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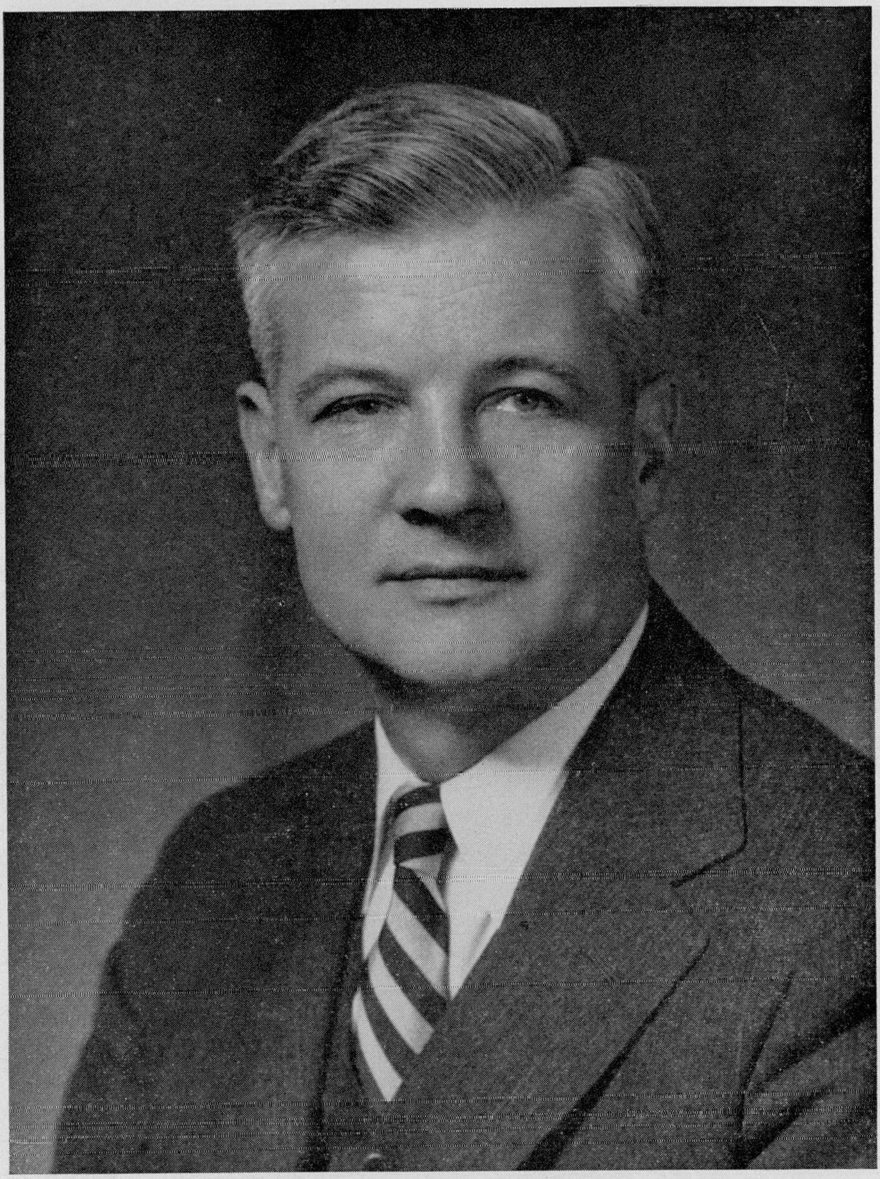


ARTHUR T. IPPEN
President
Boston Society of Civil Engineers
1960-61

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume 47 APRIL, 1960 Number 2

PROBLEMS OF BOSTON, THE CENTRAL CITY OF A METROPOLITAN AREA

Presidential Address by EDWARD C. KEANE

Boston Society of Civil Engineers, March 16, 1960.

"It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of of foolishness. . . . it was the spring of hope, it was the winter of despair. . . ."

(DICKENS, *A Tale of Two Cities*)

By the term "central city," as I shall use it here, I mean a core city which serves as the center of a large metropolitan area. Central cities have had their troubles for a long time, but the troubles have become intensified by the increasing rate of urbanization all around and outside of the core cities, during the transition from the moderately technological nineteenth century to the highly technological mid-twentieth century, in which the automobile has come to dominate our lives.

Growth of urban metropolitan areas is not a new phenomenon in the United States, but the rate of urban growth has accelerated in recent years. In the last decade, at least 85 percent of the country's population growth has been in urban areas. There is no sign that the rate is slowing down. And while the metropolitan areas are growing both in extent and in population, the central cities remain static or actually lose population.

In the case of Boston, the concept of what constitutes the metropolitan area is very different from what is used to be. Not many years ago, the metropolitan area was often taken to be the group of 46 cities and towns which receive one or more of the services of the Metropolitan District Commission. Most of these lie within 15 miles of the

State House. But with the greater mobility brought about by the automobile, the definition has had to be changed. The standard metropolitan area as used by the U. S. Census Bureau comprises 65 cities and towns. The Greater Boston Economic Study Committee, (GBESC) which was organized three years ago, found it advisable to include in its study area everything within a 30-mile radius, 149 cities and towns in all (Figure 1). The GBESC population study of December, 1959, with projections to 1970, indicates that the population of the entire study area, now at 3,130,000, will increase 19 per cent to 3,738,000. Meanwhile the City of Boston, now at about 725,000, will stabilize at something near that figure.

It has been said often that the well-being of the metropolitan area, and indeed of the New England region, depends on the vigor of the core city of Boston. This relatively tiny area must serve as the economic, social, cultural and governmental capital of the region. But Boston is in trouble, serious trouble, so deep that it cannot be remedied by the city itself. It will take the combined efforts of persons from all parts of the region to bring about a change for the better. It is to their self-interest that they make these efforts, and like all citizens, we engineers have a stake in this matter. I am well aware that many of our members spend a great deal of time in civic and community affairs. I suspect, however, that their efforts are largely in local activities, and that they do not concern themselves much with regional or big-city matters. I am confirmed in this thought by results of a survey of residences of engineers (all branches) issued in February, 1960 by the Greater Boston Chamber of Commerce. It shows that in Suffolk County, there lives one engineer for about 300 people. In the four counties surrounding Suffolk, the ratio is one engineer to about 80 people. It is obvious that most of our "Boston" engineers have their homes outside of Boston, and it is only natural that their main civic interests are also outside of Boston.

The purpose of this paper is to advance the thesis that it is for our own welfare, as well as for the common good, for all of us to be fully informed on matters affecting Boston and the metropolitan area as a whole, no matter where we live, and for us to be ready to form intelligent judgments on these matters and to lend a hand in forwarding sound proposals when they are put forward.

I should like now to comment briefly on some of the biggest problems confronting our central city. The ideas have been gathered

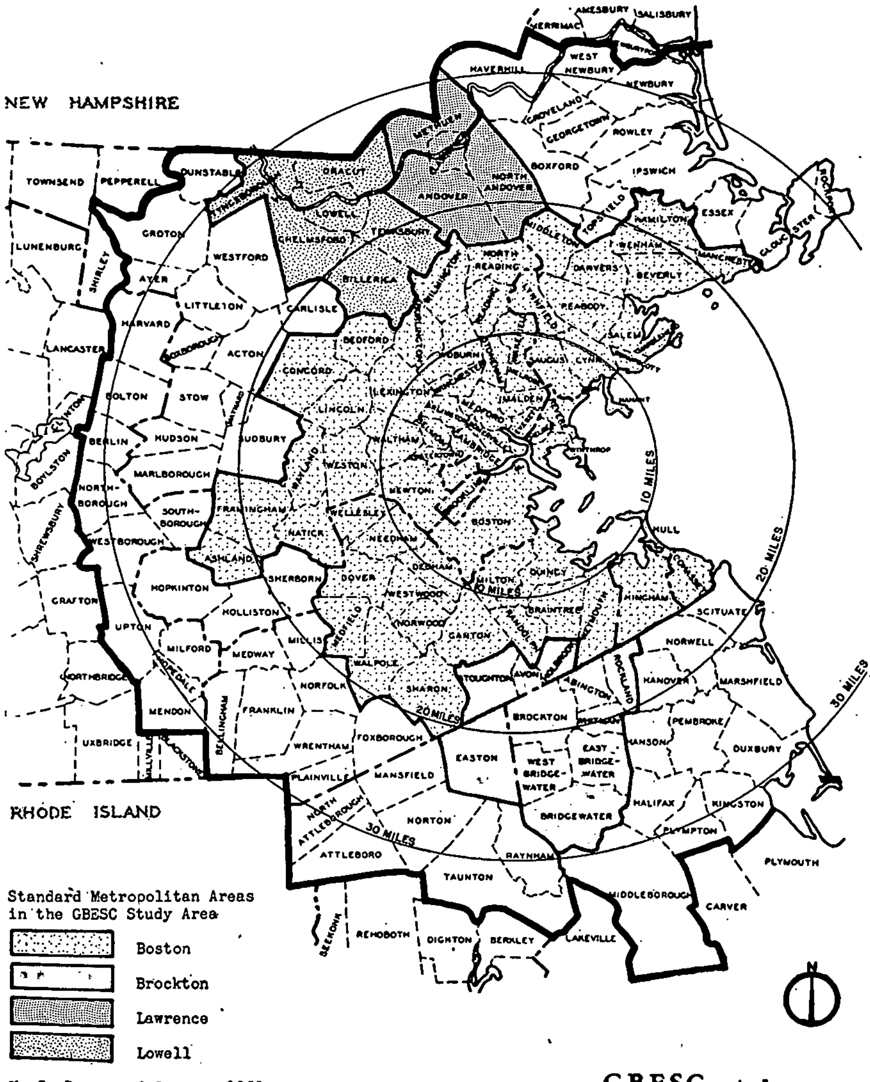

NEW HAMPSHIRE
RHODE ISLAND
10 MILES
20 MILES
30 MILES
BOSTON
CAMBRIDGE
BROCKTON
LOWELL
ANDOVER
NORTH ANDOVER
METHUEN
HAVERHILL
Standard Metropolitan Areas in the GBESC Study Area
Boston
Brockton
Lawrence
Lowell
U. S. Bureau of Census, 1950
GBESC study area

FIGURE I

during several years of service on the Boston Planning Board and as a result of working on committees of various civic organizations.

Property Taxes

Taxes, as the old saying tells us, is one of the two things we can always be sure of. It seems as though tax rates move in only one direction—up—and this makes us unhappy. We should all be glad to see the trend reversed, and we tend to think that this could be done through efficiency and economy. However, we must bear in mind that with most of our local taxes we are either buying services for ourselves or our children, or contributing to welfare or social services.

There is a continual demand for more and more services by the city. Consider the demand for better streets and all-weather maintenance of the highways and streets. (A highway maintenance official complained to me recently that the people are not satisfied to have the snow just plowed from the highways—they expect him to go out and catch the snowflakes before they land.) Think of the many services now offered in our schools in addition to the teaching of the three R's; or the free chest x-rays offered by the Health Department; or the "bookmobiles" of the Library Department. I could mention a good many other items of expanded services. Most of them are good in themselves; which of them do we wish to abolish or reduce in scope? I think we would have little success in trying to turn back the clock with respect to city services. And unless we cut back the services, we cannot do much toward tax reduction by better administration alone.

Another factor keeping taxes high in Boston is the existence of a great many tax-exempt properties. These account for 38 per cent of all the valuations on the city assessors' books. They comprise mostly governmental buildings and educational institutions. The city provides police and fire protection, streets for access, and sewer service, all without receiving tax payments. The federal government does make certain small payments in lieu of taxes, and there is a prospect that some of the large educational institutions may be willing to do the same. I think that the state should also consider reimbursement to the city for services rendered to state-owned buildings, but this seems unlikely unless the state legislature changes its attitude toward Boston affairs. An attempt was made recently to assess portions of the costs of Suffolk County courts, now paid entirely by Boston, on the three other municipalities of the county. This would seem to be only simple justice, but the legislators would have none of it. Apparently many of them still have the idea that Boston is so rich that it can readily do small favors for its neighbors, such as paying their court costs.

The biggest factor of all, contributing to the terrific property tax rate in Boston ($101.20 per thousand in 1959) is the shrinking tax base. In 1930, the total of taxable values in Boston was $1,970,-000,000. By 1944 the total had dropped to $1,440,000,000, a loss of over 25 per cent, and it has been virtually unchanged since then. If the figures were adjusted to reflect the value of the dollar, I think they would show a shrinkage of at least 50 per cent in the real tax base in the last 30 years, rather than 25 per cent.

The worst effect of a climbing tax rate is that after it reaches a certain level it automatically puts a stop to new construction of rental properties, since capital will not go into a venture which has no prospect of yielding a fair return. The Greater Boston Economic Study Committee finds that when property taxes take from the owner more than 20 per cent of the net income, there is practically no construction of new buildings for the rental market. Without new construction to bolster the tax base, depreciation takes its toll, the tax base shrivels further, tax rates rise still more, and so we have a vicious spiral. The only remedy is to develop tax sources other than real estate as has been done in so many other cities and states. For example, Philadelphia gets only 40 per cent of its income from property taxes, as against 70 per cent in Boston. A sales tax may not be the only answer, but it appears to be the only solution presented so far which is capable of affording at least a part of the necessary relief.

I believe that when a sales tax is passed (and it is surely coming) it will release a great deal of construction in the downtown area, and it will benefit us all.

The Future of the Central Business District

A great deal has been written about the changing functions of central cities and their future. It would be unthinkable for them to have no future, for a region which is to be strong economically must have an economic capital which is strong and which is a symbol of prestige. (There must be something for the satellite towns to be satellites to!) So, there will always be a central city with a central business district (CBD) and I propose now to pass on an idea as to what the future has in store for Boston's CBD.

What follows has been taken from an exhaustive study by the staff of the City Planning Board. The projections are based on assumptions that something will be done to reduce the property tax rate, and that active concern and cooperation will be had from business men, political leaders and citizens through the entire region. The Planning Board report recognizes that certain activities will gravitate to points outside the Central Business District, but states the belief that other activities will become stronger within it. It assumes that the number of employees in the Central Business District in 1980 will be about 220,000—very slightly lower than at present—but that they will need more floor area than now. The 220,000 employees in the CBD include one-sixth of all the employees in the expanded metropolitan area; this represents a terrific concentration when one considers how small the district is in comparison with the area of the region. Table I shows the floor areas required in the CBD at present and in 1980.

TABLE I—FLOOR AREAS IN BOSTON CENTRAL BUSINESS DISTRICT

	Millions of Square Feet		
	1960	1980	
Office	24.3	32.4	Up 34%
Retailing	9.5	8.9	Down 6%
Consumer Services	7.2	11.0	Up 54%
Wholesaling and Manufacturing	18.6	10.5	Down 43%
Institutions	4.1	5.4	Up 30%
Public Utilities	1.0	1.0	—
Residences (incl. Hotels)	4.7	7.6	Up 63%
Total	69.4	76.8	Up 11%

Source: Boston City Planning Board

The striking thing about the table is the predominance of the office function. This comprises offices for headquarters of all kinds, and for banking, investment, law, real estate, insurance, engineering, and many other services linked with one another, with their clients, and with government departments. These are the things which involve many face-to-face contacts, and hence are ideally located in the regional center. With the four million regional population envisioned for 1980, more office workers will be centered in Boston; also, the space per office worker will increase in accordance with a well-established trend.

The relatively minor space occupied by retailing reflects the fact that the downtown retailing area is no longer the only large shopping center in the region. However, it is and will continue to be the largest one. It will always contain the best assortment of merchandise; it will continue to be the best place for comparison shopping; and it is the only place where you will find bargain basements. A great many of its customers will be in the area anyway because they work downtown, and many other customers will still find it convenient to reach the downtown shopping area by means of rapid transit.

In order to save time, I shall omit comment on the other items in Table I, or on other aspects of the Central Business District which are covered in the Planning Board's report which is soon to be available for distribution. While there are many problems in the Central Business District there are prospects that they can be solved with the help of all those who ought to be interested in them.

URBAN RENEWAL

The term "urban renewal" refers to the process under federal and state laws by which cities are attempting to restore blighted areas to useful life and to prevent the spread of blight. I think most of us are aware of this process, through publicity about the West End project and the New York Streets area, or perhaps experience with urban renewal in our home towns; but I wonder how many of us are aware of the extent of the problem in Boston. I wish each of our members would ride or walk through parts of the South End, lower Roxbury, or Charlestown. The sights and smells would make us ashamed that we are part of a community which can let these places exist. They are a by-product of a freedom in America for owners to use or abuse privately owned property as they see fit.

It was first the trolley car and later the automobile which made it possible for great numbers of downtown employees to escape from the close-in residential areas to the great open spaces, and to leave behind them worn-out buildings to be exploited by absentee landlords, and in many cases, when milked dry, let them be taken by the city for taxes.

The flight from blight is still going on, but blight can spread faster than new suburbs can be created. Unless the metropolitan community mobilizes to fight the problem, we can look forward to the day when the present close-in blighted ring will be nothing but a wasteland, and the newly blighted ring will extend into the Miltons, the Newtons, and the Belmonts. Some of the cities in the northerly quadrant are already beginning to be places from which it is fashionable to flee.

There are about 220,000 dwelling units in Boston, and at least 70,000 of them, one-third of the total, should either be torn down, or extensively rehabilitated in order to make them fit for human habitation. A substantial part of the 70 million dollars that Boston is spending annually for welfare, hospital, fire and police costs is certainly chargeable to the excessively poor housing.

The City Planning Board staff has estimated that to restore the deficient housing to decent and livable condition would cost about 500 million dollars in renewal project costs, and 300 million more for utilities, streets, schools, and the other public buildings and facilities needed in a balanced community.

This picture leaves no ground for optimism. It is no wonder that Boston's new mayor, John F. Collins, looks on the problem of urban renewal as the city's greatest challenge. There are tools for attacking the problem, created by federal and state legislation, and we must bend every effort to put them to work. But the most we can accomplish by these means will be nowhere near enough, for the funds available are only a drop in the bucket compared with what is needed.

If there is a complete answer to this problem, I do not know what it is. But of one thing I feel sure: there must be new attitudes toward the problem, new interest in it, and a new determination to do, somehow, the job that has to be done. A publication of the Ford Foundation quotes the following from an article in the New York Times by Edward J. Logue, Development Administrator for the city of New Haven:

> "Cities must organize themselves to fight slums as efficiently and as matter-of-factly as they now organize to fight fire. Today, leaving slum-fighting to the do-gooder or the planner is as obsolete as leaving fire-fighting in Times Square to a company of volunteer firemen."

It will take a great deal of coordinated effort to do anything worth while in urban renewal. It will take much time of many people, the spending (or rather, investing) of many millions of dollars. Before the job can be well started, there must be more public awareness of the enormity of the problem, and above all, leadership of a kind which has not yet made itself felt.

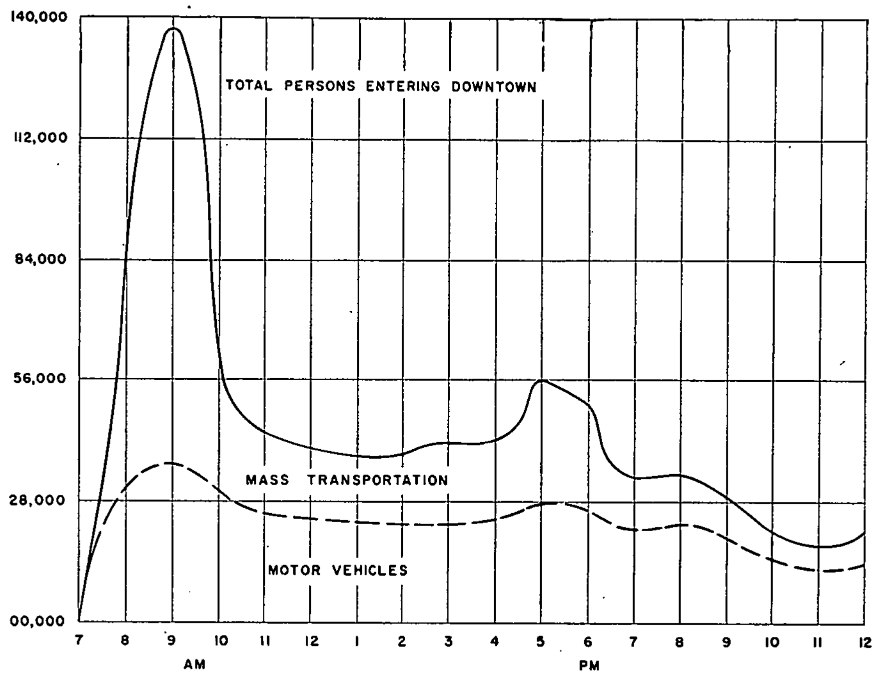
The Commuter Problem

Over a half million people travel each day to downtown Boston. About a third of them are carried by the Metropolitan Transit Authority; about 60 per cent by private automobile; and an ever declining few by commuter trains of the three railroads. The old Colony Division of the New Haven Railroad ceased operations in 1959 and no suitable replacement has been provided. The Boston & Albany Railroad has permission to get out of the commuter business by April 1, 1960 (though the decision is still being contested) and again there is no replacement in sight. Although the Boston & Maine Railroad is still saying in advertisements that it "loves commuters," it is questionable how long the stockholders will agree with this sentiment. There seems to be little doubt that commuting via railroads will be a thing of the past in this area before many years.

There is a pressing need for solutions to the problems created by the railroad suspensions and to the problems of the existing transit system. Moreover, instead of living from crisis to crisis (and failing to meet a crisis, as in the case of the Old Colony Division) there is a great need for an overall transportation policy to meet intelligently the needs of Boston and of the region.

One thing is sure: it is that commuters cannot all be handled in private cars. This is unanimously agreed upon by students of the problem. However, let me illustrate this by Figure 2, showing hourly distribution of persons entering downtown Boston. Consider the ordinates shown at 9:00 A.M.: about 36,000 persons per hour entering via motor vehicle and about 100,000 via mass transit. The vehicles carrying the 36,000 already tax the highways to capacity, as everyone will admit. Providing highways to carry the additional 100,000, and parking spaces for the vehicles, would be utterly out of the question. The only solution economically possible in a metropolitan area like Boston is to carry the bulk of the rush hour traffic by rail. A single track can carry comfortably 30,000 persons per hour, while a single 12 to 14-foot highway lane will carry only about 2,000 persons per hour.

If we grant that rail rapid transit is the one indispensable element, the next question is, how a suitable system can be created and maintained.



HOURLY DISTRIBUTION OF PERSONS ENTERING DOWNTOWN BOSTON

Source: "Transportation Facts and Public Policy for Downtown Boston" a publication of the Seminar Research Bureau, College of Business Administration, Boston College; March, 1958.

FIGURE 2

We already have the limited system of the Metropolitan Transit Authority (MTA) serving Boston and 13 other cities and towns. It carried 202,000,000 passengers in 1959. This is only about half the number that the system is capable of handling, as it did during the war years. The total number of persons entering downtown by all means has been nearly constant during recent years, but a great many riders have been enabled to change from mass transit to private cars by recent highway improvements and by the great increase in cars on the road. The highest percentage loss of riders has occurred in off-peak hours and in suburban areas.

The greatest trouble with the MTA is that its rapid transit lines fail to reach many of the populous places within the present district, such as Arlington, and that it does not reach, even by feeder lines, many heavily built-up areas just outside the district, such as Braintree on the south, Needham and Wellesley on the west, and Lynn on the north. While population has increased tremendously in areas about ten miles out, the population of the MTA district has remained about the same. In other words the MTA has not been permitted to reach out and pick up its potential new customers.

The main thing which has prevented MTA from extending its rapid transit lines to new areas is, I am sure, the fear in these areas of becoming involved in the MTA deficit. Figures just released for 1959 show that the cost of carrying the 202,000,000 passengers was 55 million dollars, or about 27.2 cents per ride. Income was 36.5 million, equivalent to 18.1 cents per ride. So the 14 cities and towns of the district are obliged to subsidize each rider to the tune of 9.1 cents per ride. This will cost me, in my property tax bill, $60.00 for the year. I live in Boston which is hit hardest by the method of apportionment. However, I feel that a charge of about $1.25 a week, above the fares paid by me and my family, is not excessive. Non-riders, those who prefer to drive, may ask why they should subsidize the system, when they rarely use it. One answer is that they are themselves enjoying a subsidy in the form of improved highways. The automobile owner has never fully paid his way on the public highways. The present gasoline taxes (state and federal) total nine cents per gallon in Massachusetts. Consider the fact that toll highway authorities, which are non-profit agencies, commonly find it necessary to charge tolls of two cents per mile. For 15 miles of turnpike travel the motorists pays 30 cents toll and burns about one gallon of gasoline; so the toll is equivalent to 30 cents per gallon—more than three times as much as the gasoline tax on a public highway. If the 30-cent figure is anywhere near the real cost of accommodating the car on a highway, and if the car owner using public highways pays only a fraction of the cost, it seems only fair that he should make up for this in some way. Since car owners and home owners are pretty much the same people, it is perhaps not too unfair to require them to help pay the transit deficit through real estate taxes.

Most students of the subject agree that it is sound public policy to keep transit fares down to levels which encourage riding, even if this involves a subsidy. For, if fares are raised, more riders turn to commuting by car, thus causing greater congestion, requiring more highways and much higher subsidies to them than formerly required for rail transit.

It is worth noting that special bond issues for state highways in Massachusetts amounted to $950,000,000 in the last eleven years (and this does not include federal aid) while public funds for transit extensions have amounted to only $20,000,000. The $20,000,000 was for rapid transit, which incurs little if any deficit. It is the surface routes, especially lightly patronized feeder lines, which are the great money losers.

There are signs that the pendulum is swinging back a little toward transit. The total of 202,000,000 passengers carried by MTA in 1959 was only a fraction of one per cent less than the 1958 figure. And in other cities some forward progress is being made in rapid transit. Cleveland has opened 15 miles of new high-speed transit since 1955 and is considering more. Toronto is happy with its first five miles and is starting on eight miles additional. Chicago has opened the first 6-½ miles of its 50-mile rail transit program. San Francisco is starting the first $125 million unit in a total program of over $700 million. Proposals for extensions or new lines are being considered in many other cities.

Let me summarize my thoughts on the commuter problem in the Boston metropolitan area.

(1) There will always be a rail rapid transit system, because the city could not exist without it.

(2) The present MTA rail system, worth hundreds of millions of dollars, must be preserved, extended to the large centers of population which it does not reach now, and made physically more attractive.

(3) An administrative set-up must be devised which will be free of the emotional reaction and the outright suspicion to which the MTA is subject. This may mean absorption of MTA by another state-created agency with broader geographical interests and responsibilities.

(4) Economies in the system must be accomplished through elimination of unnecessary employees, by relieving the system of

certain taxes and interest charges, and by eliminating certain feeder services where the income is only a fraction of the cost. (This is not to say that the MTA is not well run; I believe the MTA does a reasonably good job, though its hands are tied to some extent by legislative restrictions and cumbersome administrative procedures.)

(5) Fares from zones in the outer reaches of long rapid transit lines should be adjusted to a more realistic level. (Example: a trip from Riverside, 10 miles out, to Boston or to any part of the MTA system now costs 20 cents. At double that figure it would still be a bargain.) Fares for children and students, now five cents, should be raised to one-half the fare for adults.

(6) A reasonable method must be found for apportioning deficits incurred by the transit system. The method must be so eminently fair that no community will feel aggrieved.

I do not mean to infer, in anything I have said, that the highway program should be dropped. There is a definite need to complete the basic master highway plan of 1948, the heart of which is the inner belt, but we should be slow to go beyond that basic plan. We cannot afford to surrender everything to the automobile.

Regional Planning

In the last 15 or 20 years we have seen city planning change in status from something that was barely tolerated—an ivory tower business, not taken seriously—to a vital part of the operations of municipalities. Hard-headed businessmen and politicians now call upon planners for all sorts of information and suggestions.

Perhaps the principal function of a planner is to determine the best uses of land within the area of the governmental unit which employs him. He prepares general plans of the area, showing proposed land uses. He works out systems of street circulation, of parks and recreation, of schools, of libraries, and so on. The planner prepares zoning codes and maps, but he does not promulgate the codes; this is a legislative function. In many cities (but not in Boston) the planning board exercises control over subdivisions of land and administers the zoning code. The planner spends a great deal of time in collecting data: on population, on physical condition of the area he works in; on the needs of basic utilities; on labor forces; on operations of commerce and industry in order to find out what activities are good and can thrive in the area. He is often called upon to prepare for the city government a program of capital improvements to be made within the next few years.

As I said, the value of the planner's work is widely recognized within municipalities, and the value of planning regionally has been recognized in many metropolitan areas. In the Boston metropolitan area, a move has been on foot for years to establish a regional planning agency; bills have been presented annually for at least five years, but have got nowhere. This year's bills have been given a public hearing but none is given much chance of passage.

In the hundreds of square miles in the regional area—perhaps 2,000 square miles if we accept the 30-mile radius—there is obviously plenty of room for all the functions that must be carried on by the four million inhabitants: room for industry and commerce, for gracious living, for recreational and open spaces which can add so much amenity, for transportation facilities including airports, and so on. Many of these activities are growing in hit or miss fashion. It is obviously impossible for individual municipalities to provide proper guidance for economic forces which have no regard for city or town boundaries. To quote from "Metropolis Against Itself," a publication of the Committee for Economic Development:

> "When each jurisdiction goes on its separate way, urban sprawl continues, with its companions of spreading blight, cheap commercial developments along major highways, inadequate parks, congested schools, mediocre administration, smog, traffic jams, recurrent crises in mass transportation, and the hundred and one irritations of undirected growth."

It seems to be simple good sense to set up a regional agency to make the necessary studies and submit recommendations from which all could benefit.

Without going into the details of the regional planning bills, I can say that we could have such an agency at a cost of not more than five cents per capita annually. Most proponents advocate that the agency should be advisory only. It could make suggestions, but it would have no power to force them on any community. But the power of proper suggestion is very great. I feel that many city and town representatives might learn from their work with the regional planning agency the value of the wonderful word "compromise." I feel that they could, without giving up a spirit of competition, learn that combativeness is not good for them, either combativeness between outlying towns or between the outlying towns and the central city. We are all in this together, and if we pull in the same direction, we can make worthwhile progress.

CONCLUSION

The main purpose of this paper has been to try to interest our members in matters vital to Boston, and to instill the idea that the interests of Boston are, or should be, the concern of the entire metropolitan area.

Naturally, I do not expect many of our members to become crusaders for the cause of Boston. But I do ask them to keep informed on problems of Boston and of the region. I ask that they realize that a rebirth of Boston will mean a revitalization of the whole region, and I ask them to help to spread this idea, if only in conversations with friends or neighbors. When specific issues arise, I ask them to consider them impartially and let their elected representatives know what they think, and to join in committees for action when the need presents itself.

On this eve of March 17, it is appropriate to note that it was Edmund Burke, the Irish philosopher, who said, "All that is necessary for the triumph of evil is that good men do nothing."

ENGINEERING EXPERIENCES IN BELGIUM AND FRANCE

PAUL S. CRANDALL,* Member

(Presented at a meeting of the Structural Sectien, B.S.C.E., held on February 11, 1959.)

In 1958 we had the opporutnity to see how engineering was done in France and Belgium, in one case for repairs to an existing railway dry dock and in the other case for the construction of a new dock.

In Belgium the Service des Ponts et Chaussées had established the site location and characteristics of a new railway dry dock without having consulted with firms experienced in this type of work. As a result they chose a site which was very bad as far as river current was concerned. The Belgian contractor who undertook the job was required to adhere to the basic plan, and we were engaged by this contractor to prepare final plans and to supervise the construction of the dock. The planning was done entirely on the metric system, and the plans were submitted to the Service des Ponts et Chaussées for approval before construction began. It should be pointed out that the Ponts et Chaussées had followed very closely the characteristics of an existing railway dry dock at Ostende in preparing their specifications. As a result they duplicated all of the old errors that had been built into the Ostende dock and did not allow for any improvements which had been developed in the last 25 years. The hauling machine was made two speed although it was unnecessary, and the cradle was designed to operate with no adjacent pier to make its deck easily accessible by trucks. The finished dock therefore, although well built and functional in itself, cannot be approached by normal transportation equipment to handle heavy replacement parts needed on vessels. No crane service was anticipated for the new dock although the naval vessels to be dry docked would require such service as compared to the fishing vessels being docked at Ostende. Upon delivery of the hauling machine to Belgium from the United States, we were informed that the machine was unsatisfactory since it did not meet the standard codes for machinery of the Ponts et Chaussées. The chief complaint

* Crandall Dry Dock Engineers, Cambridge, Mass.

was that we had used overhung gears and pinions so as to keep the machine design statically determinate and simple. The problem was solved by our guarantee that any defective operation of the machine would be corrected at our expense. This is a good example of the blind application of a code to a piece of original equipment which has proved over the years to be adequate and safe.

We had the opportunity on this job to use again Azobé timber from the French Cameroons which had not been used by Crandall Dry Dock Engineers since 1933. This tropical hardwood is ideal for underwater construction in salt water because of its hardness and silica content which resist marine borer attack. Its strength and elastic properties are so unusual that we feel they should be known to more engineers doing waterfront designs. We list below the characteristics of Azobé or Ekki, as it is also called:

MECHANICAL PROPERTIES OF AZOBÉ

(Lophira procera A. Chev.)

Tests conducted by The Imperial Institute, London

Moisture Content		12.2%	20.8%
Weight per cubic foot	lbs.	65.5	70.5
Static bending:			
Maximum calculated longitudinal shear	lb. psi	896	693
Fiber stress at elastic limit	lb. psi	15,420	11,960
Modulus of rupture	lb. psi	25,460	19,400
Modulus of elasticity	lb. psi	3,000,000	2,240,000
Work in bending to elastic limit	lb. psi	4.12	2.82
Work in bending to maximum load	lb. psi	44.6	16.5
Compression parallel to grain:			
Fiber stress at elastic limit	lb. psi	10,260	6,700
Maximum crushing strength	lb. psi	11,610	8,990
Modulus of elasticity	lb. psi	3,388,000	1,674,000
Compression perpendicular to grain:			
Fiber stress at elastic limit	lb. psi	2,870	2,140
Shearing parallel to grain:			
Shearing strength:			
Radial	lb. psi	2,650	1,680
Tangential	lb. psi	2,790	2,460
Cleavage:			
Splitting strength:			
Radial	lb. per inch width	682	389
Tangential	lb. per inch width	869	603

Tension perpendicular to grain:			
Tensile strength:			
Radial	lb. psi	1,452	813
Tangential	lb. psi	2,315	1,140
Hardness:			
Load required to imbed a 0.444-inch-diameter steel sphere to a depth equal to one half its diameter:			
Radial surface	lb.	4,140	3,430
Tangential surface	lb.	3,980	3,580
End surface	lb.	4,650	4,010

The cost of Azobé in large dimensional stock is about double that of creosoted hard pine or untreated white oak, but its strength and borer resistance permit smaller quantities to be used without any added protection. This results in actual costs nearly equal to construction with domestic timber.

At Boulogne-sur-Mer, France, we had the opportunity to inspect a dry dock built by J. Stuart Crandall in 1933 and to go over in considerable detail with French engineers their studies for building a new railway dry dock for the port.

We found the public works engineers eager to consult with those who have specialized in dry dock design and construction. Their investigation of new facilities and the repairs to existing ones were very thorough. All facets of the problem were considered. The result of this open minded approach was that their existing railway dry dock has excellent crane facilities, easy access, and is very conveniently located with no real problems for good operation.

The destruction of ports during World War II has resulted in new modern construction far superior to the prewar ports, and therefore greater efficiency in cargo handling and transfer. In general, the public works staff of the French ports is very skilled in the art and science of waterfront construction. They are able therefore to prepare general plans and specifications for new construction without the aid of consultants. In most cases their planning is not detailed and a great deal of freedom is given to the entrepreneurs who bid the jobs.

The control of construction and the supervision is very strictly carried out, usually without any aid of consultants. However, the entrepreneur is held responsible for his designs as long as the structure he builds lasts, and he must make good any defects in workmanship which show up for ten years.

It is quite apparent that the prestige and professional standing of engineers in France is higher than in the United States, and a great deal can be learned from their methods of getting a job done. The French or Belgian entrepreneur, unlike our general contractors, must be qualified beyond the slightest doubt before they are even allowed to bid on a government project. Therefore, they are as much a professional organization as they are just builders. Although we can not say that one system is better than the other, we believe that the European system provides higher professional standing for engineers by making their income greater in proportion to that of skilled labor and by providing the authority to carry out the work in a first class manner.

Where esthetics are important, the European system of open contest by qualified entrepreneurs is very effective since it allows each bidder to propose one or more solutions to the project, and the design which is deemed the most desirable, both from esthetic and cost points of view, is chosen. This has the shortcoming of requiring all bidders to produce preliminary plans at their own expense for only a single proposal which is accepted. Perhaps some of our less attractive American structures, designed strictly on a basis of cost, could have been built along much more pleasing lines if this contest system were used from time to time. The entrepreneur is much freer to break away from standard codes and to produce daring and spectacular structures, his only risk being that he is always fully responsible for his design. This approach permits the designer with imagination to carry out from time to time developments which would never be tried in an atmosphere of conservative conformation. Was it not the Europeans who first developed prestressed concrete, thin shell designs and cable supported roofs?

If we wish civil engineering to remain a challenge, perhaps we should seriously consider adopting in part the entrepreneur system where competition necessitates greater resourcefulness, and the engineer-contractor organization avoids the divided responsibility which often results in over-design or structural failure.

CONSTRUCTION OF A 500 TON RAILWAY DRY DOCK AT NIEUPORT, BELGIUM

By KENNETH M. CHILDS, JR.,* *Member*

(Presented at a meeting of the Structural Section, B.S.C.E., held on February 11, 1959.)

The Entreprises Maurice Delens of Brussels, was awarded a contract by the Belgian Ponts et Chaussées to build a railway dry dock of 500 metric tons lifting capacity at the Port of Nieuport, Belgium to be operated by the Belgian Navy. Since this facility was to be similar to one constructed at Ostende in 1931 by J. Stuart Crandall, the contractor engaged Crandall Dry Dock Engineers to prepare the plans and specifications and to supervise the construction of the new dock.

The site of Railway Dry Dock No. 213 is on the side of the Yser River, in Nieuport, Belgium, approximately ½ mile from the mouth of the river, where it flows into the North Sea. Originally, this railway dry dock was to be of the sidehaul type. The site was prepared by dredging and paving of the river bank with rock before we were called in on the project. Consequently, the width of the site is approximately two times that necessary to erect an endhaul railway dry dock. Also the river width at this point allows only 50' of leeway between the stern of the ships to be docked and the jetty of the Nieuport Yacht Club which is located directly on the centerline of the railway dry dock. Mud deposits from the river are also a problem because approximately ½″ of mud is deposited in each 24 hours, and within the cofferdam, which was used for building the underwater portion of the track and which will be described later, mud was deposited at the rate of approximately ½″ per tidal period or 1″ per day. These two problems, coupled with the very strong prevailing winds and strong tidal flow in the river, made the choice of the location of this site not the best one. However, this choice of location was not ours and so we made the best of what we had.

The track of the railway dry dock was 112 meters in length. The outshore 60 meters was constructed of Azobé timber. This Azobé

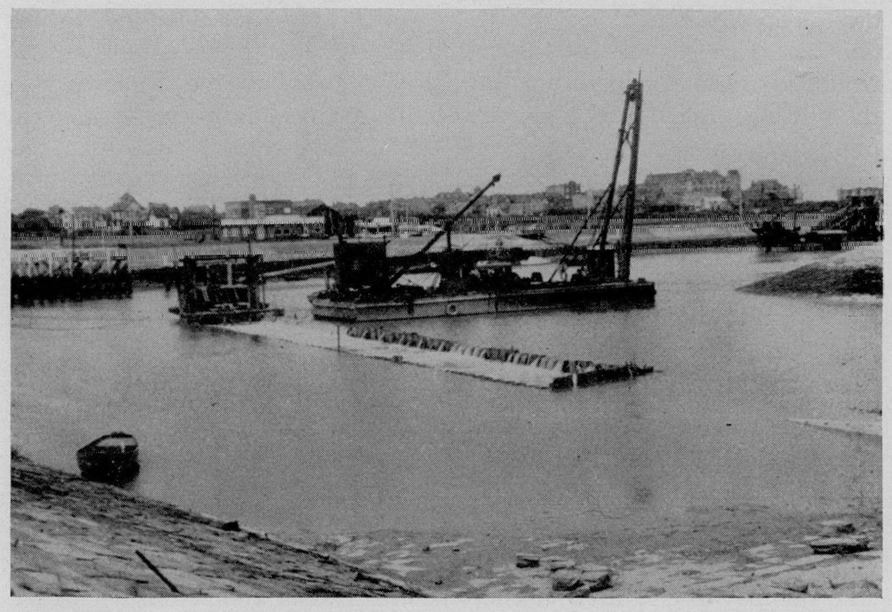
* Crandall Dry Dock Engineers, Cambridge, Mass.

was shipped to the job site in 6 meter lengths. It was our job to form the joints and then fit each piece to its adjacent piece, making sure that the joints at the nibs were a tight fit. All of the work of cutting the Azobé was done by hand with one man, an excellent carpenter, in charge of making the final fitting of the splices. He did all of the fine work with an adz and could shape the wood better with that adz than most people can with a plane. All of the cutting of the wood was done with hand saws which had to be sharpened at least once per day. The Azobé was so hard we had to make a special bit for boring two holes, approximately 1-½″ in diameter. A regular expansion bit would slip and not maintain the diameter desired. We tried welding the cutting piece to the body of the bit, but this didn't work, and we finally had to form a ring which would act as a guide for the bit. The men themselves had trouble with their tools. If they were not careful in using their chisels and saws and so forth, the cutting edges were very easily broken.

The outshore 60 meters of track were normally under water at all times. Our usual practice for building this underwater portion of track is to build the track on the beach in the dry, launch it, and then, by using divers, secure it in place. However, since both the government and the contractor wanted to build the entire track in the dry, a cofferdam 5 meters wide and 65 meters long was built by driving steel sheet piling. The piling was cut at an elevation of 2 meters above low water which meant that this cofferdam was flooded at each tidal period. By using three good sized pumps, we were able to work within the cofferdam for approximately 4 hours at each low tide period. The pumps were located at the outshore end of the cofferdam where the bottom was deepest. A sump approximately ½ meter deep was dug at the extreme outshore end and one pump ran continuously to take care of any leakage.

The piles under the wooden portion of the track were of Azobé, 30 centimeters square. After setting the elevation of the piles, all of them were cut off by the use of two man bucksaws. Since all of the piles were driven in the dry, it was possible to drive them very close to a true straight line. Because of this, no extra piles were required on the job.

When all of the piles had been cut and all the wood track prefitted on the beach, the six meter sections were put in place one by one. A crane was used to put each section inside the cofferdam after it had been pumped out, but once inside the cofferdam, each track section was then manoevered by hand. This placing of the wooden track sections was rather slow since each six meter section was 40 centimeters wide and 20 centimeters thick, weighing better than one-half ton. Once each section had been laid in place, however, there was no problem with its floating away, since Azobé is a non-floating wood. The only extensively used power machinery other than our crane



Coffer Dam Flooding During Rising Tide. All Shore Line Seen in this Picture Is Paved with Brick or Rock.

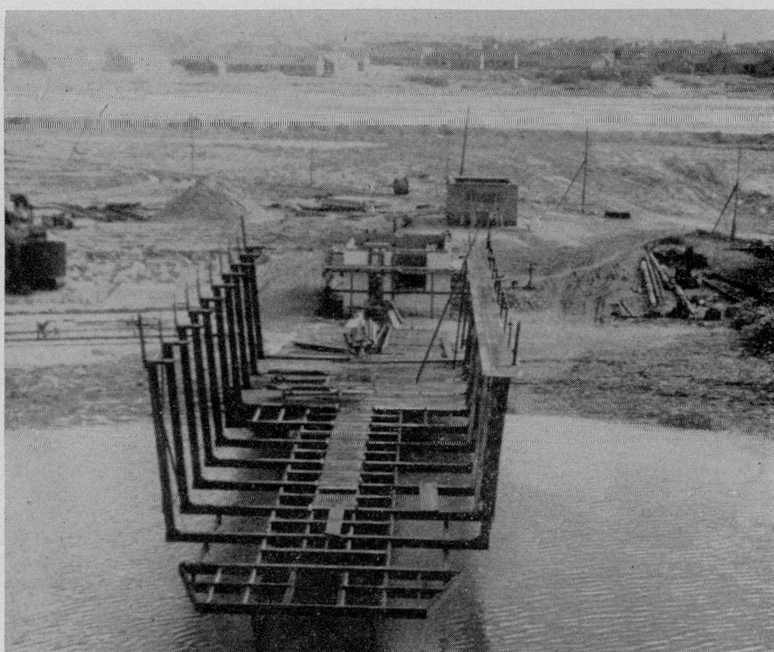
were the boring machines which we used for making all of the holes for fastening the track together, fastening the track to the piles, and fastening the steel rail plate which rested on the top of the wooden track to the track itself. The gauge of the track was maintained by wooden cross ties placed at approximately 3 meter intervals and bolted to the underside of the wooden track. On all of the cross ties on which the hauling and backing chains would rest, steel chain guides were bolted. These guides were used both to guide the chain and to cut down wear on the cross ties. At approximately 80 meters from the head of the track a large pulley was fastened to the wooden track.

The smaller backing chain, used to keep the hauling chain tight, passed around this pulley.

The inshore 40 meters of track was built of reinforced concrete, 1.2 meters deep and 30 centimeters wide. This concrete track rested on pre-cast concrete piles which had been driven and then cut off at an elevation just above the bottom of the concrete track. The reinforcing steel of the concrete piles was allowed to project above the cut-off and thus form a tie with the concrete track. When building the forms for the concrete track, small boxes were built in wood and placed at the top of the forms to make pockets. Steel plates had been welded to the bottom of the steel rails which were to rest on the concrete track. These plates, which had 5 centimeter diameter holes in them, went into the pockets left in the concrete track and, after the rails had been set in place, graded and lined, mortar was packed into the pockets to hold the rails to the concrete track. Concrete was placed by using a hopper type container which was suspended from our crane over the form work. One man guided the hopper while another man operated the releasing mechanism. Concrete was mixed with a mechanical mixer and dumped into a truck. However, it was shoveled by hand from the truck into the hopper.

The machine used for hauling the cradle up the track was of the simple open gear type with some innovations. We did incorporate the use of a two-speed herringbone speed reducer in place of a jack shaft with sliding pinions which is rather unsatisfactory because of its relative high speed and consequent noise. The speed reducer, since it is totally enclosed and continuously lubricated, is a quieter, more efficient and longer lasting solution. The main gear of this machine had a diameter of 8′-3″.

The cradle, which was of all-steel welded construction, was fabricated for the most part, in the shop. The undercarriage section, which was made up of a top and bottom chord made from a split I beam with tubular columns, was made in four pieces, each piece was assembled in the shop. With the fine system of canals which Belgium has and which we expected them to use, these prefabricated sections of undercarriage were shipped to the job via truck; evidently this method of transportation was more economical. Once at the site it was a simple matter for us to place each of the undercarriage sections on the roller system which was resting on the track, fasten it to its adjacent section, and allow the whole structure to roll down the track in order to make room for the next section to be placed. The cross beams were laid in place tack welded, as was the entire structure; the uprights were bolted into place, and then all of the final welding was accomplished. The steel uprights were bolted in place to allow for easy removal. The welding as a whole was of excellent quality as was, as a matter of fact, all of the construction. This excellence of construction was due,



Structural Steel Frame of Cradle with Forward One-third of Timber Decking and One Timber Docking Platform Completed.

I think, to three causes. First, the Belgian workman took pride in his work. Second, this particular job had many inspectors, the contractor, the government, and us, as designers. Each of us inspected the work very carefully and so very little escaped unnoticed. Finally, the contractor had been able to get a good price for his bid on this construction, thus did not object to making small changes or additions to the job.

After the steel work on the cradle was completed, the cradle was entirely decked over, using oak planking and stringers. A docking platform was built at the top of the steel uprights, fixed timber keel blocks and movable timber bilge blocks were added. Bilge blocks were controlled in their movement by chains which passed over a winch located on posts just above the docking platform. Because the major portion of the deck was horizontal, the aft section of the deck was approximately 3 meters above the track.

Maneuvering First Vessel into Position for Haulout. The Two Tugs Were Necessary Because of Strong Tidal Current and Wind.

We made the final tests using a Belgian minesweeper which displaced approximately 380 tons, well below the designed capacity of 500 metric tons. Our reason for using this vessel was that almost the entire Belgian Navy consists of just this class vessel. The capacity of the dock is greater because larger vessels are anticipated in the future.

In conclusion, although the rate of accomplishing work in Belgium is not as great as it is here in the United States, the quality of work is just as high. Part of the reason that it takes longer to accomplish any work is that power tools are not often used. When I inquired as to why almost everything is done by hand, I was told that there were two reasons for this: first, labor is inexpensive and power tools are expensive, and; second, since there are many contractors in such a small country, every contractor tries to keep as many men as possible working to keep a stable labor force within his own organization.

We found that labor costs in Belgium were about one-third those in the United States and that the costs for fabricated steel, concrete, etc. were in the order of 80% U.S. costs. On the other hand, because of the reluctance to use power equipment for labor saving, the time required to accomplish the job was about double and the number of men employed was about 25% more, resulting in actual saving over U.S. construction costs of only 15% to 20%.

THE CONNECTICUT RIVER—ITS DEVELOPMENT AND ITS VERSATILITY

By Louis D. Pierce

(Presented at a joint meeting of the Boston Society of Civil Engineers and the Hydraulics Section, B.S.C.E., held on February 17, 1960.)

We at New England Electric System are proud of the part we have played in the development of New England through the very essential function of providing the energy needed to meet the demands of the past great growth of the industrial and domestic load of this region, and anticipate with the same pride the challenge of the definite future growth of New England with the accompanying ever increasing demand for more power to meet the load requirements. I speak of this future growth as definite, mainly on the trend of the primary load of our system to its present annual total for the year 1959 of about 6 billion, 900 million KWH's. This compares with a figure of some 34 million KWH's the first full year of our operation in 1910, and an increase on an annual basis of almost 2¼ times, since the Second World War. Many present day statisticians are prone to paint a gloomy picture of New England's future, but no one connected with supplying the electrical demand will agree.

We, therefore, welcome this opportunity to present the part of the New England Electric story with which I have been most familiar, and which is the subject of my paper, "The Connecticut River—Its Development and Its Versatility." This particular phase of the power story, although more or less past history from the developmental standpoint with regards to our system, is still very much a part of the overal picture, in that the hydro generation carries the peak loads and provides the regulation for New England's largest integrated power system combining steam and hydro power sources. The opportunity to present such a paper before this group is further gratifying at this time, in that the year just past, 1959, marks the fiftieth anniversary of the first power produced on the Connecticut by our Company, because it was in June 1909 that the first unit at our Vernon Plant was placed in operation.

General Description

The Connecticut River Basin is long and narrow, extending in a north and south direction with the upper end of the basin in northern N.H. and the Province of Quebec, and its lower end at Long Island Sound. Its greatest length is about 280 miles and its maximum width about 62 miles. The drainage area of the watershed is 11,320 sq. miles of which 115 sq. miles are in Canada. The basin extends through four states and the area in each is as follows:

New Hampshire	3,110 sq. miles
Vermont	3,960 sq. miles
Massachusetts	2,710 sq. miles
Connecticut	1,425 sq. miles

The basin is distinctly mountainous in its northern and western areas, the ruggedness decreasing progressively to the south, becoming comparatively low and level in the coastal regions. Elevations in the Green and White Mountains, which form the western and eastern divides in the northern reaches of the basin run from 3,000 to 4,500 feet with a few peaks much higher.

The river itself rises in northern New Hampshire at Fourth Conn. Lake, which is nothing more than a swamp during most of the year. The length of the stream channel from Second Connecticut Lake, the most northerly developed storage reservoir, is about 400 miles, and the river falls some 1870 feet. The slope is very steep in the upper reaches averaging 25 feet per mile for the first 25 miles below First Conn. Lake. Between miles 300 and 270, the fall is 400 feet, the bulk of which is concentrated in the so-called Fifteen Mile Falls reach. From the foot of the falls to the head of tidewater above Hartford, Conn., a distance of 225 miles, the fall averages slightly less than 2 feet per mile.

The portion of the river in which the N.E.E.S. developments, Figure 1, are located covers some 250 miles of the main stream, extending from Second Lake to the Vernon Plant located just below Brattleboro, Vermont, and the Deerfield River, the principal tributary which empties into the main stream near Greenfield, Mass. In this area, the System owns and operates 6 generating stations and 2 separate storage reservoirs on the main river with total nominal capability of 456,000 KW through a developed head of 500 feet; 7 stations and 1 separate storage reservoir on the Deerfield with a

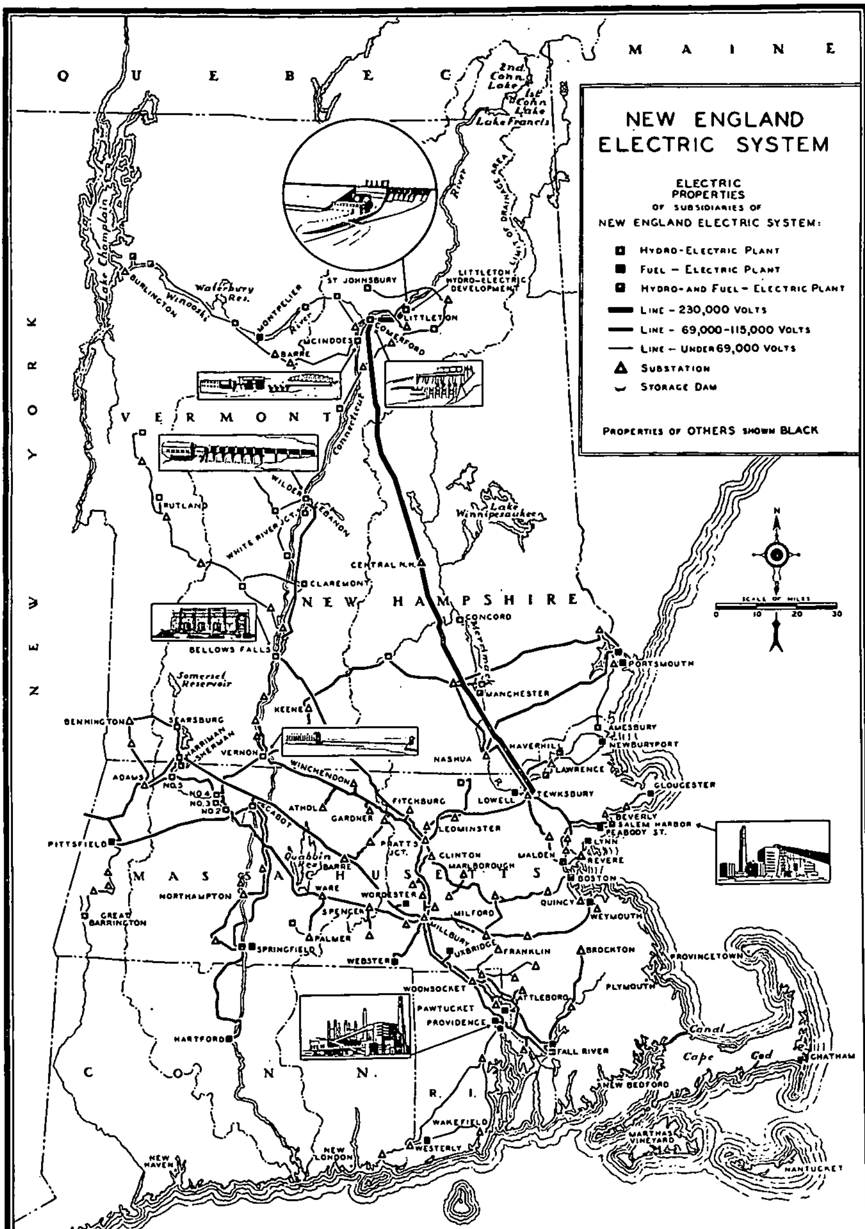


FIG. 1.—NEW ENGLAND ELECTRIC SYSTEM.

total nominal capability of 90,300 KW through a head of 1060 feet; and 3 small generating stations and 4 storage reservoirs of the Granite State Electric Co. on the Mascoma River. Descriptive matter regarding our installations will be confined to those plants on the main stream, as the Deerfield plants constitute a story in themselves. Reference will be made to these plants under several of the sections of this paper.

Geology

The geology of the valley has many interesting aspects. Before the ice age, when the extensive deposits of clay, sand, gravel and boulder clay, which now bury bedrock to varying depths over large areas, were absent, the topography of the region was different from that of the present time. It is probable that the Connecticut and other large rivers in this region had well graded courses without falls or rapids. They had developed broad valleys on the floors of which the streams meandered. It is also indicated from studies of the late Mr. Irving B. Crosby, that in preglacial times the upper Connecticut River drained a larger area than at present. The valley of the upper Ammanoosuc is broad and connects with the valley of the Androscoggin by a low pass, which is only a few feet above the present crest of the Pontoocook dam. The drainage of the upper Androscoggin came through this valley into the Connecticut,

Just before the glacial period, there was an uplift of this part of North America, amounting to hundreds of feet. This gave the streams great velocities and enabled them to entrench their channels. Where the streams meandered on the valley floor, they entrenched themselves in winding gorges. These gorges have been particularly pronounced at the locations of both our Comerford and Moore plants. At the close of the ice age this old valley was blocked to varying depths with glacial debris, and temporary lakes were formed, in which sediments were deposited.

The peculiar arrangement of the ledge in the valley walls and along the riverbanks seems strange at first, but is easily understandable when the past glacial history of the district is considered. Ledge in some reaches is visible on both banks of the river, at other points ledge appears on one side or the other, but not on both sides, and there are long stretches with no ledge on either side.

At the close of the glacial period, when the reborn Connecticut sought a course to the sea, it wandered through its old valley then partly filled with glacial deposits. Its course had no relation to the buried channel. In some places it was over the preglacial channel and in other places it was well toward one side or the other. The River soon cut down in the soft material, and where it was not over the old channel it became superimposed upon buried ledges in many places. As the river was confined to its course by high banks, it cut into these ledges. Here erosion was slow and the ledges determined the grade of the river and prevented it from cutting down to the level of the old channel.

The surface geology of the valley was also determined by the glacier movement southward, and its subsequent retreat. As the ice sheet moved southward, it picked up great quantities of debris. This had been ground up by the ice motion and mixed until it consisted of everything from boulders down to rock flour and clay. Towards the end of the glacial period the movement of the ice became weaker and this debris or boulder clay was deposited irregularly. Where the edges of the ice sheet made temporary advances during the general retreat, ridges of boulder clay known as moraines were formed. When the last of the ice finally melted, the boulder clay or glacial till was dumped unevenly over the country forming a thin mantle of stony soil, which partially clothes the rocky hills.

During the melting of the ice, lakes were formed in the hollows caused by the irregular deposition of the boulder clay and in these lakes clay, sand and gravel were deposited. The ice melted back irregularly and tongues of ice blocked the valley at different points forming temporary lakes, which were drained suddenly when the ice dams gave way. The word "Temporary" geologically speaking as used here actually covered periods ranging up to several thousand years. This caused chaotic conditions with torrents rushing here and there forming deposits of gravel and boulders. The streams from the melting ice were also bringing their loads of sand and clay, which settled out in the quieter waters. After a layer of clay had been deposited, a rush of water often deposited gravel and boulders over it and then perhaps a temporary advance of the ice sheet during cold periods rode over these deposits and laid down a bed of boulder clay. In some complicated manner, such as this, the confused arrangement of different deposits which are characteristic of the valley in general was formed and in this way the old channel of the Connecticut River became filled with a heterogenous mixture of materials, including boulder clay, clay, sand, gravel and boulders.

The history of two of the largest of these glacial lakes has been extensively studied by various geologists, who at one time or another were either students or professors at Dartmouth College, including Hitchcock, Upham, Goldthwaite and Lougee. Richard Lougee, Professor of Geomorphology at Clark University, has published several interesting articles summarizing these studies.

The earlier of the two lakes was named Lake Hitchcock and at one time stood at Elev. 650 or about 265 feet about the present Wilder Pond. The control for this lake was a gravelly glacier deposit in the vicinity of the Haddams in southern Connecticut. Following the drainage of this lake due to a break in the dam control from sudden land movement, a second lake named Lake Upham remained with a control located near the now dry and abandoned waterfall site over sandstone ledges near Turners Falls. This site is 50′ above the present river.

Much of the mystery of the existence of these two lakes was cleared up through the study of the varved clays in the Lyme-Hanover region. Each varve represented a year's deposit of sediment on the floor of the lakes and by a count of the varves the period of existence of the lakes was determined; Hitchcock—1,000 years at Hartford, 50 years at Hanover; Upham—1,600 years at Lyme, just north of Hanover. Also the actual speed of retreat of the great ice sheet could be determined from studies of the clayey stratification which amounted to about 700 ft. per year in the Hanover area.

History

The first discovery of the Connecticut was made by a Dutch sailing master named Block, for whom Block Island off the R. I. Coast was later named. He sailed up the river as far as the falls at Enfield in the spring of 1614, and stopped to visit the various Indian settlements then in existence. The Dutch soon began an active fur trading business with the Indians, establishing posts first at Saybrook, then Hartford. The first English settlers met considerable opposition from the Dutch, but their differences were finally resolved and the colonization of the valley begun.

The first English settlers came from the Plymouth Colonies and were looking for more desirable land. They proceeded by ship and established a colony at Windsor, Conn., sometime around 1633-34. By 1636 Windsor, Weathersfield, Springfield, and Hartford had been established by colonists from Plymouth, Dorchester, Roxbury and Newtown. Soon the settlers branched out up river establishing Northampton, Hadley and Deerfield, and in 1673 Northfield was established with a palisade and blockhouse for protection against the Indians. This marked the extent of northward movement for some years, as Indian resistance stiffened against any further intrusion. In the meanwhile, other settlements, such as Middletown, Lyme and the Haddams were settled to the south.

Open warfare finally broke out between the settlers and the Indians in the winter of 1675-76, which included the first sacking of Deerfield. This was also the year of the "Great Swamp Fight" which destroyed a good part of the Narragansett Indians in lower Rhode Island, and broke the power of the Indians on the lower river valley. There followed a period of continual advance and retreat in the settlements along the river to the north for a period of about 75 years until the beginning of the French and Indian War in 1756.

In spite of this, some courageous settlers continued to move northward and established Fort Dummer near Brattleboro, Vt. as a northern bastion to guard the river south, and later Fort #4 at what is now Charleston, N. H. in 1745. This fort was to bare the brunt of the French and Indian attacks around the period 1756-1760. Finally in 1759, Rogers and his rangers with their winter attack on the St. Francis Indians made the valley safe forever from these marauding parties who travelled southward and escaped northward by means of the ice covered Connecticut River. With the taking of Quebec by the English and acquisition of Canada in 1763 and the signing the Peace of Paris, the French power was ended along the Connecticut and in the New World. This also meant the end of the history of the Indians in the Connecticut River Valley.

The Connecticut during these early years was the main means of travel. The Indians had used the river for generations, and with the birch bark canoe could shoot most of the rapids except the white water at Bellows Falls, where they had to make a carry. With the cessation of the Indian menace and the rapid expansion of settlements to the north, the development of the river for navigation became a paramount issue. The end result of this activity was the construction of locks and canals at some six locations as follows:

1. Bellows Falls, Vt. 1792-1802 involved nine locks with total lift of about 52 feet.

2 and 3. Turners Falls and South Hadley Falls 1792-1795 South Hadley canal was 2½ miles long with 8 locks and Turners Falls 3 miles long with 10 locks.

4. Hartland Vermont—1794 chartered, short canal and two locks.

5. Wilder Vermont—most northerly consisted of two sections with locks in each. Built about 1810.

6. Windsor Locks sixth, last and most southerly canal, built 1825-1828.

With the construction of these six projects the Connecticut River became the first river in the country to be improved with locks and canals for navigation, and the canal at Bellows Falls held the distinction of being the first commercial canal to be started in the country. Many additional waterway proposals were advanced and actually surveyed in this period, but never built. These included schemes to connect the Upper Connecticut with Lake Champlain via the Wells and Winooski Rivers, with the Merrimack via the Pemigewasset River, the development of locks and canals to navigate the White River and at Brattleboro on the main stream, to name a few.

The early freighting and transportation was performed with flat boats approximately 70 feet by 11 feet wide with a capacity of about 30 tons and propelled by poling and sail. Timber was moved by making rafts of logs tied together in boxes each 60 feet by 18 feet wide, which were grouped together into rafts consisting of 2 boxes wide and 3 long. In the era 1820 through 1840 various types of boats propelled by steam powered paddle wheels came into use. The steamboat activity reached a climax in the early 1830's and finally died out by 1850, when the first railroads began operation in various parts of the valley. Many of the early steamships were built too wide to navigate all the various canals and locks, and consequently some of the more substantial boats operated in only limited reaches of the river. But during this period nevertheless there was considerable river traffic from the mouth to as far north as Wells River, Vermont.

New England Electric System Developments

On June 7, 1907, a small group held a meeting on an island in the Connecticut River close by Bellows Falls, Vt. It was headed by Henry I. Harriman and Jeremiah Smith, representing Malcolm G. Chace. Their purpose was to perfect the organization of a corporation to be known as the Connecticut River Power Company. At this meet-

Fig. 2.—Vernon Plant.

ing an election of officers was held and a board of directors appointed. The directors forthright authorized the construction of a hydro-electric plant on the Connecticut River between Vernon, Vt. and Hindsdale, N. H., which was later named Vernon Station. Shortly thereafter construction started and by the middle of 1909 the first unit was converting the water power of the Connecticut into electrical energy.

Here at Vernon, figure 2, was the genesis of the present far flung N.E.E.S. and the first development of the System on the Connecticut River. With this first installation began the culmination of the dream of Harriman and Chace, which has since been successfully demonstrated that the most economical power for New England was obtainable through an interconnected power system, including both steam-electric plants and hydro-electric stations.

Vernon Plant

The Vernon Development has a present nominal capability of 28,000 KW developed through 10 units under design heads of 34 and 35 feet and utilizing about 12,700 cfs. The overall length of the plant is some 950 feet of which 600 feet is the spillway. The spillway is patterned after the old school with straight Ogee crest topped with pin type flashboards, 6 and 8 feet high unbraced during the winter and 8 feet partially braced during the summer.

Additional discharge capacity is provided by 8—7′ x 9′ high hydraulically operated sluice gates located in the spillway section. There is also a trash sluice and a log sluiceway.

The powerhouse contains 10 units; 4 rated 3200 hp. each were installed in 1909 and 1910 and are the old style 3 runner type, 4 rated 4200 hp. each were installed in 1924 and 1925 replacing originally installed 3 runner types, and 2 rated 6000 hp. each installed in 1921 when an extension was made to the powerhouse. The eight units installed in the initial period 1909-1910 were of the 3 runner type, which was at the time thought to represent a highly satisfactory design, but they became obsolete almost before they went into service with the demonstrated use in 1911 of the single runner vertical turbines introduced at the Keokuk Station on the Mississippi River.

The Vernon layout had the virtue of low first cost, which was of no slight importance with a new and struggling company. The efficiency however was considerably below present standards and on account of the excessive amount of underwater gate mechanism together with the difficulty of keeping the several bearings on the long vertical shafts bolted up and aligned, the maintenance proved expensive and burdensome. Following the development of high speed runners to a point which made it possible to replace the 3 runner units with a single runner, the conversion was made to 4 of the units, with an improvement in maximum efficiency from 64% to 84%. In operating the 3 runner type units the top runner was run with gates fixed at 85% open, with the bottom and middle runner gates adjusted to the load variations.

Transmission from Vernon includes ties to the System on the

Deerfield, at Bellows and Millbury, Mass., and to the local load at Keene and Brattleboro.

Considerable damage was experienced here during the 1936 flood with a peak flow of some 176,000 cfs.

Various studies have been made for the redevelopment or further expansion of the Vernon development but none have been found economically feasible.

It might be noted that concrete placed here over 50 years ago under no particular laboratory control is just now showing slight deterioration on the spillway section.

Bellows Falls

As mentioned earlier with reference to navigation on the Connecticut River, the canal at Bellows Falls was used primarily for transportation, but a few small water powers were developed, taking water from the canal as early as 1829, and this use was increased as time went on. Between 1875 and 1883, important improvements were made which included enlargement of the canal to a 75 foot width and a depth of 17 feet, and the installation of a new headgate. In 1900 the dam was rebuilt with concrete completing the old canal company's system. The total installation amounted to about 10,000 hp. developed by some 70 individual turbines. Gradually these facilities fell into disuse and in 1927 the N.E.E.S. began the redevelopment of this site completing the job by 1929.

The plant as redeveloped results in a normal headwater some 11 ft. above the former pond, and consequently the design of the spillway was predicated on two fundamental requirements.

1. With normal operation the water surface had to be carried 11 ft. higher than previously.

2. Under flood conditions the discharge capacity at any given stage had to equal or exceed that of the old spillway in order to avoid flood damage under the increased operating heads.

The Bellows Falls plant has a present nominal capability of 45,000 KW developed through 3 units under a design head of 57 feet, utilizing about 10,400 cfs. The dam which is basically all spillway is located remote from the powerhouse. It is 640 feet in length with two fixed crest levels. For maximum reliability of operation, it consists of 3 bays of 13 foot high stanchion flashboards, two bays each 121′ long, and one bay 100′ long, and two roller gates each spanning clear openings of 115′ with sills 18 feet below normal pond. A steel truss bridge spans the entire length of the spillway and takes the thrust of the upper ends of the stanchion beams. The stanchions can either be tripped manually or can be lifted by a small gantry and secured to the upper chord of the bridge. The gantry is also used to remove the top sections of stop logs to obtain additional discharge over the boards. The roller gates are of the MAN type made up of steel cylinders 13½′ in diam. and 121′ long over all. Steel aprons attached to the cylinders are provided with oak sealing strips which bear on steel sills. Each gate is operated by a motor driven hoist, which rolls the gate up an inclined rack by a chain connected at one end. Heat is provided by electric space heaters in the pier faces at the end seals. These gates, because of the unobstructed opening provided, have proven very satisfactory at this dam where a great amount of ice, as well as the usual trash must be passed during the spring break-up.

A special flow splitter, nicknamed "The Grasshopper" was designed and installed a few years back to divert the water flow while replacing stanchions. This has operated successfully under heads up to 5.5 feet.

The canal was enlarged in cross-sectional area and further improved with a lining consisting of concrete ribs spaced 20 feet on centers along the 1 on 1¼ side slopes topped by a concrete headwall 6′ high. In addition the bottom and side slopes between the ribs were rock paved with substantial stone from old foundations to a thickness of about 1½ feet. Under normal operating conditions velocities in the canal are limited to 6 ft. per second.

The powerhouse contains three units spaced on only 44′-9″ centers, which was necessitated by the restricted area available and the desire to keep ledge excavation to a minimum. The turbines are vertical Francis type rated 18,000 hp. each with speed of 85.7 RPM, direct connected to 17,000 KVA rated General Electric generators. The powerhouse location was predicated on the maximum use of existing ledge for stability and minimum use of concrete as well as to limit the amount of ledge cut necessary. The tailrace was made in an open ledge cut. The ledge under the powerhouse was excavated only enough to accommodate the scroll cases and the draft tubes were tunneled through the rock to the tailrace. This resulted in a large mass of ledge over the draft tubes to provide stability against the headwater pressures.

Because of the unusual amount of ice running in this portion of the river during the spring break up, a boom consisting of timber floats was installed across the pond at the upper end of the power canal, which deflects the ice to the spillway. To intercept ice escaping this boom a second boom is installed across the canal upstream of the headworks and deflects ice to a skimmer gate located to one side of the powerhouse, which discharges into a sluiceway. The racks at the intake are cleared by means of a mechanical rack rake assisted by a compressed air cleaning installation. Transmission from Bellows Falls includes ties to the system at Pratts Jct., Mass., Vernon and Wilder Stations and to the local load at Charlestown, N. H., and the Central Vermont Public Service at Springfield, Vt.

Comerford

During the early days when various surveys of the river were being made with regard to improvement for transportation, DeWitt Clinton, realizing the folly of attempting to develop a system of locks to lift boats past the Fifteen Mile Falls area, did predict that sometime in the future men would develop the falls for the service of mankind. This prediction was partially fulfilled with the construction of the Comerford Plant in the years 1928 through 1930. Some commercial development did exist as early as 1800 somewhat below the Comerford site, at the location of what is now the McIndoes Plant. It included a wing dam from which water was taken to power-saw and grist mills, which were in existence up to about 1900.

Studies of the Fifteen Mile Falls area contemplated a two-stage scheme with the upper development, now our Moore Plant, planned as the first phase. But because of early power delivery contracts and the shorter construction time estimated for the lower site, it was built first.

The Comerford Plant has a rated nominal capability of 150,000 KW developed through 4 units under a design head of 180 feet, utilizing 12,000 cfs. The pond has some 32,000 acre feet of storage available through a drawdown of 40 feet. The general layout consists of an overflow spillway built on a high ledge ridge angling back from the river on the Vermont side, an intake and powerhouse located next in line about on the river bed, and a rolled-earth embankment supported by a high concrete retaining wall to tie into the earth river bank on the N. H. side. The original preglacial river bed was found located about ¼ mile toward the N. H. side resulting in ledge about 40′ below and overlain with glacial till, a typical condition in the river valley as discussed in the geology portion of this paper.

The spillway is 850 feet long with an effective water passing length of 800 feet. The fixed crest is at two elevations containing 4 bays, each 72 feet long, of 8 foot high pin type flashboards and 7 bays each 72 feet long, containing 10 foot high stanchion type boards. Additional spill capacity is provided by 6-7 ft. by 9 ft. sluice gates located some 50 ft. below the normal full pond, and 2-9 foot diameter high pressure sluices not normally operated but required for by-passing water during construction. The stanchion section is designed to be operated either by removal of the top section of stop logs, the release of a part or all of the logs by lifting the needle beams, or by the emergency release of needle beams. The total discharge capacity of the spillway including sluice gates is about in excess of 100,000 cfs.

The intake of buttress type design provides for 4-19 foot diameter penstocks tapering to 16 foot dia. at the scroll cases with sills of the intakes 90 feet below normal pond elevation. They are controlled at the upper end by Broome gates arranged to traverse the entire length of the intake on electric hoists, two gates being provided. The penstocks are located on 45′ centers in the depressed filler spaces between buttresses and are covered by concrete slabs spanning the space between buttresses for weather and temperature protection.

The retaining wall, of gravity section, is 170 feet in height extending 480 feet upstream and 410 feet downstream from the dam centerline. The embankment behind has a crest width of 25 feet with slopes of 1 on 3 upstream, and 1 on 2½, 1 on 3½ and 1 on 3 downstream. The intake structure joins the wall at center of embankment, thus providing support. The embankment consists of an ample core of boulder till with slopes of 1 on 1 and a more porous material on the outer portions. A blanket of impervious material extends from the core to the upstream slope. This embankment provides for rapid drainage during drawdown of the pond and consequent reduction in the size of the retaining wall.

The powerhouse of steel and brick is 236 feet by 99 feet and is located immediately at the toe of the intake to minimize the length of the penstocks. The extremely long tailrace channel resulted in a gain of 10 feet of additional head with the excavation for the draft tubes going down some 35 feet below the original river bed. The turbines are vertical single runner Francis type units and rated at 54,000 HP each for 170 ft. of head and speed of 138.5 RPM. The generators are Westinghouse each rated 39,000 KVA.

Transmission includes ties to the System at Tewksbury, Mass. and Moore Station, as well as supply to the local load principally through Green Mtn. Power and Central Vermont Public Service. The transmission lines to Tewksbury are also used to transmit steam power northwards to loads in N. H. and Vermont when hydro-electric generation is not available in sufficient quantity.

Comerford at the time of its development was the largest hydroelectric station ever constructed in New England.

McIndoes Plant

The McIndoes Falls Station is located about 7 miles below Comerford and was built at about the same time. The station has a nominal capability of 10,000 KW developed by four units at a design head of 29 feet.

The general layout includes a powerhouse on the Vermont shore joined immediately by the spillway which contains in order, 2 bays of 17 ft. stanchion flashboards each bay 50 ft. long, 3-24 ft. x 25 foot high tainter gates and a 300′ long section of 6′ high pin type flashboards. The pins and boards are handled by a 4 ton capacity cableway. The stanchions can be released automatically or lifted clear by a 2 ton capacity electric monorail hoist carried on a latticed girder supported on steel A frames. The tainter gates are operated by 30 ton motor driven double drum hoists and heating is provided along the side seals to prevent freezing. The total discharge capacity of the spillway at normal pond is 65,000 cfs. A skimmer gate between the Powerhouse and stanchion bays provides for trash passing. Compressed air is used to keep pond ice from forming against the tainter gates and flashboard sections.

The Powerhouse contains four units spaced on 35 foot centers. The intake is provided with trash racks which are kept clear by a mechanical rack rake assisted by compressed air. Head gates are traversed from one unit to another by a motor driven gantry. Since each intake is divided into two openings by a center pier, two gates are provided for complete closure of one unit intake. The turbines are of the single runner vertical propeller type, two with fixed blades and two with adjustable blades. At the time of installation of these turbines it was notable that it was the first hydro-electric plant in New England in which adjustable blade Kaplan turbines were used. The scroll cases and draft tubes are of concrete. The combination of 2 and 2 wheels were selected to give the utmost in efficiency of operation which results in about 6% increase over 4 fixed blade units, for a range of flow from 600 to 6000 cfs. During low flow periods only the 2 adjustable blade units are used, but during high flows the fixed blade units are operated at maximum efficiency with the remainder of the load carried between the two adjustable blade units.

Power out of McIndoes is delivered to the local market, to the Green Mtn. Power Corp., and to Comerford for further transmission over lines to other system loads.

Wilder Redevelopment

As early as 1785 various mill privileges were taking water from behind a wing dam in the area of the White River Falls, the present location of the Wilder Plant. This use of power was intermittent until the rights were purchased by the Wilder Brothers, who built a timber dam and paper and pulp mill in 1882. The mill of the Wilder Brothers, was absorbed by the International Paper Co. in 1898. In 1926 the dam was replaced with a concrete structure located upstream of the site of the Wilder Redevelopment. The power plant connected with the mill was developed to 5 units with a total capacity of about 5,000 KW. This plant was purchased by the N.E.E.S. in 1942, long after paper mill operations had ceased, and was redeveloped.

First proposals indicated a headwater at Elev. of 390 was sufficiently attractive to use for application to the F.P.C., but this was eventually reduced to Elev. 385 or 16 feet above the operating level of the old dam to limit the area of inundation of tillable lands in the valley above. The present plant as redeveloped has a nominal capability of 33,000 KW in two units under a design head of 49 feet utilizing about 9400 cfs. The dam, which is founded on ledge for the entire length of the spillway and powerhouse, is about 2900 feet in overall length of which 9400 feet is of concrete, including the powerhouse. The layout consists of the following, starting from the N. H. end: an earth dike or embankment 180′ long extending to the south abutment wall of the spillway; a skimmer gate 10 feet wide; four bays of 17 foot high stanchion flashboards, each 50 feet long; six tainter gates 36 ft. by 30 ft. high, and a second skimmer gate 15 feet wide. The pier next to the skimmer forms part of a fish ladder scheme, which was provided for future installation. The next structure is the powerhouse containing two units and space for a possible future unit. Next to the powerhouse a concrete bulkhead wall extends 220 feet to the north earth embankment.

The intake consists of two waterways per unit each provided with a head gate with individual hoists. There are two generating units of 16,500 KW Capacity each. The 18,000 KVA generators are driven by vertical shaft adjustable blade Kaplan propeller type turbines of 23,700 HP capacity at 112.5 RPM under a net head of 49 feet. The draft tubes are of concrete elbow type with horizontal steel and concrete splitters and vertical piers in the lower end. The center lines of the turbine blades are set 4′ below normal tailwater to reduce cavitation. During motoring operation a compressed air system depresses the water level in the draft tubes.

Transmission consists of a tie to the system at Bellows Falls and the local load through Central Vermont Public Service, Granite State Electric and Green Mountain Power; also the Vermont Electric Power Co. has tied to our system at Wilder.

The design of the spillway was influenced by flood discharge capacities necessary and the desire to hold flood discharge stages equivalent to the old plant. On this basis a flood the size of the 1936 discharge at this point in the river could be passed with stages at the dam and throughout the 45 mile length of the pond the same as were experienced with the old dam. The total capacity of the spillway with normal headwater is about 160,000 cfs., slightly less than twice the 1936 flood. An extensive backwater study of the 45 mile long pond was made for presentation at the State hearings prior to the construction and also for preparation of land damage estimates. These theoretical profiles have since been checked during spring run-off periods by actual field gaging with remarkably satisfactory results having been found.

Moore Station

The latest development in the series of hydro-electric plants on the Connecticut River to be built by the N.E.E.S., since the first plant at Vernon was begun in 1907, is the plant near Littleton, N. H.

dedicated as the Moore Station upon completion in 1956. This plant, figure 3, the second of the two-plant scheme to utilize the head of the so-called "Fifteen Mile Falls" has a nominal rated capability of 190,000 KW through 4 units under a design head of 150 ft. utilizing some 17,000 cfs. The pond contains some 114,000 acre feet of usable storage through a drawdown of 40 feet.

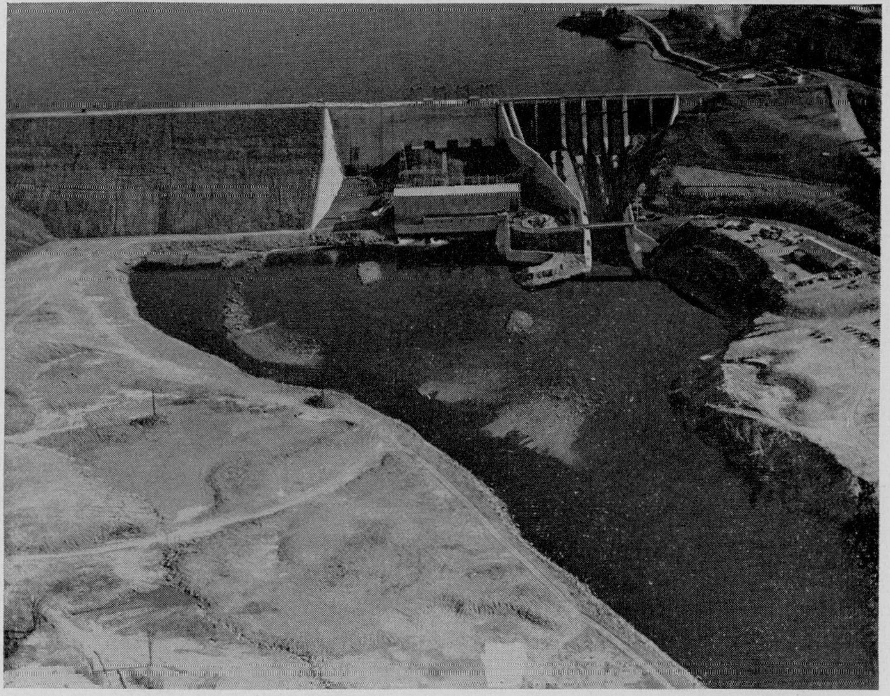


FIG. 3.—MOORE PLANT.

The general layout involves a large rolled-earth filled dam 2000 feet long and 180 feet high on the Vermont side and extending across the river bed, a retaining wall 120′ high set in ledge above the N. H. bank, a concrete nonoverflow section 115 feet long, 180 feet in height which spans the construction diversion channel, a concrete intake structure 255 feet long and a concrete spillway section 373 feet long. At the southerly end of the spillway a concrete bulkhead 120 feet long extends into an earth dike about 340 feet long to complete the dam. A spillway channel along the side hill, paved in part, and contained by a concrete gravity wall on the powerhouse side, conducts the water from the spillway to the river.

The earth structure with side slopes of 1 on 3 and 1 on 3½ upstream and 1 on 2 and 1 on 2½ downstream has an impervious boulder caly core inclined from a core trench dug to the natural underlying boulder clay at the upstream toe. The main body of the embankment consists of sandy till, a somewhat less impervious material. The outer shells consist of pervious sand and gravel. The embankment contains some 3,300,000 cu. yds. of material. Seepage records kept since completion show only some 40 g.p.m. maximum leakage through the embankment. The retaining wall, abuting the end of the earth structure, and extending 376 feet downstream and 400 feet upstream, contains 55,000 cu. yds. of concrete.

The intake structure of gravity design provides for 4 steel penstocks. There are 4 head gates of the wheel type 18 feet x 24 feet high, each with its own 60 ton electric hoist. Sills of the gates are 84 feet below normal pond to permit a 40 foot drawdown of the pond.

The spillway contains a 15 foot x 20 foot high skimmer gate, 4 bays each 50 feet long of 17′ high stanchion type flashboards and 3 tainter gates each 36 feet by 30 feet high, operated by electrically powered hoists. The discharge capacity of the spillway at normal pond is 120,000 cfs.

The powerhouse is 256 feet long by 52 feet wide housing 4 units located on 50 foot centers. The turbines are vertical single runner Francis type wheels rated at 56,400 HP, each under 150 foot head at 128.6 RPM with full load rating. The generators are rated 39,000 KVA of the umbrella type, vertical, air cooled. Penstocks are of welded construction 300 feet in length with diameter tapering from 21½ to 16½ feet at the scroll case.

Considerable grouting of the foundation rock was done because of its seamy nature, as well as relief hole borings feeding into the gallery drainage system under the concrete structures. One interesting phase of the construction was the use of one of the penstocks and open wheel pits for diversion during one stage of the closure operation. The test cylinder used for closure of the stay ring section during the water pressure test of the penstock was reconverted to a cover which was bolted to the top stay ring. Water was passed through the penstock and wheel pit using the head gate to regulate.

Transmission out of the Moore Station consists of a tie to the system at Comerford and to the Public Service Company of New Hampshire.

Storage Reservoirs First and Second Connecticut Lakes

The two storage reservoirs 1st and 2nd Conn. Lakes at the head waters complete the story of the developments of the N.E.E.S. on the main stream of the Connecticut River. Together they contain 88,000 acre feet of usable storage, which is equivalent to some 37½ million Kilowatt Hours on the hydroelectric stations below owned by N.E.E.S. They control some gross 83 sq. miles of drainage area.

A dam has been in existence at 2nd Conn. Lake since about 1879, which was built to maintain a pond for the floatation of logs cut from the nearby area preparatory to the drive down river, and for storage of water necessary for the drive. This dam was to fall into disuse and decay following the cessation of really heaving logging operations until in 1914 when a new dam of rock filled timber crib was built. At this time an auxiliary dam was built on Smith Brook, a low pass to the east, and the pond carried higher than originally or at about 1873 Elev. In 1934 the Company replaced this structure with a new dam of concrete and timber decking.

The dam as rebuilt is about 615 feet long of which the spillway gates and logway are 120 feet, south embankment 170 feet, and north embankment 330′. The spillway consists of concrete piers and crest beam with an upstream facing of timber between piers. There are 4′ high pin type flashboards on the crest. Addition spill is provided by a 4 x 5 foot waste gate. There is also a 9′ wide logway closed with stop logs. Present operating full pond level is Elev. 1869.5. Earth fill embankments on both ends complete the structure.

An early crib dam built for the lumbering and timbering operations of the late 1800's was in existence at First Conn. Lake until 1915, when a new rock filled crib dam was constructed. This consisted mainly of crib piers with ample timber gates between. The remainder of the structure consisted of earth dikes at each end. The dam including the end dikes was raised some 3 feet in 1923 to accommodate a like raise in the normal operating level. The gate section was completely housed over.

In 1930 this timber structure was replaced with a concrete dam of overall length of 1,111 ft. This included a spillway of net length of 338′, which contains stanchions-supported boards 4′ high. There are two gates 7′ x 9′ and a 10′ wide logway. The remaining length includes the two earth filled embankments at each end. A bridge runs the full length of the spillway.

Operation

The programming of the estimated daily load and the assignment of this load requirement to the various generating stations, both hydro and steam, is an interesting and absorbing phase of the electrical utility business. This all important function is performed by the load forecasters and dispatchers at our dispatching center at Millbury, Massachusetts, the nerve center of our System. I shall outline briefly the general procedure as it applies to the hydro-electric generating stations on the Connecticut River.

In order to schedule loadings for the hydro stations, a determination of available water is first made. This is done at the beginning of each week and projected through the week on an average daily basis. For this purpose the river is broken into six areas, namely the North Stratford, Moore-Comerford, McIndoes, Wilder, Bellows Falls and Vernon areas. Starting with the U.S.G.S. gage at North Stratford, the natural runoff for the area above is calculated from the indicated discharge at the gage corrected by the known storage releases from the reservoirs above. In like manner, the natural runoff for each of the succeeding downstream areas is determined.

The river flows are then reconstructed by adding in the expected storage operation for the week, which results in a day by day total water availability plan. Depending upon the time of the year, this weekly flow quantity is concentrated roughly into the five-week days and further concentrated into the daylight hours. These flow hydrographs are revised daily throughout the week with runoff from local precipitation being applied after an inch of runoff is indicated.

Before scheduling the individual plant production, reference must next be made to the System load forecast. A load forecast is made on an hourly basis for the next 24 hour period. Forecasting, probably to the layman, would appear to be nothing but a rough guessing game, but the forecaster with a wealth of experience and the utilization of certain known variables as to the habits of industry and people can determine with considerable accuracy the anticipated demand. The rough pattern is obtained by reference to the hourly load distribution of a like day in the recent past. This is then adjusted for predicted weather conditions as to degree of darkness and temperature and also unusual human activities, which would alter the daily domestic load pattern. Certain days are more difficult than others to forecast, such as days preceding or following a holiday, especially if the holiday falls near the weekend because of the possibility of partial industrial shutdown.

With the forecast of the hourly load determined, the plant loadings are then scheduled. The first generation applied to fulfill this demand is the base steam requirements for individual territory service protection called minimum steam. Next to be added is the efficient steam operated at flat loads. Finally the hydro is added from the river plan and concentrated into the hours showing the highest load demand, figure 4. If the total anticipated load requirements are not completely fulfilled, then consideration must be given to outside purchase or the addition of costlier steam from our own System, whichever will be most economical.

The dispatcher then passes the schedule, covering the next 24 hour period, to the individual plants in case of loss of communication. Should communication be lost, each plant has a plan of operation which would probably amount to repetition of the last known schedule received. Otherwise hourly contact is maintained and adjustments to the schedules made as the load pattern develops.

Regulation of the daily load or the absorption of the hourly fringe is carried most of the time during the day by Moore. Infrequently the regulating is done by Comerford or Harriman on the Deerfield River. At night and during periods of heavy river flow, when all the hydro is running wide open, Salem Harbor Steam or Manchester 60 cycle Steam will provide regulation. During these times the hydro is essentially carrying the base load.

Seasonal operation of the storage available in First and Second Lakes, Moore and Comerford, as well as those on the Deerfield, which includes Somerset and Harriman, involve a low draw in the spring to accommodate the runoff from the melting snow and the spring rains, figure 5. This results in full or nearly full reservoirs by the end of May or early June. The drawdown period generally extends from July through the following March with the timing and rate of drawdown depending upon various influences including load conditions, hydrological conditions and the availability of power from other sources. Some refill of the storage is frequently obtained in November.

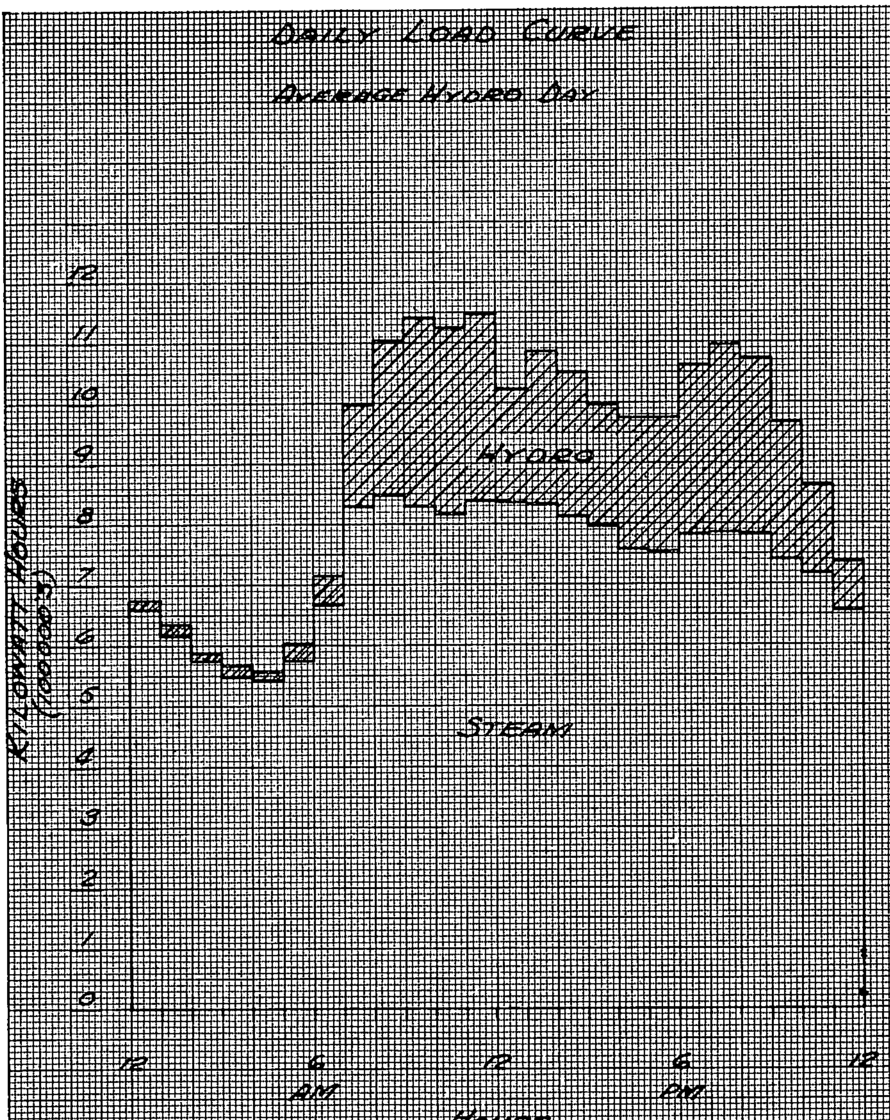


FIG. 4.—DAILY LOAD CURVE.

Although this procedure is generally followed year after year, the timing and amount of this low limit is influenced somewhat by the snow measurements taken semi-monthly throughout the snow season. The Company began a systematic measurement of snow depth and equivalent water content as early as 1924, with stations located throughout the Upper Connecticut and Deerfield watersheds. A knowledge of the water content on the ground in the form of snow is also useful in predicting the possibility of light or heavy runoff during the

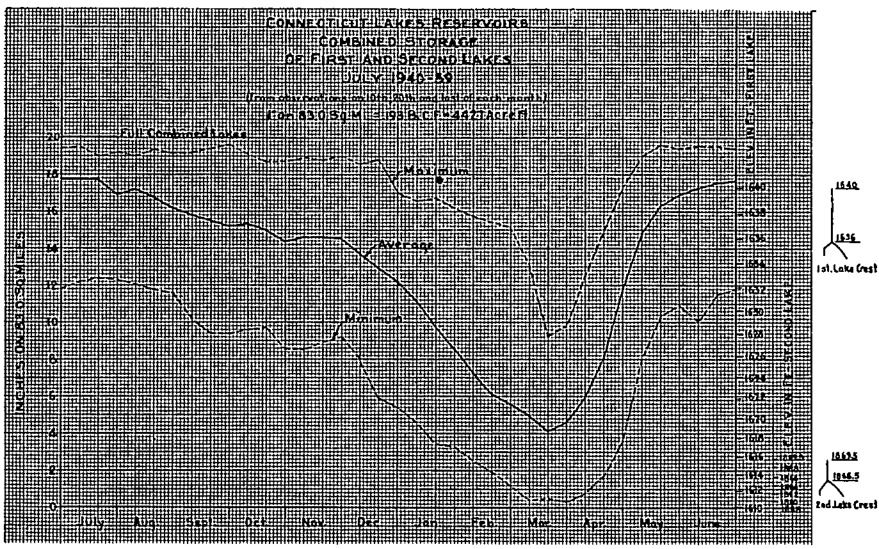


Fig. 5.—Typical Seasonal Storage Operation.

spring breakup, should contributing climatic conditions also exist at the time. For the past several years now we have, with other public and private agencies, given our data to the Corps of Engineers for the compilation of snow cover reports, which they are publishing on a weekly basis during the spring period, in connection with their flood control operations.

Flood Control

The Connecticut River valley from time immemorial has been visited by great floods and it can be concluded that the pattern of hit or miss type of stormy weather will produce other floods in the future. From studies of the long precipitation record at Boston through 1955, we find an average varying between 3 and 4 inches per month with no pronounced wet or dry season. There are of course periods of drought and of excessive rainfall as a plot of the record will show. The total annual precipitation varies between a minimum of 27.2″, a maximum of 67.7″ with an average for the period of 43.1″ indicating swings in the pattern that are unpredictable.

Although there is uniformity in the average rainfall pattern, such is not the case with river runoff which shows a well established pattern of wide seasonal variation. As indicated by the record of the United States Geological gage, the Connecticut at Turners Falls, the runoff in the average year is about 1.9″ per month or 22.6″ per year roughly 60% of the average annual rainfall that fell on the watershed in the 40-year period, 1915-1955. It is also seen that for the months of March, April and May the average runoff is very high compared to the other months and the average monthly, with totals of 3.0″, 5.5″, and 3.5″ respectively.

In spite of this uniformity in the seasonal rainfall pattern and a generally established runoff pattern of high spring and low summer and winter flows, there is no such recognizable pattern for our New England flood occurrence. As the records show, the Connecticut River has experienced large damaging floods in almost every month of the year. On the lower river, floods of significance have occurred in March 1936, September 1938, May 1854, November 1927, July 1683, April 1862, October 1869, January 1949, August 1955, and in the northern part of the valley June 1943. Considering these facts, flood control has received extensive study by many engineers, professional groups and official bodies of local, state and federal origin throughout the period since the great flood of 1927.

Some of the early preliminary map studies included occasional pretty large dams that proved, when the studies were advanced, uprooted too many people and involved too much damage to be justified. Also the small dam program as contemplated by the Department of Agriculture under Public Law 566 can furnish only a minor part of the requirement for control of major floods. From studies of the New England-New York Interagency Committee, it has been proven that very few sites exist in our crowded vallyes for the multipurpose structure as developed in the more sparsely settled areas of the Country.

It is true that straight power storage reservoirs such as the

N.E.E.S.'s Somerset and Harriman reservoirs on the Deerfield and First and Second Lake, Moore and Comerford Stations on the upper Connecticut, as well as the N. H. Water Resources Reservoir above Pittsburg, N. H. have supplied incidental flood control benefits that were widely recognized and heralded. It can be seen from the yearly average draw records of the Lakes and Harriman that during the spring months and quite frequently at other times there is available storage to hold water that would otherwise waste or cause flood damage to the lower reaches of the river.

The United States Geological Survey through studies of the 1927 flood proved the effectiveness of the Connecticut Lakes in reducing the drainage area below by 81 square miles, and the areas below the Deerfield by 184 square miles by complete retention of runoff above Somerset and Harriman which still had unfilled capacity of 16 and 28% after the flood, thus furnishing an excellent example of what power storage did toward flood control.

Again after the 1936 flood, W. F. Uhl prepared a paper subsequently published in the Transactions of the A.S.C.E., in which he showed that no water was wasted from Somerset and Harriman during the flood and no release was made until a week after the crest on the main stem, thus reducing the peak at Shelburne Falls from some 72,000 cfs. to 48,000 cfs., or a reduction in stage of 3.3 feet.

Power Storage reservoirs again provided valuable flood reduction benefits in the upper valley during the June 1943 flood. Mr. C. C. McDonald, Engineer with the United States Geological Survey, in a paper before the Boston Society of Civil Engineers showed a reduction in the peak flow at North Stratford of some 6,000 to 7,000 cfs. or 1.7′ in gage height from the operation of the Connecticut Lakes and Pittsburg Reservoirs.

But it must be recognized that the primary function of these reservoirs is providing power storage and because, as the record shows, floods are liable to occur in almost any month, there are some occurrences in which power reservoirs are not able to contribute as heavily. Such being the case, we have long recognized the need for an adequate flood control program.

Today a partial fulfillment of this program can be seen in the Connecticut River Valley with the construction in progress by the Corps of Engineers on the West, Black and Ottauquechee, as well as the completed structures on the Ompompanoosuc, Ashuelot, West-field, Millers and Ware Rivers, as well as the miscellaneous channel projection projects with the ultimate control of some 25% of the drainage area above Hartford, Connecticut.

This construction of medium "sized flood" control dams on our tributary streams tailored to control 6 to 8 inches of runoff, although causing some local disturbances, offers the best chance of cutting down on flood control losses. There has been good teamwork by the local-state-federal forces in planning a program of reasonable-sized tailor-made dams fitted to our N. E. standards and needs. The benefits from these classes of projects are so wide spread and the identification of the beneficiaries so complex, that there is ample justification for financing their development from general tax levies, provided the projects have been proven economically feasible. So in the end we have a multi-purpose system of separate dams not obtained by piling functions on top of one another to the wholesale submergence of our valleys, but obtained by fitting each dam into the contour of our small valleys with a minimum of disruption, be the purpose flood control, water supply, recreation power or what have you.

Recreation

Last but not least in this story of the river is the role of the valley as a source of enjoyment to vacationers from the New England States and from the nation as a whole. Since earliest Colonial times, as we have seen, Yankee ingenuity has proven the versatility of the Connecticut River through the many ways it has served the people of New England. Today the stations which New England Electric have constructed primarily for power also have added dignity to the beauty of the valley. Behind these dams are man-made lakes and ponds, which the Company has made available to public use. We have for a number of years now been developing a series of boat launching sites, picnic areas, and hunting and fishing grounds to make the valley a happy place where the whole family can enjoy its vacation. Included in this program are boat launching sites on practically all the ponds on the main stream and at Harriman on the Deerfield. In addition, on the ponds at Harriman, Bellows Falls, Wilder, Moore and the Lakes are some 13 picnic areas for public use. Visitors, houses maintained at Moore and Wilder contain various exhibits of interest to the tourist. In closing, I wish to extend to you all an invitation to share these facilities with us.

TRANSMISSION COEFFICIENT FOR GROUND VIBRATIONS DUE TO BLASTING

By F. J. CRANDELL, *Member**

INTRODUCTION

In 1949 the writer demonstrated that energy could be used effectively in evaluating hazards of damage from ground vibrations due to blasting.[1] In doing this, a quantity called Energy Ratio, abbreviated ER, was defined as

$$ER = \frac{a^2}{f^2} \qquad (1)$$

where a is acceleration in ft/sec^2 and f is frequency.

Energy Ratio was related empirically to distance and amount of explosive by the equation

$$\left(\frac{50}{D}\right)^2 \ C^2 \ K = ER \qquad (2)$$

where D is distance in feet from the explosive to the point of interest, C is the weight of explosive in pounds, and K is a proportionality factor depending on the terrain which transmits the vibrations. We will call K the transmission coefficient, and our present discussion is directed toward a better understanding of its characteristics.

GENERATING THE VIBRATIONS

When a column of explosives is detonated in a drill hole, the emerging shock front is not strictly spherical.

For example, let us assume a drill hole 6 inches in diameter and 40 ft. deep, with the bottom half loaded with explosives and the top half tamped. Further, assume a velocity of detonation for the explosive of 20,000 ft/sec and the shock front's velocity of travel in the rock as 10,000 ft/sec.

If detonation is initiated at the bottom of the hole, wave fronts will take the form shown in Fig. 1. As the shock front sweeps upward

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[1] "Ground Vibration Due to Blasting and Its Effect Upon Structures", F. J. Crandell. *Jour. Bos. Soc. Civ. Engs.* (1949) pp. 222-245.

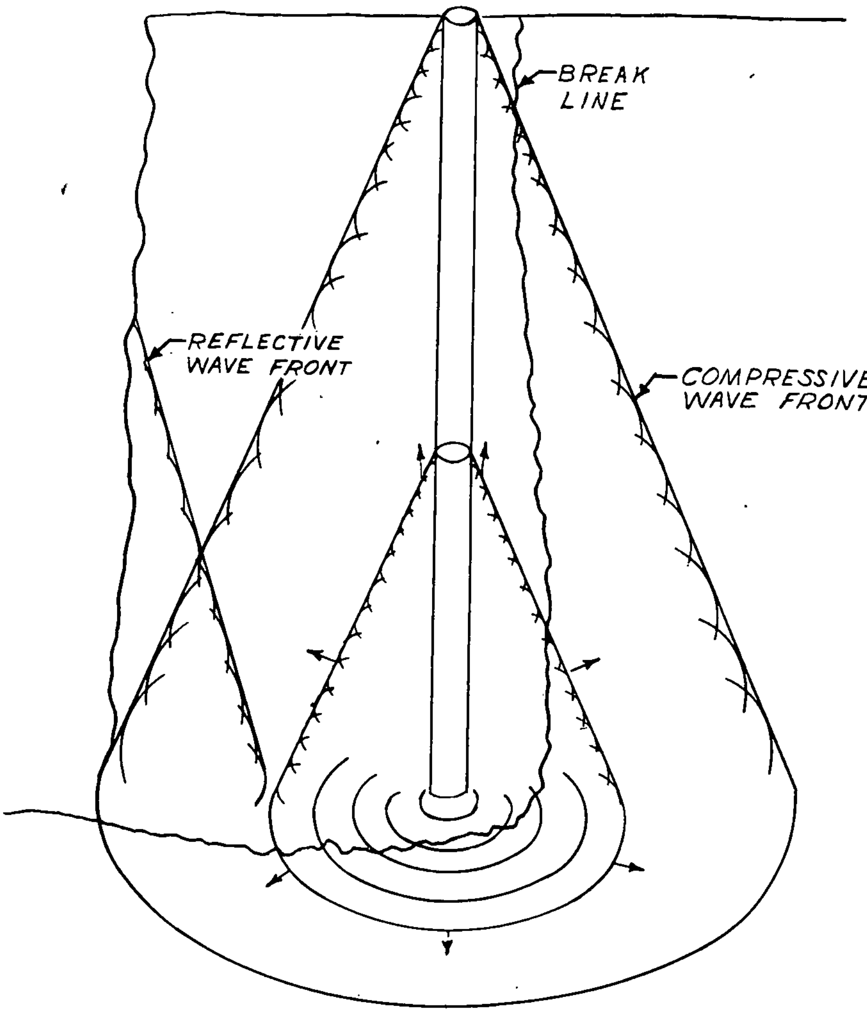

FIGURE 1.

along the free face in front of the drill hole, it is reflected and the rock is ruptured in tension.[2]

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[2] "Vibrations from Blasting Rock", L. Don Leet. Harvard University Press, in press (1959).

"Rock Breakage by Explosives", Wilbur I. Duvall and Thomas C. Atchison. U. S. Bureau of Mines Report of Investigations 5356 (Sept., 1957).

In other directions, after crushing the rock for a few inches, the shock front rapidly decays to simple elastic waves travelling at the velocity of sound in the medium. When these waves reach the surface, they set up surface waves[3] that spread out in all directions. Since this spreading is essentially in two dimensions only, it distributes the energy inversely as the square of the distance, as indicated in equation (2).

Reflection and Refraction

If, in going from their place of origin to the surface, the original waves encounter new materials, as in going from rock to soil, they are reflected and refracted according to well-known laws[3]. The efficiency with which energy is transferred from one material to the other is a function of the ratio of the materials' acoustic impedances, where this quantity impedance is defined as density times velocity of propagation.

If we let R_1 represent the acoustic impedance of material 1, R_2 of material 2, and X_1 represent the amplitude of the incident wave, while B_1 is the amplitude of the reflected wave and X_2 is the amplitude of the refracted wave, Fig. 2, that continues on into the second material, then

$$\begin{aligned} B_1 &= X_1 \frac{R_2 - R_1}{R_2 + R_1} \\ X_2 &= X_1 \frac{2R_1}{R_2 + R_1} \end{aligned} \tag{3}$$

For example, if a wave goes from limestone into top soil,

$$X_2 = .09$$

or only 9 per cent of the incident amplitude goes into the top soil. To interpret this in terms of energy, of course, changes of frequency at the boundary have to be taken into account.

Velocity

The effect of porosity on the velocity of the wave in the surface layer is of importance to us because, invariably, our measurements are taken on the surface of the soil. The thickness of this layer will be in the order of 5 to 50 ft, and the velocities may range from 500 to 2500 to 6000 to 8000 ft/sec. On the assumption that the surface layer

[3] "Earth Waves", L. Don. Leet. Monograph, Harvard University Press (1950) p. 46., p. 60.

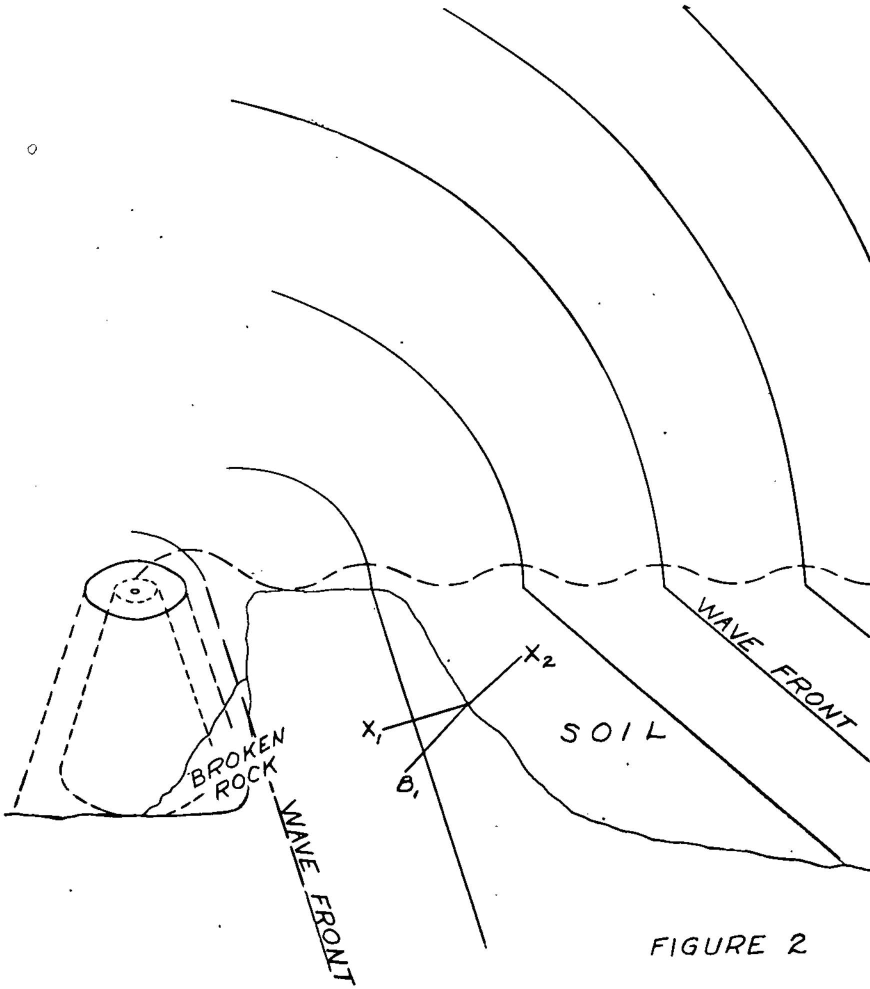


FIGURE 2

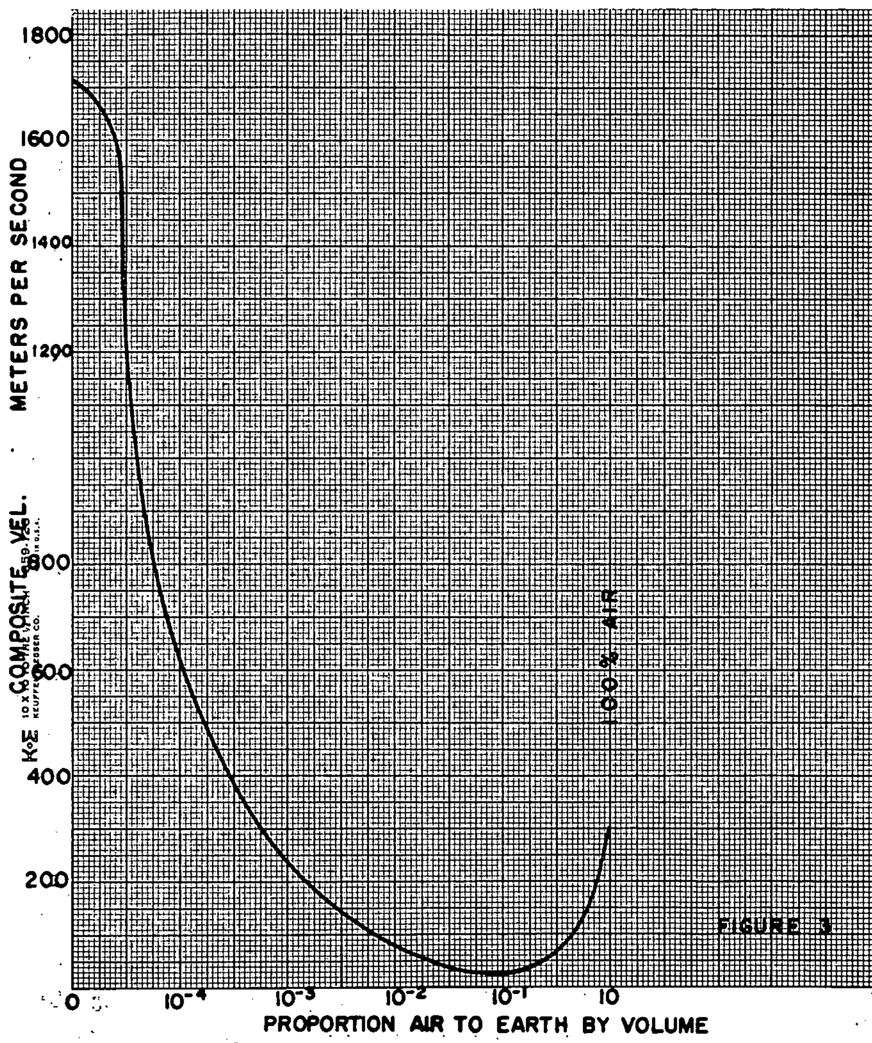
is a mixture of air and earth, the acoustical velocity in the medium can be calculated by the following equation[4]

$$v_1 = \sqrt{\frac{E_1 \; E_2}{[pE_2 + (1-p)\,E_1]\;[p\delta_1 + (1-p)\delta_2]}} \qquad (4)$$

[4] "Geophysical Exploration", C. A. Heiland. Prentice Hall Geology Series (4th Reprint, 1951).

where E_1 = elasticity of air ($1.2.10^6$); E_2 = elasticity of earth; p = proportion of air to total by volume; δ_1 = density of air (0.0012); δ_2 = density on earth; 1 − p = proportion of earth to total by volume, With a Young's modulus of $5.58.10^{10}$ and a density of 1.9, the curve shown in Fig. 3 has been computed.

The soil covering the earth's surface can contribute many, many



various velocities. It is seen from equation v_l that the velocity is dependent upon the modulus of elasticity; and it will be shown later that the modulus of elasticity is continually changing and is dependent upon the pressure of the impulse of the soil.

This fluctuation of acoustical velocity in the soil surface is, by far, the greatest variable that we are confronted with in measuring the wave on the top surface. If the air in the soil is replaced by moisture, the velocity is increased materially.

Wave speeds less than the speed of sound in air are possible in the earth's surface.

Soil

As we are working in a soil medium and the acoustical velocity determines the speed of this energy wave, it is proper that we analyze the stress-strain ratio curve of a clay.

Fig. 4 is a stress-strain ratio curve showing the loading and unloading of a sample. The load on this unconfined sample of clay was imposed at a constant rate. From A to B is the loading phase and is shown as a curve and not a straight line. From B to C is the unloading curve and bends from B to C but never reaches the starting loading point A. The area under curve A-B-C is a loss of energy.

When the clay is again loaded from C to D, it intersects the extension of A-B at D. When the load is held constant at D, the sample continues to get shorter as indicated from D to E.

This decrease in the height of the sample from D to E without any increase load can be entitled plastic flow or creep.

Under these conditions, the modulus of elasticity E cannot be expressed as a single numerical value, and the soils in question covering the surface of earth that we are interested in will vary from plastic to semi-plastic material depending upon its density.

Stress-Strain Relationship of Earth

If we take a stress-strain relationship produced by dynamic stresses in a silty clay, we obtain the curve shown in Fig. 5. This curve indicates a plastic medium and shows that the slope of the stress-strain curve decreases with an increase of pressure.

The result of such a stress-strain curve is to produce dispersion in a compressible wave as it transmits. The decrease in the slope over the curve during loading causes the high pressure level of the curve to have a lower velocity than the low pressure slope of the curve. This can be shown by the equation of velocity as a function of stress-strain.

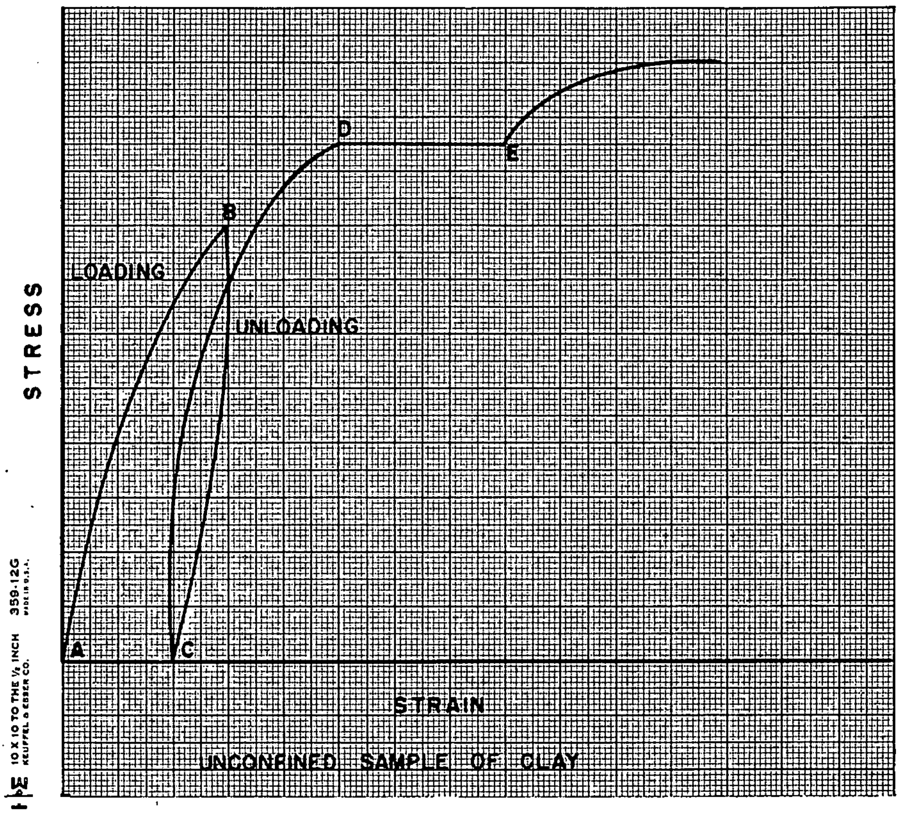


FIGURE 4.

The semi-plastic material on the earth's surface cannot support a shock wave. ∴ the wave will not exceed the speed of sound through the medium.

$$V\ (\sigma) = \sqrt{\frac{1}{\varrho}\ \frac{d\sigma}{d\Delta}} = \sqrt{\frac{1}{\varrho}\ E} \tag{5}$$

V = velocity of transmission at stress
σ = stress
Δ = strain
ϱ = density

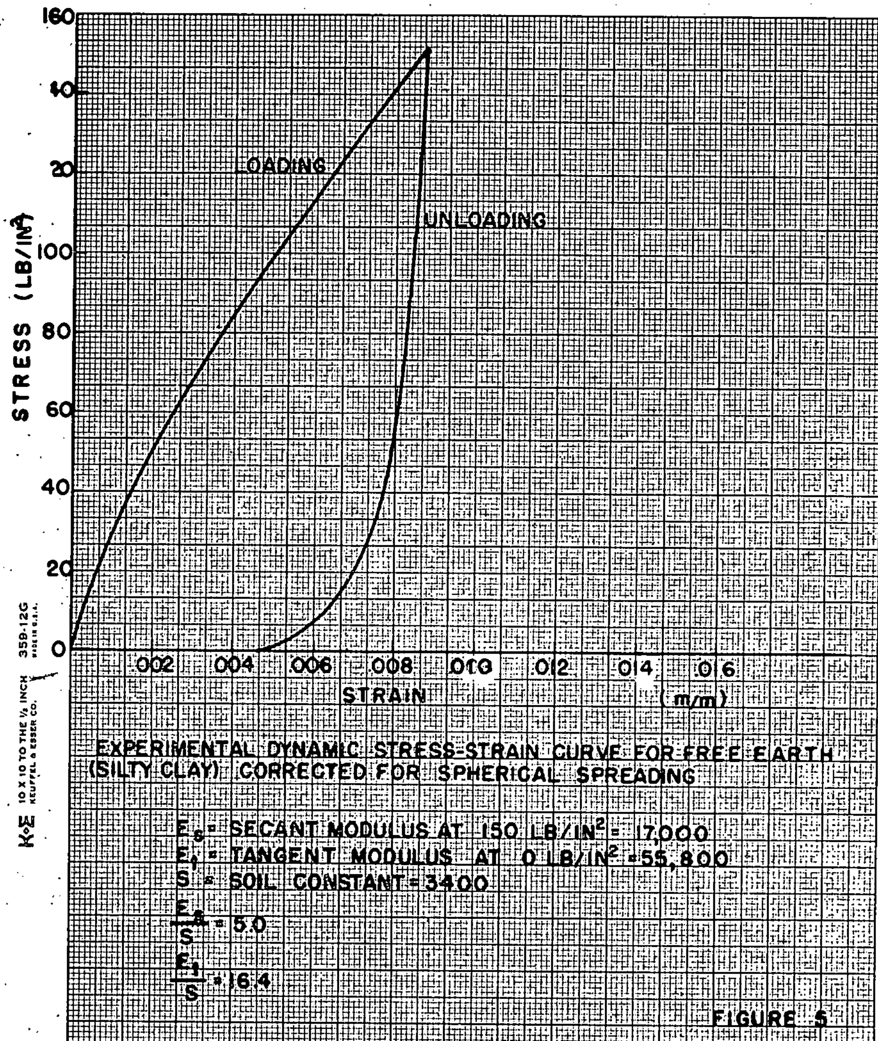


FIGURE 5

The result of such a characteristic is that the high stress wave travels more slowly than the low stress wave so that the wave continually spreads out in shape and time.

In addition, the wave suffers a continued change of shape from the rear as well as the front. This is shown by the unloading curve, which has a steeper slope than does the loading part, except at low pressures where it is flatter.

The area between the loading and unloading parts of the curve represents a loss of energy per unit volume of the soil passed over by the wave. As indicated in the velocity equation, it is dependent upon the density of the material. This is the velocity of sound through the medium, which can be determined by the seismological refraction method.

Change to Energy

It has been found that there is a correlation between the velocity[5] of sound through the soil and what can be called a soil energy constant.

The soil energy constant can be expressed by the equation

$$S = \frac{1}{2} \varrho \; V^2 \tag{6}$$

S = soil energy constant, K.E. of a unit volume of the wave
ϱ = density of the soil in slugs/in^3
V = velocity of propagation in ft/sec

Although there is a variation in the density of the soil, it is by no means as great a variation as the velocity of propagation through the medium.

The velocity in the soil energy constant S is, by far, the greatest variable in this ground transmission of waves resulting from detonation of explosives.

In the equation

$$\left(\frac{50}{D}\right)^2 \; C^2 \; K = ER$$

[5] "Final Report on Effects of Underground Explosions", C. W. Lampson. Division 2, National Defense Research Committee of the Office of Scientific Research and Development, Washington 25, D.C.

"Rock Blasting—Some Aspects on the Theory and Practice", G. E. Pearse. *Mine & Quarry Eng.* (Jan., 1955) pp. 25-30.

"Detonation of Condensed Explosives", J. Taylor. Clarendon Press, Oxford (1952).

"The Science of High Explosives", Melvin A. Cook. ASC Monograph No. 139, Reinhold Pub. Corp. (1958).

"Seismological Aspects of the Earthquake Engineering Problem", Frank Neumann. Seismologist, Univ. of Washington (March, 1959).

"Spherical Propagation of Explosion-Generated Strain Pulses in Rock," Wilbur I. Duvall and Benjamin Petkof. U. S. Bureau of Mines Report of Investigations 5483 (1959).

the function K is the transmission coefficient and can be equated to the reciprocal of the soil energy constant, or

$$K = \frac{1}{S} \tag{7}$$

If we assume an average density value equal to .002 slugs/in^3, we can establish the average soil energy constant in any soil to be equal to

$$\pm S = \frac{V^2}{1000} \tag{8}$$

We can now write K as a function of S

$$K = \frac{1000}{V^2} \tag{9}$$

Particle Velocity

The Energy Ratio measurement is $ER = \frac{a^2}{f^2}$

a being acceleration in ft/sec/sec

f being cycles/sec

$$f = \frac{1}{p}$$

p being period (10)

$$\therefore \frac{a}{f} = a\ p$$

$a\ p = u$

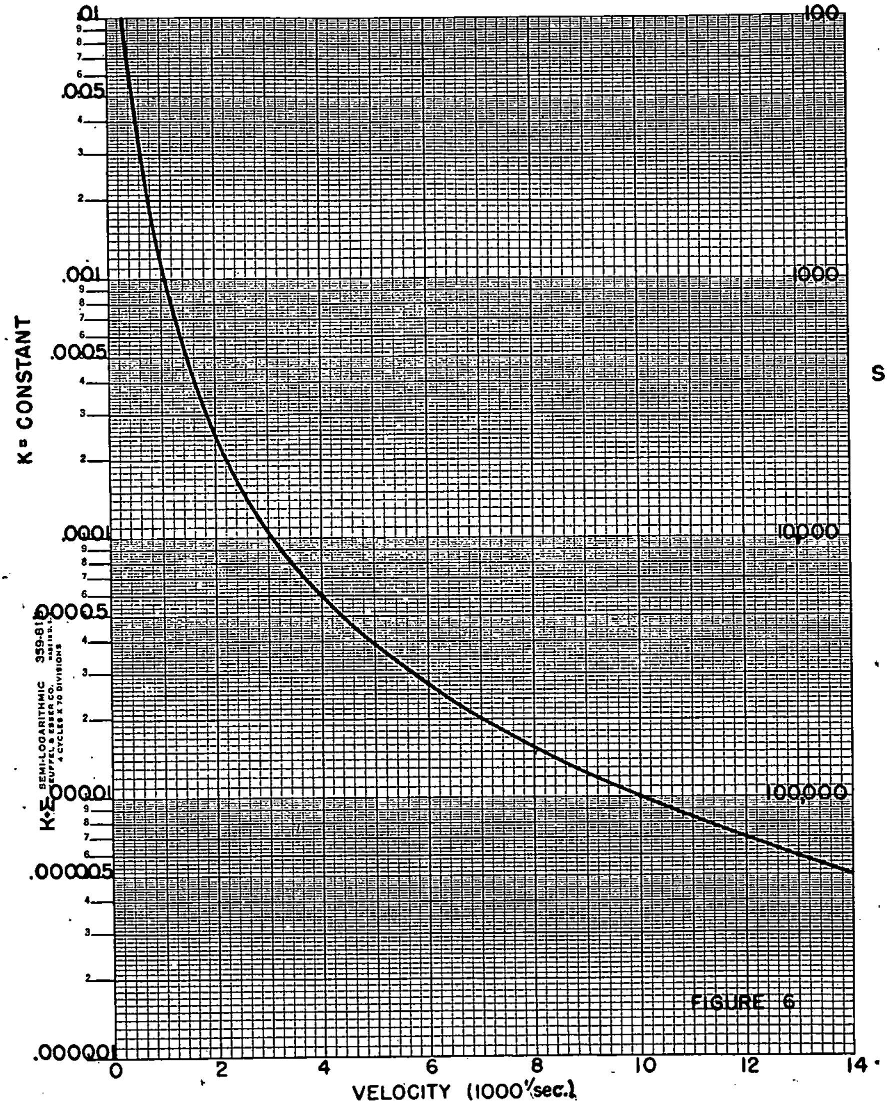
u being the peak particle velocity of the surface particles

The measurements of acceleration a and frequency f allows us to obtain the particle velocity of the surface particle.

Variation

Fig. 6 shows a plotting of the K value in the Energy Ratio equation against velocity in feet per second and in relation to S, the soil energy constant.

The measurements over the years have shown a tremendous variation of Energy Ratio vs. Distance for the same number of pounds of dynamite and also Energy Ratio vs. Pounds of Dynamite at the same distance.



In the attached charts of Energy Ratio vs. Distance with Constant Number of Pounds of Dynamite, Fig. 8 and Energy Ratio vs. Pounds with a Constant Distance, Fig. 9, we see a tremendous variation in the Energy Ratio points.

On these same charts, if we plot the K values included in these tests, which were all on the surface of the ground and 90 per cent of them on earth as a medium and remember that these were uncontrolled shots all take at different locations, we begin to see that the scatter is due to the transmission coefficient K which, in turn, varies inversely as the square of the velocity.

The medium upon which the measurements were taken varied in velocity (light, dry top soil of 600-900 ft/sec to rubble and gravel at 2000-2600 ft/sec to shaley materials at 7000-11,000 ft/sec) and the variation under these conditions in the S value would be somewhere between $S_1 = 262$ to $S_2 = 156{,}000$.

$$\frac{S_1}{S_2} = \frac{262}{156{,}000} = \frac{1}{600} \tag{11}$$

Micro-Delays

In the 1949 paper, the majority of the data came from the measurement of the ground vibration produced by long period delays, and it was found then that the earth's attenuation was such that, in all cases, the movement of the ground had returned to zero before the following long period delay detonated its explosive charge.

Such an explosion in the case of the long period delay, threw the ground surface into a free vibration which, in all cases, would be the preferred frequency of the ground in that area. I use the word preferred here because there is no single natural frequency in the earth's cover.

If you look at the record shown in Fig. 7, which was taken while using micro-delays, it will be seen that under the micro-delay condition in which the delays are .025 seconds apart, the ground follows the

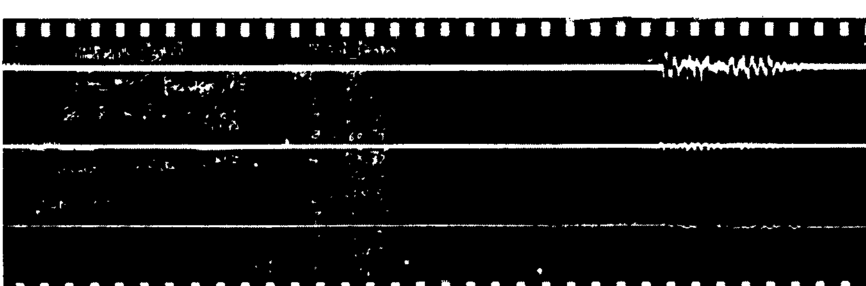


Figure 7.

TABLE I

TABLE OF DERIVED VALUES* OF THE SOIL CONSTANT S FROM SEISMIC VELOCITIES IN VARIOUS SUBSURFACE MATERIALS

K = Ground Transmission Coefficient

Soil Type	V (ft/sec)		S (lb/in²)		K	
	min	max	min	max	min	max
Top soil: Light dry	600	900	262	590	.00382	.0017
Moist, loamy silty	1,000	1,300	812	1,370	.00123	.00073
Clayey	1,300	2,000	1,420	3,370	.000707	.000297
Semiconsolidated						
Sandy clay	1,250	2,150	1,510	4,150	.000662	.000241
Wet loam		2,500		5,600		.000179
Clay, dense wet, depending on depth	3,000	5,900	8,850	34,100	.000113	.0000294
Rubble or gravel	1,970	2,600	6,400	11,100	.000156	.00009
Cemented sand	2,800	3,200	9,700	12,600	.000103	.0000793
Sand clay	3,200	3,800	10,000	13,900	.0001	.000072
Cemented sand clay	3,800	4,200	17,800	21,700	.000056	.000046
Water-saturated sand		4,600		22,500		.0000444
Sand	4,600	8,400	26,200	87,000	.0000382	.0000115
Clay, clayey sandstone		5,900		45,000		.0000222
Loose rock talus	1,250	2,500	1,750	7,000	.00057	.000143
Weather fractured: Rock	1,500	10,000	3,100	140,000	.000323	.00000715
Shale	7,000	11,000	63,000	156,000	.0000159	.0000064
Sandstone	4,250	9,000	23,500	116,000	.0000435	.0000086
Granite slightly seamed		10,500		160,000		.00000625
Limestone, massive	16,400	20,200	390,000	590,000	.00000257	.0000017

* Values derived from relationship $S = \frac{1}{2} \rho V^2$.

impact produced by each delay; and if the delays are all .025 seconds apart, the record will give you a frequency of 40 cycles/sec.

Under these conditions, the ground, during the firing of the delays, does not vibrate in its preferred frequency, but is forced to vibrate in the frequency of the micro-delays.

At the end of the detonation of all delays, the ground will again endeavor to follow its own preferred frequency until the wave decays.

The amplitude of the wave in the micro-delay detonation is of the same proportion in relationship to the pounds of dynamite as the long period delays were, and the equation

$$\left(\frac{50}{D}\right)^2 C^2 K = ER$$

still holds for each micro-delay.

It is further noted that when measuring acceleration, we may get a one-component, two-component or three-component wave; and because Energy Ratio $= \frac{a^2}{f^2}$ the low frequency curve will produce the greatest Energy Ratio for a same corresponding acceleration. Therefore, it is advisable, in reading the records, to be sure that the low frequency curve is detected.

Plotted Data

Figure 8 shows plotted data of Pounds of Dynamite Vs. Energy Ratio with Constant Distance. Figure 9 shows plotted data of Distance Vs. Energy Ratio with Constant Pounds of Explosive.

The location of the instrument in recording the Energy Ratio measurements was, in all cases, on the surface of the ground and in virtually all cases, on soil. Thus, we have a continuous variation of soil conditions. It appeared as though the scatter of Energy Ratio either with Pounds of Dynamite or Distance had very little relationship. This was true until the nest of curves was incorporated into the data sheet. This nest of curves was the plotting of the transmission coefficient K.

This shows that when the K factor was known for the soil, all the measurements in any one type of soil would follow the proportions as indicated in the Energy Ratio equation

$$\left(\frac{50}{D}\right)^2 C^2 K = ER$$

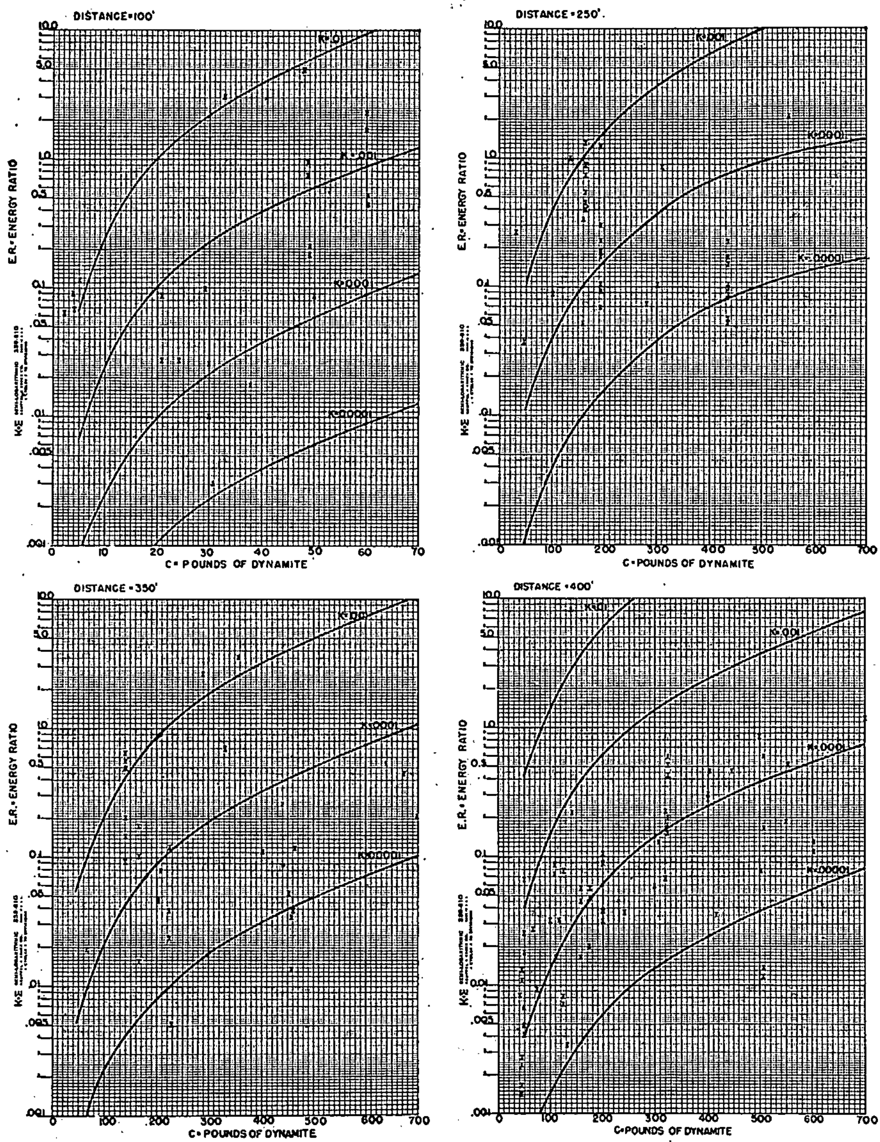

DISTANCE = 100'
DISTANCE = 250'
DISTANCE = 350'
DISTANCE = 400'
E.R. = ENERGY RATIO
C = POUNDS OF DYNAMITE
K = .01
K = .001
K = .0001
K = .00001

FIGURE 8.

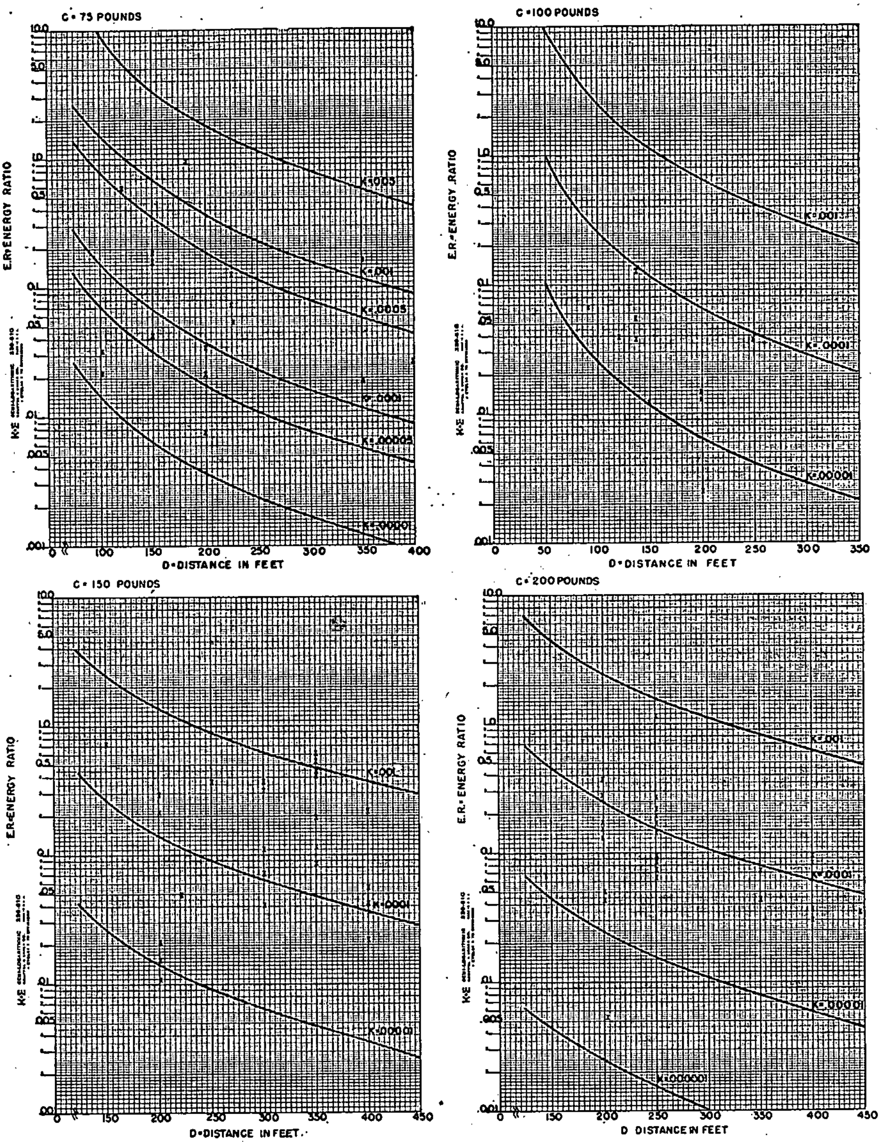

C = 75 POUNDS
E.R.=ENERGY RATIO
D=DISTANCE IN FEET
K=.005
K=.001
K=.0005
K=.0001
K=.00005
K=.00001
C = 100 POUNDS
E.R.=ENERGY RATIO
D=DISTANCE IN FEET
K=.001
K=.0001
K=.00001
C = 150 POUNDS
E.R.=ENERGY RATIO
D=DISTANCE IN FEET
K=.001
K=.0001
K=.00001
C = 200 POUNDS
E.R.=ENERGY RATIO
D DISTANCE IN FEET
K=.001
K=.0001
K=.00001
K=.000001

FIGURE 9.

As we have indicated in other parts of this paper, this transmission coefficient is inversely proportional to the square of the velocity of sound through the medium.

In all these measurements, there are some interesting factors to be noted. Virtually 80 to 90 per cent of all the Energy Ratios measured were enveloped by the curve where K is equal to .001. As we have seen previously, this would, therefore, be in soils having a velocity of sound equal to 1000 ft/sec or greater.

In addition to this transmission function, it can again be noted from the data sheet that 90 per cent of all of the Energy Ratio measurements were below an Energy Ratio of 1. Only ½ of 1 per cent of the measurements were as high as an Energy Ratio of 3 to 5.

Nomenclature

KE = Kinetic Energy
ER = Energy Ratio
C = pounds of dynamite
D = distance in feet from center of explosive.
K = transmission coefficient
S = soil energy constant
a = acceleration in feet per second squared
f = frequency in cycles per second
B_1 = reflective wave
X_1 = incident wave
X_2 = refracted wave
v_l = acoustical velocity—longitudinal
E_1 = elasticity of air
E_2 = elasticity of earth
p = proportion of air to total by volume
δ_1 = density of air
δ_2 = density of earth
$1 - p$ = proportion of earth to total by volume
V = velocity of transmission at stress
E = modulus of elasticity
σ = stress
Δ = strain
ϱ = density in slugs per cubic inches
V = velocity of propagation in feet per second
p = period
u = maximum particle velocity

RESPONSE OF AN ELASTIC STRUCTURE TO BLAST-TYPE LOADING

By E. T. Selig*

ABSTRACT

A method is provided whereby a structural designer or analyst may rapidly investigate the effects of structural and blast loading parameters on maximum displacements, stresses and strains. The structures considered are those which may be adequately represented by a linear elastic, single-degree-of-freedom system. Blast-type loads considered are those represented by an initial impulse together with a suddenly applied, linearly decreasing force. The designer is still faced with the problem of determining the values of the parameters which fit his particular case.

INTRODUCTION

Design and analysis of structures subject to blast-type loads require an estimation of the dynamic response of the structures due to the induced forces. To do this the designer or analyst must first determine the appropriate structural and blast loading parameters and then investigate their effects on maximum displacements, stresses and strains. This paper provides a rapid method for investigating these effects once the parameters are selected.

The structures for which this method is applicable are those which may be adequately represented by a linear elastic, single-degree-of-freedom system. Loads considered are those represented by an initial impulse together with a suddenly applied, linearly decreasing force.

A dimensionless maximum dynamic displacement factor is given which depends only on two dimensionless groups formed from previously determined structural and load parameters. The maximum dynamic displacement factor is presented in convenient chart form for a wide range of these parameters. The application of the results is discussed.

IDEALIZED STRUCTURE

A system is called linear elastic if its resistance is directly proportional to displacement over the range of displacements to be considered. For

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a structure which may be considered as a linear elastic, single-degree-of-freedom system one has

$$R(x) = K \cdot x, \tag{1}$$

where

$R(x)$ = resistance of structure in direction of motion, lbs,
K = constant structural parameter, lbs/ft,
x = displacement, ft.

As an example consider a single story building. In this case Eq. 1 implies that the columns be the principal resistive elements and that the roof be rigid. For brittle columns, or for ductile columns subject to small displacements, the condition of linear elasticity may be adequately met.

Representation as a single-degree-of-freedom system requires the assumption that the mass of the building be lumped as an equivalent mass at some point, usually at the roof, and have a displacement in the horizontal direction only (Figure 1). The equivalent mass is determined so that its vibration period is the same as that of the fundamental mode of the building which it is representing. The building is not limited to a single story if the portion which moves, moves as a unit. Values of the appropriate structural parameters may be determined by methods discussed in the bibliographical references 1, 2, and 3.

IDEALIZED BLAST-TYPE LOADS

Blast-type loads will be represented by an initial impulse I_o (lb-sec), together with a suddenly applied, linearly decreasing force F(t). This representation is shown graphically in Fig. 2. The time varying force F(t) is given analytically by

$$F(t) = F_0\left(1 - \frac{t}{t_0}\right) \text{ for } 0 \leq t \leq t_0, \tag{2a}$$

$$F(t) = 0 \qquad \text{for } t \geq t_0. \tag{2b}$$

where F_0 (lbs) is the initial value of F(t) and t_0 (sec) is the time at which F(t) has decayed to zero. The method presented in this report is applicable to any force which may be adequately represented by a combination of this I_0 and F(t), including the case where either one is non-existent.

As an example consider blast-type loading on a building. It is a function of both the incident blast wave characteristics and the exposed geometry of the structure. The pressure, p, of a blast above atmospheric is known as "overpressure". Figure 3 shows a typical overpressure-time variation for a blast wave at a fixed distance from a nuclear explosion[2]. At time t_1 the shock front arrives. Overpressure rises suddenly to its peak value, p_σ, and then decreases to zero (atmospheric-pressure) at time t_2. A negative overpressure phase follows before the effects of blast wave die out.

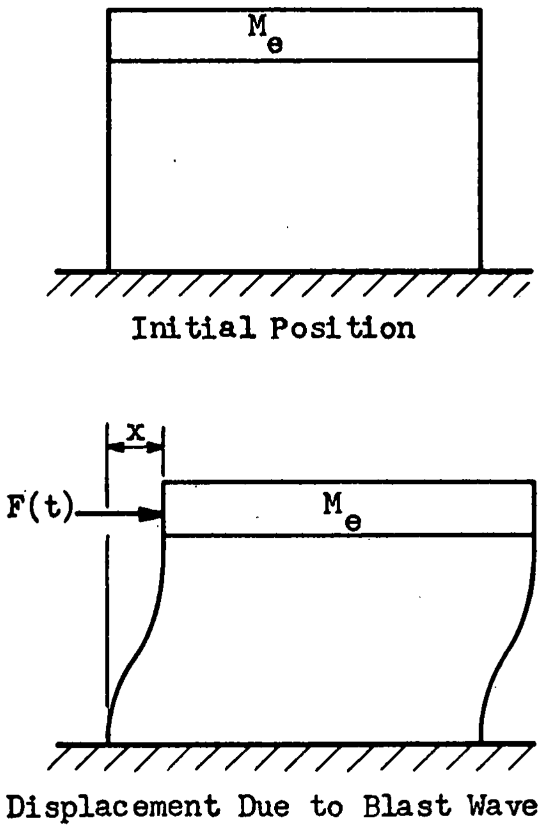

FIG. 1.—IDEALIZED BUILDING SUBJECTED TO BLAST LOAD.

The broken line in Fig. 3 represents the overpressure-time characteristics for a chemical explosion. It differs from the nuclear explosion in degree but not in kind.

The interaction of this blast wave with the structure is a very complicated phenomenon. In many cases, the effect of this pressure on

2 "The Effects of Nuclear Weapons," Reference 4.

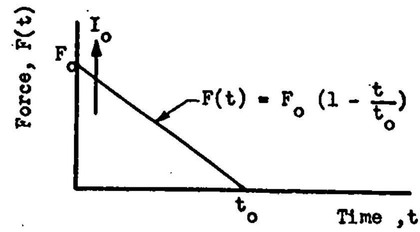

Fig. 2 Force Representation for Blast-type loads

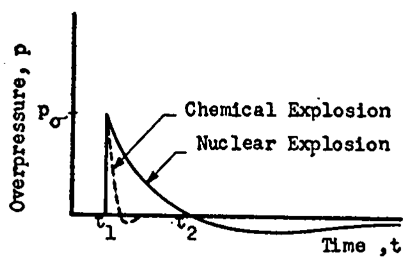

Fig. 3 Blast Overpressure-Time Distribution for a Fixed Distance from Explosion

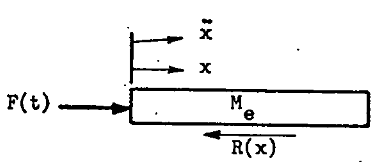

Fig. 4 Free Body Diagram of Idealized Structure

the building may be approximated by the initial impulse, I_0, together with the suddenly applied, linearly decreasing force as shown in Fig. 2[3]. For a particular building analysis the parameters I_0, F_0, t_0 are found by methods discussed in references 1 through 3.

3 "An Engineering Approach to Blast-Resistant Design," Reference 5.

EQUATION OF MOTION

The differential equation of motion of the structure is usually determined from Newton's Second Law which may be restated as: The sum of the forces acting on a system is equal to the equivalent mass of the system multiplied by its acceleration in the direction of the forces. Equation 3 states this mathematically.

$$\sum F_x = (M_e)\,\ddot{x}, \tag{3}$$

where: $x = \dfrac{d^2x}{dt^2} =$ acceleration of system in direction of motion, ft/sec²,

M_e = equivalent mass undergoing acceleration, slugs,

$\sum F_x$ = summation of forces in direction of motion, lbs.

Since the structure has been represented by a single-degree-of-freedom system, Eq. 3, together with Eq. 1 and 2 determine the motion of the structure. A free body diagram (Fig. 4) of the idealized structure shows that the forces acting on the equivalent mass, M_e, are the blast force, $F(t)$, and the resistance, $R(x)$. Making these substitutions, Equation 3 may be rearranged to read as

$$\ddot{x} + \frac{R(x)}{M_e} = \frac{F(t)}{M_e}. \tag{4}$$

Substitution of the values for $R(x)$ and $F(t)$ from Eq. 1 and 2 leads to

$$\ddot{x} + \left(\frac{K}{M_e}\right)x = \frac{F_0}{M_e}\left(1 - \frac{t}{t_0}\right) \text{ for } 0 \leq t \leq t_0 \tag{5a}$$

$$\ddot{x} + \left(\frac{K}{M_e}\right)x = 0 \qquad \text{for } t \geq t_0 \tag{5b}$$

The dynamic response of the structure may be found by solving Eqs. 5a and 5b using the appropriate initial conditions.

SOLVING EQUATION OF MOTION

According to the normal procedures for solving differential equations, the solution for Equation 5a, where the time is restricted to the range $0 \leq t \leq t_0$, will be of the form:

$$x = A\cos wt + B\sin wt + \frac{F_0}{K}\left(1 - \frac{t}{t_0}\right) \text{ for } 0 \leq t \leq t_0, \tag{6}$$

where

$$w^2 = \frac{K}{M_e}, \tag{7}$$

and where A, B are integration constants to be determined from the initial conditions.

At the instant the load pulse hits the structure the displacement is zero and an impulse, I_0, is applied creating a momentum, $(M_e)x$. Thus the initial conditions ($t = 0$) for Eq. 6 are

$$x = 0, \tag{8}$$

$$x = \frac{I_0}{M_e}. \tag{9}$$

By means of these initial conditions one finds that

$$A = -\frac{F_0}{K}, \tag{10}$$

$$B = \frac{wI_0}{K} + \frac{F_0}{Kwt_0}. \tag{11}$$

And hence, for $0 \leq t \leq t_0$, the motion of the structure is given by

$$x = \left(\frac{wI_0}{K} + \frac{F_0}{Kwt_0}\right) \sin wt - \frac{F_0}{K} \cos wt + \frac{F_0}{K}\left(1 - \frac{t}{t_0}\right). \tag{12}$$

The solution to Equation 5b, $t \geq t_0$, is

$$x = C \cos wt + D \sin wt \tag{13}$$

The initial conditions for Equation 13 are the values of x and $\dot{x}$ from Eq. 12 when $t = t_0$. Substitution into Eq. 13 gives

$$C = \left(\frac{\sin wt_0}{wt_0} - 1\right)\frac{F_0}{K}, \tag{14}$$

$$D = \frac{wI_0}{K} + (1 - \cos wt_0)\frac{F_0}{Kwt_0}. \tag{15}$$

And hence, for $t \geqslant t_0$, the motion of the structure is given by

$$x = \frac{F_0}{K}\left(\frac{\sin wt_0}{wt_0} - 1\right) \cos wt + \left[\frac{wI_0}{K} + (1 - \cos wt_0)\frac{F_0}{Kwt_0}\right] \sin wt. \tag{16}$$

In preparation for a dimensionless presentation of the final results, let x_0 be the displacement of the structure due to a static force of magnitude F_0. Then

$$F_0 = K \cdot x_0 \quad \text{or} \quad x_0 = \frac{F_0}{K}. \tag{17}$$

Equations 12 and 16 may now be put in non-dimensional form by dividing the left hand side by x_0 and the right hand side by its equivalent $\frac{F_0}{K}$. Doing this one gets

$$\left(\frac{x}{x_0}\right) = \left(\frac{wI_0}{F_0} + \frac{1}{wt_0}\right) \sin wt - \cos wt + \left(1 - \frac{t}{t_0}\right) \text{for } 0 \leq t \leq t_0, \tag{18a}$$

and

$$\left(\frac{x}{x_0}\right) = \left(\frac{\sin wt_0}{wt_0} - 1\right) \cos wt + \left[\frac{wI_0}{F_0} + \frac{(1 - \cos wt_0)}{wt_0}\right] \sin wt \text{ for } t \geq t_0. \tag{18b}$$

Equations 18a and 18b together represent the displacement of the structure for all time, t. The ration $\left(\frac{x}{x_0}\right)$ is called the dynamic displacement factor which it can be seen is a function only of the parameter groups (wt_0) and $\frac{wI_0}{F_0}$. The first few cycles of Equations 18a and 18b are shown graphically in Fig. 5.

MAXIMUM RESPONSE

Fig. 5 shows that the dynamic displacement factor increases until its first relative maximum, $\left(\frac{x_m}{x_0}\right)$, is reached at time t_m. Due to the nature of the forcing function this maximum is the greatest one. In a large class of problems the maximum dynamic displacement factor is the most important information to be determined since the maximum resisting forces, stresses and strains will occur at the corresponding displacement.

The time of maximum displacement, t_m, is determined by finding the earliest non-zero time at which the velocity equals zero. Differentiating Eqs. 18a and 18b with respect to time and setting equal to zero one has

$$0 = \left(\frac{wI_0}{F_0} + \frac{1}{wt_0}\right) \cos wt + \sin wt - \frac{1}{wt_0} \text{ for } 0 \leq t \leq t_0 \quad (19a)$$

$$0 = -\left(\frac{\sin wt_0}{wt_0} - 1\right) \sin wt + \frac{wI_0}{F_0} + \frac{(1 - \cos wt_0)}{wt_0} \cos wt \quad \text{for} \quad t \geq t_0 \quad (19b)$$

The smallest non-zero value of t which satisfies Equations 19a and 19b is t_m. A substitution of these values of t_m into Equations 18a and 18b gives $\frac{x_m}{x_0}$.

Since this maximum dynamic displacement factor is a function of only two groups of parameters, wt_0 and $\frac{wI_0}{F_0}$, it can be tabulated graphically for any desired range of these parameters. Within the limits of

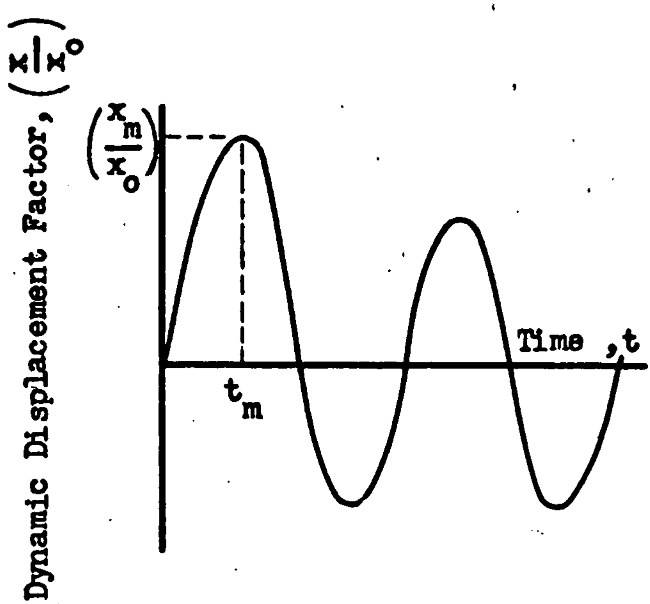

FIG. 5.—TYPICAL PLOT OF DYNAMIC DISPLACEMENT FACTOR VS. TIME.

$$0 \leq \left(\frac{x_m}{x_0}\right) \leq 6, \tag{20}$$

$$0 \leq \left(\frac{wI_0}{F_0}\right) \leq 5, \tag{21}$$

$$0 \leq \left(\frac{wt_0}{2\pi}\right) = \frac{t_0}{T} \leq \infty, \tag{22}$$

the solution has been presented in Figure 6. The quantity wt_0 has been divided by 2π to give $\frac{t_0}{T}$ where T (sec/cycle) is the period of vibration of the structure. The data represented by the solid lines have been determined by means of a desk computer. The broken lines represent $\left(\frac{x_m}{x_0}\right)$ as a function of $\frac{t_0}{T}$ for constant values of $\frac{t_m}{T}$. The family of curves represented by the broken lines have been determined only approximately by drawing contour lines between known values of $\frac{t_m}{T}$ along the solid curves.

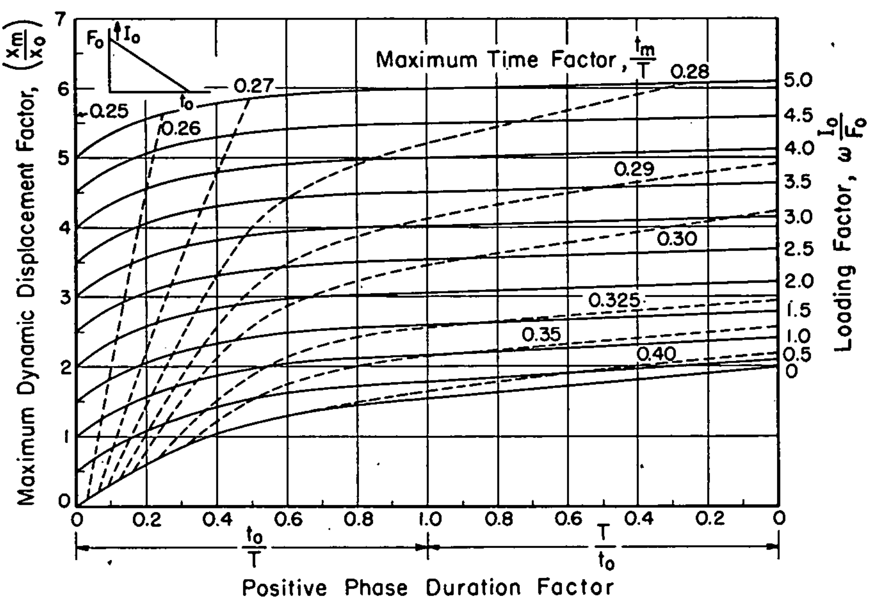

Fig. 6 Maximum Response of an Elastic Structure to Blast-Type Loading

APPLICATION OF SOLUTION

With Fig. 6 available, the designer or analyst may investigate the effects on maximum displacements, stresses, and strains of variations in structural and blast loading parameters without having to go through the lengthy computations necessary to solve the equation of motion. Since stress, S, strain, ϵ, and resisting forces, R, are directly proportional to the displacement, x, of the structure, the maximum stresses, strains, and resisting forces may be found with the help of Fig. 6. It is first necessary to compute S_0, ϵ_0 and R_0 which are values corresponding to a static force of magnitude F_0 acting on the structure. Knowing the values of $\frac{wI_0}{F_0}$ and $\frac{t_0}{T}$, the appropriate $\left(\frac{x_m}{x_0}\right)$ may be selected from Fig. 6. Then the maximum values are determined from the expressions

$$S_m = \left(\frac{x_m}{x_0}\right) S_0, \tag{23}$$

$$\epsilon_m = \left(\frac{x_m}{x_0}\right) \epsilon_0, \tag{24}$$

$$R_m = \left(\frac{x_m}{x_0}\right) R_0. \tag{25}$$

SPECIAL CASES

In addition to the general case where F_0, I_0, and t_0 have non-zero values, there are several special cases of interest whose solution may be obtained from Fig. 6. The curve associated with zero loading factor, $\frac{wI_0}{F_0}$, represents the dynamic response when the forcing function F(t) is acting without an initial impulse (Fig. 7). If the positive phase duration factor, $\frac{t_0}{T}$, is chosen to be infinity, i.e., $\frac{T}{t_0} = 0$, the dynamic response is that associated with a constant forcing function, F_0, of infinite duration and an initial impulse, I_0 (Fig. 8).

When the impulse, I_0, acts alone (Fig. 9), x_0 and F_0 have no meaning and so Fig. 6 provides no direct means of determing the response. However, for this case the maximum displacement, x_m, is known to be

$$x_m = \frac{I_0}{M_e w} = \frac{I_0}{\sqrt{M_e K}}. \tag{26}$$

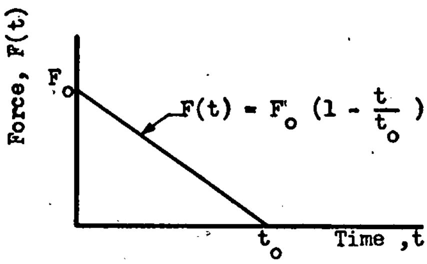

Fig. 7 Varying Force With No Initial Impulse

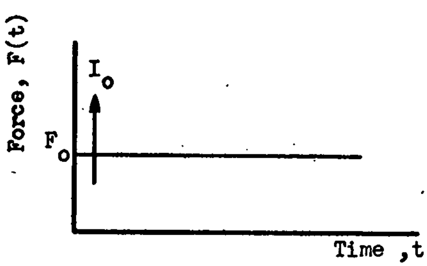

Fig. 8 Constant Force With an Initial Impulse

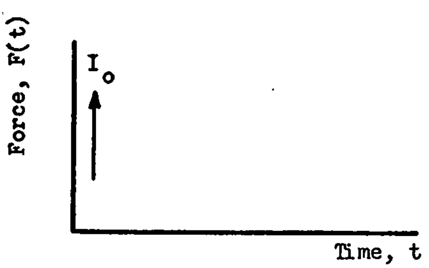

Fig. 9 Impulse Acting Alone

Equation 26 may be verified by Fig. 6 as follows: The effect of the forcing function, F(t) may be removed by letting $\frac{t_0}{T} = 0$. From Fig. 6 it may be observed that in this case

$$w\left(\frac{I_0}{F_0}\right) = \left(\frac{x_m}{x_0}\right). \tag{27}$$

But

$$w = \sqrt{\frac{K}{M_e}}, \tag{28}$$

and

$$F_0 = Kx_0. \tag{29}$$

Substituting Eq. 28 and 29 into 27 and rearranging one arrives at an expression identical to Eq. 26.

CONCLUSION

The design and analysis of structures subject to blast-type loading is somewhat involved. A mathematical representation of the forcing function and the resistance must be formulated. Values for the parameters F_0, I_0, t_0, K and M_e must be determined and then the equation of motion must be solved.

In this paper a suddenly applied, linearly decreasing force together with an initial impulse was chosen for the forcing function. The structure's resistance was chosen to be directly proportional to its displacement. The equation of motion assuming a single-degree-of-freedom system was solved for a wide range of the structural and loading parameters. These results are presented graphically for convenient use by the designer or analyst.

The designer is still faced with the problem of determining the values of the parameters which fit his particular case. Once he has done so, however, he may use Fig. 6 to determine the response for his given set of conditions, and he no longer needs to repeat the lengthy calculations necessary to solve the equation of motion.

NOMENCLATURE

The following nomenclature is used in the paper:

A, B, C, D = coefficients in solution to equation of motion.

$F(t)$ = time varying force, lbs.

F_0 = $F(t)$ when time = 0, lbs.

$\sum F_x$ = summation of forces in direction of motion, lbs.

I_0 = initial impulse load, lb-sec.

K = constant structural parameter, lbs/ft.

M_e = equivalent mass of structure, slugs.

p = blast pressure above atmospheric, psi.

p_σ = peak value of p, psi.

$R(x)$ = resistance of structure, lbs.

R_0 = resistance due to static force of magnitude F_0, lbs.

R_m = maximum resistance, lbs.

S_0 = stress due to static force of magnitude F_0, psi.

S_m = maximum stress, psi.

t = time, sec.

t_0 = time at which F(t) becomes zero, sec.

t_1, t_2 = time parameters of blast pressure wave, sec.

t_m = time of maximum displacement, sec.

T = period of vibration of structure, sec.

$w^2 = \frac{K}{M_e}$, $\sec^{-2}$.

x = displacement of structure, ft.

$\dot{x} = \frac{dx}{dt}$ = velocity of structure, ft/sec.

$\ddot{x} = \frac{d^2x}{dt^2}$ = acceleration of structure, ft/sec^2.

x_m = maximum dynamic displacement, ft.

x_0 = displacement due to static force of magnitude F_0, ft.

ϵ_0 = strain due to static force of magnitude F_0.

ϵ_m = maximum strain.

$\left(\frac{x_m}{x_0}\right)$ = dimensionless maximum dynamic displacement factor.

$\left(\frac{t_0}{T}\right)$ = dimensionless positive phase duration factor.

$\left(\frac{wI_0}{F_0}\right)$ = dimensionless loading factor.

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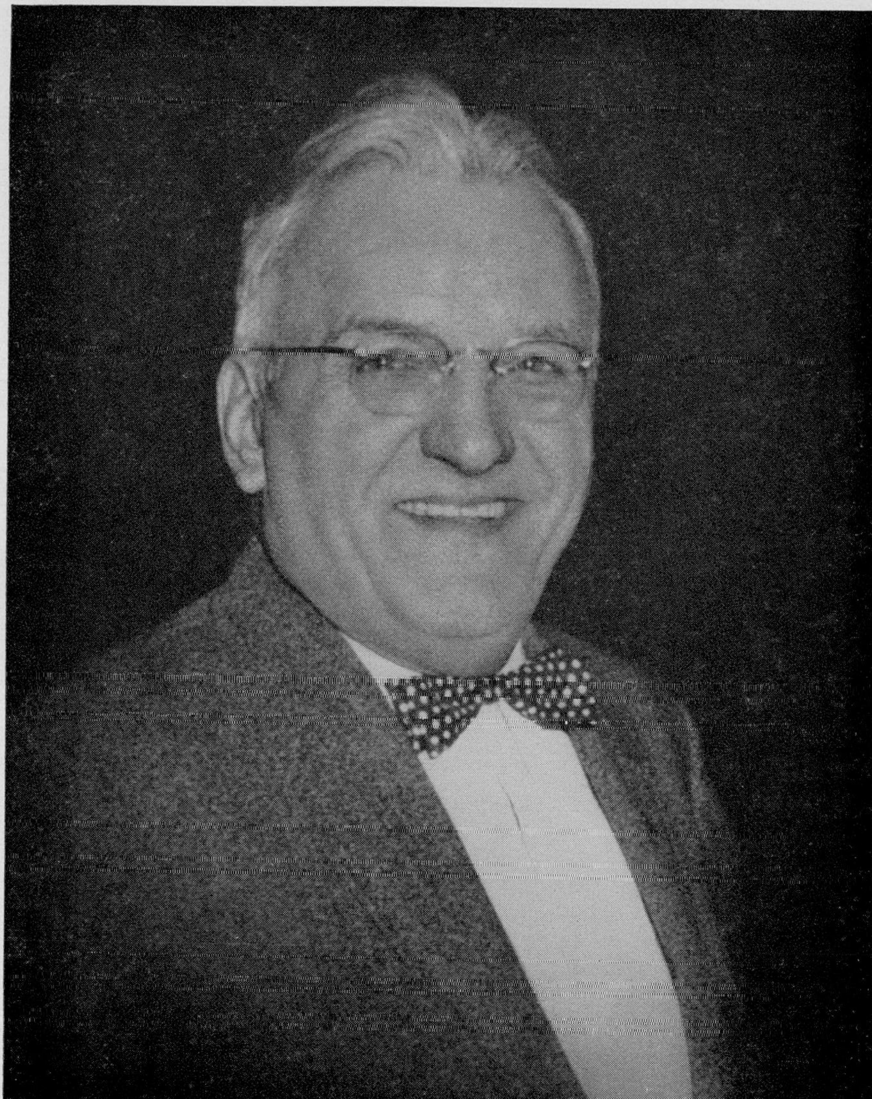

ROBERT W. MOIR

ROBERT W. MOIR

1903—1959

Robert W. Moir was born in Newton, Massachusetts, November 18, 1903 and was a life-long resident of the Auburndale section of that City. He attended Massachusetts Institute of Technology in the Civil Engineering Department and followed the practice of Civil Engineering until his death on October 22, 1959.

He is survived by his wife, M. Ellen (Moore) Moir; a son, Robert W. 3rd., and a daughter, Mrs. Anna-Louise Banks.

In 1926 he joined the Metropolitan District Water Supply Commission which was engaged in the development of new sources of water supply and extensions to the distribution system for the Boston Metropolitan District. He continued to serve in that department for the rest of his life. He was located at first with the field office forces on construction of Quabbin Reservoir near Ware, Massachusetts, and the Quabbin Tunnel constructed to carry water from Quabbin Reservoir to Wachusett Reservoir. Later he served as a resident engineer on sections of the Pressure Aqueduct Line built between Marlborough and Newton as a principal carrier of water to the District.

In 1941 he resumed work in the headquarters office in Boston as a Senior Civil Engineer in the design section assuming the supervision of design on numerous water supply and sewerage projects in the Construction Division of the Metropolitan District Commission. In this connection he was concerned with the design and construction of trunk line sewers in Natick and Wellesley, as well as similar projects in the So. Charles drainage district. He was closely connected with the design and construction of the Nut Island Sewage Treatment Plant built in Quincy, Mass., and from 1950 on worked actively on the designs for a sewage treatment plant to be built on Deer Island in Boston Harbor as part of the present extensions planned in the Metropolitan District.

Mr. Moir gave a great deal of his time to engineering society matters and as a member of the New England Water Works Association and the local Sewerage Works Association served on committees and in other capacities as a contribution to the success of such organizations.

Mr. Moir joined the Boston Society of Civil Engineers February 18, 1942. In addition to committee membership he was active in the affairs of the various Sections of the Society. He was elected to the office of Secretary on March 31, 1948 and served in this office until his death. This work became one of his most important interests and he gave his time and energy to the Society unstintingly.

During the many years in the practice of his profession he had many younger engineers working under his supervision. Those who knew him will agree that he would gladly go out of his way to encourage and help such younger men giving freely of his knowledge and experience. Mr. Moir was a person of high ethical standards who practiced those standards to the best of his ability at all times.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

JANUARY 27, 1960.—A regular meeting of the Boston Society of Civil Engineers was held this evening at Northeastern University, 260 Huntington Avenue, Boston, Mass., and was called to order by President Edward C. Keane, at 7:00 P.M.

President Keane stated that the minutes of the previous meeting held December 16, 1959 would be published in a forthcoming issue of the Journal and that the reading of those minutes would be waived unless there was objection.

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership on January 25, 1960.

Grade of Member—Richard F. Battles, Robert M. Bender, Raymond W. McNamara*.

Grade of Student Member—Philip N. Buchanan, Paul F. Hadala.

President Keane requested the Secretary to present a recommendation of the Board of Government to the Society for action and stated that this matter was before the Society in accordance with the provisions of the By-Laws and notice of such action published in the ESNE Journal dated January 18, 1960.

The Secretary presented the following recommendation of the Board of Government to the Society for initial 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 $1,800 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 $1,800 from the Principal of the Permanent Fund to the Current Fund for current expenditures".

President Keane stated that final action on this matter would be taken at the February 17, 1960 meeting of the Society.

President Keane then introduced the speaker of the evening, Dr. Ruth D. Terzaghi, Lecturer on Engineering Geology, Harvard University who gave a most interesting illustrated talk on "Storage Dam Founded on Landslide Debris". Following the talk a discussion was given by Dr. Arthur Casagrande, Prof. of Soil Mechanics & Foundation Engineering, Harvard University.

The meeting was preceded by a dinner and 36 members and guests attended the dinner. Ninety members and guests attended the meeting.

The meeting was adjourned at 9:00 P.M.

CHARLES O. BAIRD, JR., *Secretary*

FEBRUARY 17, 1960.—A Joint Meeting of the Boston Society of Civil Engineers with the Hydraulics Section, BSCE was held this evening at the United Community Services Building, 14 Somerset Street, Boston, Mass., and was called to order by President Edward C. Keane, at 7:30 P.M.

President Keane stated that the minutes of the previous meeting held January 27, 1960 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 Keane announced the death of the following members:—

Thomas W. Clark, who was elected a member March 20, 1912, and who died January 12, 1960.

Hiram R. Chubbuck, who was elected a member December 22, 1922 and who died in 1958.

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership on February 15, 1960:—

Grade of Member—Leon A. Antosh*, Patrick F. Cox, James E. Macauley, Robert C. Marini*, Frank A. Marino*, Charles W. Terenzio*, Norman A. Whalen*.

President Keane requested the Secretary to present a recommendation of the Board of Government to the Society for action and stated that this matter was before the Society in accordance with the provisions of the By-Laws and notice of such action published in the ESNE Journal February 7, 1960.

The Secretary presented the following recommendation of the Board of Government to the Society for final action to be taken at this meeting.

* Transfer from Grade of Junior.

MOTION "to recommend to the Society that the Board of Government be authorized to transfer an amount not to exceed $2000 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 $2000 from the Principal of the Permanent Fund to the Current Fund for current expenditures".

President Keane stated that this was the final action on this matter.

President Keane stated that this was a Joint Meeting with the Hydraulics Section and called upon Lee M. G. Wolman, Chairman of that section to conduct any necessary business at this time for that section.

Chairman Lee M. G. Wolman then introduced the speaker of the evening Mr. Louis D. Pierce who presented a most interesting illustrated talk on "The Connecticut River, Its Development and Its Versatility".

The meeting was preceded by a dinner and 37 members and guests attended the dinner. Forty-two members and guests attended the meeting.

The meeting was adjourned at 9:30 P.M.

CHARLES O. BAIRD, JR., *Secretary*

MARCH 16, 1960.—The 112th 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 4:37 P.M., by President Edward C. Keane.

President Keane announced that the reading of the Minutes of the Society meetings had been omitted during the year. The Minutes of the January and February 1950 meetings will be published in a forthcoming issue of the

Journal. The Minutes of the April, May, September, October, November and December 1959 meetings to be declared approved as published.

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

President Keane announced the death of the following members:—

Caleb M. Saville, who was elected a member February 18, 1891 and who died February 14, 1960.

William H. Balch, who was elected a member January 22, 1908 and who died February 6, 1960.

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership on March 14, 1960:—

Grade of Member—Frank J. Cullati*, John D. Goodrich*, Robert W. Hart*, Philip R. Lindquist*, Richard H. Olney, Ulderico M. Schiavone.

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, Membership, Advertising and Joint Legislative Committee.

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

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

President Keane stated that all foregoing reports would be published in the April, 1960 issue of the Journal.

The Report of the Tellers of Election, Frank T. Smith, Jr., and John C. Adams, Jr., was presented and in accordance therewith the President declared the following had been elected Officers for the ensuing year:—

President — Arthur T. Ippen

V-President (for two years) — Charles H. Norris

Secretary (for one year) — Charles O. Baird, Jr.

Treasurer (for one year) — Paul A. Dunkerley

Directors (for two years) — John F. Flaherty, William A. Henderson

Nominating Committee (for two years) — Fozi M. Cahaly, Robert J. Hansen, Harold A. Thomas, Jr.

The retiring President Edward C. Keane then gave his address entitled "Problem of Boston, Central City of a Metropolitan Area".

Twenty-seven members and guests attended the business meeting.

The meeting adjourned at 5:30 P.M., to re-assemble at 8:00 P.M., the Annual Dinner being held during the interim.

The President called the meeting to order at 8:00 P.M.

Following general remarks and the introduction of the newly elected President Arthur T. Ippen, and other guests at the head table, President Keane announced that Honorary Membership in the Society had been conferred on one of the Society's distinguished members, in accordance with the vote of the Board of Government on February 15, 1960.

Frank Alwyn Marston, who has been a member since February 17, 1909. President Keane presented the newly elected Honorary Member with a Certificate of Honorary Membership which read as follows:

FRANK ALWYN MARSTON
has been duly elected an
HONORARY MEMBER
By direction of the
Board of Government
February 15, 1960
CHARLES O. BAIRD, JR., *Secretary*
EDWARD C. KEANE, *President*

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* Transfer from Grade of Junior.

President Keane 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 Keane presented the Awards and Scholarships (see below).

President Keane introduced the guest speaker of the evening, John W. Roberts, Lecturer who gave a most interesting illustrated talk on "Switzerland Today".

At the conclusion of the talk President Keane on behalf of the Society thanked Mr. Roberts for a most enjoyable talk and then turned the meeting over to President elect Arthur T. Ippen.

President Arthur T. Ippen presented retiring President Edward C. Keane with a certificate of appreciation for services rendered.

President Arthur T. Ippen made announcement of a Joint Dinner Meeting with the Northeastern University Civil Engineering Society to be held March 30th at Northeastern University.

The meeting adjourned at 10:35 P.M.

CHARLES O. BAIRD, JR., *Secretary*

Award	*Recipient*	*Paper*
Desmond FitzGerald Medal	Peter S. Eagleson	"Hydraulic Model Studies of Protective Works for Fleet Berths in Narragansett Bay".
Clemens Herschel Award	Arthur Maass Maynard M. Hufschmidt	"In Search of New Methods for River System Planning".
Sanitary Section Award	John F. Flaherty	"Boston South Bay Incinerator—The Events Leading to Its Construction".
Hydraulics Section Award	John Wm. Leslie	"Development and Design of Hopkinton-Everett Reservoir Project".
Surveying & Mapping Section Award	Harry R. Feldman	"Surveys in Connection with the Preparation of Construction Plans for Sewers in Derry, N.H."
Student Chapter Prize Award	Alfred J. Schiff	"Proposed Changes to Intersection of Centre Street, Natick with Mass. Route 9".
Desmond FitzGerald Scholarship	Bernard X. Ohnemus	Northeastern University
William P. Morse Scholarship	Michael A. Covell	Tufts University

SURVEYING AND MAPPING SECTION

Wednesday, October 21, 1959

Nelson W. Gay, Chairman

OCTOBER 21, 1959.—A regular meeting of the Surveying and Mapping section was held this evening. The subject of the meeting was "Bids-Negotiations". The speakers included Mr. Herman J. Shea of the James W. Sewell Company, Mr. Llewellyn T. Schofield of Schofield Brothers, and Mr. A. Russell Barns of Barns & Jarnis.

Mr. Barns outlined the views of the American Society of Civil Engineers on the subject of competitive bidding for engineering services. He also presented his own personal views on the subject, concluding that bidding was not only unethical but also impractical.

Mr. Shea outlined the work of the ASCE Task Committee on surveying and mapping and the various reports which the ASCE Committee has presented to date. This included a discussion of the definition of professionalism, the subject of professionalism versus technical activity, and related questions treated by the ASCE Task Committee reports.

Mr. Schofield discussed the subject from the views of a practicing surveyor.

A rather lively discussion session followed the presentations by the three speakers.

The meeting was attended by thirty-four members and guests.

R. A. SLAYTER, *Clerk*

ANNUAL REPORTS

REPORT OF THE BOARD OF GOVERNMENT FOR YEAR 1959-1960

Boston, Mass., March 16, 1960

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 16, 1960:

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

Honorary	7
Members	987
Associates	6
Juniors	84
Students	9
Total	1093
Student Chapters	2

Summary of Additions

New Members	34
New Juniors	7
New Associates	1
New Students	3

Reinstatements

Members	1

Summary of Transfers

Junior to Member	7
Student to Junior	2

Summary of Loss of Members

Deaths	21
Resignations	17
Dropped for non-payment of dues	26
Dropped for failure to transfer	4

Life Members	98
Members becoming eligible today for Life Membership	6
Remission of dues	0
Applications pending on March 16, 1960	12

Honorary Membership is as follows:

Frank M. Gunby, elected, February 15, 1950
Karl R. Kennison, elected February 7, 1951
Frank A. Marston, elected, February 15, 1960
Charles M. Spofford, elected, December 19, 1945
Howard M. Turner, elected, February 18, 1952
William F. Uhl, elected, February 7, 1955
Karl Terzaghi, elected, March 3, 1952

The following members have been lost through death:

William H. Balch, Feb. 6, 1960
George D. Brown, 1959
Alfred A. Burns, Oct. 22, 1959
William F. Condon, Feb. 7, 1960
Hiram A. Chubbuck, 1958
Thomas W. Clark, Jan. 12, 1960
Irving B. Crosby, Sept. 18, 1959
Alonzo B. Crowell, 1959
Wilbur W. Davis, Apr. 15, 1959
Harold J. Duffy, Oct. 14, 1959
John L. Howard, June 11, 1959
Sumner Hazlewood, June 23, 1959
Harvey B. Kinnison, Mar. 14, 1959
William H. Kraphol, Aug. 12, 1959
Charles A. Leary, Oct. 14, 1959
Robert W. Moir, Oct. 22, 1959
Daniel M. Moore, Apr. 14, 1959
Bernard J. Parker, Aug. 13, 1959
Frederick H. Paulson, Sept. 29, 1959
Caleb M. Saville, Feb. 14, 1960
Louis P. Vuona, Nov. 18, 1959

Meetings of the Society

March 18, 1959. Address of the retiring President William L. Hyland. "Trends in the Engineering Profession".

April 15, 1959. Joint Meeting with the Massachusetts Section, American Society of Civil Engineers. "The Fairchild Aluminum Bridge". W. Dean Devereux, Technical Advisor, Olin Mathieson Chemical Corp.

May 20, 1959. Joint Meeting with Structural Section, BSCE. "The Engineering and Design Features—General and Contruction Phases of the Niagara Power Project". George R. Rich, Director, and Wilfred M. Hall, President of Chas. T. Main, Inc.

September 23, 1959. Joint Meeting with the Transportation Section BSCE. "Evolution of a Bridge", John M. Kyle, Chief Engineer, Port of New York Authority.

October 28, 1959. Joint Meeting with the Massachusetts Section of the American Society of Civil Engineers. Student Night. "Recent Expeditions to the Antarctic", Rev. Father Linehan, S.J. Director of Weston Observatory.

November 18, 1959. Joint Meeting with the Massachusetts Section of the American Society of Civil Engineers and the Structural Section of BSCE. "Prudential Center Foundations, Exploration, Design and Early Construction Problems". Donald G. Ball, Chief Soils Engineer, Metcalf & Eddy.

December 16, 1959. Joint Meeting with the Sanitary Section BSCE. "Water Pollution". Panel discussion. Moderator, Joseph C. Knox, Exec. Secretary, New England Interstate Water Pollution Control. Panelists, Russell A. Eckloff, Water Pollution Engineer, New Hampshire Pollution Comm; Reinhold W. Thieme, Commissioner, Vermont Water Conservation Board; Worthen H. Taylor, Chief Sanitary Engineer, Mass. Dept. Public Health; William S. Wise, Director, Connecticut Water Resources Comm.

January 27, 1960. "Storage Dam Founded on Landslide Debris". Karl Terzaghi, Prof. of the Practice of Civil Engineering, Div. of Engineering Sciences, Harvard University.

February 17, 1960. Joint Meeting with the Hydraulics Section, BSCE. "The Connecticut River, Its Development and Its Versatility". Louis D. Pierce, New England Power Service Company.

Attendance at Meetings

Date	*Place*	*Meeting*	*Dinner*
March 18, 1959	Hotel Vendome	45	110
April 15, 1959	Hotel Lenox	54	40
May 20, 1959	United Community Services Bldg.	113	54
September 23, 1959	United Community Services Bldg.	95	73
October 28, 1959	University of Massachusetts	190	190
November 16, 1959	United Community Services Bldg.	202	110
December 16, 1959	United Community Services Bldg.	90	61
January 27, 1960	Northeastern University	90	36
February 17, 1960	United Community Services Bldg.	42	37

Average Attendance — 81

Sections

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 was presented and large attendance at these meetings has continued. The Annual Report of the various Sections will be presented at the Annual Meeting and will be published.

*Funds of the Society**

Permanent Fund. The Permanent Fund of the Society has a present value of $63,711.33. 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 January 27, 1960.and February 17, 1960 meetings, the Board of Government was authorized to transfer an amount not to exceed $2000 from the Principal of the Permanent Fund for current expenditures. The amount necessary to transfer from Principal of Permanent Fund for current expenditures was none.

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. A scholarship was awarded Robert G. Dean, member, for year 1958-1959.

Edmund K. Turner Fund. In 1916 the Society received 1,105 books from the Library of the late Edmund K. Turner, and a bequest of $1,000, "the income of which is to be used for library purposes". The Board voted to use $50 of the income for the purchase of books for the Library. The expenditure from this fund during the year was $36.50.

Alexis H. French Fund.. The Alexis H. French Fund, a bequest amounting to $1,000 was received in 1931, from the late Alexis H. French of Brookline, a former Past President of the Society. The income of the fund is "to be devoted to the Library of the Society". The Board voted to use $50 of the available income for the purchase of books for the Library. The expenditure from this fund during the year was $50.00.

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 $2,338.16 on June 30, 1959. Arrigo P. Mongini of Roslindale, Mass., a student in Civil Engineering, class of 1961 was awarded this Scholarship of $200 for year 1959-1960.

Desmond FitzGerald Fund. The Desmond FitzGerald Fund established in 1910 as 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 on April 8,

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

1957 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 student at Northeastern University. It was voted on January 19, 1959 "to adopt the recommendation of the Committee at Northeastern University, namely, a $100 Scholarship be given to Walter O. Spofford. Presentation to be made at the Annual Meeting of the Society March 18, 1959.

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 6, 1959 that payment of the Herschel Prize Award and Section Prize Awards be appropriated from the income of this fund. The expenditure made during the year from the income of this fund was $91.75.

Edward W. Howe Fund. This fund, a bequest of $1,000 was received in 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

Prizes

Award	Recipient	Paper
Desmond Fitz-Gerald Medal	Peter S. Eagleson	"Hydraulic Model Studies of Protective Works for Fleet Berths in Narragansett Bay".
Clemens Herschel Award	Arthur Maass Maynard M. Hufschmidt	"In Search of New Methods for River System Planning".
Sanitary Section Award	John F. Flaherty	"Boston South Bay Incinerator—The Events Leading to Its Construction".
Hydraulics Section Award	John Wm. Leslie	"Development and Design of Hopkinton Everett Reservoir Project".
Surveying & Mapping Award	Harry R. Feldman	"Surveys in Connection with the Preparation of Construction Plans for Sewers in Derry, N. H.".
Student Section Award	Arthur J. Schiff	"Proposed Changes to Intersection of Centre Street, Natick with Mass. Route 9".

the Board of Government was that the fund be kept intact, and that the income be used "for the benefit of the Society or its members". No expenditures 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 upon the use of this money, but the recommendation of the Board of Government was "that this fund be kept intact and that the income be used for the benefit of the Society or its Members". Upon recommendation of a 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 student at Tufts University. It was voted on February 19, 1959 to adopt the recommendation of the Committee at Tufts University, namely, that a $100 Scholarship be given jointly to Richard J. Devine and LeRoy E. Christie. Presentation of $50 to each to be made at the Annual Meeting of the Society March 18, 1959.

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.

EDWARD C. KEANE, *President*

REPORT OF THE TREASURER

Boston, Massachusetts
March 16, 1960

To the Boston Society of Civil Engineers,

Article I—Objects of the Constitution states:

"The objects of this Society are: The professional improvement of its members, the encouragement of social intercourse among engineers and men of practical science, and the advancement of engineering. For the promotion of these objects, stated meetings of the Society shall be held and a library maintained for the use of its members."

A study of the fiscal year, March 1, 1959 through March 1, 1960, by your treasurer, indicates the financial aspects of the Constitution's Article I is:

MEETINGS:

The total expenditures for all meetings held during the year were $2,276.11.

JOURNAL and LIBRARY:

This account includes the Editor's salary and expenses, printing and postage, periodicals and binding of periodicals and other journals. This year it amounted to $6,684.51.

SCHOLARSHIPS:

The John R. Freeman Scholarship, began in September 1958, was completed August 1959. Mr. Robert G. Dean, the recipient, receivd $2,499.98 this year and $2,500.02 last year.

Two Tufts' University students, Mr. Leroy G. Christie and Mr. Richard J. Devine, each received $50.00 at our last annual meeting. This scholarship is the William P. Morse Scholarship.

The Desmond Fitzgerald Scholarship of $100.00 was awarded to Mr. Walter O. Spofford, a Northeastern University student.

PUBLICATIONS:

The previous issue of Volume I, "Contributions to Soil Mechanics" became exhausted and a new printing was made which required an expenditure of $2,199.50. The need to the profession is indicated by the fact that the above expenditure was made June 18, 1959 and as of March 1, 1960 the Society had a net income of $388.42 to the Volume I account.

Volume II, "Contributions to Soil Mechanics", also, is being widely used, for the gross income this fiscal year was $522.44.

"Boring Data for Boston" should be ready for distribution in the near future, and the "Sanitary Lectures" are expected to be published during the fiscal year 1960—1961.

The financial status of our Society can be best represented by the six attached tables, namely:

It has been a distinct privilege to serve as your treasurer and I wish to take this opportunity to thank every Member for his help during my tenure as treasurer.

CHARLES O. BAIRD, JR., *Treasurer*

TABLE I
COMPARISON OF BOOK VALUES AND MARKET VALUES OF STOCKS, BONDS, CO-OP BANK, AND INVESTMENT CASH

	BOOK VALUE 3/1/60	MARKET VALUE 3/1/60
Bonds	$ 51,942.25	$ 44,690.65
Stocks	52,108.32	133,957.52
Co-op Bank	4,291.23	4,291.23
Available for Investment	725.74	725.74
Total 1960	$109,067.54	$183,665.14
Total 1959	$110,334.78	$188,528.64
Decrease	$ 1,267.24	$ 4,863.50

TABLE II
COMPARISON OF OUR FUND'S BOOK AND MARKET VALUES

	BOOK VALUE 3/1/60	MARKET VALUE 3/1/60
Permanent	$ 63,711.33	$107,287.20
John R. Freeman	32,623.26	54,936.20
Edmund K. Turner	1,296.75	2,183.67
Desmond Fitzgerald	2,502.46	4,214.04
Alexis H. French	1,292.01	2,175.69
Clemens Herschel	1,083.13	1,823.95
Edward W. Howe	1,249.44	2,104.00
William P. Morse	2,480.86	4,177.66
Publication	627.86	1,057.29
Surveying	471.51	794.00
Structural	340.51	573.40
Boring	1,000.00	1,683.96
Vol. 1	388.42	654.08
Totals	$109,067.54	$183,665.14

TABLE III

DISTRIBUTION OF FUNDS—RECEIPTS AND EXPENDITURES

BOSTON SOCIETY OF CIVIL ENGINEERS

REPORT OF TREASURER—MARCH 1, 1960

	Distribution of Funds			Receipts and Expenditures				
				Net Profit or Loss at Sale or Maturity		Transfer of Funds		
	Book Value March 1, 1959	Interest and Dividends Cash	Credit	+	—	Purchased +	Sold —	Book Value March 1, 1960
	1	2	3	4	5	6	7	8
Bonds	$ 52,944.75	$2,133.52			235.90	$6,997.50	$8,000.00	$ 51,942.25
Co-op Bank	4,155.11		$136.12					4,291.23
Stocks	52,026.74	5,000.46				81.58		52,108.32
Available for Investment	1,208.18						482.44	725.74
Total	$110,334.78	$7,133.98	$136.12		$235.90	$7,079.08	$8,482.44	$109,067.54

Columns 1 + 3 + 6 — 7 = 8

TABLE III—Continued

Funds	Book Value March 1, 1959	Allocation of Income-Profit and Loss		Received	Expended	Book Value March 1, 1960
		Income Col. 2 & 3	Net Loss Col. 5			
Permanent	$ 65,517.28	$ 4,361.91*	$141.54	$ 380.00	$ 6,406.32*	$ 63,711.33
John R. Freeman	33,195.96	2,210.07	71.71		2,711.06	32,623.26
Edmund K. Turner	1,260.10	83.89	2.73		44.51	1,296.75
Desmond Fitzgerald	2,459.65	163.75	5.31		115.63	2,502.46
Alexis H. French	1,268.38	84.44	2.74		58.07	1,292.01
Clemens Herschel	1,110.41	73.93	2.40		98.81	1,083.13
Edward W. Howe	1,180.87	78.62	2.55		7.50	1,249.44
William P. Morse	2,439.24	162.40	5.27		115.51	2,480.86
Publication	135.42			522.44	30.00	627.86
Surveying Lectures	445.64	29.67	0.96		2.84	471.51
Structural Lectures	321.83	21.42	0.69		2.05	340.51
Boring Data	1,000.00			0.00	0.00	1,000.00
Vol. I	0.00			2,617.92	2,229.50	388.42
	$110,334.78	$ 7,270.10	— $235.90	$ 3,520.36	$11,821.80	$109,067.54
Current	1,500.00	3,790.18*		17,360.51	21,150.69	1,500.00
Totals	$111,834.78	$11,060.28	— $235.90	$20,880.87	$32,972.49	$110,567.54

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

Cash Balance

Investment Fund	$ 725.74
Current Fund	1,500.00
Total Cash	$2,225.74

Net income to Permanent Fund = $3,945.27

* $3,790.18 transferred from income to Permanent Fund

TABLE IV—RECORD OF INVESTMENTS—BONDS
MARCH 1, 1959 TO MARCH 1, 1960

Bonds	Date of Maturity	Interest Rate	Interest Received	Par Value	Book Value March 1, 1960	Market Value March 1, 1960
Aluminum Company of America	April 1, 1983	3⅞%	$ 193.75	$ 5,000.00	$ 5,037.50	$ 4,590.65
U. S. Savings Bond Series G[1]	May 1, 1960	2½%	28.10		0.00	0.00
U. S. of America Savings Bond Series K[2]	Aug. 1, 1966	2.76%	96.60		0.00	0.00
Columbia Gas System Inc., Deb., Series D	July 1, 1979	3.50%	70.00	2,000.00	2,066.17	1,725.00
Consumers Power Co. 1st Mtge.	Sept. 1, 1975	2⅞%	129.39	3,000.00	3,140.35	2,437.50
Florida Power Corp. 1st Mtge.	July 1, 1984	3.125%	31.25	1,000.00	1,017.50	760.00
Florida Power Corp. 1st Mtge.	July 1, 1986	3.875%	193.75	5,000.00	5,037.59	4,312.50
General Motors Acceptance Corp. Deb.	Sept. 1, 1975	3.625%	271.90	5,000.00	5,101.80	4,300.00
Georgia Power Co. 1st Mtge.	Dec. 1, 1977	3.375%	168.75	5,000.00	5,162.50	4,300.00
Province of Ontario	Sept. 1, 1972	3¼%	146.25	3,000.00	2,936.25	2,542.50
Public Service Electric & Gas Co.	June 1, 1979	2⅞%	115.00	4,000.00	4,097.50	2,920.00
Scott Paper Co. Cov. Deb.	Mar. 1, 1971	3.00%	45.00	1,000.00	1,123.79	1,015.00
So. Pacific 1st Series A, Oregon Lines	Mar. 1, 1977	4.50%	270.00	4,000.00	4,191.30	3,655.00
Superior Oil Co. Deb. S.F.	July 1, 1981	3.75%	150.00	4,000.00	4,000.00	3,445.00
Tidewater Oil Co. S.F. Deb.	April 1, 1986	3½%	70.00	2,000.00	2,032.50	1,610.00
Associates Investment Co. Deb.[3]	Aug. 1, 1979	5⅛%	153.78	6,000.00	6,000.00	6,075.00
U.S.A. Treasury Notes Series A[4]	May 15, 1964	4¾%	0.00	1,000.00	997.50	1,002.50
Totals			$2,133.52	$51,000.00	$51,942.25	$44,690.65

1 and 4—Exchanged U. S. Savings Bond Series G for U. S. A. Treasury Notes, December 8, 1959.
2—Sold U. S. of America Savings Bond Series K, September 2, 1959.
3—Purchased Associates Investment Co. Deb., September 18, 1959.

TABLE V—RECORD OF INVESTMENTS—STOCKS
MARCH 1, 1959 TO MARCH 1, 1960

Stocks	Classification	Number of Shares	Dividend Received	Book Value March 1, 1960	Market Value March 1, 1960
American Telephone and Telegraph Co.	Common	207	$ 667.59	$ 7,729.00	$ 18,552.38
Consolidated Edison Co. of New York, Inc.	Common	50	140.00	2,494.03	3,106.25
Continental Insurance Co.	Common	150	286.00	3,506.71	7,537.50
General Electric Co. of New York	Common	150	300.00	2,341.47	13,500.00
Hartford Fire Insurance Co.	Common	26	78.00	1,472.75	4,992.00
Jewel Tea Co., Inc.	Common	62	74.40	1,467.10	2,929.50
National Dairy Products Corp.	Common	100	195.00	1,154.74	5,000.00
New England Electric System	Common	198	205.92	3,075.89	4,108,50
Pacific Gas and Electric Co.	Preferred	100	150.00	2,704.89	3,000.00
Pacific Gas and Electric Co.	Common	105	273.00	3,625.34	6,785.63
Radio Corporation of America	Preferred	20	70.00	1,720.75	1,412.50
Scott Paper Company	Common	75	153.75	4,860.86	5,793.75
Southern California Edison Co., Ltd.	Preferred	40	104.00	1,140.24	2,130.00
Southern California Edison Co.	Common	55	143.00	1,918.64	3,272.50
Standard Oil of New Jersey	Common	324	729.00	3,260.66	14,539.50
Southern Railway Co.	Preferred	75	75.00	1,136.80	1,293.75
Texas, Inc.	Common	217	553.80	3,066.72	16,213.76
Union Carbide Corp.	Common	100	450.00	2,958.44	13,300.00
Union Pacific Railroad	Common	220	352.00	2,473.29	6,490.00
Totals		2274	$5,000.46	$52,108.32	$133,957.52

TABLE VI—RECORD OF INVESTMENTS—CO-OPERATIVE BANK

Co-operative Bank	Classification	Number of Shares	Dividend Received	Book Value March 1, 1960	Market Value March 1, 1960
Suffolk Co-operative Federal Savings and Loan Association, Account No. 1S-631	Savings Account		$136.12	$4,291.23	$4,291.23

REPORT OF THE SECRETARY

Boston, Mass., March 16, 1960

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 16, 1960

	Expenditures	Receipts
Office		
Secretary, salary & expense	$ 757.83	
Treasurer's Honorarium	400.00	
Stationery, printing & postage	583.65	
Incidentals & Petty Cash	133.77	
Insurance & Treasurer's Bond	74.50	
Quarters, Rent, Tel.	4,139.65	
Office Secretary	4,550.40	
Social Security	134.90	
Meetings		
Rent of Halls, etc.	240.00	
Stationery, printing & postage	42.00	
Hospitality Committee	1,259.51	$ 1,181.20
Reporting & Projection	24.00	
Annual Meeting, March, 1959	569.91	408.00
Sections		
Sanitary Section	14.70	
Structural Section	62.25	
Transportation Section	20.30	
Hydraulics Section	17.60	
Construction Section	7.75	
Surveying & Mapping Section	18.09	
Journal		
Editor's salary & expense	779.95	
Printing & Postage	5,675.95	
Reprints	—	
Advertisements	—	1,808.70
Sale of Journals & Reprints	—	1,761.70
Library		
Periodicals	61.50	
Binding	93.50	
Forward	$19,661.71	$ 5,159.60

REPORT OF THE SECRETARY (Continued)

	Expenditures	Receipts
Brought Forward	$19,661.71	$ 5,159.60
Miscellaneous		
Binding Journals for Members	55.25	60.41*
Badges	—	
Bank charges	12.85	
Miscellaneous	290.45	95.50
Engineering Societies Dues and charge for Journal space	1,056.82	
Public Relations Committee	73.61	
Membership Committee	—	
Dues from B.S.C.E. Members		12,045.00
Trans. Income Perm Fund		3,790.18
	$21,150.69	$21,150.69

Entrance Fees to Permanent Fund $380.00

34 New Members; 1 Associate Member; 7 New Junior Members; 3 New Student Members; 7 Juniors transferred to Member; 2 Students transferred to Junior Member

The above receipts have been paid to the Treasurer, who's receipt the Secretary holds. The Secretary holds cash amounting to $30 included as payment under item 23 (Petty Cash) to be used as a fixed fund or cash on hand. $122.70 withholding tax and $51.23 Social Security which is payable to the Collector of Internal Revenue and State of Massachusetts in April, 1960 is not included in the above tabulation.

CHARLES O. BAIRD, JR., *Secretary*

REPORT OF THE AUDITING COMMITTEE

Boston, Mass., March 16, 1960

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.

JOSEPH C. LAWLER
FRANK L. HEANEY

* Includes payment for previous year

REPORT OF THE EDITOR

March 14, 1960

To the Board of Government
Boston Society of Civil Engineers

The Journal was issued quarterly, in the months of April, July, October, 1959 and January, 1960 as authorized by the Board of Government on December 20, 1935.

During the year there have been published 23 papers presented at meetings of the Society and Sections.

The four issues of the Journal contained 392 pages of papers and proceedings. 7 pages of Index and 39 pages of advertising, a total of 438 pages. An average of 1625 copies per issue were printed.

The cost of printing the Journal was as follows:

Expenditures	
Composition and printing	$3,671.43
Cuts	1,477.13
Wrapping, mailing & postage	297.59
Editor, salary & expense	763.95
Copyright	16.00
Envelopes	229.80
	$6,455.90
Receipts	
Receipts from sale of Journal and reprints	$1,761.70
Receipts from Advertising	1,808.70
	$3,570.40
Net cost of Journal to be paid from Current Fund	$2,885.50

CHARLES E. KNOX, *Editor*

REPORT OF THE LIBRARY COMMITTEE

Boston, Mass., March 16, 1960

To the Boston Society of Civil Engineers:

The Library Committee met at the Society Rooms on January 27, and February 1, 1960.

A letter was sent to the Chairman of each Section in December requesting that they submit a list of books to be considered. These lists were not submitted by all sections. An attempt was made by the Committee to purchase books which would be useful to all sections and representative of many sections.

The following books were purchased:

Ground Water Hydrology, David K. Todd
Open Channel Hydraulics, Ven Te Chow

Energy Dissipators, E. A. Elevatorski
Centrifugal and Axial Flow Pumps, Stepanof
Prestressed Concrete Structures, August Komendant
Timber Design and Construction Handbook, Timber Engrg. Co.
Sewage and Industrial Wastes Index

In addition Clair N. Sawyer donated to the Library a copy of his book "Chemistry for Sanitary Engineers".

It is believed that the policy of reappointing a certain number of members from the previous year should be continued.

LELAND F. CARTER, *Chairman*

REPORT OF THE HOSPITALITY COMMITTEE

Boston, Massachusetts, March 16, 1960

To the Boston Society of Civil Engineers:

The Hospitality Committee submits the following report for year 1959-1960.

The Annual Dinner, two joint meetings with the American Society of Civil Engineers, a Student Night Meeting, and five regular meetings of the Society were held during the past year.

Catered dinners were served prior to all meetings of the Society.

The average attendance of members and guests for all nine meetings or dinners (using the larger attendance figure) was 110, as compared to last year's figure of 126. The attendance at regular meetings of the Society was 86 persons per meeting. This was somewhat greater than last year's 81 average.

SUMMARY OF MEETINGS AND ATTENDANCE

Date	Place	Attendance Meeting	Attendance Dinner
March 18, 1959	Hotel Vendome	45	110
April 15, 1959	Hotel Lenox	54	40
May 20, 1959	United Community Services Building	113	54
September 23, 1959	United Community Services Building	95	73
October 28, 1959	University of Massachusetts	190	190
November 16, 1959	United Community Services Building	202	110
December 16, 1959	United Community Services Building	90	61
January 27, 1960	Northeastern University	90	36
February 17, 1960	United Community Services Building	42	37

JOSEPH E. HENEY, *Chairman*

REPORT OF THE MEMBERSHIP CENTRAL COMMITTEE

Boston, Mass., March 16, 1960

To the Boston Society of Civil Engineers:

The Membership Central Committee has been relatively inactive during this year. The activities have been confined to solicitation of new members by individuals serving on the Committee.

Persons elected to various grades within the Society during the past year are:

Members	34
Juniors	7
Associates	1
Students	3
Transfers—	
Juniors to Members	7
Student to Junior	2
Total Society Membership as of this date	1093
Additional applications pending	12

The Committee is aware of the importance of continued growth of the Society and strongly urges that each member seek to increase our number through their daily association with other engineers. It is the Committee's recommendation that the membership at all gatherings be reminded of the importance of individual efforts, on the part of all members, toward increasing membership in the Society and thus assuring continued growth.

Respectfully submitted,

JEROME DEGAN, *Chairman*

REPORT OF THE ADVERTISING COMMITTEE

Boston, Mass., March 14, 1960

To the Boston Society of Civil Engineers:

The advertising committee held no meetings during 1959, as it has been the policy to have Mrs. Virginia Boudia act as advertising solicitor for the JOURNAL. Mrs. Boudia has written many letters soliciting new business, but the results are discouraging. Many firms are dismayed to find that the advertisements are placed at the back of the JOURNAL only.

The following advertising has been carried in the JOURNAL during the year ending January 1960:

	April	July	October	January (1960)
Professional Cards	40	40	40	39
½ page	1	1	1	1
¼ page	21	21	21	20
Inside Front Cover	1	1	1	1

Amount collected from Advertisers—$1808.70

The committee concurs with previous reports recommending assistance for Mrs. Boudia, either in the form of a part-time solicitor or conducting a campaign by the members to obtain advertisements.

LORRIN M. PITTENDREIGH, *Chairman*

REPORT OF THE JOHN R. FREEMAN FUND COMMITTEE

Boston, Mass., March 16, 1960

To the Boston Society of Civil Engineers:

Mr. Robert G. Dean, our last year's Freeman Scholar, completed his work last autumn and we have received the major part of his report on research on floating breakwaters, including experimental work in the hydromechanics laboratory.

The Freeman Fund Committee is not planning to award any scholarship this year. It is planned to provide funds for the publication of the Society's Committee on Floods, which it is expected will be ready for publication this spring.

HOWARD M. TURNER, *Chairman*

REPORT OF THE LEGISLATIVE COMMITTEE

Boston, Mass., March 16, 1960

To the Boston Society of Civil Engineers:

Some 20 bills have been or now are before the current Legislature having to do directly or indirectly with Engineering matters. Most of these bills have had to do with the awarding of contracts in which this committee has taken no action. However, one bill House 2271 would extend the "Grandfather" clause for registration of engineers until June 1961. This bill is now part way through the Legislature but such action as is practicable is now being taken jointly with other engineering societies to defeat or amend it.

Representatives of the B.S.C.E., the Chairman of this committee and other engineers have urged the passage of House 1113 to classify certain Sanitary Engineers in the Service of the Commonwealth.

Your committee is keeping in touch with representatives of other engineering groups on various bills effecting the B.S.C.E.

The committee is still disturbed with the delay in processing applications for engineer registration due to the inadequate appropriations of the Registration Board and will assist that Board in obtaining the necessary funds if called upon.

EDWARD WRIGHT, *Chairman*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SANITARY SECTION

Boston, Mass., March 2, 1960

To the Sanitary Section,
Boston Society of Civil Engineers:

Six meetings of the Sanitary Section were held during the past year. A brief account of each meeting follows.

March 4, 1959.—Annual Meeting. The following officers and members of the Executive Committee were elected.

Harold A. Thomas, Jr.	Chairman
George M. Reece	Vice Chairman
Robert H. Culver	Clerk
James L. Dallas	Member
George W. Hankinson	Member
Charles Y. Hichcock, Jr.	Member

Paul E. Langdon presented an illustrated paper on the Deer Island Sewage Treatment Works. Eighty-eight members and guests were present.

June 6, 1959.—Annual Outing. This meeting was held at the Woods Hole Oceanographic Institute where short talks and moving pictures describing the work of the Institute were presented by Dr. Jan Hahn and Mr. Bostwick Ketchum. The talks were followed by a short tour of the Institute. Sixty-seven members and guests were present.

October 7, 1959.—A paper on the subject of "Copper and Brass Tube Mill Waste Treatment" by John S. Bethel, Jr., Dr. Clair N. Sawyer and Charles Y. Hitchcock, Jr. was presented by Dr. Sawyer and Mr. Hitchcock. About seventy members and guests were present.

December 2, 1959.—Professor Joseph J. Fitzgerald presented a paper on the subject of "Sanitary Engineering in the Nuclear Industry", about 90 members and guests attended.

December 12, 1959.—A joint meeting of the Sanitary Section and the Society was held at the United Community Services Building. The meeting was preceded by a catered dinner. Then a panel discussion on the subject of Stream Classification Standards was presented by Mr. Russell Eckloff of New Hampshire, Mr. R. W. Theim of Vermont, Mr. Worthen Taylor of Massachusetts, and Mr. W. S. Wise of Connecticut and was moderated by Mr. Joseph Knox.

February 3, 1960.—A joint meeting was held with the Hydraulics Section at which time a "Symposium on Solving Network Problems with Analog and Digital Computers" was presented by Dr. R. S. Kleinschmidt, F. G. Arey, Jr. and S. E. Dore, Jr. About 70 members and guests were present.

A nominating committee consisting of Darrell A Root, John F. Flaherty and Clair N. Sawyer were appointed.

Five meetings of the Executive Committee were held during the year. Progress was made toward publishing in book form the Sanitary Section Lectures on Waste Water Treatment and Disopsal. It should be in print in 1960.

ROBERT H. CULVER, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE STRUCTURAL SECTION

Boston, Mass., March 16, 1960

To the Structural Section,
Boston Society of Civil Engineers:

Six meetings of the Structural Section were held during the year as follows:

April 8, 1959, Mr. Harl Aldrich, of the firm Haley and Aldrich, spoke on the subject "Engineering Properties of Peat; Design and Construction in Peat Areas". Attendance 62.

May 20, 1959.—This was a joint meeting with the parent society. Mr. Wilfred M. Hall, President and Mr. George R. Rich, Director of Chas. T. Main, Inc. were the speakers. Their respective subjects were "General and Construction Phases of the Niagara Power Project" and "The Engineering and Design Features of the Niagara Power Project." Attendance 110.

October 14, 1959.—Mr. Kenneth Goodell, Chief Engineer of The American Bridge Company, spoke on "The Carquinez Bridge", emphasizing modern developments in structural welding. Attendance 36.

November 18, 1959.—This was a joint meeting with the parent society and with the Massachusetts Section of The American Society of Civil Engineers. Mr. Donald C. Ball, Chief Soils Engineer, Metcalf & Eddy, spoke on "Prudential Center Foundations. Exploration, Design and Early Construction Problems." Attendance 115.

December 9, 1959.—Mr. T. William Lambe, Professor of Soil Engineering, Mass. Inst. of Technology, was the speaker of the evening. His subject was "Soil Engineering in the Soviet Union". Attendance 95.

February 10, 1959.—Mr. Lee Pare, of Charles A. Maguire & Associates, Providence, Rhode Island, and Mr. John M. Biggs, Associate Professor of Structural Engineering, Mass. Inst. of Technology, were the speakers. Their subject was "Design and Construction of the Experimental Post Office in Providence". Attendance 56.

Total attendance for the year was 474; average attendance was 79.

MYLE J. HOLLEY, JR., *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE HYDRAULICS SECTION

Boston, Mass., March 1, 1960

To the Hydraulics Section,
Boston Society of Civil Engineers:

The following meetings were held during the past year:

May 9, 1959.—This meeting was an inspection trip to the Alden Hydraulic Laboratory of the Worcester Polytechnic Institute in Holden, Mass. Professor Leslie J. Hooper the Director of the laboratory reviewed the background and growth of the laboratory. He also described the present role of the laboratory both in the instructional and industrial fields. A conducted tour of the laboratory and the various projects under study followed the formal description. Attendance 52.

November 4, 1959.—Professor Leslie J. Hooper of Worcester Polytechnic Institute and Chairman of the Technical Committee No. 4 of I.E.C. spoke on the "Problems and Pleasures of a Test Code". Professor Hooper discussed the various reasons for a test code and the problems in developing a world-wide uniform code. In addition the speaker described in detail a number of the methods of flow measurement in use in the field at the present time. The meeting was held in the Society Rooms and the attendance was 29 members.

February 3, 1960.—A joint meeting with the Sanitary Section was held in the Society rooms. A group of three speakers presented a "Symposium on Solving Network Problems with Analog and Digital Computers".

Mr. S. F. Dore, Jr. of Coffin and Richardson, Inc., discussed the McIlroy Analog Computer touching on its development and history as well as bringing out the advantages of such a system.

Mr. F. G. Arey, Jr. of Charles T. Main, Inc. discussed the use of the digital computer and its various advantages. In particular the application of this computer to the study of electrical power distribution systems was reviewed.

Dr. R. S. Kleinschmidt of Northeastern University drew on his operating experience with both types of computer to point out both advantages and disadvantages on each type. The total attendance was 49 persons.

February 17, 1960.—A joint meeting with the Society was held at the United Community Services Building. This meeting was preceded by a dinner in the same building.

Mr. Louis D. Pierce of the New England Power Company was the speaker. The topic of his paper was "The Connecticut River, Its Development and Its Versatility".

Mr. Pierce traced the geological and historical development of the Connecticut before reviewing in detail the part the New England Power Company has played and is playing in the development of the river and the northeastern section of the country.

Two excellent motion pictures of New England Power Company activity on the river were also shown. Attendance was 42.

The total attendance for the year was 172; the average attendance 43.

L. C. NEALE, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE TRANSPORTATION SECTION

Boston, Mass., March 8, 1960

To the Transportation Section,
Boston Society of Civil Engineers:

The Transportation Section of the B.S.C.E. held four meetings during the year 1959-1960 as follows:

April 22, 1959.—The speaker was Ephraim A. Brest, Chairman of the Massachusetts Port Authroity, whose subject was "The Massachusetts Port Authority—Past, Present, and Future".

Mr. Brest, having just returned from a visit to the West Coast, where he attended an International Air Conference, digressed from his prepared talk to comment on the great advances being made in passenger transportation by air, and said he was confident that the jet age had arrived. Attendance—41.

September 23, 1959.—This was a joint meeting with the Main Society. John M. Kyle, Chief Engineer of the Port of New York Authority, gave an illustrated talk on the "Evolution of a Bridge".

Mr. Kyle described the problems involved in double decking the George Washington Bridge, and the revamping of its approaches. He also briefly reviewed features of the proposed Narrows Bridge connecting Brooklyn and Staten Island, which he claimed would be the World's greatest suspension bridge. Attendance—75.

November 23, 1959.—The scheduled speaker for this meeting was Mr. Charles E. Hall, Division Engineer, U. S. Bureau of Public Roads, but due to illness he was unable to attend.

Substituting for Mr. Hall was Charles E. Whitcomb of the Massachusetts Department of Public Works. Mr. Whitcomb spoke on the status of the Interstate Highway Program in Massachusetts. Attendance—40.

February 24, 1960.—Annual Meeting of the section for the election of officers for the ensuing year.

The speaker at this meeting was Mr. F. Houston Wynn, of the firm of Wilbur Smith & Associates.

Mr. Wynn talked on the transportation study made by his firm for the City of Washington. This was an over-all study of all the types of transportation used in the city, in order to develop a program for expanding and modernizing transportation facilities to meet present and future requirements.

Officers were elected for the ensuing year, as follows:

Robert A. Snowber	Chairman
William A. Fisher	Vice Chairman
Joseph D. Guertin	Clerk
James W. Haley	Executive Committee
James E. Roberts	Executive Committee
Gordon F. Woodberry	Executive Committee

Attendance—40.

MARCELLO J. GUARINO, *Chairman*

REPORT OF THE EXECUTIVE COMMITTEE OF THE CONSTRUCTION SECTION

Boston, Mass., March 2, 1960

To the Construction Section,
Boston Society of Civil Engineers:

One meeting was held during the past year on March 25, 1959 at which Mr. Horatio L. Bond, Chief Engineer, National Fire Protection Association presented an illustrated talk on "Fire Protection Factors in Building Design". Twenty-five members and guests attended an informal dinner at Purcell's Restaurant prior to the meeting.

The newly elected officers of the Construction Section for the coming year are as follows:

Frank J. Heger	Chairman
John Burdick	Clerk
William F. Duffy	Executive Committee
Albert Adelman	Executive Committee
John D. M. Luttman Johnson	Executive Committee

JOHN BURDICK, *Clerk*

PROFESSIONAL SERVICES AND ADVERTISEMENTS

The advertising pages of the JOURNAL aim to acquaint readers with Professional and Contracting Services and Sources of Various Supplies and Materials. You would find it of advantage to be represented here.

Volume 47 APRIL, 1960 Number 2

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROFESSIONAL SERVICES

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1960-1961

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Paul S. Crandall
H. Lowell Crocker
Myle J. Holley, Jr.
(Term expires March, 1961)

Edwin B. Cobb
Fozi M. Cahaly
Robert J. Hansen
Harold A. Thomas, Jr.
(Term expires March, 1962)

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Armand Phaneuf

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