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JOURNAL OF THE
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Volume 50 OCTOBER, 1963 Number 4

RECONSTRUCTION OF DRY DOCK NO. 3 AT THE PORTSMOUTH NAVAL SHIPYARD
(Part One)

BY CAPTAIN J. E. REHLER*

(Presented at a joint meeting of the Boston Society of Civil Engineers and the Construction, Hydraulics, and Structural Sections, BSCE, held on May 8, 1963).

Mr. Frank Lincoln, Mr. Al Watts and I are pleased to be here with you this evening to have the privilege of telling you something about the Reconstruction of Dry Dock #3 at the Portsmouth Naval Shipyard. The reconstruction was part of a major construction program undertaken to provide the Portsmouth Naval Shipyard with the facilities, first in the country, for the construction, overhaul, and repair of nuclear-powered Polaris submarines.

A brief outline of the history of submarines will be of interest. Ancient history includes occasional records of attempts at underwater operations in warfare. For example, divers were used by the Athenians in the fourth century B.C. to clear the harbor entrance of Syracuse, and by Alexander the Great during his fourth century B.C. siege of Tyre.

In 1580 appears the first record of a craft designed to be navigated under water. The designer, a British Naval Officer named William Bourne, never built his craft, however. It is to Cornelius Van Drebel, a Dutch physician, that credit is usually given for actually building the first submarine. In 1620, the year the pilgrims landed, he constructed a wooden craft covered with greased leather and which carried twelve oarsmen for propulsion. It could stay submerged for several hours by obtaining air through tubes supported on the surface by

* Civil Engineer Corps, United States Navy.

floats (the first snorkel). Although the craft operated successfully and James I actually embarked, it failed to arouse the interest of the British Navy; perhaps they were awaiting nuclear propulsion!

Submarine boats seem to have been numerous in the early years of the 18th century. Ideas were plentiful, some of them fanciful and grotesque, but some containing elements capable of practical application. Despite the rather remarkable success of these crafts, and the attempts of the disheartened designers to sell their ideas to any country that would have them, submarines received only fitful support. This was due to the lack of understanding of the physical and mechanical principles involved, coupled with the well-nigh universal conviction that underwater navigation was impossible and of no practical value.

During the American Revolutionary War, a submarine was first used as an offensive weapon in naval warfare. The plan was for David Bushnell's one-man submersible (see Fig. 1) to attach a charge of gunpowder to the bottom of the *HMS Eagle* with screws and explode it with a time fuse. Failing to penetrate the copper sheathing of the hull, the *Turtle* was forced to release the charge and withdraw. Upon explosion of the powder, the *Eagle* at once considered it prudent to shift to a berth farther out to sea. David Bushnell was a college student at Yale; in that instance Yale apparently was ahead of Harvard!

During the Civil War, the South, under heavy handicap for lack of a sizeable Navy, built a small hand-propelled submarine notable for its persistence. After many months of frustrations and the loss of five test crews, the Confederate *Hunley* (see Fig. 2) succeeded in sinking the *USS Housatonic* using a charge held on a spar a few yards ahead of herself. Unfortunately the first sinking of an enemy ship by a submarine also resulted in the sinking of the *Hunley*. So we can consider this a standoff!

Between the end of the Civil War and 1900, advances were made which resulted in what might be called the beginnings of the "modern" submarine. Among them were the self-propelled torpedo, perfection of the steam engine, and development of electric motors and the gasoline engine. The U.S. Navy invited bids for a submarine when Admiral Dewey testified after the Spanish American War that if Spain had had two submarines at Manila, his forces could not have held the harbor. Dominant figures in the U.S. Submarine design at that time were John Holland and Simon Lake. (See Fig. 3 and Fig. 4).

All illustrations in Part One are Official Photographs, U.S. Navy.

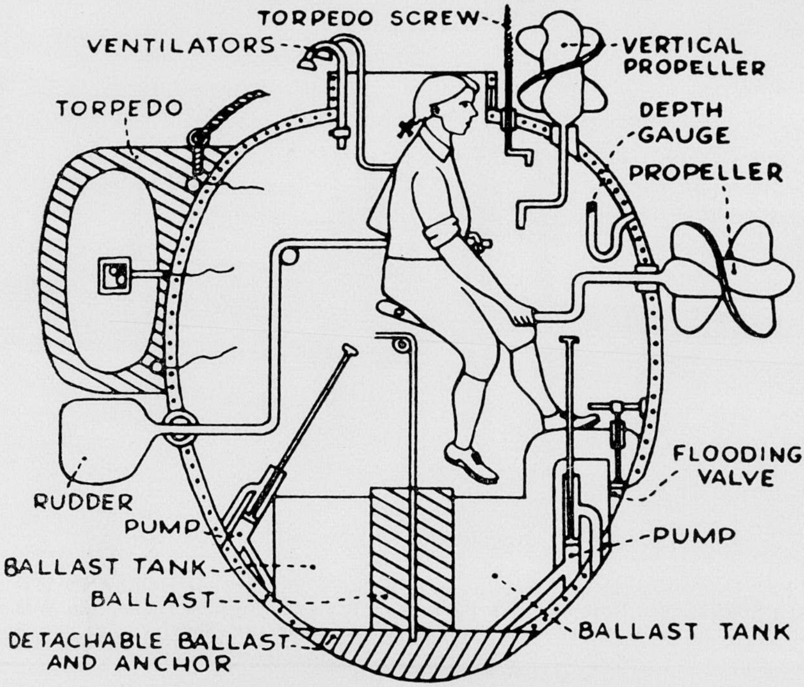


FIG. 1.—THIS CROSS-SECTION PICTURES THE TURTLE, AN INGENIOUS SUBMERSIBLE DESIGNED BY DAVID BUSHNELL WHILE HE WAS A STUDENT AT YALE. IN ATTEMPTING TO BLOW UP THE HMS EAGLE, WHICH WAS ANCHORED OFF NEW YORK CITY DURING THE REVOLUTIONARY WAR, THIS CRAFT BECAME THE FIRST SUBMARINE USED AS AN OFFENSIVE WEAPON IN NAVAL WARFARE.

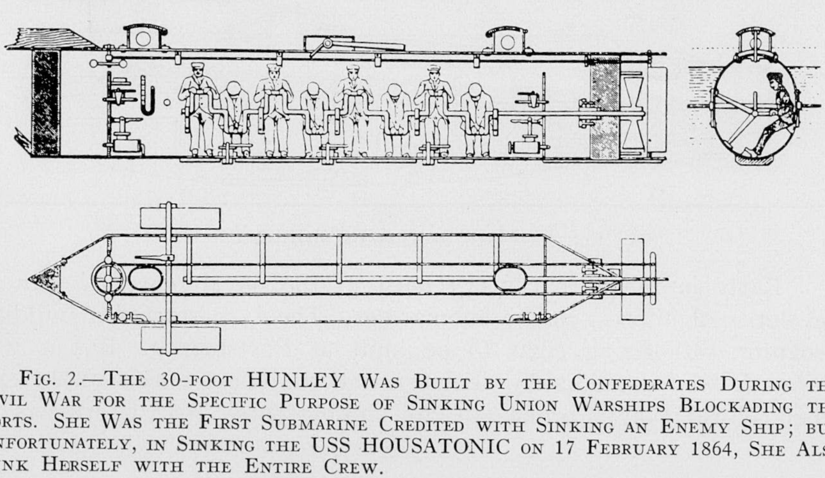


FIG. 2.—THE 30-FOOT HUNLEY WAS BUILT BY THE CONFEDERATES DURING THE CIVIL WAR FOR THE SPECIFIC PURPOSE OF SINKING UNION WARSHIPS BLOCKADING THE PORTS. SHE WAS THE FIRST SUBMARINE CREDITED WITH SINKING AN ENEMY SHIP; BUT UNFORTUNATELY, IN SINKING THE USS HOUSATONIC ON 17 FEBRUARY 1864, SHE ALSO SUNK HERSELF WITH THE ENTIRE CREW.

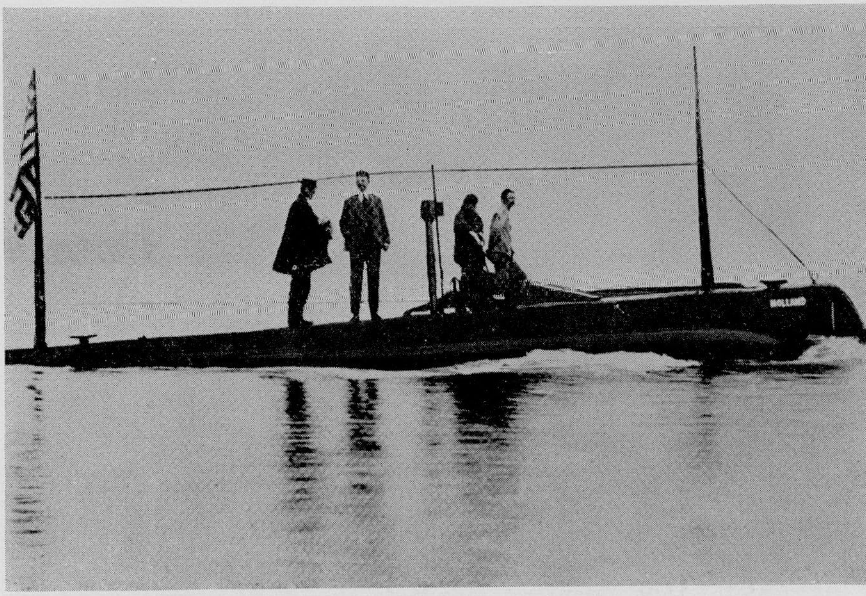


FIG. 3.—COMPLETED IN 1900 FOR THE U. S. NAVY, THE 54-FOOT HOLLAND WAS THE NINTH SUBMERSIBLE BUILT BY HER PERSISTENT BUILDER, JOHN HOLLAND, AND WAS THE FIRST EVER TO BE ACCEPTED AS A REGULAR ELEMENT OF ANY NAVY.

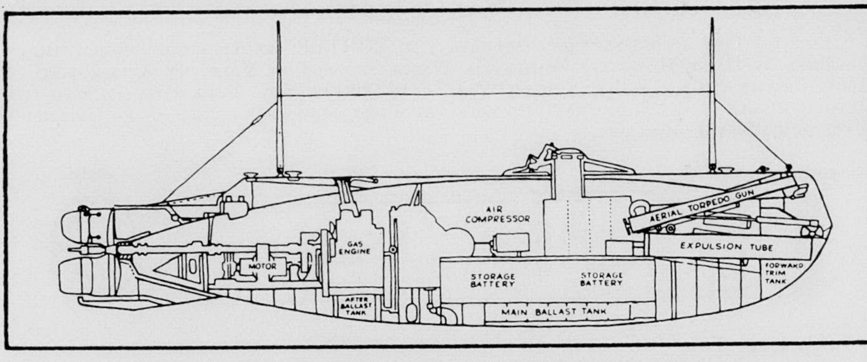


FIG. 4.—CROSS SECTION OF HOLLAND.

Early in the 20th century most of the naval powers began to develop real interest in the submarines. The U.S. started a building program authorizing eight to be built at Portsmouth. But it was Germany who immediately demonstrated the effectiveness of the sub when World War I broke out, by sinking three British cruisers in the North Sea on 22 September 1914. The first was hit and the other two came back to find out what had happened; they found out first-hand!

After the First World War, Portsmouth took her dominant place in the design and construction of submarines, completing 27 boats between 1924 and 1941, ranging in length from 300 to 381 feet. (See

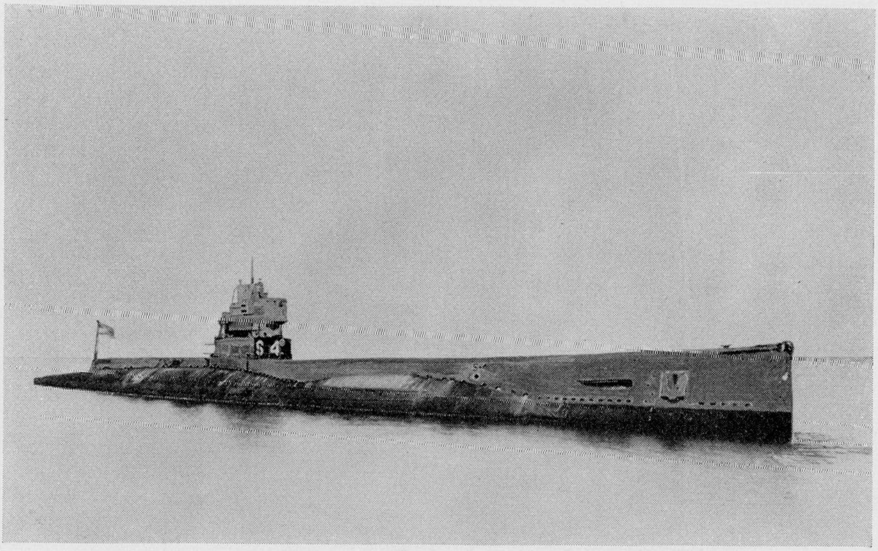


FIG. 5.—LAUNCHED IN 1919 BY THE PORTSMOUTH NAVAL SHIPYARD, PORTSMOUTH, NEW HAMPSHIRE, THE S-4 WAS 220 FEET LONG, WITH A 22 FOOT BEAM AND DISPLACEMENT OF 854 TONS. THE U.S. ENTERED WORLD WAR I WITH 24 DIESEL-POWERED SUBMARINES, BUT RECORDED NO CONFIRMED VICTORIES IN 21 CONTACTS WITH THE ENEMY.

Fig. 5 and Fig. 6). Of note was the completion in 1935 of the *Pike*—the first all-welded submarine. From 1942 to 1945, Portsmouth performed a production miracle of World War II by building 75 submarines. (See Fig. 7). During the war, U.S. submarines sank 5.6 million tons of Japanese shipping, including 5/6 of the entire Japanese merchant fleet. It is worthy of note that 63% of the shipping sunk was sent to the bottom by the U.S. Submarine Fleet which comprised 1.6% of our combatant ships.

One of the most radical changes in sub design was the introduction of the "Schnorkel" by the Germans during the latter part of the Second World War. The snorkel is a breathing device which permits a sub to run at periscope depth with diesel engines for unlimited periods of time.

About this time, ASW developments emphasized the importance of even a little more speed, depth capability, submerged time, and quietness. An interim step was the conversion of 20 World War II fleet subs to *Guppy* Class (see Fig. 8) which consisted of streamlining outer

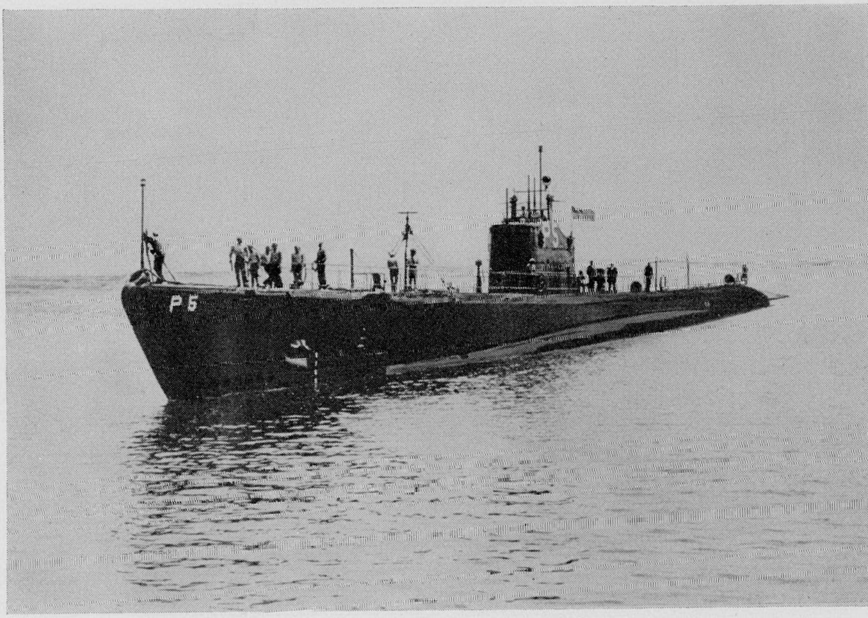


FIG. 6.—THE PERCH WAS TYPICAL OF THE SUBMARINES BUILT BETWEEN 1924 AND 1941. THEY AVERAGED 300 FEET IN LENGTH, WITH A BEAM OF 25 FEET AND DISPLACEMENT OF 1460 TONS.

hulls, increasing battery capacity, installing snorkel, and improving sonar, radar, and radio.

In 1953, a hydrodynamic research product of the David Taylor Model Basin, the Portsmouth-built *Albacore*, was commissioned. (See Fig. 9). She was the first sub designed for optimum submerged speed, rather than optimum surface operation with submerged operation only when required. Her radical hull shape made her the fastest sub in the world at that time, and due to continued experimentation in hull and propulsion modifications, she will soon again be the world's fastest sub.

Probably the most significant advance of all, however, was the commissioning of the nuclear-powered *Nautilus* in 1955. (See Fig. 10). This gave the submarine an almost unlimited range and eliminated all restrictions on deep-submerged time except the limitations of the crew itself. Four years later the first Fleet Ballistic Missile, or Polaris submarine, the *George Washington*, was commissioned, thus providing the Navy with the nation's foremost deterrent to a nuclear holocaust.

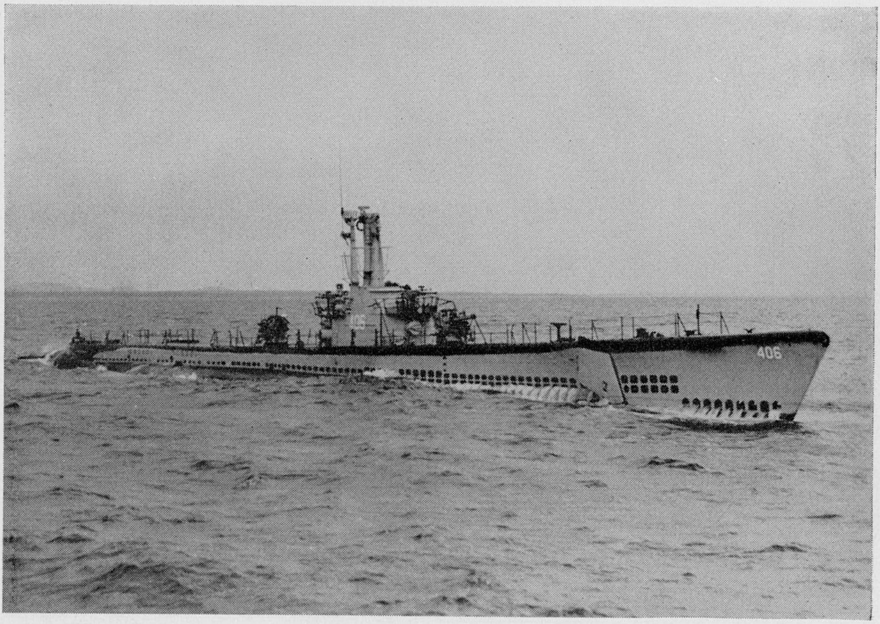


FIG. 7.—LAUNCHED IN 1944 BY THE PORTSMOUTH NAVAL SHIPYARD, PORTSMOUTH, NEW HAMPSHIRE, THE SEA POACHER WAS TYPICAL OF THE 75 FLEET TYPE SUBMARINES BUILT BY THAT YARD BETWEEN 1942 AND 1945. THEY AVERAGED 310 FEET IN LENGTH, WITH A BEAM OF 27 FEET AND DISPLACEMENT OF 1525 TONS.

It is difficult to conceive that the warhead of each of the 16 missiles on an FBM submarine packs more explosive power than was unleashed during the entire Second World War.

In 1961, the Portsmouth-designed-and-built *Thresher* was completed. She was the country's leading attack sub, incorporating improved living conditions, advanced sonar and weapon system; and was the world's fastest, quietest and deepest diving submarine. The Portsmouth Naval Shipyard and the Navy as a whole was, and is, proud of the *Thresher*, and she will continue to be the basis for new and improved attack submarines.

Having completed that brief sketch of the development of the submarine, I'm now at a point to tell you where the Civil Engineer Corps officer fits into the picture. Through his parent organization, the Bureau of Yards and Docks, he is responsible for the construction and maintenance of the shore establishment of the Navy, which, of

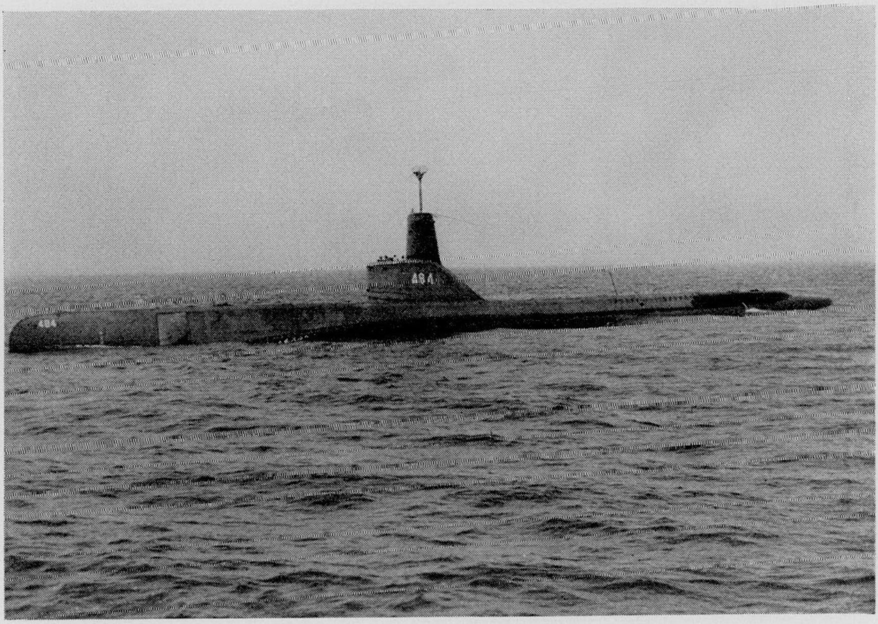


FIG. 8.—BASED ON LESSONS LEARNED DURING WORLD WAR II, PORTSMOUTH NAVAL SHIPYARD, PORTSMOUTH, NEW HAMPSHIRE PIONEERED IN THE DESIGN AND CONVERSION OF 20 WORLD WAR II FLEET SUBS TO GUPPY TYPES, WHICH CONSISTED OF STREAMLINING OUTER HULLS, INCREASING BATTERY CAPACITY, INSTALLING SNORKEL, AND IMPROVING RADAR, SONAR, AND RADIO.

course, exists solely to support the fleet. As the composition of the fleet changes, so must the supporting shore establishment change to keep pace with the fleet. To prolong the life of a ship, to inspect, to repair, or to modernize it, requires that from time to time, it be removed from the sea to permit work in the dry. Here then is one of the jobs of the Navy's Bureau of Yards and Docks—the planning, design, construction, maintenance, and operation of dry docks.

A dry dock, or as it is sometimes called a graving dock, is defined as an elongated, narrow basin excavated in the foreshore of a harbor. The word "graving" incidentally means to clean or scrape the bottom of a ship, which was the original purpose of the graving dock. The graving dock's entrance is closed by a movable caisson or gate. The basin is constructed so that a vessel may be placed in it and the water removed, allowing the vessel to settle on supports located on the

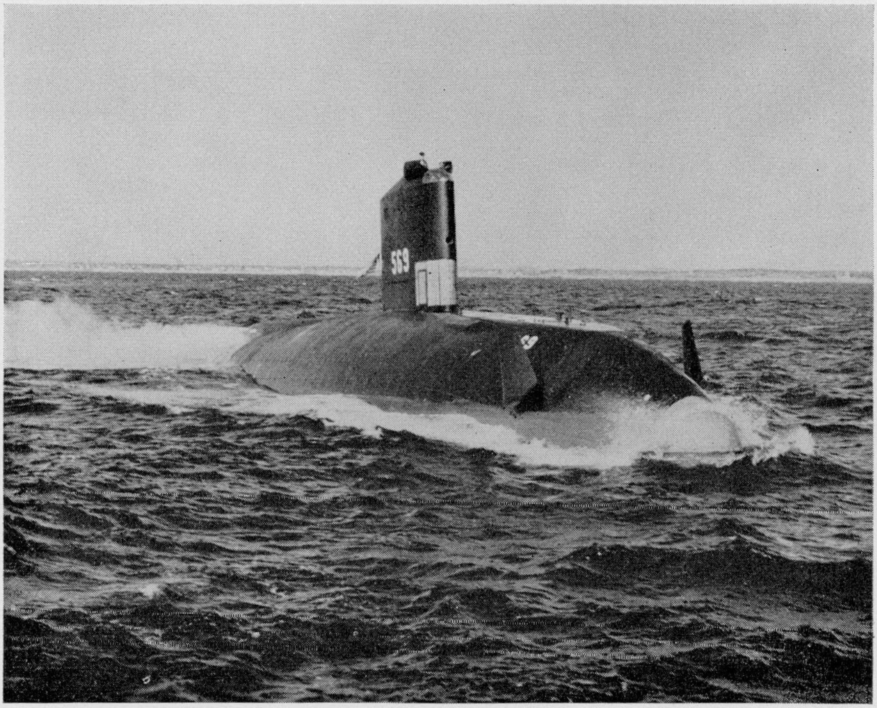


FIG. 9.—IN 1953 A HYDRODYNAMIC RESEARCH PRODUCT OF THE DAVID TAYLOR MODEL BASIN, THE PORTSMOUTH-BUILT ALBACORE, WAS COMMISSIONED. HER RADICAL WHALE-SHAPED HULL MADE HER THE FASTEST SUBMARINE IN THE WORLD.

dock floor. In this way, the underwater portion of the vessel is exposed for inspection and convenient performance of repair and maintenance.

The early Egyptians initiated graving dock operations by making use of shallow natural basins with mud bank entrances built or excavated for each docking by abundant slave labor. The water was removed by water wheels and hand-carried containers. A dock was flooded by excavating the entrance earthwork during low water and the vessel was docked or undocked at high water. The early Greeks pulled their vessels up far enough on sandy beaches at high tide to get them out of the tidal reach and then built temporary protective earth works around them. Repairs were made in these expedient shelters and vessels refloated at high tides by reversing the procedure.

An early improvement on these ancient docks was the construction of inclined timber planes at the water edge. Vessels were beached at high water of spring tides, repaired, and refloated on following high

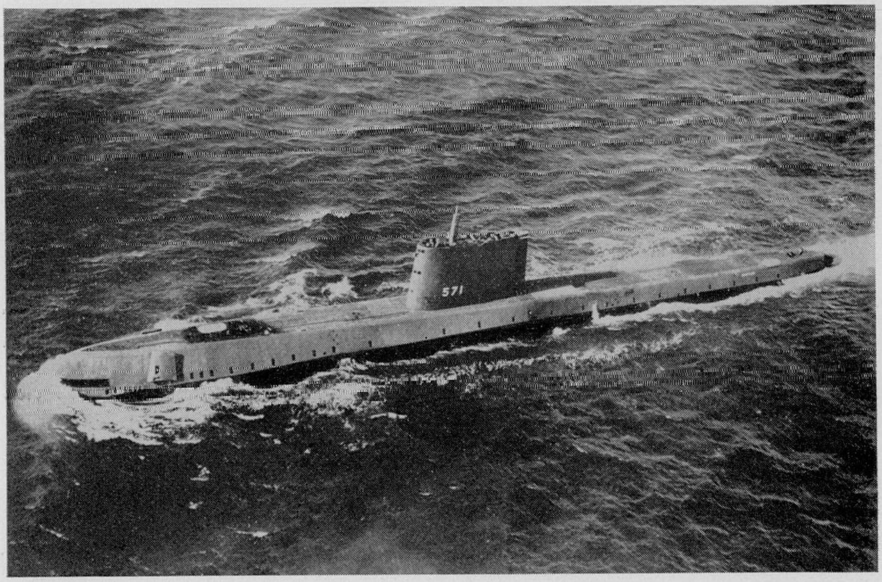


FIG. 10.—COMMISSIONED IN SEPTEMBER 1954, THE NUCLEAR-POWERED NAUTILUS IS THE FIRST TRUE SUBMARINE EVER BUILT, AND HAS REVOLUTIONIZED NAVAL WARFARE.

fall tides. A variation of the timber plane, known as the gridiron, was subsequently developed and, in some ports, are still employed for the rapid inspection and repair of small vessels. In early dockings shores were not used and the vessels, because of their rounded bottoms, acquired a large list and only one side was exposed for maintenance operations. To expose the other side, the ships were careened by lines attached to their masts.

Progress in the development of graving docks was slow. Records indicate a primitive form of dock existing at Southampton, England, in

1434. This was a narrow natural inlet, and the entrance was closed at low tide by a temporary brushwood-clay-log structure. The first permanent graving dock was built in 1496 at Portsmouth, England; and by 1656 docks equipped with gates existed in six English ports.

The first so-called watertight graving dock was constructed of granite. One of the first docks of this type in this country was built right here in Boston in 1826. This type of dock is no longer built in this country but several are still in use, including the one at Boston and one at the Portsmouth Naval Shipyard, built in 1904.

During the past century and a half, the modern graving dock has developed from a small, muddy pit with an unreliable pumping plant and hazardous operational machinery to a vast structure of concrete and steel.

There are today three major material types of graving docks—the sheet pile dock, the composite and the concrete. Floors may be of two general types—one known as the "gravity" in which hydrostatic uplift forces are negated by the mere mass of the dock and floor. In one modification, steel H-piles provide anchorage and permit reduction in mass of concrete. The second type is the "relieved" floor, in which the floor thickness is designated to take only the weights imposed thereon by the vessel or by the over-flooding water; the uplift created by hydrostatic pressure is relieved by a subfloor drainage and pumping system.

The entrance to a graving dock is closed by various types of gates or caissons. Generally speaking, caissons have replaced gates almost entirely in the U.S., since extensive repairs to gates are difficult to perform and they require expensive special construction features for adequate support and protection. Of the sliding, rolling, and floating type caissons, the latter is the most extensively used. Caissons of the floating type contain means of ballasting, flooding, and dewatering to achieve changes in buoyancy and trim by pumps or pneumatic displacement. Many docks have double caisson seats, a feature which allows the caisson to be accepted at either the inner or outer position and permits maintenance and repair work on the seats while the dock is in use.

The original Dry Dock #3 at Portsmouth, as you will learn in more detail later, was a very shallow sheet-pile structure completed early in World War II for the purpose of constructing fleet-type submarines, rather than for overhauling and repair. There are two other docks at the Shipyard whose depths below mean high water to keel blocks are 21 feet and 28 feet respectively. As early as 1953, the need for another deep dock became evident since the latter two existing dry docks were already overtaxed by the yard's workload, and dockings of even shallow draft fleet type subs could be accomplished at Dry Dock #3 only during periods of extreme high tides.

Initial planning was based on providing two parallel, relatively shallow, but long docks capable of handling fleet type submarines, at a cost of approximately $16,000,000. These docks were to be serviced by the central dividing strip or quay which would be equipped with cranes, railroad tracks, and the like, with partial rail-mounted movable covers over each of the docks. An interesting side-light is the fact that very serious consideration is now being given to provision of complete all-weather protection over the newly reconstructed Dry Dock #3.

By the time the planning was firm, around 1957, the anticipated project was reduced in scope—first from two new parallel docks to one new dock, and then to the reconstruction of the existing Dry Dock #3 —thus reducing the anticipated cost to $4 to $5,000,000.

In the meantime the Navy had already moved into nuclear submarines and was planning the *Triton*, a 450 foot behemoth which is the longest sub ever built or planned by this country. Therefore the advanced planning report prepared by Fay, Spofford and Thorndike in 1957, and their preliminary engineering report in 1958, were based on providing a dock capable of handling nuclear-powered submarines as long as the *Triton*. By 1959, however, the major mission of the Portsmouth Naval Shipyard was changed to that of constructing, overhauling, and refueling nuclear-powered submarines including the new 425 foot Polaris ships. At that time the Shipyard had no drydocking facilities capable of handling an emergency docking of a fully-loaded FBM submarine with a draft of 32 feet. Therefore it was necessary to revise the preliminary engineering to provide a facility long enough to handle the *Triton* and deep enough—37 feet below MHW—to accept the FBM's. To the 32 foot draft of the submarine it was necessary to add four feet for the keel blocks and one foot for the tide, thus giving the requirement for 37-foot depth.

After years of close cooperation between representatives of the Shipyard, the Bureau of Ships and Bureau of Yards and Docks in Washington, the District Public Works Office in Boston, and the Architectural Engineers, final plans and specifications were completed in 1960 for the reconstruction to handle the largest submarine the Navy now envisions. The project was one which was followed very closely by the Bureau of Yards and Docks since it involved modification of a dock to a far greater extent than ever before attempted; i.e., increasing the depth from 17 feet to 37 feet or more than doubling the depth of the original temporary dock, and making it permanent. It is of interest that this took us below the foundations for the walls of the existing dock, and was accomplished within a few feet of the Piscataqua River.

For details of the design and the supporting utilities, it gives me great pleasure to turn over the podium at this time to Mr. Frank L. Lincoln, Vice President and a Director of Fay, Spofford and Thorndike, Inc.

RECONSTRUCTION OF DRY DOCK NO. 3 AT THE PORTSMOUTH NAVAL SHIPYARD
(Part Two)

BY FRANK L. LINCOLN,* *Member*

(Presented at a joint meeting of the Boston Society of Civil Engineers and the Construction, Hydraulics, and Structural Sections, BSCE, held on May 8, 1963).

THE SITE

The new Dry Dock No. 3 in the Portsmouth Yard occupies the same area and is an enlargement of the original Dry Dock No. 3 built during World War II, but the dimensions, the design, and the method of operation of the old and the new docks are entirely different.

The original dock was for shipbuilding rather than repair purposes and was 375 feet long, 83 feet wide, and very shallow with the level of the dry dock floor only 17.3 feet below mean high water. The sidewalls were formed by a series of connected circular cells of steel sheet piling filled with gravel. The decks or aprons beside the dock were of steel and concrete supported on steel H piles driven through the fill inside the cells and to a greater depth than the sheet piles of the cells, a detail which complicated the new construction work. The original dock had sufficient width to accommodate two fleet type submarines, side by side. The support for each sub was provided under the keel line by a longitudinal concrete beam on wooden piles. The rest of the floor of the original dock was a thin concrete slab supported directly on the soil and was drained to relieve it of upward water pressure which would otherwise lift it. The entrance to the dock was closed by a single wall steel dam spanning from abutments to a center pier. It required considerable work and time for erection or removal but served the purposes of a shallow building dock with infrequent ship movements. Such a gate is not practical where frequent dockings and undockings occur, or for a dock of the greater depth now required.

DESCRIPTION OF THE PROPOSED DOCK

The new dock is designed for repair and overhaul service, is much longer and deeper but of slightly less width than the old one,

* Vice President and Director, Fay, Spofford and Thorndike, Inc., Boston, Mass.

and will accommodate one large nuclear-powered submarine. (See Fig. 1). It utilizes the entire length of the original dock and extends an additional 130 feet into the river to provide a total clear inside length of 480 feet. The width is 67 feet at the floor level and 71 feet at the coping. The depth of the dry dock floor is lowered from the 17.3 feet

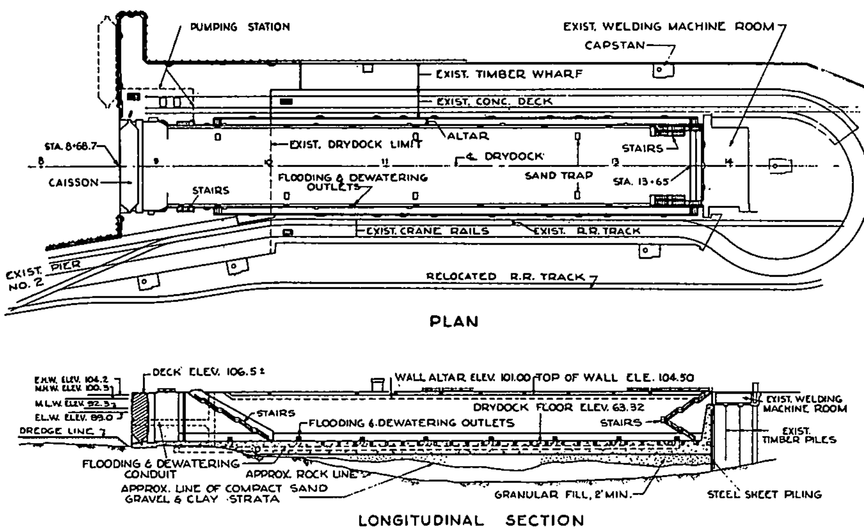
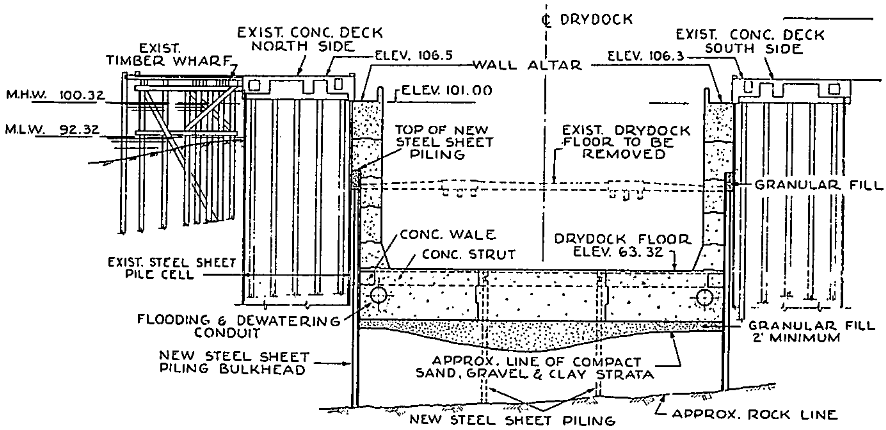


FIG. 1.

of the original dock to 37 feet below mean high water. (See Fig. 2). Providing the extra depth was the most troublesome feature and required deep excavation between the present cells and in some cases below the bottom of the cells.

The walls and floor of the new dock are of heavy concrete construction with sufficient weight over most of its length to resist flotation. For the inboard portion of the new dock where the hard bottom is low the concrete floor is 11-1/2 feet thick and the sidewalls are from 5 to 8 feet thick. At the outboard end where the ledge is high the weight of the thin concrete floor is not sufficient to balance the full hydraulic pressure and it is relieved by underdrains.

The closure of the new dock is by means of a reversible floating caisson gate held in place against the dry dock seat by gravity and the pressure of the water. The caisson is a rectangular steel box 81 feet long, 44 feet high, and 15 feet wide and is ballasted with concrete to provide upright flotation. (See Fig. 3). Water ballast is added to the caisson to sink it in place in the seat. The de-ballasting system consists of two 3,500 gallons per minute, vertical, motor-driven pumps. This pumping system will raise the caisson at an average rate of 8 inches per minute. The flooding system is through two 12-inch valves which will sink the caisson at an average rate of 12 inches per minute.

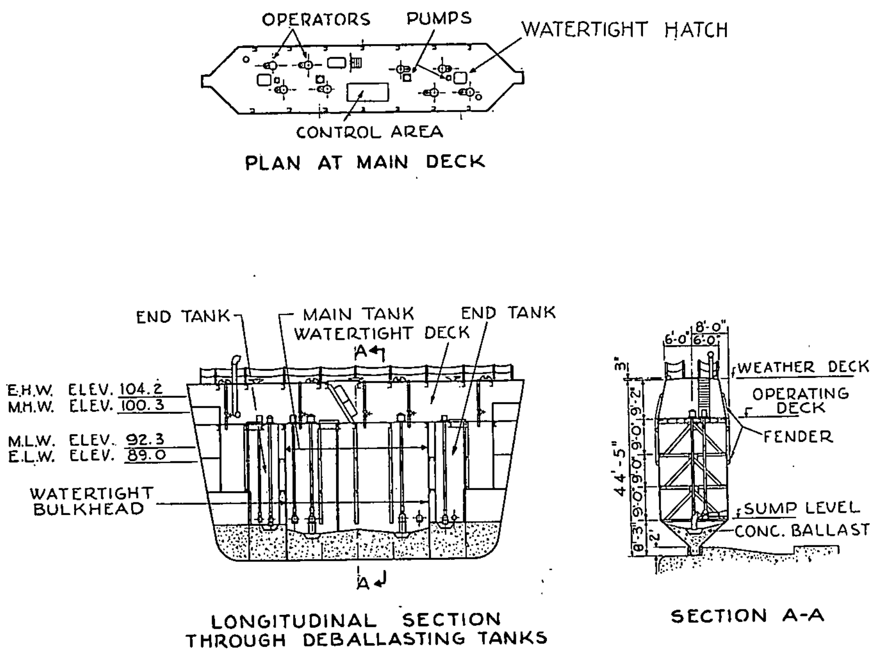


TYPICAL CROSS SECTION
AT EXISTING DRYDOCK

FIG. 2.

The unwatering of the dock itself is by two 36-inch, 30,000 gallons per minute pumps which require about 3 hours to completely unwater the dock from high tide level when operating in parallel and with no ship in the dock. (See Fig. 4). Two much smaller drainage pumps, each with a capacity of 1,500 gallons per minute and with automatic float control are provided to take care of leakage or rain water which accumulates in the unwatered dock. All pumps and the various valves are electric motor operated. The dock is flooded by two large sidewall conduits varying in diameter from 36 to 42 inches through which water flows with a maximum velocity of 25 feet per second; the flooding time is 2 hours at high tide with no ship in the dock. The same sidewall culverts are used to convey water to the pumps in unwatering the dock.

The utilities provided include electric driven winches for pulling a ship into the dock and centering it in place, DC and AC electric power for welding and other work, heavy electric power for test



CAISSON

FIG. 3.

purposes on atomic ships, steam, compressed air, fresh water, salt water, and oxygen for various working purposes, all connected to and available at outlets located at service galleries along each sidewall.

FOUNDATION CONDITIONS

In the planning stage an extensive investigation was made of the soil and ground water conditions at the site. Although there was much data available from the construction records of the original dock, more than fifty new test borings were made. The soil samples were tested in the laboratory for consolidation, shear, and permeability characteristics. During the test boring work observations were made of ground water and soil permeability and well points were installed in three of the bore holes to provide permanent observation

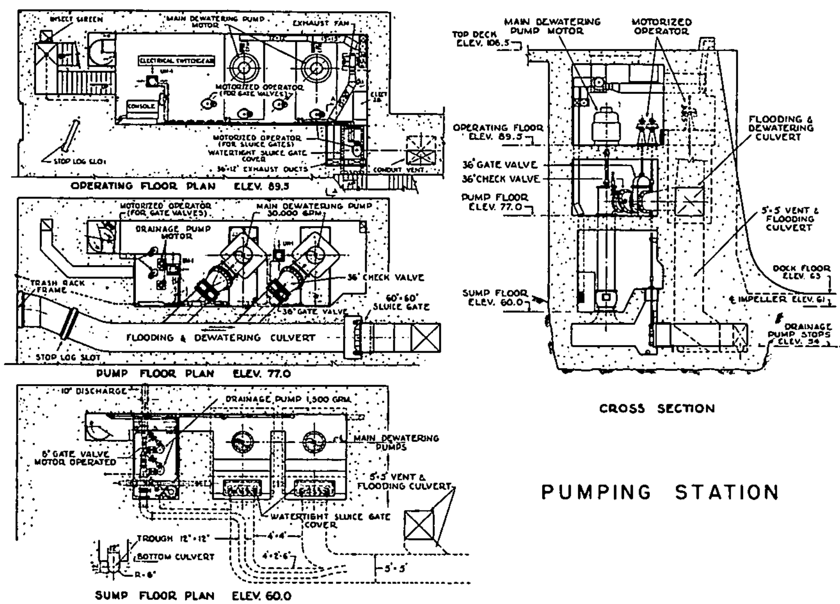
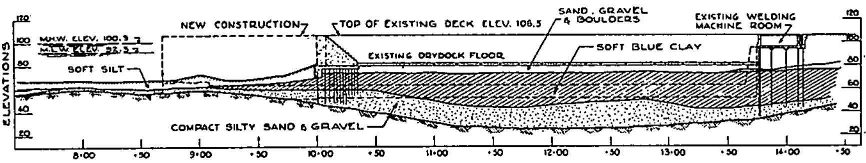


FIG. 4.

wells. Further tests of the water conditions were made by installing a test well and a series of piezometers on each side of the existing dock, pumping the wells continuously for 4 day periods, and recording the water level in each of the piezometers at frequent intervals throughout the pumping period.

The boring information showed three layers of material between the floor of the present dock and the underlying bed rock. (See Fig. 5). The layer of material immediately beneath the floor of the present dock was a thin layer of sand and gravel fill placed when the dock was built. The next layer was soft blue clay varying in thickness from 5 to 25 feet. The final layer is compact silty sand and gravel (glacial till) which varies in thickness from 5 to 20 feet and overlies the rock. The rock is predominantly a medium hard, gray quartzite containing many tight, closely spaced vertical and inclined joints. Outboard from the present dock and in the area of the extension the rock rises above the elevation of the floor of the new dock, and rock excavation was required. The new dock is founded partly on rock, partly on the glacial till with a thin gravel cushion, and partly on a new thick layer of compacted gravel placed on the till. Where the surface of the glacial till is lower than the bottom of the concrete floor, the soft clay above the till is removed and replaced with compacted gravel, the maximum thickness of this new gravel layer under the floor being 14 feet. There are no piles supporting the new dock.



GEOLOGICAL PROFILE ℄ OF DRYDOCK

FIG. 5.

The greatest bearing pressure on the soil under the dock is 1-1/2 tons per square foot, and occurs when the dock is over flooded to its extreme height for the locking operation.

GENERAL FEATURES OF THE DESIGN

Early in the planning of such a structure far reaching decisions must be made as to the general methods to be followed in the design and construction. Some of these decisions may be of interest.

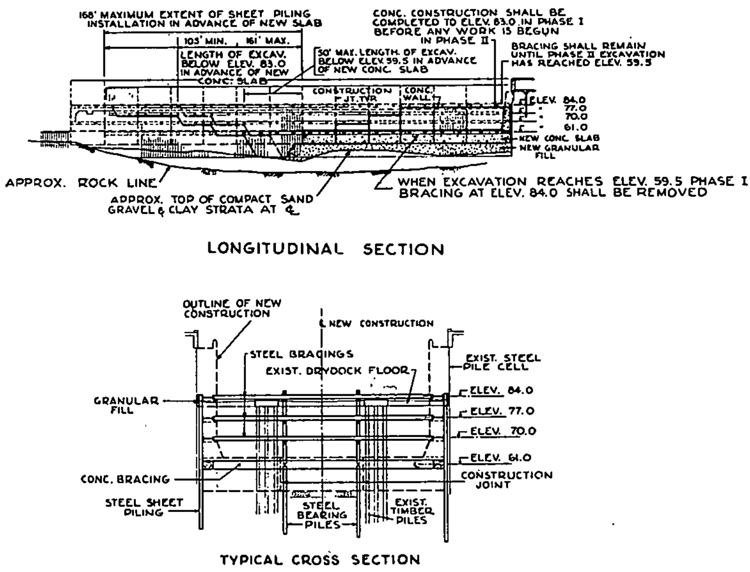
After study of the boring and well tests, it was decided that the control of the water during construction should be accomplished by dewatering the pervious soil surrounding the dock and beneath the clay blanket with pumping units located in the ground outside of the steel sheet pile bulkhead rather than by pumping from the open excavation. By this method the side pressures on the excavated areas are kept to a minimum, the upward water pressure in the bottom of the excavation is eliminated, and the possibility of blows or boils in the bottom of the excavated area is minimized. The pumping units were installed at high and low elevations to draw water from the glacial till underlying the clay and from the granular fill material above the clay. The clay forms a watertight barrier between the two strata. The depths to which the ground water should be drawn were determined during the planning period, the design pressures on the cofferdam were based on the water being drawn down to these depths, and the contract required such a drawdown before the excavation could be made. The extent of drawdown was measured by a number of piezometers installed along the sides and within the body of the dock.

The soil and pump tests showed the underlying glacial till to vary widely in composition and to be formed of discontinuous layers, lenses, and pockets. During the design stage, it was concluded that the total quantity of water to be pumped to de-water the area would not be high but that relatively close spacing of dewatering units would be required to remove this small quantity of water from this particular soil. The experiences during construction proved this to be an accurate prediction.

Another early decision which governed much of the design and construction work, was that the job should be divided into increments which would restrict to a small size the area which would be excavated to full depth. This would lessen the risk of a cofferdam failure and would also localize the damage should a failure occur. This also minimized the danger of the entire cofferdam shifting to the north, the pressures on the south side of the dock being greater than those on the north and the entire mass resting on the layer of soft clay.

The Navy adopted the policy that the cofferdam design should be made by the dock designers with complete details included in the contract drawings. The more general practice is to consider the design of the cofferdam as falsework and include it in the contractor's work with the choice of structure made by him.

For economy it was desirable to make use of the old steel sheet pile cells by continuing them in service, but they were obviously incapable of resisting by themselves the overturning, shearing, and sliding forces present when the excavation was carried down approximately 30 feet below the old dock floor. In fact, it had been necessary to add ties to the cells at the time of the original construction to take care of some local movements. The most economical and safest means of preserving the stability of these original cells during the new construction was to drive a steel sheet pile bulkhead in front of the cells and well below both them and the new excavation. The new steel sheet piling was braced from one side of the dock to the other by three levels of steel wales and struts, the entire assembly being preloaded by jacking at each bracing level before the excavation was made below it. A fourth wale and strut system of concrete was provided at a lower level and left in place to become a part of the floor slab. (See Fig. 6). The critical load in the sheeting and that which



COFFERDAM

FIG. 6.

governs the design of the cofferdam is the cantilever load which occurs just before the installation of any set of braces.

To stretch out the working area and facilitate the installation of wales, and still adhere to the principle of having a minimum of deep excavation open at any one time, the excavation was opened up in steps, extending in a longitudinal direction, with the entire process advanced one step when each floor monolith was placed. The various operations went on simultaneously in each step to produce most rapid progress.

The longitudinal profile of the modern submarine is so shaped that it requires very high keel blocks at each end with low blocks amidships. To avoid making the floors so deep that the mid ship section of the submarine could float in over the high blocks at the outer end the submarine is docked in an off-center position. This permits it to be floated in on the opposite side from the blocks and then moved sideways over them in their cradle shaped longitudinal profile. To raise the submarine even higher than it would float at high tide, a locking arrangement is used by which water is pumped into the dock after the gate is closed. The locking arrangement, which is patented, raises the water and the ship an extra four feet in this case. To accomplish this the caisson seat must be two-faced with the caisson bearing on the outer side while the water surface is higher in the dock than outside and reversing when the water is lowered inside. The water to overflood the dock is handled by pumps in the caisson, taking it from the harbor.

DESIGN DETAILS

Some of the smaller details of design are unusual and may be of interest for that reason.

A substantial saving in the amount of reinforcing steel in the side walls was made by utilizing the steel sheet piles of the cofferdam for this purpose. The sheet piles are left in place, the concrete was poured directly against them and special shear connectors were attached to the steel to assure sufficient bond.

The Z sheet piling in the cofferdam across the inboard end of the dock is the heaviest on the market but it is incapable of taking the earth load imposed. The piling was reinforced by driving 12" WF 120 pound structural steel shapes as soldier beams on the outside of the sheet pile wall and in the valleys made by two adjoining sheet piles. There is no connection between the sheet piles and the soldier piles except that provided by the soil. The soldier piles were removed after the concrete wall was placed but the Z piles were left in place.

The pressures on the cofferdam wales and struts were calculated in accordance with the different theories advocated by various authorities and investigators in the soils mechanics field. The results vary considerably with the heaviest loads occurring in the lower struts under some theories and in the higher struts under others. However, the maximum strut load is about the same in each analysis although it might occur at a different elevation. The solution in this case was to make all struts and wales the same which satisfied each of the conflicting theories as to distribution of load and simplified the construction by making the units, which are reused several times, completely interchangeable.

One of the by-products of the method of unwatering which was used in this construction is the increase in weight of the unwatered soil surrounding the dock. In its completely saturated state the soil is lightened by the buoyant effect of the water and in such condition weighs about 60 pounds per cubic foot. When the water is pumped down and the buoyancy is lost the soil weighs about 100 pounds per cubic foot. This means that the load on the low strata of clay is almost doubled during the period of water drawdown, and settlement takes place. In this case we reached the opinion that the nearby buildings would not be seriously affected, that the undergound utilities near the dock might settle enough to require some rebuilding, and that those sheet pile cells of the old dock which are founded on clay would settle considerably during the construction period. Because the deck structure over the cells is supported by heavy steel piles driven into the hard material beneath the clay it is held up while the cells settle away from it. This permitted the entrance of water over the cells to the working area at times of extreme high tide. This leakage was a real nuisance during construction, but it is corrected by the new sidewalls in the completed dock. The settlement of the cells also added an indeterminate load to the steel piles within them because the friction of the settling soil is dragging down on the piles rather than helping to support them.

The reconstruction of Dry Dock No. 3 at Portsmouth was carried out by the District Public Works Office, First Naval District, Boston, with the office of Fay, Spofford & Thorndike, Inc., engaged as Architect-Engineer and the firm of A. S. Wikstrom, Inc., engaged as Construction Contractor.

TRANSPORTATION PLANNING

By Donald W. Cather*

(Presented at a meeting of the Transportation Section, B.S.C.E., held on April 24, 1963).

Since it was requested that the subject of this paper be "Transportation Planning" I have included some facts concerning the history of rapid transit throughout the world and the role of the civil engineer in planning transportation facilities.

Historically, the civil engineer has played the principal part in the development of transportation facilities throughout the world, and it is only of late that other professions have assumed what appears to be the emerging role in the planning of transportation facilities. It is my hope that you will consider my remarks as relative to the importance which I place upon the leadership of civil engineers in the transportation field, a leadership which we should guard zealously. The civil engineer has the background and education to deal with the actual implementation of a plan into a facility which can be used by the traveling public to reap the enormous benefits which accrue from good transportation planning. One of the remarks that I remember most from my student days is a quotation from Daniel Burnham, "Make no little plans, they stir not the hearts of men." This is one of the keynotes to good transportation planning.

The difficulties and disfavor which the transportation engineer has encountered in the past twenty years have tended to make us somewhat timid and discouraged. Consequently, our plans are too little to stir the hearts of men or to completely revitalize an outmoded transportation system. A good case in point is one with which the people in Boston are most familiar. The local press has created a measure of antipathy with adverse criticism of the deficit of the Boston Metropolitan Transit Authority—deficits of some $16,000,000. Very little is said of where Boston would be today without these civil engineering works that after 50 years are still doing the job. No mention is made of the deficit of the New York City Transit Authority which exceeds $100,000,000. This cost is accepted as a part of living

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in New York, the subway system there with its 15¢ fare must be subsidized and little comment is made in the press. The existing subways in New York operate with a high degree of efficiency and little political pressure.

Boston was the birthplace of the American subway system. Yet, a rather interesting but old barrier to good transportation planning exists here, in that the M.T.A. can plan expansion of its lines but the capital cost must be authorized by the State Legislature. Furthermore, a referendum is required to extend the M.T.A. to any new community. *No new communities have ever approved such an extension.* As a result, the system's potential *has never been developed.*

Obviously, the greatest impediment to implementing a good transportation plan is lack of salesmanship. Engineers tend to expect the riding public to comprehend easily the benefits which we plan for them with great effort, with many nights of labor, with much research —but, like anything else on the market today, it must be sold.

We have here in the United States an automotive-minded community who have been sold on the idea of more and better roads. None of us can quarrel with this basic idea because of our inherent need for more road facilities. But, at the same time, we know that this engrossment with automobile transportation creates an unbalanced transportation system. We would have a more balanced transportation system today if the interests of the transit community had been as actively promoted and sold as those of the automotive community. Our company has participated substantially in two major highway projects in the New England area, much needed and useful facilities, but at the same time we have also participated in an excellent expansion of the Metropolitan Transit Authority System, the Riverside Extension. This is a case where a rail line carrying 3,000 passengers, by the simple expedient of direct service to downtown Boston, improving headways and reducing fares, such as is now being tested on the B. & M. today, resulted in increasing the daily ridership almost ten times.

American engineers, I'm afraid, are a little hesitant about selling transportation facilities which our forebears, the Boston engineers, pioneered in developing. The American developments in rapid transit have been copied throughout the world, sometimes with marked improvements, other times almost identically.

Interest in rapid transit is at a high peak at the present time.

Those of us associated with rapid transit have hopes of expansion ahead. The automobile is no longer considered the ultimate in transportation for the central city. Substantial strides in rapid transit are being made in San Francisco, Philadelphia, Cleveland, Chicago, Montreal and Toronto, to name a few of the major cities. With publicity being given to new methods of rapid transit such as rubber-tired trains and monorail, we can reflect to see how the past hundred years have brought us to this point in transportation history.

Archibald Black, in his "Story of Tunnels," written in 1937, gives us a marvelous history of the difficulties which were experienced by early subway constructors. This is a story in and of itself. The courage and foresight of these men would be a lesson for all of us to long remember. Until the development of the shield and compressed air tunnelling, subway construction was limited to places where good rock or dry soil was present. The shield and compressed air method permitted the great strides in tunnelling made in the 1900's—the extension of Manhattan's Subway under the Rivers to the East and North, the tunnels under Boston Harbor, and the subways of London under the Thames. The other method of subway construction is called "cut and cover." There are variations of these methods, such as the use of roof shields, rock tunnelling and the so called Paris method where the arch is built from the street and covered over and the subway floor or invert excavated last. In the construction of the Marunouchi line of Tokyo, where extremely bad water conditions were encountered, a reinforced concrete box section was built above ground with a shield incorporated into the box on the two bottom outside edges. The underneath side of the subway was then excavated under compressed air, material was removed through an air lock, and the subway was slowly sunk into the ground to the desired depth, at which point the excavated section below the tunnel proper was filled with concrete and the tube was then back-filled.

One of the latest methods of subway construction is the Benotti method. A caisson is dug with a power auger or trencher with drilling mud used to carry the excavated material to the surface. The drilling mud will, in most cases, support the side walls during drilling. When the required depth is reached, the reinforcing is placed in the drilling mud and concrete is tremied into the excavation displacing the drilling mud. It is reported that no loss of bond is experienced due to the drilling mud coating the reinforcing bars. One of the principal advantages of this method is elimination of pile driving with its accompanying noise and possible damage to adjacent foundations. This basic method was used for a portion of the University Avenue subway in Toronto.

London pioneered the rapid transit field with the first subway in 1862; it was a brick arch tunnel through whch coal burning locomotives were operated. The successful first subway in London was followed by many other routes. The next subways to be built were in Glasgow and Budapest, with Boston following soon thereafter. The construction of the first Boston subway was cut and cover with a steel beam and jack arch roof. Certain portions of the initial routes on Boylston Street are brick arch and are still in use today. It is also interesting to note that the Boylston Street subway, of which the original Tremont subway is a part, still has the most uniformly high load throughout the day of any subway line in Boston, which speaks well for the planning of the civil engineers who laid out this line.

It is only natural with the success of the Boston subway, that New York should follow and in the course of the years it surpassed Boston in subway construction. New York is fortunate in having many, many miles of four-track system which permits the operation of local and express trains with excellent schedules being available. As a matter of fact New York and London are the only systems with extensive four-track routes. New York subways are not complete yet; they are constantly being added to and extended. The Chrystie Street Improvement and the Rockaway line are two of the most recent additions to the New York City subways. It is generally conceded that the New York subway system is the largest in the world and, as far as I can determine, the Toronto subway—5.6 miles of double track—is one of the shortest, but present plan calls for 10 more miles by 1967.

London and New York have almost identical route miles, but as anyone who rides the New York subway can attest, the loading there is considerably heavier. New York carries roughly two and a half times as many passengers as London. When comparing riders, it must be remembered that most European cities have four peaks, as against two in the United States, since many Europeans go home for lunch. This, of course, is a great financial advantage to those foreign systems. From the passenger standpoint a most encouraging development in rapid transit has taken place in Paris. In 1942 the

Regie Autonome des Transports Parisiens—that's the equivalent of the Paris MTA—began experiments with rubber-tired trains and in 1952 a rubber-tired rapid transit train was put into operation in the Paris subways. I had an opportunity to examine this car in considerable detail when I visited this system in 1956. Its passenger appeal is excellent; extremely quiet, soft riding, excellent acceleration and deceleration. The Parisians are so pleased with it that they have petitioned the RATP to equip another line as soon as possible. This same system will be used in Montreal, which is well along with the construction of its subway.

Almost all of the Paris subways were built by cut and cover methods except where lines cross. At one point, Republique, five different lines cross each other. Here there is an elevator to the various stations, a distinct contrast to the remainder of the line, where the absence of escalators and stairs is immediately apparent, the pedestrian traffic being handled almost exclusively by ramps. An efficient innovation of the Paris subways is the gate at the entrance to the platform. As a train approaches the platform, the gate shuts off access to the platform and only those passengers on the platform are permitted to board the train. This eliminates the mad scramble and rush down ramps and stairs for a train and aids in keeping the rigid train schedule. The headways on the Paris subways are excellent throughout the day and the coverage of the city is as fine as any in the world. The Paris system has an excellent system of directional signs. At one station there is an illuminated map of the system which permits the rider to determine routing by pressing a button at the destination, thereby lighting up the route.

From all that can be gathered the most beautiful subway is in Moscow. Stockholm's newest line is also a work of art; it is the ultimate in functional design and represents the finest of Swedish modern art—something the Swedes are noted for throughout the world, the simplicity and beauty of their design. This, incidentally, was probably the most difficult subway construction project in recent times. The Swedes had to resort to several unique construction methods in order to build this subway which included freezing the ground to eliminate underpinning. Where this was not feasible chemical soil stabilization was used. Several rock tunnelling records were set in the construction of the subway. The difficult phases from rock to mud presented additional challenges to the engineers. This is the first subway in Europe to install cab signal controls, eliminating the need for wayside signals. The cab signal is a three-or-four-position signal in the cab. If the motorman does not respond to the signal indication by reducing speed, the governor on the axle actuates the brakes automatically making it virtually impossible to strike the train ahead except at coupling speed. This same basic system is used on the Long Island Railroad in New York.

The Marunouchi line of the Teto Rapid Transit Authority Tokyo, was opened in March of 1959. This line employed several unusual engineering methods, although the major portion of the line was constructed by open cut and cover. One of the interesting methods used in an area with a serious water problem was the caisson method described earlier. The maximum air pressure used was 1.9 atmospheres. It is reported that the roof shield method used set a record for this type of construction. A single arch was constructed for both tracks. Another interesting part of the construction of this line was the underpinning of two bridges—one carrying trains, the other an electric car line. A reinforced concrete girder was used to keep loads off the subway and to carry the bridges themselves. Needless to say, the construction of a subway in this very built-up city greatly increased the cost. The integration between the private electric lines and the Japanese National Railways is well developed. Most Japanese seem to prefer to ride the electric trains and subways over automobiles, which accounts for the intense coverage of the city as compared with American cities of comparable size. However, they are now running into extensive traffic problems.

In contrast to the claim of simple design employed in the stations in Tokyo, Stockholm and Toronto, the previously mentioned Moscow Metro is a thing of truly ornate beauty. The subway stations themselves have high vaulted ceilings and contain national works of art. (They obviously do not have the vandalism problem encountered in American cities.) We would like to paraphrase the description of the Moscow Metro contained in the Official Moscow Guide Book.

> "The Moscow subway was considered before the Revolution but the property owners opposed the venture. After the Revolution, these obstacles were eliminated. Thousands of Communist members were sent by their organization to construct the subway. The first section of the Metro built was 11.5 kilometers of double track. This was followed by a bridge across the Moskva River and reached Kiev Station by a shallow tunnel. During

the great Patriotic War builders worked on the third section and two more lines were opened in 1943 and 1945. In 1954 another 20-kilometer circle was opened. Total length of all operating lines is 65 kilometers. The length of the various lines are from 11 to 20 kilometers (7 to 13 miles). Travel time is from 17 to 30 minutes. An average of 3,000,000 passengers make use of the various lines every day. The Moscow Metro is reported to be an outstanding feature of engineering. It has a superior air-conditioning system which adjusts the temperature in the subsurface stations to 20°C in summer and 12°-14°C in winter. The capacity is reported to be 55,000 passengers per hour in each direction. There is no switching along the route and no crossings at grade. Minimum headway is 1.5 to 1.7 minutes. The walls and columns are finished in polished marble, stained glass, or glazed tile, adding the sensation of airy space and eliminating the oppressive subway feeling. The stations near the theaters are adorned with columns bearing porcelain bas-reliefs illustrating the arts or people of U.S.S.R. The most impressive station is Mavakovskaya. The station interior is made both simple and impressive by the use of stainless steel ribbed strips which are set in dark marble pillars faced with pink rhodolit. The ellipsoid cupola is lighted illuminating 35 colored mosaics. Another station is famous for 32 stained glass panels used for the first time in decorating subway palaces."

Major construction now contemplated in the United States is the Trans-Bay Tube to run from San Francisco to Oakland and eventually tie in with the Bay area rapid transit system. This tube alone is estimated to cost in excess of $100 million, with the major part of the cost to be paid for by automobile tolls on the Oakland Bay Bridge, an indication of the changing attitude of public officials toward the need for rapid transit and its place in the total transportation complex in our metropolitan areas.

The honor of the most modern subway on the North American continent goes to our neighbor to the north, Canada. The Toronto Subway, initially 4.4 miles long, has 10 miles under construction or in the design stage.

As can be seen from the foregoing, there are vast differences in subway design practices throughout the world. The subways built in the past have many, many years of functional life remaining. But, the aforementioned systems will give you an idea of the progress made in transportation throughout the heavily populated areas of the world. Only last week, I was talking to a gentleman who had recently returned from Japan where he had ridden a train which traveled at a rate of 156 miles per hour over a 30 mile test section. He told me that this railroad gave him absolutely no sensation of speed, that it was completely automatic in almost all respects, acceleration, deceleration, train stops, and that furthermore, part of the Tokyo Subway System was also being tested for automatic operation.

The administration in Washington is seeking a transportation solution for the Northeastern Megalopolis (the Boston to Washington D.C. area), the backbone of which would be a high-speed railroad employing 150 mile an hour service from Boston through New York to Washington. The first question is the economic desirability of such a system which would have to compete against the airlines operations at speeds exceeding 300 miles per hour. However, we must remember that people do not live in airline terminals, they live in Newton, Canton, Arlington, Belmont. They work in Brookline, they work in Newton, they work in Downtown Boston and it is from this point they must initiate their travel and their destination may be Wall Street, 42nd Street, or the Pentagon, and I believe that such a railroad could successfully compete with the airlines for a satisfactory portion of travel. The railroads have one distinct advantage, all-weather service ability.

Another point in favor of development of our Rapid Transit Systems and our Rail Systems, is their immense capacity. Granted we all have heard the ratios of ten to twenty times that of the highway, which has been in most part countered by the 24 hour volume carried by highways and the fact so many times stated that the Rapid Transit Systems and their terrific initial cost are not justified because of the pending advances in the art which will make all present forms of rapid transit obsolete. No one can dispute in this modern age of advancing technology the possiblity of a radical form of transportation appearing upon the scene. But at the same time, we must remember that many highways that have been built in the United States in the past ten years have become obsolete at the time of opening by their inability to handle the rush hour capacity loads thrown upon them. I merely have to point out to you the example of the Southeast Expressway to Quincy. During our work in conjuction with the study of the Old Colony Railroad, we were told that once the Southeast Expressway was built there would be very little need for any further rapid transit in this area because everyone would be able to drive freely into Boston. I think this points out very vividly the inherent value in a line like the Cambridge-Dorchester line. And I would like to stick my neck out and make a slight prediction that with the introduction of the new equipment and the acquaintance of the people in that vicinity with this new equipment that they will see a marked increase in the usage of this line and perhaps even a change of opinion as to the necessity of extending Rapid Transit to the South Shore. I would like to make only one suggestion and that is that the engineers present today who are interested in transportation planning look beyond our own shores for ideas and do the same amount of traveling and inspection that is done by the English and the Japanese and the Germans in looking at developments throughout the world. I have in the last two years given personally guided tours of the New York Subway System for three different groups of foreign visitors. Unfortunately, I feel that most of us here, either through the press of business or other reasons, have not had an opportunity to see the terrific advances being made in Europe and in Asia and in Russia in transportation planning. One of the most important things about transportation planning is looking at the total transportation picture, not merely at a local individual problem. Transportation planning involves all the elements of civil engineering. It involves coordination with highways, coordination of land use, with available resources such as water, sewers, utilities, existing facilities, major transportation corridors that are well developed, the development of businesses along existing transportation routes and the effect of re-routes or bypasses upon established businesses and residences along the routes. At times these problems can become extremely complex and technical, calling upon all of the skill and background of a civil engineer. This is not merely a land-use problem or a highway problem but a total transportation problem. I believe that it would be worthwhile for every engineer to acquaint himself with some of the basic transportation principles just as he is required to know the basic formulas for a beam, the basic formulas for hydraulic flow through pipes, the formulas for electrical current, voltage, power. So that in looking at any particular problem in transportation, he is well equipped in these transportation fundamentals as he is in other fields of basic engineering fundamentals.

I would like to close upon the one thought that was presented to me the other day when a friend of mine who happens to be in the research department of one of our leading corporations stated that in his opinion there would be very little need for future highways or rapid transit systems or railroads since the development of our communication facilities would reach a point in the very near future where we would have television connected to our telephones and this would avoid almost any need for you visiting my office or my visiting your office. I can't help but believe that we must give serious consideration to every such new idea of this nature that comes along and although we can all think of many jokes about the possibilities of television connected to our telephone, these are some of the overall transportation problems which must be considered.

PLANNING AND ZONING

By Normand O. Pothier*

(Presented as Lecture 3 of the Surveying and Mapping Section, B.S.C.E. 1963 Spring Lecture Series, April 2, 1963).

The wide interest in community planning in Massachusetts is relatively recent due to many obvious reasons that have made people conscious of the need to plan and to plan soon so as to cope with advancement and growth. However, planning as we know it today is indebted tremendously to many people for the progress that has been made in this state. Such people as Philip Nichols, Elizabeth Herlihy, Professor Frederick Adams, Arthur Comey, Arthur A. Shurcliff, Flavel Shurtleff and many others can be credited with the advance of planning in this state at a time when planning was frowned on and in many instances bitterly opposed. These people spent many hours in the advancement of planning within the Commonwealth, especially in the field of legislation, since the state statutes are the backbone of planning. This increased interest in planning that is prevalent today indicates that people are concerned with the future development of their community and although the process has been a long time in developing, the groundwork developed by the above-mentioned pioneers established a sound foundation for the future of planning. Admittedly there have been many changes in the legislation but in most instances it was either further refinement or modernization to cope with the changing times. Their work was most creditable since the legislation has withstood attacks that have reached as high as the tribunal of the Supreme Court of the United States and there upheld.

It is true that planning as we know it goes back only fifty years. However, there are forces that can be pinpointed over the past two or three centuries that assisted in illustrating the effectiveness of physical development and environment in our towns that naturally led to the basic planning process we are now familiar with. However, it can be said that it is the extensive growth that we have been witnessing in the past fifty years and especially since World War II that has really hastened the acceptance of planning as it now is. There are

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two or three of the "forces" of the past centuries that are unique to New England, and are worth mentioning in passing, and which have formed a lasting imprint throughout the nation.

In the New England town and village common is to be found one of the best examples of excellent town planning. Around these commons were grouped the meeting house, churches and other community buildings located in most instances around a beautiful area of open space. This common was the center of town activities with a very informal design, that in many towns has been able to survive over the centuries. Excellent illustrations of this can be found in Lexington, Deerfield and Bradford, Massachusetts.

It was also in New England that the most attractive industrial towns were planned and built in the 19th and the early part of the 20th Century. The town of Hopedale was first planned and built as a Christian Socialist community in 1841 and further developed as an industrial village in 1856. Other excellent examples of industrial planned towns are Whitinsville and Shawsheen Village in the Town of Andover. However, in contrast to these exemplary developments, two factors developed in the last century that had a tremendous influence on the planning and development of our cities and towns—namely, the railroad and power derived from our streams. These two factors were instrumental in developing some of our most unplanned communities for which we are now paying dearly. Industries were built where hydraulic power was available, followed in most instances by the railroad to service the industries and the people working in these industries. This brought a mixture of land uses that has plagued municipalities ever since, requiring huge expenditures for renewal.

The most significant step taken in planning during this century was back in 1913 when the legislature passed the first planning board act in Massachusetts. However, the City of Salem pre-dated this enactment and established a five member planning board in 1912, thus becoming the first community in Massachusetts to officially organize a planning board. Through the years the establishment of planning boards progressed very slowly with approximately one hundred and twenty cities and towns establishing planning boards in the first twenty-five years. During this period the control of the subdivision of land was in the hands of the Board of Survey, this legislation having been passed in 1907.

However, after extensive research and studies a new planning statute was presented to the General Court and was enacted into law in 1936. This is the present legislation under which a community establishes a planning board. It requires city council and town meeting vote to re-establish the "old type planning board" established under the enabling act of 1913 to the "new type planning board" of the enabling act of 1936. There are fewer than ten planning boards in Massachusetts still functioning as an "old-type planning board."

One of the significant changes brought about by the 1936 municipal planning act was placing the control of the subdivision of land in the hands of the planning boards. This act has been changed and expanded several times. To illustrate its expansion, the original act in 1936 was contained in Sections 81A through 81J, of Chapter 41 of the General Laws. In 1947, this was expanded to 81A through 81K and in 1953, it was further expanded from 81A to 81GG. The same powers and duties were in the 1936 statute as are in the present law. At present there are 292 out of 351 cities and towns in Massachusetts that have a planning board, which means that approximately 80% of the cities and towns have planning boards. However, over 97% of the population of Massachusetts live in cities and towns having planning boards. The planning board membership by law can be from five to nine members, whichever the city or town votes to accept. However, the majority of the boards have five members.

There are certain powers and duties that the statute gives to the planning board, that, if properly administered will direct the community's growth in an orderly manner making it a better community in which to live. These powers and duties are as follows:

1. The planning board shall from time to time make careful studies and when necessary prepare plans of the resources, possibilities and needs of the city or town, and, upon the completion of any such study, shall submit to the city council or selectmen a report and recommendations.
2. A planning board *shall* prepare a master or study plan.
3. Each city or town having a planning board established under Section 81A may, by action of its city council or town meeting adopt an official map prepared under the direction of the planning board. (An "official map" is a map showing the public ways and parks that have been laid out and established by law

and private ways then existing and used in common by more than two owners.)

4. No public way shall be laid out,altered, relocated or discontinued unless it has been referred to the planning board, for a report on the laying out, alteration, relocation or discontinuance. Forty-five days must elapse after such reference before any action can be taken if the planning board has failed to report.
5. Any city or town having a planning board established under Section 81A may, by ordinance, by-law or vote, provide for the reference of any other matter or class of matters to the planning board before final action thereon. The planning board shall have full power to make such investigations, maps and reports, and recommendations on any subject referred to it. (Few municipalities have taken advantage of this mandatory referral clause.)
6. The planning board must hold a public hearing on the original adoption of a zoning ordinance or by-law and on any amendment thereto.
7. The planning board established under Section 81A has the power of administering the Subdivision Control Law as described under Section 81K to 81GG. This function is the most important and the most time consuming duty of the planning board. This particular subject, because of its importance, will be the subject of another lecture to be given by Mr. Louis Smith, who has had over twenty years experience with this subject of subdivision. [Mr. Smith's paper is included in this issue—Ed.]

From the duties described for the planning board, the most important functions are the preparation of a Master Plan and the administering of the Subdivision Control Law. Since subdivision control will be the subject of another lecture, the Master Plan or the community plan as it is frequently called, will be discussed here in some detail, along with zoning.

Section 81-D of the Municipal Planning Law states the following, "A Planning Board established under Section 81A *shall* make a master or study plan of such city or town or such part or parts thereof as said board deems advisable and from time to time may extend or perfect such plan." Even though the language of this quote from the law makes it mandatory for a planning board to prepare a comprehensive plan, it is only in the last six or seven years that the planning boards have, to any appreciable extent, conformed to this section. Lack of necessary funds in the appropriation, or planning boards not "deeming it advisable" to prepare a master plan, have been the most frequent reasons for non-compliance with the mandate of this section to prepare a plan.

Community planning can be defined as a sequence in the process of thinking which may be applied to the solution of community problems so as to promote orderly development, economic stability and a more harmonious social environment for the future of the community.

There are many reasons for preparing a community plan but the following seem to be the principal reasons:

a. The Community Plan serves as a basic pattern or framework for the future growth and development of the community, or in the term of an engineer it is a blueprint for the future.
b. The Community Plan provides a way in which various elements of a community structure may be brought into their proper relationship and made to function together effectively with the minimum of conflict and the maximum of economy and stability.
c. The Community Plan provides a way of assuring that each new improvement which is made in the community makes its full contribution to the transforming of the present community into an increasingly better one.

A Community Plan must have several important characteristics which are fundamental to community development if the plan is to be of any value whatsoever to city or town. In order to have its full impact and usefulness on the community, each one of the following characteristics must contribute its full value to the implementation of the plan. The omission or the minimizing of any one of these characteristics weakens and sometimes nullifies an entire effort.

All planning must of necessity be LONG-RANGE. Even the meeting of immediate needs is in effect long-range, since decisions made today influence the future of a community. The plan must be long-range in scope to cover ten, fifteen or as far into the future as twenty-five years.

Good community planning must possess FLEXIBILITY within its fundamental framework to permit revision to meet changing conditions and needs. It must be flexible so as to cope with social and technological advancements. There are many changing conditions that even the small communities are required to face today. Such changes as a new super-highway being built through or near a city or town, or a large industry newly located within a community, are some that we are all familiar with. The city or town in which the proposed NASA research center will finally be located will be required to cope with tremendous conditions, changes and needs and there must be enough flexibility in the plan to meet with these impacts.

The third characteristic is COMPREHENSIVENESS. The Community Plan must have comprehensiveness so as to consider all aspects of community development and growth. The Community Plan is not highways alone, or recreation alone or schools alone. To be of its fullest value to a community, the plan must be an overall study of the community with all its elements being integrated in the most comprehensive manner.

It is very obvious that after citing the three previous characteristics that the fourth must be CONTINUITY. One of the principal reasons that community planning has suffered failures in many cities and towns is due to the lack of continuity in the community's planning. Planning, no matter in what field you are delving, is never completed. Whether it is in the field of industry, commerce, research, education or any that you wish to mention, there is continuous planning for the future. The industry that isn't continually planning for the future usually falls by the wayside. Similarly, community planning is never complete, it is a progressive procedure which must be constantly reviewed, revised and amended to meet the changing needs of the community. In a growing community, a Community Plan may require yearly review to make revisions required by rapidly changing conditions in the community.

Finally, community planning must have REGIONALITY. No city or town can plan without thorough knowledge of what is going on in neighboring communities. You cannot zone for the highest type of residential use on one side of the town line if on the other side it is zoned for heavy industry nor should you plan a new road to the town line without knowledge of where the neighboring town wishes to locate its section of the road. These examples may sound ridiculous. However, ridiculous as they may sound, it is being done much to the embarrassment and sorrow of the municipalities.

To re-enumerate the characteristics of a Community Plan: Long-range, Flexibility, Comprehensiveness, Continuity and Regionality.

A Community Plan is a collection of documents, reports, statistics, maps and recommendations that has four basic elements as the framework of the plan.

These four basic elements are:

1. The land use plan
2. Circulation and transportation plan
3. The public facilities plan, and
4. The public utility plan.

To obtain a fuller understanding of the basis of the four major elements other specialized studies are also required. These studies include population and housing studies, economic base study, central business district, industrial and commercial development, etc.

The most important of all studies and plans is the land use plan. All the other elements are closely related to the determination of the future use of the land within the community. No sound determinations can be made on other service facilities without knowing where people are going to live—where it is most desirable that they live or work. It is true that existing highways have been one of the major factors influencing the shaping of the current land use pattern, yet a future land use pattern determines the directions of major traffic generation. Because of this interaction of land uses on highway needs and the effect of highway on land use development, highway and land use planning must go hand in hand. In the preparation of a future land use plan close consideration must be given to the economic and population growth, trends and future potential. The shape and pattern of the future land use plan must be controlled by existing facilities and growth on the ground, the suitability of various adjacent areas for expansion and use, and a decision as to the general shape of urbanization and open space that would best suit the future needs of the community. The Future Land Use Plan tries to give a general vision of what the city or town will and should look like. It partly answers the question: "What kind of an environment do we want in the future?"

The second element—circulation and transportation—is also very important because no well designed future land use plan can materialize without well-thought-out circulation and transportation plans to fit the desired pattern of future land use. This plan would vary in its intensity depending on the size of the community being planned. It would cover highways, parking, mass transportation and airport facilities needed to serve the future of the community.

As in the circulation and transportation plan, the proposed land use will dictate the location of future facilities and utilities. They serve the people and have a direct relationship between the location of the major uses and traffic and transportation. These plans (public facilities and utilities) would indicate a general priority scheme of the needs of the public facilities and utilities which would involve sewerage and water developments, future school locations, recreation areas, open spaces and sites for public buildings.

Although it is not included in the major elements of a comprehensive plan, the Economic Base study is of significant importance to the community. Studies of the economic base of a community are essential in (1) forecasting the growth of the area and the facilities and the land that will be required for various purposes; and (2) in formulating a sound program for the further development of the economic resources of the community. The economic studies that are desirable or required for either forecasting the growth of an area or formulating a program for further development of its economic resources are, for the most part, identical. These studies would include the study of people, their income and their jobs. It would also involve the competitive advantages and disadvantages in the area for retaining and strengthening its present industries and attracting new ones.

The economic base study will develop programs for the future development of the economic resources of the community. A sound program of this character will aim to secure full utilization of the available labor supply, to minimize seasonal and cyclical fluctuations in employment, to secure increased business and industrial efficiency through the establishment of interrelated business and industries, and to secure a favorable balance between the cost of the community services for industry and business and the income derived by the community therefrom. The success of all the efforts for improving community living conditions rests upon a stable and strong municipal economic base.

The most important phase of the Community Plan comes not during the different stages of its preparation but at the completion of the plan. The Community Plan has the "blue-print" for the future guidance of the city or town. However, by itself it cannot go very far. In fact, by itself it will most likely land on a shelf and become a very expensive "dust collector," the fate of innumerable other studies and plans. The plan in order to accomplish what it was designed to do needs understanding, public backing, and action. This is the stage in the course of the Community Plan that is known as the effectuation stage. Without it, the Community Plan is doomed to complete failure. This, incidentally, brings in one of the characteristics previously mentioned, namely—continuity. Continuity and effectuation go hand in hand. Each is heavily dependent on the other. I would like to stress to any city or town contemplating the preparation of a Community Plan only because it is "stylish" to have a plan and have no intention of using it, they would be wise to save their money and devote their time to some other undertaking.

In order to effectuate properly a Community Plan, it is necessary to have essential "tools." There are a number of such "tools" which are described as follows:

1. The Community Plan report itself. Sufficient reports should be made available so as to furnish copies to all agencies, and individuals that will be concerned with the plan. Additional copies should be placed in libraries, schools and similar locations so that the public may have access to the study.
2. A brief and concrete summary report of the Community Plan should be printed in quantity for distribution to the general public. This procedure has proven very successful in many communities as a means of informing the public of what is in the "Plan," what it will do and how it can be done.
3. Zoning. Zoning is one of the most significant tools in effectuating the Community Plan. It makes certain that the use of land and the intensity of that use occurs in a constructive and organized manner rather than in a hit-or-miss and uneconomic manner. Zoning is established after a careful analysis of present conditions and the expectable future trends as determined in the Community Plan. It provides protection to those who are carrying on any type of activity in the community, yet insures that new developments in the community will be

on a sound and well-organized basis and in conformity with the Community Plan.

4. Subdivision Control. Subdivision Control is as important a "tool" for the effectuation of the Community Plan as Zoning. It is the guide for the development of the vacant land within a community under rules and regulations so as to insure that the new streets laid out will form, as they are built and extended and connected together, an adequate pattern of circulation so that all land will be readily accessible and that the circulation elements of the Community Plan are carried out.
5. Building Codes. Building Codes provide adequate standards for design and construction of new buildings and for significant alterations to old buildings. Building codes assure minimum standards of construction for long life and proper maintenance of buildings which serve as a property tax base for all communities. It assists in the stability of valuations which are the source of financing the local government.
6. Housing Codes. Housing Codes prescribe the minimum conditions under which a building may be lawfully occupied as a dwelling. Housing regulations set standards for occupancy to prevent over-crowding, for basic sanitary facilities, for light and ventilation, for maintenance, and for heating. Housing codes have been developed in recent years as a means of preventing the development of slums and sub-standard housing. Both the building and housing codes are, in the simplest terms, based on the proposition that the community cannot afford to have situations develop which are injurious to the public health, safety and welfare, if the community is later to be forced to take aggressive and expensive action to overcome the deficiencies as is required under the Urban Renewal Program.
7. Capital Improvement Program. Since the fiscal stability of our communities is extremely important, the Capital Improvement Program is the logical means to implement the recommendations proposed in the Community Plan and still stay within a sound financial plan. The Capital Improvement program sets forth the public building needs and the services of the community in the immediate years ahead (usually 6 to 8 years) integrated with a long-term community plan. Such

a program is not definitive in nature but guides the action of the legislative body. While usually a planning function, it is also closely related to the actions of the finance or advisory committee of the city or town as it reviews operating budgets from year to year and should be prepared with the co-operation of such a group.

8. Urban Renewal. Urban renewal is becoming a more important tool for the effectuation of the Community Plan. Urban renewal is a joint effort of the Federal, state and local government to revitalize our older neighborhoods which are in the process of decaying and to prevent the spread of blight into areas which are still sound. In order to qualify for an urban renewal program, the community must indicate to the Federal government (the Housing and Home Finance Agency) its willingness to participate in a community improvement program (also known as the Workable Program) which is basically an outline of community's effort or plans to help itself prevent slum and blight. The Workable Program has seven elements that the community takes action on in order to qualify for urban renewal. One of the important elements of the Workable Program is the Comprehensive Community Plan, which must include zoning and subdivision regulations. The other elements are:

    a. Codes and ordinances
        (1) Building, plumbing, electrical codes
        (2) Housing codes
    b. Neighborhood analysis
    c. Administrative organization
    d. Financing
    e. Housing for displaced families
    f. Citizen participation

9. Conservation Program. Open space is fast becoming a critical problem in many of the rapidly urbanizing communities. So as to be sure that there be the proper amount of open space within a community the conservation program is becoming an an important element of the Community Plan. This program should be prepared in close conjunction with a Conservation Commission of the community, if one exists. The purpose of a

conservation plan is to help curb urban sprawl and help prevent the spread of blight, to provide recreational, conservation and scenic areas and to increase the amenities of the community. It has been proven so many times that blight spreads more rapidly in areas where open space is lacking. This problem is becoming so acute that the Federal government, under the Open Space Land Program, is now making cash grants to state and local communities of from 20% to 30% to assist in the acquisition of land in urban areas for permanent open-space land use.

If these "tools" are used to their fullest extent, the chances are that a Community Plan has an excellent chance of attaining its goals and will be the determinating factor of whether a community will have orderly development, economic stability and a harmonious social environment that will be attractive to people, commerce and industry.

Summarizing what has been discussed herein can best be done by quoting from a publication recently published by Sears, Roebuck & Co. entitled "ABC's of Community Planning."

"Planning can help to:

REVEAL and DESCRIBE problems and opportunities
CLARIFY needs and objectives
DEVELOP plans and programs, and
ACHIEVE solutions and goals."

However, let me just add another "tool" to make planning succeed within a community and that is PEOPLE. The plan will not succeed unless the people of the community are well aware of the Community Plan and its purpose, and the only way that this can be achieved is through a comprehensive educational program that will stimulate the interest of the people in the plan, thus adding to the forces to obtain proper effectuation. With this type of effectuation there is no doubt that the solutions and goals prescribed in the Community Plan will be achieved.

SUBDIVISION CONTROL

By Louis H. Smith,* *Member*

(Presented as Lecture 4 of the Surveying and Mapping Section, B.S.C.E., 1963 Spring Lecture Series, April 9, 1963).

The authority for Subdivision Control is found in the Subdivision Control Law, which consists of Sections 81K through 81GG of Chapter 41 of the Massachusetts General Laws. In Section 81L we find Subdivision Control defined as follows: " 'Subdivision Control' shall mean the power of regulating the subdivision of land granted by the subdivision control law." At first glance this seems like a pretty good definition but the more you have to do with Subdivision Control the more you realize that the term "Subdivision Control" is somewhat of a misnomer. Subdivision Control is largely the control of the layout and construction of streets or ways within subdivisions, by the community, acting through its Planning Board or in a few instances through its Board of Survey. Subdivision Control has very little to do with the land other than the streets or ways and I stress this at the start and I will stress it again in order that we all will visualize the same process, and, in our thinking, will be emphasizing streets and ways and relegating house-lots to the background.

Why does a community need the process of Subdivision Control and when did it originate? Both answers will be found in the following lengthy quotation. "When a real estate developer with no interest in the welfare of a town buys a tract of land and has a survey and plan of streets and house-lots made, with a view only to deriving the greatest profit to himself in the shortest time, and offers the lots for sale, often by 'high-pressure' methods of salesmanship, he often is not merely cheating the purchasers of the savings of a life-time, but is also dealing a deadly blow to the welfare of the whole community in which the development is situated. The streets in the development may be completely out of line with the general street plan of the neighborhood; they may be to narrow, or too steeply graded; it may be difficult if not impossible to provide sewerage and other public utilities; the lots may be too small or too narrow for decent and comfortable living.

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If the lots are sold and built upon, the city or town will be put to great expense in grading and constructing the streets and providing water and sewerage. If it fails to provide the essential improvements, serious problems of health and safety will arise; and even if it provides them, the development is likely to soon develop into a rural slum. Many of the lots usually remain unbuilt on and before many years cause another type of injury to the public interest due to tax delinquency. This problem became so serious that in the year 1907 legislation seeking to guard against it was adopted." The quotation is from "The Massachusetts Law of Planning and Zoning" by Philip Nichols, published in 1943. The legislation referred to was Chapter 191 of the Acts of 1907 which authorized the establishment of boards of survey. In all fairness I should say that the subdividers and builders today are not the villains of 1907.

Under the Board of Survey law which later became Sections 73 to 81 of Chapter 41 it was provided that no person could open for public travel any private way the location, direction, width, grades, and in cities the plan of drainage, of which had not previously been approved in writing by the board of survey and also that no register of deeds could record any plan showing thereon proposed ways unless there was endorsed thereon a certificate of said board that all laws applicable to such plan had been complied with. Therefore we find that Subdivision Control is not the infant child of the post-war housing boom but is the adult progeny of land speculation at the turn of the century.

In cities the board of survey consisted of three members appointed by the Mayor with the consent of the Council, and in towns consisted of the Selectmen. Consequently, we have had Subdivision Control, at least of a sort, for 50 years. These boards of survey in cities and towns increased in numbers over the next twenty to thirty years.

Planning Boards came into the picture in 1913. Chapter 494 of the Acts of 1913 required that planning boards be established in cities and towns having a population in excess of 10,000. Chapter 283 of the next year provided that towns with less than 10,000 could establish planning boards. These planning boards did not have the authority to exercise Subdivision Control, but the boards of survey still did, to a degree. Planning boards wanted some authority or means by which their recommendations might be effectuated. There was a conflict of interest between the two boards.

In 1931 the Legislature provided for the establishment of a special commission "to Study and Revise the Laws Relative to Zoning, Town Planning and the Regulation of Billboards and other Advertising Devices." The commission was able to make only a report of progress before the following session of the Legislature, and it was continued in office for another year. Its final report was printed in 1933. This commission was a strong one and it had placed at its disposal by the Harvard School of City Planning the results of extensive original researches into existing legislation on city planning and zoning, together with drafts of model enabling acts embodying suggestions for reasonable further advances. These researches were made by three of the leading authorities in the field of planning and zoning at the time, Edward M. Bassett, Robert Whitten and Frank B. Williams. The final report of the commission is considered by many planners as one of the most constructive contributions to the subject of planning and zoning legislation. The planning act met with considerable opposition and it was only after four years of further study and discussion and the acceptance of a number of amendments that the major provisions of the bill proposed by the commission were enacted into law.

The statute thus enacted was designated as Chapter 211 of the Acts of 1936 which established in the General Laws Sections 81A to 81J, inclusive of Chapter 41. It was entitled, "Improved Method of Municipal Planning" and it contained within those sections the first provisions for Subdivision Control by planning boards. The statute did not, in and of itself, terminate the existence of planning boards under the older law, or boards of survey, but left the matter of the substitution of a planning board under the new law optional with each city or town having such a board. The planning boards in existence on December 31, 1936 continued to function indefinitely unless and until the city or town voted to establish a planning board under the new law, and in such case the old board members remained in office until the members of the new board were elected and took office. The same is true of boards of survey. There are in fact some old-law planning boards and boards of survey still in existence.

Under Sections 81A to J, or Chapter 211 of the Acts of 1936, planning boards had the authority for Subdivision Control but the powers were mixed in with the general powers of planning boards. In 1947 (Chapter 340) the whole act was revised and expanded and became 81A to 81Y of Chapter 41. In 1953 a new revision was enacted which separated the powers of the planning board and provided a definite line of demarkation between the planning powers and Subdivision Control (Chapter 674), and again expanded the number of sections. The new law of 1953 exhausted the alphabet and contained Sections 81A through 81GG of Chapter 41. The first seven sections contained the general powers and duties of the planning board. The rest contained the powers of the planning board in relation to Subdivision Control, and were designated as "The Subdivision Control Law."

This legislation of 1953 was the result of a study and report by a Special Commission on Planning and Zoning which reported the previous year. The report had this to say about the subdivision control law in effect in 1952: "It is not made sufficiently clear that the application of the law is limited to the design and construction of ways in subdivisions, and some well-intentioned but overzealous planning boards have attempted to use their power of approving or disapproving plans of proposed subdivisions to enforce conditions doubtless intended for the good of the public, but not relating to the design and construction of ways within subdivisions, and it is said that some town counsels have approved this usurpation of power." The legislation of 1953 was not entirely successful on this score and we find today a few planning boards which would use their authority to enforce conditions not related to streets or ways.

Since 1953 there have been thirty-four legislative amendments, five in 1955, two in 1956, nine in 1957, four in 1958, three in 1959, seven in 1960, two in 1961 and two in 1962. Another complete revision such as was done in 1953, has been suggested now and is probably in order. Why have there been so many amendments and who sponsors them? Some of the amendments have been sponsored by the Massachusetts Federation of Planning Boards and have been attempts to clarify the law. Some amendments have been sponsored by the Home Builders Associations and they too have been attempts to clarify the law or to more specifically define procedures under the subdivision control process. It can be safely said that most or all of the amendments sponsored by the Home Builders have been prompted by dilatory, delaying or arbitrary actions by planning boards. A few amendments have been sponsored by individuals or groups other than the two agencies just mentioned. During the current session of the Legislature several amendments will probably be enacted. Fourteen amendments have been proposed and are pending. It has been the custom for the past few years for the Home Builders, the Federation and the

Planning Division to meet in the early fall to discuss proposed legislation. In the last two or three years no bill has been introduced unless the three groups have been in unanimity as to the substance of the proposed amendment.

All legislative bills require a public hearing before the committee to which they are referred. Bills to amend the Subdivision Control Law are usually referred to the Committee on Mercantile Affairs. The Home Builders, the Federation of Planning Boards and the Planning Division of the Department of Commerce are always represented and take a stand on the proposals. I would urge a greater interest in subdivision control legislation by engineers and surveyors who are involved in the subdivision process and particularly the sponsoring organizations of these lectures. I would further urge, although this may not be the proper place to do so, a more active interest in Subdivision Control legislation, and planning and zoning legislation, by several other organizations and agencies such as the new Massachusetts League of Cities and Towns, the Massachusetts Federation of Taxpayers Associations, and the Planning Departments of our Universities. The co-operation or involvement of such agencies would undoubtedly make for better legislation and especially if the co-operation is timely. I say this because a few weeks ago one of the organizations mentioned attempted to kill a bill which had nearly reached the Governor's desk for his signature and had the unanimous approval of the Home Builders, the Federation of Planning Boards and the Planning Division of the Department of Commerce. Co-operation in the fall before bills are finally drafted would be helpful and I shall suggest to the Federation and to the Home Builders that other organizations be invited to participate next fall. Co-operation in January, with attendance of the representatives of these organizations at the public hearings would be helpful to all concerned.

Before discussing the Subdivision Control Law, in more or less detail, let us recapitulate. Subdivision Control is the power of regulating the subdivision of land, according to the definition, but actually it is the control of the layout and construction of streets within subdivisions. A city or town acquires this power by the establishment of a planning board under Section 81A of Chapter 41, acquiring this power automatically and as has been the case in the past perhaps inadvertantly, unless it specifically rejects the power of Subdivision Control. A city or town may also vote the power of Subdivision Control to an existing board of survey. Hereafter the words "Planning Board" shall be synonymous with "Board of Survey" if such latter board has been granted the power of Subdivision Control.

To exercise the power of Subdivision Control the planning board must adopt, after a public hearing, reasonable rules and regulations regarding the subdivision of land, consisting of procedural requirements, and specifications for construction of the ways and the installation of municipal utilities therein. The regulations must be filed in the office of the planning board, with the city or town clerk, with the appropriate registry of deeds and with the Recorder of the Land Court. More about rules and regulations later.

In addition to filing the rules and regulations, in order to be legally in business, a planning board must notify the register of deeds and the recorder of the land court that the city or town has accepted the provisions of the Subdivision Control Law and that the rules and regulations were adopted as provided therein, and further, that the board shall have furnished the said register and recorder with a copy of the vote of the city council or town meeting under which the Subdivision Control Law was accepted, certified by the city or town clerk.

According to records of the Land Court as of June 1, 1962, 234 communities had adopted Subdivision Control and had met the qualifying requirements. As of the same date 14 additional communities had adopted Subdivision Control by vote but were deficient in one or more of the qualifying requirements, and hence not legally qualified to exercise it. The 234 communities encompass about 90% of the population of the Commonwealth. Only one community has abolished its planning board and thus done away with Subdivision Control. Apparently Subdivision Control is here to stay.

Let us examine two important sections of the Subdivision Control Law.

Section 81L of Chapter 41 consists of definitions of words or terms found in that law. Most of them are routine definitions and can be passed over without comment. One definition that requires recognition and perhaps amplification is the definition of "Subdivision." The first few words of the definition, taken out of context, would seem to refute previous statements that "Subdivision Control" deals with street layout and construction and with little else. The definition starts out as follows—" 'Subdivision' shall mean the division of a tract of land into two or more lots. . . ." We can't stop here however because the definition goes on to say that the division of a tract of land into two or more lots shall not constitute a subdivision if at the time that it is made every lot within the tract so divided has the frontage required by zoning or if there is no required frontage by zoning, then twenty feet in both cases on a public way, a way previously approved as a subdivision way, or on a way in existence when the Subdivision Control Law became effective, in the city or town, and that way having, in the opinion of the planning board, sufficient width, suitable grades and adequate construction to provide for the needs of vehicular traffic in relation to the proposed use of land. Also, conveyances or other instruments adding to, taking away from, or changing the size and shape of, lots in such a manner as not to leave any lot so affected without the frontage above set forth, or the division of a tract of land on which two or more buildings were standing when the subdivision control law went into effect in the city or town in which the land lies into separate lots on each of which one of such buildings remains standing, shall not constitute a subdivision. To put it very simply the division of a tract of land into two or more lots is a subdivision if a new street or way is required to accomplish the division, and if no street or way is required the division will usually not constitute a subdivision.

Section 81M describes the purposes of the Subdivision Control Law. It perhaps will be worth-while to quote this section in its entirety. Section 81M reads as follows:

> "The subdivision control law has been enacted for the purpose of protecting the safety, convenience and welfare of the inhabitants of the cities and towns in which it is, or may hereafter be, put in effect by regulating the laying out and construction of ways in subdivisions providing access to the several lots therein, but which have not become public ways, and ensuring sanitary conditions in subdivisions and in proper cases parks and open areas. The powers of a planning board and of a board of appeal under the subdivision control law shall be exercised with due regard for the provision of adequate access to all of the lots in a subdivision by ways that will be safe and convenient for travel; for lessening congestion in such ways and in the adjacent public ways; for reducing danger to life and limb in the operation of motor vehicles; for securing safety in the case of fire, flood, panic and other emergencies; for insuring compliance with the applicable zoning ordinances or by-laws; for securing adequate provision for water, sewerage, drainage and other requirements where necessary in a subdivision and for co-ordinating the ways in a subdivision with each other and with the public ways in the city or town in which it is located and with the ways in neighboring subdvisions."

The section originally stopped here. But because some planning boards were accused of disapproving definitive plans arbitrarily and which were identical with preliminary plans which they had already approved, the following amendment sponsored by the Homebuilders was enacted and the following sentence became a part of this section.

> "It is the intent of the subdivision control law that any subdivision plan filed with the planning board shall receive the approval of such board if said plan conforms to the recommendation of the board of health and to the reasonable rules and regulations of the planning board pertaining to subdivision of land; provided, however, that such board may, when appropriate, waive, as provided for in section eighty-one R, such portions of the rules and regulations as is deemed advisable."

We now know what a subdivision is, and the purpose of the Subdivision Control Law. Before any person may make a subdivision of land in a city or town in which the Subdivision Control Law is in effect, he must submit to the planning board a plan of his proposed subdivision. The plan must show the lots into which such land is to be divided and existing and proposed ways, and the plan must be approved by the planning board. After approval of the plan, the location and width of ways shown on the plan may not be changed unless the plan is amended by the board, but the number, shape and size of lots may be changed from time to time without action by the board provided that every lot so changed still has the required frontage, and of course complies with other requirements of zoning.

After due notice and a public hearing, a planning board is required to adopt, and may from time to time amend, reasonable rules and regulations relative to Subdivision Control. Such rules and regulations may prescribe the size, form, contents, style and number of copies of plans, and rules of procedure for submission and approval thereof; and will set forth the requirements of the board with respect to the location, construction, width and grades of the proposed ways and the installation of municipal services therein.

In establishing such requirements regarding ways, says the law, due regard shall be paid to the prospective character of different subdivisions, whether open residence, dense residence, business or industrial, and the prospective amount of travel upon the various ways therein, and to adjustment of the requirements accordingly. This sentence has been almost entirely ignored by planning boards, they having established one set of standards applicable throughout the community regardless of density or proposed use-classification. Only the Town of Canton, to our knowledge has separate specifications for different types of subdivisions, in this case, three, and based on density. Planning boards would do well to examine and heed this mandatory but ignored requirement.

Subdivision rules and regulations cannot require as a condition for approval that land be dedicated to public use without just compensation to the owner. No rule or regulation shall relate to the size, shape, width, frontage or use of lots within subdivisions except insofar as it may require compliance with zoning. A planning board may waive strict compliance with its rules and regulations when such action is in the public interest and not inconsistent with the intent and purpose of the Subdivision Control Law.

Any person, before submitting a Definitive Plan for approval may first submit to the planning board and to the board of health a Preliminary Plan and he must give written notice to the city or town clerk by delivery or by registered mail that he has submitted such plan. Within sixty days each board shall tentatively approve the plan with or without modifications or disapprove the plan and, in the case of disapproval, state its reasons therefor. The Preliminary Plan and a Definitive Plan evolved from it will be governed by the planning boards rules and regulations in effect at the time of the submission of the Preliminary Plan provided the Definitive Plan is submitted within seven months from the date on which the Preliminary Plan was submitted.

Any person submitting a Definitive Plan for approval or submitting a plan for a determination that approval is not required, must give written notice to the city or town clerk by delivery or by registered mail, that he has submitted such a plan. The notice must describe the land and must state the date of submission and the name and address of the owner.

When a Definitive Plan of a subdivision is submitted to a planning board, a copy thereof shall also be filed with the board of health or to the board or officer having like powers and duties. Such health board or officer shall, within forty-five days, report to the planning board in writing approval or disapproval of the plan. In event of disapproval the board shall make specific findings as to which, if any, of the lots cannot be used for building sites without injury to the public health and the reasons therefor, and shall make recommendations for the adjustment thereof. Failure to report shall be deemed approval.

Before approval, modification and approval, or disapproval of a Definitive Plan is given, the planning board must hold a public hearing and notice of the time and place and of the subject matter sufficient for identification must be given by advertisement in a newspaper of general circulation in the city or town once in each of two successive weeks, the first publication being not less than fourteen days before the day of the hearing and by mailing a copy of the advertisement to the applicant and to all owners of land abutting on the land included on the plan as appearing on the most recent tax list, or if no newspaper then by posting in the city or town hall for fourteen days.

After the public hearing and after the report of the health board or officer or the lapse of forty-five days without a report, the planning board must approve, or if such plan does not comply with the rules and regulations or the recommendations of the health board or officer, will modify and approve, or disapprove, the plan. In the event of disapproval the planning board must state in detail the plan's deficiencies and must revoke its disapproval and approve the plan when those deficiencies have been corrected. The planning board files a certificate of its action with the city or town clerk and notifies the applicant by registered mail.

Before approval of a definitive subdivision plan, or before endorsement of approval, if current legislation is enacted this year, a planning board must require provision for the construction of ways and the installation of municipal services in accordance with its rules and regulations, such construction and installation to be secured by one of two following methods, or in part by one and in part by the other, the method being selected and from time to time varied by the applicant.

The first method is by a proper bond or a deposit of money or negotiable securities, sufficient in the opinion of the planning board to secure performance of the required construction. The second method is by furnishing a covenant, executed and recorded by the owner, which will provide that the ways and services required by the board will be furnished to serve any lot before such lot may be built upon or conveyed.

When all construction and installation have been completed the applicant may notify the city or town clerk and if the planning board determines that construction and installation have been completed, it must release the interest of the city or town in the bond or release the covenant. If the board determines that construction and installation fail to comply with its rules and regulations, it shall specify to the applicant in writing the details wherein said construction and installation fail to comply.

A planning board may modify, amend or rescind its approval of a subdivision plan or require a change in the plan as a condition of its retaining the status of an approved plan, on its own initiative, or on petition. This is rarely done, but if it is, the law says that for a modification, rescission or change, all of the provisions relating to submission and approval of a plan will apply "so far as apt." We would assume that this means a repetition of the whole process of advertising, public hearing, adhering to the prescribed time-table and so on. What step would not be "not apt" and consequently eliminated would be up to the planning board, but the safe way would be to complete every step of the process.

Up to this point we have discussed the history of Subdivision Control, and the course of the Preliminary and Definitive plan, the latter, briefly I admit. You may have gotten the impression that I have talked all around the subdivision control process, rather than about it. This may be true but for a reason. The subdivision plan often follows a smoother course than the plan of land which does not constitute a subdivision, yet under the Subdivision Control Law is submitted to the planning board for an endorsement that approval under the Subdivision Control Law is not required.

As has been stated before, any person wishing to record a plan, and who believes that his plan does not show a subdivision, may submit his plan to the planning board and if the board agrees, it shall, without a public hearing and without unnecessary delay endorse thereon the words "approval under the Subdivision Control Law not required" or words of similar import.

It is our observation at the Planning Division that such determination involves a substantial part of the planning board's time and that also almost everyone consulting the members of the staff of the Division of Planning asks for a piece of paper, draws a sketch with varying degrees of draftsmanship and then asks "Is this a subdivision?" If our answer is "no" the invariable answer is, "Well, we're not going to endorse it anyway because the lot does not meet the requirements of our zoning by-law."

One of the purposes of the Subdivision Control Law as stated in the statute is to insure compliance with zoning. But a plan submitted for endorsement which does not show a subdivision, does not come under the Subdivision Control Law, and hence the planning board has no power to require compliance with zoning, by withholding its endorsement of a plan which does not show a subdivision.

About three years ago, after a session such as this, a member of the audience stated to me that he was a member of a planning board, that they had before them a plan which they had been requested to endorse "approval under the Subdivision Control Law not required." They were refusing to endorse it. The plan showed a single parcel of land, containing several times the minimum required area and had adequate frontage. The lot was in all respects not a subdivision, nor did it violate the local zoning by-law. The reason they were withholding endorsement was that on the plan one leg of a perimeter survey did not show a bearing!

As a result of this incident and others, a bill was introduced and enacted into law which provided that the endorsement of a plan by a planning board should be withheld only if the plan showed a subdivision. The bill as originally written contained the words "and for no other reason." The words were deleted by Senate Counsel as being redundant and unnecessary. I wish the words had been left in. They would have added force. The fact remains that any plan which does not show a subdivision regardless of zoning or any other deficiencies should be endorsed "approval under the Subdivision Control Law not required." As the purpose of the endorsement is to meet the prerequisite for recording or registering, the register and recorder should be the judges whether the plan qualifies, not the planning board. A note may be added on the plan however, by the planning board and below the endorsement, which states that endorsement does not constitute an approval insofar as zoning is concerned or words of similar import.

As we discussed the Subdivision Control procedure above I deliberately omitted any reference to a board of appeals. The Subdivision Control Law devotes two complete sections to the establishment of a board of appeals and to the rules under which it is supposed to operate. These sections constitute one of the inconsistencies of the current Subdivision Control Law. The board as established has only one duty, namely to issue a permit for a building where such a permit has been denied and where the location of such building has no relation to a street or way. The occasion rarely occurs and hence a board of appeals is seldom called upon to act. A board of appeals established under the Subdivision Control Law has no authority to hear appeals, issue permits for special exceptions or to grant variances, as does a board of appeals under the Zoning Enabling Act. In other words, a board of appeals under the Subdivision Control Law even if legally established has practically no power and might well be non-existent. Any appeal from an action of a planning board except in the case of the remote instance cited, must be taken to the Superior Court, really the sole arbiter in Subdivision Control cases.

In closing I would like to say a little about the role that the Planning Division of the Department of Commerce plays in Subdivision Control throughout the Commonwealth. The Division maintains a constant and continuing consultation service answering questions on Subdivision Control through the telephone, correspondence, visits to our office and by staff members at planning board meetings.

Proposed subdivision regulations are reviewed by the staff when requested, and if such regulations are drafted by our consultants under the Urban Planning Assistance Program such review is required.

The Division publishes annually "The Muncipal Planning and Subdivision Control Law" into which have been incorporated the recent legislative amendments. Also available is a booklet entitled "Suggested Rules and Regulations for the Subdivision of Land" which has proved helpful to those communities initially adopting such regulations, and when amending them. Other pamphlets are entitled "Zoning and Its Relation to Plans not Requiring Approval Under the Subdivision Control Law," and "Powers and Duties of a Board of Appeals Established Under the Subdivision Control Law" and these pamphlets elaborate on points made herein. Still another publication describes the "Duties of the Town Clerk in Relation to Planning, Subdivision Control and Zoning," first compiled in 1957 by the Division at the request of the City and Town Clerks Association, and revised from time to time. Other publications are available on planning and zoning as well as Supreme Court Decisions on the more important cases. I invite you to take advantage of the facilities of the Planning Division of the Massachusetts Department of Commerce.

ELECTRONIC DISTANCE MEASURING DEVICES

By Robert E. Cameron,* *Member*

(Presented as Lectures 7 and 8 of the Surveying and Mapping Section, B.S.C.E., 1963 Spring Lecture Series, April 30 and May 7, 1963).

It had been my firm conviction that surveying equipment and techniques had lagged far behind other sciences. The modern steel or invar tape is little removed from the measuring ropes of the Ancient Egyptians. It seemed that with a smattering of geometry, a "trig" table, a transit and chain one could undertake and perform all surveying operations. But this is obviously a gross understatement of the profession of surveying where, in particular with cadastral surveys, procedures and decisions are carefully made from wide experience and a consideration of, among other things, legal factors. Here the equipment and measuring devices are important but secondary. Nevertheless, in many types of surveys such as in geodesy, aerial ground control, and traversing over long distances or difficult terrain the equipment is of great importance.

Actually many advances have been made over the years, in particular with optical theodolites and precise levels, but to my mind the greatest breakthrough (next to aerial photogrammetry) has occurred in the last ten years with the advent of electronic distance measuring devices.

Distances in surveying are indispensible. In the classic technique of triangulation a known base distance is necessary because obviously angles alone will not "fix" a figure. On the other hand, with trilateration, distances only will suffice.

There are presently several types of distance measuring devices available and suitable for land surveying. Among them are:

Cubic Electrotape
Fairchild Stratos Decor-G
Tellurometer "Micro-Distancer"
Wild Distomat
AGA Geodimeter

* General Manager, Harry R. Feldman, Inc.

These devices have many things in common but the most outstanding, from a practical point of view, is that they have been designed for rugged field use in conjunction with theodolites and other standard field equipment.

Before making a comparison of their various characteristics and discussing their operating principles, it might be well to point out that, although electronic distance measuring is quite new in the field of surveying, the basic techniques have been employed in other areas for some 40 years. In 1920 sound wave echoes were used to determine underwater depths. Marchese Guglielmo Marconi suggested the use of radio echoes as an aid to navigation in 1922. Radio echoes were used in 1925 by American scientists to detect and measure the range of the ionosphere. And in the thirties and succeeding war years the renown RADAR (Radio Detection And Ranging) came into being, this occuring after many improvements in electronic techniques and the development of microwave radar, operating on short-wave lengths (1 to 100 centimeters). There followed many devices and systems which were and are used primarily in the field of radio aids to navigation such as Loran, Shoran and GCA (Ground Controlled Approach). Also the application of the principle of the Doppler frequency shift was used for detecting and ranging moving targets at the close of World War II and is presently used for tracking rockets.

Since in survey work we are concerned with determining the unknown distance between fixed points, the problem is somewhat simplified; but on the other hand, the apparatus must be refined to give consistent results in the precision range of 1/10,000—1/50,000. With the devices that we are herein concerned, this is accomplished by phase comparison systems. The various systems differ mainly in the method of transmitting and displaying the phase information. In all of these devices, except the Geodimeter, high frequency radio waves are used and the operating principle is an instantaneous sampling of the phase of independent oscillators at each end of the line to be measured. The geodimeter makes an internal phase comparison using light waves as the carrier, reflected from a passive prism.

One of the main characteristics of electronic distance measuring devices is their compactness. They are somewhat box-like in appearance (about a 1 ft. cube), the box housing the electronic circuits, transmitters and receivers, with a convenient operating panel. They are mounted on theodolite tripods (or similar) and powered by storage batteries or small gasoline generators. The average weight is about 25 to 30 pounds.

All of the devices require line-of-sight conditions, that is, distances cannot be determined through hills, buildings, or thick forests. This, however, is not a disadvantage because in most cases we are dealing with traverses where horizontal angles are needed as with conventional tape and transit surveys and obviously line-of-sight is required from station to station. Furthermore, all of the measuring devices give the slope distance which has to be corrected to the horizontal (and with geodetic work reduced to sea level) by vertical angles or known differences in elevation.

The several electronic distance measuring devices are compared in Table 1.

Although each of the measuring devices indicated in Table 1 have certain desirable features, our firm has found the Geodimeter to be the most practical for our needs. Also, since my own actual experience has been with this instrument, I will discuss the Geodimeter in greater detail.

In the desire to know the distance from one point to another using light waves, one might say that since we know very accurately the velocity of light (and radio waves) to be 186,000 miles per sec. (3×10^{10} cm/sec.) we have a simple distance-rate-time problem and all we have to do is measure the time elapsed for a beam of light to travel from one point to another. But we would have to build a "super stop-watch" which cannot be readily done. What has been done, however, is to build a device which will transmit a modulated light with a very exact wave length and a receiver which will be able to determine what portion of the wave is entering the apparatus. The geodimeter transmits light with a quarter wave length of 2.500 meters. One might very well ask, "Well, this is fine to be able to tell what portion of the wave enters the instrument, but if we don't know how many complete waves there are between one point and the other, how can we determine the distance?" Now we have the key.

Dr. Erik Bergstrand (a Swedish physicist) reasoned that if a shorter wave length were emitted that particular wave would "fit" between two points so many times and now have a different remainder which again would be measureable; and now with a comparison of these remainders with the known wave lengths the distance travelled could be ascertained.

TABLE 1

COMPARISON CHART OF ELECTRONIC DISTANCE MEASURING DEVICES FOR LAND SURVEYING

Name	*Range*	*Features*	*Cost*
(1) Cubic Electrotape	30 Feet—30 Miles	Direct number readout Transistorized fiberglass houses 10.0 to 10.5 Kmc carried frequency. ± 1 cm resolution.	$6,040. ea. 2 required
(2) Decor-G	50 Feet—5 Miles	Separate ART (Antenna, Receiver, Transmitter) & CRC (Computor Readout Control) units. Accuracy ± 0.2 foot.	$12,000. Includes 3 ART Units & 1 CRC Unit
(3) Tellurometer Micro-Distancer	50 Feet—35 Miles	Reading on Cathode Ray Tube. Operating frequencies 2.8-3.2 Kmc.	$6,000. ea. 2 required
(4) Wild Distomat	100 Meters—50 Kilometers	Not yet on American Market. Characteristics and cost are expected to be competitive.	
(5) AGA Geodimeter	4-B 50 Feet—5 Miles 4-D 50 Feet—15-20 Miles	Uses light waves. Reflector station is passive & relatively inexpensive. Accuracy ± 0.04 foot.	4-B $5500 + Accessories 4-D $6500 + Accessories

(1) Cubic Corporation, 9233 Balboa Ave., San Diego 23, California
(2) Fairchild Stretos Electronic Systems Division, Wyondanch, Long Island, New York
(3) Tellurometer, Inc., 4435 Wisconsin Avenue, N. W., Washington 16, D. C.
(4) Wild Heerbrugg Instruments, Inc., Main & Covert Sts., Port Washington, New York
(5) AGA Corporation of America, P.O. Box 447, South Plainfield, New Jersey

A very crude analogy would be as follows: If we had two sticks —one 10 feet long and the other 9.5 feet long and we laid them on the ground side by side with one end of each on a line and then turned each of them end over end 10 times there would be a distance gap between them of 5 feet. ($10 \times 10' - 10 \times 9.5' = 5'$). If I had started by saying that if we had two sticks one 10 feet long and the other 9.5 feet long and after they had been moved ahead x times the distance between the two was 5 feet you could readily determine they must have been moved 10 times.

With the Geodimeter a third wave length is emitted with still a different remainder which gives a check and a greater refinement of values. Three distances are determined, therefore, with a very close agreement by comparison of F_1 & F_2, F_2 & F_3, and F_3 & F_1.

A better example, then, to the actual Geodimeter principle would be this: when measuring an unknown distance with a 100′ tape and the chainman fails to record the number of complete tape lengths but only gives you the information that the last break was 10′, then you have measured some number of 100′ lengths plus 10′. Now the line is measured with a 99′ tape and again the full tape lengths are not noted but the last break is recorded as 20′. Finally if the same line is measured in a similar manner with a 95′ tape the last break is found to be 60′. The distance, therefore, must be some number of 100′ lengths plus 10′, the second measurement will be some number of 99′ lengths plus 20′ and the third some number of 95′ lengths plus 60′.

If x = number of units of length and y = unknown distance

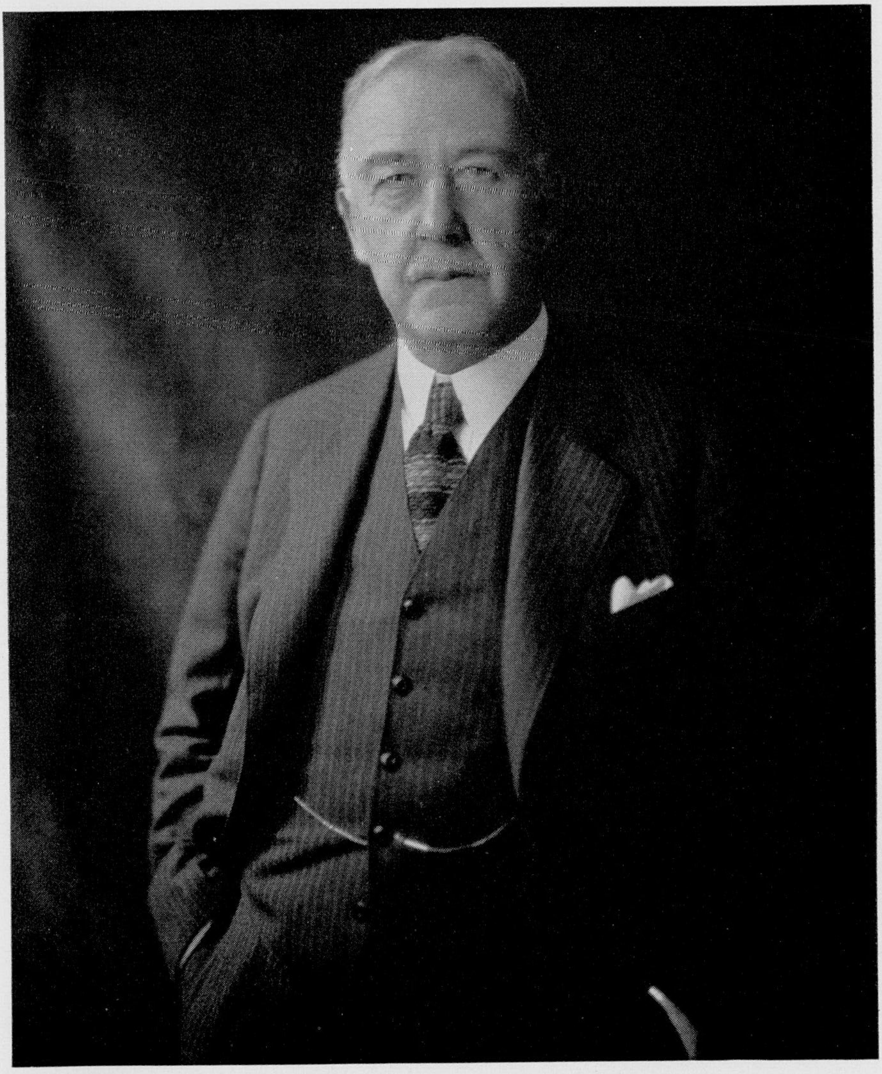
$$
\begin{aligned}
x\,(100) + 10' &= y \\
x\,(\ 99) + 20' &= y \\
x\,(\ 95) + 60' &= y \\
x &= 10 \\
y &= 1{,}010 \text{ ft.}
\end{aligned}
$$

For the Geodimeter the "tape lengths" are 2.500 M, 2.494 M, and 2.381 M which are highly stabilized by thermostatically controlled crystal oscillators coupled with an electronic shutter known as a Kerr-Cell. The instrument can be used at night or in bright sunlight but the operating range is less during the day.

Briefly, the transmitted light is returned to the Geodimeter by means of prisms in metal housings attached to tripods. Mirrors would not make practical reflectors because they would have to be too carefully aligned since the angle of incidence equals the angle of reflection. The 90° corner cube prisms are precisely ground and will return light to the source even if misdirected by as much as 20°.

It occurs to me, at this point, that in attempting to describe some of these electronic measuring devices it is somewhat like trying to describe a cow to someone who had never seen one—it's not easy—and the best way is to actually see one.

In conclusion I might state that the economies over conventional distance measuring are very substantial but not clear cut. For example, it is usually more economical to measure lines up to about 1000′ with a steel tape, on the other hand where you have difficult terrain—rivers, ravines, etc. a 500′ measurement with an electronic instrument may be exceedingly worthwhile. I firmly believe that with the advent of this equipment surveying technology has taken a giant stride ahead.



CHARLES MILTON SPOFFORD

CHARLES MILTON SPOFFORD
1871–1963

Charles Milton Spofford was born in Georgetown, Massachusetts, September 28, 1871. He passed away at Newton Center on July 2, 1963, following an illness of several years. Mr. Spofford is survived by a daughter, Mrs. Walter J. Beadle of Wilmington, Delaware, and three grandchildren.

For nearly half a century, Professor Spofford was a distinguished member of the faculty of Massachusetts Institute of Technology. An authority on structures, he published extensively in this field and his *Theory of Structures* was for many years a widely used text at engineering schools in this country and abroad. He was the recipient of a number of notable awards, and the Spofford Room in the Civil Engineering Department at M.I.T. was named in his honor. In 1958 he was awarded the Frank F. Brown Medal by Franklin Institute of Philadelphia for invention and discovery in the building and allied industries.

He received the S.B. degree from M.I.T. in 1893 and was a graduate student in civil engineering there in 1893 and 1894. After a year with the Phoenix Bridge Company, he joined the teaching staff at M.I.T. in 1896 and became assistant professor in 1903. From 1905 to 1909, he was professor of civil engineering at Brooklyn Polytechnic Institute. He returned to M.I.T. as Hayward Professor in 1909 and served as Head of the Department from 1911 to 1933. From 1925 to 1927 he also served as Chairman of the Faculty.

As a partner in the consulting firm of Fay, Spofford & Thorndike, of Boston, which he helped to found in 1914, Professor Spofford participated in numerous major engineering undertakings, including the building of the Boston Army Base and of several major bridges in New England and elsewhere. He was a past vice president and director of the American Society of Civil Engineers and a member of the Institute of Civil Engineers, the International Association for Bridge and Structural Engineering, the American Society for Testing Materials, and the American Railway Engineering Association. He was a past president of the Boston Society of Civil Engineers.

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