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A CITY PLANNER LOOKS AT THE URBAN EXPLOSION

BY ROLAND B. GREELEY*

(Presented at a Joint Meeting of the Boston Society of Civil Engineers and Structural Section, BSCE, held on December 14, 1960.)

I BELIEVE it was Mark Twain who observed that everyone complained about the weather, but no one did anything about it. The urban explosion is in much the same position as the weather: most everyone complains about it, but little effort is made to cope with it systematically. To be sure, there have been many umbrellas raised, and a few suburbs have gone so far as to install central heating and air conditioning. But, at least in Metropolitan Boston, no fundamental efforts have been made to control the explosion rather than just gain protection from its worst effects.

Despite this, it seems to me that the urban explosion is in one major respect quite unlike the weather: it can be controlled; we can do a great deal about it. Rather than resorting to protective devices we could, if we wished, guide the explosion so that it would be beneficial rather than harmful.

Let us look at the existing situation, and at the phenomenon which we call explosion.

Metropolitan Boston is defined in many different ways, including anywhere from 43 to more than 100 towns and cities. The area that has been "Tracted" and for which census data has been reported by Census Tracts includes 90 cities and towns, with a total of 471 Census Tracts, averaging about 6,000 persons each. It is that area to which I refer when I use the term Greater Boston.

Greater Boston had a population of two-and-a-half million in 1950; according to preliminary Census figures the 1960 population

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was 200,000 more, or about 2¾ million. If growth continues at the same rate—a not unlikely assumption—the population will reach 3¾ million by about the turn of the Century.

During this period at least half of the existing physical plant—houses, schools, factories, etc.—should have become recognized as obsolete and thus have been replaced: certainly a half-life of 40 years is not unreasonably short for a modern city. On this basis then, by the year 2000 nearly two-thirds of the physical plant will have been built since 1960: half of what is needed to accommodate the present number of 2¾ million people, plus all of that needed to provide for the additional one million of net increase.

If we think of redesigning Greater Boston, with 2/3 of it new, the possibilities become amazing. From the planning viewpoint, these possibilities are very real. We could get virtually any kind of environment, any basic urban pattern, any distribution of land uses and transportation facilities we wanted. Only two basic qualifications enter the picture: first, we would have to decide what we want; and second, we would have to demonstrate a willingness to work together to carry out these decisions. These are major qualifications. However, they should not be hard to meet, especially if we recognize that the omni-present stumbling block—money—is not an obstacle in this case. By and large the differences in costs would be negligible.

We are going to build all the major facilities anyway. Regardless of what kind of pattern we choose, it will cost only a few percent more, or less, than what we would normally spend. The distribution of costs might vary appreciably; more for apartment-type construction and transit in one scheme; more for land services and highways in another; but the grand total will be little affected, irrespective of what scheme we select. There is only one difference in cost which appears likely: if we work concertedly toward pre-conceived goals we will probably spend less than if we drift along an uncharted and probably wasteful course. So that, whether we spend more or less than would be "normal," we could logically expect to get more for what we do spend.

What are some of the patterns for Greater Boston which we might hope to achieve in the next three or four decades? The possibilities are almost limitless, but I will mention four basic, and widely divergent types.

1. *Suburban Sprawl.* This is the pattern toward which we are

now evolving, in an unsystematic way. We could continue: to disperse our employment and shopping centers along Route 128, the datials outside of 128, and even a new circumferential such as Interstate Route 495; to scatter single-family housing on ½-to-2-acre lots throughout the region; and replace the obsolete housing in the built-up areas with apartments for childless families, with about the same number of dwelling units, but appreciably fewer persons per net acre. There is plenty of land to do this within the 90-town area, and still leave reasonable reserves of "open space." Unless something spurs us into following some other course, I predict that this is what will have happened by the year 2000 (except that we may have failed to preserve a respectable amount of open space).

2. *Recentralization.* We might elect to plan for recentralization—for concentration of most major regional facilities in the central core, and for clustering most residences within a reasonable commuting distance of this core. Such a policy could easily allow a significant fraction of industrial employment to remain decentralized, but it would necessitate development of an expanded radial rapid transit system—say from six to eight points on 128 to the central core. The core and principal intown slum areas could all be redeveloped for central employment—office, trade, government and some manufacturing; and outside of this the residential areas would decrease in density with distance from core or transit station. Such a pattern could contain virtually all the assumed development within Route 128.

3. *Segregated Concentric Pattern.* This would be only a relatively minor modification of the present trend in the direction of: (a) a relatively strong central employment core, probably supported by somewhat improved rapid transit; (b) an inner band of relatively high-density housing, accommodating anywhere from half to 90% of the population, and from which the workers commuted either inward to the central core or outward to the middle band; (c) a middle band of employment and retail trade centers, roughly corresponding to Route 128, and accounting for something like half of the "activity" of the Metropolis; and (d) an outer band of low-density housing, averaging an acre or more per family, and oriented economically toward both the middle band and the central core. Such a pattern could eventually, be augmented by an outer circumferential of employment, activity centers, and higher-density residence, in some such location as Route 495; but there is adequate space to accommodate a

population of 4 million, in such a segregated concentric pattern, without necessitating development of the outer circumferential.

4. *Satellite Pattern,* The pattern for the year 2000 could be essentially a core of about the same size and density as the present central area, plus a constellation of satellite communities separated by generally low-density residence and open space. Such a polynucleated metropolitan area might well include: reduction of the population inside Route 128 by some half-million people, to give more open space and low-density residence and industry; development of ten or a dozen cities the size of Framingham, or Brockton, or Lynn, spaced half-a dozen miles apart, and from one to ten miles beyond Route 128. Each satellite could be clearly separated by greenbelt from its neighbors, and each could be relatively self-contained for most economic and social activities: but a system of expressways could inter-connect all so that frequent trips, and even daily commuting, would be quite feasible between any two points in the complex. Rapid transit from each satellite to the central core might be desirable, but the amount of inter-satellite travel would probably make it unnecessary. All residents living under strictly urban conditions could be within a couple of miles of rural-like surroundings. All families with children could, if they so desired, live in single houses on relatively large lots (½ Acre to 1 Acre).

There are many other, perhaps much more desirable, patterns which could be devised, and brought into being. Those above are all very real possibilities. We can have any one of them, or any other equally tangible pattern, if we wish to plan for it. As for me, I choose the satellite pattern; and I'll tell you why.

The Case for Satellites

The past century or more of urbanization has witnessed a continuing struggle to reconcile the advantages and disadvantages of the intensively urbanized area. Most of the arguments seem to fall into two categories: (1) the advantages of the big City stem from the variety of opportunities, facilities, and social and economic choices it can afford; (2) the disadvantages stem chiefly from the crowded, non-natural, anonymous environment of the large, amorphous urbanized area. The paradoxical question has recurred: how can we capture the advantages which can be supported only by really large numbers of people, without losing the intimacy, human scale, easy access to light, air, and nature which characterize the small town? The flight to suburbia has been the answer for those who had the means to make that choice.

Since World War II the numbers who have elected to flee the centers of all our great metropolises have been phenomenal. The result adds up to one simple fact: we have become a nation of suburbanites. In order to get the variety and choice of jobs, shopping facilities, cultural and recreational opportunities that only a large population can support, we have—millions of us—elected to live in suburbia and commute many miles and many quarters-of-an-hour to enjoy virtually all these benefits.

Let me cite a few statistics about Greater Boston:

More than half of all Census Tracts lost population between 1950 and 1960.

Of those that lost population, 85% are tracts having dominantly multifamily housing; the remaining 15%, though not dominantly group housing, are old, inner suburban, transit-oriented areas.

Of the Census Tracts which gained population, nearly three fourths were dominantly single-family suburban in 1950, and still are.

All of the net growth of 200,000 persons between 1950 and 1960 can be accounted for by 40 rapidly growing Census Tracts which were, in 1950, relatively undeveloped, inexpensive land in the fringe areas.

Except for publicly subsidized housing, about 90% of all new units built in the area since the end of World War II were single-family units, intended for owner-occupancy.

There have been some relatively strong influences, such as tax policies, which have influenced this marked trend toward suburbia. But I believe that it reflects, to a very significant extent, consumer preference. If this is the case, why do I recommend satellites rather than "suburbia unlimited"?

It seems to me that the same social and economic processes which have made it possible for the wage-earner to own his own home in suburbia have also made it possible for him to gain the same advantages, and more, in well-planned satellite communities. He can live next door to small green space, and within a mile or two of green belt; he can have most of his daily and weekly needs, including his work, within a couple of miles; and he can be in a situation where it is easy to get to the central core to satisfy the occasional needs which can be satisfied only in the central core: he can get all of these as well in the satellite community as in typical suburbia. And he can also get a variety of housing, easy pedestrian access to many daily activities, a wide variety of social contacts, and efficient provision of the whole list of urban services and facilities in the satellite to an extent that is virtually impossible in typical suburbia. Suburbia is fine when you live in a small, relatively compact community surrounded by much open space; or it is eminently satisfactory to some who enjoy the solitude of the 2- or 5-acre lot, with an auto trip for every outside contact. But suburbia loses its allure when the whole area is built up to 10,000 sq. ft., or even 30,000 sq. ft. lots. It is neither urban or rural—it is just a neutral gray.

One more advantage to the satellite pattern, implicit in what was said above, is worth special emphasis. The satellite pattern offers truly desirable living conditions to the entire cross-section of our society in a way that has not seemed possible under our present patterns. Increasingly we have tended to divide all society into two great groups: (1) families with children, who shall live in suburbia; (2) families without children, who shall live in central-city apartments. To accentuate this segregation is not only basically unkind to such significant minority groups as the aging and retired persons; it is also folly because of the way it breaks up natural social contacts and stratifies the social and economic burdens of our communities. To me this is a major, not an incidental, reason for redesigning our metropolitan areas to provide for a more intimate mixture of basically different housing types. I think the satellite pattern is the best way of doing this.

Thus far I have talked very freely about the satellite without defining it. I have not defined it because I believe the term can embrace a great variety of communities. They must all, however, satisfy at least two criteria: (1) they must comprise a variety of housing types and densities and a nearly complete set of community facilities and services: shopping, churches, libraries, entertainment and recreation facilities, some basic employment, and if at all possible a relatively autonomous governmental organization; and (2) they must be small and compact enough so that they incorporate green areas within easy walking distance of all parts of the compact area, and so that large-scale open space is never more than a mile or two away. As long as these two criteria are satisfied, I think it unimportant whether the satellites contain only a few thousand families—though small ones tend to be economically inefficient—or whether they have populations of 100,000 or more. Once they exceed 100,000 by much, they tend to get too large to satisfy open space requirements readily, and perhaps get unwieldy socially and politically.

Bringing About the Satellite Era

Supposing we do want to guide our future development in the direction of such a satellite pattern—or in any other predetermined direction—how do we go about it? I shall make three specific suggestions, just by way of illustration, and one more basic general proposal.

First, we must integrate the various components of our transportation plan with each other and with the land use objectives we have established. Once our basic transit and highway systems are designed to serve and encourage the land use pattern we desire, much of the development will quite naturally and easily fall in line. Our transit system and our expressway will, especially if they are designed to complement each other, constitute a skeleton which will do much to determine the pattern of future land use and activities. If we recognize fundamental design objectives, rather than just current demands, we can utilize these systems to help obtain the future patterns we desire.

Secondly, we must sharpen up our old tools, and acquire some new tools to help us in guiding land use. Traditional zoning, applied uniformly to each individual lot, has tended to produce stultified patterns. Over-segregation of use, subdivisions of uniform lots and houses, "class zoning" have been all too common. "Cluster zoning," development districts, etc., seem to offer opportunities to apply zoning regulations at a larger and more fundamental scale, and thus allow good plans and variety in a way that is now inhibited by most zoning laws.

At present we have very little experience with preservation of open space, except through direct acquisition. Many communities seem to believe they can preserve open space through the device of large-lot zoning; but this appears to be more an illusion than a reality. Further techniques must be developed, and widely applied, if our environments are to incorporate the amount and patterns of open space that generally recognized as both desirable and functionally feasible.

Thirdly, we must learn to integrate more closely our utilities planning with our land use planning. Obviously, there are varying optimum or minimum sizes for lots, depending upon the types of public facilities (water, sewerage, sidewalk) which serve those lots—however much "standards" may vary with either local taste or conditions of soil, topography, etc. Yet it is only the rare set of planning controls which currently recognizes these variations, and the fundamental inter-relationships between these two elements of the total planning picture. Greater recognition of these relationships would make possible more efficient planning for whatever types of settlement we desire, and would also afford an additional opportunity to guide development in the directions we want to take.

Metropolitan Planning

All these objectives and all these tools will be relatively useless, unless we have a metropolitan planning program to integrate planning policies and objectives for the region as a whole, and to express these policies in the form of meaningful land use, circulation, open space and utilities plans. It is impossible for the municipalities, independently, to plan their future development along lines that make maximum sense for the region as a whole. It is inconceivable that we could have an integrated effort to envolve the kind of metropolitan environment we want, unless there is an over-all program, a Metropolitan planning program, to articulate our objectives and outline the major steps toward their attainment.

Thus far Boston has experienced many serious attempts to get a bona fide Metropolitan Planning program on an operational basis—but without real success: The Boston Contest and the Greater Boston Development Committee of the mid-forties; the Boston College Seminars and associated research endeavors; the Greater Boston Economic Study Committee: these are all noble efforts to fill, through one or another type of private auspices, the gap which exists in our governmental planning structure. But not until we have established on a functioning basis an official Metropolitan Planning Agency, responsive to the municipalities throughout Greater Boston, can we expect to concentrate our efforts systematically on building the kind of future environment we really want. Metropolitan Planning is a realistic way of "doing something" about the urban explosion.

THE CARRIER REPAIR SITE—PUGET SOUND NAVAL SHIPYARD

By William H. Mueser*

(Presented at a joint meeting of the Boston Society of Civil Engineers and the Structural and Construction Sections, BSCE, held on April 12, 1961.)

One year from now the Navy's largest graving dock will be completed and ready to comfortably dock the largest carriers now in service, under construction or on the drafting board. Many of you will have read one or the other of the articles or papers in the various engineering magazines and proceedings of the ASCE. This structure is remarkable in many aspects and I intend to deal with some of them.

Viewing the installation from a low-flying plane, a layman would see a rectangular shaped hole below the water level which is the pattern at the bottom of the graving dock and some large cranes and high towers at yard grade. You know very well that behind that inconspicuous facade, a very complex engineering structure is being hidden. As in so many civil engineering structures, very little shows the casual observer how much engineering had to be done to finish the job satisfactorily.

The dry dock's inside measurements are 1180 feet from the head end to the outboard face, 180 feet wide at the coping, 198 feet wide at the floor level and 61 feet deep.

A general view of the Puget Sound Naval Shipyard indicates its congestion and the dry dock had to be located in an extremely crowded area. At first, it seemed impossible to squeeze a large dry dock, with its laydown area and an outfitting pier into it without doing a lot of demolition and excavation. A dry dock is a big hole in the ground. It was, therefore, a logical decision to build the dry dock out into the water and add valuable acres (13¼) to the Shipyard area.

Various sites were considered. In the framework of an Advance Planning Report, an extensive study of the site and subsoil conditions were undertaken. The actual site was selected by weighing

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operational, economical and structural aspects. The jutting out into the Sound was limited because of a sharp drop of the bottom of the soft material at the southeast corner. Also, predominant in these considerations was the question, which type of dry dock would be appropriate for this site and how could the type and construction procedure be integrated.

Original mud line at the site is 50 feet below mean sea level, 60 feet below yard grade. Beneath the mud line a stratum of soft organic silty clay extended to a depth of as much as 35 feet. This is underlain by 5 to 10 feet of relatively clean sand followed by a very compact, heterogeneous mixture of silt, sand and gravel (glacial till) containing pockets of clean coarse-grained material.

Dry docks have been built in the past as gravity or hold-down or relieved-type structures. The advancement of soil mechanics has made prediction of the behavior of soils more reliable than, lets say twenty to thirty years ago. This dry dock is unprecedented as to the combined features of length, width and depth. Therefore, the selection of the type had to be resolved very carefully for economic and structural reasons and this led to a radical design for the graving dock.

The bottom of the harbor in the vicinity of the Shipyard is approximately at the same elevation as that proposed for the dock floor. Therefore, every foot of construction depth would require excavation and fill or concrete. The width between copings being 180 feet (originally 205 feet were considered by the Navy) would have caused large moments in the center of the slab if the weight of the walls would have been used as a help against the uplift. The slab of a gravity structure would have been 43 feet thick which would have required nearly one-half million cubic yards of concrete forgetting the substantially increased quantity of excavation also required, the cost of the concrete slab above would have been as much as the completed carrier repair site as it is now being built. The conventional method of holding down the dry dock by piles was ruled out because of the layer of soft clay on top of very hard material and in the belief that not enough penetration could be economically obtained for sufficient grip on piles. Prestressed cables anchored deep into the glacial till would have reduced the thickness of the slab to a reasonable amount, but the walls would still have had the same thickness as in a gravity structure. Furthermore, the installation of prestressed cables could have been accomplished only in a dewatered site. The logical choice was, therefore, a relieved dock.

The construction procedure was designed so that its features could be used for the operation of the completed dock. An earth dam with a sheet piling core driven to the glacial till which served as a cofferdam during construction would also serve as a cutoff during the operation of the dock. The earth dam would also serve as an integral part of the mole fill around the dock.

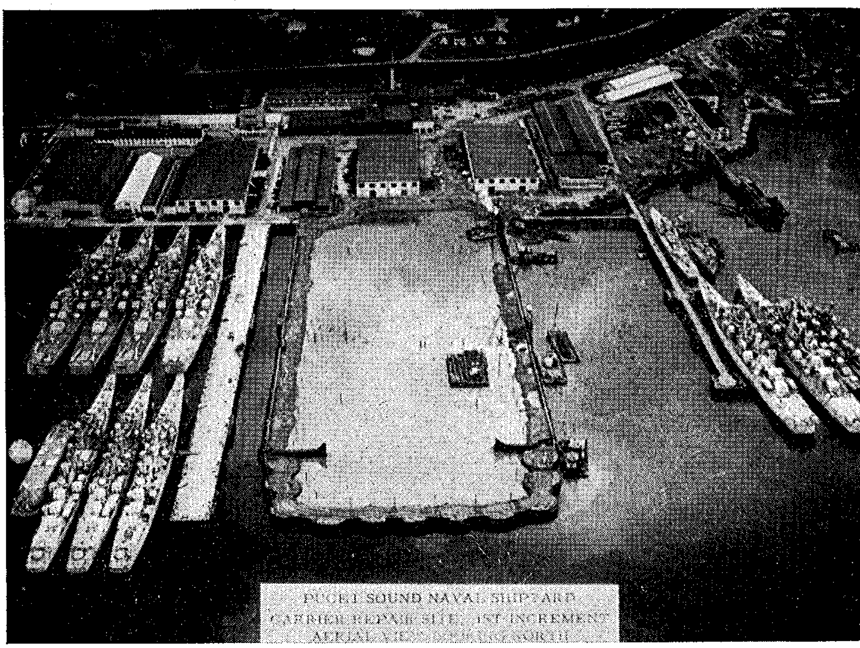
In order to provide a practically incompressible foundation for the dry dock and the laydown area, the soft material overlaying the gravel glacial till had to be dredged, altogether 550,000 cubic yards. The stability of the banks at the periphery of the dredged area was analyzed, the result being that an average slope of one vertical on 1¾ horizontal had to be maintained.

The cofferdam, which protects the site during the construction period, consists of earth dams at the east and west side, with eleven (11) circular cells arranged as a half ellipse at the south end and the existing group at the north end. The cross section of the earth dam was designed for placement of the fill material by sluicing it off barges or other similar methods. Placement by dump barges was only permitted for fill below Elev. 70 and before the sheet piles were set into place. Thus, impact against the sheet piles was prevented and the height differential at the sides of the sheet piles could be held to a minimum. It was computed that underwater slope of the fill material would be 1 to 2¾, a prediction which subsequently was borne out in the actual construction.

Fill material for the earth dam and the cells was carefully selected and rigidly specified and inspected. The fill had to stand on relatively steep slopes during underwater placement, provide high shear resistance for stability of the dams and cells, be free draining during drawdown, and to be incompressible in the foundation of the moles. Material was specified to be reasonably well graded in the following ranges: no sizes larger than 3 inches, not more than 60 per cent passing the No. 4 sieve, not more than 10 per cent passing the No. 100 sieve. The gradation selected was supplied with little or no processing from the abundant glacial outwash materials in nearby areas.

The dam with its cutoff wall was designed for the various stages and water levels during construction and where the sheet piling was used to its full cantilever value. It retained the construction roads at a level 12 feet below the final yard grade. For the final stage, the sheet piling becomes an integral part of the bulkhead or is tied back to deadmen.

The cells of the entrance cofferdam have a diameter of 60 feet. Their height above the dredged bottom is about 90 feet or at about

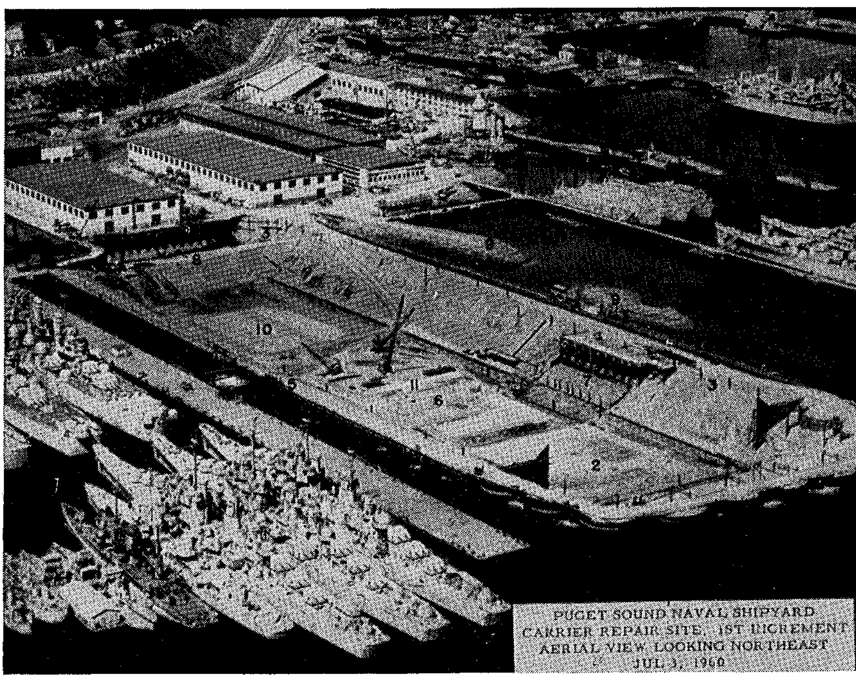


COFFERDAM COMPLETED

Elev. 123. At the land side a berm was provided 27½ feet below the top of the cofferdam.

The selection of the dewatering procedure was left to the contractor, subject to the Navy's approval. We made, however, a thorough study of the amount of water to be removed during construction and of the groundwater pressure in the slopes and bottom. The elevation to which the water had to be drawn and the location of controlling piezometer was specified in the contract. The actual water pumped after the initial dewatering was 7,000 to 9,000 gpm as compared to the anticipated underseepage estimated conservatively to be 15,000 gpm.

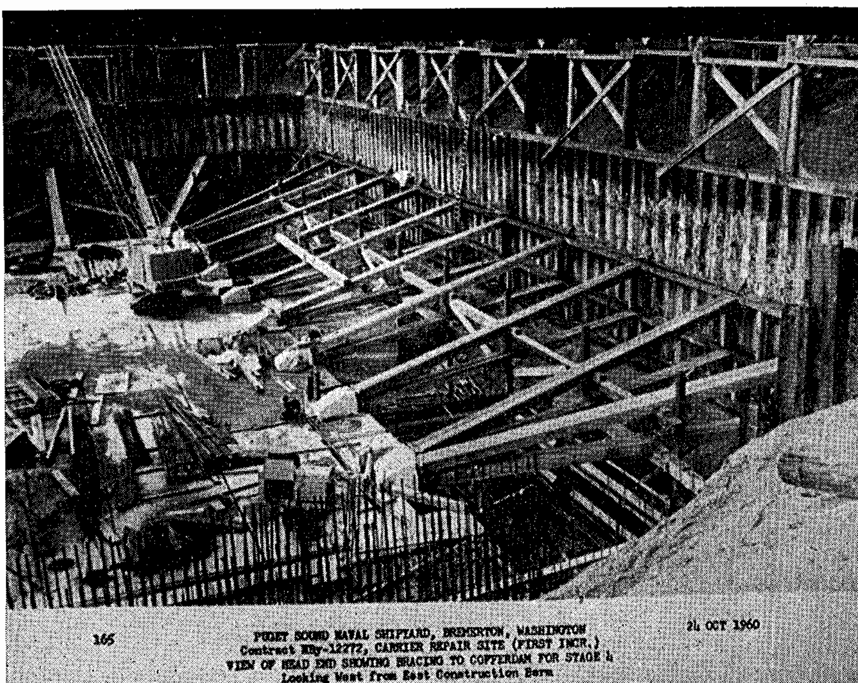
In addition to the main cofferdam, several secondary cofferdams were designed, one at the head end and a second at the pumpwell. The head end cofferdam was required to shorten the length of the excavation at the north end and to reduce the demolition of adjacent structures to a minimum. The pumpwell cofferdam was required to cut a shaft into the main cofferdam because of the shape and the depth of the pumpwell. The deepest section of the pumpwell



General View—Note Pumpwell Location

is more than 80 feet below mean high water. Both cofferdams are spur braced and their layout and construction procedure is conventional. However, construction procedure, the size of members and their connections were specified and were not left to the discretion of the contractor unless he could submit an alternate which could be approved as its equal.

Assured a safe and dry cofferdam around the construction site, the design of the more important features of the Carrier Repair Site, the drydock itself, could be undertaken. The design philosophy of a relieved graving dock is radically different from that of a conventional gravity dock. In the latter type of dock design the quantity of materials is tantamount to the safety of the structure against a tremendous hydrostatic uplift. The dimensions of the slab and walls are such that flooding and drainage tunnels, service galleries and mechanical tunnels, etc., can easily be carved into it without impairing their strength. The keel block loads, insignificant



HEAD END COFFERDAM BRACING

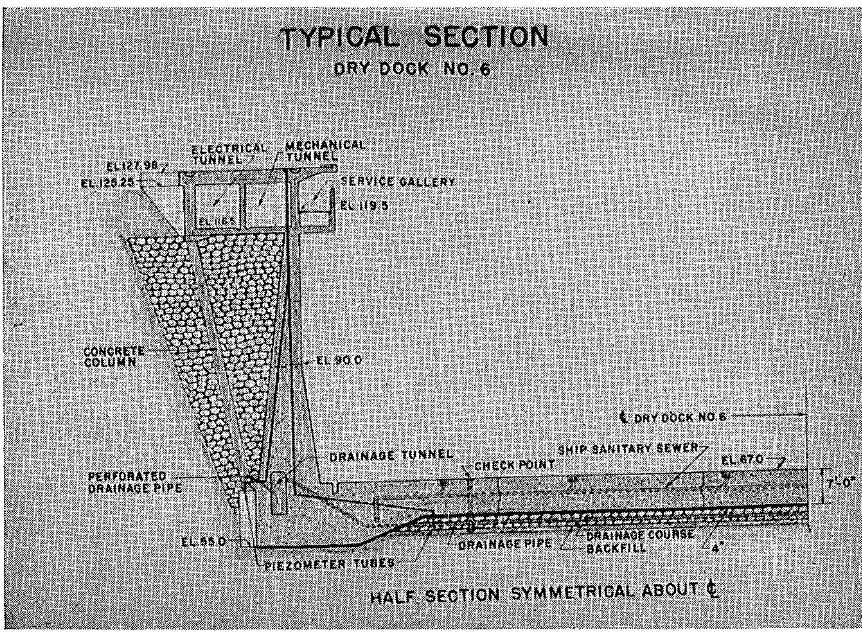
on massive concrete slabs, become major criteria in a relieved dock's slab design.

In a relieved graving dock design, the approach is quite different from that of a gravity dock. The size of each member must be selected economically to withstand the loads acting on it and just increasing materials will add nothing to the safety of the structure. However, they must be thick enough to provide a minimum of maintenance and simplify construction.

Let's therefore, start with the design of the slab. The ship considered was a nuclear carrier with a displacement of 95,000 tons and the unit pressure under a keel block equals 32.8 kips per square foot. It is well known that for any slab on an elastic subgrade, there is a direct ratio between the thickness of the slab and the moments induced by loads on it. The thicker the slab the greater the bending moments, but at least the soil pressure decreases. In this case the coefficient of subgrade reaction was evaluated as 260 kips per square foot per foot, i.e., a soil pressure of 6 kips per square foot would cause a deflection of roughly a quarter of an inch. The final thickness of a 7 foot slab was thus based on an optimum between strength, soil pressure and economy. Due to the great width of the dry dock, many computations could be simplified by assuming an infinite or semi-infinite length of the slab. The bottom slab is a relatively simple member to design as long as it is approximately 20 feet away from the wall. However, its intersection with the wall, the wall itself with its tunnels at the top and bottom make it a much more complicated structure.

The wall does not only retain the fill, but must also provide a drainage tunnel, support the service gallery and the mechanical and electrical tunnels and also the heavy loads from the portal crane tracks. The width between the copings was originally planned to be 205 feet, but was reduced to 180 feet for economic reasons by the Navy. Between the dock railing and the first crane rail, there is a distance of 3 feet to allow clearance for personnel between railing and crane. This requirement makes an overhang imperative as the wall is a natural support for the track. Below the yard grade there are separate mechanical and electrical tunnels which house all the utility lines except oxygen. Originally the wall design was considered to integrate these tunnels and the support of the crane rails into a counterforted structure, but this thought was abandoned as it required a greater width of the bottom slab at the base of the wall. A greater width at the base would have necessitated a larger distance between the two cutoff sheet pile walls and either Pier B or Mooring A would have been demolished. The final solution is that shown by dock's cross section in which sloping precast concrete columns support the outer wall of the utility tunnels.

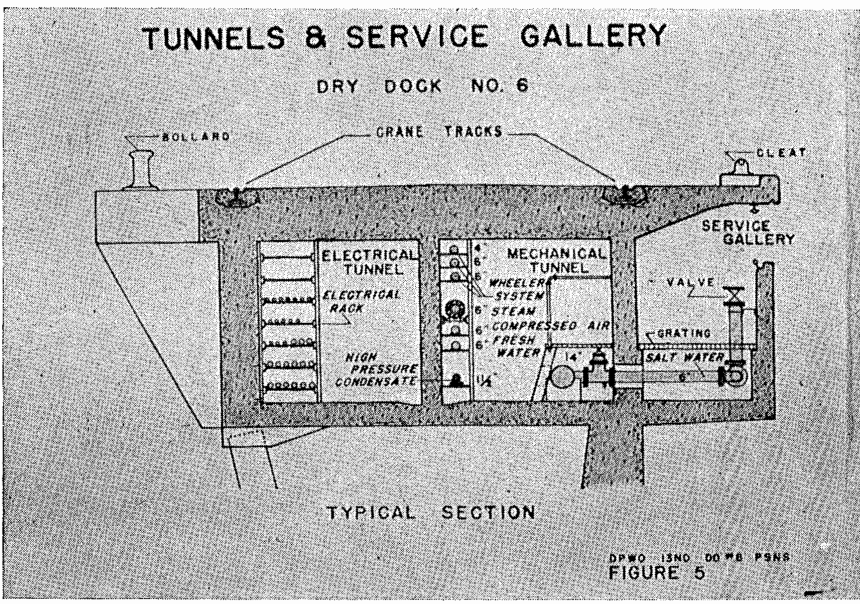
The dewatering of a dry dock requires a conduit near the base of the wall. Tunnels were placed in each longitudinal wall within the intersection of slab and wall, where the material was stressed the least. The top of the tunnel was placed above the dock floor but the floor elevation had to be consistent with the arrangement of the underdrainage system, which will be described later. Due to the hydraulic requirements for the dewatering tunnels, the slab thickness at the base of the wall was increased from 7 to 12 feet and the same dimension was adopted for the over-all thickness of



Dock Wall—Cross Section

the wall at its base. The top of the wall, below the utility tunnels, was selected from a functional standpoint for ease of construction. In between these elevations, the section was shaped to suit economy and appearance.

The service tunnel structure has four walls including the parapet of the service gallery. Each of them has a different thickness depending on its function. The standard Navy Yard twenty-foot track-gage set the center to center distance of the supporting walls, the wall between the electrical and mechanical tunnel thickness was considered a practical minimum, for the height of about 9 feet serves as a distributing member for loads on the top slab. The wall between the mechanical tunnel and the service gallery acts also as a support for the crane rail and was accordingly dimensioned. The parapet of the service gallery, designed for water pressure acting on the outside and with a pull from utility lines, has a thickness of 10 inches for its height of 4½ feet. The wall under the outer crane will serves also as a retaining wall against the fill. This wall needed a rigid support, therefore, the precast columns, inclined and supported



Service Gallery—Cross Section

at the lower end by brackets extending outward from the bottom slab was the answer. Thus, the dry dock wall, the gallery structure and these precast columns became a monolithic structure elastically restrained by the bottom slab. The design was developed to incorporate the actual behavior of the structure as much as feasible and reasonable. As mentioned before, the wall between the electrical and mechanical galleries acts as a distributing plate for the portal crane loads at the crossovers and in case of heavy truck crane loads equal to 30 kips per foot. The twin box structure also acts as distributing girder against horizontal loads. The distributing capacity of the gallery structures is of such a magnitude that isolated horizontal loads did not need to be considered individually in the design of the wall below.

The head end wall of the dry dock was designed as a slab restrained on three sides. Due to the varying moment of inertia and the stiffening effect of the mechanical gallery at the top, the design of the head end wall required the development of thirty simultaneous

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equations, the solution of which was developed with the help of a digital computer.

The wall at the entrance of the dry dock was designed as a gravity structure subject to the water pressure. This part of the structure is honeycombed by the filling culvert, the dewatering culvert, drainage discharge, salt water intake and traveling screen, and appurtenances for these conduits. Secondly, the size of a gravity structure was very convenient for the integration of the drydock structure with the adjacent Pier 9 and the connection to the temporary circular cell cofferdam at the entrance of the drydock.

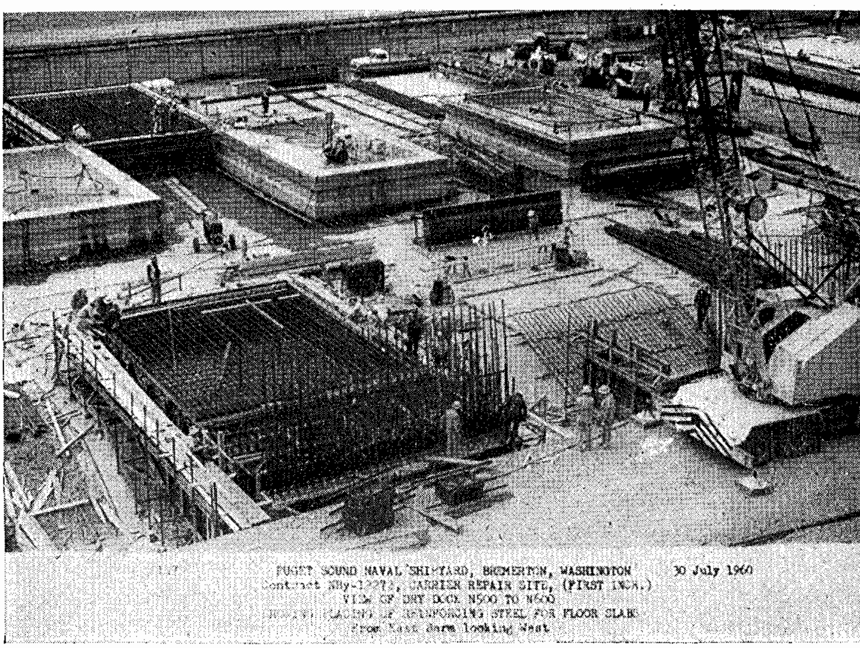
The pumpwell of the dry dock is subject to uplift and hydrostatic and earth pressures during the flooding of the drydock. Yet the bottom slab is subject to economic considerations as a thick slab which will increase the cost of excavation and dewatering during construction. The bulk of the weight of the pumpwell is contributed below Elev. 76 where the foundation for the pumps, the concrete around the discharge culverts and other conduits under water pressure, required heavy concrete thickness. The width of the pumpwell was reduced to a minimum by designing and using large pilasters which cantilever at the main pump motor floor.

The location of the pumpwell was a compromise created by four considerations. First, to have it as near as possible to the point of discharge; second, as near to the center of the drydock for ease in dewatering; thirdly to fit it into the crane track layout, and fourth, the construction procedure requirements due to the greater depth of the pumpwell's subgrade.

A large part of the design of this project, and not the least one, was its coordination with the multitude of fittings, utilities, crane tracks, stairs, mechanical and electrical cross tunnels into the structural design of the walls and slab. First, consider the sub-division of the slab and the walls themselves. A modular length of 12 feet was arbitrarily chosen for the spacing of the construction joints. The 7 foot slab was originally divided into 24 by 48 foot blocks, however, after the reduction of the width of the dry dock the 48 feet were reduced to 40 feet but in the longitudinal direction the 12 foot modulus was retained. The walls were poured in 48 foot lengths with a horizontal joint just below the utility tunnels and one intermediately halfway between top and bottom. The vertical construction joints in the walls were offset 12 feet from the transverse construction joints in the slab. The spacing of the precast columns of 16 feet fitted both the 24 foot length of the slab and the 48 foot lengths of the wall pours.

To handle a ship being brought into the dock cleats and bollards are needed for the lines and capstans to pull the ship into the dock and its proper lateral position. The cleats located along and close to the coping offered no particular problems. However, the bollards and capstans are located beyond the crane tracks. Inasmuch as the foundations for both could be incorporated into the tunnel structure, the shear and bending resistance of slabs, walls and utility tunnels was utilized, thereby considerably reducing the weight of their foundations to withstand a pull of 100 kips acting 30° above the horizontal.

The support of the turnout of the tracks was similarly treated. However, the transition between the rigid support of the track on the wall structure and the elastic support on fill was provided by an approach slab, similar to that used by highway slabs at bridge abutments.



Floor Slabs—Large Detail

In addition to the fittings and turnouts previously mentioned, there are sewage systems, sand traps, manholes, equipment hatches, piezometers and other installations such as the stairs to the service gallery and the dry dock floor and the proposed elevator to be fitted into the structural design.

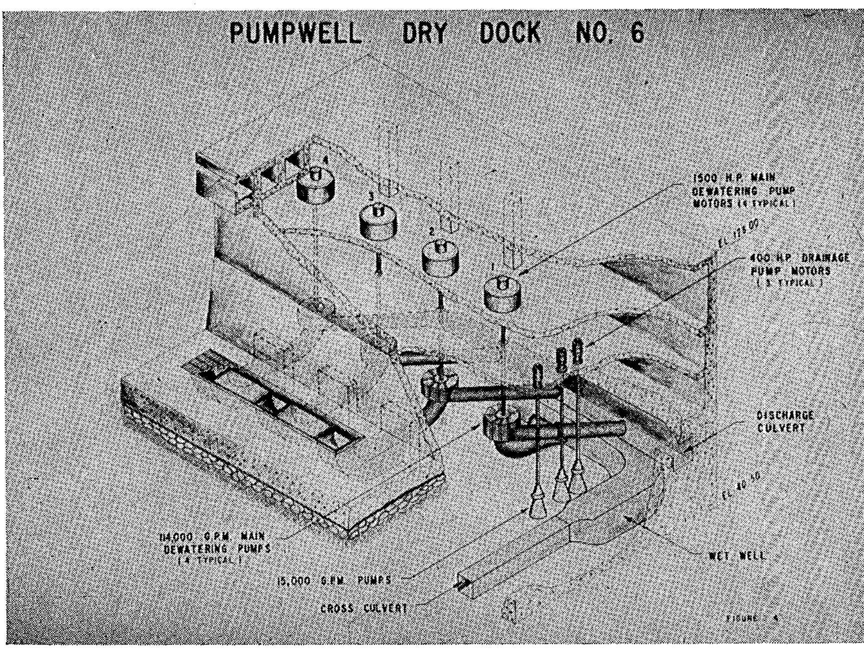
Let us return to a basic problem—water—which must and should always be respected. The best way to deal with it, is to get rid of it. In a drydock you have to depend on water to bring the ship into the dock. Thus, the design of the dewatering and filling of the dry dock play a big role in the dry dock's over-all design considerations. Two-hundred-seventy-acre feet must be moved in and out of the dock chamber. Filling, while it can be done relatively easy, requires serious consideration of culvert openings, the size of the flooding conduit, the velocity of the water on to the dock floor during the initial filling period in order to not disturb the pattern of keel blocks laid out for the ship entering the dry dock. The keel blocks are made of concrete sandwiched between timber and an inrushing wave might move them. Therefore, the initial flow of water into dry dock must be carefully controlled until the blocks are covered and protected against undesirable currents or wave action. Subsequently, the flooding procedure is limited only by the size of the conduits and the velocity within them.

A proven, efficient manner of flooding a dry dock is by means of a cross culvert located in the bottom slab near to outboard end of the dock through openings in the dock floor slab. We provided 18 openings of varying widths distributed evenly across the floor of the dock. The total flooding period was set to be 90 minutes and during an initial period of 20 minutes the water level in the dock was to be raised 10 feet. Therefore, to satisfy these criteria it was necessary to provide the equivalent of an 11 × 11 foot culvert at each side of the dock with a maximum entrance velocity of about 20 feet per second. Gates for that size were not considered to be economical, thus the intakes were split into two 8 × 8 foot openings with flush bottom sluice gates. These culverts were funneled into an outer opening of 14 × 11 feet at face of the entrance to compensate for the trashrack losses. The gates are operated by motorized equipment and can be opened or closed in 8 minutes.

The caisson used to close the dry dock and permit its dewatering was designed by Foster & Cafarelli, Consulting Engineers, New York. The caisson is a steel structure with high specific gravity concrete used as ballast and a minimum of equipment, such as flooding valves and pumps to empty the ballast tanks.

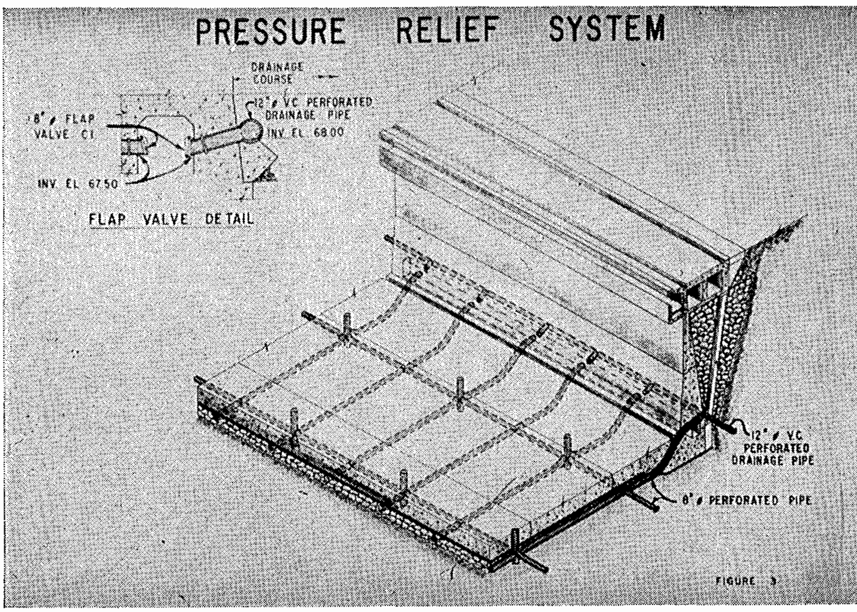
The caisson is reversible and can be used at either the inner or outer seat. Futhermore, when the caisson is in place it serves as a roadway across the width of the dock at its outboard end. The caisson is positioned in its seat by means of lines and the drydock's most southerly capstans.

In dewatering the dock we are not as fortunate, as it must be done within a reasonable time. The dewatering pumps are used infrequently and are required to pump against a varying head of 0 to 55 feet. It takes four 54-inch diameter pumps with a capacity of 114,000 gpm and 1500 HP motors to empty the dock in about 4 hours. A crucial point in the dewatering procedure of a dry dock is the removal of the last few feet as it is obvious that this depth of



Pumpwell Arrangement

water is not sufficient to feed the intake of one let alone all four major pumps. Generally speaking, the supplementary smaller drainage pumps are used for holding down the ground water and cleaning up the dock floor, however, it would take about 2 hours to remove the last 2 feet of water in the dock with two 15,000 gpm drainage pumps. This dilemma was solved by an arrangement of the intakes whereby the three dewatering pumps having separate intake conduits are fused into one for a shallow depth below the dock floor. This has the advantage that the intake circumference has been artificially enlarged to deliver water to one pump when the dock water level approaches the floor level. However, there are still the last inches of water at the far end of the dock where even this arrangement is inadequate. The fourth pump, therefore, was not connected to the dry dock chamber proper, but to the wet well. This wet well is required by the underdrainage system so that all or any combination of 1—54-inch—114,000 gpm or 3—15,000 gpm pumps can discharge the water entering from the opening in the dry dock walls, required as access to the drainage tunnels, and floor drainage gutters which feed into



Drainage Details

the drainage tunnels either directly or through a cross culvert into the wet wall. The openings and conduits are adequate to deliver at least 75,000 gpm to the fourth pump when it pumps against the highest possible head.

The second, and most important water problem for a relieved hydrostatic pressure designed structure, is its removal from outside the structure. The dry dock pressure relief system consists of two main elements, a drainage blanket beneath the floor and a wedge of drainage material behind the walls. Underdrainage of the dock floor is provided by a 3 foot thick layer of select free draining material, underlain by 1 foot of typical fill material where the floor is placed in cut in natural soils. The drainage layer is a clean, coarse-grained material specified as follows: no sizes larger than 3 inches, 50 to 65 per cent smaller than ¾ inch, 25 to 45 per cent smaller than No. 4 sieve, no particles smaller than No. 40 sieve. The drainage layer plus the 1 foot thickness of granular fill were designed as a two-layer filter against the natural soils to be encountered in cut areas. A grid of 8 inch perforated, closed joint, vitrified clay drain pipe is placed within the drainage course at 48 foot centers. This drainage system discharges through a cast iron line extending through the base of the dry dock wall and a flap valve into the drainage culvert.

A triangular-shaped wedge of the same drainage material surrounds the entire dry dock walls. This drainage wedge is 30 feet wide at the top of the wall and 5 feet wide at the level of the dock floor. Practically the entire active wedge of material exerting pressures on the dock wall falls within the drainage wedge. During the rapid dewatering of the dock interior the ground water levels within the active wedge outside the wall will drop almost as rapidly as water levels inside the dock. The wedges drain to 12 inch closed joint, perforated, vitrified clay pipe placed outside the wall at the level of the base of the dock floor, which is connected to the drainage culvert within the wall. The remainder of mole is built up with the clean, coarse-grained material supplied for the general fill.

This graving dock, while it was sponsored by the Bureau of Ships, U.S. Navy, the design and construction was conducted and supervised by the Bureau of Yards and Docks through the Public Works Officer of the 13th Naval District, Seattle, Washington. The Public Works Officer of the Shipyard acted as the Resident Officer in Charge of Construction and supervised all testing and construction. The Advanced Planning Report and the design of the graving dock proper was undertaken by Moran, Proctor, Mueser and Rutledge of New York and Carey and Kramer of Seattle. The latter firm designing, primarily, the utilities, power and architectural work, whereas the former undertook the remaining design problems including the site investigation.

For more detailed information on the design and construction of this dry dock see "Journal of the Waterways and Harbors Division," Proceedings of the American Society of Civil Engineers, dated March 1960.

CONSTRUCTION OF DRY DOCK NUMBER 6, PUGET SOUND NAVAL SHIPYARD

By Capt. Perry Boothe*

(Presented at a joint meeting of the Boston Society of Civil Engineers and the Structural and Construction Sections, BSCE, held on April 12, 1961.)

My contacts with this dry dock started in a very small way back in 1947 at which time the Puget Sound Naval Shipyard had the first indications that they would need to expand their dry dock facilities. Preliminary work was started at that time and continued with increasing intensity as the necessity for increasing the dry dock capacity became more acute. Finally, with the addition of the Forrestal Class carriers to the fleet it became very obvious that a dry dock was necessary to maintain them and the Puget Sound Naval Shipyard was selected as the site of this important Facility to serve the backbone of the fleet. I think a look at the world map would show an obvious need for a dry dock in the strategic North Pacific area. With no facilities on the Pacific Coast for docking a badly damaged Forrestal carrier, it would have been necessary for it to go 15,000 miles to the East Coast since it could not go through the Panama Canal. Concurrent with the decision to locate the dry dock at the Shipyard was the decision as to where would be the best place in the shipyard to locate it. Mr. Mueser has given you a description of the underlying geology and after many borings and conferences the present location was decided upon as offering the maximum advantage of economical construction while providing the shipyard with a much needed additional 13½ acres of land.

At first blush, the decision to locate the dry dock in open water appears rather startling but there was no sound engineering reason that rendered this decision infeasible.

I was not a partner in the early stages of the design of the dry dock. I left the shipyard in 1948 to return in 1957 at which time the dry dock was in the final design phase. I must confess that I oftentimes was confused with the many design problems that confronted me upon my reporting.

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* C.E.C., U.S.N.

Dry Dock Number 6 is considered the world's largest. There are one or two that are wider and one or two that may be longer but I know of none that are deeper. From the standpoint of volume, this is clearly the world's largest.

Waterfront structures frequently have a habit of becoming construction problems and right from the start the Bureau of Yards and Docks, who had the responsibility for constructing this dock, recognized that this dock could not be "business as usual." I think the first evidence of this was when the officer in charge of the design contract, Captain Zola, also District Public Works Officer for the 13th Naval District, recognized the fact that the shipyard was the customer and that for this important facility, to include as many of the desired features as possible it would be necessary for the shipyard to be a partner in the design.

For this reason, the Public Works Officer of the shipyard ran the design conferences with the architect-engineer, Moran, Proctor, Mueser & Rutledge and Carey & Kramer. The shipyard engineers had been living with these problems for so many years that they had worked out their requirements and it was only by their intimate association with the architect-engineer that these requirements could be factored into the design.

Another decision by the officer in charge was that we would have a pre-advertising conference. This conference was held about three or four weeks before advertising the contract. It was attended by 175 contractors and material suppliers from all over the country. The shipyard acted as host in order that everyone could see and evaluate the construction site. A briefing lasting one hour and five minutes complete with about 40 slides covered every aspect of the construction. The briefing had in mind two major objectives. The first was to inform prospective bidders as to the scope and magnitude of the work so that by proper evaluation of its magnitude, contractors could determine the best organization that would be required to handle the job.

The second one, while not voiced openly, was to indicate to marginal contractors and small contractors not familiar with the hazards of major waterfront contracts the magnitude and difficulties of the construction so that we would not have the problem of rejecting bids by unqualified contractors. The pre-advertising conference took a great deal of effort but it was considered as being worthwhile.

One contractor stated that the briefing had saved him at least two weeks of studying blueprints in order to understand the scope of the work.

Another indication that the Navy did not consider this project in the "business as usual" category was the early decision that we would depart from our usual procedure of leaving construction procedures up to the contractor. Past experience with major waterfront structures and particularly with dry docks has indicated that contractors frequently do not know the sequence of construction events that the designers had in mind. Disastrous results can and have occurred when a contractor does something out of sequence planned by the designers. Consequently, we directed in our specifications the sequence of events that we expected the contractor to follow and even designed the cofferdam. Admittedly, the Government took responsibility in doing this but we felt that the end justified the means. There were four major phases that the contractor had to follow. He was allowed considerable freedom within the four phases but each phase had to follow the other.

Lastly, the decision was made to make the Architect-Engineer a partner during the construction phase. On most government jobs the architect-engineer does not continue into the construction phase except possibly to check shop drawings. To this end, a supplemental contract was entered into with Moran, Proctor, Mueser & Rutledge and Carey and Kramer to provide a resident engineer as adviser to the Resident Officer in Charge of Construction. This man proved invaluable to me. He was that rare combination of a good design man and a good construction man. In addition, although he was on the shady side of 55, he was in such good physical condition that he could make underwater dives to determine the suitability of the foundation clean up prior to the deposition of our selected fill. The confidence that we could place in having a qualified engineer make these inspections greatly simplified the decision-making process because obviously we did not have to rely on the reports of a diver who was not quite sure what he was looking for.

Bids were opened on 17th of December 1958 after a 105-day advertising period. There were 9 bids received ranging from $21,645,000 to $24,990,000 with the second low bidder only $244,000 higher than the low bid. This relatively narrow range speaks well for the quality of the plans and specifications prepared by the design contractor. The completion time was set forth in the specifications at 1065 days and to date there have been 124 days of extension granted which will bring the completion into late March 1962.

The contractor started demolition work on 8 January 1959 and shortly thereafter moved in a 16-inch hydraulic dredge. This dredge, even though it had had the ladder extended, could only dredge to a depth of about 65 feet below the surface. All dredging below that was by clam bucket. One of our first problems which demonstrated the necessity of not taking anything for granted was an unanticipated clay pocket.

There had been several cruisers of the Pacific Reserve Fleet alongside the pier and in the subsurface investigations it had been considered impractical to move these ships in order to ascertain the bottom conditions under them. Drilling on both sides of the ships showed that the ground should have been continuous but almost immediately we discovered that in that particular location we had about 3,000 cubic yards of overdredging.

The next major problem came when we uncovered the hard clay layer in the center of the dry dock. Preliminary borings indicated that this material would make a suitable foundation but upon exposure to water it turned to soft clay and it was necessary to remove this layer. There was about 70,000 cubic yards of overdredging involved in this pocket and since the hydraulic dredge had left the site it was necessary to clam all of this material out of the bottom.

A diver's inspection of the bottom just prior to depositing the selected fill showed that despite all efforts there still was a 6″ to 30″ layer of soft semi-liquid clay that could not be removed. We were afraid this would create a plane of weakness. To overcome this problem it was necessary to place a three-foot blanket of coarse gravel from about one-inch to 3-inch diameter. This gravel penetrated the layer and keyed the fill into the basic glacial till support. Subsequent borings proved that this had been accomplished

A derrick barge was used to clam material from the dredging area. All in all there was about 625,000 cubic yards of material that was removed before we could replace it with suitable foundation material. About 125,000 cubic yards was removed by clamming and the balance of 500,000 cubic yards by hydraulic dredge.

The contractor was fortunate in locating foundation material less than three miles from the contract site. The pit was about

1500 feet in diameter and 75-80 feet deep. All together there were about 1,500,000 cubic yards of material removed from this pit. The material from the pit was barged to the site and hydraulic monitors sluiced the fill off the barge. Bottom dump barges were allowed in certain locations but were prohibited by the specifications adjacent to the cut-off walls.

When the free water had been removed, large quantities of soupy mud in thicknesses from 6 to 10 feet deep were found in the center of the site. This was believed to be caused by the slow settlement of the fine silt particles during the fill operation. This material was bulldozed to collection points where most of it was trucked out of the site.

Under water the fill material held a natural slope of 1 on 2 and ¾ while in the dry a slope of 1 on 1 and ¾ could be maintained. The excess material had to be removed in order to work the site. Approximately 400 well points placed on 10 feet centers were the prime means of keeping the construction site dry. A conveyor belt was used to remove and stockpile a good deal of the material and this saved the contractor a great deal of time and effort in moving the extra material from the site. This material was later used for backfill between the walls and the construction dams.

The outboard end of the dry dock was all supported on fill. When the time came to place the concrete floor it was apparent that the fill had not consolidated sufficiently to be assured that no further consolidation would take place. For this reason, it was determined that is was necessary to artificially consolidate the material in order to avoid any settlement of the dock after construction. After considerable discussion the vibro-flotation method was decided upon. The method proved quite successful. The effect of the vibration and additional material was felt up to a radius of about 8 feet. The holes were compacted to varying depths from 8 to 23 feet deep. All in all a total of 824 holes were compacted. There was about 6 cubic feet of material added for each lineal foot of each vibrated hole. It was estimated that the vibro-flotation operation increased the relative density of the fill material by 20-30%.

Drainage tile were imbedded in the drainage course which is immediately under the floor slab to assure that there be no hydraulic uplift on this type of dock. A concrete working mat four inches thick was placed over the drainage course. In order to assure that there would be no filling of the interstices of the drainage mat, a polyethylene sheet was laid on top. The working mat was reinforced by 6 x 6 x 6 wire fabric.

The first structural concrete was poured on 7 July 1960, just shortly before I left the job. Each block of the concrete slab was 24 x 40 x 7 feet thick and contained 250 cubic yards of concrete and 16 tons of reinforcing steel.

The contractor elected to set up a batching plant about 600 feet from the dry dock site. The shipyard made available to him a pier alongside which he brought his materials and delivered them directly to the hoppers of the batching plant. The batching plant consisted of two, two-cubic-yard Koehring mixers. The plant had a theoretical capacity of about 1,000 cubic yards a day. Electronic control and recording devices were required.

Flooding is accomplished by gravity through a culvert incorporated in each of the dock side walls through the entrance abutments and terminating in a transverse culvert just inboard of the inner caisson seat.

Three of the four main dewatering pumps take their suction from the dry dock floor through a shallow intake well. Large steel gratings will cover the well when completed. Temporary steel struts were used to support the pumpwell side walls. As the concrete was raised the steel struts were removed.

The contractor used the temporary false work required to drive the sheet piling cut-off wall at the head end of the dry dock to support a roadway between the East and West sides of the dry dock.

As excavation of the native material adjacent to the headend cofferdam progressed, additional temporary shoring was required.

Moveable gantrys were used to support the concrete wall forms. After aligning and bracing, concrete was placed from a concrete bucket through an elephant trunk in the wall forms. A total of 40,000 cubic yards of concrete were used in the dock walls.

After completion of concrete placement, the gantry is moved and the concrete forms were loosened 12 to 24 hours after completion of concrete placement. Concrete forms on the wall sections were removed 24 hours after concrete placement was finished. Intermediate concrete wall pouring proceeded in the same manner as described for the primary blocks.

Once begun, work progressed rapidly on the construction of the dry dock walls. Specifications required a 7-day curing period between the placement of adjacent blocks so the walls progressed in a checkerboard fashion. The inboard face of the wall is battered out for the bottom 24 feet and straight for the upper 24 feet. The outboard face slopes in from bottom to top.

TABLE I

SUMMARY OF MATERIAL QUANTITIES (ESTIMATED)
DRY DOCK NO. 6

MATERIAL			UNIT	QUANTITY
DREDGING				
TOTAL			CY	550,000
FILL & BACKFILL				
INITIAL FILL			CY	451,000
BERM FILL			CY	515,000
COFFERDAM FILL			CY	90,500
BACKFILL	CY	352,000		
SPILLOVER	CY	153,000		
EXCAVATION	CY	100,000		
FROM C'DAM	CY	45,250	CY	53,750
TOTAL			CY	1,110,250
SHEET PILE				
BERM			TONS	3,050
COFFERDAM			TONS	2,390
TOTAL			TONS	5,440
CONCRETE				
DRY DOCK			CY	151,000
PIER 9			CY	900
SUBSTATION #83			CY	1,100
FLOODLIGHT TOWERS			CY	255
TOTAL			CY	153,255
PRESTRESSED CONCRETE PILE				
TOTAL			LF	12,700

MATERIAL	UNIT	QUANTITY
REINFORCING STEEL		
DRY DOCK	TONS	8,300
PIER 9	TONS	115
SUBSTATION #83	TONS	80
FLOODLIGHT TOWERS	TONS	15
TOTAL	TONS	8,510
MISC. IRON & STRUCT. STEEL		
DRY DOCK	TONS	360
RAILS & RAIL PLATES	TONS	320
SWITCHES & FROGS	TONS	70
SERVICE BUILDING	TONS	35
FLOODLIGHT TOWERS	TONS	81
TOTAL	TONS	866
RIP RAP		
TOTAL	CY	8,400
DRAINAGE COURSE		
TOTAL	CY	92,000
BITUMINOUS CONCRETE PAVEMENT		
TOTAL	SY	32,500
CONCRETE MASONRY		
TOTAL	SF	4,400

DPWO 13ND D.D. #6, PSNS

Table I is a summary of the estimated material quantities. This was prepared prior to the construction and the quantities have changed slightly. For example, the total amount of dredging was about 625,000 cubic yards instead of the 550,000 shown here. There was also an increase in the backfill to about 1,200,000 cubic yards but the other quantities are substantially as shown.

SOME PROBLEMS OF THE SURVEYING PROFESSION AS SEEN BY A RETIRED ENGINEER

By Carroll F. Merriam*

(Presented at a meeting of the Surveying and Mapping Section, B.S.C.E., held on April 5, 1961.)

Your chairman has referred to a past president of this Society, the late Charles M. Allen, as having made the introduction which led me to thirty very satisfying years in the employ of the Pennsylvania Water & Power Company in Baltimore, Maryland. I can assure you that if it had not been for the unusual experience with the engineering department of this company I should not be speaking before you this evening. I consider myself extremely fortunate to have profited by the encouragement of a public utility executive who had extraordinary foresight and who permitted me great latitude of interest and activities. If the views that I express seem to you a bit starry-eyed and idealistic, please consider the happy circumstances which have led me to believe as I do, and kindly appraise these thoughts accordingly. Realizing that I have never as far as surveying is concerned been faced with the problems of making both ends meet financially, I do not wish to assume a position of dictating to practical men as you are.

The one excuse that I have for taking the time of busy men, is that I am not a busy man myself. Generally my week's work is done by 10 o'clock each Sunday morning, having wound two clocks. In whatever of the week there is left after that, I have opportunity for contemplation, experimentation, fragmentation of the woodpile, elimination of dandelions and other minor distractions. Yet with all this leisure, and in spite of the long boring winter evenings that friends predicted would be my fate on retirement to a little Maine Coast fishing village, bedtime usually finds me at the drafting board, the computer or the typewriter engrossed in some study so interesting that I am reluctant to set it aside.

My own interest in surveying began as a mere incidental in connection with the development of a controlled base for property surveys for the power company. One thing led to another and in 1938 I was asked by Abel Wolman, then chairman of the Maryland State

* Past President of The American Congress on Surveying and Mapping.

Planning Commission, to serve on the committee charged with drawing up the enabling act authorizing the use of statewide plane coordinates, an act which in addition to following the pattern of the so-called "model law," established a Bureau of Control Surveys and Maps. In spite of the fact that I have never considered myself either a surveyor or a mapper, I was accepted into membership of the American Congress on Surveying and Mapping at its first public meeting in 1940 and fourteen years later became its tenth president. Thus I have had opportunity to gather many impressions from a wide range of contacts.

The impression that stands out in my mind most vividly is that surveyors, in contrast to the freedom from pressure that I have enjoyed both before and after retirement, are so pressed and harassed either because of the actual job at hand, or else worrying where the next job is going to come from, that they have little time to consider the larger aspects of their profession. One of my respected professors had an apt expression when confusion reigned in his class in shop management, "Gentlemen, let's sit down and see where we stand." It might be well for surveyors to do the same. There is always the possibility of settling into a rut.

I don't mean to imply that surveying has become stuck in the mud, far from it, although I must admit that many people including some deans of engineering colleges regard surveying as a subject so outmoded that it is hardly worthy to hold a position in engineering. A common view appears to be that surveyors should now be turned loose to ply their trade along with the butcher, the baker and the candlestick maker. The answer to those who hold doubts as to the progress that is being made in surveying is to see for themselves the exhibits at our annual meeting in Washington, to hear the papers discussed, and to talk with the men who are attracted to this annual assembly. If a trip to Washington is out of the question, the magazine "Surveying and Mapping" should convince the most skeptical that the profession is far from passing over to the status of a trade.

That we are advancing at a rapid pace is not subject to debate. The facts are clear; and I shall not attempt to review the accomplishments which continue to astonish me. Instead I shall turn to the other side of the picture, and pose for you one question which seems to me vital. Are we making comparable progress on all fronts, or are we blind to those sectors where we may be lagging? This is my main theme. While I am no longer in a position to give you an authoritative dissertation on the latest applications of photogrammetry, the measurement of distances by the speed of light, the use of the self levelling level, new and improved instrumentation, electronic computers, optical tooling, and a long list of others, I can still ask you to stop and consider whether in our rapid advance we are still leaving stones unturned along the path.

We can take as our point of beginning just a personal hobby of mine. When I first became associated with the U. S. Coast & Geodetic Survey and because of interest shown in the work was asked to become what they term a collaborator my reaction was that even at headquarters they failed to see the full importance of future potentialities. To be sure the men of the Survey have done excellently in adhering to the principles laid down by their founder, Ferdinand Hassler, a century and a half ago, but I find on looking over the text of the first paper that I was asked to give before the American Congress on Surveying and Mapping, even then I questioned seriously whether my friends in the Survey fully appreciated what lies beyond. The foundation is well laid, but I fear that few see the cathedral that is to rise upon it. To be sure the need for an accurate base for maps is well appreciated, but do we see the importance of this same framework as affecting the lives and fortunes of Smith and Jones? It is merely an extension of the same idea, to use that framework which holds maps together, to establish the true relation between surveys of property. When we accomplish this we shall be fairly on the way to solve one of the pressing and incidentally distressing problems of modern society.

The immediate answer is that this is too much to expect, merely impractical wishful thinking. Certainly at present we must admit that in by far the majority of situations, the ideal tie to horizontal control is out of the question. The cost is generally too great for the job to bear. The reason—because in only a relatively few locations is there sufficient density of control.

Should we let the matter drop here, thus taking a defeatist attitude? We must keep in mind that there are cases where a tie to established triangulation stations is relatively easy. The question is whether surveyors are alert to recognize these situations and take advantage of them, and so bring us a step nearer the ultimate goal?

If the stumbling block is insufficient density, how then can it best be overcome? Right now I am well aware of the density required for general application of plane coordinates for property surveys, and it is obvious that it is not reasonable to assume that the U. S. Coast and Geodetic Survey should undertake the entire burden of providing it. There must be some point at which the federal government leaves off and the state takes over. In many states this line of demarkation has already been established and there is set up within these states some form of organization, which is to the state what the Coast & Geodetic Survey is to the nation. Under the leadership of inspired engineers, some cities, such as Baltimore as far back as 1895, appreciated the importance of a fixed and stable base for property surveys and made wise provisions which in the light of more than a half century of experience have proved excellent investments. Unfortunately the states which have been willing to look to the future in this respect appear to be few in number. Is this failure a stone we are leaving unturned?

In the states that can be ranked as progressive, and I certainly consider my native state of Massachusetts in that category, are we taking all the advantage that we can to obtain the desired density of control points? You know more about that than I do.

Where, in general, can surveyors in the less progressive states look for help? What state agency is at present doing the major amount of surveying, has on hand the greatest wealth of survey records, and is in the best position to profit by further advance in control surveys? I believe that there is not a state in the Union where the answer would not be the Highway Department. Still in at least one of these New England states, and even after 16 years since the adoption of plane coordinate systems, highway surveys are still made with reference to a magnetic or even an arbitrary meridian while as far as position on the face of the earth is concerned, they are "free floating." Beyond the purpose for which they were made they are without permanent value. Now from the point of view of road construction alone, and considering only the requirements of the immediate present, such a policy is good economy. Why burden the road with additional cost that doesn't add a cent to its value as a means of transportation?

This is true, but just consider an ordinary right of way map. Regard the amount of work that has gone into the delineation of property lines alone. Think of what this would mean if all this information were to be recorded with reference to an established cadastral base and so made a permanent record available to land surveyors. To be sure plans are filed in county court houses where they may be looked at and studied by surveyors, but there is no ready means by which surveyors could with confidence take advantage of what has been done, and be sure that the final result will be in harmony with the surveys of adjacent properties. Have we failed to impress upon highway commissions the vast potentialities of savings for the public, as well as eventually for the taxpayers, if with a little foresight they could plan for future economy.

Perhaps we should consider the problem a step further. Commissions are not altogether their own masters. Above them stand the taxpayers. What are surveyors doing to convince the general body of taxpayers that the present policy of failing to provide for the future is penny wise but pound foolish? Of course the politician is to be considered, but remember that the Coast & Geodetic Survey was founded by a man who had the courage to tell politicians exactly where they got off in no uncertain terms. Thanks to the fact that he did not yield to political pressure, the modest beginnings made over a century ago still meet modern standards and did not have to be done over again at great expense. We now benefit as a result of the strength of character shown by a man who would not compromise between scientific truth and expediency. Should we not still follow his example?

How may this task best be picked up where the Coast & Geodetic Survey ought to leave off and the state take over. There are conventional methods which require somewhat specialized knowledge of geodesy, specialized equipment for running precise traverses, and specialized talent. The new methods for measuring distances by the speed of light are coming into use and proving valuable for extending control nets. But are we aware what can be accomplished by more modest equipment, less advanced mathematical knowledge and skill? For example can the average common or garden variety of surveyor help himself by a little triangulation now and then? Can a central agency build up a valuable collection of basic control data without specialists in the field of high order surveying, or even without instruments of high precision? My answer is "yes," because I have seen it done.

However, to accomplish this it is first necessary to accept a somewhat new concept as applied to plane surveying. It is an elementary concept found at the outset of any course in analytic geometry, and even in school texts on algebra. It is merely that a straight line can be defined by an equation in the form $x = ay + b$. If a surveyor takes a sight from a point having known coordinates and observes the azimuth, then all of the information is available for describing that sight by an equation of the first degree. Now, if two sights are taken on a common intersection point, the unknown coordinates of that point may readily be found by solving two simultaneous equations. All of the complication of the oblique triangle is entirely eliminated.

Why has this not been commonly practiced previously? For a very definite reason; which is that equations in the above form are not convenient for solutions by logarithms. Now here is a snag which has led me to an interesting observation. I have found, by and large, that surveyors have been surprisingly slow to appreciate the introduction of a new element which greatly alters the situation. This is the advent of the desk computer. Too often the surveyor looks to the computer as a handy and quick substitute for logarithms. He is quick to see that the machine combined with use of natural functions, is more rapid than use of logs, but unfortunately he is all too prone to follow the same mathematical procedure, oblivious to the fact that the machine frees him from a serious limitation that you cannot add and subtract with logs. Consequently, many simple and useful formulas are disregarded by the surveyor.

Let us now look beyond the solution of a single oblique triangle. Let us suppose that three or more sights have been taken on a common intersection point. Mathematically a precise solution is impossible because of ever present error and the fact that we have more equations than there are unknowns for which to solve. That is a common dilemma and in spite of application of least squares we can at best arrive only at the most probable result. Should we stop there?

Please understand that I am in no way critical of procedure used by the Coast & Geodetic Survey at national level. The adjustment of large triangulation networks is a specialty in which the Survey excels, but when we come to work at state level again a new element comes into the picture. This is the use of plane coordinates which enable a surveyor with no knowledge beyond that of plane surveying to make surveys of as much as 140 miles in extent with a maximum scale error of less than one part in 10,000. By proper supplementary corrections this error may be still further reduced to any desired practical limit still without resort to what is commonly known as geodetic surveying.

The use of plane coordinates at state level for applications that would otherwise require geodetic surveying may seem in itself rather unimportant since it would appear to be merely permitting work to be effectively done by men with less specialized training. But there are other factors to be considered. One of the fundamental limitations in adjusting a triangulation net is that the number of data must equal the number of conditions to be met. If more data are available some must be neglected, and the selection has to be made on the basis of first determining which of the given quantities are the most likely to give the strongest solutions. All others must be neglected and there is no assurance that along with them go observations that may actually be more reliable than those that are retained, particularly if in the data actually used there is what your former president termed "snish."

The method developed by the Maryland Bureau of Control Surveys and Maps completely eliminates this undesirable feature. Inasmuch as all of the data are retained, no study of strength of figure is required, and furthermore when "snish" does creep in, the effect becomes so obvious that it does not fool anybody, at least for long. I shall not go further into the details since description of the method is available on request in Publication No. 3 of the Maryland Bureau of Control Surveys and Maps.

I have found that by application of the method so described, under some circumstances, use can be made of observations of surprisingly low order of accuracy. Hence, there is an interesting possibility that with proper supervision in compilation and computation, a central agency could collect miscellaneous observations from many and diverse sources without danger of misleading results.

I have in the past seen great concern when coordinates of stations as determined by one survey fail to jibe with those as determined by other surveys. I have witnessed acrimonious debate for example when city surveys of supposedly high order of accuracy have been extended to connect with previously established points of a larger triangulation net. There has been much fuss and fury over a matter the solution of which has been found to be rather simple as shown in Publication 2 of the above mentioned Maryland Bureau of Control Surveys and Maps. Another danger that faces us is that when connection is made between arcs of triangulation, both adjusted within themselves as well as possible by least squares, discrepancies of appreciable magnitude will show up. From personal experience, I am of the opinion that much of this fear is unfounded and that the little discrepancy that may become evident is rather easily adjusted. My question at this point is whether we are prepared to meet such situations when they arise, with assurance that we shall not make a mountain out of a mole hill?

I personally have great confidence in the ultimate use that is to be made of state-wide plane coordinate systems, but some of my observations regarding their adoption and use to the present time incline to make me feel that the engineering mind has not been as influential as it should be in this scientific age. In the first place, what little experience I have had in urging the passage of enabling acts in two states makes me believe that few legislators have more than a very vague idea what they voted for. Apparently the respect that they have for some outstanding engineers is depended upon, and they are willing to support any bill on the "say so" of these engineers providing it carries no appropriation. Consequently we have lots of enablement without any means of implementation. The result is that in most states there is, at least for the present, practically complete stagnation.

I am not sure that this is a bad sign, because if each state were to be carried away with wild enthusiasm and immediately jumped into poorly considered moves such as publishing coordinates as determined by Tom, Dick, and Harry, untold confusion would certainly be the penalty. I consider it far better to let the law rest in peace, wrapped in mummy cloth until influential engineers and surveyors become sufficiently familiar with risks of impetuous action to cause them to proceed with caution.

It is interesting to trace the history of adoption of plane coordinates. In general, certain eastern seaboard states were the first to act. These states being close to the coast naturally possess an initial start of relatively dense control networks established by the Coast & Geodetic Survey. They are also the states with high population density and high land values. Following the initial start consisting of Massachusetts, New York, New Jersey, Pennsylvania, Maryland, and North Carolina, the idea began to spread from one state to another in general along both Atlantic and Pacific Coasts. There can be observed contagion which causes one state to follow the lead of those adjacent, the notable exception to this rule being the case of New Hampshire which even yet has not legally adopted the system in spite of the fact that it is the sole remaining "hold out" in New England. Some of the Great Lakes States have recently joined, but in general the vast interior of the country resists invasion. There is probably some connection between such reluctance and the fact that these states were fortunate enough to have rectangular division into townships, sections, quarter sections, etc. Either the need is not felt, or else there is an unfounded fear that state co-ordinates will be in conflict with the established system. Another curious observation is that the greatest progress in obtaining converts coincided with the latter years of World War II. Since that time only one new state has been added and at the present time only three are considered as about to hit the saw-dust trail. It is sad to think that progress in such a humanitarian endeavor as mapping should throughout history have been so generally associated with times of conflict.

I have recently been greatly impressed with the adaption of high speed computers to surveying problems. It is obvious when we consider the tremendous capacity that these machines have, and incidentally the rentals charged, that more and more we shall turn to data processing centers designed to receive the raw product from large numbers of surveying concerns and to deliver in short order the fully adjusted results. The question is whether we are not jumping too rapidly from the time honored hand computation with traditional logarithms to the highly developed data processing devices, which may be all right for surveyors near at hand, but not so convenient for many firms in more remote localities. Are we perhaps neglecting a middle course more suited to the surveyor not fortunately situated so that he can rush his data in and get it back again almost while he waits? I am convinced that before we go too far we should consider how the conventional procedures when using logs, can be greatly simplified by recourse to the ordinary desk computer. For example, do you use the DMD method to compute the area of a polygon of which the coordinates of the corners are already known?

Can you solve this directly on the machine without touching pencil to paper. Still again can you compute a traverse without listing sines and cosines, eastings, westings, northings, and southings? Can you solve for the diagonal distance between two points with given coordinates without setting anything down on paper but the final answer? Can you solve a three point fix without referring to your trigonometric tables except once to look up the cotangents of the observed angles? If you are not so placed that you can get this work done for you almost instantaneously, would you be interested in knowing how your desk computer can be of greater help?

Returning now to the question as to whether the land surveyor of the common or garden variety, not the big firm, can use control surveys more advantageously than at present, we may ask how many surveyors have the impression that suitable triangulation cannot be performed without instruments of high precision. It is interesting to note that there are a number of published coordinates of triangulation stations in the vicinity of Baltimore which have been determined in part if not wholly on the basis of observations made with a one minute transit of not too high quality even before it was damaged by accident. This instrument is still in use and capable of giving results, judged by horizon closures, of about 3 second accuracy, which is about the limit that could be expected from daytime observations. Such accuracy is far above what would be expected by conventional procedure using a comparable number of repetitions. Are transitmen informed as to how such performance can be obtained when conditions warrant?

We are all familiar with the danger of an open end traverse. To insure reliability necessitates a double run—double cost. On the other hand if such traverse can be made to touch on previously established control points, there is in general an appreciable reduction in cost, and at the same time, an increase in dependability.

When the closed traverse fails to close, there is the wild hunt for the "snish," as Prof. Allen would put it. Where does the mistake lie? The chief of party is ready to grasp at any straws in the hope of saving him from running the whole thing over again. Frequently the straws are within reach, provided the instrument man is alert enough to see them. They are side shots on points of determined positions, church steeples, radio towers, air beacons, water tanks, finials on tall buildings, and all kinds of prominent objects springing up in densely settled communities. But does the chief have the technique to use these aids effectively? It is a question of being ready. It can be done, and quite simply too.

Another striking impression is the contrast that I experience as I return each year from the annual meeting in Washington and pass as I do from an atmosphere of highly developed technique to that of my little corner on the Coast of Maine where the common concept of a surveyor has advanced little since the days of George Washington and where surveyors are not even registered. Among the hundreds of deed descriptions that I have read, I do not recall any other than those that I have written myself in which any meridian other than magnetic has been used. In spite of the fact that the needle has swung 8½ degrees westward since the original layout of the township, very seldom is any mention made of the date of the survey. Deeds many of which are blindly copied for a small fee from transfer to transfer until they become practically meaningless, with references to long since obliterated landmarks and bearing always on the lands of abutters so long dead that nobody has any idea where they lived, frequently bear only coincidental resemblance to the land they purport to describe. Why we may ask has the influence of progress been so little felt in the realm of the small and isolated surveyor? Are we after all fighting a losing battle against the complexities which are impeding the transfer of real estate? As engineers can we not rise to devise some means of bringing order out of the present chaos?

I now come to what I consider the most serious aspect of the problems to be met by the profession—reproduction of our own kind. Contrary to the habit of old soldiers, surveyors do die. Some retire before passing out completely but many die in harness. Replacement is necessary in order that the work may go on. One solution would be possibly lower expenditure in man hours per survey resulting from more efficient organization as the work becomes concentrated more into the hands of larger firms. It is however, hardly conceivable that this can be counted upon to fill more than a fraction of the gap between the number of surveyors dropping out and the number of new recruits. A striking fact is that the number of recruits needed far exceeds the proportion of technical graduates that should rightfully be channeled into the field of surveying, assuming that we had dictatorial powers over the lives of young men. It has long been felt that the senior, or four year colleges are not doing much to help the situation by reducing the number of hours devoted to the subject, assigning surveying courses to the younger and less experienced instructors as the place where they can probably do the least harm, and in general depreciating the respect that this profession should have. As a result, the profession must depend more and more on the junior, or two year, colleges. In my opinion even then a supplement will have to be made up of boys unable to go to any college who will enter the ranks through a course of apprenticeship. Consequently, we have the peculiar situation of a profession which holds high responsibility for safeguarding human welfare, at a time when almost anybody with an ambition can find a place in some college, obliged to fall back upon recruits with far from ideal educational background.

This failure of the senior colleges to fill the demand, combined with the rise of the junior colleges to meet as well as possible a situation that is far from ideal, is the natural result of the tremendous drain of technical school graduates into other more interesting and perhaps more spectacular fields. Consequently, these branches which do not have strong appeal have just got to take the pickings or else pull themselves up to a position of higher respect in the eyes of young men making choice of career. Knowing the responsibility that rests on the shoulders of the surveyor, is he going to continue to suffer this loss of potential man power?

Greater reliance on the junior college gives rise to a new situation. Approach to the profession now becomes a double channel, one a full four years course and the other a two year short cut. The first is a broader technical education with surveying, at present, only a rather unimportant incidental and in the future even less important if the present trend continues; the other is a training specifically for technicians. In some professions the lack of fully qualified men is made up for by the technician grade. To this grade is assigned the more functional work where lack of complete knowledge is not a serious handicap. Perhaps this is the division of labor that is to be expected. Whether or not a similar division of labor in the engineering field is a good thing is a matter concerning which I have grave doubts, but still it is apparently the way the world turns, and we may have to accept it as such.

This double approach is something that we must face whether we like it or not. It is for the educators to evaluate both the advantages and disadvantages of each avenue, and do their best to turn out men as well suited to meet life as conditions permit.

To teachers in the four year colleges, I consider it a responsibility in view of the very limited time that will be allowed for surveying, to concentrate on the more philosophical aspects, generalization of principles common to other branches of engineering, ingenuity in the minimizing of errors, appreciation of the importance of surveying in the social whole, penalties paid for poor surveys, etc., as well as the discipline afforded by study of a branch of engineering in which the factor of ignorance is reduced nearly to the vanishing point. But I should urge particularly, in view of this double avenue of approach, the cultivation of appreciation and understanding of the men not so fortunate as to be able to afford the longer training period, but men who will know how to do many things which the four year man may never learn to do for himself.

Likewise to teachers in the two year colleges, I consider it a responsibility not only to teach technique, but to instill a sense of dignity of mastery of operations seemingly elementary but from which "sermons in stones" may be learned, to develop regard for the part played by those who have had the longer period of preparation and above all to provide the inspiration to aim always for higher things, remembering that in the field of engineering the way upward is not yet closed to those who have had limited opportunities at the beginning.

Of necessity the two groups are bound to meet in the field and office. I can imagine nothing to me so undesirable as the development of a caste system based solely on years of formal education. Scorn on the part of one coupled with envy on the part of the other could break up the fellowship which is characteristic of American engineering. My hope would be that each individual as he enters the profession will seek his appropriate place according to his merits and ability in a thoroughly united brotherhood of engineers.

In closing I should like to pass on to you the words of another of your past presidents, Ira N. Hollis, whose valued personal friendship continues through the surviving members of his family to this very day. When he was asked to speak to the boys taking a course of one of his colleagues, I remember well his theme, "When all factors are taken into consideration, theory and practice will agree."

Those entering the profession of surveying will have two points of view characterized as theory and practice. Let us build our educational system and indoctrination into the ranks so that new recruits will take all factors into consideration and find that harmony of which your past president told us when I was one of his boys.

SURVEY FOR THE CAMBRIDGE ELECTRON ACCELERATOR

By David D. Jacobus*

(Presented at a joint meeting of the Boston Society of Civil Engineers and Surveying and Mapping Section, BSCE, held on May 17, 1961.)

The hydrogen atom may be described as a single proton with a single electron in orbit around the proton. In the isotope of hydrogen, deuterium, the core consists of one proton and one neutron. The elements from hydrogen with an atomic weight of one to uranium with an atomic weight of 238 are progressively complex combinations of protons, neutrons, and electrons.

The Cambridge Electron Accelerator can be likened to a supermicroscope that is designed to study the sub-atomic properties of the elementary particles—protons, neutrons, and electrons. The accelerator will produce a beam of electrons of very high energy, something of the order of six billion electron volts, and this electron beam will be used to bombard a target. Energies of this order of magnitude are not needed to break up atoms. They are needed to disintegrate the more elementary particles. A preferred target is liquid hydrogen, which is a relatively pure mass of protons. One of many billions of the high energy electrons may strike the core of a proton and disintegrate the proton into fragments. The number, the weight, the energy and the life span of the fragments can be observed with a view toward learning more about the nature of that very fundamental particle, the proton.

Electrons are injected into the annulus of the Cambridge Electron Accelerator at an energy of 20 million electron volts. A linear accelerator performs this function. The annulus of the accelerator consists of 48 magnetic lenses, each precisely located on a circle of 236 foot diameter. Acceleration of the electrons from an energy of 20 million electron volts to a final energy of 6 billion electron volts occurs in about 8 milliseconds. In this time interval the electrons will have traversed the annulus of the machine about 10,000 times, and will have traveled a distance of about 1,500 miles. The electrons

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enter the orbit and leave the orbit at essentially the speed of light. At the final energy of 6 Bev, the mass of the electron has been increased almost 12,000 times.

Each of the magnetic lenses consists of a laminated steel core with electrically excited coils around the pole tips of the magnet. The contour of the steel at the magnet pole tip determines the shape of the magnetic field. Each magnetic lens must hold the electrons in the orbit, and must also focus the beam to keep the electrons away from the walls of a surrounding vacuum chamber. The accelerator employs two types of magnetic lenses, one lens focusing the beam in the horizontal plane and the following lens focusing the beam in the vertical plane. The contours of the pole tips were determined by an extensive program of modeling and measuring, and carbide dies were manufactured to produce stamped laminates that do not deviate by more than ± .002 inches from the calculated values. Girders were machined flat to ± .002 inches, and guide rails were located radially to the same order of accuracy to align the magnet core blocks on the girders. A twelve foot long girder with superimposed core blocks and exciting coils comprises a magnetic lens. Forty-eight such magnetic lenses, twenty-four vertically focusing and twenty-four horizontally focusing, have been surveyed into place to better than the following of accuracies.

± .005 inches in the vertical coordinates
± .020 inches in the radial coordinates
± .060 inches in the azimuthal coordinates

A girder deflects .008 inches when loaded with the magnet core blocks. Forty-eight symmetrical deflections of this order of magnitude do not distort the electron beam. The girders can be leveled with precision jacks to accuracies of the order of ± .001 inches. The jacks in turn are supported on steel plates which can be moved radially and azimuthally after all of the equipment is in place. Each of the jack supports, which normally rests on a contacting flat surface, can be carried on ball bearings by applying hydraulic pressure to a cylindrical support. When the end of a girder is carried on the ball bearings, radial and azimuthal adjustments to accuracies of the order of ± .001 inches can be made by adjusting the positions of peripheral machine screws. After all adjustments are complete, the hydraulic pressure which holds the supporting cylinders against the ball bearings is relieved, and the girders are again supported on contacting flat surfaces. The entire jack supporting mechanism is coupled to the end of a steel girder with a single 1¼ inch diameter locating pin. A second locating pin is inserted in the underlying base plate. When both pins are in true alignment, the end of a girder is in its correct nominal location, but with the very important consideration that precision adjustments in level, radial, and azimuthal coordinates can be readily made after all equipment is in place.

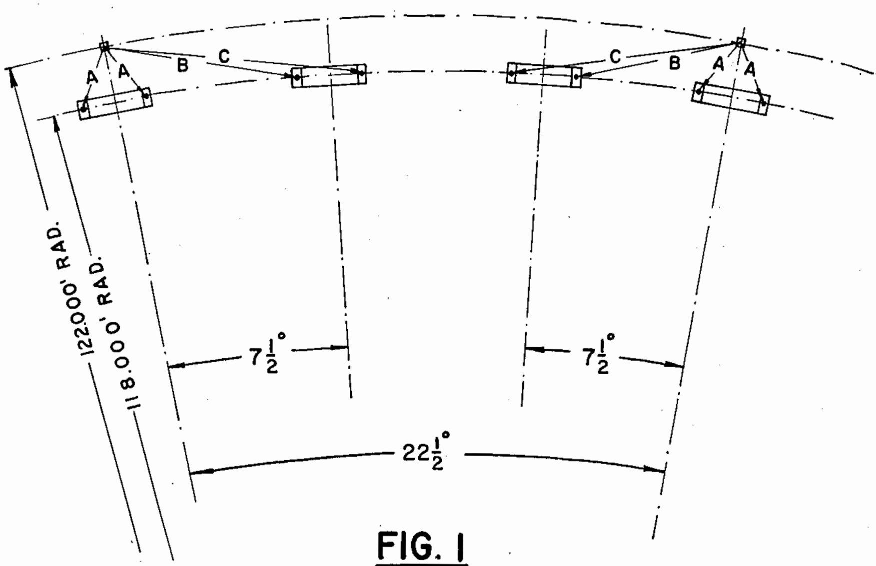

FIG. 1

Ninety-six base plates locate the jack supporting mechanisms. The 1¼ inch diameter holes in the centers of the plates were precisely surveyed into position on a circle of 118.000 foot radius, to form the pattern shown in Figure 1. When the foundations of the building were in process of construction, ninety-six 12 inch building piles were driven 30 feet into the subsoil on a circle of 118 foot radius. A concrete cap was subsequently cast on pairs of adjacent piles. Forty-eight caps support the entire ring of magnet girders. Each cap supports the downstream end of one girder and the upstream end of an adjacent girder. The girder supports have no contact with the floor or with other building components. Magnet girder supports have now been in place for a period of four years. Severe floor settlement has taken place, particularly in areas adjacent to new building construction, but the magnet supports appear to be relatively stable.

Sixteen survey monuments are equally spaced on a 122.000 foot radius. Four of these monuments can be viewed through radial tunnels from a monument at the center of the accelerator. The supporting pile caps are within ± ½ inch of their nominal locations. There exists a location of the central monument which will put the jack supports on top of the supporting pile caps. A suitable location for the central monument was determined by making a preliminary survey, and the central monument was then welded in place. The central monument and the sixteen peripheral monuments are ¾ inch thick stainless steel plates, each with a 3½ inch diameter tapered hole that will accept a spherical surveying target.

The four monuments at the ends of the tunnels were surveyed into place with the transit at the center of the accelerator. The monuments were held in place with bolted clamps, and were welded to an underlying steel plate when a location was finally established. With the four radial monuments in place, the remaining twelve monuments were equally spaced on a circle of 122 foot radius. A survey made after all plates were welded in place showed that the following accuracies had been achieved.

Monuments at Radial Tunnels

Maximum recorded angular error	= 3 seconds of arc
Maximum recorded error in radial length	= .0003 feet

Sixteen Monuments in Tunnel

Maximum recorded error in angular alignment	= 40 seconds of arc
Maximum recorded error in linear displacement	= .0025 feet

Note that the measured lengths are relatively more accurate than the measured angles.

The sixteen peripheral survey monuments were used in conjunction with three spacer bars, "A", "B", and "C", to locate all 96 jack supporting plates, as indicated in Figure 1. Each spacer bar terminated in a spherical insert that fitted into the tapered hole of a survey monument. The other end of the bar contained a pin for holding the base plate, with superimposed optical target that could be sighted with a transit to locate the bar in the desired angular position. When a jack supporting plate was aligned with spacer bar and transit, it was immediately tack welded in position to the underlying steel plate. After all 96 jack supporting plates were welded in place, a final survey of the locating holes was made. This showed that all holes lay within ± 1/16 inch of the 118.000 foot radius, and that the linear distance between adjacent holes in no case deviated by a larger amount from the true nominal value. This final overall accuracy, after a total of as many as seven successive operations, was achieved by making each individual measurement to a precision limited only by the performance of the instruments.

Invar tapes, inscribed at one end with graduations at each .005 foot interval, calibrated to overall accuracies of ± .0003 feet and to relative accuracies in a one foot interval of ± .00005 feet, were furnished by Keuffel & Esser Company. The tapes were observed with a Bausch & Lomb shop microscope with special illuminated scale graduated at each .0001 foot interval. Farrand optical targets were used to show the centerline locations of the tapered holes in the surveying monuments. A Wild T2 theodolite was used to make all angular measurements.

With the jack supports and the magnet girders in place, the sixteen peripheral survey monuments have served their function and may never again be used. The tops of all magnet core blocks have subsequently been brought to a common level with an accuracy of about ± .002 inches. Fixtures have been devised to secure direct measurements of the relative radial locations of the magnet core blocks. The positions of the core blocks have been adjusted to bring the radial coordinates within the desired ± .005 inches of nominal. Leveling and adjusting the magnet core blocks to suit the needs of the accelerator is an extensive program that is still in progress under the direction of Dr. William Shurcliff.

The author gratefully acknowledges the skill and care exercised by Harry R. Feldman and Company, who performed the survey that is described in this paper.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

MAY 17, 1961.—A Joint Meeting of the Boston Society of Civil Engineers with the Surveying and Mapping Section was held this evening at the United Community Services Building, 14 Somerset Sreet, Boston, Mass., and was called to order by President James F. Brittain, at 7:00 P.M.

President Brittain stated that the Minutes of the previous meeting held April 10, 1961 would be published in a forthcoming issue of the Journal and that the reading of those Minutes would be waived unless there was objection.

President Brittain announced the death of the following members:—

Walter J. Reed, who was elected a member February 15, 1928, and who died April 21, 1961.

Charles W. Newcomb, who was elected a member April 18, 1928, and who died May 1, 1961.

President Brittain stated that this was a Joint Meeting with the Surveying and Mapping Section and called upon Roy L. Wooldridge, Chairman of that Section, to conduct any necessary business at this time. Prof. Wooldridge announced names of applicants for membership in the Society.

President Brittain introduced speaker of the evening:—Dr. David D. Jacobus, Senior Mechanical Engineer, Harvard University—Cambridge Electron Accelerator, who gave a most interesting talk on "The Survey for the Cambridge Electron Accelerator."

A short discussion period followed the talk.

Eighteen members and guests attended the meeting.

The meeting adjourned at 8:30 P.M.

CHARLES O. BAIRD, JR., *Secretary*

STRUCTURAL SECTION

APRIL 12, 1961.—A joint meeting with Main Society and Construction Section was held in United Community Services Building.

President James Brittain opened the meeting asking Dr. Arthur Casagrande to introduce a guest, Dr. H. Leussink, Rector of the Technical University, Karlsruhe, Germany, a specialist in Soil Mechanics.

Then the meeting was turned over to Chairman Robert Bierweiler of the Construction Section, who had no business to transact; then to Chairman Myle Holley of the Structural Section, who presented Mr. William Mueser of the firm of Moran, Proctor, Mueser and Rutledge, and Capt. Perry Boothe, C.E.C., U.S.N. who spoke on the "Design and Construction of Bremerton Base Drydock," Carrier Repair Site—Puget Sound Naval Shipyard, located about 30 miles N.W. of Seattle.

Mr. Mueser spoke first on design features, showing about 30 slides. This is a graving dock, used for repairs rather than construction, and therefore has to be deep enough to take a carrier which may be heavily damaged and riding low. Also although not the longest nor the widest, it is the deepest, and is the largest dock in terms of volume. It is 1180′ long, 180′ wide at the coping, 198′ at the deck and 61′ deep.

Instead of being dug out of the land, the drydock is built out into the Sound adding 13 acres to the shipyard.

Choice had to be made between the gravity type of structure and the relieved type. If the former had been used, the floor slab would have had to be 43′ thick, requiring nearly one-half million cubic yards of concrete. The possibility of holding down the slab by the use of piles had to be ruled out due to the nature of the material: soft clay on top of very hard material in which sufficient penetration for grip was considered uneconomical. The slab as designed was 7′ thick except under the walls where it was 12′. The walls themselves were 12′ at the base, 3′ at the top.

Earth dams along the sides served as a cofferdam during construction, as a cutoff during operation and also as an integral part of the fill around the dock. The outer end of the cofferdam consisted of eleven cells of 60′ diameter, arranged in a half ellipse.

Filling and de-watering of the dock proved an interesting problem. Filling is to be done in an hour and a half with low velocity at first so as not to disturb the keel blocks. De-watering is accomplished in about 4 hours with four 54 inch diameter pumps with a capacity of 114,000 g.p.m. and 1500 HP motors.

Capt. Boothe spoke of a pre-advertising meeting with interested bidders, briefing them on problems of construction. This was a great aid to the responsible contractors and helped to keep out those not fitted to do the work. The Navy departed from their usual procedure in two ways: The architect-engineer continued through the construction in a consultant capacity, and the construction procedure was not left up to the contractor. Any variation from methods laid down have to be O.K.'d by the Navy.

Preliminary work on the design was started as early as 1947, but bids were not opened until mid-December 1958, with construction beginning about three weeks later. The work is to be completed April 1, 1962 and the total cost expected to be $22,000,000.

The attendance was about 65.

P. S. Rice, *Clerk*

May 10, 1961.—Chairman Myle J. Holley, Jr. introduced Mr. Fred U. Severud of Severud, Elstad, Krueger Associates of New York City and Dr. Hannskarl Bandel of the same office. The subject was "The Structural Design of the New Earth Sciences Building at M.I.T.", but since some complications have arisen, Mr. Severud spoke of problems involved and then went on to other work he has done recently.

In the M.I.T. Building there were basic architectural requirements which set up the structural problems. These were: open court space, free space at the base, a relatively tall concrete frame with fenestration which limited the stiffening which could be used. The design which finally went out to bid was based on two towers as end walls connected by full-story Vierendeel Trusses on the other two walls. Bids came in higher than had been planned, so further study is being made.

Mr. Severud showed slides of this building and also of the other recent buildings showing some radical structural approaches. A paper is being prepared for publication.

There were about 45 present.

P. S. Rice, *Clerk*

HYDRAULICS SECTION

May 3, 1961.—The meeting was called to order by Donald R. F. Harleman, Chairman of the Section at 7:10 P.M. at the Hydraulics Laboratory of MIT. The minutes of the previous meeting of the section were read and approved. Mr. Harleman announced the dates of the section meetings scheduled for November 1, 1961, February 21, 1962 and May 2, 1962. He also made some comments about the hydraulic lecture series now being planned.

The Chairman then introduced the speaker, Mr. Philip A. Drinker, Research Geologist, Agricultural Research Service, Hydrodynamics Laboratory, Massachusetts Institute of Technology, whose subject was "Boundary Shear Stress Distribution in Trapezoided Channel Curves."

Mr. Drinker discussed erosion and erosion control of small streams. The boundary shear stress is a parameter of erosive force of water in a channel. The speaker pointed out the tendency of a channel to approach a smooth surface and presented a mathematical correlation between the erosive force and the boundary shear stress. A hydraulic model of a channel curve was described, and later demonstrated, in which experimental results could be observed and measured. The effect of friction and of the radius of curvature of the channel for attenuating erosive forces were studied. A pitot tube developed by J. R. Preston was calibrated and used for determining velocities at the channel surface and throughout the channel cross section. Slides were shown of the effect of flood erosion and the effectiveness of stone revetments in its control.

The meeting adjourned to the hydraulics laboratory where the above model was demonstrated, followed by an informal inspection of other models in operation in the laboratory. The meeting closed at 8:30 P.M. Twenty people were in attendence.

RICHARD F. DUTTING, *Clerk*

SURVEYING AND MAPPING SECTION

APRIL 5, 1961.—The April meeting of the Surveying and Mapping Section was called to order by Chairman Roy L. Wooldridge at 7:15 P.M. The clerk's report of the previous meeting was read and accepted. Chairman Wooldridge announced that a letter will be sent to the Eastern Mass. Association of Professional Engineers and Land Surveyors indicating our schedule for the forthcoming year in order to avoid a conflict of schedules. The dates for the forthcoming meetings were announced as follows:

May 17, 1961 Joint with BSCE which will be held at the Community Services Bldg. The featured speaker will be Dr. Jacobus of the Cambridge Electronics Accelerator.

October 26, 1961, January 17, 1962 April 4, 1962 Annual Meeting and Election of Officers

Chairman Wooldridge then introduced the speaker of the evening, Mr. Carroll F. Merriam, who spoke on "Some Problems of the Surveying Profession as seen by a Retired Engineer."

This very informative presentation was followed by a question and answer period. The meeting was adjourned at 9:00 P.M.

The meeting was attended by 10 members and guests.

RICHARD D. RASKIND, *Clerk*

CONSTRUCTION SECTION

MARCH 22, 1961.—The meeting was called to order at 7:00 P.M. by past Chairman Frank Heger who introduced the new officers of the Construction Section; R. A. Bierweiler, Chairman; J. P. Archibald, Vice-chairman; J. H. Cullinan, Secretary; and L. Tucker, Member of the Advisory Committee.

Chairman Bierweiler introduced the speaker of the evening, Mr. John J. Scheuren, Jr., Overseas Manager for Metcalf and Eddy.

The subject of Mr. Scheuren's talk was "Arctic Construction." His talk, illustrated with slides from various construction projects in Greenland compared the problems of construction in the Arctic with those of the more temperate Northern climate with which we are more familiar. Mr Scheuren illustrated that the problems in the Arctic were not unlike except for the problem of logistics and the severity of climate which requires careful planning in the construction effort and in most cases air transportation support.

Following Mr. Scheuren's talk was a short movie prepared by the Corps of Engineers showing construction of the Dew Line extending across Greenland and the BMEWS installation at Thule.

Twenty-eight members and guests were present. For those who may have missed the interesting talk it is planned to present Mr. Scheuren's talk in the Journal of the Boston Society of Civil Engineers.

The meeting was adjourned at 8:45 P.M.

JOHN H. CULLINAN, *Secretary*

ADDITIONS

Members

Robert E. Barrett, Jr., 92 Woodbridge St., So. Hadley, Mass.

Henry W. Buck, Buck & Buck, 650 Main St., Hartford, Conn.

William H. Coombs, 10 Sunny Knoll Terr., Lexington, Mass.

Michael A. Donnelly, 11 Whitman Ave., Melrose, Mass.

Gerald T. Fagan, Pine Knoll Rd., Franklin, Mass.

Myron B. Fiering, 3410 Club Dr., Los Angeles, Calif.

Harold S. Gillis, Jr., 11 Beacon Street, Boston, Mass.

Charles W. Lockwood, 53 Sunnyside Rd., Norwood, Mass.

Perry L. McCarty, 4 Lockeland Rd., Winchester, Mass.

Saul Nuccitelli, Cooper Union, Cooper Square, New York

John M. Rufo, 72 Forest St., Waltham, Mass.

Athanasios A. Vulgaropulos, 26 Tudor St., Waltham, Mass.

Janis Zagarins, 40 Berry St., Framingham, Mass.

Juniors

Gerald R. Cichy, 222 Cambridge Rd., Woburn, Mass.

Robert F. Daylor, 71 Liberty St., Rockland, Mass.

Joseph D. Guertin, 9 Lemoyne St., Braintree, Mass.

Joseph H. Metelski, 119 Webster St., Haverhill, Mass.

Joseph Yamello, 10 Knox Park, Everett, Mass.

Deaths

Alfred Colletti, June 20, 1960

Frank H. Potter, April 15, 1961

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ADVERTISEMENTS

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

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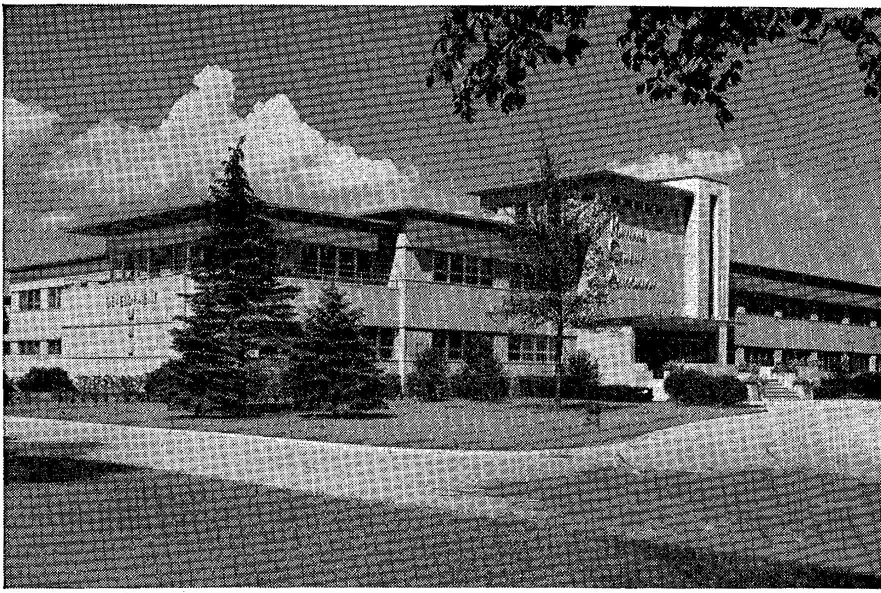

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