 should be added to show total cash

Cash Balance—Investment Fund		$3,772.21
Current Fund		1,500.00
Total Cash		$5,272.21

$8,132.22 Transferred from Permanent Fund to Current Fund
$4,158.97 Transferred from Income to Permanent Fund
$3,973.25 Transferred from Principal of Permanent Fund

TABLE III
RECORD OF INVESTMENTS—BONDS
March 1, 1964 to March 1, 1965

Bonds	Date of Maturity	Interest Rate	Interest Received	Par Value	Book Value Mar. 1, 1965	Market Value Mar. 1, 1965
Aluminum Company of America	Apr. 1, 1983	3⅞%	$ 193.75	$ 5,000.00	$ 5,037.50	$ 4,700.00
Associates Investment Co. Deb.	Aug. 1, 1979	5⅛%	307.50	6,000.00	6,000.00	6,191.28
Columbia Gas System, Inc. Deb. Series D	July 1, 1979	3½%	70.00	2,000.00	2,066.17	1,810.00
Consumers Power Co., 1st Mortgage	Sept. 1, 1975	2⅞%	86.25	3,000.00	3,140.35	2,595.00
Flintkote Co.	Apr. 1, 1981	4⅝%	462.50	10,000.00	10,450.00	10,100.00
Florida Power Co., 1st Mortgage	July 1, 1984	3⅛%	31.25	1,000.00	1,017.50	836.25
Florida Power Co., 1st Mortgage	July 1, 1986	3⅞%	193.75	5,000.00	5,037.59	4,637.50
General Motors Acceptance Corp.	Sept. 1, 1975	3⅝%	181.25	5,000.00	5,101.80	4,656.25
Georgia Power Co., 1st Mortgage	Dec. 1, 1977	3⅜%	168.75	5,000.00	5,162.50	4,481.25
Marine Midland Corp. Deb.	Aug. 15, 1989	4½%	112.50	5,000.00	5,000.00	5,012.50
Province of Ontario	Sept. 1, 1972	3¼%	97.50	3,000.00	2,936.25	2,745.00
Public Service Electric and Gas Co.	June 1, 1979	2⅞%	115.00	4,000.00	4,097.50	3,300.00
So. Pacific 1st Series A Oregon Lines	Mar. 1, 1977	4½%	180.00	4,000.00	4,191.30	4,010.00
Superior Oil Co., Deb.	July 1, 1981	3¾%	150.00	4,000.00	4,000.00	3,720.00
Tidewater Oil Co., Deb.	Apr. 1, 1986	3½%	70.00	2,000.00	2,032.50	1,745.00
U.S.A. Treasury Notes, Series A	May 15, 1964	4¾%	47.50	2,000.00	0.00	0.00
U.S.A. Treasury Bonds	Aug. 15, 1973	4%	200.00	5,000.00	4,928.13	4,926.55
U.S.A. Treasury Bonds	May 15, 1974	4¼%	42.50	2,000.00	2,000.00	2,011.26
Totals			$2,710.00	$73,000.00	$72,199.09	$67,477.84

TABLE IV
RECORD OF INVESTMENTS—STOCKS
March 1, 1964 to March 1, 1965

Stocks	Classification	Number of shares	Dividend Received	Book Value Mar. 1, 1965	Market Value Mar. 1, 1965
American Telephone & Telegraph Co.	Common	320	$ 637.00	$ 5,767.52	$ 21,480.00
Commercial Credit Co.	Common	240	432.00	9,963.21	9,270.00
Consolidated Edison of New York, Inc.	Common	0	123.75	0.00	0.00
General Electric Co.	Common	150	330.00	2,341.47	14,775.00
General Motors Corp.	Common	126	560.70	5,576.32	12,600.00
Hartford Fire Insurance Co.	Common	107	149.80	1,534.39	7,958.13
Jewel Tea Co.	Common	125	124.40	4,998.38	7,312.50
Monsanto Co.	Common	102	95.00	7,183.64	9,027.00
National Dairy Products Corp.	Common	100	240.00	1,154.74	8,975.00
New England Electric System	Common	208	231.66	3,332.89	6,058.00
Pacific Gas and Electric Co.	Common	315	346.52	3,573.37	11,103.75
Scott Paper Co.	Common	263	236.72	5,944.04	9,599.50
Southern California Edison Co.	Common	177	199.12	1,932.99	6,991.50
Standard Oil of New Jersey	Common	200	653.75	2,012.76	16,225.00
Texaco, Inc.	Common	236	558.75	1,515.72	18,319.50
Union Carbide Corp.	Common	0	0.00	0.00	0.00
Pacific Gas and Electric Co.	Preferred	100	150.00	2,704.89	3,300.00
Radio Corporation of America	Preferred	0	70.00	0.00	0.00
Southern California Edison Co., Ltd.	Preferred	120	130.50	1,140.24	4,230.00
Southern Railway Co.	Preferred	75	75.00	1,136.80	1,518.75
Totals			$5,344.67	$61,813.37	$168,743.63

TABLE V

RECORD OF INVESTMENTS—SAVINGS BANK

Savings Bank	Classification	Interest Received	Book Value Mar. 1, 1965	Market Value Mar. 1, 1965
First Federal Savings and Loan Assoc. of Boston, Acct. No. 1S-631	Savings Account	$216.00	$5,231.44	$5,231.44

TABLE VI

Comparison of Book Values and Market Values of Stocks, Bonds, Savings Bank, and Investment Cash

	Book Value March 1, 1965	Market Value March 1, 1965
Bonds	$ 72,199.09	$ 67,477.84
Stocks	61,813.37	168,743.63
Savings Bank	5,231.44	5,231.44
Available for Investment	3,772.21	3,772.21
Total March 1, 1965	$143,016.11	$245,225.12
Total March 2, 1964	130,240.68	233,573.59
Increase	$ 12,775.43	$ 11,651.53

TABLE VII

Comparison of Book and Market Values of Funds

Funds	Book Value March 1, 1965	Market Value March 1, 1965
Permanent	$ 76,112.32	$131,155.23
John R. Freeman	44,342.95	76,410.88
Edmund K. Turner	1,837.25	3,165.91
Desmond FitzGerald	3,587.91	6,182.62
Alexis H. French	1,815.75	3,128.86
Clemens Herschel	1,385.21	2,386.97
Edward W. Howe	2,006.64	3,457.80
William P. Morse	3,741.64	6,447.52
Frank B. Walker	1,659.83	2,860.19
Ralph W. Horne	3,223.78	5,555.15
Surveying Lectures	622.66	1,072.96
Transportation Lectures	395.01	680.67
Structural Lectures	601.79	1,036.99
Boring Data*	270.50	270.50
Soil Mechanics*	3,548.74	3,548.74
Sanitary Lectures*	−2,135.87	−2,135.87
Subtotal	$143,016.11	$245,225.12
Current*	1,500.00	1,500.00
Total	$144,516.11	$246,725.12

* These funds are not interest-earning invested funds, but are cash, assets or publications representing a cash outlay.

TABLE VIII
Comparison of Book Values During Last Five Years

	1961	1962	1963	1964	1965
Bonds	$ 51,942.25	$ 50,818.46	$ 62,293.77	$ 62,293.77	$ 72,199.09
Stocks	55,193.47	55,960.99	53,228.79	58,293.09	61,813.37
Savings Bank	4,442.74	4,616.55	4,808.92	5,015.44	5,231.44
Available for Investment	3,091.79	1,998.10	2,919.21	4,638.38	3,772.21
Totals	$114,670.25	$113,394.10	$123,250.69	$130,240.68	$143,016.11

TABLE IX
Comparison of Market Values During Last Five Years

	1961	1962	1963	1964	1965
Bonds	$ 47,112.52	$ 45,747.51	$ 58,323.13	$ 57,442.50	$ 67,477.84
Stocks	150,583.26	177,346.88	156,477.51	166,477.27	168,743.63
Savings Bank	4,442.74	4,616.55	4,808.92	5,015.44	5,231.44
Available for Investment	3,091.79	1,998.10	2,919.21	4,638.38	3,772.21
Totals	$205,230.31	$229,709.04	$222,528.77	$233,573.59	$245,225.12

TABLE X
Comparison of Earnings from Invested Funds During Last Five Years

	1961	1962	1963	1964	1965
Interest from Bonds	$1,922.50	$1,907.50	$1,892.50	$2,402.50	$2,710.00
Dividends from Stocks	5,028.66	5,259.55	5,515.00	5,505.58	5,344.67
Savings Bank Interest	151.51	173.81	192.37	206.52	216.00
Totals	$7,102.67	$7,340.86	$7,599.87	$8,114.60	$8,270.67

REPORT OF THE AUDITING COMMITTEE

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

We have reviewed the records and accounts of the Secretary and Treasurer of the Boston Society of Civil Engineers, and we have compared the bank statement of securities held by the Boston Safe Deposit and Trust Company with the enumeration submitted by the Treasurer.

We have found them to be in order and to account accurately for the Society's Funds.

RICHARD F. DUTTING
HARL P. ALDRICH, JR.

REPORT OF THE EDITOR

Boston, Mass., March 5, 1965

To the Boston Society of Civil Engineers:

The Journal was issued quarterly, for the months of April, July and October, 1964, and January, 1965, as authorized by the Board of Government on December 20, 1936.

During the year there have been published 16 papers, including 11 which were previously presented at meetings of the Society and Sections.

The four issues of the Journal contained about 410 pages of papers and proceedings, 11 pages of index and 40 pages of advertising, a total of about 461 pages.* An average of 1,650 copies per issue were printed.

The cost of printing the Journal was as follows:

Expenditures

Composition and printing	$5,890.82
Cuts	731.43
Wrapping, mailing & postage	346.58
Editor	750.00
Copyright	16.00
Reprints	434.05
	$8,168.88

Receipts

Receipts from Sale of Journals	$2,607.84
Receipts from Sale of Reprints	343.16
Receipts from Advertising	1,597.98
	$4,548.98
Net cost of Journal to be paid from Current Fund	$3,619.90

ROBERT L. MESERVE, *Editor*

* These figures and those for costs following are estimated, since the January issue is still in production.

REPORT OF THE HOSPITALITY COMMITTEE

Boston, Mass., February 26, 1965

To the Boston Society of Civil Engineers:

The Hospitality Committee submits the following report for the year 1964-1965.

A total of eight meetings of the Society were held during the past year. Included in this total were the Annual Dinner, a Student Night meeting, a joint meeting with the Massachusetts Society of Professional Engineers and the American Society of Civil Engineers, and five regular meetings of the Society.

Catered dinners were served prior to five of the eight meetings.

The average attendance of members and guests for all eight meetings or dinners (using the larger attendance figure) was 111, as compared to last year's average of 85.

Attendance at regular meetings of the Society during the past year was 58 persons per meeting. This represents a 26% increase in attendance over last year.

SUMMARY OF MEETINGS

		Attendance	
Date	Place	Meeting	Dinner
March 16, 1964	M.I.T. Faculty Club	191	191
April 15, 1964	M.I.T. Faculty Club	56	56
May 13, 1964	Society Rooms	85	
October 21, 1964	Tufts University	152	152
November 18, 1964	Smith House, Cambridge, Mass.	79	49
December 16, 1964	Society Rooms	33	
January 27, 1965	Arthur D. Little Co.	250	190
February 17, 1965	Society Rooms	39	

ROBERT L. FULLER, *Chairman*

REPORT OF THE LIBRARY COMMITTEE

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

The Library Committee held its first meeting December 17, 1964, at the Society headquarters. The meeting was devoted to obtaining new books and a general discussion on maintaining the excellent facilities which now exist at the headquarters. Additional business throughout the year was conducted by phone and correspondence.

The Committee recommends that the new Library Committee for 1965-66 devote some time to updating the reading material. It is felt many books could be taken from the active shelves and stored or discarded.

The following is a list of books purchased for the year. The books purchased have a list value of $163.50 and were purchased for $152.32.

Who's Who in Engineering
Principles of Soil Mechanics, Scott
Process of Creep and Fatigue in Metals, A. J. Kennedy
City of New York Building Code for Reinforced and Plain Concrete Construction, Concrete Industry Board, Inc.
Cities and Space: The Future Use of Urban Land, L. Wingo, Jr.
Water Resources Engineering, Linsley and Franzini
Water Supply Engineering, 6th Ed., H. E. Babbitt, Doland, Cleasby
Engineering Economy, Grant
Symposium on the Design of High Buildings, Sean Mackey
The Buckling of Plates and Shells, H. L. Cox
Handbook of Fluid Dynamics, 1st Ed., V. L. Stretter
Earth and Earth Rock Dams, Sherard, Woodward, Gizienski, Clevenger

The Committee wishes to express its thanks on behalf of the BSCE for receiving the following books for the Library from author and companies mentioned:

Structural Dynamics, from John M. Biggs
Dynamics of Structures, W. C. Hurley & M. F. Rubinstein, from Prentice Hall
Oceanographical Engineering, R. Wiegel, from Prentice Hall
Principles of Dynamics, D. T. Greenwood, from Prentice Hall
Dictionary of Civil Engineering, R. Hammond, from Philosophical Lib. Inc.
The Agadir, Morocco Earthquake; Anchorage and the Alaska Earthquake March 27, 1964; the Skopje, Yugoslavia Earthquake, from Bethlehem Steel Company

GEORGE W. HANKINSON, *Chairman*

REPORT OF JOINT LEGISLATIVE COMMITTEE

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

The following Legislative acts of interest to engineers were enacted during the 1964 session of the Massachusetts General Court:

Bill No.	Subject	Chapter No.
H979	An act providing that notice be given to the applicant of action taken relating to a subdivision plan.	105
S774	An act relative to Regional Planning procedures in the Commonwealth.	327
S74	An act extending the duration of the Board of Schoolhouse Construction Standards and increasing the membership thereof.	546
H3562	An act providing for the Commonwealth's participation in cooperative Federal-State navigation, beach erosion control and hurricane barrier projects.	543
H3646	An act establishing the Massachusetts Bay Transportation Authority and providing for the acquisition and maintenance of mass transportation facilities and services which shall be coordinated with highway systems and urban development plans throughout the Commonwealth.	563

A review of bills filed for the 1965 session shows the following items of interest:

Bill No.	Subject	Report
H3227	Petition of John J. Cusack for legislation to provide the Board of Registration of Professional Engineers and of Land Surveyors with an executive Secretary and increasing the renewal fee for certificates of registration.	Hearing Jan. 27. Favorable Committee Report. Changes by Ways and Means Committee to H3361
S383	Petition of James R. Hanlon and another for legislation relative to the acceptance or approval of plans and specifications for the construction, reconstruction, enlargement or alteration of buildings or structures.	Hearing Feb. 16. No report as of March 1.

Bill No.	Subject	Report
S590	Petition of Wallace P. Orpin for legislation relative to work to be performed by registered professional engineers. Would require only registered professional engineers or registered land surveyors to be in charge of engineering or surveying departments of public agencies.	Hearing Feb. 18. No report as of March 1.
H1359	Petition of Massachusetts Association of Land Surveyors and Civil Engineers, Inc., relates to the certification of copies of plans required to accompany the master plan and the first deed in condominium.	Signed by Governor Feb. 23 as Chapter 56.
H2135	Petition of the Massachusetts Association of Consulting Engineers, Inc., that provision be made for a two-year limitation for bringing actions of contract or tort for malpractice against architects and professional engineers.	No hearing scheduled as of March 1.
H2208	Petition of John G. Jarnis and another that provision be made for methods of payments on public consulting services performed by architects and engineers.	Hearing Feb. 19. No report as of March 1.

In addition, there are many other bills of interest to engineers, relating to competitive bidding, public contracts, performance bonds, subdivision control, and solid waste disposal, which are too numerous to list, but which your Committee will follow to protect the interest of Professional Engineers and Land Surveyors.

The Committee has met on several occasions with the ESNE Joint Committee on Legislative affairs and discussed possible revisions of the engineering registration laws.

EDWARD WRIGHT
CHARLES A. PARTHUM
RALPH M. SOULE, *Chairman*

REPORT OF THE JOHN R. FREEMAN FUND COMMITTEE

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

The financial support of Mr. E. R. Holley, Graduate Student at M.I.T., was continued through this past year. A final report covering one phase of his work has been received and a second is expected shortly.

No fellowship has been offered in 1965.

The current year has been marked by the resignation of Howard M. Turner, Chairman of the Committee. Recognizing his long time of service in the guidance of this Committee, his resignation was accepted with the deepest regret. Mr. Clyde W. Hubbard and Mr. Lee M. G. Wohlman were selected as the new members of the Freeman Fund Committee. The continuing members are Mr. George R. Rich and Mr. Thomas R. Camp.

L. J. HOOPER, *Chairman*

REPORT OF COMMITTEE ON SUBSOILS OF BOSTON

Boston, Mass., March 11, 1965

To the Boston Society of Civil Engineers:

Last year's Subsoil Committee report referred to the current U.S. Geological Survey project which will publish maps and a description of the Boston subsoils. The project is in effect an extension of work done by the BSCE in publishing boring data and will be of great help to the local engineering community.

We find, however, that the local USGS Office is understaffed to complete the project within a reasonable length of time.

This committee is preparing a recommendation to our Board of Government that the BSCE write to the Director of the USGS expressing our great interest in and concern for this project, urging him to take necessary action to complete the work at an early date.

It is also suggested that we encourage other local engineering societies and municipal organizations to make known to the Director of the USGS their interest in this project and their desire to see it expedited.

DONALD G. BALL, *Chairman*

REPORT OF THE MEMBERSHIP CENTRAL COMMITTEE

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

The Membership Central Committee has been relatively inactive during the year 1964-65. Solicitation of new members has been accomplished principally by individual contacts. The increase in membership during the current year has been as follows:

New Members	19
New Juniors	12
New Students	5
Reinstated	2
Juniors transferred to Members	3
Life Members	107

Members eligible today for Life Membership	11
Honorary Members	11
Total Membership as of March 1, 1965	1,099
This compares with a total membership a year ago of 1,091	

Summary of Loss of Members

Deaths	12
Resignations	7
Dropped for non-payment of dues	13
Dropped for failure to transfer	5

The continued growth of the Society is important, and every one of us is strongly urged to seek new candidates for membership through his association with other engineers. The Committee recommends that a strong appeal for new members be made at all meetings of the Society and its various sections.

F. M. Cahaly, *Chairman*

REPORT OF THE COMMITTEE TO STUDY ASEE "GOALS OF ENGINEERING EDUCATION"

Boston, Mass., March 15, 1965

To the Boston Society of Civil Engineers:

The Committee to Study ASEE "Goals of Engineering Education" is one of the institutional and organizational study committees representing engineering colleges, professional societies, and the users of engineers that are participating in the "Goals" Project of the American Society for Engineering Education. Our committee, appointed in April 1964, by President Henderson, consists of:

Harry L. Kinsel, *Chairman*
Prof. John M. Biggs
Robert L. McGillicuddy
Joseph C. Lawler

Copies of the information documents published by ASEE concerning the project have been obtained for each member of the committee. Study of these documents has been undertaken on an individual basis by committee members, but to date the committee has not met for discussion, due to extended absences of two of its members.

Because this is a continuing project, on which the final report is scheduled to be rendered June 1, 1966, continuation of this committee is considered appropriate.

Harry L. Kinsel, *Chairman*

REPORT OF COMMITTEE ON PUBLIC RELATIONS

Boston, Mass., March 18, 1965

To the Boston Society of Civil Engineers:

No formal meetings of the Committee on Public Relations were held during the year. An inquiry was received from the Committee on Public Relations of the American Society of Civil Engineers requesting the cooperation of this Committee in disseminating information concerning civil engineering. This Committee offered to work with the American Society of Civil Engineers in any joint project. However, no further contact has been had with the American Society of Civil Engineers' Committee.

Last year the Society received excellent publicity in the Boston Herald and in the Wakefield Daily Item and in the Boston Sunday Globe.

ROBERT H. CULVER, *Chairman*

REPORT OF THE EXECUTIVE COMMITTEE OF THE CONSTRUCTION SECTION

Boston, Mass., March 18, 1965

To the Construction Section
Boston Society of Civil Engineers:

The Construction Section held two meetings and co-sponsored one lecture series in 1964:

May 27, 1964—Mr. Sepp Firnkas, Consulting Engineer in Boston, described design and construction features for Children's Hospital Medical Center Parking Facilities. Attendance was 94.

January 6, 1965—Christopher J. Murray, Jr., superintendent for George A. Fuller Co. Inc., described the "Construction of the Behavioral Science Building at Harvard University." Attendance was 36.

The lecture series was co-sponsored with the Structural Section. Cooperative effort in formulating the program, arranging speakers and supporting the program with financial assistance was given also by Prestressed Concrete Association of New England, New England Concrete Pipe Corporation and the Portland Cement Association. A summary of cost, expenses and contributions was submitted to the Board of Government during 1964 by the Chairman of the Structural Section. Attendance at the nine lectures averaged one hundred forty-seven to make a total count of thirteen hundred and nineteen for the entire series.

The annual election of officers was held January 6. The following were elected by unanimous vote of those attending:

Chairman	Herman G. Protze
Vice Chairman	Robert J. Van Epps
Clerk	William Wiley

ROBERT J. VAN EPPS, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE HYDRAULICS SECTION

Boston, Mass., February 25, 1965

To the Hydraulics Section
Boston Society of Civil Engineers:

The following meetings were held during the past year:

May 6, 1964—Dr. Joseph Harrington, Associate in Environmental Health Engineering, Harvard University, spoke on "Application of Non-Linear Programming to Hydraulic and Sanitary Engineering Routing Problems." Attendance 20.

October 28, 1964—Chairman Devenis appointed the nominating committee of:

Richard F. Dutting, Chairman
Lawrence C. Neale
Donald F. Harleman

to present a slate of officers at the next meeting. The guest speaker was Dr. R. Stevens Kleinschmidt, Hydraulic Engineer, Great Northern Paper Company, who described and illustrated with slides the growth of the hydroelectric system required in the manufacture of paper. Attendance 30.

February 19, 1965—The following slate of officers for the coming year were approved by voice vote at the annual meeting:

Chairman	Peter S. Eagleson
Vice-Chairman	Nicholas Lally
Clerk	Allan Grieve, Jr.
Executive Committee	Athanasios A. Vulgaropulos
	Ronald T. McLaughlin
	Stephen E. Dore, Jr.

The speaker of the evening, Mr. Lyle E. Branagan, Hydraulic Engineer, Chas. T. Main, Inc. spoke on "Vortex Investigations of a Submerged Intake at Cornwall Pumped Storage Plant." His remarks were confined primarily to the results of model testing conducted at the Alden Hydraulic Laboratory to determine a design that would prevent the drawdown of air into the submerged intake at the upper pool. Attendance 20.

NICHOLAS LALLY, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SANITARY SECTION

Boston, Mass., March 15, 1965

To the Sanitary Section
Boston Society of Civil Engineers:

Four meetings of the Sanitary Section were held during the past year:

April 29, 1964—Annual outing held at the Deer Island Sewage Treatment Plant (under construction) of the Metropolitan District Commission. Guided tours were conducted from 3:30 to 5:30 P.M., followed by a full course roast beef dinner which was catered in the dining hall of the Suffolk County House of Correction.

Mr. Edgar L. Shepard, Master, SCHC, welcomed ninety members and guests and gave a short history of the Island and the Institution.

An illustrated progress report on the construction of the plant was presented by Mr. Martin F. Cosgrove, Deputy Chief Engineer, Construction Division, Metropolitan District Commission. There were 120 members and guests who toured the plant and ninety reservations for dinner.

December 2, 1964—Dr. Alexander Cohen, Research Psychologist, Dept. Health, Education and Welfare, Cincinnati, Ohio, presented an extremely interesting paper entitled, "Physiological and Psychological Effects of Noise on Man."

Thirteen members and guests attended the dinner prior to the meeting and there were twenty-two at the meeting.

January 21, 1965—Joint Meeting with ASME. Meeting jointly with ASME at Arthur D. Little Co., 25 Acorn Park, Cambridge, approximately one hundred and twenty-five people attended the social hour and dinner prior to the meeting. The speaker was E. Sherman Chase, Honorary Member of BSCE, who selected as his subject "Water Resources—Facts, Fads and Fancies."

Of the one hundred and twenty people who attended it is estimated that approximately twenty-five were members of BSCE.

March 3, 1965—Annual Meeting. The officers and members of the Executive Committee elected were:

Chairman	William C. Traquair
Vice-Chairman	Robert L. Meserve
Clerk	Walter M. Newman
Executive Committee	Charles A. Parthum
	David A. Duncan
	Allison C. Hayes

Prof. N. Bruce Hanes of Tufts University presented a paper entitled "Relationship between *Escherichia Coli,* Type I, Coliform and Enterococci in Water."

Thirty-two members and guests attended the meeting and twenty attended the dinner prior to the meeting.

During the year three meetings of the Executive Committee were held.

FRANCIS T. BERGIN, *Chairman*

REPORT OF THE EXECUTIVE COMMITTEE OF THE STRUCTURAL SECTION

Boston, Mass., March 18, 1965

To the Structural Section
Boston Society of Civil Engineers:

The seven meetings held by the Structural Section during the past year were as follows:

April 8, 1964—Dr. James L. Sherard of the firm of Woodward, Clyde, Sherard & Associates, spoke on "Earth Dams—Design Procedures to Minimize Construction Problems and Claims by Contractors." Attendance was 69.

May 13, 1964—Mr. William J. LeMessurier of the firm of William J. LeMessurier & Associates, Inc., spoke on "Structural Design of Tall Buildings." This was a joint meeting with the Main Society. Attendance was 85.

October 14, 1964—Professor John M. Biggs and Professor Robert D. Logcher of M.I.T. spoke on "Computer Analysis of Structures: On-Line Demonstration." Attendance was 51.

November 18, 1964—Mr. Robert E. White, Vice-President of Spencer, White & Prentis, Inc., spoke on "Slurry Trench Walls." This was a joint meeting with the Main Society. Attendance was 79.

December 9, 1964—Dr. Ivan Viest of the Bethlehem Steel Company spoke on "Alaskan Earthquake—Effects on Structures." Attendance was 40.

January 13, 1965—Dr. Howard Simpson of Simpson, Gumpertz and Heger, Inc., spoke on "The Computer Analysis of Complex Structures." Attendance was 62.

February 10, 1965—Dr. Joaquim L. Serafim, Visiting Professor at M.I.T. and Consulting Civil Engineer in Lisbon, Madrid and Rio de Janeiro, spoke on "Foundations of Concrete Dams." At this annual meeting of the Structural Section the following officers were elected for the forthcoming year; Chairman, Donald T. Goldberg; Vice-Chairman, Robert L. Fuller; Clerk, Charles C. Ladd; Executive Committee, Fritz F. Hampe, Richard C. Jasper and Albert B. Rich. Attendance was 62.

The total attendance at the seven meetings was 448, averaging 64 per meeting.

ROBERT L. FULLER, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE TRANSPORTATION SECTION

Boston, Mass., March 3, 1965

To the Transportation Section
Boston Society of Civil Engineers:

The following four meetings of the Transportation Section took place during the past year:

April 22, 1964—Dr. Joseph Maloney, Executive Director of the Mass. Transportation Commission, presented the results of the year-long multimillion dollar "Demonstration Project" conducted by the M.T.C. Ten were in attendance at this very interesting meeting.

September 16, 1964—Mr. William Leong, Civil Engineer and City Planner of Lowell, Massachusetts, presented a detailed talk on transportation planning problems that were solved and created by the Central Artery. Seventeen members were present.

November 23, 1964—Mr. Philip E. Clerke, Highway and Lighting Engineer with Westinghouse, gave a very interesting illustrated talk on highway lighting design and application. Twenty-seven attended this talk.

February 24, 1965—Meeting date was changed at the request of the Board of Government to February 17, 1965 on which date Mr. Oscar Bakke, Regional Director of the FAA, gave an extremely interesting talk on coordination of transportation facilities and questioned, with interesting statistics, whether or not those transportation plans now under way are in phase with the times and requirements. There were thirty-nine members and guests present. This meeting was the Section's annual meeting and the following officers were elected:

Chairman	Mr. B. Quirk
Vice-Chairman	Mr. W. McLea
Secretary	Mr. P. LaRosa
Executive Committee	Mr. Kas Kray
	Mr. Thomas Giblin

This Section held seven Executive Committee meetings during the year, polled its membership and established a roster of members willing to serve on committee or present papers.

ERNEST A. HERZOG, *Chairman*

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AND

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