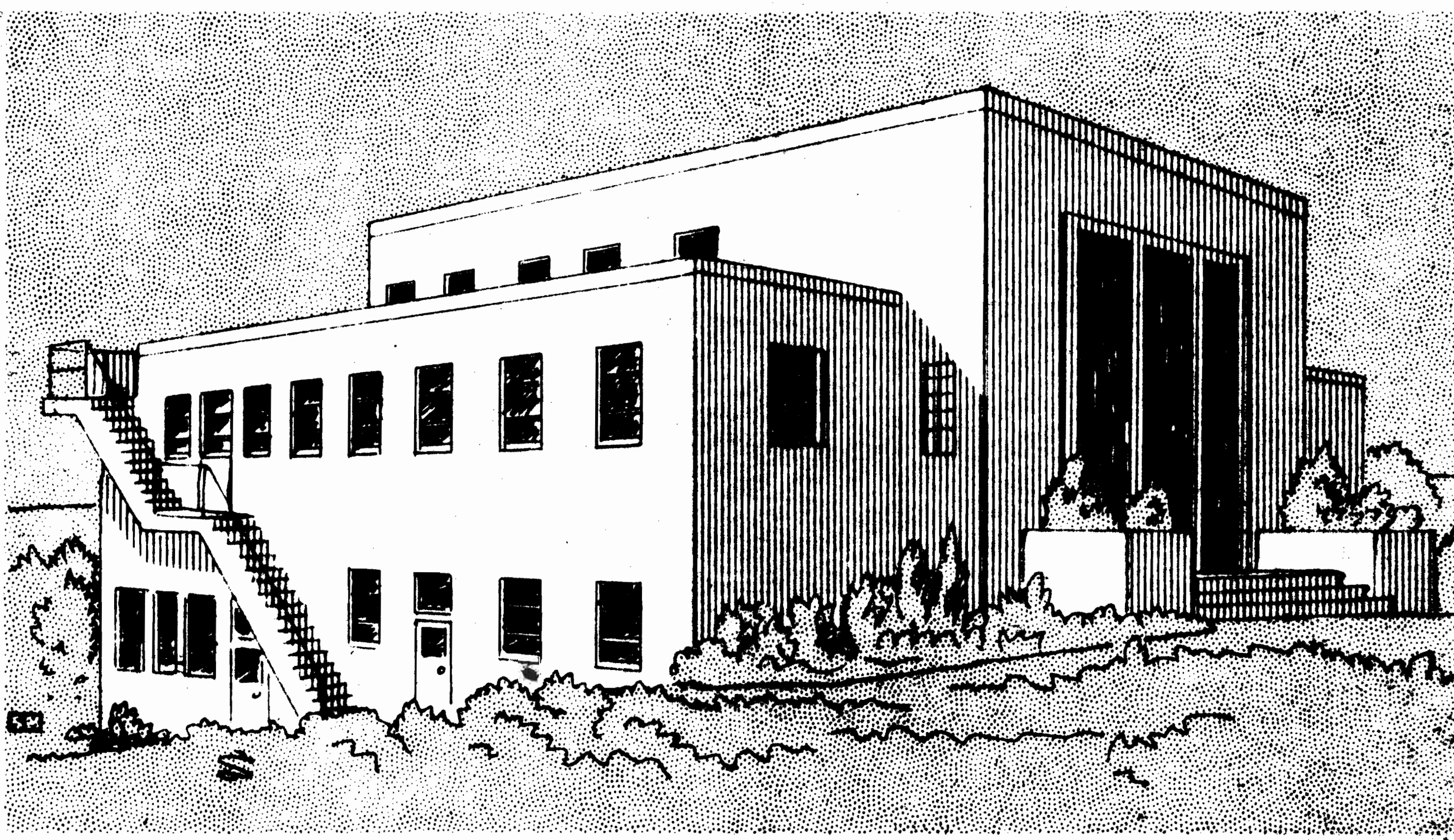
JAN, 1958

The T. WAYLAND VAUGHAN
AQUARIUM-MUSEUM



UNIVERSITY of CALIFORNIA
Scripps Institution of Oceanography

La Jolla, California

TABLE OF CONTENTS

Introduction	Page 1
General Information	2
Water System	6
Pumps	6
Piping	10
Temperature Control	13
Aeration	14
Tanks	15
Fouling Problems	24
Lighting	27
Labels	30
Collecting Gear	32
Boats	32
Nets, Traps, etc.	33
Transporting Equipment	34
Workshop	35
Printing and Art Equipment	36
Feeding Equipment	36
Laboratory	37
Emergency Equipment	37
Bibliography	38
Figures	43 et. seq.

THE T. WAYLAND VAUGHAN AQUARIUM-MUSEUM, LA JOLLA, CALIFORNIA

INTRODUCTION

The public aquarium is unequalled as a means of arousing and maintaining the public interest in certain fields of science; an increasing number of communities are showing an interest in developing aquariums of their own. We have received requests for information from interested individuals and committees in many parts of the world, and this report is, in part, an answer to these requests.

The material in this pamphlet deals with the construction and operation of the T. Wayland Vaughan Aquarium-Museum of the Scripps Institution of Oceanography, a campus of the University of California, located in La Jolla, California. In addition, however, there is some mention of general aquarium principles - with which other aquarists may or may not agree. It must be remembered that every aquarium is unique; factors of size, location, water supply, budget, method of financing, type and size of the potential public - all make a different formula for every institution, and each one must solve its problems through the closest cooperation of the aquarist, the architect, the engineers, and the financiers.

This report is not an official publication of the Scripps Institution of Oceanography, representing no more than the personal opinions of the undersigned. Mention of any firm or commercial product should not be construed as an endorsement by the University. Many friends have contributed their thought and knowledge to this summary, but the responsibility for any errors is mine alone.

If further information is desired, please write to

Sam Hinton, Curator
Aquarium - Museum
Scripps Institution of Oceanography
La Jolla, California

1958

GENERAL INFORMATION

The Scripps Institution of Oceanography is a campus of the University of California, and is devoted to education and research in the various sciences of the sea. Its formal instructional program is on the graduate level; about fifty graduate students are working toward their advanced degrees in oceanography. Also to be considered as an instructional agency, but on a more informal basis, is the Aquarium-Museum, which has served since its beginning as a liaison between the research staff and the general public. We have had a museum since 1910 and an aquarium since 1905. The museum and aquarium have always had a single combined staff, but were housed in separate buildings until the completion of the present building in 1951; this was named in honor of the Institution's second Director (1923 - 1936), and is known as the Thomas Wayland Vaughan Aquarium - Museum.

Built at a cost of about $225,000.00, the new building has three floors (see Fig. 1). In the basement are the curator's office, conference room, the museum workshop, the fish and invertebrate study collections, and the photographic laboratories; the latter is a separate department, serving the entire Institution as well as the Aquarium - Museum. On the ground floor are the Aquarium and Museum, while the smaller upper floor is presently occupied by some of the general administrative and fiscal offices of the Scripps Institution. This upper floor is designed for eventual use as a museum room upon the construction of an Administration Building.

Entrance to the ground floor is through a small lobby, containing an information desk and bookshop, as well as the entrances to the Museum and the Aquarium corridor. The aquarium tanks are in a row surrounding three sides of the building, with the museum room at the center. Tanks are constructed on only one side of the corridor, as a means of preventing unwanted reflections and of simplifying traffic flow. We have not found it necessary to use a guard rail in order to keep visitors away from the glass tanks; to the contrary, a six-inch terazzo step is built in, so as to allow children a closer approach. The resulting noseprints and fingerprints are easily wiped off the glass in the course of the daily cleaning. The floor, step, and wainscot (up to the glass) are of red terazzo; the blank wall opposite the tanks is of a warm, but much grayed, color. These colors were selected to offset the cold effect of light filtering through the aquarium water - and this light is all that is normally used. Above the tanks, sloping out toward the observer, are the label frames, containing back-lighted illustrated labels (mostly 7" x 10") for identification and information. During open hours, no general illumination is used in this corridor; the light coming from the tanks is ample for safety and comfort. Flush ceiling fixtures are turned on only for janitorial purposes. The corridor is heated and ventilated by a part of the building's built-in duct system; our attendance has been larger than was originally expected, however, and it has been necessary to install an auxiliary circulating fan at the back of the corridor.

The Aquarium - Museum is visited by approximately 200,000 people per year, with by far the heaviest attendance on Sundays and holidays; 3,500 were clocked last Labor Day, and 2,000 is not unusual for a Sunday. Many of the visitors are tourists, but there is a satisfyingly large percentage of local folks who come again and again. An average of more than four school classes per week visit the Aquarium - Museum during the school year, many of them from several hundred miles away. Because the teachers of out-of-town groups have not had a chance to familiarize themselves with our facilities, we usually conduct such groups on a guided tour. Time and personnel are not available in sufficient quantities to allow such tours for all the local groups; each year however, the curator gives several talks and guided tours for groups of teachers, after which it is assumed that the teacher himself is capable of conducting his classes. We have also developed the practise of having the curator or his assistant meet with the children in an informal session on the lawn, where questions are answered and discussions conducted. Letters from the teachers and their students indicate that this technique is a successful one. Especially for larger groups, this is more satisfactory than a conducted tour, as it is impossible for more than 20 or 30 people to gather around one tank.

The five members of the aquarium-museum staff cooperate in all phases of the division's work, which makes it rather difficult to say just how many man-hours go into the maintaining of the aquarium itself. Two men spend all their time feeding, cleaning tanks, building and repairing collecting gear, etc. Two other men work mainly in the museum, but spend a good portion of their time in aquarium work - making and installing labels, doctoring sick specimens, etc. The fifth staff member is our departmental secretary. On collecting operations - especially when the 150-foot beach seine is used - help is borrowed from other Divisions of the Institution. Practically all our janitorial work and building maintenance is handled by the Division of Buildings and Grounds, which serves the entire campus; the same division supplies a general guard service at all times, and in the course of their night-time campus rounds, the guards check pump operations, water level in the sea water storage tank, etc. It can readily be seen that a staff of five would not be large enough if the aquarium existed as an independent organization; seven would be an absolute minimum, and more would be desirable.

The total yearly payroll for our five staff members comes to about

$25,000. Operating costs are not easy to figure, since some expenses - gas, lights, gardening, building repair and maintenance, for example - are not charged directly to the Aquarium - Museum budget, but are included in the general campus expenses. These expenses are very little different from those of any other building of similar size and layout. Following are some of the operating expenses for a typical year; it has been necessary to add some museum expenses which are not separable from those of the aquarium (office supplies, telephone, etc.).

Fish food - - - - - - - - - - - - - - - - $	350.00
Light bulbs, heaters, etc. - - - - - -	250.00
Collecting gear - - - - - - - - - - - -	200.00
Paint, cement, stonework - - - - - - -	100.00
Photography (labels, etc.) - - - - - -	100.00
Travel (campus car pool) - - - - - - - -	125.00
Telephones - - - - - - - - - - - - - - -	300.00
Office and art supplies - - - - - - - -	200.00
Tools, lumber, hardware - - - - - - - -	100.00
$	1,725.00
Salary Roll - - - - - - - - - - - - - -	25,000.00
TOTAL EXPENSES - - - - $	26,725.00

This may be considered as a bare minimum of operating expense; in many years, some of the items will necessarily be much higher - a new net may be required ($300.00 at least), or a new outboard motor. If it were not for the services and assistance rendered by other divisions of the Scripps Institution, both as to personnel and equipment, our expenses would be a lot more; an independent organization the size of ours should count on spending at least $30,000.00 per year.

We have set up the Aquarium Bookshop as a means of bringing in a little extra income. This shop sells books, and sea shell specimens for collectors, and requires approximately one and one-half employees to man it. We have a regular full-time departmental secretary who is in charge;

she is assisted, during lunch periods, coffee-breaks, etc., by the curator and his assistant. On week-ends a college student is employed. The yearly income of the bookshop is around $14,000. We feel that it provides a beneficial public service, and in addition brings in a profit of a least $1,000 per year after deduction of salaries, cost of goods for resale, furniture depreciation, etc. If we had planned the lobby so as to allow a larger stock, the figure could probably easily be doubled.

WATER SYSTEM

The T. Wayland Vaughan Aquarium - Museum specializes in the display of marine creatures from Southern California; since the sea water at the Scripps Institution is clear and uncontaminated, this water is used directly, without treatment. The system is an open one, in which the water flows constantly through the tanks and overflows to the beach. Our well-point is at the end of the 1,000-foot pier, where two six-inch deep-well turbine pumps are located. These pumps move the water through a six-inch Transite line to a sand and gravel filter at the landward end of the pier. After filtration, the water is pumped to two 50,000-gallon reserve tanks. (see Fig. 2.) From these tanks the water flows by gravity through two pipelines - one to the Aquarium - Museum and one to the research laboratories.

PUMPS - Our present pumps are deep-well turbine pumps, and are so arranged on the main line that either one or both may be used at the same time. The pick-up point is located about six feet above the sea floor, in a well-pipe attached to one of the pier pilings; the water at this point averages about twenty feet in depth, depending upon the tide, which has here an extreme range of a little under ten feet. When the pumps are working at their maximum efficiency, pressure in the line is up to 36 p.s.i., and each pump delivers about 300 gallons per minute; these conditions are by no means always met, and it is sometimes necessary to run both pumps at once. It is not required of the pumps that they run constantly, since they deliver water at a greater rate than it is used; the aquarium itself uses about 85 gallons per minute, and the research laboratories an approximately equal amount; this rate of use will, however, be greatly increased upon the completion of the projected research aquarium building.

The selection of a proper pumping system for the particular conditions of any given aquarium is a job for an expert; fortunately, the pump manufacturers seem happy to give advice. In many ways, the problems are greater when a recirculating system is used, since at least some pumps in the system will have to run constantly. Furthermore, the combination of sea water with the waste products of fishes and other aquarium animals results in a compound of high corrosive activity. Not only is such corrosion hard on pumps, but it releases and builds up metallic salts in the water, which may quickly reach concentrations fatal to many of the aquarium inhabitants. In this connection, it has been found that a number of small pumps, made of such non-corrosive materials as neoprene, hard rubber, ceramics, etc., are preferable to a single large one; each little pump is the center of its own circulation system, and control of all sorts is easier (COATES, 1946). The Belle Isle Aquarium in Detroit uses single-tank recirculating systems powered by air streams. We have used a modification of this system for single tanks as shown in (Fig. 3).

It is important to see that all water pumps (especially pressure-boosters) are air-tight; if air is taken in through leaky packings, it may result in the water's being supersaturated with air, which could bring about the deaths of many specimens. (MARSH, 1905; RUCKER & HODGE-BOOM, 1953.)

The exact pumping rate required is another problem, one which is subject to many variables. In the first place, it does not appear wise (in an open system, at any rate) to depend upon the constant operation of the pumps, since a breakdown or power failure would immediately shut off the water supply. The pumps should therefore empty into a storage tank containing a supply of water sufficient to last for at least several hours; and this means that the pumps must deliver, in a given time, substantially more water than the aquarium can use. It might appear that the best storage tank would be the largest, so as to provide for the longest possible period during which the pumps could be turned off. In practice, however, this is not the case, since a number of undesirable chemical changes are known to occur when sea water is stored for more than a few hours (COLLIER and MARVIN, 1953). These changes become still more pronounced if the storage place is dark (HARVEY, 1955), and this often has an adverse effect upon the health of captive fishes and other animals (MacGINITIE, 1947). This is not true, of course, in a closed system where chemical control of the water is maintained, but is a problem in an uncontrolled open system. A storage tank should therefore not hold more than a 36-hours' supply of sea water, and a 24-hour supply is usually plenty. The crux of the matter is that the stored water must last as long as the time required for repair or replacement of pumps, valves, pipes, etc.

In our aquarium, the water flows at such a rate as to be completely changed in all the display and reserve tanks about once every three hours. Such a figure in itself has relatively little meaning, since different sizes and shapes of tanks require different change-rates. Our smallest tanks (20 to 30 gallons) change about three times per hour, while the 2,000 gallon tanks require about five hours for a complete turnover. We cannot say that these rates represent the ideal, but our fish do quite well, so we may assume that it is all right. The figures agree roughly with those recommended for small recirculating tanks (STOYE, 1935) and for trout hatchery ponds (SHAW, 1946). When in doubt, remember that it is hard to have too much water, and that the higher flow-rate is likely to be best.

The desired flow rate of water depends upon many factors, such as the total volume of water in the tank and in the system, the relation of tank volume to surface area, water temperature, the number and kinds of fishes in the tank, etc. The individual requirements of various species varies widely. A resting freshwater pike, for example, requires three and one-half times as much oxygen as a resting carp of the same weight (KROGH, 1941). Differences of comparable magnitude occur among marine fishes (see BALDWIN, 1924; HALL, 1929; and PEARSE, 1950), and where several species are kept in the same tank, it is necessary to meet the oxygen needs of the heaviest user, and to ascertain that all waste products are carried off.

Water requirements vary also with temperature. Freshwater trout, for instance, at 68 degrees F. use four times as much oxygen as they do at 45 degrees F. (SHAW, 1946). At the same time, the warmer water, if in equilibrium with the atmosphere, contains only 75% of the amount of oxygen contained in the colder water (DAVIS, 1953).

In an uncrowded tank with a good ratio of surface area to volume, an ample supply of oxygen is taken in at the surface. The main reason for changing water, and aerating it, is to get rid of carbon dioxide (ATZ, 1949). The relations between carbon dioxide quantity and oxygen consumption are very complex (FRY, 1957).

As far as the tanks are concerned, the larger volume of water is better for its inhabitants in every way. We have a number of species that will not live for more than a few months in the 500-gallon tanks, but thrive in the 2,000-gallon ones. Other aquariums report similar experiences (e.g., WILSON, 1952). One important reason for this is that in a large tank it is possible to keep a number of individuals of each species, and it has been shown (SCHUETT, 1934, SHLAIFER, 1940) that fish are more active, more "alive", when this is the case. Locomotor activity increases, as does oxygen consumption, and our experience has been that active fish are healthy fish.

PIPING - Until recently, aquarists had little choice as to the materials they could use for their salt water pipes. They could use lead, which corrodes very slowly, but is unsuitable in closed systems because the small quantities of metallic salts produced are highly poisonous to most fish; or they could use pure cast iron, which corrodes somewhat more rapidly but produces harmless salts. A later development was hard rubber, of which the chief drawbacks were expense and fragility. But in recent years, a number of materials, such as the various synthetics and plastics, have been adapted to this use. Some of these are relatively inexpensive, and are durable and inert to sea water. For the long run from the end of the pier to the water storage tank, we have used a line of Transite, a mixture of asbestos and cement, with success. Transite is a little hard to work with, and cannot be bent; it is not available in small sizes for the inter-aquarium distributing system, and the choice of fittings is extremely limited. So, for the smaller pipes, we have used other materials, especially polyvinyl chloride plastics. These may be cut and threaded with standard tools, or may be firmly welded with certain solvents (such as methyl-ethyl-ketone); they may be softened by heat and be bent in curves of small radius; and they may easily be drilled and tapped for the insertion of stopcocks and hose bibs. In the thinner-walled types, this latter operation calls for the local thickening of the wall by the welding on of a "saddle" of the same material, but this is a simple operation. These pipes may be joined by butting the two ends inside a slip joint of the same piping in a larger size, and the whole assembly welded by application of the proper solvent.

At this writing (Jan. 1958) we have not seen any hose bibs, stopcocks or straightway cocks made of these plastics, but they are expected to appear on the market at any time. We have used fittings of this sort made of hard rubber, and they have been completely satisfactory. Our basic fitting is a 3/8" stopcock made by the Luzerne Rubber Co., plus a sprinkling of 3/4" hose bibs and a pair of 2-inch straightway cocks.

Here is a brief description of the system now in use at the Scripps Institution: raw sea water is pumped from the end of 1000-foot pier by two 300-gpm. vertical turbine pumps. It passes through a 6-inch Transite pipe, which is firmly anchored to the pier and is provided with cleanouts every 100 feet. The water discharges into a reinforced gunite filter box, 10x20x12 feet deep, filters down through a bed of sand and gravel supported on a transite grid, and passes into a pump sump 3 x 4 x 12 feet deep.

From the sump, two pumps identical to those on the pier move the water to two storage tanks, an old one holding 53,000 gallons and a new one with a capacity of 60,000 gallons. From the storage tanks, two 6-inch Transite lines lead to the Aquarium building and to the laboratories. (see Fig. 2.)

Inside the aquarium, distribution pipes are mostly of hard rubber, although all replacements and new sections are of Uscolite, a vinyl plastic pipe. We intend to install a separate distribution system, giving us two lines which can be dried out alternately as a means of reducing fouling.

Overflow water from the aquarium tanks is piped into an open, lead-lined gutter, then through standard cast iron drain pipes to the concrete storm drain leading to the sea-wall. Through the force of habit, the cast iron drains were supplied with standard goose-neck traps; these have proved not only unnecessary (since the drains do not lead to a sewer) but actually detrimental, as they form an ideal place for the growth of fouling organisms - especially mussels - and have to be reamed out occasionally. Furthermore, the iron in some of the drain lines is corroding rapidly, and leaks have developed where imperfect casting left thin spots in the pipe walls. All the drain pipes will eventually be replaced with some more durable material. A purer grade of cast iron would be satisfactory (MacGINITIE, 1947), but we will probably use the less-expensive plastic.

Overflow water is piped directly to the beach, and discarded. There is a by-pass, however, to divert this water through the filter, thus providing a closed system to be used in an emergency.

Also provided is a method for by-passing the storage tanks. While these are being cleaned or repaired, water is pumped directly into the distribution system. An overflow is provided, since the pumps deliver more water than the aquarium can use.

The filter is provided with a freshwater supply for backflushing, and freshwater inlets are also available to flush out the low point of the distribution system.

In all of these by-passes and optional systems, the greatest care must be used in the selection of valves. Brass and bronze should be avoided becuase of the toxic effects of copper in sea water; these effects are cumulative in a closed system. High grade cast iron is probably best, since the salts released by its corrosion is not harmful. Whatever material is used, it should be consistant throughout the system, partly because of the danger of damage to the equipment by electrolysis, and partly because certain combinations of metal salts seem to be more poisonous to fishes than the pure salts of a single metal. In an experiment conducted by Gunnar Rollefsen in Norway, copper bits placed in sea water with plaice larvae brought about a 70% mortality; lead resulted in a death rate of 3%. Lead and copper together, however, killed all of the young fish. (Personal communication, 1952, from Dr. Rollefsen of the Norwegian Fisheries Laboratories, to Dr. Carl Oppenheimer, then of the Scripps Institution.)

TEMPERATURE CONTROL - As we have mentioned, most of our specimens are from local waters, and are accustomed to the temperatures prevailing in our source of water supply. We do have a few creatures, however, which in nature leave the La Jolla region during the cold winter months, or which were collected in the warmer waters of the nearby Gulf of California, in Mexico; for these, some sort of temperature control is necessary. Heating and cooling is much easier in a closed circulating system, and we have set up extremely simple one-tank recirculating systems for the Mexican fishes. (See Fig. 3.) No reservoir is used, but the same water is recirculated and filtered by small air-lift units, operating off our regular compressed air line. Sometimes the water is warmed with immersion heaters, but it is usually enough to let it take on the room temperature, which is held between 72 and 78. A small reservoir would improve this system a great deal, and we will install one in the near future. Several excellent small systems of this sort have been described; especially BREDER, 1957, and THOMOPOULOS, 1955.

There can be no doubt that a properly-designed recirculating system allows more flexibility and versatility than does an open system, and much better control of the water can be maintained at all times. (See for example BREDER and HOWLEY, 1931.) Entirely new problems will arise with the closed system, however, and so long as a good supply of clean water is available, and one plans to exhibit chiefly local specimens, the open system works very well; our records for the longevity of aquarium specimens compares favorably with those of any other aquarium of which we have knowledge. The best answer is a flexible system, one that can be operated either as an open system or a closed one, depending upon circumstances, and such an arrangement is one of our goals. (For a description of such a system, see WILSON, 1952.)

AERATION - Every public aquarium should be provided with an ample supply of compressed air, piped to the tanks and available through a simple gas-jet type of stopcock. The air should be clean, and free of oil droplets. Air stones of carborundum or other (and less expensive) material are extremely useful in keeping the water in good shape. These stones should be so made that bubbles emerging from them should not exceed about one-thirtieth of an inch in diameter (EMMENS, 1953). The most important result of aeration is perhaps the air stream's action in keeping the water in vertical circulation, so that all of the water eventually benefits by exposure to air at the surface. It is possible to calculate the rate of solution of atmospheric oxygen in water under controlled laboratory conditions, but it is very difficult to express such rates in relation to the demands and preferences of organisms living in the water (DOWNING and TRUESDALE, 1956).

TANKS

Our display tanks vary in capacity from 100 gallons to a little over 2,000 gallons; the majority contain about 500 gallons each. There are also a number of small movable tanks, holding ten or more gallons each. The ten tanks of the 500-gallon size are about 8 feet long, three feet high, and three feet from front to back. (See Fig. 4.) We now wish that the latter measurement were greater; three feet isn't very much, and even of this, one-third is lost to vision because of refraction, so that the back wall of a full tank appears only two feet from the glass. Also, larger tanks are better for the fish.

All the permanent tanks are made of waterproof concrete; the reinforcing rods are located toward the outside, away from the sea water to help prevent their rusting through (MacGINITIE, 1947). The interior faces were cast against oiled hardboard to produce a smooth surface, since such a surface reduces the work of cleaning and makes it more difficult for fouling plants and animals to gain a foothold.

Concrete has proved to be a good material, although there is some trouble in the rusting through of reinforcing rods; mainly for this reason, there may be other materials better than concrete. Coates (See ATZ, 1947a) recommends the use of a heavy die-stock material, which we have not been able to try out. We have, however, begun experimenting with fiber-glass and plastic resin compounds; these are meeting with increasing approval in boat construction, and their use in aquarium tanks is promising. At least one firm on the Pacific coast is now producing portable bait tanks, made of a fairly rigid fiber glass laminated matt in a synthetic thermo-setting resin, and there seems to be no reason why a similar tank, suitably reinforced, should not be practicable in an aquarium. We have found that none of the present compounds available to us were designed to adhere to concrete, and it is impossible to line our present tanks with it. It does bond with wood, however, and we are now using several small portable display tanks made of marine plywood and glass, and lined with a couple of layers of fiber glass fabric and resin. The resin makes a fairly good bond with glass.

Each of our permanent tanks is provided with a scum-gutter type of overflow, which we strongly recommend. (See Fig. 4.) In the old building here, overflow was effected through a single outlet in the back wall of the tank; at feeding time, an oily scum developed on the surface of the water, and just stayed there, the overflow water passing out beneath it. But with the scum gutter running the full length of the tank, this scum is carried off as quickly as it forms, and our cleaning work is reduced accordingly. Small fish occasionally jump into the gutter; a small screen prevents their going down the drain pipe, however, and there is usually enough water to support the fish in the gutter until help arrives. The entire gutter can easily be screened if necessary.

Set into the floor of the work space behind the tanks, there is an open gutter lined with lead. Being lower than the floor of the tank, this makes possible the use of a simple siphon for cleaning purposes;

we use a one and one-half-inch rubber hose for this. This siphon is also used for draining the tanks, since no outlet drains were built in. This lack of drains was admittedly an oversight - one of the many changes that inevitably creep in during repeated revisions of the plan, and which I should have noticed immediately - but it has not proved to be so great a drawback as we feared. Even if we had drains, we should probably not use them in routine cleaning operations; they would make emptying a tank faster when it must be dried out for painting or repair, but two or three siphon hoses work very well. We have wished for proper drains when it was desirable to display some surface-dwelling creature, such as grebes, murrelets and other birds, and the Galapagos marine iguanas who reposed on a floating board. We had to use a bulky self-starting siphon made of two inch pipe, to keep the water at a level below the scum-gutter line; if drains had been set in the tank floor, as originally planned, a vertical pipe of the desired length could have been placed in them, and the water level maintained wherever it was desired. Drains of this sort, equipped with valves on the outside of the tank, add but little to the cost of the tank, and should by all means be included.

We have used a tempered plate glass, Herculite, in all our tanks. This is a high grade plate glass that is annealed after having been cut to size, and is much harder to break than ordinary untreated plate; it is also more flexible, which is a point to consider in this area where minor earthquakes are not unknown. Because of its added strength, it is possible to use this glass in thicknesses less than those required by standard plate glass; half-inch Herculite is used in all our tanks. This fact makes Herculite very little more in cost, and the thinner glass has the further advantage of creating less refractive distortion when the inhabitants of a tank are viewed at an angle. It must be admitted that several aquarists mistrust the tempered glass because of its tendency to break into small fragments if its surface is broken. We have not experienced any difficulty in this connection, but the possibility should be discussed with the engineers and architects of any new installation.

Our glass panes are set against Monel metal frames, with rubberized cork gaskets between frame and glass on the front side; another Monel frame is bolted against the glass from the back, being fastened to a Monel plate set solidly in the concrete at the time of casting. The glass is packed all around with high grade aquarium cement. (See Fig. 5.) An equally good but less expensive method was used in the tanks of our old aquarium, and will be used if replacements are necessary in the new building. This involves the casting of grooves, as straight and true as possible, in the end walls and bottom of the tanks; a one-eighth inch rubber gasket is fastened to the front side of the glass with rubber cement, and the pane slid down into the grooves. The glass is then forced forward against the gasket by a series of wooden wedges, driven between the back of the glass and the rear lip of the concrete groove. The space between the wedges is filled with aquarium cement - more for appearance than anything else, as this construction is quite waterproof even without it. Along the bottom groove, we have used a single side-tapered wedge across the full width of the tank; this is driven home until its top edge is flush with the tank floor. Otherwise, spiny lobsters and some kinds of crabs have the bad habit of tearing out the aquarium cement with their sharp feet, with very unsightly effects.

One advantage of the latter method is that the glass fits into the side of the tank, leaving no small blind spot such as that produced by the Monel frame. If such a spot is present, many specimens will head straight for it, and hide in it most of the time. Another point is that the wedges hold the glass forward against the gaskets even when the water-pressure is reduced by draining the tank; with the system of glass mounting we now use, changes in water pressure cause a little play in the glass, and the tanks always leak a little upon being refilled; this leakage stops when the water gets deep enough to force the glass forward again. Perhaps the most important fact of all is that the groove-in-the-concrete method does not require the presence of any metal at all in the water; for although Monel does react very slowly with sea water, the reaction is still observable, and we find spots of corrosion where the copper in the metal has formed an oxide. This would be extremely serious in a closed system, and even in an open system such as ours, it is, to say the least, highly undesirable.

The concrete walls and floors of our tanks have been painted, both as a protection for the concrete and as a means of decoration. Several types of paint have been found to stand up fairly well in sea water, but we have resigned ourselves to painting each tank every eighteen months or so. One of the paints used is Amercoat, designed especially for use on concrete in sea water, and available in a wide variety of colors. Standard swimming-pool and masonry paints have been tried, but have not worked at all well.

In our choice of colors, we have by no means stuck to the realistic blues and greens of the submarine world, but have used colors partly for dramatic effect and partly to break up the monotony of a row of tanks identical in size and shape. The tanks are turquoise, light green, dark green, light blue, deep blue, maroon, gray, and black. The red tones have been sparingly used, mainly because their "advancing" quality makes the rear wall of a red tank seem even closer to the glass than it actually is. In one maroon tank, the back wall is almost completely covered with natural-colored rock work, only the end walls and floor being visible; from the artistic viewpoint, this is one of our most successful tanks. Tints and tones of yellow have been discarded as too "nervous" for the relaxed atmosphere of the aquarium. In one tank, containing the garibaldis, we have used a deep green-blue - the direct complement of the bright orange-red fish. This background color is slightly grayed to prevent an optical vibration, but it nevertheless snaps out the fish in a most dramatic way.

Rock work is important to the appearance of a tank, as well as to the health and happiness of its inhabitants (HEDIGER, 1950). The severe rectangular outlines of a tank are softened if the rocks are built up and back in a staircase effect; but even if space requires that the rocks be cemented directly to the vertical back wall, the appearance of the tank is improved. We have not used rock work in every tank, but have employed it as we have color - to break the montony of otherwise-identical tanks. Several kinds of rock have been used; flat, irregular, rather thin pieces of natural shale were installed horizontally in a staircase arrangement in the anemone tank; rounded beach cobbles have formed the background and a number of crevices, grottoes and tunnels for the spider crabs, spiny lobsters, opaleyes, and some others. The scorpionfish tank is equipped with a background of two-inch thick flagstone, laid flat in an arrangement of ledges and hollows; the aquarium staff usually refers to this tank as the "barbecue pit", but, with some green algae allowed to grow on the stones, it presents an extremely pleasant prospect. All stonework, by the way, is improved by allowing some of the marine growth to grow on it (TOWNSEND, 1928). In most of the tanks we have arrangements of loose stones, sometimes placed quite near the glass, so as to allow the fish a hiding place that is still within view of the public.

In arranging any kind of rock work, it is important that the requirements of cleaning operations be kept in mind; any hollows or pockets should have their opernings in the vertical plane, so as not to hide specimens, not to trap dirt, and not to hold water when the tank is drained.

The new tanks in the aquarium of the Institut Océanographique at Monaco are attracting enthusiastic comment from aquarists fortunate enough to see them. The larger tanks have their ends sloping away from from the observer at a 45° angle, so that the back wall is longer than the glass; this makes the wall invisible to the viewer, and gives the effect of a tremendous tank. Between these trapezoidal tanks are smaller triangular tanks, which are also very effective. Other details of the Monaco system are worth emulating, and every aquarist should read Dr. Garnaud's paper (GARNAUD, 1952).

Routine cleaning is accomplished by siphoning the water down to the lowest level that will allow the fish to remain submerged; the tank man, in rubber boots, can then wade gently among them, scrub the walls and the inside of the glass with a stiff brush, and scrape off the more stubborn hard-shelled fouling organisms. This technique, which does not involve moving the fish, is used in other public aquariums (e.g., TOWNSEND, 1928). The walls are then rinsed off with salt water from a hose, which is left running at the speed of the siphon until the water in the bottom of the tank is clear. Then the siphon is removed and the tank allowed to fill. Every day, a certain amount of siphoning is done, but the scrubbing and major cleaning is performed only once a week. Gravel on the tank floors is siphoned out directly into a screened wash box; after washing, it is allowed to dry for a week or so, then is washed once more and replaced. Where sand is used, it is handled in much the same way, although it is more difficult to retain and wash.

During the summer months, there are a few occasions when the air in the public corridor is enough warmer than the water in the tanks to cause fogging of the glass. When this happens, wiping the glass with a liberal quantity of a detergent solution prevents the fogging for several days.

Some kinds of fish and invertebrates (especially octopuses) have a distressing habit of crawling or leaping out of the tanks - usually with fatal results. Some sort of covering is necessary to keep these intractable species in their places. A simple wooden frame, covered with chicken wire, is usually adequate; it should be made in several sections to allow for easier removal. Some fish, such as California Sheepheads, may be kept in the tank by extending the sides of the tank upward with a frame of ten-inch boards, standing on edge, leaning inward at an angle of ten degrees or so; the wire netting is not required in this case, and the tank man's operations are easier.

If tanks are to be located on both sides of a corridor, it is advisable that the front glass be leaned out toward the observer about five degrees, so as to minimize the reflections of lighted tanks on the opposite side (ATZ, 1947a). If the slope is made much greater than this, dirt has a tendency to collect on the inside of the glass, which must therefore be more often cleaned. (Personal communication from Donald Simpson of the Steinhart Aquarium, San Francisco.) In our aquarium, the tanks are on only one side of an unlighted hallway, and no reflections are possible; therefore the glasses are vertical.

Although reserve tanks are not visible to the public, they are extremely important; most aquarists agree that the volume of the reserve tanks should be at least half that of the display tanks, and many of them would hold out for a volume equal or even greater. This figure was not originally met here at the Vaughan Aquarium, but we are about to build a pair of outdoor tanks that will bring us close to it. One such tank has already been constructed by the aquarium staff; it is about 9 feet by 12 feet by 34 inches, and holds about 2,000 gallons. Water is supplied from the overflow of the smaller reserve tanks inside the building. This tank has proved very useful as a holding tank and a quarantine station. We find that a large tank without glass is by far the best to get new fish acclimated to aquarium conditions. The inside reserve tanks are much smaller, but nonetheless useful to hold fish, and especially useful in the treatment of sick specimens, using fresh water or other healing and antiseptic solutions, such as copper sulfate, sulfa drugs, etc., where the treatment is of short duration (ATZ, 1947c; DAVIS, 1953; FISH, 1939). Sorting tanks raised to comfortable table height and about six or eight inches deep are very useful in sorting collections of small tide pool animals, etc., as soon as these are brought in from the field. A good general rule in planning a public aquarium is to make provisions for as many reserve tanks as possible - then add a few more! With a limited budget, it may be necessary to sacrifice a little display space in order to provide adequate reserve space, but the aquarist will never regret that this was done, and the public exhibits will be of higher quality.

Two of our tank spaces were left without built-in tanks; a pane of quarter-inch plate glass makes this space waterproof. A mask is cut out to fit up against the outside of this glass, containing openings to fit small (10 - 30 gallons) aquaria behind the glass front panel. This system has been beautifully used in the New York Aquarium's temporary quarters in the lion house of the Bronx Zoo (COATES, 1942). Our tanks are used for the display of small fish and other animals, such as the brilliantly-colored nudibranch mollusks, and our public seems to enjoy them. Some are built with glass backs as well as fronts, which makes possible the construction of a background in the open air, but looking as if it were under water. The front glass of these small tanks should be at least six inches from the large masked plate glass, to allow for the insertion of a chamois skin and a hand; otherwise, the tanks must be moved for frequent cleaning, which is hard on fish and tanks alike.

FOULING PROBLEMS

In an open system, with sea water continually flowing in and carrying the larval stages of many marine animals, the problem of fouling is a major one. These larvae settle down and grow up inside the pipes, wherever they can find a footing; in southern California, we are particularly annoyed by spirorbid worms, acorn barnacles, small sponges, and two kinds of mussels. Without a doubt, the most practical system for combating this problem is the one long used at the Plymouth Laboratory of the Marine Biological Association of the United Kingdom (WILSON, 1952). This consists of a completely double system of pipes, one set of which is drained dry while the other is in use. Alternation of the two sets of equipment at weekly intervals kills fouling organisms before they get started; in fact, during much of the year, alternation is required less frequently.

Where the pipes are not too long, frequent back-flushing with hot (90 degrees F.) water will keep them clear; this method is particularly effective for servicing the lines between the reservoir and the aquarium tanks. (MacGINITIE, 1947.) It is sometimes preferable to use hotter water for a shorter length of time; a temperature of 100 degrees F. will kill even the most stubborn organisms in the course of one hour (CHADWICK, CLARK and FOX, 1950).

It has been shown (DOOCHIN and SMITH, 1951; SMITH, 1946) that the velocity of water flowing through a pipe, or across a surface, has a strong influence on the amount of fouling; in general, a velocity greater than 25 feet per minute has prevented larvae from settling under experimental conditions. This knowledge is, however, of limited application in the construction of a salt water system for an aquarium, since it is virtually impossible to maintain an even rate of flow in all parts of a pipe, and there are bound to be turbulent spots where the flow is much below the critical point. Furthermore, if the flow is intermittent, fouling organisms may get a foothold during the quiet periods; and once hanging on, they are hard to dislodge. In our six-inch main line, the flow rate is much above the critical point, being about 100 feet per minute; but, because of turbulence and intermittent flow, mussels find the opportunity to take hold, and we have quite a bit of fouling at the outer end of the line. And even in and around the pump intake, where the velocity is still higher, we have a very heavy growth of mussels, especially the bay mussel, *Mytilus edulis*. At one time it has been considered that it might be advisable to decrease the diameter of some of the pipes inside the building, so as to increase the flow velocity and decrease fouling; but it now appears that nothing would be gained by such a procedure.

Partly to clarify the water, and partly to filter out the larvae of fouling organisms, we have installed a large sand and gravel filter. It does not seem to have prevented fouling, however, and has raised a problem in connection with the bacterial population of the sand bed, and we do not recommend such a filter in an open system.

No matter what sort of system is used, all lines should have plenty of flange unions and cleanout plugs, and the aquarium's equipment should by all means include a plumber's "snake" long enough to reach over halfway from any cleanout point to the next. Where straight runs are joined together, it is desirable to have the inner surface smooth; if a threaded nipple is used, the two ends of the pipe are not butted together, and the short stretch of increased diameter provides an ideal spot for the attachment of fouling creatures. If threaded connectors must be used, make them flange unions or plugged "tees" rather than nipples; the plug may be removed for cleaning. Tees may also be used instead of "ells" at right angled bends, although a smooth rounded curve is still better, and this may be obtained with polyvinyl chloride or other thermoplastic pipes.

Another fouling point is at the attachment of the water spigots or stopcocks; placing these in tees with reducer bushings is not a good practice, as the stopcocks will have to be removed frequently to allow the scraping out of the inside of the tee. As mentioned in the section on piping most of the hard rubber or plastic pipes may be drilled and tapped for the direct insertion of the stopcocks; this is much to be preferred.

Some organisms - especially the tube worm, Spirorbis, - settle on the vertical inner walls of the display tanks; weekly scrubbing with a piece of wood or plastic keep these in check and do not unduly damage the paint. In this connection, it is important to make the walls as smooth as possible, as this greatly facilitates the removal of these animals. Our tank walls were cast against oiled hardboard, and the resulting smooth surface has been very satisfactory. In the Danish Aquarium at Charlottenlund, the walls were at one time lined with colored glass, and routine cleaning was enough to remove young fouling organisms (WILSON, 1952). The aquarium of the Institut Océanographique uses white tile on the invisible end walls. (GARNAUD, 1952). There are a number of ceramic products, such as the smooth panels designed for use on modern store fronts, that are available in a wide variety of colors, and these might bear consideration; a few tests in salt water would be required to determine the extent of their usefulness, and concrete tanks would have to be designed expressly for them.

LIGHTING

Although our aquarium is located in a part of the world with an excellent reputation for sunshine, we have found sunshine undependable as a constant source of illumination, and prefer the greater control possible with artificial lighting. Sunlight has not been excluded from the work space behind the tanks, and occasional beautiful effects are observed when the late afternoon sun of the winter slants down through the south windows and into the tanks; but this is frosting on the cake, and the tanks are adequately lighted even on our rare dark days, or at night.

We have not yet found a lighting system that is ideal in every way. A lot of experimenting has been done on the subject, here and elsewhere (COATES and ATZ, 1949). It is desirable to locate the lights in such a way as to display fish in the tanks to their best advantage;

to this end, light coming from the observer's side of the glass would prevent silhouetting of the specimens, which would be fully lighted without visible shadows. This is impractical. The staff of the New York Aquarium tried a compromise system in which the lights were placed vertically at the end of the tanks, on the observer's side of the glass, but shielded from his eyes. This made for a beautiful, even illumination of the entire tank - but the fishes died. Apparently, fishes must have their light source in the same position as the sun - above the surface of the water (COATES and ATZ, 1949.) All in all, it appears that the best place for the light source is above, as near as possible to the front glass. This gives the fishes their desired light from the top, but does not allow them to be silhouetted with light from behind, and does not cause any light to shine directly into the observer's eyes.

Our aquarium was designed with eight-foot slimline fluorescent tubes, three to a tank, suspended parallel to one another about twelve inches above the water, close to the front of the tanks. The suspending chain had a ring in it, which could be looped up over the hook in the ceiling, to raise the fixture while cleaning the tank. In practice, it was found that raising the light to the higher position reduced the light intensity by an almost imperceptible amount; the color of the tank walls and the varying clarity of the sea water had a great deal more effect upon the total brightness. Thus we have stabilized these fixtures in their raised position, two feet or so above the water; the general illumination is not demonstrably lessened, and feeding and cleaning are simpler and safer.

But even with the fixtures farther from the water, our aerators cause enough spray to corrode their contact points very rapidly. Vapor-proof glass-covered fixtures are available, but they are far more expensive, and servicing them is inconvenient. When one of our original fluorescent fixtures reached an irreparable state, it was experimentally replaced with three inexpensive (less than $2.00 each) universal outdoor aluminum fixtures for incandescent lamps, and each was supplied with a 150-watt self contained outdoor spot or floodlight. To our surprise, the appearance of the tank was improved. We had avoided incandescent lamps, thinking that the more evenly distributed illumination of the long fluorescent tubes was preferable; but in the opinion of all who have seen the tanks, the uneven illumination is more pleasing. Where spots are used, the beam of light is visible, giving the effect of a shaft of sunlight; the fish do not avoid this sort of beam, but often swim through it - and when they do, their colors are more brilliant and more sharply defined than under diffuse light. Our spotfin croakers, for example, had always appeared rather dull; but now the directly focused rays of light give brilliant specular reflections of gold and silver. Several spots can be used parallel to one another, or they may be aimed at a center of interest; some fish congregate in the vicinity of a rock, for example, and will continue to do so with the lights all aimed at them. Lights of this sort also serve to increase the apparent depth of a tank (from front to back) by having the front much the more brilliantly illuminated. The undersea effect is enhanced by ripples on the surface, which, with focused lighting, produce a changing pattern of light and dark over the floor and walls of the tank. Diffuse lighting does not do this.

The aluminum incadescent fixtures are subject, of course, to the same rigors of corrosion as are the fluorescent fixtures; they are more easy to repair, however, and fifty new ones can be purchased for the price of a single fluorescent fixture. Each of our fixtures is mounted on a simple clamp fastend to the salt water pipe; it may be slid along the pipe to any location, and, with its universal joint, aimed in any direction.

It is probably unnecessary to add a warning to the effect that all electrical fixtures and appliances must be designed and installed with the conductive qualities of salt water in mind; a tank man, even if wearing rubber boots, is well grounded when he stands in salt water. All circuits should be grounded. Even with this precaution, a tank man should turn off the lights at the switch box before climbing into a tank.

The public corridor, from which visitors view the aquarium tanks, is without windows, and the only light there is from the tanks themselves. The visitor can see where he is going, and can even read, if he likes - but he is not distracted from the exhibits. Flush ceiling fixtures are set in the acoustic tile of the ceiling, but are used only for sweeping up.

LABELS

Our label frames are located above the tanks, leaning outward toward the observer. There are certain disadvantages to this location, but on the whole it has more to commend it than any other we have considered. One trouble is that people wearing bifocals have to tilt their heads 'way back. If, however, the labels were at the bottom of the tanks, they would be hidden from the view of all but the first row of visitors. By and large, our audience seems pleased with the labels and with their location. If should be remembered that labels at the bottom of the tanks may be destroyed if the tanks leak, even a little bit.

The labels are lighted from behind; each frame contains a single eight-foot slimline fluorescent tube behind a pane of flashed opal glass. Permanent labels are photographically printed on Kodalith film;

they are entirely opaque except for the clear letters and the illustrations. Text material is set in type by hand and run off on a small proof press, using black ink on white proof paper; a picture is drawn on scratchboard, in reverse - that is to say, the picture is black with white lines, on a white background. This illustration is mounted on a sheet with the block of type, and the whole is photographed; in essence, the negative produced in this way is used as the label. Actually, we do not have access to camera holding film of the proper size, so we have to reduce the sheet on a 4" x 5" negative, make a contact print on Kodalith, then use that print in the enlarger to blow up our label to the proper size. Finally, white bond paper is glued to the back of the label, behind the illustrations, and this paper is colored with water colors; pieces of colored cellophane are fastened behind the blocks of type. Occasionally, a color photograph is made of a specimen, and the transparency (on 4 x 5 film) spliced into the Kodalith label. This makes a beautiful label, but is expensive - especially as the transparencies fade rather rapidly, and must be replaced frequently.

Labels of a more temporary nature are drawn and lettered (by hand or with the LeRoy lettering device), or sometimes set up on the printing press, on a high-grade single-ply white drawing board; colored inks are used for the name of the specimen, while the main text is in black. The illustration is drawn in ink and colored with water colors. These labels are much improved when the outline of the drawing is masked off with frisket paper, and surrounded with a bright-colored airbrushed vignette. Prepared in this way, the temporary labels are almost as attractive as the permanent ones; each frame as a whole, holding up to ten labels, is more pleasing if both sorts of labels are in it.

Our labels are written in an informal style, but we are careful not to "talk down" to the general public. Technical names are used without apology: common names are given too, of course - even if, as with some of the less-common invertebrates, we have to make them up ourselves! Perhaps most of the visitors read only the name of the animal and look at the picutre, but a satisfying number is observed reading through the entire text. In labels for species that are to be found on display at most times, we try not to repeat the same information for different species; in the labels for the five most common local starfishes, for example, each one tells some fact about that particular species, plus some information about starfishes in general, and a reading of all five labels will constitute an elementary and informal introduction to the biology of this interesting group of animals. Labels for specimens that do not live long, or are not often captured, must be complete in themselves, since they may not be posted all the time so as to "key in" with the others.

The importance of labels to the general atmosphere of a public aquarium cannot be overemphasized, and we feel that the staff is justified in spending a substantial portion of its time in making them and moving them as necessary.

COLLECTING GEAR

BOATS - The T. Wayland Vaughan Aquarium-Museum has only one boat of its own; a 14-foot Fibre-glass skiff with a 7½ h.p. outboard motor, which is kept at the end of the pier, where there is a power winch for lowering and raising it. For setting traps and set-lines, and for hook-and-line fishing in nearby waters, the skiff is used from the pier; for seining operations at the bays and beaches some distance from the Institution, it is transported by truck. This skiff would not constitute an adequate collecting fleet for an independent aquarium; we can, however, draw upon the Scripps Institution's boat and ship pool in cooperation with other divisions. This gives us access to five vessels, from 80 to 140 feet in length, as well as to a number of smaller craft.

NETS, TRAPS, etc. - Our basic collecting tool is a 150-foot beach seine; our preference is for a straight seine, but other workers prefer a seine with a bag. This seine is used in bays and in the surf. Before using this (or indeed, any other sort of collecting gear) permission should be secured from local Fish and Game authorities; in California, a State permit is required for each individual participant. These permits are for scientific collecting only, and may not be available to independent aquariums operating on a commercial basis.

For work in narrow bay inlets and tide pools, smaller seines - down to 5 feet in length - are used. We also use a number of dip nets with stout hardwood handles and strong hoops of brass or stainless steel. Two men using these nets at low tide can secure many of the smaller fishes. When we collect underwater, using self-contained underwater breathing apparatus, we use collecting nets of fine plastic screening mounted on hoops of heavy wire; these serve both as collecting nets and as specimen bags, to prevent the annoyance of frequent returns to the surface. With the cooperation of the Institution's Diving officers, this method of collecting has produced excellent results; two men working together can secure great numbers of fish and invertebrates, many of them formerly thought to be rare.

Long-handled dip nets are useful in collecting surface specimens from shipboard at night. Short-handled dip nets are needed in the aquarium, although it is wise to handle the fish as little as possible.

This is an important consideration in all operations involving the handling of live fish. Even a slight touch may wipe some of the mucus away, and open the pathway to infectious skin diseases. (VAN OOSTEN in BROWN, 1956.)

Our traps are of several sorts. Most are made of iron concrete-reinforcing rod, bent and welded into five-foot hoops; two of these, fastened together with straight two-foot pieces, make a short cylinder which is covered with chicken wire or hardware cloth. Two of these traps are kept baited at the end of the pier, and keep us supplied with spider crabs and several kinds of sea perch; a line of traps in the kelp bed catches spiny lobsters, sheepheads, moray eels, and others. Loss of these traps is frequent, so we use inexpensive materials. If a trap is not lost, the chicken wire rusts out in a year or so, and must be replaced; but if the trap is lost, complete replacement is a matter of small expense.

We also use regular fishing gear - rods and reels, hand lines, and set lines. On the rod and reel line and hand lines, the barbs of the hooks are usually removed or depressed; many fish are lost because of this, but those that are not arrive in much better shape. If long-shanked barbless hooks are used, it is usually possible to seize the shank and tip it up, allowing the fish to fall into the live tank without having been handled. Set lines are not much used, as they injure the fish too badly.

TRANSPORTING EQUIPMENT - For use in the skiff, we have found standard washtubs of various sizes, painted inside with some non-toxic paint, to be most useful. New galvanized tubs should be treated, before painting, to remove some of the zinc which might otherwise produce lethal salts; vinegar is rubbed onto the metal, allowed to set for a few minutes, then wiped off. The tub is then washed and painted. For the larger ships, we have welded up larger tanks of sheet metal. For land transportation - which involves most of our fish, since they must be transported from the seining place or from the ship docks - we have built a four-wheel tandem trailer, carrying a 350-gallon tank. (See COPELAND, 1947.) A small gasoline engine powers a pump for recirculation on longer trips; on short hauls, it is more convenient to use tanks of compressed air with regular air-stones. The trailer also contains compartments for the transport of the wet net, the dip nets, and buckets. The latter item - buckets - should be available in plenty. Whenever possible, fish should be carried in a bucket rather than in a dip net, even if only for a few feet. This is especially important in handling the larger, heavier species.

Transporting tanks should be provided, if possible, with equipment to fill them with water at the collecting site. Mortality may be greatly reduced by keeping fishes in their native water until they may be gradually accustomed to the water of the aquarium (PLESSIS, 1956).

We have recently made use of small plastic bags for the shipment of little fish; two divers collecting at Bahia de Los Angeles, 500 miles south in Mexico, filled such bags with water and specimens, and put them aboard a private plane bound for La Jolla. This system is becoming widely used by fish dealers, and we intend to use it more.

WORKSHOP - Our shop is set up mainly for the construction of museum exhibits, but every tool has its use in the aquarium too. Most standard power tools are available - drill press, band saw, table saw, jig saw, wood lathe, metal lathe, grinder, router, sanders, electric drill, power hand saw, etc. Welding equipment and powered pipe-fitting tools are available in the shops of other local divisions. We also have a full quota of standard hand tools, as well as more specialized museum equipment such as plastics ovens, ceramic kiln, etc.

An independent aquarium would need a larger, more fully-equipped shop (especially in the realm of metal-working equipment); but we are fortunate in our access to the Buildings and Grounds division for most maintenance and repair work, and the Special Developments instrument shop for aid in the construction of certain kinds of new equipment.

PRINTING AND ART EQUIPMENT - For the making of labels, we use a standard Nolan proof press, and have a number of fonts of two type faces (Futura and Stymie) in several weights and sizes. We also have a fairly complete drafting office, and regular artist's supplies - airbrushes, lettering guides, large tracing table, good lettering brushes, etc. We are gradually building up a small library of books on drafting, illustration, art principles, museum techniques, lettering, typography, etc.

FEEDING EQUIPMENT - This includes a 500-pound freezer, a meat grinder, good knives, cutting boards, etc. The freezer should maintain a temperature within 5 degree of 0 degrees F., so as to preserve all the vitamin and protein constituents of stored food (DAVIS, 1953). If at all possible, a walk-in deep-freeze room should be included in the plans of a new building. This will pay for itself in the long run, since a year's supply of food can be purchased and stored at a great saving.

An electrical blender or liquefier is very useful in preparing food for small species and young fish (ATZ, 1948b). Vitamin and mineral content may be controlled in this way, which is an important thing to the health of the specimens (HALVER, 1953, for example). Recent experiments show that even better foods are prepared when the liquefied material is bound in a "jell" (WOOD, GRIFFIN, and SNIESZKO, 1954). We make a standard food for small fishes by liquefying mussels, sand crabs, lettuce, mackerel, and bone meal, then jelling the liquid with carboxylmethylcellulose (CMC) powder.

LABORATORY - A small laboratory, equipped for at least routine analysis of water and examination of dead fish, is essential to every aquarium (ATZ, 1947c; 1948c; NIGRELLI, 1940; 1943). Our own laboratory equipment is meager, but we have access to other very well-equipped labs on the campus. Personnel and equipment in these other divisions are extremely helpful to us, particularly in times of emergency - stomach content analysis, chemical analysis of water, parasitological investigations, and bacteriological studies (see OPPENHEIMER, 1953) are often handled in this way. Routine water analysis is essential, especially in a closed system; but a schedule of equipment and procedure is quite simple to set up (ELLIS, 1948).

EMERGENCY EQUIPMENT - In the event of power failure, which will cause the pumps to shut off, it is highly desirable to have an auxiliary power source for use during the emergency. At the very least, the aquarium should have access to an emergency air supply, so that tanks may be aerated even if the water flow is stopped. We use a portable gasoline-powered air compressor (usually used to power a pneumatic hammer) which may be plugged in to the regular air system.

BIBLIOGRAPHY

ADOLPH, EDWARD F.
1925 - Some Physiological Distinctions Between Freshwater and Marine Organisms - Biol. Bull., vol. XLVIII, no. 5. pp. 327 - 335.

ATZ, JAMES W.
1947a - New Tanks for Old - Animal Kingdom, 50 (3), pp. - 88.

1947b - Water is Much More Than H_2O - Animal Kingdom, 50 (4) pp. 114 - 119.

1947c - Ailing Angels and Other Problems - Animal Kingdom, 50 (5). pp. 158 - 163.

1948a - Catch 'Em Little, Grow 'Em Big! - Animal Kingdom, 51 (1). pp. 8 - 12.

1948b - Feeding the Fishes - Animal Kingdom, 51 (5). pp. 136 - 139.

1948c - Functions of a Laboratory in a Public Aquarium - Parks and Recreation, Sept., 1948. pp. 1 - 5.

1949 - The Balanced Aquarium Myth - The Aquarist, vol. XIV, Oct. 1949, pp. 159 - 160. Nov. 1949, pp. 179 - 182.

1950 - The Functions of Plants in Aquaria - Aquarium Journal, Feb. & Mar., 1950, 21 (2 and 3). pp. 40 - 43. pp. 56 - 60.

BAERENDS, G. P.
1957 - The Ethological Analysis of Fish Behavior - Part I of Chap. III of Brown, Physiology of Fishes, Vol. 2. pp. 229 - 269.

BLACK, VIRGINIA SAFFORD
1957 - Excretion & Osmoregulation - Chap. IV of Brown, Physiology of Fishes, Vol. 1. pp. 163 - 205.

BREDER, C. M. Jr., and T. H. HOWLEY
1957 - Miniature Circulating Systems for Small Laboratory Aquaria - Zoologica, vol. 42, part 1, May 20, 1957. pp 1 - 10.

BROWN, MARGARET E. (ed.)
1957a - The Physiology of Fishes - vol. 1; Metabolism. NY: Academic Press Inc., pp i-xiii, 1-447.

1957b - The Physiology of Fishes - vol. 2; Behavior. NY: Academic Press Inc., pp i - xi, 1 - 526.

CARPENTER, KATHLEEN E.
1927 - The Lethal Action of Soluble Metallic Salts on Fishes - British Journal of Experimental Biology, vol. IX. pp. 378 - 390.

CHADWICK, W. L., F. S. CLARK, and D. L. FOX
1950 - Thermal Control of Marine Fouling at Redondo Steam Station of the Southern California Edison Company - Trans. Amer. Soc. Mechanical Engineers, Feb. 1950. pp. 127 - 131.

COATES, CHRISTOPHER W.
1942 - Pisces in Leo - Animal Kingdom, Mar. - Apr. 45 (2). 47 - 50.

1946 - Pumps Are a Problem Too - Animal Kingdom, 49 (3). pp. 111 - 112. pp. 120.

1948 - Planning a Public Aquarium - Parks and Recreation, 31 (12). pp. 735 - 739.

COATES, CHRISTOPHER W. and JAMES W. ATZ
1949 - Lighting the Tank In a Public Aquarium - Parks and Recreation, 32 (8). pp. 480 - 485.

COLLIER, ALBERT W. and KENNETH T. MARVIN
1953 - Stabilization of the Phosphate Ratio of Sea Water by Freezing - Fishery Bulletin of the Fish and Wildlife Service, vol. 53, bulletin no. 79. pp. 1 - 9.

COPELAND, T. H.
1947 - Fish Distribution Units - Prog. Fish-Culturist, Oct. vol. 9, no. 4. pp. 193 - 202.

DEMPSTER, ROBERT P.
1954 - The Effect of Aurofac-Enriched Diet (Aureomycin & B12) Upon Young King Salmon - Calif. Fish and Game, vol. 40, no. 4. Oct. pp. 415 - 421.

DAVIS, H. S.
1953 - Culture and Diseases of Game Fishes - Berkeley: University of California Press. pp. i - x. pp. 1 - 332.

DOOCHIN, HERMAN and F. G. WALTON SMITH
1951 - Marine Boring and Fouling In Relation to Water Currents - Bull. Marine Science of the Gulf and Caribbean, vol. 1, no. 3. pp. 196 - 208.

DOUDOROFF, PETER
1957 - Water Quality Requirements of Fishes and Effects of Toxic Substances - Chap. IX of Brown, Physiology of Fishes, Vol. 2. pp. 403 - 429.

DOWNING, A. L., and G. A. TRUESDALE
1956 - Aeration in Aquaria - Zoologica, 41, part 4. Dec. 31, 1956. pp. 129 - 143.

ELLIS, M. M., B. A. WESTFALL, and MARION D. ELLIS
1948 - Determination of Water Quality - Fish and Wildlife Svc Research Rep. 9; pp. 1 - 122.

EMMENS, C. W.
1953 - Keeping and Breeding Aquarium Fishes - NY: Academic Press, Inc. pp. i - x. pp. 1 - 202.

FARRIS, DAVID A.
1956 - Diet-Induced Differences in the Weight-Length Relationship of Aquarium Fed Sardines (Sardinops caerulea) - Journal of the Fisheries Research Board of Canada, 13 (4) July. pp. 507 - 513.

FISH, FREDERIC F.
1939 - Simplified Methods for the Prolonged Treatment of Fish Diseases - Trans. American Fisheries Society, 57, Aug. 1927. pp. 120 - 142.

FISHER, ED. L.
1954 - Marine Tropicals. Sub-Marine Studios, Miami. pp 1 - 56.

FRY, F. E. J.
1957 - The Aquatic Respiration of Fish - Part I of Chap. I of Brown, Physiology of Fishes, vol. I. pp. 1 - 63.

GARNAUD, J.
1952 - Structure Nouvelle de l'Aquarium Moderne et Autres Ameliorations Techniques - Bulletin de l'Institut Océanographique, Monaco; no. 1011, Avril, 1952.

GORDON, MYRON
1950 - Fishes as Laboratory Animals - Chap. 14 in Farris, The Care and Breeding of Laboratory Animals, pp. 345 - 449. N.Y.: John Wiley and Sons, Inc.

HALVER, JOHN E.
1953 - Fish Disease and Nutrition - Paper read at American Fisheries Soc., Symposium, Milwaukee, Sept., 1953.

HARVEY, H. W.
1955 - The Chemistry and Fertility of Sea Waters - Cambridge: University Press. pp. i -viii. pp. 1 - 224.

HEDIGER, H.
1950 - Wild Animals in Captivity - London: Butterworth's Scientific Publications. pp. i - ix. pp. 1 - 207.

HERALD, EARL S., ROBERT P. DEMPSTER & HOWARD McCULLY
1954 - The Effect of AuroFac-Enriched Diet (Aureomycin & B12) Upon Young King Salmon - Calif. Fish and Game, 40 (4). Oct. 1954. pp. 415 - 421.

HUBBS, CARL L.
1930 - The High Toxicity of Nascent Oxygen - Physiological Zoology, 3 (4). pp. 441 - 460.

KNOWLES, F. G. W.
1953 - Freshwater and Salt Water Aquaria - London: George G. Harrap & Co. Ltd. pp. 1 - 174.

KROGH, AUGUST
1941 - The Comparative Physiology of Respiratory Mechanisms - Philadelphia: University of Pennsylvania Press. pp. i - vii. pp. 1 - 172.

MacGINITIE, G. E.
1947 - Sea Water Systems at Marine Laboratories - Science, Aug. 22, 1947. 106 (2724) pp. 171 - 173.

MacGINITIE, G. E.
1948 - Choice, Operation, and Care of Boats at Marine Laboratories - Turtox News, vol. 26 (5). May 1948.

MARSH, M. C. and F. P. GORHAM
1905 - The Gas Disease in Fish - Report of Bureau of Fisheries for 1904, pp. 343 - 376.

MELLEN, IDA
1927 - The Natural and Artificial Foods of Fishes - Trans, American Fisheries Society, 57, Aug. 1927. pp. 120 - 142.

NIGRELLI, ROSS F.
1940 - Mortality Statistics for Specimens in the New York Aquarium - Zoologica, 1939, 1940 25 (33). pp. 525 - 552.

1943 - Causes of Diseases and Death of Fishes in Captivity - Zoologica, 28 (22). pp. 203 - 216.

OPPENHEIMER, CARL H.
1953 - An Unusual Mortality of California Yellowtail (Seriola dorsalis) in a Marine Aquarium - Calif. Fish and Game, 39 (1). pp. 133 - 135.

PEARSE, A. S.
1950 - The Emigrations of Animals from the Sea - Dryden, N.Y.: The Sherwood Press. pp. i - xii. pp. 1 - 210.

PEDLEY, LIONEL
1956 - New Sea Water System Installed at Aquarium - Southwest Builder and Contractor, 128 (24). Dec. 14, 1956. pp. 50 - et. seq.

PLESSIS, Y.
1956 - Le Transport D'animaux Marins et Leur Adaptation en Aquarium - Bulletin du Museum National d' Histoire Naturelle, XXVIII, June 1956. pp. 433 - 434.

RUCKER, R. R. and HODGEBOOM, K.
1953 - Observations on Gas Bubble Disease of Fish - Progressive Fish-Culturist, Jan. 153. 15 (1). pp. 24 - 26.

SCHAPERCLAUS, PHIL. WILHELM
1954 - Fischkrankheiten - Berlin: Akademie-Verlag. pp. i - xii. pp. 1 - 708.

SCHUETT, J. F.
1934 - Studies in Mass Psychology: The Activity of Goldfish Under Different Conditions of Aggregation - Ecology, 15. pp. 258 - 262.

SHLAIFER, ARTHUR
1940 - Locomotor Activity of the Goldfish, Carassius auratus L., under Various Conditions of Homotypic and Heterotypic Grouping - Ecology, 21 (4). pp. 488 - 500.

SHAW, PAUL A.
1946 - Oxygen Consumption of Trout and Salmon - Calif. Fish and Game, Jan. 2, 1946. 32 (1). pp 3 - 12.

SMITH, F. G. WALTON
1946 - Effects of Water Currents Upon the Attachment and Growth of Barnacles - Biological Bulletin, 90. pp. 51 - 70. (Contribution no. 301 from Woods Hole Oceanographic Institution.)

STOYE, FREDERICK H.
1935 - Tropical Fishes for the Home - Carl Mertens, Pub. pp. 1 - 238 (plus plates).

SWINGLE, H. S. and M. C. Johnson
1935 - Water Sampler and Water Analysis Kit - Progressive Fish-Culturist, 15 (1). Jan. 1954. pp. 27 - 30.

TAYLOR, R. S., and MILTON C. JAMES
1928 - Treatment for Removal of Chlorine from City Water for Use in Aquaria - Appendix 7 to Rep. U. S. Comm. Fisheries. pp. 332 - 327.

TOWNSEND, CHARLES HASKINS
1928 - The Public Aquarium: Its Construction, Equipment, and Management - Department of Commerce, Bureau of Fisheries Document 1045, pp. 249 - 337.

VAN OOSTEN, JOHN
1957 - The Skin and Scales - Chap. V in Brown, Physiology of Fishes, Vol. II. pp. 207 - 244.

WILSON, DOUGLAS P.
1952 - The Aquarium and Sea Water Circulation System at the Plymouth Laboratory - Journal of the Marine Biological Association of the United Kingdom, May 1952. vol. xxxi pp. 193 - 212.

WOLF, LOUIS E.
1952 - Experiments with Antibiotics and Vitamin B12 in the Diets of Brown Trout Fingerlings - Progressive Fish-Culturist, 14 (4). Oct. 1952. pp. 148 - 153.

WOOD, E. M., P. J. GRIFFIN, and S. F. SNIESZKO
1954 - Synthetic Binding of Trout Diets - Progressive Fish - Culturist, 16 (1). Jan. 1954. pp. 19 - 24.

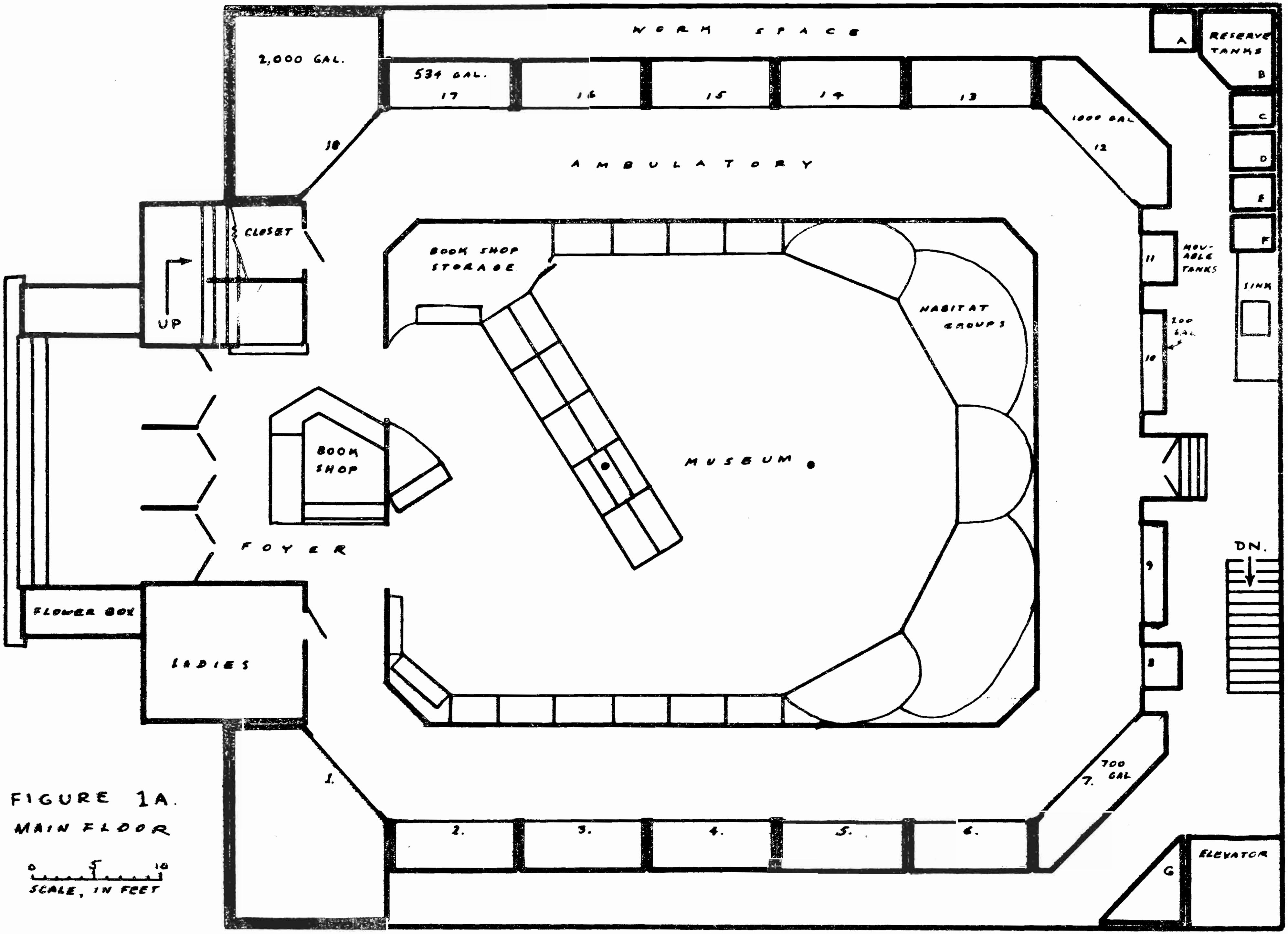


FIGURE 1A.
MAIN FLOOR

0 5 10
SCALE, IN FEET

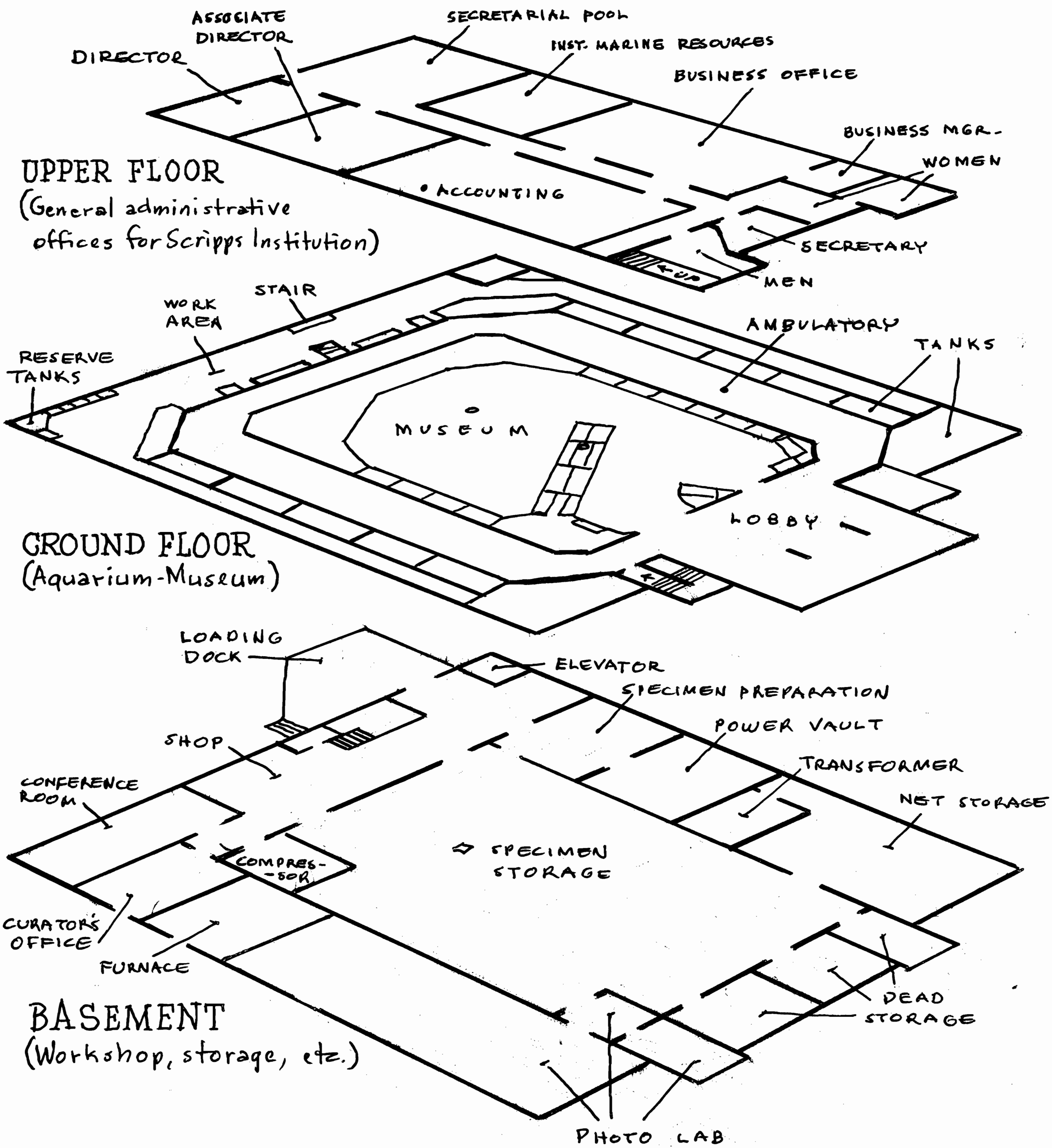
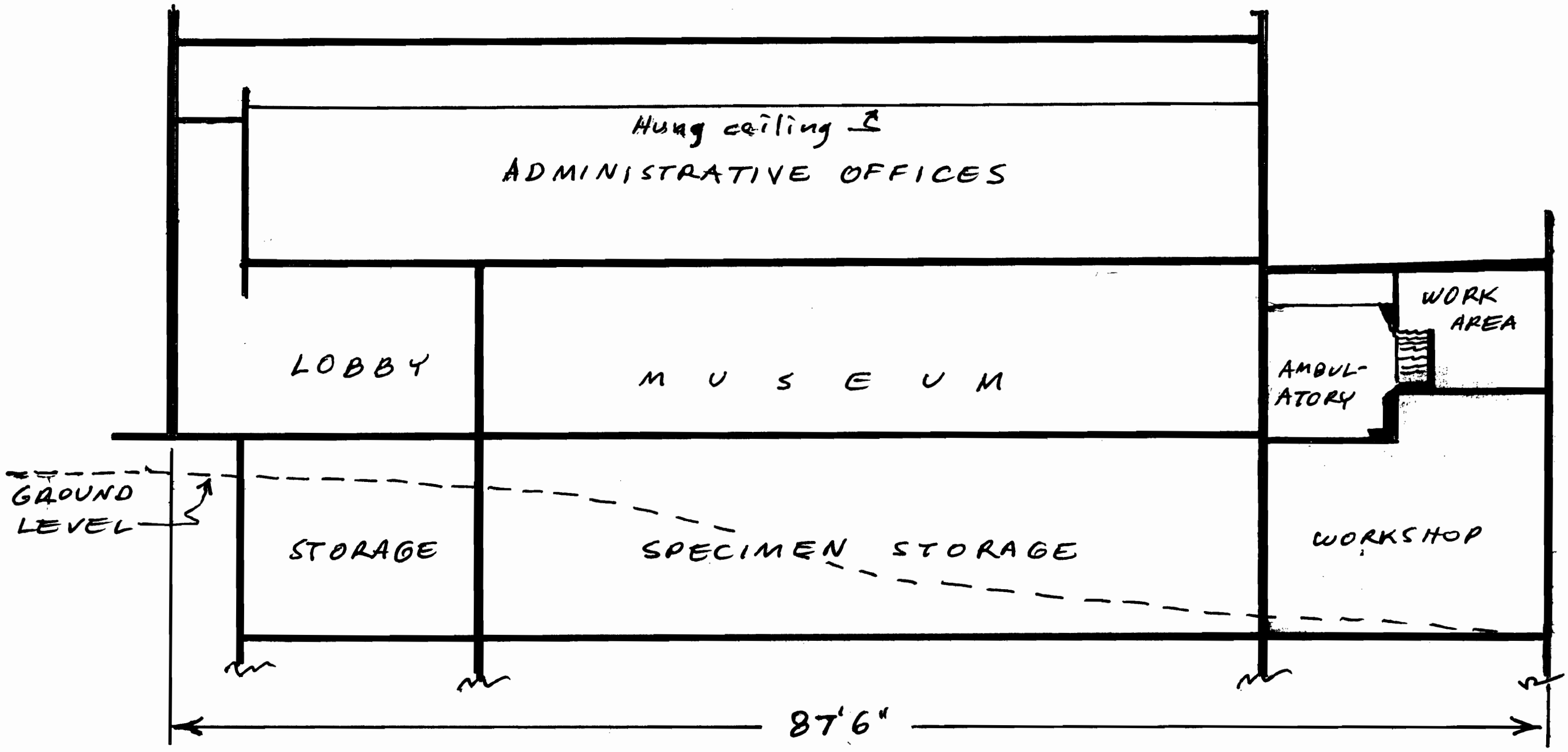


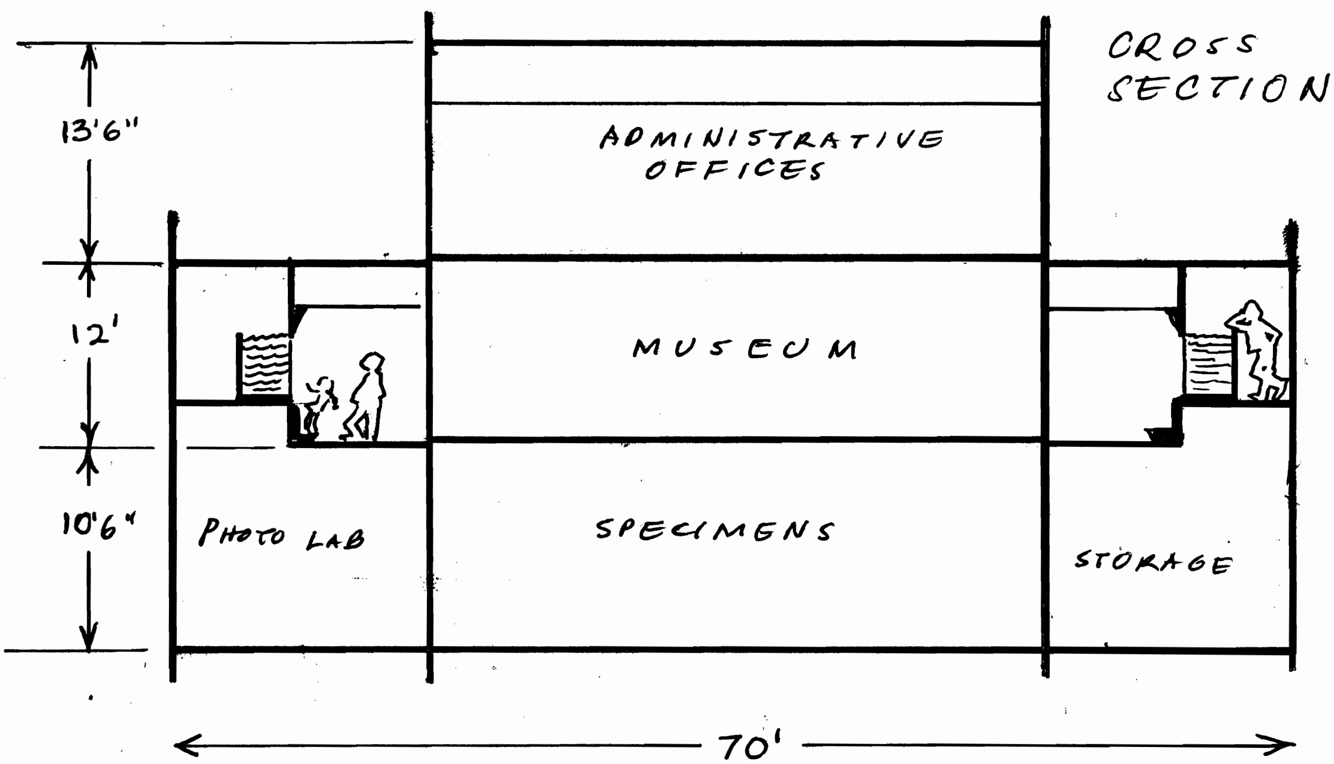
FIGURE 1

The T. WAYLAND VAUGHAN AQUARIUM-MUSEUM
70'×90'

LONGITUDINAL SECTION



CROSS SECTION

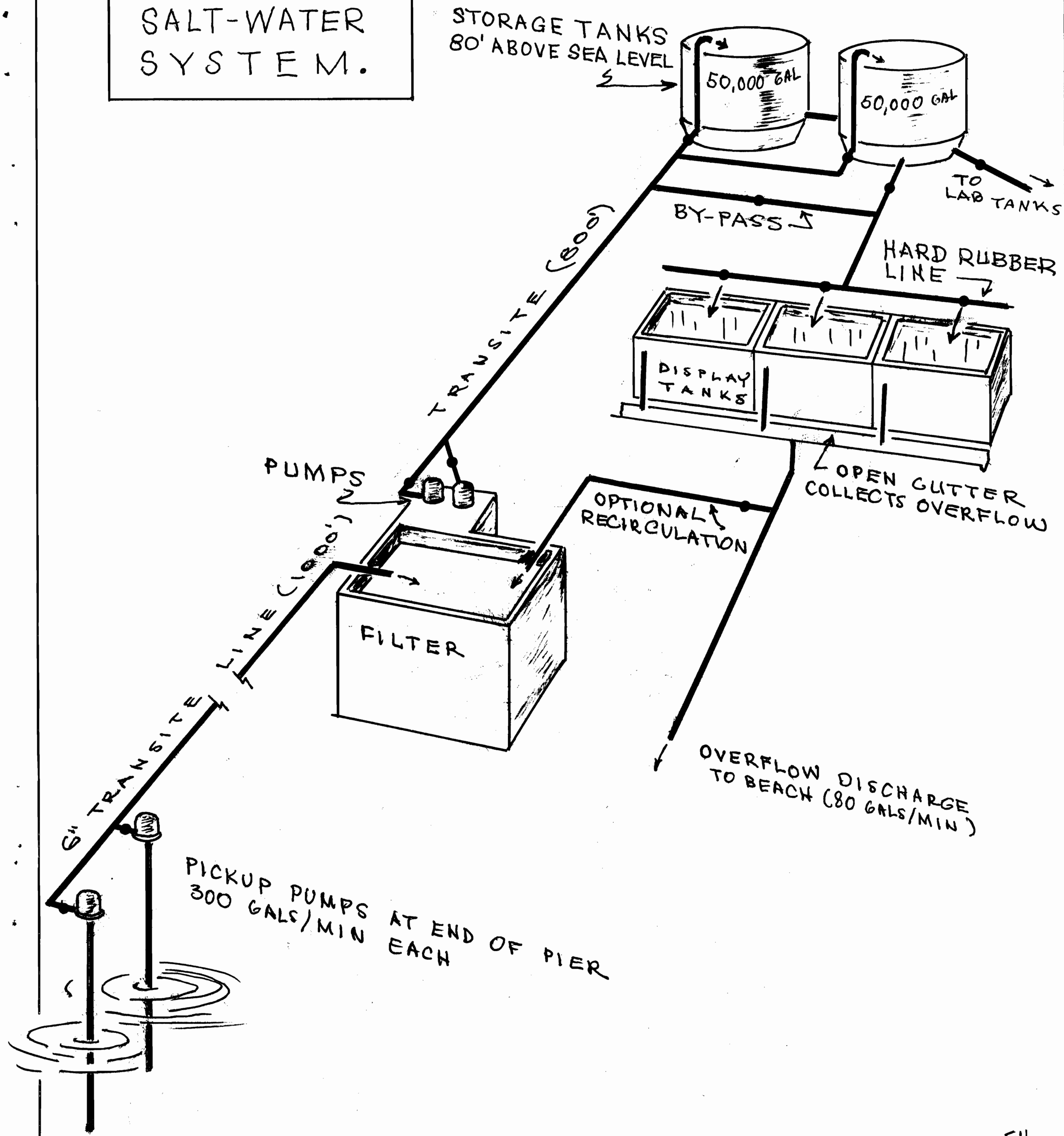


Scale = 1/12" = 1 FOOT

PLATE 1B
SECTIONS

FIGURE 2

DIAGRAM OF SALT-WATER SYSTEM.



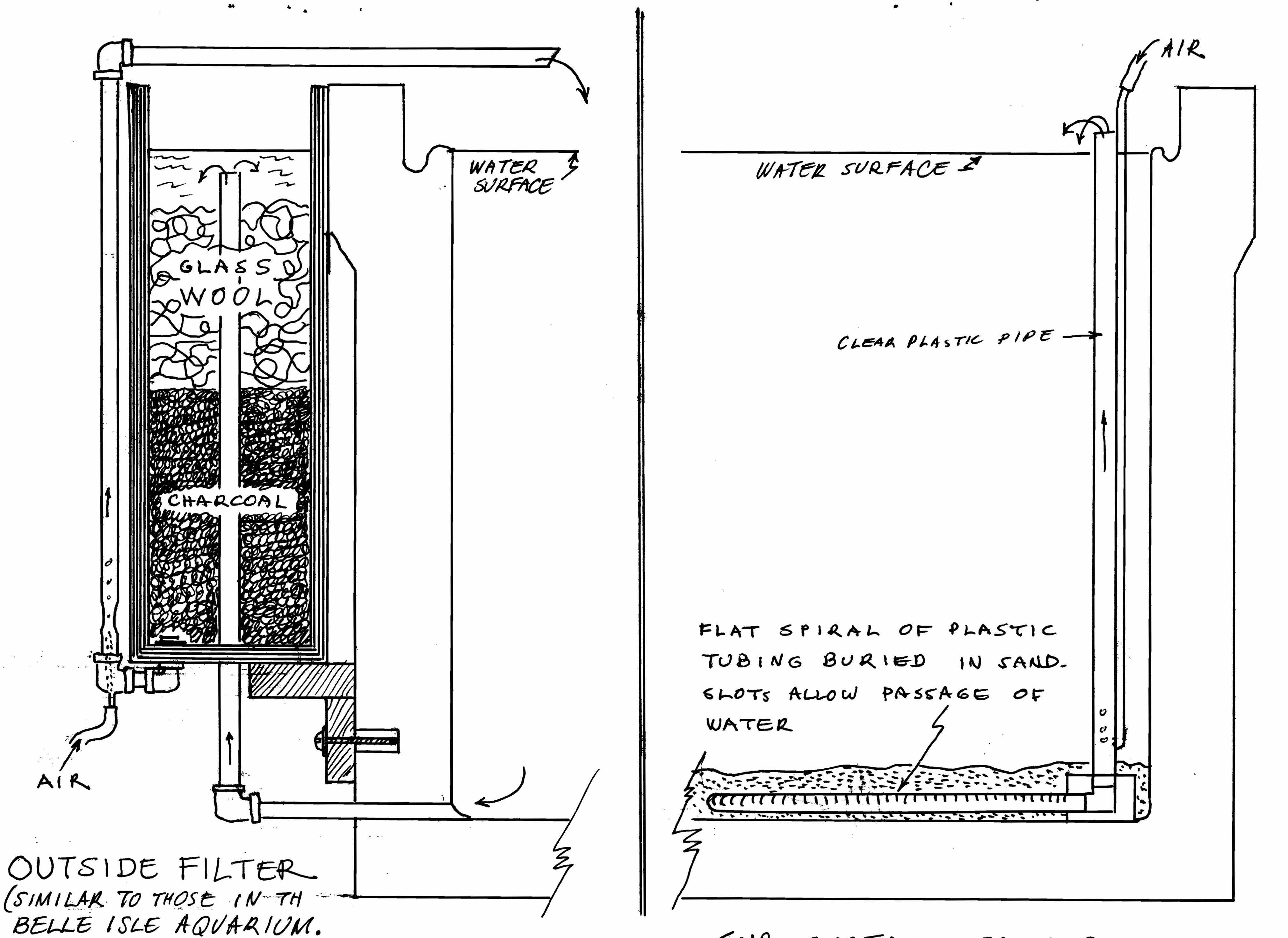


FIG. 3 - SIMPLE RECIRCULATING TANKS.

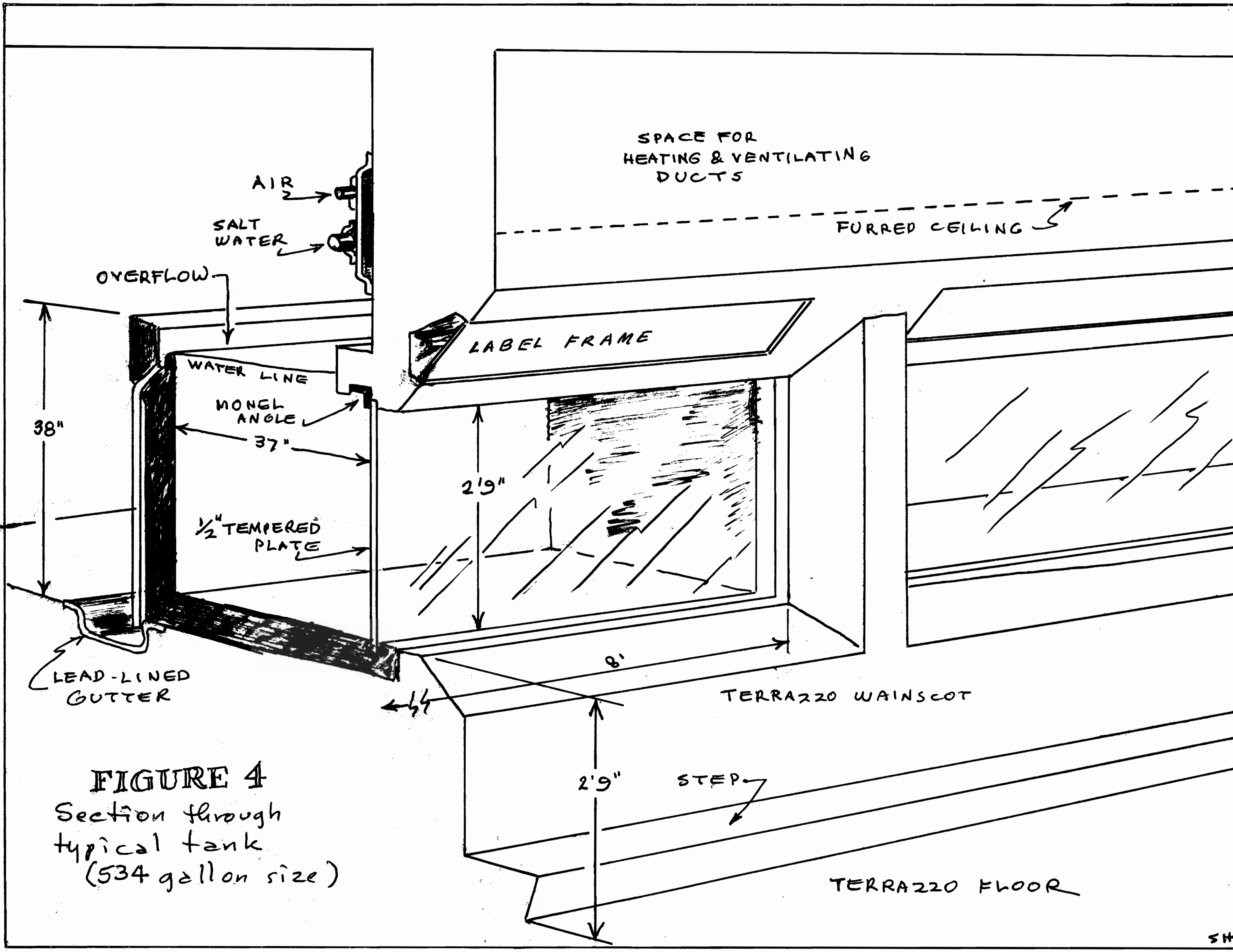


FIGURE 4
Section through
typical tank
(534 gallon size)

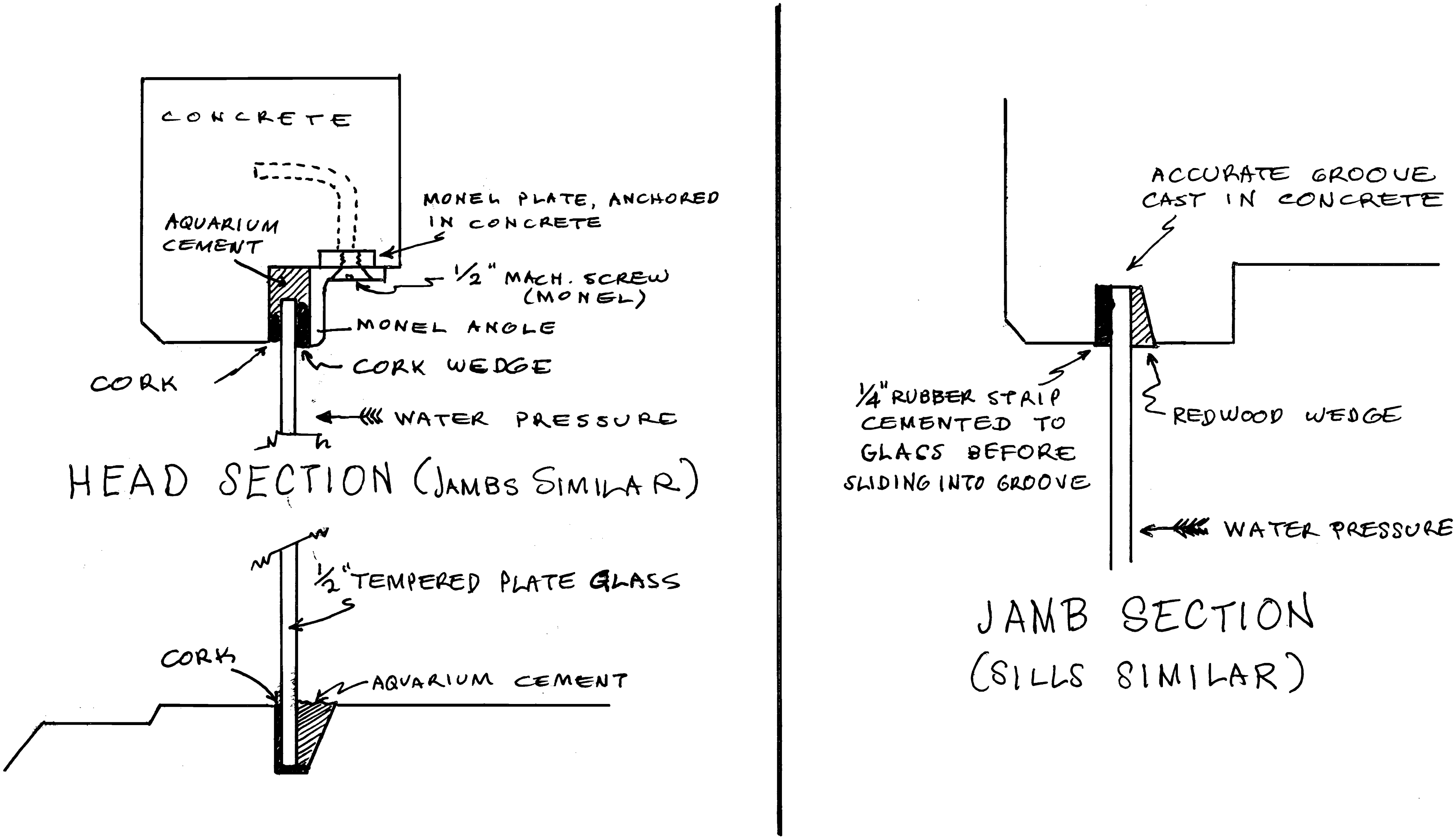


FIGURE 5

ALTERNATIVE METHODS OF MOUNTING GLASS