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CONTENTS AND INDEX — VOLUME 46, 1959

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THE JOCHENSTEIN POWER AND NAVIGATION PROJECT ON THE DANUBE

BY HANS-WERNER PARTENSCKY*

(Presented at a meeting of the Hydraulics Section, B.S.C.E., held on February 4, 1959.)

THE PAPER deals with the design and construction of the Jochenstein Project on the German-Austrian border, and with associated model tests. Models were used to investigate the relations between river flow, power turbine operation and navigation and lock operation. Unique features of construction are described. The influence on navigation of waves caused by turbine stoppages and methods of wave control are discussed.

LOCATION AND SIGNIFICANCE (1)

In Passau, the old Bavarian town, which is situated close to the Austrian-German border, the rivers Inn and Ilz flow into the Danube (fig. 1). It is here that the depth and width of the Danube increase. Here also the Danube starts to form the border between Germany and Austria for about 12 miles. Above Passau its drainage is 30,000 square miles and covers the area between the Alps, the Black Forest and the mountains of Swabia and Franconia (fig. 2).

Significant in the development of this site are the following two facts: The Bavarian Danube has its maximum discharge in the winter and spring, while the tributaries, Inn and Salzach, originating in the Central Alps and the glacier areas, have their maximum flow in the summer months when the snow melts. This explains the equalization of the high water peaks in the Danube at Passau so that the mean annual water quantity of about 36.4 millions of acre feet (45 Milliarden m^3)

* Visiting Research Associate, Hydrodynamics Laboratory, M.I.T., on leave from the Theodor-Rehbock-Hydraulic Laboratory, Institute of Technology in Karlsruhe, West Germany.

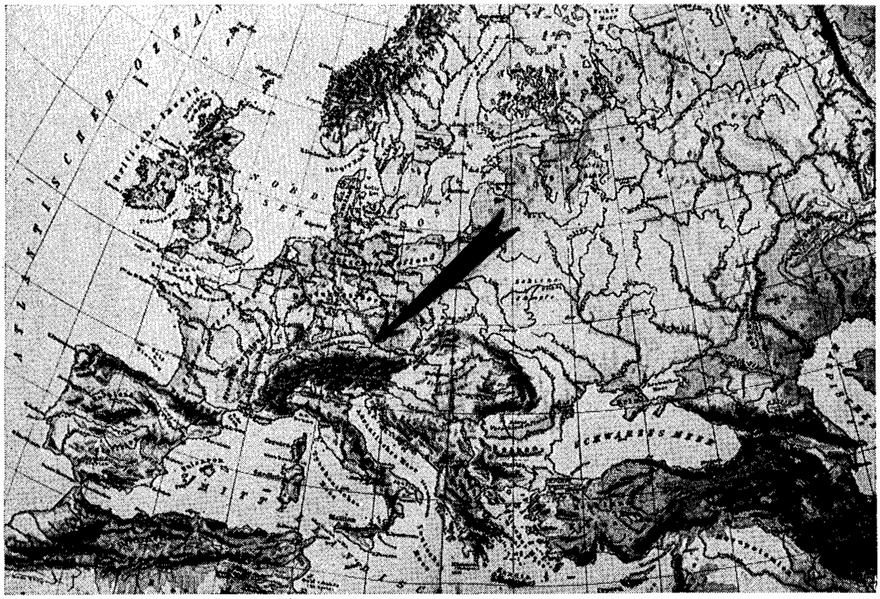

FIG. 1.—MAP OF EUROPE SHOWING LOCATION OF JOCHENSTEIN PROJECT.

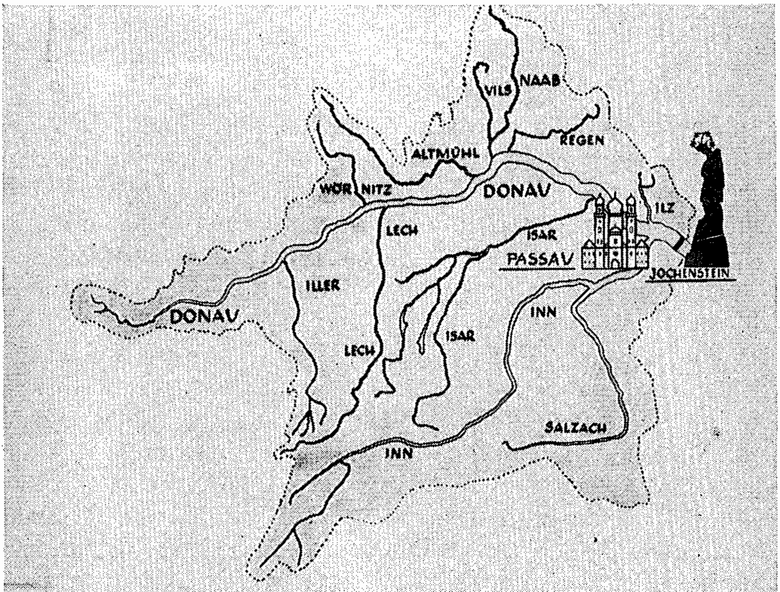

FIG. 2.—DANUBE BASIN ABOVE JOCHENSTEIN.

is distributed equally through the entire year. Thus, the conditions were ideal for the construction of a river power plant.

Preliminary investigations for the Danube power plant were made in 1920, but they were not finished until 1942. Because of the war and the conditions during the post war years, further steps could not be taken until 1951 when the governments of West Germany and Austria reached an agreement about definite construction plans and the later operation of the power plant. The agreement between the two countries declared, that the power produced should be divided equally between Germany and Austria.

The geological characteristics of the foundations, the inflow to the weir and power station, the high water discharge as well as the preservation of the natural beauty of the landscape were taken into consideration in determining the location of the power plant in the river.

PLAN VIEW OF THE POWER STATION

Thorough investigations of the various possible arrangements of the power plant proved the layout of a "gulf power station," as shown in figure 3 to be the best solution.

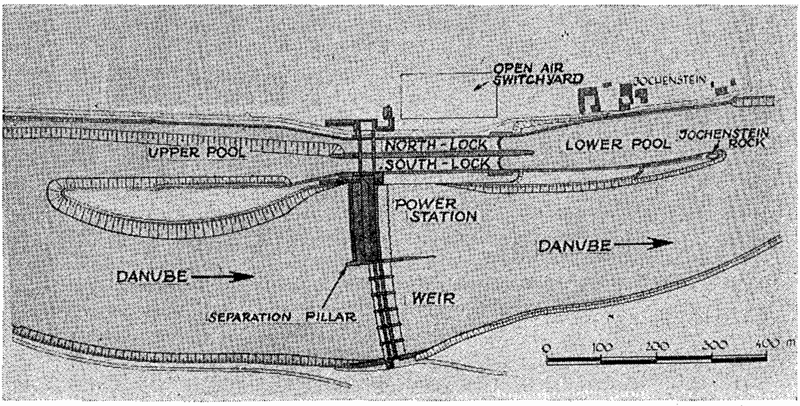

FIG. 3.—GENERAL PLAN OF JOCHENSTEIN PROJECT.

All other possibilities, such as: "divided power station," "Tubular turbines located in the weir piers," or locating the power station in the main river current at the south shore, turned out to have too many disadvantages. In the device of this design, the requirement of favorable high water and ice discharge was a determining factor. This could best be obtained if the weir was located in the direction of the main current in the river, that is near the south shore. For this reason, the plan generally used in Europe for power plants was abandoned because in such a plan the power station and lock are usually connected by the weir.

To determine the details of the general view, model investigations were carried out at the Institute of Technology in Graz, Austria. The important result of these model tests was the curved arrangement of weir and power station in the plan view (see figure 3). This arrangement made possible a substantial improvement in the inflow to the turbines located at the southern end of the power station.

THE SPILLWAY SECTION OF THE DAM

The spillway section has 6 sluices, each with a width of 78.8 ft, closed by double sluice gates with overflow guide. The maximum depth to which the upper sluices can be lowered is 14.0 ft, and the total height of the weir gates is 37.7 ft. In order to reduce their heights, weir thresholds with a height of 8.2 ft were provided.

As shown by the model tests, the weir openings with these thresholds have approximately the same discharge as those with a plane bottom.

The stilling basin of the weir is protected from scour by means of a granite lining. The width of the weir openings was chosen such that the same stop logs could be used as in the lock chambers.

The weir is able to discharge a flow of 298,000 cfs, (8400 m^3/s). This flow can be expected in this section of the Danube once in a hundred years.

THE POWER STATION

The power station was designed for a normal operating discharge of Q = 61,800 cfs (1750 m^3/s). This flow is available about 100 days a year, on the average.

After the lowering of the river bed downstream for a distance of about 4.4 miles an effective head of 31.0 ft (9.60m) was obtained.

For the power station, 5 units were chosen with Kaplan-turbines and generators, each with a rating of 38,700 HP. On the average, a yearly output of 940 million KWh is expected, of which about 46% is produced in the winter and 54% produced in the summer. The height of the power station is 166 ft. Two rack cleaning machines are provided to keep the rack clean from floating debris.

The offices of the power station are situated at the north side of the plant. Beside them, the switchyard is located. From here the produced energy is carried by means of a 220 KV-power line over a distance of about 37 miles to a transformer station which supplies both the Austrian and the German network.

LOCKAGE FACILITIES

The lock facilities situated on the German side of the Danube, consist of 2 lock chambers, each with a length of 750 ft and a width of 79 ft (see fig. 3).

Each lock is able to hold a whole tow, as usual on the Danube, consisting of a tug and 4 barges coupled in pairs. The expected traffic capacity of the whole navigation area amounts to about 16 million t/year, that is about 5 times the preconstruction tonnage.

The navigation channels, located upstream and downstream from the locks have lengths of 1600 ft and 1100 ft respectively and serve to keep the ships out of the main stream in the Danube during the operation of the sluices or the power station. Simultaneously, they give the necessary space for waiting ships.

For the design of the filling equipment and the gates of the lock it was important, that:

a) one of the locks must be able to function merely as a navigation channel without raising the water level during the construction of the power plant.
b) both locks must be able to be used for high water and ice discharge and
c) the filling and emptying of the lock chamber should be carried out by means of the lock gates themselves.

These requirements resulted in the construction of filling and emptying systems in conjunction with the chosen lock gates. The operation of both locks was investigated by model tests in the Theodor-Rehbock-Research-Laboratory at the Karlsruhe Institute of Technology, headed by Professor Wittmann.

The upper end of the south-lock was built with a deep entrance in order to maintain ship traffic during the construction period, as well as to use the lock for high water and ice discharge.

The upper gate of the lock consists of two parts. In order to fill the chamber, first the lower part of the gate is lifted about 4.3 ft with a certain velocity. To obtain a quiet inflow into the lock, the under part of the gate is aligned with a curved shield to guide the inflowing jet. When the lock is filled, the upper part of the gate is lowered, leaving the exit free for the ships waiting in the lock.

The upper end of the north-lock was designed with a high lying entrance, that means this lock can be used only after the reservoir is filled. The upper gate was chosen in such a way that it can be opened only by lowering. In order to fill the chamber, the gate is slowly lowered about 5.5 ft and when the lock is filled completely, the gate is lowered about 12.4 ft more, leaving the exit free for the ships in the chamber.

At the lower ends of both locks miter gates were arranged. In each wing 3 openings are provided which are closed by movable sluice gates. In order to empty the lock, these gates are opened at a constant rate. The best arrangement of the baffle blocks and thresholds downstream from the lower gates was determined by means of model tests in the Karlsruhe Laboratory.

In using both of the locks for the high water discharge a maximum flow of 388,000 cfs (11.000 m^3/s) of the Danube can be discharged, a quantity which can be expected once in 1000 years. By this measure, the savings in construction costs compared with a corresponding enlargement of the weir were considerable.

THE CONSTRUCTION PERIOD

There were 4 different phases which are to be distinguished in the construction period. Their order was determined by the requirements of safe high water discharge during the building periods as well as of undisturbed navigation. For the latter especially free passage had to be guaranteed.

Therefore in the spring of 1953, the building of the power plant started with the construction of the locks and of a part of the weir. During this first phase, traffic was displaced to the middle of the river and the navigation channel was kept free by means of dredging. Figure 4 shows the construction progress during the first phase in May 1953.

At the end of 1953, two spillway openings were put into operation and the excavation of the construction pit II as well as the construction of the power station was started. Figure 5 shows the construction pit II during the winter of 1953-54 as seen from the Austrian side.

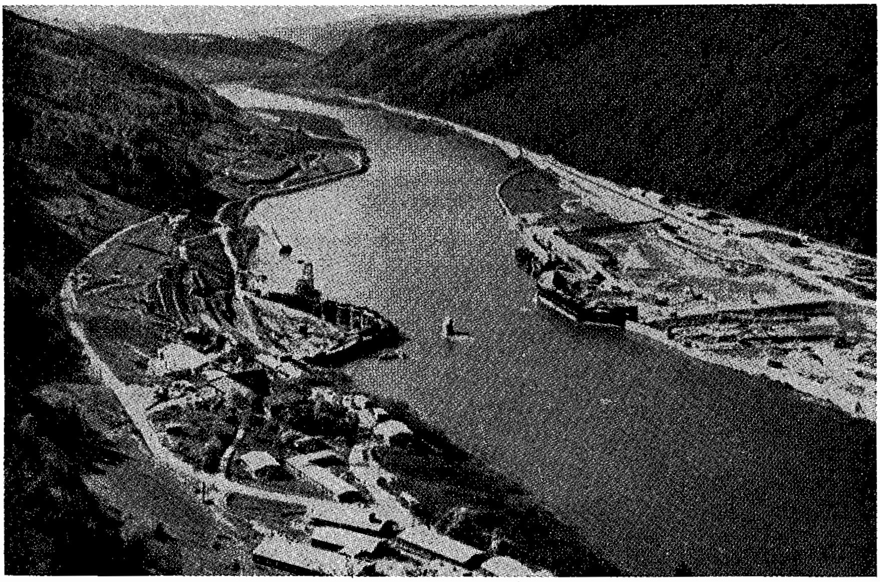

FIG. 4.—VIEW UPSTREAM DURING FIRST CONSTRUCTION PHASE.

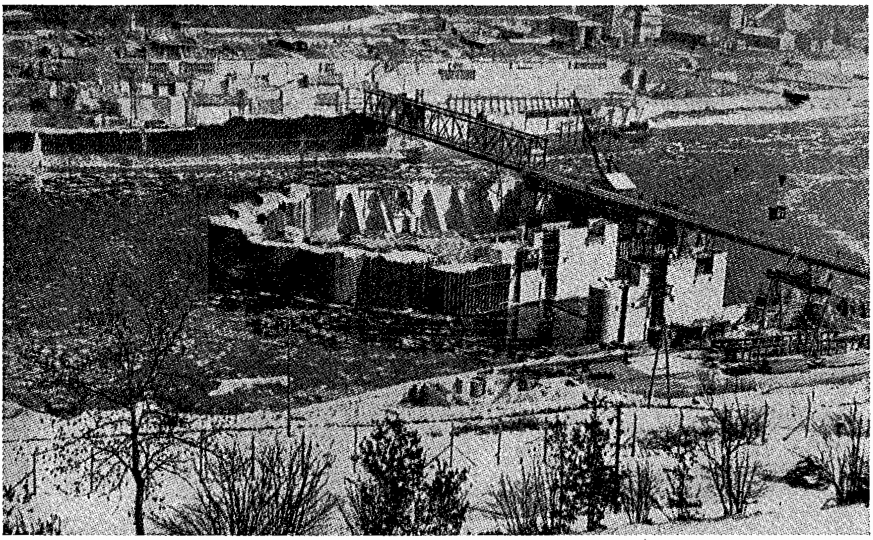

FIG. 5.—VIEW FROM AUSTRIAN SHORE OF CONSTRUCTION PIT II DURING WINTER OF 1953-54.

The height of the cofferdams surrounding the construction pits was calculated for a high water level of a 6 to 7 year recurrence interval. During the second construction phase, however, in July 1954, an unexpected flood flow of about 339,000 cfs (9600 m^3/s) occurred. This was caused by extremely unfavorable weather conditions and continuous heavy rain. At the location of the power plant, the discharge of the Danube rose from 91,700 cfs (26000 m^3/s) to a maximum flow of 339,000 cfs (9600 m^3/s) within 40 hours (fig. 6). This peak is equal to a discharge with a recurrence interval of approximately 350 years, and it is perhaps of interest that the last recorded flood of equal stage occurred 450 years ago.

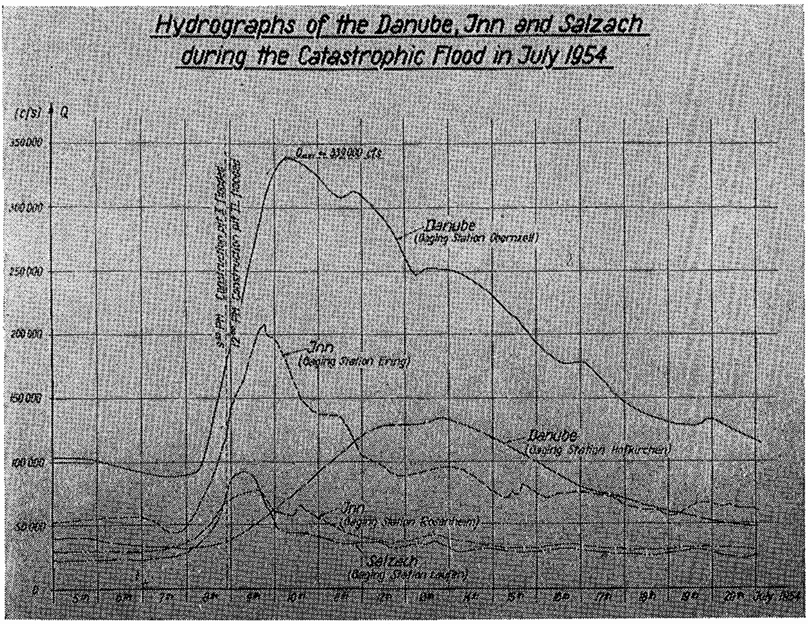

FIG. 6.

Construction pits II and I had to be flooded in order to prevent greater damages and overflow catastrophes. Figure 7 gives an impression of the high water discharge in July 1954. Nevertheless, the loss of equipment and time was large enough to require an increase in manpower and equipment to offset it. The maximum number of workers at the construction site reached about 3300 men at this time.

FIG. 7.—FLOODED CELLS OF CONSTRUCTION PIT II DURING JULY 1954 FLOOD.

In spite of all these unfortunate incidents, in October of 1954 the southlock could be opened to shipping and the construction of the cofferdam for the construction pit III was begun. In April of 1955 the power pool was partially filled and the first three turbines were put into operation. The whole power and navigation project was completed at the beginning of 1956.

Figure 8 shows an upstream view of the completed project in operation.

MODEL TESTS FOR LOCK AND TURBINE INTAKES

Before the beginning of construction, the filling and emptying characteristics of both locks were investigated by means of model tests in the Karlsruhe Laboratory.

During the operation of the lock, the permissible longitudinal forces on a ship, caused by the filling waves in the lock chamber, should not exceed a magnitude of 1/700 to 1/800 of the ship's weight. The transversal forces, however, should be only half of that value.

With these limits, a maximum force of about 25% to 30% of the

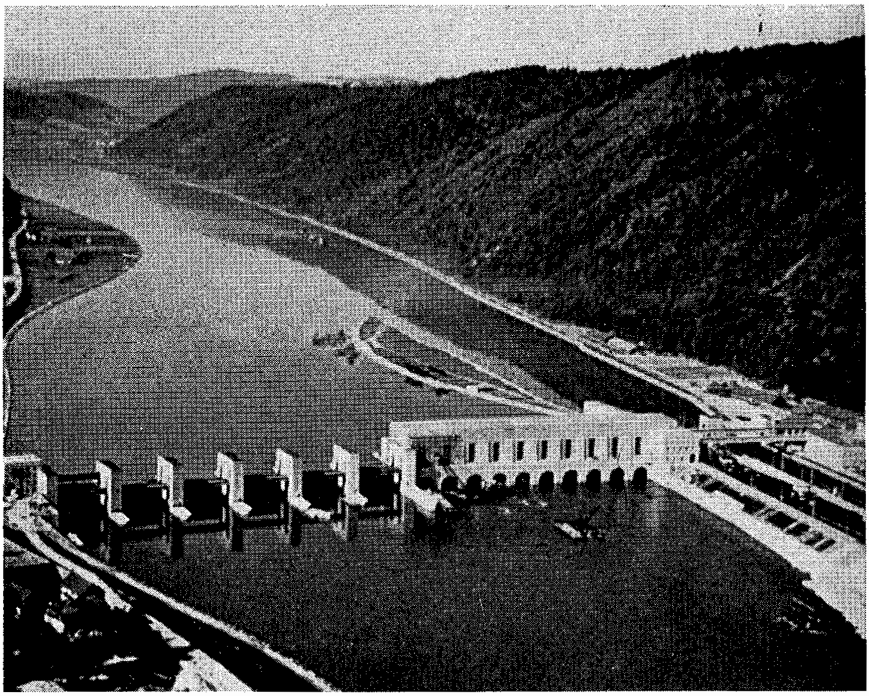

FIG. 8.—VIEW UPSTREAM OF COMPLETED PROJECT.

breaking load can be expected, as the actual force on the tow ropes, the type and diameter of which are determined for each size of ship according to its tonnage.

By assuming this, it was possible to obtain from the model tests the permissible velocities of the gates and sluices, the times for the filling and emptying processes as well as the most effective design for the "lock heads" with their energy dissipators.

In addition to these investigations, pressure measurements at the lock gates gave some idea about their buoyancy in several positions and with various water levels in the lock.

Other model tests covered the necessary shape of the upstream "separation pillar," which must be located between spillway and power station (see fig. 3). The width and shape of the former is important for efficient operation of the turbine nearest the spillway. Because of poor streamlining, the flow often does not follow the shape of the pillar, and separation and vortices in the turbine intake are the result. As shown by measurements, carried out at existing power plants in the prototype, the performance loss of the first turbine, caused only by the separation from the pillar, can amount to 5%.

The pillar shape, as shown in figure 9, was obtained by means of extensive model tests for the Jochenstein power plant. In order to get the necessary curvature for the diversion of the inflow, the pillar head was enlarged in the direction of the weir. In this way it was possible to save the length b for the dam.

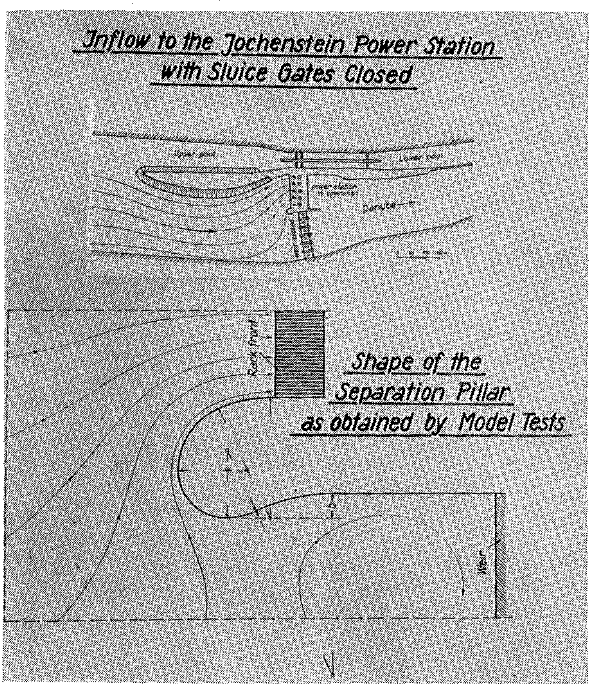

FIG. 9.—SEPARATION PILLAR.

Because of the special position of the Jochenstein spillway in the main current of the Danube, this pillar shape could be used without influence on the discharge performance of the sluice beside the power station.

MODEL TESTS FOR WAVE PHENOMENA IN THE REACH OF THE RIVER UPSTREAM OF THE POWER PLANT AND THE LOCK

As long as the power plant and the spillway operate under normal conditions, there will be no disturbance of the navigation from the river flow. The forebays of the lock upstream and downstream are chosen with a sufficient length to guarantee a safe entrance and exit of the ships into and from the lock (see fig. 3).

But there is another possibility which we have to consider. When the network suddenly breaks down due to fluctuations in electrical load or due to lightning, all generators may be put out of service. In this case normally with a river power station the wicket-gates of the Kaplan-turbines close in a few seconds, throttling the flow to about 10% of its normal value, called "idling flow."

Suppose this diminution of the inflow does not take place immediately then a very rapid increase of the turbine R.P.M.'s would result and the danger of burning the turbine bearings arises.

The quasi-steady flow upstream and downstream of the power plant is changed as a consequence of the closing wicket-gates. Upstream, the kinetic energy of the inflowing water changes into potential energy in front of the power plant. Thereby a difference between the water level in front of the power plant and that further upstream arises and a positive translation wave, moving upstream with a certain wave velocity w results.

Downstream, a negative translation wave is created, caused by the sudden diminution of the flow going through the power plant.

Mathematically, the wave height produced upstream and downstream depends on the change of flow dQ [m^3/s] and the cross-section and width of the river.

It is: $$dz = \frac{dQ}{W_m \cdot \omega} \text{ with } w \cong \sqrt{g \cdot \frac{A_m}{W_m}} \pm v$$

where: z = wave height

v = average river velocity

A_m = mean cross-sectional area of the river upstream or downstream from the power plant

W_m = mean width of the water surface upstream or downstream from the power plant.

The slopes of the waves S_W however depend very much on the rate of change of flow, in other words on the value $\frac{dQ}{dt}$ [m^3/s^2], as shown in the following equation (2):

$$S_W \cong \frac{1}{\omega^2 \cdot W_m} \cdot \frac{dQ}{dt} \text{ with } \omega \cong \sqrt{g \cdot \frac{A_m}{W_m}} \pm v$$

The meandering and the variation in depth of the river cause deformations of the wave because of their reflections on the banks and changes in the wave velocities.

When the positive or negative translational wave reaches the beginning of the navigation channel, a part of it will be reflected in the direction of the lock. Height and slope of this reflection increase whenever the navigation channel is narrowed.

With regard to this fact, it is extremely unfavorable, if the wave can enter the lock chamber itself through an open lock gate. In this case, wave heights and slopes in the lock can be expected to be considerably larger than those which are observed in the navigation channel. The reflections of the waves on the other lock gate which is closed cause an oscillation of the whole water surface in the lock.

These waves, propagating in the navigation channel, the forebay of the lock, or even in the lock chamber, can become a serious problem for the ships which are waiting in the forebay or lying in the lock. Thereby it is the slope of the waves rather than their height, which can become a danger for the ships.

A ship, floating on a sloped water surface, is subjected to the laws of the inclined plane. That means that there is acting on the ship a force F_s, which depends on the weight of the ship W_s and the water surface slope (fig. 10). For small wave slopes the following formula applies:

$$F_s = W_s \cdot S_W.$$

A ship which is not held fast would be accelerated from its position of rest under the action of this component of its weight. Collisions in the lock forebay or bumping of a ship against the lock gate could result.

However, if a ship is fastened by means of tow ropes, the force acting on the ship has to be compensated by the ropes. In reality, the ship will be able to move slightly under the effect of the force F_s

because of the slack which normally exists in the tow ropes. The kinetic energy gained by the ship in moving on the wave slope must be changed into elastic energy in the tow rope. Measurements in the prototype on tow ropes made from the Karlsruhe Laboratory and theoretical calculations showed, that in this case the peak forces, produced in the tow ropes, can reach easily three to five times the acting force caused by the wave slope. If the tow ropes are very long and slack, even greater peak forces can be caused because of the possibility of greater motion of the ship.

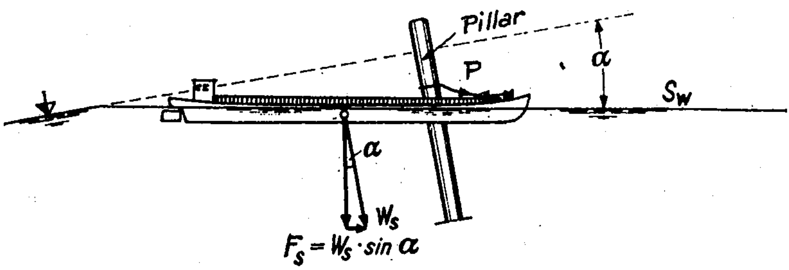

FIG. 10.—SHIP ON SLOPED WATER SURFACE.

Theoretical considerations and calculations showed that the permissible slope of the waves in the lock chamber should not exceed a value of $S_W \leqq 1.3$ o/oo, since the safety factor existing in the tow ropes would otherwise become too small.

Now, for a certain power plant with a given discharge and river cross section there are several possibilities for the reduction of the slopes of waves, caused by sudden load rejection, in the upstream area of the power plant as well as in the navigation channel and in the lock chamber:

The first possibility would be that the inflowing water might be diverted the same instant of load rejection when the wicket gates close. This can be done in different ways:

By directing the power water through "bypass conduits" or "déchargeurs," especially arranged in the power plant for this purpose, as built in the new French power plants at the Rhine-Side-Canal in Alsace (Ottmarsheim, Fessenheim, Vogelsgrün). However, it is very expensive to place those large additional openings in the power plant. Therefore, this method is only used in cases where the effects of the translation waves must be expected to be extremely dangerous. For example, in locations where a navigation canal is used as the head race of a power plant.

The second possibility would be to change the kinetic energy of the inflow into heat in so called "water-resistances." In this case it is possible to switch the network to the water-resistances in about 0.2 sec. Therefore, an oscillation of the water level upstream is not to be expected. But, this method too is an expensive one, because of the relatively great space which is needed for the installation of these "water resistances." Therefore, today it is seldom used.

A third possibility would be to direct a part of the arising positive translation wave over the weir in lowering the sluice gates as quickly as possible in the moment when the network breaks. Tests in the model and in the prototype showed that the available lowering velocity of the gates in general is not high enough to obtain sufficient effect on the wave heights and slopes upstream. Even if the gates are allowed to fall freely, as has been tried at the Rhine-power-plan Birsfelden, near Basel, Switzerland, they still don't open quickly enough, to be effective. Because of the temporal delay, the positive translation wave caused by load rejection can be followed by a negative translation wave caused by the lowering of the sluice gates. The superposition and crossing of these two waves together with the effect of their reflections can easily give a greater wave slope in the navigation channel, or in the lock chamber, than would have occurred without the weir operation. Therefore, today this method is used but little. The results considered were proved by model tests and theory for some individual cases. However, the irregularly shaped ground plan of the river cross section upstream and downstream of the power plant, make an exact calculation of the wave motions including all possible effects of wave reflections very difficult. Therefore, model tests always will give the best results for the special case.

For the Danube powerplant Jochenstein, model tests were carried out at the Theodor-Rehbock-Research Laboratory in Karlsruhe/Germany (3). The water level changes were recorded in each test at 40 measuring points, which were distributed over the whole water surface of the model upstream of the weir and powerplant as well as in the navigation channel and in the lock chamber (fig. 11). The measurements were carried out with a special electric measuring and recording

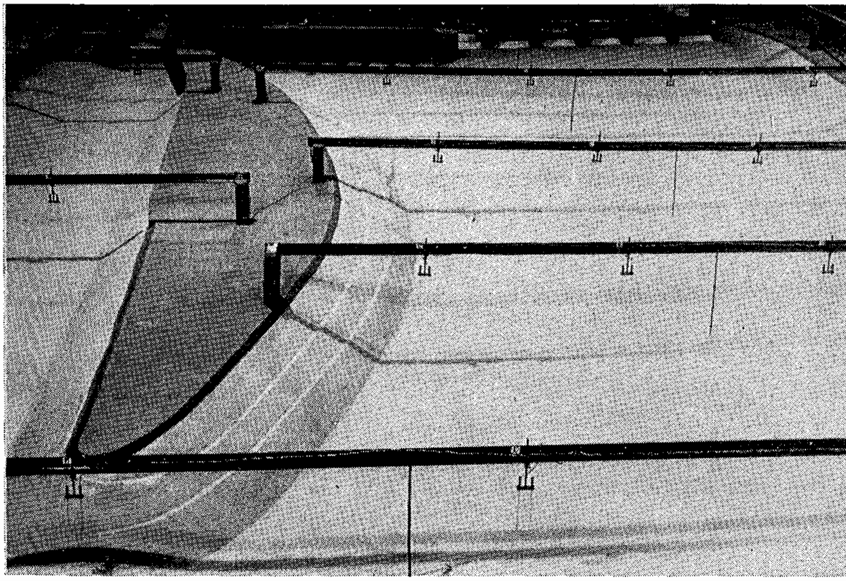

FIG. 11.—MODEL OF JOCHENSTEIN PROJECT WITH MEASURING POINTS.

device. All runs were made with throttling of the turbine discharge to several "idling flows" within a closing time limit of 7 or 10 sec. The influence of the weir lowering on the wave slopes in the lock chamber was determined by the tests. The results of these investigations are shown in figure 12 (4).

The slope of the positive translation waves measured in the lock chambers increased about linearly till a flow of Q = 61,800 cfs (1750 m^3/s), if the turbines were closed in 7 sec to an "idling flow" of 0.08 Q. The wave slope was a little greater, if only one of the lock chambers was open. However, in both cases it was higher than permissible. The measured slope was 1.70/1000 with two locks open and 1.87/1000 with one lock open (curves 1 and 1′).

By means of enlargement of the "idling flow" through the turbines to 0.3 Q (curves 4, 5 and 6) and 0.5 Q (curve 3) and an additional lowering of the sluice gates, finally the wave slope in the lock chamber could be limited to a permissible magnitude. If the turbines close in 10 sec to an "idling flow" of 0.3 Q, closing further within the following 66 sec to a steady flow of 0.08 Q, with additional lowering of the sluice gates, starting 5 sec after the beginning of the turbine stoppage, the wave slope in the lock chambers could be reduced to 0.69 o/oo (curve 6, both chambers open) and to 0.81 o/oo (curve 6′, only one chamber open). With these wave slopes there seemed to be no longer any danger for the navigation.

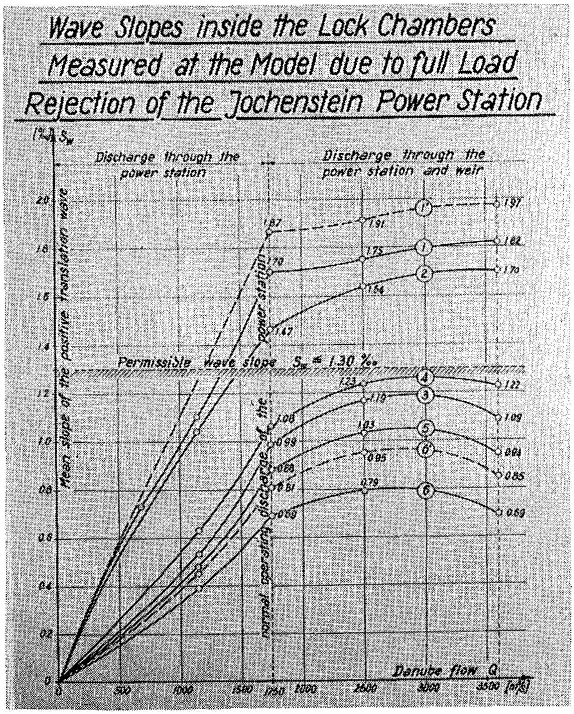

FIG. 12.

The model tests showed, that additional lowering of the sluice gates had only a very small influence on the magnitude of the wave slopes.

INVESTIGATIONS OF SOME TURBINE FACTORIES

By means of tests on a model turbine at a scale of 1 : 10.3, the turbine factory VOITH, in Heidenheim, Germany, made investigations, about the effects of enlarging the "idling flow" to 0.3 Q (5).

Of special interest in the investigations were the pressure conditions in the draft tube as well as the tendency of the turbines to run away after load rejection. Possibilities were tested to avoid low pressure or even cavitation in the draft tube.

The measurements showed that pressure oscillations of large magnitude were superimposed on the mean pressure in the draft tube, when the turbine flow was diminished only to values between 0.4 Q and 0.55 Q. These pressure oscillations reach about the range of the head H in the draft tube elbow (31.5 ft). Along the dividing wall in the draft tube fluctuations of about 0.1 H occurred.

With an increase of the turbine r.p.m. to 30% of normal revs, the pressure values increase at the draft tube wall to about 0.6 H and in the draft tube elbow to about 1.5 H.

By means of aeration it was possible to diminish the pressure oscillation to about 50% of the previous values in the model. Since there was no guarantee about the similarity between the model and prototype with regard to the volume of air required, the VOITH company recommended that the desired increase of the "idling flow" be obtained by adjusting the turbine blade angle to prevent an increase in r.p.m.'s.

The Escher Wyss Company, Switzerland, proposed another method (6). They consider a runaway speed of 40% above normal as permissible during load rejection.

The wicket gates are closed only until the turbine power output is reduced to zero, at the same time however the r.p.m.'s increase. During this first phase, the opening of the propeller blades remains approximately invariable. Then, the wicket gates are closed so that the steady turbine r.p.m.'s for the constant "idling flow" will be reached after an additional 60 to 80 sec. Because of its relatively long time, this second phase of the closing operation can be easily combined with an effective lowering of the sluice gates.

For a general case, figure 13 shows the variation of these operations with time. At point B, the discharge through the turbines is greater than 75% of rated discharge because of the higher turbine revs. This circumstance has of course a very good effect on the wave phenomena upstream from the power plant.

Further closing of the wicket gates throttles the turbines to the final "idling flow" of about 0.1 Q. However, this diminution of the discharge need not be considered dangerous since the wave slopes produced are very flat since $\frac{dQ}{dt}$ is now small.

As shown on the diagram of figure 13 further reduction of the wave phenomena can be obtained, if the sluice gates are lowered simultaneously in the second phase.

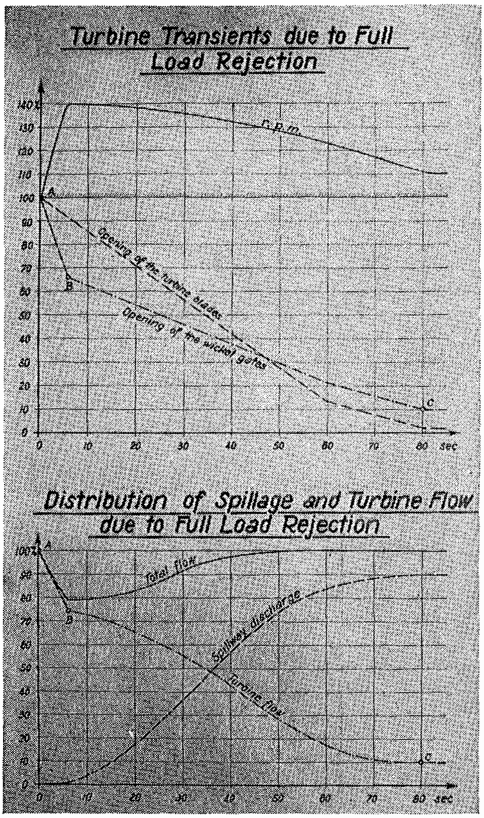

FIG. 13.

Measurements in the prototype at some existing river power plants on the Rhine, Inn, and Danube, carried out by the Escher Wyss Company showed the good effect of this method. The wave heights and slopes could be reduced to 25% or 50% of their original values in this way. The minimum pressure, measured at some places in the draft tube was also less than it was before. Figure 14 shows the results obtained during the tests at the Birsfelden power plant on the Rhine. A comparison of the waves, recorded upstream and downstream from the

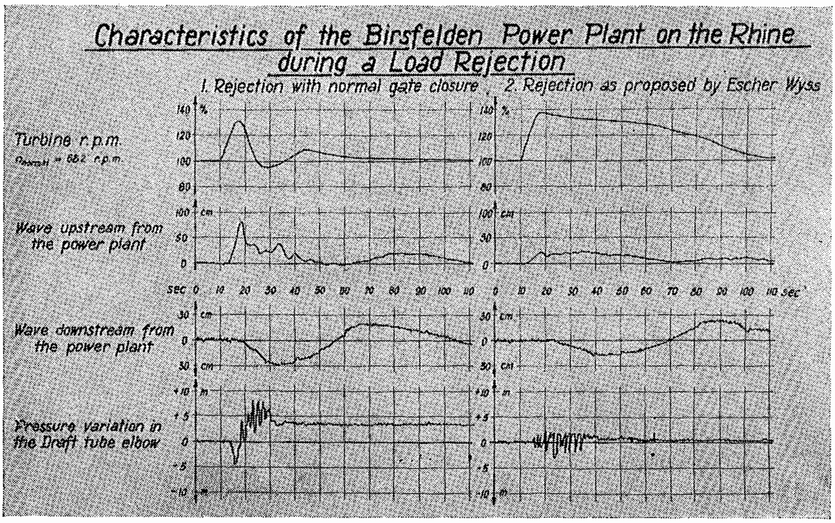

FIG. 14.

power plant as well as a comparison of the pressure oscillations measured in the draft tube show the beneficial effects of the method described.

Summarizing, it can be stated, that the methods developed by both turbine companies were satisfactory in reducing the heights and slopes of positive and negative translation waves upstream and downstream from the power plant.

The application of either method will depend on the type, size and performance of the turbines as well as on the local conditions and the navigation demands prior to the construction of the power plant.

The best and safest way of judging the efficiency of various methods in reducing the wave slopes in the region of navigation facilities would be to make a model test in each case.

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THE DEER ISLAND SEWAGE TREATMENT WORKS

BY PAUL E. LANGDON*

(Presented at a meeting of the Sanitary Section, B.S.C.E., held on March 4, 1959.)

BRIEF HISTORY

THE discharge of untreated sewage and mingled storm water and sewage into Boston Harbor has been a subject of numerous reports to the Massachusetts Legislature over a period of more than 50 years. Prior to 1935 these reports found that the discharges did not cause detrimental pollution of the harbor waters that required remedial measures, even though there were many complaints of shore deposits and pollution of shellfish and bathing areas. These reports also dealt with the effect of overflows on the inland streams and waterways, and indicated a public desire for relief from objectionable conditions resulting from such overflows.

By 1935 the appearance of solids of sewage origin on the beaches, the slick extending from over the outfalls and restrictions on the taking of shellfish resulted in the authorization by the Legislature of a comprehensive report on the discharge of sewage into Boston Harbor and its tributaries. This report, published as House Document 1600 of 1937, did not find that conditions required immediate remedial action. However, the report recognized the probability that such measures would become necessary in the relatively near future and recommended the advance preparation of plans for treatment for the three sewerage systems. This included treatment for the North Metropolitan System at Deer Island, for the South Metropolitan System at Nut Island and for the Boston Main Drainage at Moon Island.

In 1939 a report to the Legislature by consulting engineers, as a part of House Document 2465, recommended the construction of sewage treatment plants at Deer Island, Nut Island and Moon Island, essentially as considered in House Document 1600.

Various authorizations for construction were made in 1939, 1941, 1945 and in 1949. The Acts of 1945 included authorization for the construction of the treatment works at Nut Island. This installation

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* Greeley and Hansen, Chicago, Illinois.

has been constructed and has been in operation since May, 1952. This Act also authorized investigations, designs, plans and specifications for treatment works at Deer Island.

In 1949 the construction of treatment works at Moon Island for the Boston Main Drainage was authorized and directed. A report and plans and specifications were made for treatment works at Calf Pasture in Boston, to be operated by the City of Boston.

In 1951 a report was made by Charles A. Maguire and Associates entitled "A Proposed Plan of Sewerage and Sewage Disposal for the Boston Metropolitan Area." This report recommended that all of the sewage from the Boston Main Drainage, from the South Charles System of the South Metropolitan District and from the North Metropolitan District be collected and conveyed to Deer Island for treatment in a single plant. The Acts of 1951 authorized the construction of the project recommended in the Maguire Report and repealed the Act of 1949 which had authorized and directed the construction of separate treatment works for the Boston Main Drainage at Moon Island. Some parts of the project, as recommended in the 1951 report, have been completed and some others are now under construction. Designs and contract plans and specifications have been completed for essentially all of the parts of this project.

DESCRIPTION OF THE PROJECT

Although this discussion is intended to be related to the proposed treatment facilities at Deer Island, a general outline of the entire project may be helpful. The facilities involved in collecting and conveying sewage to Deer Island, for treatment, include the following principal parts:

A. The South Charles Relief Sewer, which extends along the south bank of the Charles River and Basin from Framingham to the Boston University Bridge, is designed with a capacity to intercept about 4.5 times the average dry weather flow in 1985. This will reduce materially the frequency and quantity of mingled sewage and storm water discharged to the Charles River.

B. The North Charles Relief Sewer extends along the north bank of the Charles River Basin from near Mt. Auburn Hospital to the Boston University Bridge with a branch from the east to the Boston University Bridge, designed with capacities to intercept about 9 and 5 times the dry weather flow in 1985, respectively.

C. A storm water detention basin and chlorination station is located adjacent to the Boston University Bridge which will provide skimming, some settling and chlorination before the quantities in excess of approximately 2¼ times the dry weather flow are discharged to the Charles River Basin. This pretreatment of storm water flows, in excess of the quantities diverted to Deer Island for treatment, will result in improved conditions in the Charles River Basin.

D. A connecting sewer from the junction of the North and South Charles Relief Sewers and the storm detention basin to the upper end of the tunnel to Deer Island near Ward Street.

E. A relief connection from the west side interceptor of the Boston Main Drainage to the Ward Street Headworks.

F. The existing Ward Street Pumping Station is to be abandoned and the sewage now collected at this station, together with the flow from the North and South Charles Relief Sewers, will pass through headworks before being discharged into the Boston Main Drainage tunnel to Deer Island. This pretreatment at the headworks comprises trash racks, mechanically cleaned screens, grit chambers and Parshall measuring flumes.

G. The Boston Main Drainage Tunnel is now essentially completed. It comprises a section from the Ward Street Headworks to a shaft at Columbus Park. This section of the tunnel is about 14,500 feet in length, has a diameter of 10 feet and has been built in hard rock about 300 feet below sea level. The designed average dry weather flow in this section of the tunnel is 113 MGD and the maximum rate of flow is estimated at 256.1 MGD. Construction of this tunnel is completed.

H. A connecting sewer from the Boston Main Interceptor near Columbia Circle to the headworks located near the shaft of the Main Drainage Tunnel at Columbus Park.

I. Headworks, at Columbus Park, similar to those at Ward Street, comprise trash racks, mechanically cleaned screens, grit chambers and Parshall measuring flumes.

J. The Main Drainage Tunnel from the Columbus Park Headworks to the treatment plant at Deer Island is about 24,600 feet in length, has a diameter of 11 feet 6 inches and is also located in hard rock about 300 feet below sea level. The designed average dry weather flow in this section of the tunnel is 179.1 MGD and the maximum rate of flow is estimated at 438.4 MGD.

K. The main outlet sewers of the North Metropolitan District are to be intercepted near Chelsea Creek where connections are to be made into headworks comprising trash racks, mechanically cleaned screens, grit chambers and Parshall measuring flumes.

L. The North Metropolitan Tunnel extends from the Chelsea Creek Headworks to the treatment plant at Deer Island. This tunnel is 10 feet in diameter, is 21,500 feet in length and has a capacity for the designed dry weather flow of 94.5 MGD and a maximum flow of 350 MGD. Construction of this tunnel is completed.

M. The main pumping station at Deer Island is connected to the downstream terminals of the two tunnel systems and raises the sewage into the treatment works.

N. The treatment plant at Deer Island comprises, as basic features, the removal of grease and floating materials, and heavy solids, including about 45 per cent of the suspended solids, chlorination of the effluent for sterilization, separate sludge digestion and an outfall to deep water off Deer Island Light.

These are the principal components of the over-all project. Some parts have been completed, other parts are now under construction, and essentially all of the designs have been completed. There have been many difficult problems encountered in the development of this project. The ultimate improvement in quality of the inland waters and of Boston Harbor will be a credit to the careful engineering work that has been accomplished.

DEER ISLAND PUMPING STATION

The location of the main pumping station at Deer Island, at the terminus of the long tunnels from the Ward Street and Columbus Park Headworks and the Chelsea Creek Headworks, introduces many difficult problems involving hydraulics and control of the pumping operation. The quantities to be pumped are such that surge chambers to accomplish stability of flow are impractical, both because of the levels involved and the areas and volumes that would be required. It is essential that the rate of pumping be equal to the rate of inflow at the headworks to avoid flooding of the headworks, and particularly of the Parshall flumes, which would interfere with the measurement of the flow into the tunnel systems and functioning of the grit chambers. The pumping equipment must be operated at variable speeds and deliveries in order to meet this requirement. Also, to insure against flooding, in the event of the failure of one pumping unit, it was concluded that one unit, in addition to the number required by the rate of flow, should always be in operation. If a failure occurs, the resulting deficiency in pumping rate can be overcome by speeding up the remaining operating units without the delay that would be involved in starting a standby unit and placing it in complete operation.

It was recognized that pressure waves and surges could be developed in the tunnel systems which could affect, seriously, the operation of the headworks and the pumping station. A comprehensive study was made of waves, surges, hydraulic transients and pump controls. The basic conclusions of this study include the following:

A. Each tunnel system should be pumped independently, with no interconnection at the pumping station, to minimize hydraulic interferences.

B. The normal control of the pumps should be automatic.

C. To insure proper control the following must be measured:

   1. The rate of flow at each of the headworks.
   2. The water level in the tunnel shaft at each of the headworks.
   3. The pump discharge quantity.
   4. The water level in each tunnel shaft at the pumping station.

The signals of remote measurement at the headworks must be available at the pumping station at all times. It is therefore proposed to provide duplicate transmission of these signals. The basic transmission will be by micro wave with an alternate of leased telephone lines. It is proposed that both transmissions will be in continuous operation and always readily available in the event of any transmission failure.

A feedback control system has been devised, based on a complete analysis of hydraulic conditions, which will actuate pumping units to accomplish a rate of discharge of the pumps equivalent to the rate of inflow and, at the same time, anticipate transient hydraulic conditions that could result in surges and unstable flow conditions in the tunnels. The basic controls involve maintaining a level at the upstream headworks within narrow limits and, by comparing inflow rates with pump discharge rates, to actuate speed control devices on the pumping units that will result in continuously stable hydraulic conditions.

An exhaustive study was made of available equipment that could be applied to meet the required delivery conditions and which could also be satisfactorily controlled. In this study various sizes and types of pumping equipment were considered. All known methods of driving the pumping equipment were examined and detailed analyses of initial and operating costs, as well as practicability, were investigated for some 18 different arrangements. The most promising included the following:

Wound rotor motors with purchased power.

Wound rotor motors with generated power.

Variable frequency with each unit comprising a dual fuel engine, an alternating current generator, a synchronous motor and a pump.

Variable voltage motor driven pumps with dual fuel engine driven direct current generators.

Horizontal dual fuel engines direct connected to vertical pumps through right angle gears.

Direct connected radial vertical shaft dual fuel engines.

The least initial cost was involved in the arrangement comprising wound rotor motors using purchased power, but the cost of purchased power made this alternate one of the most expensive in total annual cost. Because of the available size of the radial engine an arrangement comprising direct connected radial dual fuel engines and vertical pumps resulted in the next lowest initial cost and in the lowest total annual cost. An installation comprising 9 pumping units, with space for a future unit, was concluded to represent the most favorable installation to meet all requirements for the pumping station. At maximum rated speed of 400 RPM each pumping unit will deliver between 90 MGD at 105 feet total dynamic head and 130 MGD at 50 feet of head, depending on combinations of units in operation. At 65 per cent speed or 260 RPM, the delivery will be about 45 MGD at 52 feet total head.

The hydraulics of the tunnel systems, resulting from the requirement for maintaining essentially constant levels at the headworks, together with the wide range in quantities to be pumped, result in a wide variation in suction level at the pumping station. This requires a low level setting of the pumps to insure a suction head on the pumps under all conditions of operation. Consideration was given to various methods of providing a containing structure for this equipment with the conclusion that the most feasible and economical procedure would be to sink a circular caisson. With the setting of the pump centerline about 70 feet below mean sea level, the cutting edge of the caisson founded in rock, will be at a level about 110 feet below mean sea level. The structure is 109 feet in internal diameter with walls 9 feet thick to provide weight for the sinking operation. The sealed slab in the bottom has an average thickness of about 25 feet to provide weight to resist uplift. The mass of concrete in the bottom slab introduces serious problems of construction. Various methods were considered with a conclusion to place this mass by the Intrusion-Prepakt method. The principal objectives are to control the heat of hydration and to eliminate leakage by avoiding construction joints and shrinkage.

Connections with the shafts at the downstream ends of the tunnel systems are to be constructed in tunnel, entering through the bottom slab. Separate manifolds for each tunnel system are provided with connections to each of the 9 pumping units to be installed.

SEDIMENTATION TANKS

The history of the condition of the waters of Boston Harbor, together with the proposed discharge of treated effluent into the vast tidal flow off Deer Island Light, indicated little oxygen depletion and no need for treatment other than the removal of floating solids of sewage origin, grease and the heavier solids that can be removed by sedimentation. There has been little evidence of significant bacterial pollution of beach areas in the past, but it has been necessary to restrict shellfish taking from many areas within the Harbor. The discharge of significantly increased quantities of treated sewage off Deer Island Light may result in different effects on beach areas and for this reason chlorination of the treated sewage during the summer recreational period is included.

Extensive studies were made of various arrangements to accomplish the objectives outlined. One of these included only skimming to remove floating solids and grease and did not contemplate sedimentation or the removal of suspended solids. Under this alternate, the removed solids would be disposed of by incineration. Other arrangements included conventional sedimentation tanks with variable displacement periods anticipating variable degrees of suspended solids removal. Under these alternates, separate digestion with gas recovery was included.

Detailed analyses of these alternates resulted in a conclusion that the recovery of gas for power for pumping and power generation for other plant uses accomplished significant economies in over-all operating costs. There appeared to be little gain in economy by providing increased displacement periods and thereby accomplishing removal of additional quantities of solids for digestion and gas recovery. The most desirable installation comprised skimming and sedimentation tank capacity providing a displacement period of one hour for the 1980 annual average sewage quantity of 343 MGD. This volume of sedimentation tanks will provide a displacement period of 25 minutes on the maximum rate of flow to Deer Island of 848.8 MGD.

The proposed installation of sedimentation tanks comprises 8 units each 100 feet in width, 245 feet in length with an average water depth of 10 feet. Studies of available sludge removal equipment resulted in a conclusion to equip these tanks with the traveling bridge type of mechanism which has no operating parts below water and involves the simplest tank construction.

PRETREATMENT OF REMOVED SOLIDS

The solids removed from the sedimentation tanks comprise the floating material removed from the surface and the deposited solids removed as sludge. All of this material will be digested in separate tanks.

Pretreatment facilities will be provided both for skimmings and for sludge. The floating materials are to be removed mechanically and pumped, with considerable quantities of carrying water, to a pretreatment unit. The pumping rate for skimmings will be constant at about 2.0 MGD. The discharge from these pumps will be handled in scum separation tanks providing a displacement period of 36 minutes and a surface loading rate of 3,200 gallons per square foot per day. The tanks will be provided with mechanical scum removal equipment. The removed material will be pumped into the digestion tanks and the underflow will be returned to the settling tank influent.

Deposited solids as sludge will also be pumped at a constant rate from each of the 8 settling tanks with considerable quantities of carrying water. The pumping rate from each tank will be about 650 gallons per minute and the total quantity of about 7.5 MGD will be pretreated in sludge thickening tanks. These are of the conventional picket fence type designed with an overflow rate of about 800 gallons per square foot per 24 hours and a solids loading of 21.8 pounds per square foot per 24 hours. The installation comprises four circular tanks 55 feet in diameter with a side water depth of 9.0 feet and a bottom cone 6 feet 5 inches in depth and a floor slope of one to 2.85. It is anticipated that the thickened sludge will have a solids content of about 10 per cent and that an even more concentrated sludge may be obtained. The thickened sludge will be pumped to the digestion tanks.

SLUDGE DIGESTION

Recent tests and operating procedures with sludge digestion tanks have demonstrated that the displacement time in the tanks is the most important consideration in accomplishing complete digestion and recovery of maximum quantities of gas. Many observations have also shown that conventional designs leave much to be desired in the effective use of the tank volumes. In the design of digestion tanks for the Deer Island Treatment Plant, most effective use of capacity and of displacement has been provided. The concentration of sludge before it is introduced to the digestion tanks results in an economical use of the digestion tank volume by eliminating considerable quantities of water added in conventional sludge pumping procedures.

Consideration was given to several arrangements to assure most effective use of the volumes provided. The adopted design includes fixed covers with four draft tube mixing devices in each tank for continuous circulation of the contents of each digestion tank. In addition, continuous recirculation of the contents of the tanks by pumping through heat exchangers will assure adequate temperatures and assist in maintaining homogeneity within the several tanks. The arrangements for introducing thickened raw sludge and skimmings provide for adding these materials to the heated circulated sludge after it leaves the heat exchangers. Such additions of raw sludge will be made continuously so that optimum conditions can be maintained with the continuous feed and mixing with heated circulated sludge. The piping arrangements have been made flexible so that alternative operating procedures can be adopted without revisions.

The digestion tank installation comprises three circular tanks with an internal diameter of 108 feet and a side water depth of 30 feet. It is anticipated that the sedimentation tanks will remove an average of about 45 per cent of the suspended solids or an annual average of about 207,000 pounds per day in 1985. The total digestion tank volume thus provides an average designed solids loading of about 7.3 pounds per cubic foot per month. With the anticipated results of thickening to 10 per cent solids, the displacement time within the digestion tanks will be about 26 days. It is anticipated that more than 90 per cent of the available gas will be produced by this operation.

A fourth tank of the same dimensions is provided for sludge storage. This tank is also equipped with a fixed cover and with pumps for circulation within the tank through a system of spray nozzles discharging above the liquid surface for the purpose of preventing undue accumulations of scum. This method of control has been effective in the digestion tanks at Nut Island.

With the continuous introduction of raw sludge into the three digestion tanks there is an equal displacement from these tanks into the storage tank. Provisions are included for gravity or pumped removal of stored sludge for ultimate disposal through a pipe line to deep water off Deer Island Light, on outgoing tides. The initial installation will discharge into the sewage effluent outfall at the beginning of the subaqueous section, but arrangements are included which will permit the extension of a separate line to deep water, if this is found necessary or desirable. The discharge of digested sludge to the deep waters off Deer Island Light is parallel to the present operations for sludge disposal at the Nut Island Treatment Plant.

The anticipated gas production and recovery from the digestion tanks and the storage tank are estimated to be sufficient for all power requirements under normal or average operating conditions, but are inadequate during periods of maximum pumping rates. To assist in conservation of gas a storage sphere is included. This sphere is 60 feet in diameter and will be operated, normally, within a pressure range between 75 and 45 pounds per square inch. All of the gas produced will be compressed within these ranges to provide direct pressure for use in the pumping and generating engines, with the reserve stored in the sphere. When the sphere is filled and gas production exceeds the requirements, the excess will be burned in waste gas burners.

Within the normal operating pressure range, the sphere will store 230,000 cubic feet (atmospheric) or about four hours of average anticipated production. Facilities are provided that will permit the use of all of the stored gas, to atmospheric pressure, which amounts to about 575,000 cubic feet or about 40 per cent of a day's production.

OUTFALL

At the present time all of the sewage from the North Metropolitan District system is pumped at the East Boston Pumping Station near Chelsea Creek into the 9-foot diameter Winthrop sewer and again at the existing Deer Island Pumping Station through a subaqueous outfall discharging off Deer Island Light. The present outfall is inadequate for the increased quantities, particularly during periods of high pumpage and high tides. The new outfall comprises a box section receiving the effluent from the sedimentation tanks and extending to Deer Island Light and a new subaqueous outfall section more or less parallel to the existing outfall. Interconnections are provided with the existing outfall south of the existing Deer Island Pumping Station so that the existing and new sections will operate in parallel. Both the existing and the new subaqueous sections will be used continuously.

With a tidal variation of 12 feet or more and a range in discharge between a minimum of about 200 MGD and a maximum of about 850 MGD, it was concluded to provide a relief or optional outlet at times combining high tide and high flow conditions. This is accomplished as follows:

1. Under normal flow conditions and normal tidal levels all of the effluent from the treatment plant will be discharged through the subaqueous outfalls.
2. When the hydraulic gradient at the sedimentation tanks rises to a level that would submerge the sedimentation tank weirs, because of high tides and/or high rates of flow, a relief outlet to a shore line overflow at Deer Island Light will be opened automatically.

3. With increasing flow quantities or tidal level, beyond the capacity of the subaqueous outfalls and the shore outlet at Deer Island Light, a second shore outlet will be opened near the treatment plant to discharge into the tidal waters in Boston Harbor.

This arrangement permits considerable economy in construction of the entire outfall system by permitting infrequent shore line discharges, only under high tide and high and diluted flow conditions.

CHLORINATION

Studies were made of routine analyses, starting in 1948, and of special investigations made during 1954 and 1955 to determine the chlorine demand of the sewage that will be treated at the Deer Island plant. This survey revealed records of above normal chlorine demands in some areas, particularly in the North Metropolitan System. More recent data have indicated a trend toward lower demands in these areas. Based on the best information available, a design basis for satisfying the chlorine demand was indicated to be about 18 ppm or 150 pounds per million gallons, or about 51,000 pounds per 24 hours. Studies were made of the effectiveness of sub-residual chlorination with a conclusion that the application of chlorine in the amount of 75 per cent of the demand would result in a bacterial kill of more than 90 per cent.

The chlorination facilities to be provided include an initial installation adequate for application of about 40,000 pounds per 24 hours or 80 per cent of the anticipated demand with space for increasing the capacity to 56,000 pounds per day. Under average or normal flow conditions the chlorine will be applied in the effluent conduit along the south side of the sedimentation tanks. Under these conditions the contact time in the effluent conduit and in the outfalls will be in excess of 15 minutes.

Provisions are also made for prechlorination during periods of high flows to use the displacement period in the settling tanks as a part of the contact time. Split treatment can be practiced continuously if this is desirable, either for odor control or for increased contact period.

The location of the plant on Deer Island some 5 miles distant from the nearest railroad siding required consideration of methods for delivering the relatively large quantities of chlorine required. The most feasible method of delivery is by trailer-mounted tank trucks of 15 tons capacity which would probably be filled at the point of manufacture and delivered either by tractor from the factory or on flat cars. This method of delivery requires special facilities for the handling and storing of trailers and careful scheduling of units to assure continuity of operation.

Again, the location of the treatment plant presents problems of a supply of solution water for the application of chlorine. There will be a water supply system complete with intake screens, pumps, storage and distribution system for salt water to be used as a carrying medium for chlorine and also for emergency engine cooling and for flushing uses. The potable water supply is relatively limited in quantity and will be used only where the salt water supply is not suitable.

WINTHROP SEWER TERMINAL FACILITIES

As previously described, the sewage from the North Metropolitan System will be intercepted near Chelsea Creek and conveyed to Deer Island through the North Metropolitan Tunnel. This sewage is now conveyed through a 9-foot diameter sewer through Winthrop and discharges through the existing outfall off Deer Island Light. Some areas will not be intercepted at Chelsea Creek and will continue to be connected to the existing sewer. This amounts to an estimated average sewage quantity of about 24.2 MGD in 1985. At the treatment plant site this sewage flow will be diverted to a separate pumping station which will be equipped with trash racks, mechanically cleaned screens and aerated grit chambers with discharge into the sedimentation tanks. Because of the large size of the sewer, arrangements are also included for periodic flushing. Normal operations of pumping will be accomplished by four variable speed, motor driven pumping units each with a rated capacity of 15 MGD. The station also includes two diesel engine driven standby pumping units, each with a capacity of 37.5 MGD, which will be used, principally, during flushing operations in the Winthrop Sewer.

MISCELLANEOUS

In addition to the principal functional parts of the Deer Island Treatment Plant, there are other miscellaneous facilities including the following:

A. An administration building housing offices, laboratories and other facilities.
B. A garage building for the storage of operating and maintenance equipment.
C. A power plant building, located adjacent to the main pumping station. Principal items of equipment will include four dual-fuel engine-driven generator units each of 875 KVA capacity and control and distribution switchgear. Adjacent to the generator room will be a machine shop housing maintenance and repair equipment, considerable areas for storage of materials and supplies. Lockers, showers, toilets and lunchrooms for operating personnel will be included in this building along with a boiler plant for space heating and to supplement engine heat recovery for sludge heating.
D. An incinerator for burning screenings and grit. This unit will have sufficient capacity to handle these materials as removed by the Winthrop Facility and as may be brought to the site from the Chelsea Creek Headworks.

ESTIMATED COSTS

The cost of the entire project, including the completed Nut Island Plant, is now estimated at about $98,000,000. Of this total, about $23,000,000 is for the two tunnels under Boston Harbor and about $20,000,000 for the works at Deer Island, including the Pumping Station, Power Plant, Treatment Works and the Outfall.

CONCLUSION

It has been difficult to condense the many features of a complex project such as this into a relatively brief presentation. Many interesting features which have involved extensive study have been only mentioned or may have been omitted. A more comprehensive presentation of individual features may be worthwhile at another time.

The entire project has been progressed with the cooperation of the Metropolitan District Commission. Commissioner Charles W. Greenough has been most helpful in his over-all administrative assistance.

Technical administration for the Commission has been by Mr. Frederick W. Gow, Chief Engineer of the Construction Division of

the Metropolitan District Commission. His assistants, Messrs. Cosgrove, Ginder, Leary, Bergin and McRoberts, have been helpful in progressing the engineering work.

The detailed design of the two tunnel systems was done by the Construction Division of the Commission under Mr. Gow. The detailed designs and the preparation of Contract Plans and Specifications for the sewers and headworks has been done by Charles A. Maguire and Associates, with the cooperation and advice of Elson T. Killam.

The designs and the Contract Plans and Specifications for the Deer Island Pumping Station, the Treatment Works at Deer Island and the new outfall have been done by a joint venture group, comprising Charles A. Maguire and Associates, Elson T. Killam and Associates, and Greeley and Hansen.

HYDROGRAPHIC SURVEYS

By Edward J. Mullaney*

(Presented at a meeting of the Surveying and Mapping Section, B.S.C.E., held on April 1, 1959.)

Land measurement has always been with us. We don't know, but in all probability neolithic man had his own particular type of boundary markers to show the extent of his domain. We do know that Egyptian priests practiced some of the crafts of land measurement. Evidence of this is positive and a matter of record. A plan of an Egyptian noble's villa was found in the ruins of Thebes. There was also found, on the walls of a tomb in the same ruins, a representation of two chainmen measuring a field of corn. The earliest known land surveys of any extent occurred about 1300 B.C., when the Egyptians utilized the Great Pyramid in making cadastral surveys.

The history of the measurement of sea areas with resultant charting of sea routes is somewhat more obscure. We know that as early as 300 B.C. the early Greeks used a sort of log line for measuring distances between points of land, and prior to that in about 1300 B.C., the Chinese had discovered the value of a lodestone as a magnetic compass. Early charts were vague and inaccurate, made as they were from the use of crude astronomical instruments. It is thought that the first charts were made by Arabs in the Mediterranean Sea in Medieval times. They used the astrolabe discovered by Hipparchus in 150 B.C. These charts were not very accurate and left most of their sailing accuracy dependent on well-known landfalls. After the shape of the earth was established, and the great Mercator developed his method of conic projection, charting of sea routes became progressively more accurate. The use, first of the octant which in turn was followed by the sextant about the mid-18th century, did much to establish accurate marine charting. The sextant is still in use in many forms of hydrography, but its use is becoming more limited as various electronic methods of location are being employed.

So much for historical background. It is a large field and hours could be spent on it. I've treated it rather briefly as a sort of introduc-

* U. S. Army Engineer Division, New England.

tory lead into the purpose of this paper. One more historical fact, I started working for the Corps of Engineers in the middle thirties. Methods used at that time had not changed for probably a century. What I'd like to bring out is the difference between the usual surveying methods at that time and the more modern methods gradually being incorporated into the Corps of Engineers' work.

Before we get into specific methods of hydrographic surveying it might be well to localize the functions of each particular government agency directly concerned with them. In the United States hydrographic surveys are performed by three Federal agencies—The U. S. Coast and Geodetic Survey; the Corps of Engineers, United States Army; and to a lesser extent, The Navy Hydrographic Office. The Coast and Geodetic Survey has the primary responsibility of charting all seas adjacent to its continental and territorial waters. As well as charting these waters, it is responsible for all primary control, both horizontal and vertical and any hydrographic work of any extent is referenced to this control. The Navy Hydrographic Office usually accomplishes all work inimical to Fleet movements, cooperating with the other agencies in final findings. The Corps of Engineers is responsible for improvement, and maintenance as required, of all navigable channels, both coastal and inland, and for the improvement of harbors and rivers. In connection with its work, it has improved the Great Lakes, Mississippi River, its tributaries, such as the Missouri and Ohio Rivers, and several lesser tributaries. As the needs of commerce demand, it deepens and improves harbors and channels to accommodate the larger ships constantly being built. For example, the five Great Lakes are now under study to provide connecting channel depths to its harbors consistent with the St. Lawrence Seaway, now under construction. A closer example of successive improvement is our own Boston Harbor, which has been deepened from an original twenty feet to 40 feet below mean low water. Several branch channels such as Chelsea Creek, which was originally a mud flat, the Mystic River, and Weymouth Fore River Channels have been deepened to accommodate deep draft vessels. The President Roads anchorage has also been deepened to 40 feet, which allows anchorage space for several deep draft vessels awaiting dockage. Needless to say, this takes a lot of field surveys. Since the greater part of my hydrographic experience has been with the Corps of Engineers, naturally most of my discussion will treat of past and present Corps of Engineers methods.

Surveys of harbors may be broken down into several categories. These categories may be defined as: surveys of harbors which have never been improved and in which improvement is desired, or proposed; surveys of harbors which have been improved and need further improvement; and periodical surveys for maintenance purposes only. One other category that I should mention now is one that is practiced infrequently but none the less important. It is in surveying for obstructions and sunken wrecks that may impede navigation. In the category of unimproved harbors, which in New England is now confined to fishing and recreational boat harbors, it is first necessary to establish vertical and horizontal control. Vertical control is the easier of the two, and usually obtained by ordinary leveling methods to establish the plane of MLW from the nearest Coast and Geodetic Bench Mark. A tide staff is then set at mean low water. In some instances, such as the Cape Cod Canal, it was necessary to set up automatic tide gages at different points in the canal. It was found that as the canal was progressively widened from its original 100 feet to its present width of 480 feet the range of tide fluctuated with its width. This was due to different tidal ranges on opposite ends of the canal. The eastern entrance has a mean range of 9.4 feet and the west entrance a range of 4.5 feet. So, naturally, the range fluctuated as the gap widened.

The next step is horizontal control. Reconnaissance of the area to be charted is made both by field observations and examination of available maps and charts. Tentative points are selected, with a view to establishment of a good triangulation network and the necessity of being able to observe the open parts of the harbor where the hydrography is to be secured. Triangulation is then effected, efforts being made to include all Coast and Geodetic points for overall control. The control is usually integrated into the state coordinate system, such as transverse Mercator for Maine and the Lambert polyconic grid for Massachusetts, Rhode Island and Connecticut. Third order accuracy in triangulation is usually obtained as the harbor areas are small enough for this accuracy.

Next in order sounding is effected. A sounding crew for small boats usually consists of three men in a boat, an oarsman, leadman and notekeeper, two transitmen on shore and a man reading the tide staff. Several different methods of obtaining the hydrography may be employed. Shore flag ranges in pairs may be erected at regular intervals about normal to the natural channel lines, and the boat rowed or propelled at a slow pace along the projection of these ranges. The slow pace is necessary to avoid trailing of the lead which could cause an appreciable error. In such cases only one transitman is necessary. The boat is established on range and sounding begins. The sounding man establishes a cadence or rhythm to his soundings, taking them at regular intervals, usually 6 per minute, and the boat's location is usually taken at half or full minute intervals. The transitman has oriented his instrument to some triangulation point and reads the azimuth to the boat at a signal from the note keeper who waves a colored flag. Strict adherence to range lines is necessary, for any displacement of the boat off range results in considerable error. Variation in colors of flags determines the intermediate minute, five minute and 10 minute intervals on the sounding range. These color variations may be red for even minutes, white for odd minutes and red and white for 5 minute intervals. Tide readings are taken continuously while the survey is being accomplished.

Ranges fixed by signal flags on shore are not always employed. Chiefs of Party with long experience can select natural ranges and keep control of the survey within the desired limits. In this case two transits on shore or two sextants in the boat can be used. Advantage of this method lies in accurate locations. In localities in which large areas of open water are involved it is usually more practical to have two sextants in the boat. In connection with this method of securing location by sextant, sometimes what is known as a sextant circle chart is employed (sextant circle slide). Three triangulation points are utilized for this method. The points selected are joined together by straight lines. Using one end point and the mid-point, a perpendicular bisector is erected on the line between two of the points. To scale, the natural tangents of angles which will have circles containing the two points and which traverse the area concerned are then plotted on the bisector. Arcs of the circles are then plotted in the area. After this, the mid-point is connected to the third point and arcs drawn in a similar manner. Thus, the area being surveyed has two sets of concentric arcs intersecting each other. If care in the selection of points is taken the arc intersections are sharp enough to make the plotting of two simultaneous sextant angles quickly with sufficient accuracy. In narrow areas, with careful selection 4 points may be used. The advantage of this system lies in the fact that the survey can be contained solely in the boat and the chief of party is aware at all times of his location and whether or not he is getting sufficient coverage for his survey.

After all soundings have been taken, probings to determine the nature of the bottom are in order. Probing essentially means pushing a pipe through the bottom to determine the extent and nature of the material underlying it. In the New England Division, probings are taken from a small barge, 50′ × 20′. Probings are taken by either jetting or driving. In jetting a stream of water is forced through a one-inch pipe and pushed by hand to the proposed grade or refusal, whichever is encountered first. Drive probings are taken by counting the number of blows necessary to drive the pipe per foot into the bottom without jetting, thus determining the relative hardness of the bottom. Prior to dredging, core samples are usually taken in order that the nature of the materials may be known.

This completes the survey for a new harbor which has never been improved. Supplementary topography may be necessary to show shore installations, high water marks and general layout of the harbor. If not available from local maps such topography is taken, as it is very necessary that all marine terminals and shore installations be fixed accurately in relation to the hydrography already accomplished.

The same procedures are followed in harbors which have been improved and need further improvement, except that both horizontal and vertical control have already been established, and it usually needs only reestablishment of some points that may have been destroyed or have been subject to the usual ravages of nature. In the case of further improvement, not as extensive surveys are required. Channel lines are usually well defined and unless change is contemplated sounding ranges are taken at 100-foot intervals to cover the limits of the defined channel. Enough soundings are taken beyond channel limits laterally to cover specified side slopes, 1 on 3 for ordinary materials and 1 on 1 in rock. Probings for possible ledge excavation are also taken. If ledge is encountered above the proposed grade, then sufficient probings are taken to make an accurate determination of the amount of ledge to be removed. As mentioned before, probings are taken from a flat barge 50 feet long and 20 feet wide. I might mention at this time that the New England Division has recently built itself a new barge for this work. It is self-propelled by means of a 50-HP Murray and Trequrtha engine. Two Sprague-Henwood sampling units are mounted on each side of the barge so that probings may be taken on either or both sides of the barge simultaneously. Probings for quantity estimates of rock are taken on 10 × 10 or 20 × 20 foot centers. Location is established by means of shore ranges. Parallel back and front signals are placed about normal to the channel lines. Similar ranges are placed longitudinally in the channel. Range intervals are determined by the accuracy of the estimate required, usually 10′ by 10′. If sufficient range ground is not possible for parallel range ground, some outstanding object, such as a spire or chimney back of the shore line, is located and the ranges fanned from that point.

After the dredging has been accomplished, soundings are taken to determine the quantity of materials taken out. Soundings are taken as near as possible along the same ranges as used prior to dredging so that comparison can be made. But, in cases of excavating for ledge or channel bottom composed of very hard materials which may, due to the inaccuracies of dredging and inability to see any sub-aqueous high points above grade, one more refinement is added. The channel is swept to the designated grade. By sweeping, it is not meant that a large rake or similar object is trailed along the bottom to drag down any high points; although this method is sometimes used by dredging companies to knock down high points or loose piles of rock projecting above grade. Sweeping in surveying terms means suspending a light T-Bar to the designated grade and traversing the whole section with it. The bar is kept at grade by relaying each tidal change from shore. If a high spot is encountered its height above grade is determined by sounding and its location determined by either range intersection, or transit locations. The 50-foot barge is used for this purpose. Two 25-foot T-Bars are suspended from the barge with graduated chains at either end. Four men tend the two bars and after a little experience can determine the type of shoal and its extent. The barge is allowed to drift with the tide normal to channel limits. Range on the channel limits is ordinarily set on a combination of land signal and a range buoy close to the channel so that sensitivity of ranges is at a maximum. The propulsion unit on the barge keeps the stern on range laterally and outboard motors on the side are utilized to overcome adverse wind or wave action. After a channel is swept clean, a set of ordinary soundings for estimate is made.

Sweeping for wrecks or obstructions is accomplished in the same manner as for dredging, except that a greater width of sweep is utilized. This method, called wire dragging, utilizes two launches, about 40 or 50 feet in length. A length of wire cable called a drag-wire, about 1000 feet long, is placed on one of the launches. This wire has beckets or ring bolts fastened to it at 100-foot intervals. Eleven buoys with wells running through the entire length of them, and a small hand reel on top, are also put on the boat. A graduated cable is reeved on the reel. Two 300-pound weights and nine 100-pound weights are also on the launch. In setting up dragging operations, one boat carries all the equipment. For setting operations the second boat comes alongside and fastens a tow line to one end of the 1000-foot wire. It then proceeds underway laterally across the area to be swept. In the meanwhile, a 300-pound weight is attached to the end of the drag-wire and one of the buoys with the hand reel and wire. As the drag wire is payed out, buoy and the 100-pound weights are fastened to the drag-wire at 100-foot intervals, the final end having the remaining 300-pound weight. A small boat then visits each buoy in turn letting down the drag-wire to the grade of the channel or in deeper waters usually to 50 feet. Then the drag is towed in a 1000 foot swath in the locale of the reported obstruction or wreck. Locations are taken by double sextant angles. If reporting is fairly accurate as to location, it seldom takes more than two or three passes to locate a wreck. The wreck is then accurately located and a buoy set adjacent to it. The Coast and Geodetic Survey often uses this method to locate high spots in specific localities. Successive passes are made on the location, the drag being raised a foot after each pass until a pass is made free of shoal.

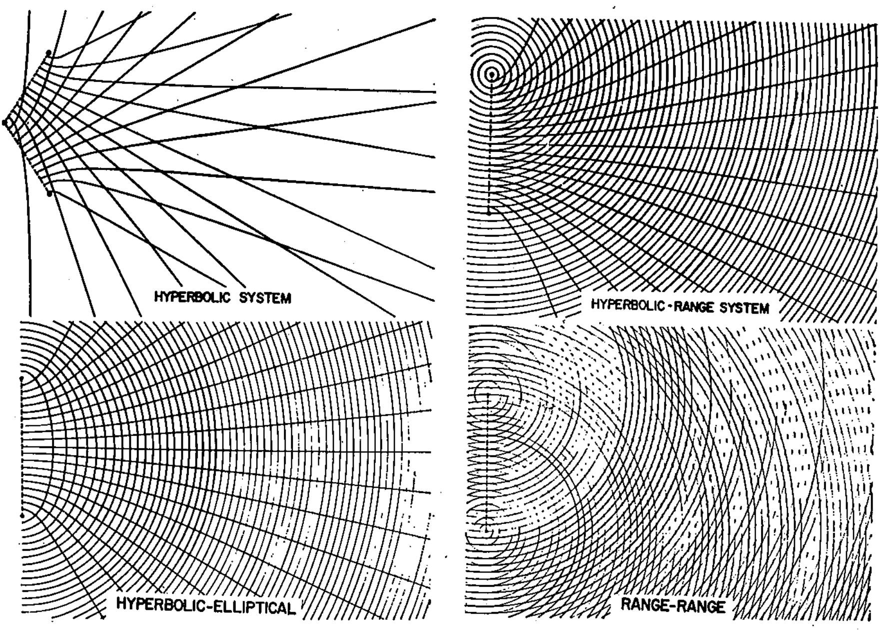
So far, we have talked only about lead line surveys and ordinary surveying instrument methods of obtaining locations. The lead line is gradually disappearing and echo sounding apparatus is superseding it. Echo sounding apparatus can be portable, operated from a rowboat or small power launch with 6 or 12 DC volt battery power. It can also operate from a larger launch with a 115 AC power source from a motor generator. Essentially the system employs a transmitter for the output of sound at a certain decibel value. The sound is relayed to the bottom, picked up by a receiver and amplified to produce an electrical impulse on a sheet of carbon backed paper, which is placed on two rollers normal to the striking arm. The interval between the sending of the sound and the receiving of it is plotted graphically on a continuously moving sheet of the previously mentioned carbon backed paper. The paper is so calibrated that the arc made by the impulse corresponds to the depth. About 200 soundings per minute are taken, giving a profile of the bottom over which the boat is passing. A mechanical device can change the position of the paper in order to compensate for tide. Thus the soundings appear on the paper automatically reduced to the plane of mean low water.

A further refinement is effected by the use of walkie-talkie radios. With one set on shore and one on the boat, constant communication is established between the tide man and the boat. Each tenth change of tide is reported and set on the depth finder and any unusual happening that may occur on shore can be reported directly to the boat.

Locations of this method of sounding have, until recently, been done as previously described, usually with transits or sextants at stated intervals. However, this system of location has its limitations, particularly in open waters where fixed points are fairly distant and obscured by fog or haze. A system of radar or continuous wave radio reflections to obviate some of these limitations on location has been developed. It was first used in the Norfolk District Corps of Engineers and has been employed in Hampton Roads and on the James River for the last five years.

This system employs continuous radio waves and depends on the measurement of the relative phase between continuous wave signals. The system consists of three fixed radio relay units or stations and one set of recording or indicating apparatus. The equipment for each fixed relay station includes a receiver, a constant output amplifier and a radio transmitter. All are packaged in a single unit with two 6- or one 12-volt battery for power. The relay stations are placed at triangulation points on the shore. The indicating and recording instrument, called the mobile transmitter unit, is placed on the survey launch, usually a 50-foot or larger boat. The mobile transmitter unit is a continuous wave transmitter with a power output of 10-watts. It transmits an unmodulated signal on 1.738 Mc, the frequency obtained by application to Federal Communications Commission for this system. A reference transmitter is conveniently placed so that it can be readily received by each of the relay stations.

In order to indicate the position of the mobile transmitter, which remember is in the boat, it is necessary that all three relay stations be placed in operation. A signal is then broadcast by the mobile transmitter and received by each of the relay stations. The reference transmitter then transmits a continuous-wave signal which is also received by each of the three relay stations, where it heterodynes with the signal from the mobile transmitter and is reflected back to it. The phase relations or phase counts are intercompared continuously. The position of the mobile station with respect to each of the relay stations is determined by the phase counts. The phase relationship of two stations is constant along the path of a hyperbola which has the two relay stations as its foci. Thus, if the mobile transmitter moves in a



COMPARISON OF AREAS OF HIGH PRECISION
WITH VARIOUS SYSTEM CONFIGURATIONS

hyperbolic path with respect to two of the relay stations, it has a constant phase between the two stations. Any deviation will give a different phase which is recorded on the phase indicator. The third relay station in connection with one of the other stations forms a second path of hyperbolae with reference to the base line between them. The end of this base line is referenced to the first base line. Thus, moving in any direction in the area covered by these two systems can be detected by comparing the phase of one pair of stations against the other.

In practice, quite a lot of preparation is necessary for this type of survey. The relay hyperbola stations have to be selected with care so that the segments of the hyperbola approaching a straight line would fall within the area to be sounded, and that the systems would be as near as possible at right angles to each other. The system is very practical for areas in which recurrent surveys are made and where comparisons of surveys can be made.

I'd like to cite one example of its practicability and economy. In Hampton Roads, Virginia, about 10 miles of deep channel is now being dredged. Dredging is being accomplished by a sea going hopper-dredge, the "Goethals." This dredge has a capacity of 5000 cubic yards of materials. Instead of disposing the spoil at sea as is usually done, it was determined that a nearby spoil area adjacent to the main channel could be utilized more effectively and economically. The spoil is transferred to a hydraulic rehandler and pumped to a diked-in spoil disposal area. Dredging of the channel is being accomplished by sections. Each section is brought down to grade before another section is started. A round-trip from dumping grounds to the dredging area and return averages about one hour. As the dredge works 3 shifts or 24 hours five days a week it is discernible that quite a large amount of material is removed every 24 hours and it is necessary to know all about it in a hurry. Consequently, a hydrographic party must spend at least part of every day keeping progress over the dredged sections. This is necessary not only to see that the dredge does not leave any shoal areas, but also to be sure that the dredge is not digging too deep a channel. Therefore, the dredge must often be shown the progress of its work.

With prior methods of sounding a lot of time would be expended sounding. Then the sounding record would have to be forwarded to the office for plotting and a plan showing the results forwarded to the dredge. The minimum time for this procedure would be about a week. The Raydist system reduces this time considerably. By use of a piece of vellum over a chart of the phase system, soundings can be taken direct from the chart and as the different phase intersections are also shown on the echo-sounding graph, plotting becomes merely a writing down of numbers on the vellum. It is reported that a day's work can be plotted in about three quarters of an hour. Besides this shortening of time in plotting, other advantages have been shown for this system. As the system does not depend on visual observations, the sounding can be accomplished in fog or hazy weather, or if need be, at night. The dredge also locates itself by means of this system so that with both the dredge and survey party using it the chance for error is minimized.

The Corps of Engineers does not believe that the ultimate in sounding methods is achieved by this system. At the present time research is being made whereby the echo sounding chart may be fed into a digital or analog computer and an estimate of the amount of materials be made directly from the chart, obviating the usual method of plotting and planimetering.

Another device that is being investigated by the Corps is called a Tellurometer. It consists essentially of two portable microwave units mounted on tripods. One is a master station which operates on radio microwaves of 10 cm. The master station is set on a known point and the remote station on the point to which a measurement is desired. The set is then adjusted for the particular meteorological conditions prevailing in the locality and placed in operation. The linear measurement is obtained by means of measurement of the waves reflected back from the remote station. Accuracy of three parts in a million or ± 2 inches in 35 miles have been reported in recent tests.

THE MASSACHUSETTS PORT AUTHORITY

By Ephraim A. Brest*

The Massachusetts Port Authority is basically the redesign of a governmental function to meet the needs of our Commonwealth. It is a synthesis of government and business to reduce costs, develop efficiency, encourage investment, and create jobs.

The Massachusetts Port Authority is a new governmental body for government and business cooperation. It synthesizes the needs of the public welfare and private enterprise far better than the railroads, the steamship companies, or transit companies were able to do in the past—or various types of governmental agencies are able to do at present.

The Massachusetts Port Authority was created by Chapter 465 of the Acts of 1956, and signed into law by Governor Christian A. Herter on June 21, 1956.

I was named chairman, and all members were sworn into office on June 23, 1956. The other members of the Authority are: Philip H. Theopold, partner of Minot, DeBlois & Maddison, real estate; O. Kelley Anderson, president of the New England Mutual Life Insurance Company; Nicholas P. Morrissey, New England representative of the International Brotherhood of Teamsters, Chauffeurs, Warehousemen and Helpers of America; Vice Chairman Carl J. Gilbert, chairman of the Board, the Gillette Company; Secretary Treasurer William B. Carolan, President of the Union Savings Bank of Boston; and John S. Pfeil, retired vice president of Stone and Webster, Inc.

In 1958, an amendment was enacted by the Legislature and signed by Governor Foster Furcolo permitting the interest ceiling on the bonds to be raised from 4 per cent to 5 per cent.

The Massachusetts Port Authority marketed $71,750,000 of revenue bonds and took over operation of the Mystic River Bridge, Logan International Airport, Hanscom Field, and the Port of Boston facilities on February 17, 1959.

The Massachusetts Port Authority paid the State $21,722,157

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* Chairman, Massachusetts Port Authority.

for funds advanced to the Authority in 1956, and for retirement of over $21 million of outstanding airport bonds.

Operation of the facilities had cost the taxpayers of the Commonwealth over $50 million since the war. Under the Massachusetts Port Authority investment has been substituted for taxation. All expenses of the facilities will be met from bridge, airport and port revenues.

The Authority will spend $19 million on making Logan International Airport ready for the jet age. The terminal building will be redesigned and a second floor constructed with a spacious dining room overlooking the field. Plane loading positions will be increased to 78. Finger ramps will extend onto landing apron to give sheltered access to airliners. Baggage will be handled speedily in newly designed areas. Runways, taxiways, aprons and access roads will be improved. A double-deck parking area may be designed in the near future.

The Authority will spend $3 million on improvements and repairs to the Port of Boston facilities. The initial improvements of the Port Properties, which will take two years to complete, include the following:

Castle Island Terminal—Replace fender system, patch deteriorated concrete, construct new firewalls, replace untreated piling, install cathodic protection to steel piling, pave roads, relocate railroad tracks and install drainage system.

Commonwealth Pier No. 5—Replace water supply and sprinkler system, realign building columns, replace cargo doors, clean and paint structural steel, modernize wiring and heating system, reroof, repair external walls, etc.

Hoosac Pier No. 1—Install cathodic protection for bulkheading and miscellaneous repairs.

Hoosac Grain Elevator—Install fire protection standpipe system and dust collection system.

Mystic Pier No. 1—Install cathodic protection.

East Boston Pier No. 1—Install cathodic protection.

East Boston Grain Elevator—Install fire protection standpipe system and dust collection system.

A summary of the estimated cost of these initial improvements follows:

Castle Island Terminal	$ 784,000
Commonwealth Pier No. 5	1,343,000
Hoosac Pier No. 1	111,000
Hoosac Grain Elevator	127,000

Mystic Pier No. 1	100,000
East Boston Pier No. 1	100,000
East Boston Grain Elevator	127,000
Estimated Cost for Improvements	$2,692,000
Contingencies	269,000
Total	$2,961,000

Now, what else do we propose to do?

One of the first things our Authority is going to do is to explore the possibilities of more trade with Cuba, Puerto Rico, Brazil and other Latin American countries. (Perhaps our coast now extends to Rio de Janeiro—rather than to Miami.)

New England has a big investment in Latin America—40.7 per cent of the foreign investment of New England's corporations and other organizations is in Latin America. One of New England's leading economists estimates that Latin America is already a $400 million market for New England manufacturers. By the year 2000—two years after our bonds will have been retired—Latin America is expected to have a population of almost 600 million. This total will be more than double that of the United States in the year 2000.

It has been estimated that approximately 63,000 of New England's 1,436,700 manufacturing jobs are dependent on exports to South America today. To Venezuela alone, Beverly is shipping shoe findings and machinery . . . Cambridge—cameras, carbon paper, films, industrial chemicals, ink, insulated cable, office supplies, shoe fabrics, shoe findings and machinery, textiles, wire and cable . . . Everett—duplication machines . . . Framingham—paper tags, labels and seals . . . Lynn—chemical specialties, shoe blacking . . . Malden—paints and pigments . . . Waltham—electronic equipment . . . And we could mention other Greater Boston communities.

Preparations for jet operations by commercial airlines at Logan International Airport will require the expenditure of approximately $4 million for work to begin this summer. Jet airliners will carry about 125 passengers, compared to about half that number on present day propeller planes. Jet aircraft weigh almost twice as much as old style planes.

Jet airliners burn up 1000 pounds of fuel just taxiing to the end of the runway. A new fuel system will be required to fill their tanks.

At present these planes are carrying 17,000 gallons, but before long they may be carrying considerably more.

The improvements to the field at Logan will include:

1. Rehabilitation of Runway 15R-33L and South Taxiway	$ 493,000
2. Rehabilitation of Central Taxiway	80,000
3. Paving Open Areas in Apron in Vicinity of Terminal Building	1,443,000
4. Riprap, and Fill area between Runways 27 and 33L	775,000
5. Approach Light Pier for Runway 33L	500,000
6. Fill for Localizer at end of Runway 15R	27,000
7. Complete Paving between Inner and Outer Taxiways — North Apron Area	700,000
Total Project Costs, incl. engineering and contingencies	$4,018,000

The Massachusetts Port Authority is faced with a challenge in the expansion of the airport and the promotion of the port. We believe that we have the management brains on the Authority, thanks to my colleagues, to do the job.

ENDING THE HIGHWAY AND TRANSPORTATION PROBLEMS IN UPTOWN BOSTON

By William B. S. Leong, *Member*

THE AREA

Until about twenty-five years ago, Boston's business development had been concentrated in the downtown area east of Massachusetts Avenue; west of it lay some of the finest residential neighborhoods and cultural institutions in Boston. Businesses requiring greater mobility were found along Commonwealth Avenue, Brookline Avenue, and Boylston Street.

With the increasing use of automobiles and expansion of the downtown business district, the area west of Massachusetts Avenue was gradually being built up. Now the area bounded by Massachusetts Avenue roughly to the east, Huntington Avenue and Longwood Avenue to the south, Harvard Street and Babcock Street to the west, and the

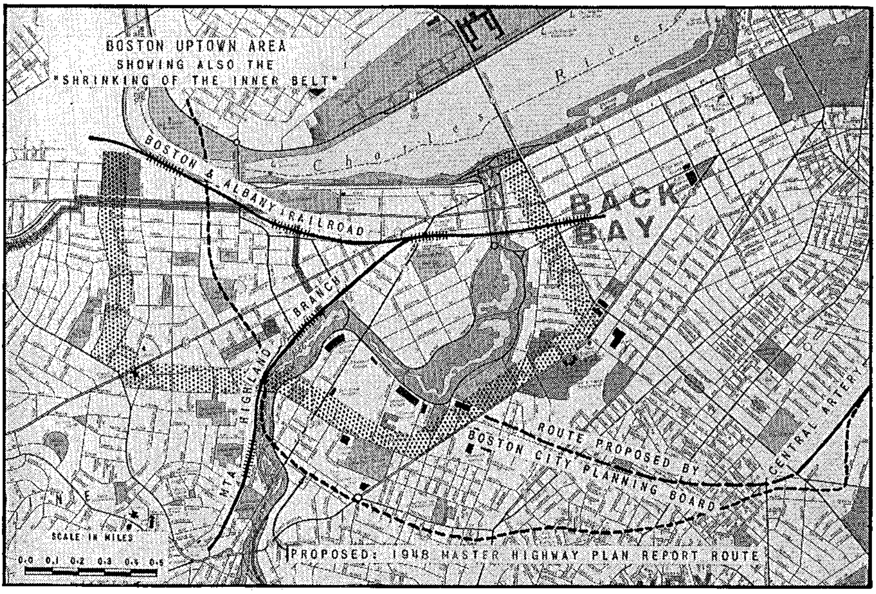

Fig. 1.

Charles River to the north, has grown to assume an identity that is socially, economically, and physically different from that of the downtown district. Although part of the area thus arbitrarily drawn lies in the town of Brookline, which is predominantly a residential community tied economically to Boston, it will appropriately be considered as the uptown district of Boston for the planning purposes of this paper (Fig. 1).

The core of the uptown district is triangular in shape, formed by Kenmore Square (Fig. 2), the Boston University Bridge and Commonwealth Avenue intersection (Fig. 3) (to be known as B.U. Bridge

FIG. 2.—AERIAL PHOTOGRAPH OF KENMORE SQUARE AREA.

intersection below), and the Park Drive—Brookline Avenue—Boylston Street intersection (Fig. 4) (to be known as the Sears Roebuck intersection below). In this core and its immediate vicinity are located, in addition to residential apartments, some noted schools and institutions, such as Boston University, Simmons, Emmanuel, Boston Latin and English high schools, and Harvard Medical school, the Lahey

FIG. 3.—AERIAL PHOTOGRAPH OF B.U. BRIDGE AREA.

Clinic, the Children's, Lying-In, and Beth-Israel hospitals; the Boston Museum of Fine Arts and Gardner Museum (Fenway Court); the Red Sox's Fenway Park; Temple Israel; the Somerset and Kenmore hotels; Sears Roebuck and S. S. Pierce Companies; the Yankee Network; electric, electronic, and automotive industries; other offices, businesses, research laboratories, and freight warehouses.

On the "fringe" area of the uptown district are found such places as Boston Symphony Hall, New England Conservatory, Northeastern University, the Y.M.C.A., Commonwealth Armory, and Boston University's Athletic Field (formerly Braves Field).

Geographically, the uptown district is more centrally located than elsewhere in Boston. Being easily accessible by highways to Cambridge, Somerville and points north, Waltham and points west, and Brookline, Dedham, and points south, the area is also served by M.T.A. lines on Commonwealth Avenue and Beacon Street and by the Boston and Albany railroad.

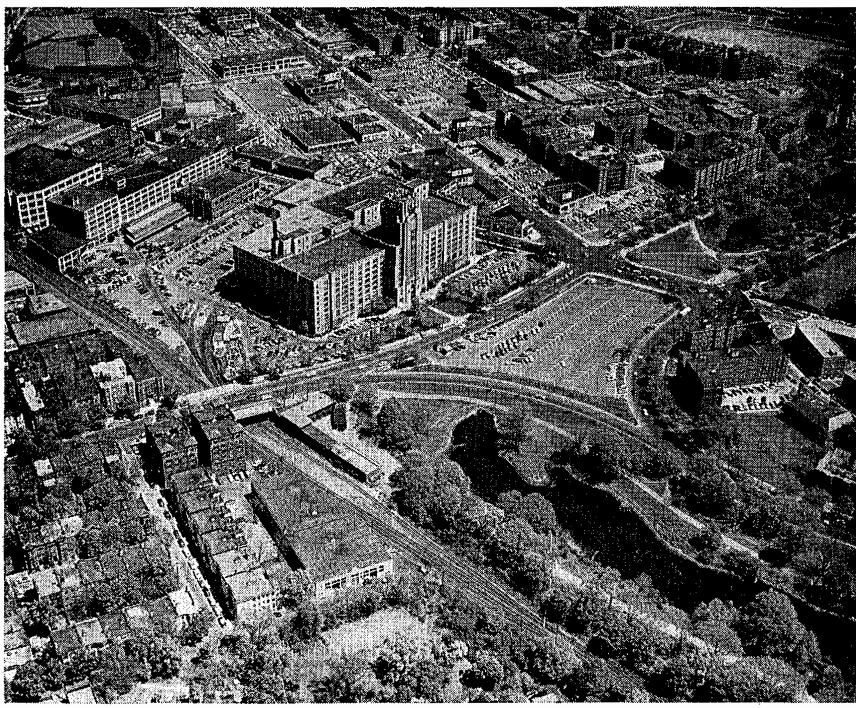

FIG. 4.—AERIAL PHOTOGRAPH OF SEARS ROEBUCK AND VICINITY.

THE PROBLEMS

But what was considered to be a more spacious and low density area of quality and amenity is now gradually being strangled by traffic congestion. The uptown district has more than its share of traffic accidents. The Massachusetts Safety Council has listed Kenmore Square, the B.U. Bridge intersection, and the Sears Roebuck intersection as three of the most dangerous points in Boston.

Parking is another problem in this uptown district. Parking facilities are badly needed for the residents, businessmen, office workers, customers, baseball fans, and students in the area. Despite efforts by local civic groups, nothing practical has been done to ease the situation. Special permission by the Metropolitan District Commission to allow the baseball fans to park their cars on both sides of the median strips on Fenway and Park Drive during the ball games is at best a temporary solution.

In the downtown district, where congestion caused by automobile traffic has taken away its beauty, hampered its functions, and created hopelessly impossible conditions, one might as well conclude that the only logical solution lies in the creation of shopping malls exclusively for pedestrians.* In the uptown district, however, the traffic congestion has not yet reached a point of intolerance, but the problem should be faced squarely now before it is too late.

The City has not been unaware of the seriousness of this situation, but has not been in any financial position to correct it. Moreover, the City has no specific proposals for improving the traffic congestion in the uptown district while awaiting relief from the Inner Belt eventually to be built through the general area.

In 1957 the City turned over to the jurisdiction of the M.D.C. both Park Drive and the Fenway and the responsibility for improving traffic conditions in these areas. But so far, with the uncertainty of the Inner Belt location, the improvements made by the M.D.C. have been minor and temporary.

After a period of indecision following the construction of the Central Artery, the Massachusetts Department of Public Works has retained engineering consultants for the Inner Belt. The picture of transportation has changed since the formulation of the Master Highway plan in 1948. The Inner Belt has become a part of the 41,000-mile interstate system to be financed by the Federal Government and the State in the proportion of 90 per cent to 10 per cent in the new national highway program.

It is evident that, with the rapid urbanization of the nation as a whole and of the Boston area in particular, not only highway but all traffic and transportation measures are regional in character, and all problems pertaining to them must be solved jointly by all levels of government for the long-range benefit of the people in the area. Public inaction and piece-meal disconcerted planning will simply prolong the agonizing highway and transportation situation.

THE CONSIDERATIONS

This is no less true in the Boston uptown area. To find the most satisfactory solutions to the highway and transportation problems,

* Communities considering the downtown pedestrian mall idea include urban centers like Detroit, Kansas City, and San Francisco, and suburbs like Alexandria, Clarendon in Virginia, and San Jose in California. A well-intended but poorly coordinated experiment was unsuccessfully tried last year for several months on two downtown streets in Boston.

local and regional factors must be taken into consideration. Among them are the following:

Land Use. Land use in the uptown area, especially the core, is unique in many ways. Contrasting interests often exist side by side or across the street. Residents along Park Drive and The Fenway desire complete privacy. Educational institutions and museums desire both privacy and transportation convenience. Stores, warehouses, and ball parks desire transportation convenience and ample parking facilities.

Public lands in the area fall under two jurisdictions. The land between Charlesgate East and Charlesgate West from Boylston Street to Storrow Drive, and the land between The Fenway and Park Drive south of Brookline Avenue in a residential area, belong to M.D.C. and the Fens, to the City of Boston. All city streets permit mixed traffic, and all M.D.C. streets, except B.U. Bridge, restricted traffic for passenger vehicles, and light delivery trucks only.

There is little or no room for expansion on Commonwealth Avenue, Beacon Street, Brookline Avenue, or Boylston Street. However, on the south side of Brookline Avenue, most buildings which are only two-stories high and not too substantially built, may be replaced by new and more efficient commercial structures for primary or secondary business and office use when the traffic condition of this narrow street, having a 60-foot right-of-way, is improved. However, between Brookline Avenue and Boylston Street there is still some elbow room for development.

Circulation and Physical Obstacles. A relatively small area, the uptown district is traversed by many major thoroughfares—Commonwealth Avenue, Beacon Street, Brookline Avenue, Boylston Street, Park Drive, Mountfort Street, B.U. Bridge, and Huntington Avenue. All but Boylston Street are numbered routes representing the primary road system, and are heavily traveled.

Physical obstacles are even more numerous. There are the B. & A. railroad main line, M.T.A. Highland Branch, Beacon Street subway, Commonwealth Avenue street-car line, Kenmore subway station, bridges on Brookline Avenue, Beacon Street, Commonwealth Avenue, St. Mary Street and Storrow Drive—not to speak of the utility and sewer lines.

Boston University Expansion. Boston University at present has no definite developmental master plan, perhaps because of the uncertainty of the Massachusetts Turnpike extension and of the Inner Belt locations. Its frontal development seems to be concentrated on Commonwealth Avenue, where administrative offices, classrooms, and the chapel are located on the north side, and research facilities on the south side. The area near the railroad may be considered as the "service area," where the Buildings and Grounds Department and more research facilities are located, and the area facing the river as the "living area," where there are several dormitories. The University has recently announced that its Law School will be moved from Beacon Hill to 881 Commonwealth Avenue, where a new Legal Center will be built. In the planning stage is the Graduate Center with dormitory facilities, Students' Union Building, and others. Thus, by this pattern of growth, it can be certain that the ultimate development will cover an area from Kenmore Square to the University's athletic field, with Beacon Street as its southerly limit and the Charles River the northerly limit.

Massachusetts Turnpike Extension, or Western Expressway. According to the 1948 Master Highway Plan for the Boston Metropolitan Area, the Western Expressway, now the Massachusetts Turnpike, is to connect with the Inner Belt. The Massachusetts Turnpike Authority has announced its intention to continue the turnpike to the South Station as a toll road, using the right-of-way of the B. & A. railroad connecting with the Central Artery, but so far there has not been any visible activity.

Parking. In the general vicinity of Kenmore Square there are about 4000 commercial off-street parking spaces. According to the M.D.C. police, there will not be any acute shortage of parking spaces even during the ball-game days, if only all the ball fans would pay to park their cars. Among those on-street parking violators, some just dislike paying to park, while others find it impossible to leave the jam-packed commercial off-street parking areas before the end of the game, or the end of the first game in case of a double-header. One large commercial parking operator said that he could use one thousand or more parking spaces, and that it would be a paying proposition if he could be sure of a full capacity during the 77 to 80 ball-game periods, and of normal business the rest of the year with regular patronage from the hotels, restaurants, businesses, offices, and Boston University. At present, some hotels and businesses are providing their staff and customers with very limited parking facilities, but it is not believed that they can adequately serve the purpose. Prospects of the parking business will be even better after the construction of the Inner Belt, and especially if the parking facilities can be located near the access and egress ramps of the expressway.

On-street parking by students of Boston University, depriving others of this use has been the constant complaint of businessmen and doctors. It is undeniable that both off-street and on-street parking facilities are needed if only the latter will not impair the operating efficiency of the streets.

Inner Belt. Success of the solutions to the highway and transportation problems in the uptown district depends mainly on the location of the Inner Belt. However, other improvements are no less important, but since the Inner Belt will be an eight-lane limited-access urban expressway with a design speed of 50 miles per hour, the roadway itself (measuring a minimum of 124 feet wide if the inbound and outbound lanes are on one level) and the ramp system will take up much room, and thus in all probability will affect the areas needed for other improvements. Therefore, the first and foremost task will be determination of the Inner Belt location.

Recent land use and traffic studies by various planning agencies have indicated the necessity of shifting the Inner Belt location from the 1948 Highway Master Plan report location farther to the east in the following manner: After leaving the Central Artery at Southampton Street in a westerly direction, the Inner Belt will cross Shawmut Avenue, Harrison Avenue, and Tremont Street, and then will take a course due north to roughly follow Ruggles Street, Louis Prang Street, and The Fenway, heading for Cambridge north on Charles River (Fig. 1). Between Southampton Street and Huntington Avenue, the Inner Belt will pass through some of the worst depressed industrial, commercial, and residential areas of Boston, thus assisting the city's program for urban renewal. Between Huntington Avenue and The Fenway (and perhaps as far as Brookline Avenue) the Inner Belt will use public park land.

The "shrinking" of the Inner Belt (Fig. 1) will achieve three objectives: (1) to relieve traffic congestion and improve operating conditions on Massachusetts Avenue, which is the only north-south street through Boston, the heaviest traveled, and the most hazardous; (2) to minimize the right-of-way cost by taking properties of low assessment in the blighted areas and public park land; and (3) to minimize property taking in Brookline,* which has no great need for the expressway except for by-passing through traffic.

City planners and highway engineers are in almost complete agreement on locating the expressway through blighted areas. Neither will they find any objection to taking park land for the expressway in the residential area, provided it can be replaced, and the characteristics of the neighborhood preserved. Route planning there is a relatively easy task.

It is the section between Brookline Avenue and the river where city planners will differ from the highway engineers in the approach to the problems and in the solutions. And this may be true even among their own colleagues, for here lies a challenging situation of greatest complexity.

The author will present his own proposal for this section of the Inner Belt as an element in relation with the overall improvement proposals in the uptown area.

THE OBJECTIVES

Based on the foregoing considerations, it is now possible to list the minimum improvement objectives as follows:

1. Traffic congestion and operating conditions on major streets; namely, Commonwealth Avenue, Brookline Avenue, Beacon Street, Boylston Street, Park Drive, and Mountfort Street, to be relieved.
2. Traffic bottlenecks at B.U. Bridge intersection, Sears Roebuck intersection, Kenmore Square, Charlesgate East and Charlesgate West area, and Boylston Street-Commonwealth Avenue intersection to be eliminated.
3. Residential neighborhoods on Park Drive and the Fenway, and M.D.C. park land to be preserved.
4. Normal business and transportation services to be maintained.
5. M.D.C. park land to be replaced.
6. Restricted traffic on M.D.C. streets to be observed.
7. Possibility of Massachusetts Turnpike extension to be provided.
8. Boston University expansion to be considered.
9. Parking problem to be solved.
10. Property damage to be minimized.

The areas to be covered in the proposals will therefore include:

1. Inner Belt between The Fenway and the Charles River.
2. Sears Roebuck intersection.

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* Brookline would suffer disproportionate property damage if the 1948 Master Plan report route for the Inner Belt were adopted (Fig. 1).

3. M.T.A. Commonwealth Avenue car-line relocation and service extension.
4. B.U. Bridge intersection.
5. Boylston Street-Storrow Drive-Commonwealth Avenue interchange.
6. Kenmore Square.
7. Boston University expansion.
8. Parking at Kenmore Square.
9. Boylston Street and Commonwealth Avenue intersection.

Some of the proposals are aimed at providing the maximum solutions for the improvement, the construction of which now will depend on (1) traffic conditions to be affected by the construction of the Inner Belt and the Massachusetts Turnpike extension from Weston, whether as a toll road or freeway; (2) acceptance of the improvement by the Federal Bureau of Public Roads and by the State Department of Public Works as a part of the interstate system, to be financed by the Government and the state on a 90%-10% basis or under the ABC program on a 50%-50% basis; (3) the cost of the improvement; and (4) special advantages of the improvement upon other important developments, such as parking facilities to the Red Sox ball games.

Although the proposals have been tailored for stage construction, indeed there would be greater savings in time and money if more proposals could be carried out at the same time.

THE PROPOSALS

All proposals herein are considered preliminary, although sufficient studies have been made to substantiate their feasibility from an engineering standpoint, barring unforeseen conditions. Since no reliable over-all topographical plans are available for this area, the base plans used for this paper have been prepared from a number of plans obtainable from sources mentioned at the end of this article. Naturally, there will be areas of discrepancy and inaccuracy. In critical areas, however, actual on-site measurements have been taken, and design studies have been made on large-scale 1″-to-50′ plans.

INNER BELT. Proceeding in the northerly direction after leaving The Fenway, the Inner Belt will be a "tunneled" or cut-and-cover section following Muddy River, which will be covered. The Fenway and the River Drive will be relocated and combined to form a six-lane roadway to go directly over the Inner Belt. This surface street and the land on both sides of it from the edge of the roadway pavement to the back of the existing sidewalk will be under the jurisdiction of the M.D.C. Thus, not only the park land can be replaced, but the problem of maintaining Muddy River, once a beautiful landmark but now a scummy, and hazardous (for children especially) body of water, can be eliminated. For those who will use this public land, there will no longer be the danger of crossing The Fenway and the existing heavily-traveled Park Drive in order to get to it. As to the residences and educational institutions on Park Drive and The Fenway, traffic will now be farther away from them, giving them more privacy, peace, and quiet (Fig. 5).

Still as a "tunnel" the Inner Belt will take a turn to the right behind the freight areas and warehouses of Sears, Roebuck and Co. The M.T.A. Highland Branch incline and perhaps the adjacent tunnel grade will be raised to permit the expressway crossing under it. The Inner Belt will then reverse to the left to cross Beacon Street, between the pavement surface of Beacon Street and the Beacon Street subway. At this crossing, Beacon Street will be raised and the subway lowered slightly to provide the vertical clearance required for the bridge for the Inner Belt at this point (Fig. 6).

During construction of this crossing traffic routing for the M.T.A. Beacon Street line may be a relatively simple matter. For example, a temporary turn-around for the Beacon Street car tracks may be constructed west of the existing subway portal or around Audubon Circle. The St. Mary Street stop on the Beacon Street line and the Park Drive stop on the Highland Branch may be used as transfer stops for the Beacon Street line riders. By such routing the complications experienced during the construction of the Central Artery under Dewey Square at South Station but over the Harvard Square-Ashmont rapid transit line while keeping the normal train services open will not be encountered. The same method may also be applied to the expressway tunnel construction at the Highland Branch crossing.

After crossing Beacon Street, the Inner Belt will surface to go over the B. & A. railroad, and following it the expressway will be elevated to cross Commonwealth Avenue as an overpass on the same location as the railroad under Commonwealth Avenue. West of the B.U. Bridge, the expressway will connect with the Massachusetts Turnpike extension and with Storrow Drive before crossing the Charles River to Cambridge.

Some filling on the Boston side of the river will be necessary for

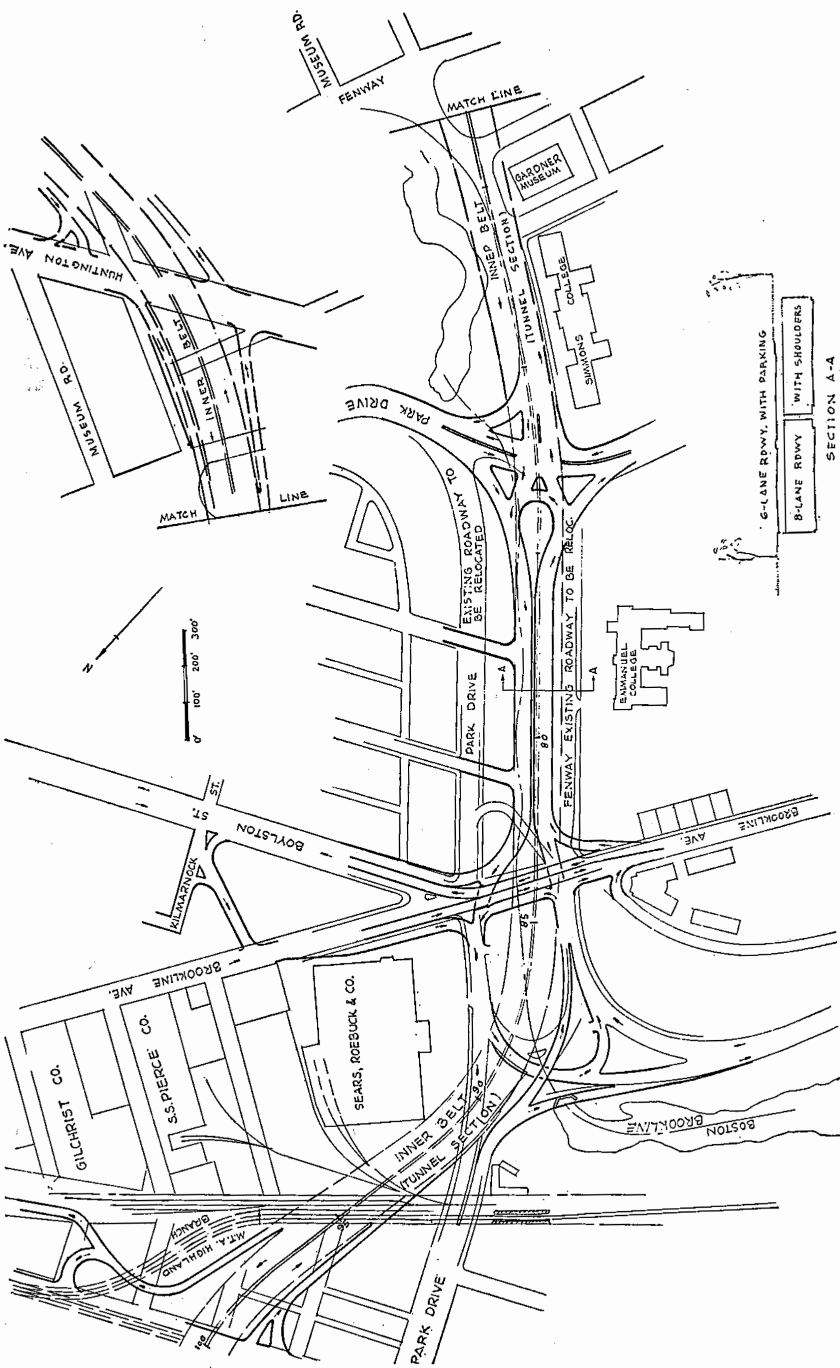

Fig. 5.—Proposed Improvement for Sears Roebuck Intersection and Residential Neighborhoods in Relation to Proposed Inner Belt.

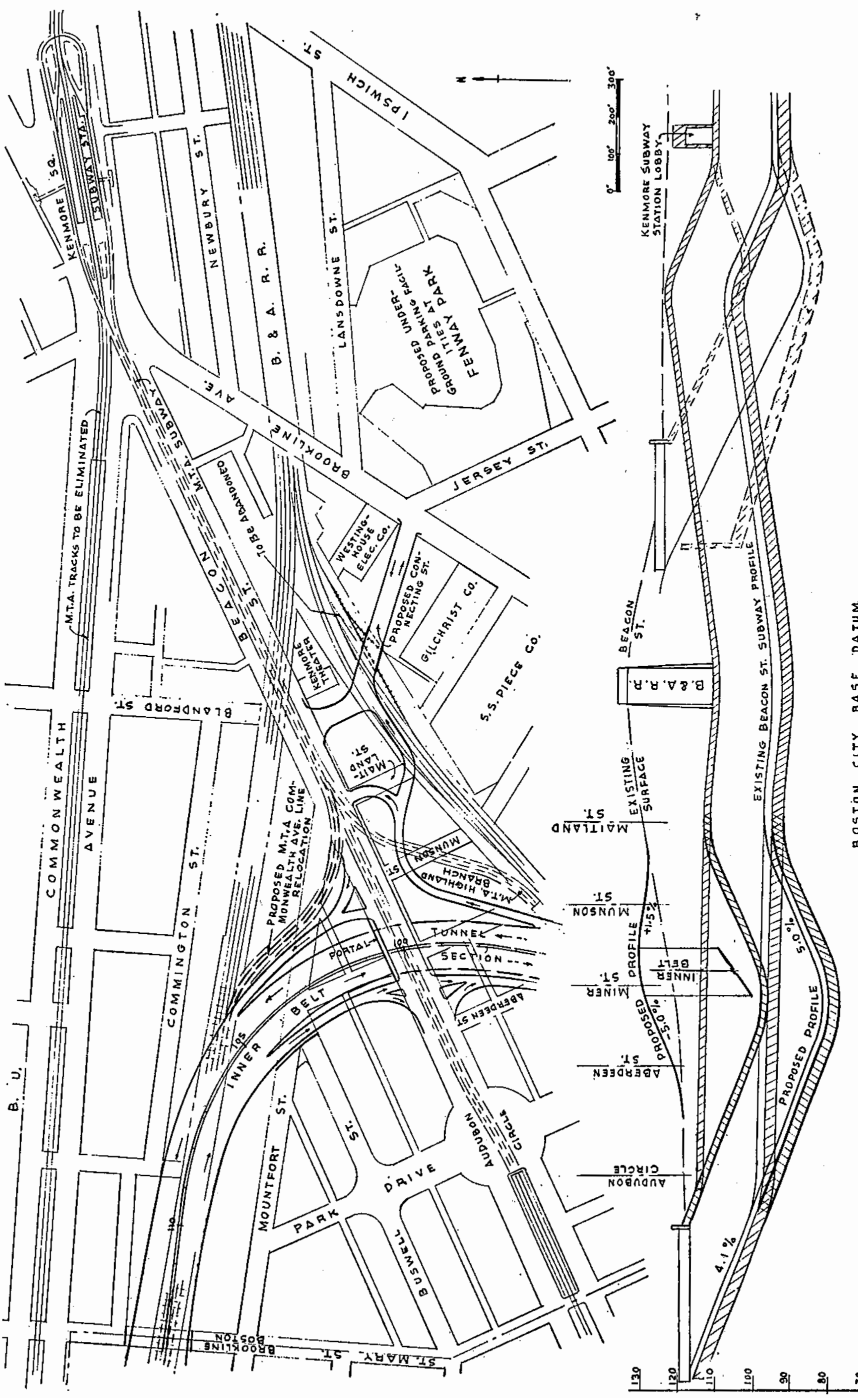

FIG. 6.—PROPOSED INNER BELT BEACON STREET CROSSING IN RELATION TO PROPOSED UNDERGROUND PARKING FACILITIES AT FENWAY PARK.

the ramp connections but the Cambridge side may be cut back. Taking advantage of this proposed embankment work, an added effort will be made to improve the narrowest roadway section of Storrow Drive under the B. & A. Grand Junction Branch railroad bridge. A maximum proposal would add three traffic lanes under another railroad bridge span (Fig. 7). The channel width of the Charles River basin at this point will be narrower, but it will not be any narrower than certain other channel crossings farther up the basin. Provision will be made for possible extension of the Turnpike to the South Station to go on the upper level of the Inner Belt for some distance over the B. &. A. railroad tracks (Fig. 7).

St. Mary Street on the Boston-Brookline border will be closed to traffic to allow the expressway to go on the street level in order to make a connection with Commonwealth Avenue in the vicinity of the Boston University Chapel.

Profile for the Inner Belt, together with the profiles for the Commonwealth Avenue through traffic underpass and the tunnel and incline for the relocated M.T.A. Commonwealth Avenue street-car line to be described later, is shown on Figure 8.

The main reasons for this alignment are (1) to serve the general area at Kenmore Square better by locating the Inner Belt more easterly from B.U. Bridge than by taking a course due north from Brookline Avenue between Park Drive and The Fenway; (2) to reduce property damage by using the B. & A. railroad right-of-way; and (3) by accommodating Massachusetts Turnpike Authority which has announced its intention to use the B. & A. railroad right-of-way for its extension to the South Station.

Taking all proposed improvements for the uptown area, and the route location for the Inner Belt as a collector-distributor, there will be need for four interchanges, not including one at Huntington Avenue (Route 9): a complete 4-ramped interchange with Beacon Street west of Kenmore Square; a complete 4-ramped interchange with Commonwealth Avenue, with one pair of ramps northwest of the B.U. Bridge intersection and another pair southeast of it; a partial interchange with Storrow Drive; and a 2-ramped interchange with the Massachusetts Turnpike extension or Western Expressway. These ramp locations have been based on land use information, highway proposals, and traffic studies, the sources of which are listed at the end of this article, and on physical possibilities and personal observations. Al-

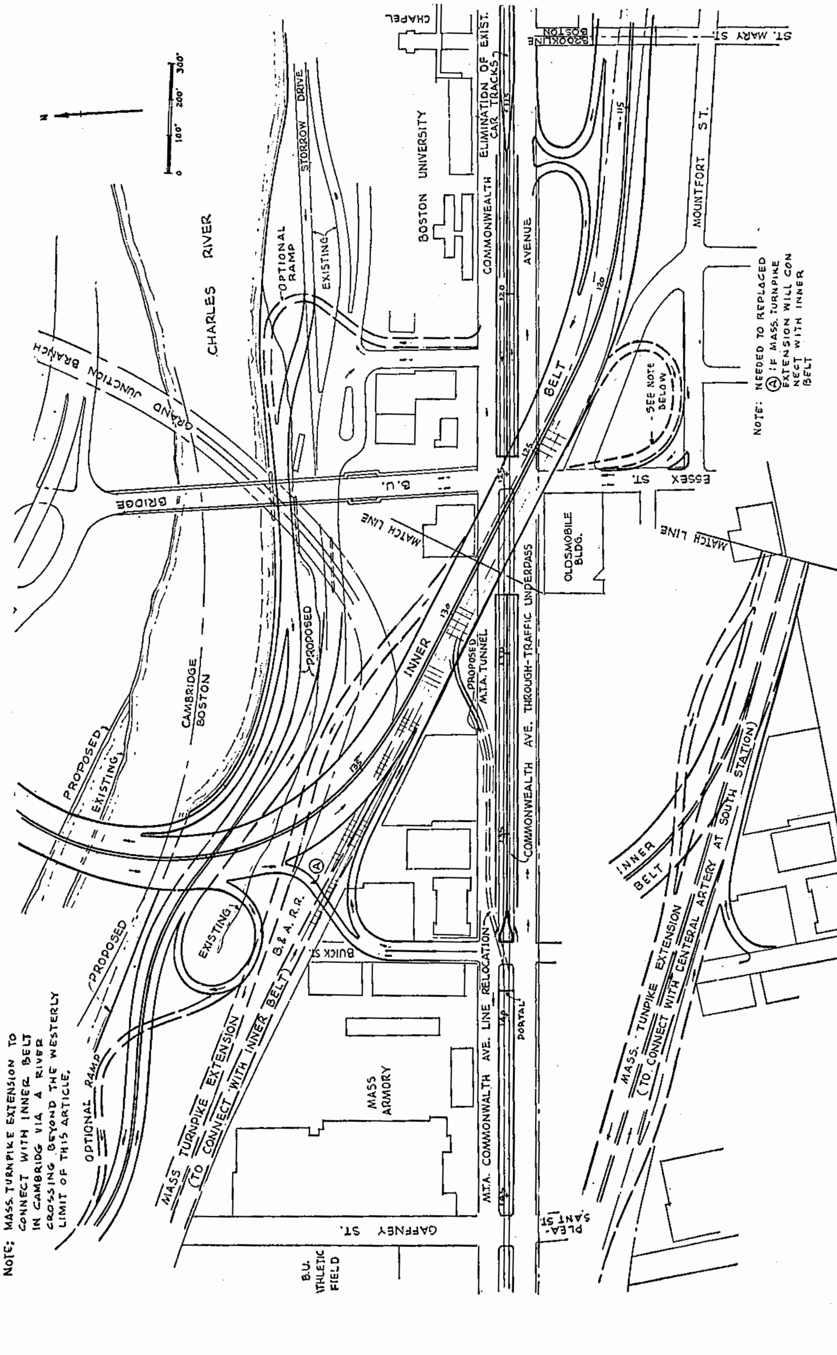

FIG. 7.—PROPOSED IMPROVEMENT FOR B.U. BRIDGE INTERSECTION IN RELATION TO PROPOSED INNER BELT.

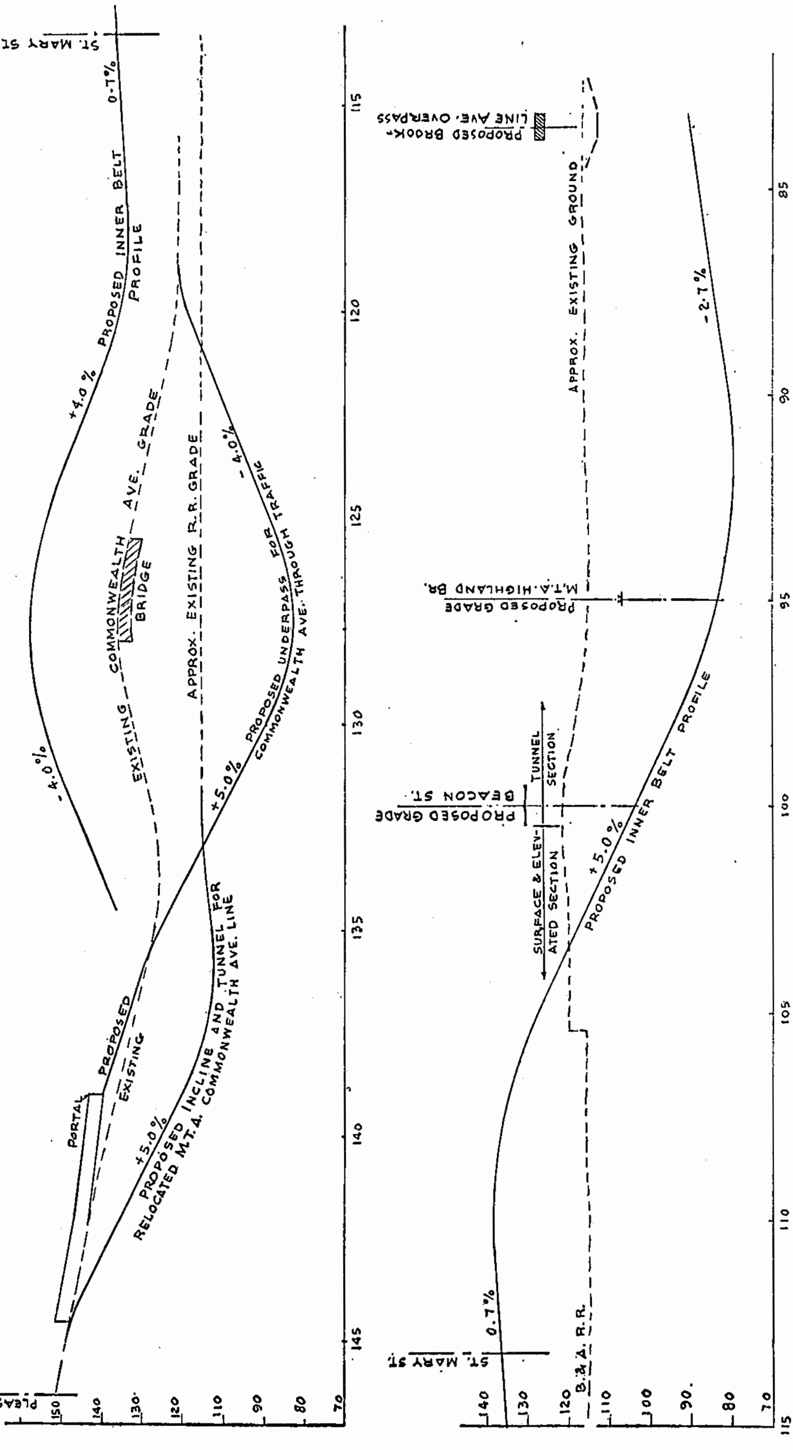

Fig. 8.—Profile of Proposed Inner Belt.

though the interstate system policy has not specified the frequency for interchanges in urban areas, the need of access and egress and safe operation seem to be the general rules.

This article will omit the connection between the Massachusetts Turnpike extension with the Inner Belt in Cambridge, since the connection will be made by a river crossing beyond the westerly territorial limit of this article.

SEARS ROEBUCK INTERSECTION. Even when the Inner Belt takes away a substantial portion of the traffic from this intersection, whether it will be entirely free from congestion is questionable because of traffic that will be induced to use the expressway and because of the possible intensified business development on Brookline Avenue and Boylston Street.

The congestion at the intersection now is due not so much to the over-capacity of Brookline Avenue, Park Drive, Boylston Street, The Fenway, Riverway, and Pilgrim Road, but rather to turning movements and to the operation of the large department store parking lot.

The present traffic improvement by the M.D.C., using signalization, channelization, and one-way streets, will definitely be helpful.

The proposal included in this paper represents a maximum solution within the physical limitations (Fig. 5). It will not reduce the parking area of Sears Roebuck and Co., but will improve its operation. The cost of construction will not be high, since the plan calls for only two overpasses; right-of-way cost is nil. The present M.D.C. improvement will lend itself well to the proposed scheme. If the proposed improvement can be considered as pertinent to the approach to the expressway and can be financed as an interstate system, there is no reason why its construction should be delayed.

RELOCATION OF COMMONWEALTH AVENUE STREET-CAR LINE. This is the first step toward improving operating conditions on Commonwealth Avenue.

At the Kenmore Subway Station the Commonwealth Avenue cars will use the Beacon Street car tracks, switching over to two of the four tracks on the main line of the B. & A. railroad, through a tunnel to be constructed between the Beacon Street car tracks and the railroad (Fig. 6), in the same manner as the Beacon Street car tracks now switching over to the Highland Branch through a tunnel just completed, using approximately the same profile for the Highland

Branch. Rail service will use the remaining two tracks, which will be sufficient for the purpose, according to the railroad. The Commonwealth Avenue street cars will be switched back to Commonwealth Avenue after B.U. Bridge by another tunnel to be constructed, reaching street surface at Pleasant Street before the Boston University's athletic field. This relocated line will have about the same number of stops as the present Commonwealth Avenue car line, but will have its own right-of-way with no cross traffic interference. This arrangement will provide another opportunity for the M.T.A. service extension to Auburndale in Newton using two tracks of the B. & A. railroad main line. It will also enable this Auburndale line to link with the Highland Branch to complete a circuit service (Fig. 9). It is believed that it will be a complementary line rather than a competitive line since they are so far apart, and since more services are being demanded on the Highland Branch.

The cost of construction will consist of two tunnels, conversion of rail facilities for the use of rapid transit trains, and right-of-way cost. If it were not for an additional tunnel, it would be comparable to the cost of the Highland Branch, the service of which was initiated last month. This improvement can be financed by the M.T.A.

With the removal of the street-car tracks, it will now be possible to add two new traffic lanes or a wide landscaped median strip to Commonwealth Avenue.

B.U. BRIDGE INTERSECTION. The second step toward improving the traffic conditions on Commonwealth Avenue is to eliminate the traffic bottleneck at B.U. Bridge intersection by constructing an underpass for the through traffic on Commonwealth Avenue (Fig. 7).

From the east, ramping for the underpass will begin just west of the Boston University Chapel. The underpass will be under the main line of the B. & A. railroad and will come to the surface on Commonwealth Avenue at St. Paul Street.

It is believed that the cost of construction of this improvement could come under the financing arrangement of the interstate system inasmuch as it will facilitate the access and egress to and from the system's two great expressways, the Inner Belt and the Massachusetts Turnpike extension, or Western Expressway.

BOYLSTON STREET-STORROW DRIVE-COMMONWEALTH AVENUE INTERCHANGE. Another traffic bottleneck is the dual intersection of Commonwealth Avenue with Charlesgate

East and Charlesgate West east of Kenmore Square. No less than thirty M.D.C. policemen are assigned traffic duty during the peak hours of the day from Boylston Street to Storrow Drive. Over the years several solutions have been made public by the M.D.C., but no serious attempts made to carry out plans for the improvement, pending construction of the Inner Belt, which might give the area some relief.

However, judging by the experience with Storrow Drive, the Central Artery, and the Southeast Expressway, especially with the recent and anticipated rail transportation curtailment between Boston and some of the suburbs, any new urban highway facility will reach design capacity soon after it is open. For this reason, and for the reason that Storrow Drive is performing a different and separate function as a restricted semi-limited access expressway, the traffic volumes there will not be expected to be reduced by the construction of the Inner Belt. Direct and improved connections between Storrow Drive and Boylston Street and between Storrow Drive and Commonwealth Avenue are urgently needed now and in the future after construction of the Inner Belt. Any delay will worsen traffic conditions and adversely affect the over-all activities in Kenmore Square.

The proposed improvement plan covering almost the entire area under the jurisdiction of the M.D.C. in the uptown represents an independent study by the author (Fig. 10) with no reference to any of the M.D.C. schemes except for the traffic data. The author has but one thought in mind: that should his proposals be incidentally similar in many areas to the M.D.C. studies, they would be so much more meritorious, for there would have been a meeting of the minds in solving the problems.

KENMORE SQUARE. With the traffic bottleneck on Commonwealth Avenue at B.U. Bridge and Charlesgate East and Charlesgate West, Kenmore Square can be effectively controlled by signalization and channelization. It should be pointed out, however, that with the Commonwealth Avenue car tracks eliminated, the present Kenmore Subway Station will not present too difficult though still a costly problem for a grade separation for the Commonwealth Avenue through-traffic if it should be needed in the future. Better operating conditions will be gained, however, by moving the M.T.A. terminal in the middle of Kenmore Square to the Beacon Street side of the Square, and the space vacated by the terminal will be used for left-hand-turn waiting lanes, and also for a landscaped median strip (Fig. 10).

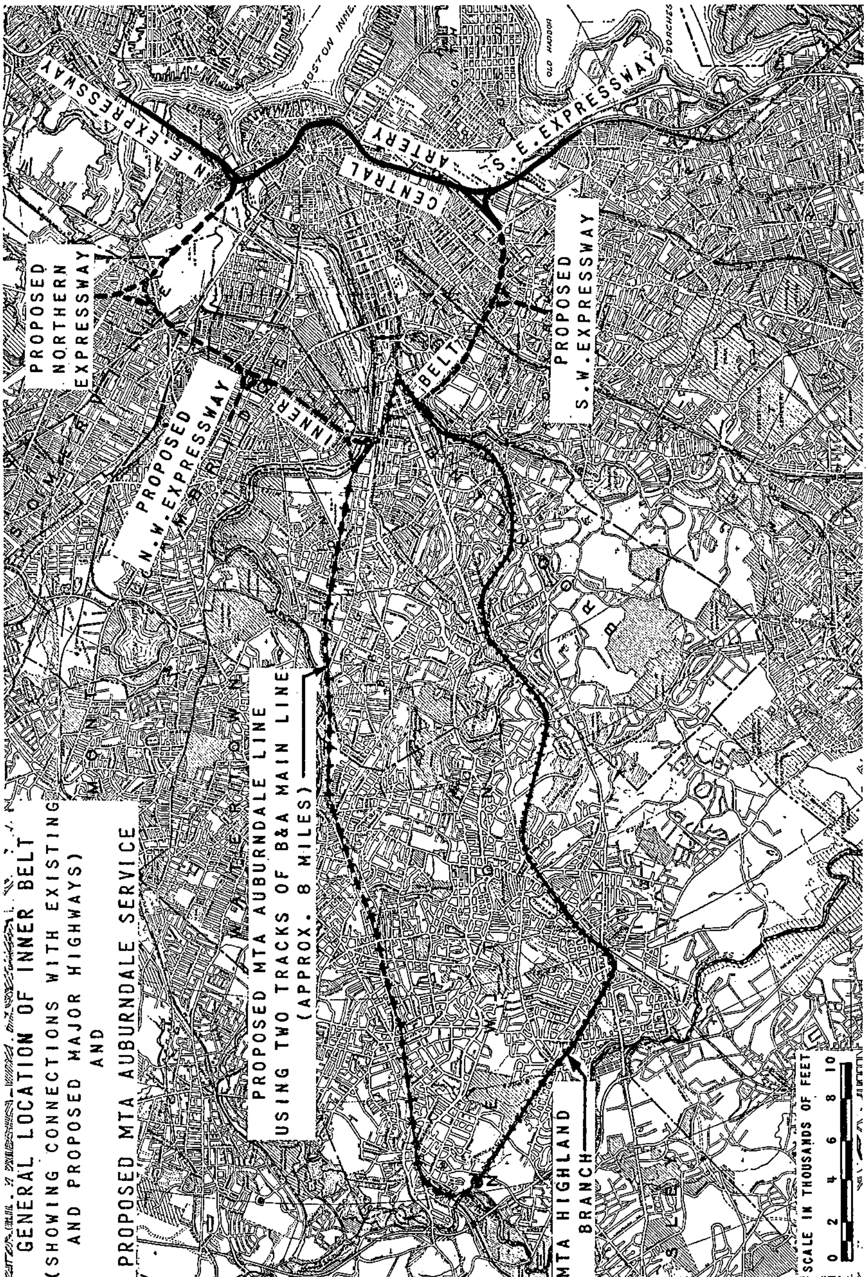
GENERAL LOCATION OF INNER BELT
(SHOWING CONNECTIONS WITH EXISTING
AND PROPOSED MAJOR HIGHWAYS)
AND
PROPOSED MTA AUBURNDALE SERVICE
PROPOSED MTA AUBURNDALE LINE
USING TWO TRACKS OF B&A MAIN LINE
(APPROX. 8 MILES)
MTA HIGHLAND
BRANCH
SCALE IN THOUSANDS OF FEET
0 2 4 6 8 10
PROPOSED
N.W. EXPRESSWAY
PROPOSED
NORTHERN
EXPRESSWAY
N.E. EXPRESSWAY
CENTRAL
ARTERY
S.E. EXPRESSWAY
PROPOSED
S.W. EXPRESSWAY
INNER
BELT

Fig. 9.

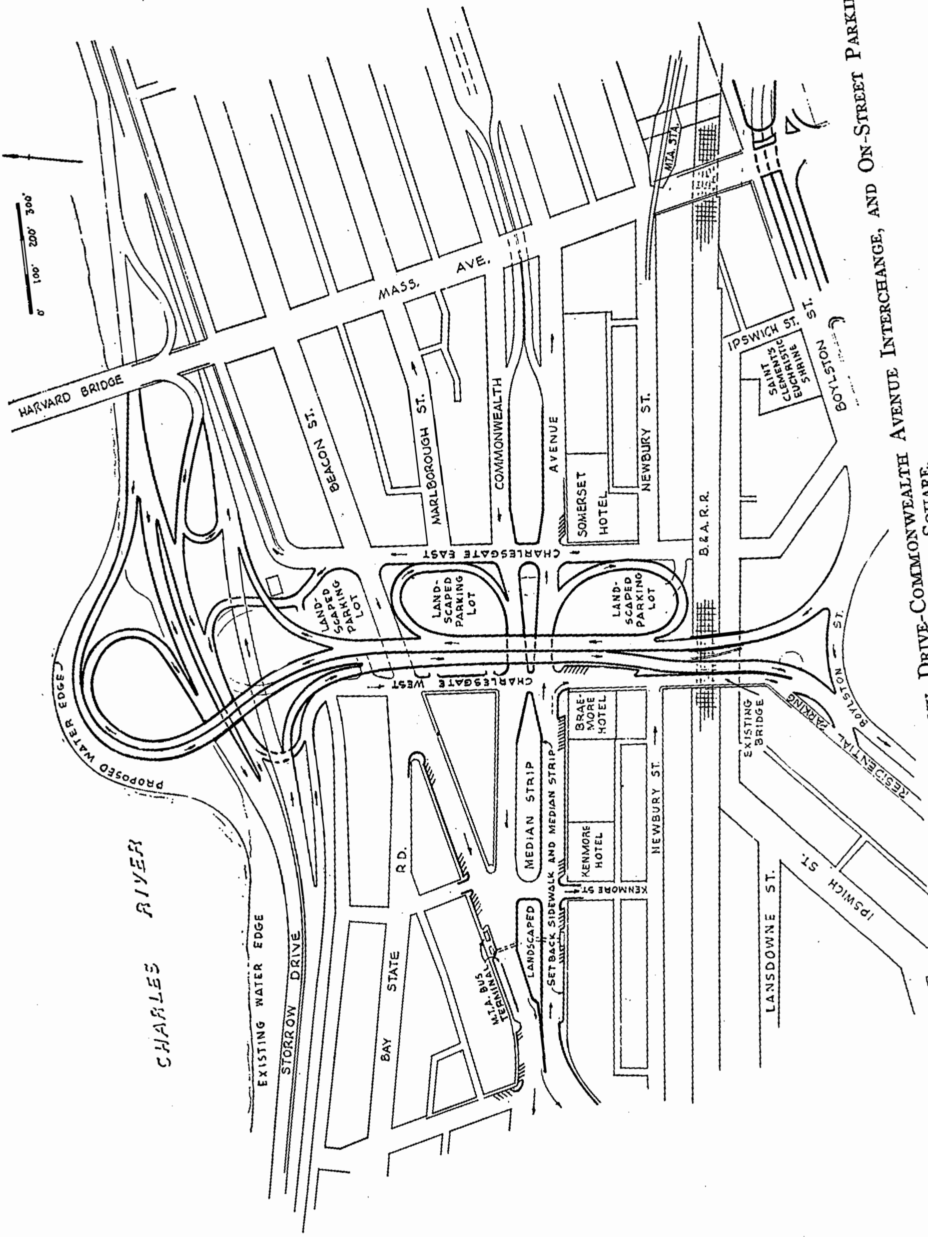

FIG. 10.—PROPOSED BOYLSTON STREET-STORROW DRIVE-COMMONWEALTH AVENUE INTERCHANGE, AND ON-STREET PARKING AT KENMORE SQUARE.

After the construction of the Boylston Street-Storrow Drive-Commonwealth Avenue interchange, with the entire length of Charlesgate West for one-way traffic going south, it will be necessary to reverse the traffic directions on Kenmore Street and Newbury Street adjoining it.

BOSTON UNIVERSITY EXPANSION. Boston University is an urban university, and as such it is tied in with the destiny of Boston, a great urban center. But unfortunately at times, the growth of this institution of higher learning is not compatible with other inherent elements of the city, such as the expressways designed to serve an urban area. While Boston University would like to preserve an adequate area for expansion, the Inner Belt also should be strategically located in order effectively to facilitate traffic movement, and help relieve congestion. To deny the uptown area of this expressway now is to deny the opportunity of a sick one to be cured when there is time to do so, because the area will soon be robbed of its vitality and life by traffic ailment. Boston University, having the largest stake in the uptown district, would like least of all to see this happen.

In an urban area, planning is usually a give-and-take, live-and-let-live proposition. With the Inner Belt routed and and the M.T.A. Commonwealth Avenue car line relocated on the B. and A. railroad right-of-way, along and adjacent to the "service" area of the University, Commonwealth Avenue will be left for the frontal development of the University. The Inner Belt will cross Commonwealth Avenue as an elevated roadway at the same location as the Commonwealth Avenue Bridge over the B. and A. railroad main line thereby using no buildable land on either side of Commonwealth Avenue for the crossing.

These improvements will enable Boston University to have a wide tree-lined landscaped boulevard, with no street-car tracks or overhead power lines and with much less traffic annoyance. Commonwealth Avenue now has a right-of-way of 160 feet. From buildings on one side of Commonwealth Avenue to the other side, the open area will easily measure 250 feet, and a great deal can be done in the way of landscape treatment to create an intown campus.

Parking facilities will be provided by the University for both staff and students.

The Graduate Center with dormitory facilities will be developed between the Inner Belt, Beacon Street, and St. Mary Street. There will be pedestrian overpasses connecting the developed section of the

University with the Graduate Center. Extra land, remnants of parcels acquired through taking for, but not used by, construction of the expressway, may be sold to Boston University for developmental purposes.

The planning for new buildings, including laboratory and parking facilities, and the Graduate Center along the railroad will be the responsibility of a team of architects, planners, and landscape architects.

PARKING PROPOSALS. There is a scarcity of convenient sites at Kenmore Square and general vicinity for parking garages.

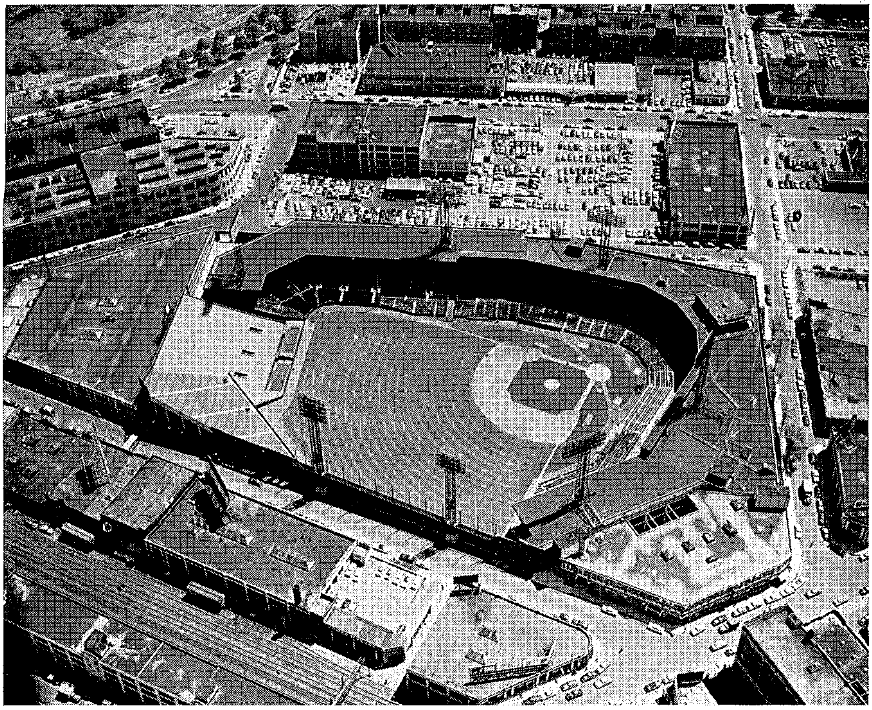

FIG. 11.—AERIAL PHOTOGRAPH OF FENWAY PARK.

To solve the problem of parking at Kenmore Square, an underground garage is proposed on the site of Fenway Park (Fig. 11). It will be constructed under the open area of more than 100,000 square feet in the ball park, and can accommodate more than 330 cars comfortably on one level, with passages open for cars to get in and out at any time. By using three levels, the garage will have a capacity of approximately 1000.

There are several reasons for choosing this location for the garage rather than some other location, in the vicinity of Kenmore Square. It will be more convenient for the Red Sox fans, but no less direct for other users from Kenmore Square and the general vicinity. Fenway Park, idle most of the year when there are no ball games, will be financially more productive; and more land of high value at Kenmore Square, at least the equivalent of the floor area of one level of the garage, will be available for primary business and office use. It will better serve the Beacon Street interchange of the Inner Belt. There will be little clearing and demolition cost, and the land cost will be inconsequential but construction cost will be higher because of the need of waterproofing and air-conditioning.

Nevertheless, from preliminary information gathered, it would seem that the operation of the garage could still be a paying proposition as a publicly financed or subsidized (that is, with tax concessions) facility, because of the constant turnover of patronage from the ball games, hotels, restaurants, businesses, and offices, and Boston University. Some motoring workers, too, may want to leave their cars at the garage and use the M.T.A. transportation for their final destinations in the downtown area.

It would be more practical, if the Red Sox Baseball Club, which has constantly voiced the parking need for the fans, could join in this undertaking. Further investigation is recommended.

It is estimated that it will take from 17 to 24 months for construction of the garage, depending on the soil conditions. During that time, the inactive Boston University's Athletic Field on Commonwealth Avenue could be loaned to the Red Sox Baseball Club for the games.

The former Braves Field had a slightly larger capacity (36,000) than Fenway Park (33,000), but the recent removal of a portion of the stadium structure considered unsafe by the City's Building Department has somewhat reduced the seating capacity of the field. If necessary, however, the structure can be rebuilt. The legality of using tax-exempt property of an educational institution can be settled, for example, by requiring the Red Sox Baseball Club to pay the City the real estate tax on the field during the playing season or seasons.

Another possibility for a parking garage within convenient walking distance to Kenmore Square and vicinity is the site now occupied by two parking lots on Newbury Street behind the Kenmore Hotel. Jam-packed, they now have 150 parking spaces and might have a capacity for about 350 to 400 cars in a three-story ramped garage. This site is not likely to be affected by the possible Massachusetts Turnpike extension to the South Station using the B. and A. railroad right-of-way.

In addition to these two sites, it is suggested that parking facilities be provided by Boston University for its staff and students. Space near the railroad and the Inner Belt may be used advantageously for this purpose.

With these facilities provided, it would therefore seem that the problem of parking would not be so acute that it could not be met by local individual efforts. At present practically all on-street parking in the uptown area is parallel to curb. The linear curb distance required is approximately 22 feet for each car. Diagonal parking, on the other hand, requires less than half of this distance for each car, although additional width equivalent to one traffic lane is needed. The mathematical advantage is obvious, if the additional width can be provided by narrowing existing sidewalks and median strips, and by permitting only one-way operation on some of the two-way streets.

Figures 10 and 12 show some examples of what can be done.

The last, but not the least, factor in connection with the successful operation of parking facilities is strict law enforcement, which, of course, needs no emphasis.

BOYLSTON STREET AND COMMONWEALTH AVENUE INTERSECTION. The last area considered for improvement is the Boylston Street and Commonwealth Avenue intersection. The reason for the proposal is not because of serious traffic congestion there, but because of the future development of the Prudential Center and Boston's Convention Hall, both of which will be traffic generating points. One of the busiest intersections along Massachusetts Avenue, nevertheless, it has lower traffic volumes than the grade-separated intersections at Huntington Avenue to the south and at Commonwealth Avenue to the north of it.

Development of the Prudential Center will directly add to the activities of the Huntington Avenue intersection, which is now being taxed to full, if not already beyond capacity. Because of the physical

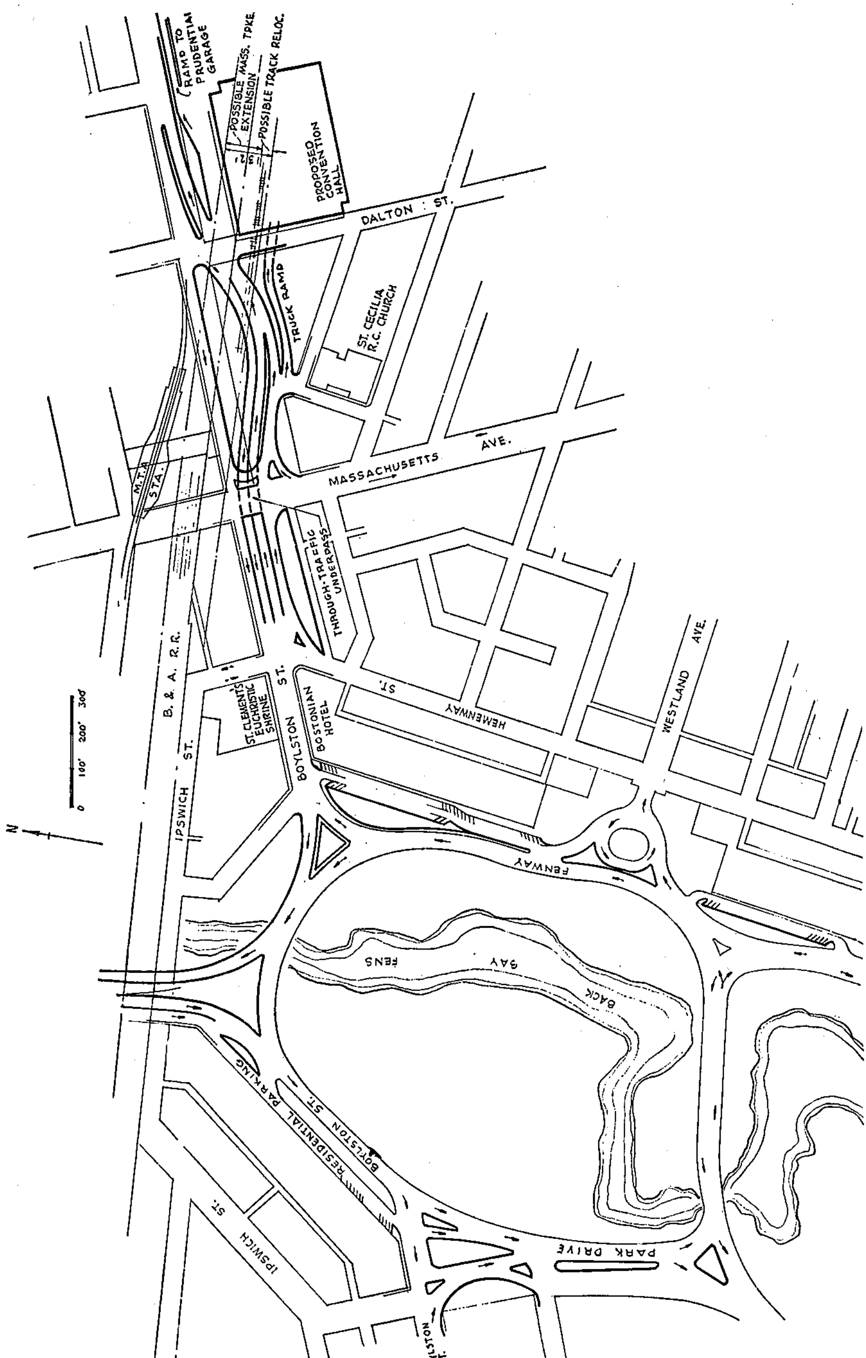

FIG. 12.—PROPOSED IMPROVEMENT FOR BOYLSTON STREET-MASSACHUSETTS AVENUE INTERSECTION, AND ON-STREET PARKING FOR RESIDENTIAL NEIGHBORHOODS AT THE FENS.

limitations imposed by the Huntington Avenue subway (underpass) the Christian Science Church, Horticultural Hall, and Symphony Hall, any improvement will necessarily be on the opposite commercial and residential blocks, and it will be impractical, difficult, and costly. On the other hand, it will be a much lesser task to improve the Boylston Street intersection, because of more open area of the B. and A. railroad yard, wider Boylston Street, and fewer physical restrictions.

Improving this intersection will mean more convenient access to Prudential Center and the Convention Hall, lighter traffic load at the Huntington Avenue intersection, and better operating conditions on the surrounding streets; hence, the efficiency of the Boylston Street-Storrow Drive-Commonwealth Avenue interchange.

The proposal will consist of an underpass at Boylston Street (Fig. 12). The Boylston Street bridge will be retained, despite its poor aesthetic quality, for cost consideration and convenient traffic control during construction of the underpass. Possible extension of the Massachusetts Turnpike in the future over the B. and A. railroad tracks may necessitate the rebuilding of the Boylston Street bridge.

On a primary road system, this project may be carried out under the ABC program, with the Federal Government paying 50 per cent and the State 50 per cent of the cost. It would be less time-consuming, however, if it were done as a Chapter 90 work, with the State paying 50 per cent and the City paying 50 per cent; and since the improvement is vital to the development of the Prudential Center with an underground garage for over 4,000 cars, the City would certainly appreciate, if the Prudential Insurance Co. could help in some practical ways to bring about early realization of this improvement.

THE RESULTS

The accrued results can now be summarized as follows:

1. For the Inner Belt:
   - *a.* An 8-lane "tunneled" limited-access expressway serving the uptown area, with four interchanges and a possible connection with the future Massachusetts Turnpike extension, or Western Expressway.
   - *b.* Minimum land and property taking and minimum disturbance to local communities.
2. For the Metropolitan District Commission:
   - *a.* Retention of park land, traffic restriction, and one-way streets.
   - *b.* Elimination of maintenance problem for Muddy River.

   c. More developed play area.
   d. No traffic bottlenecks.
   e. Substantial savings in traffic policing.
3. For the City of Boston:
   a. No traffic bottlenecks on Commonwealth Avenue throughout the uptown area.
   b. An improved 8-lane Commonwealth Avenue with parking on both sides, a landscaped median strip, no street car tracks, and no overhead power lines.
4. For the Metropolitan Transit Authority:
   a. A relocated Commonwealth Avenue line having its own right-of-way, with no cross traffic from Kenmore Square to the Commonwealth Armory.
   b. An opportunity for service extension to Auburndale, Newton, on two of B. and A. railroad main line tracks.
5. For Massachusetts Turnpike Authority:
   a. Provision for an interchange with the Inner Belt.
   b. Provision for an extension on the upper level of the Inner Belt to proceed to the South Station over the Boston and Albany railroad tracks.
6. For Boston University:
   a. Little property damage.
   b. Inner Belt and relocated M.T.A. line along the "service" area of the University only — not the "front door."
   c. An opportunity for capitalizing on the improvements for the development of an in-town campus.
   d. An assist to the development of a master plan.
7. For Emmanuel College, Simmons College, Gardiner Museum, and the residential sections in the vicinity:
   a. More privacy, less traffic disturbance.
   b. More park and play areas.
   c. No dangerous crossing for residents to get to these areas.
8. For Sears Roebuck and Co., S. S. Pierce Co., Gilchrist Co., etc.:
   a. No service disruption.
   b. More efficient parking, loading, and shipping operations because of better traffic conditions.
9. For Red Sox Baseball Club, businesses, and offices at Kenmore Square area:
   a. Better service by Inner Belt, by virtue of its location.
   b. An underground parking garage at Fenway Park.
   c. Increased on-street parking spaces.
   d. Better opportunity for business and office development.

Reference to the minimum planning objectives set forth will reveal that they have been excelled in many respects by the above-listed results, which can be accomplished only by planning on a comprehensive basis without the territorial and functional restrictions of a planning agency for any one community or facility.

CONCLUSIONS

While there is no disagreement as to the wisdom of basing highway and transportation planning on a regional or metropolitan concept, the working mechanism has been a subject of controversy usually on account of traditional city-suburb rivalries and conflicts of interest.

The recent formation of the 11-member Massachusetts Transportation Commission with appointees representing the Boston Port Authority, Massachusetts Department of Public Works, Massachusetts Turnpike Authority, Boston Traffic Commission, M.D.C., M.T.A., and other related fields, with the purpose of integrating and coordinating all planning for the metropolitan area, is a step in the right direction. Until this organization has become an active, effective, and constructive unit, highway engineers and city planners should be doubly aware of the regional significance of their highway and transportation problems, and should work out their proposals in the long-range interest of their own communities as well as others in the metropolitan area.

This is a gigantic task. The first step will be for the highway engineering offices to equip themselves with qualified city planners, and for the planning offices, with competent highway, traffic, and transportation personnel, so that both agencies can understand the common problems they are dealing with, and can agree at least on the logical common approach to the problems, if not the common solutions. It is not infrequent to hear questions raised at meetings between the highway engineers and city planners such as "Will the difference of one-foot in right-of-way mean shifting a highway alignment hundreds of feet away?". "Will an expressway spell ruin to the public land or a residential neighborhood?" "Will a body of water or a railroad mean an impasse?" The answers would likely be arbitrary. But in planning a facility in an urban area, nothing should be arbitrary. The assumption that city planners are determining the general locations, and the highway engineers the feasible details, is no longer valid; for as long as they can agree on the common planning objectives, acceptable solutions will eventually be found. There is always room for maneuverability in engineering and planning.

The second step will be for the highway engineers and city planners to take their programs to the political office-holders and the citizenry, and their proposals must be realistic and presented in plain everyday language. Nothing will be gained if they (highway engineers and city planners) stay professionally aloof, or if their proposals are too high-sounding to gain some measure of acceptance by the general public at large.

No plan, however good, will have a chance of being realized if it cannot interest at least one politician. Indeed, politicians today, unlike those of yesterday, are not afraid of constructive public works programs, especially pertaining to highways and transportation, even if they necessitate displacement and dislocation of some industry, business, and residence units. But they cannot go too far beyond what their constituency believes, or can be persuaded to accept. So, in the final analysis, it is the citizenry which holds the destiny of these programs.

Under our democratic system, no problems are too complicated to be understood, and no responsibility too heavy to be undertaken, by private individuals. This has been proven time and again in the history of our nation, even in this age of scientific research. The time for delegating our own responsibility to our technical know-how, public office-holders, and local, state, and Federal governments is past. Private citizens must be informed, with the assistance from the professional men, and participate in the decision of policies which they accept and support. Their views will be expressed through their elected officials and implemented by the responsible administration.

The author does not claim credit for the original thinking in the solutions for many of these highway and transportation problems. Many readers of this article, even if not highway engineers or city planners, might have been, when they wished that they could go over or under an intersection when annoyed by traffic congestion, or wished that there could be more services like the M.T.A. Highland Branch, so that mass transportation problems could be simpler. The author, however, will be indeed gratified, if this is the first time that these problems affecting the general area, together with the proposed solutions are presented in tangible terms.

This article is written with the earnest hope that its information and appraisal may prove useful to those who are concerned with ending the highway traffic and transportation problems in the uptown district of Boston.

The author wishes to express his sincere appreciation to the following sources of information:

Boston Public Works Department, on streets and bridges.
Boston Traffic Commission, on traffic data.
Boston City Planning Board, on land use and for library materials.
Metropolitan Transit Authority, on subway system.
Metropolitan District Commission, on traffic data at B.U. Bridge and at intersections between Boylston Street and Storrow Drive.
Greater Boston Chamber of Commerce, for regional planning information.
Massachusetts Department of Commerce, for regional base plans.

Thanks are due to Rand McNally and Company, of Chicago, for their kind permission to use the Boston Road map as a base plan, and to Lenscraft Photos, Inc., of Boston, for kind permission to use their excellent aerial photographs.

The author is especially indebted to Mr. Harold K. McAfee, experienced structural engineer, Mr. Charles R. Kurz, experienced highway engineer, and friends, Mr. Robert F. Mulloney, Vice President of Kenmore Association, Inc., and to Mr. Charles Newton of N. B. Newton Realty, for many helpful suggestions and information.

Important References

Master Highway Plan for the Boston Metropolitan Area, 1948.
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Policy on Arterial Highways in Urban Areas — A.A.S.H.O.
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Transition Curves for Highways — Joseph Barnett, Public Roads Administration.
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Of General Interest

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

SEPTEMBER 23, 1959.—A Joint Meeting of the Boston Society of Civil Engineers with the Transportation Section, BSCE, was held this evening at the United Community Services Building, 14 Somerset Street, Boston, Mass., and was called to order at 7:00 P.M., by President Edward C. Keane.

President Keane expressed regret concerning the serious illness of Robert W. Moir, Secretary of the Society.

President Keane state that the minutes of the previous meeting held May 20, 1959 were published in the July, 1959 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:—

John L. Howard, who was elected a member March 19, 1890, and who died June 11, 1959.

Sumner Hazlewood, who was elected a member June 25, 1924, and who died June 23, 1959.

William H. Kraphol, who was elected a member May 17, 1948, and who died August 12, 1959.

Bernard J. Parker, who was elected a member March 17, 1937, and who died August 13, 1959.

Alonzo B. Crowell, who was elected a member December 18, 1894, and who died June, 1959.

Irving B. Crosby, who was elected a member January 23, 1924, and who died September 18, 1959.

Prof. Charles O. Baird, Jr., Secretary pro-tem announced the names of applicants for membership in the Society and that the following had been elected to membership on June 15, 1959:—

Grade of Member—J. Richard Braks, Woody L. Cowan, Carmin J. DeVito, Louis A. Forti, Jr., Richard W. Knapp, Henry E. Linden, Jose A. Tabush

President Keane stated that this was a Joint Meeting with the BSCE Transportation Section, and called upon Marcello J. Guarino, Chairman of that Section to conduct any necessary business of the Section at this time.

President Keane introduced the speaker of the evening, Mr. John M. Kyle, Chief Engineer, Port of New York Authority, who gave a most interesting talk on "Evolution of a Bridge". The talk was illustrated with slides.

The meeting was preceded by a dinner and seventy-three members and guests attended the dinner. Ninety-five members and guests attended the meeting.

The meeting adjourned at 8:45 P.M.

CHARLES O. BAIRD, JR.,
Secretary, pro-tem

ADDITIONS

Members

Donald G. Ball, 1 Payson Street, Lexington 73, Mass.

Richard J. Braks, 44 Rockmont Road, Arlington 74, Mass.
Laurits Bjerrum, Frostarudveren 42, Oslo, Norway
Edwin F. Coffin, Jr., 21 Crown Ridge Road, Wellesley 81, Mass.
James P. Collins, 3 Hammond Street, Cambridge 38, Mass.
Woody L. Cowan, 14 Carriage Lane, Winchester, Mass.
William L. Fletcher, 28 Glen Road, Reading, Mass.
William M. Kinch, 57 Boston Avenue, Somerville 44, Mass.
Karl H. Kinder, 4752 E 2nd Street, Tucson, Arizona
John Wm. Leslie, 42 Whitney Road, Medford 55, Mass.
Robert C. Libbey, 491 Commonwealth Avenue, Boston 15, Mass.
Henry E. Linden, 10 Cape Cod Lane, E. Braintree, Mass.
Eliot Sargent, 284 Commercial Street, Weymouth, Mass.
Bradford Savitz, 330 Adams Street, Quincy, Mass.
Brig. Gen. Alden K. Sibley, N.E. Div. Corps of Engs., 424 Trapelo Road, Waltham 54, Mass.
William Swift, Tashmoo West, Vineyard Haven, Mass.
Jose A. Tabus, 6a Ave 10-71 Jona 1, Guatemala, Guatemala, C.A.
Donald C. Taylor, 23 Samoset Road, Woburn, Mass.
Walter C. Woods, Vineyard Haven, Mass.
Mason Young, R.F.D., Derry, N. H.

Juniors

Cosmo D. Capobianco, 55 Avon Street, Somerville 43, Mass.
John A. Bushey, 141 Congress Street, Albans, Vermont
Domenic Frangioso, 155 Savannah Avenue, Mattapan, Mass.
Neal B. Mitchell, 1318 Commonwealth Ave., Apt. 16, Allston, Mass.

Deaths

Alonzo B. Crowell, — 1959
Willbur W. Davis, April 15, 1959
Sumner Hazlewood, June 23, 1959
John L. Howard, June 11, 1959
William H. Krapohl, August 12, 1959
Daniel M. Moore, April 14, 1959

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