AN OPEN AIR SWIMMING POOL

USING SEA WATER

Thesis

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THE LONG BEACH SWIMMING POOL

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ABSTRACT

This thesis is presented in two parts: the first consists of a general description of different features and characteristics of swimming pools with emphasis on the sanitary aspects of pool water and the hydraulic design; the second part involves the actual design and construction of a swimming pool at the Long Beach Club in Beirut.

The Long Beach Club swimming pool, an important feature of which is, the utilization of sea water, was designed and constructed with the help of the author in 1963. The design criteria and drawings in addition to other pertinent information is presented in the text.

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INTRODUCTION

Swimming has now become an exceedingly popular and useful sport because of its recreational and health values.

In places lacking favourable weather conditions that permit swimming in natural bodies of water, swimming pools have made it possible for any person to indulge in this type of sport at any time, day or night, regardless of season and climate.

Even though Lebanon borders the sea and enjoys plenty of sunshine, an appreciable number of swimming pools have been recently constructed. The reasons for this trend are:

- Limitations imposed by the sea shore structure at certain localities - rock formation and deep shore water.
- Frequent roughness of sea, particularly at beaches exposed to currents.
- Unsanitary beach conditions resulting from improper waste disposal.
- Attraction of tourists by providing swimming facilities at all seasons.

- High standard of living, increasing wealth and desire for luxury.

Typical examples of swimming pools constructed along the Lebanese beaches are those of Tabarja, Long Beach Club, Coral Beach Hotel and Beach Club.

The Long Beach Club has two existing swimming pools constructed several years ago. These have proved to be inadequate as users have increased and the demand for a large properly designed pool was found necessary. Therefore, the management of Long Beach Club agreed with ARKBUILD Consulting Engineers to design and construct an Olympic size swimming pool that utilizes sea water.

The author was involved in the design and construction of this project which constitutes the subject of this thesis. Details of the criteria for the design and construction are reported in the text. As a background general information relating to swimming pools is also presented.

I- TYPES AND CHARACTERISTICS OF SWIMMING POOLS

Swimming pools may be of different types and have different characteristics. They may be constructed for public or private use. They may be built either indoor or outdoor in several geometric shapes to fit a lot or to suit a landscape; while they may utilize sea or sweet water depending on the intended usage and the type of water available. The following discussion briefly outlines the different features of swimming pools.

A. Indoor and Outdoor Swimming Pools

Indoor or outdoor swimming pools have several common design features, but differ widely in some respects.

Depending on the climate, three to five months a year is the usual period for the swimming season in many areas. The rains and cold winds of fall and spring make outdoor swimming uncomfortable, even if the water is heated, and winter swimming is usually impossible. In areas with short summers, an indoor pool would extend the summer's recreational season. The advantages of enclosed pools include lengthening the period of use to all year, providing shelter from winds, making night swimming feasible, reducing heating costs, protection from insects and debris, and privision of a climate control for the pool area. However, there are disadvantages for indoor pools. Enclosing the pool encourages moisture condensation and develops a "green house" atmosphere. Therefore, a completely enclosed swimming place can become quite steamy and uncomfortable when the temperature outside begins to drop. Another problem is cooling the swimming pool area; shelters are easily heated with a pool heater or small furnaces and fireplaces, but they are difficult to cool because of lack of circulation. The most important factor lacking in enclosed swimming pools is sunshine which is a desirable adjunct to swimming.

Indoor swimming pools should be sited as centrally as possible in a city or town, should be easily accessible, and provided with ample parking space.

Indoor pools, as indicated later, should be of rectangular shape with deep water at, or near, one end and shallow water at the other. Small outdoor pools should be of the same general design.

Outdoor pools are best suited to places where favourable weather lasts through a long period of the year. The selected site should be as far removed from industrial areas as the geographical position of the town will allow. Public parks or recreational grounds offer beautiful landscaping around pool vicinity that adds to enjoyment and pleasure of swimming. Sites are to be carefully selected so as to afford a degree of protection from prevailing winds, and provide a relaxing and healthy atmosphere.

B. Public and Standard Swimming Pools

The best shape for large outdoor swimming pools depends largely on the size and on local conditions. General public or semi-public pools, both indoor and outdoor, are rectangular in shape because of the convenience of excavation, construction and efficiency in use. In addition, such a shape offers the largest swimming space and capacity in terms of the number of users at any given time, given that there must be separate zones for diving, swimming and general play.

The dimensions of rectangular public pools are usually standard. The length should not be less than 18.0m and the width should ordinarily be some multiple of

1.5, 1.8, or 2.1 metres[1,2]. For strictly competitive pools the Amateur Swimming Association[3] recommends a length of 50m with a lane of 2.1m wide for each competitor. The depth of water at the shallow end of a pool is usually about 0.75 metre. The bottom should slope gradually toward the deep end, where the depth of water varies with the size of pool and height of diving boards - usually not less than 1.8 metres.

The general purpose pool, intended to provide diving facilities, should have a depth of water in the diving area governed by the requirements of the Amateur Swimming Association[4], which are:

a) The spring boards shall be one metre and three metres above water level, at least 4.5m long and 50cm wide, and covered along the whole length with rough coconut matting. They shall be installed at an angle of not more than one degree from the horizontal, rising from back to front. The front of each board shall project at least 1.5m beyond the edge of the pool.

b) The platform shall be five and 10m above water level, and the provision of an intermediate board of 7.5m is strongly recommended. They must be rigid, at least two metres wide and covered with coconut matting. The 10m platform shall be not less than six metres in length and the five and 7.5m platforms not less than five metres in length. The front of the 10m platform must project at least 1.5m beyond the edge of the pool and 75cm beyond the platform immediately underneath, which must project at least 1.5m beyond the edge of the pool. The back and sides must be surrounded by a handrail, and each level must be accessible by suitable staris (not ladders) to avoid possible hazards.

The minimum depth of water over an area measured from a vertical line dropped from the centre of the front end of the Board shall be:

	1m	3m	5m	10m
Depth of water	3m	3.5m	3.8m	4.5m
Distance in front	5.3m	6.2m	7.0m	10.5m
Distance behind	Nil	Nil	Nil	Nil
Distance on each side	2.2m	2.7m	3.0m	3.0m

The angle at which the bottom of the pool may be constructed to reduce the depth outside the minimum area shall in no case exceed 45 degrees from the horizontal.

C. Private and Irregular Swimming Pools

Private swimming pools are often irregular, designed to be best suited, functionally and architecturally, to the plot and its surrounding.

The following are the most popular irregular shape swimming pools[1]:

L-Shape : Fits easily into corners with diving and shallow areas clearly separated by the natural break.

Teardrop : Fits well in most places. A similar shape is the oval, with both ends equal in size and shape.

Kidney : Fits well with most landscaping, and is the most popular shape. Curves can be modified to fit site needs.

Circle : Usually used as a shallow wading pool, but can be deep enough for diving.

Good for small areas and requires little space.

Free Form: Best for landscaping, crowded areas and irregular space. The shape is actually dictated by the topography of the available plot.

The Kidney shaped pool is the most widely used type and, in addition to its pleasant appearance, its curves and landscaping create an illusion of greater space.

D. Usage of Fresh or Sea Water

Fresh water pools, required for competitive swimming, are designed to recirculate and treat the water for economy. Pools utilizing sea water are based on a flow-through system and, compared to fresh water pools, require less attendance in respect of the purification process, especially if the inlet location and pool orientation are carefully studied in relation to shore currents and prevailing winds.

Sometimes fresh water is prefered for use in swimming pools constructed along the coastlines, due to high contamination and turbidity of sea water near the pool site. Moreover, fresh water being less complex in composition and less corrosive is easier to handle and treat.

Swimming pools that utilize either fresh or sea water are equally subjected to contamination from bathers; if the water is not well treated and purified it could be hazardous to swimmers. Therefore, the increasing popularity of swimming warrants the imposition of regulations to maintain adequate public health standards.

II- DESIGN CRITERIA

A. Public Health Standards

In developing standards of design for swimming pools the engineer must bear in mind:

a) The protection of the bathers against

   i) infection transmitted through pool water.

   ii) infection transmitted outside of pool.

   iii) physical injury within and outside of the pool.

b) The maintenance of the pool, its waters and of the pool surroundings in a clean, comfortable and attractive condition.

c) The protection of the pool water itself as well as the supply from which it is drawn against backflow from the drainage system of the pool and that into which it empties.

Public health standards for swimming pool water can be classified into bacterial, chemical and physical qualities.

1- Bacteriological Quality

Water, especially when polluted, is a favourable medium for bacteria to flourish and multiply. Some bacteria in polluted swimming pool water may transmit diseases to bathers[5]. Deseases that have been associated with bathing are of the intestinal type such as typhoid and paratyphoid fevers, dysentery and gastrointestinal upsets; eye, ear, nose and throat infections, including respiratory diseases; skin diseases, such as ring-worm and swimmer's itch.

To determine a bacteriological safety of the water the coliform test has to be performed. The American Public Health Association recommends that

> "not more than 15% of the samples covering any considerable period of time, when incubated for 24 hours at 37°C on standard nutrient agar, shall not contain more than 200 bacteria per ml, nor shall show a positive confirmed test in any of five 10 ml portions of water at times when the pool is in use"[3,5,6].

Table I below shows the relative classification on natural bathing water by the American Public Health Association[3,5].

Table I - Relative Classification of Natural Bathing Water

Relative Classification	A	B	C	D
Indicated No. of Coliforms per 100 ml	<50	51-500	501-1000	1000 >
Quality designation	Good	Doubtful	Poor	V.Poor

2- <u>Chemical and Physical Qualities</u>

To have a chemically safe and attractive pool, the water must be clear of dirt, algae, mineral deposits and foreign matter. Also, many of the troubles that arise with the pool's interior finish, equipment, and accessories are due to improper water treatment. A system of cleaning and purifying the water can be easily set up that will prevent any of the serious problems from developing under normal conditions, and if an unexpected problem arises, adequate treatment beforehand will make its solution much easier and less expensive.

Under normal conditions, there are two phases to water control. First is the maintenace of the water at a moderately alkaline level; and secondly is the introduction of a sterilizing agent.

For the correct application of chemicals and elimination of other problems, the pH of pool water should be maintained at between 7.2 and 7.6[7,8]. Below 7.2, the acid condition will corrode pipes, attack the pool's interior surface and irritate the eyes and mucous membranes of swimmers. On the other hand, an excessively alkaline water particularly at a pH of 8.4 and above causes the precipitation of calcium carbonate on the walls and heater tubes upon the addition of chlorine. Moreover, such water has an objectionable odour.

The pool water must be sterilized to control bacterial growth and to check the development of algae.

Chlorine is the most popular disinfecting agent, and it can be applied in one of the following forms:

a) Chlorine Gas. This is used for large public pools. It needs careful handling; is expensive and requires an authomatic chlorinator for application.

b) Sodium Hypochlorite. This is marketed as a liquid with a chlorine content of up to 16%. It can be applied simply by hand without the use of a mechanical feeder. Its quick deterioration upon storage, hence loss of its disinfecting power, limits its use.

c) Calcium Hypochlorite. This is marketed as powder, granules or tablets with a 70% available chlorine content. It is more expensive than the liquid form but much more stable on storage. This last quality makes it popular and hence widely used.

The effectiveness of chlorine treatment is based on the amount of free-residual chlorine. A range of 0.3 to 0.6 mg/l[3,5] of free-residual chlorine is considered ample; below this range, the water may have the ability to support the growth of bacteria and algae. In water with high alkalinity and a pH range of 8.0-8.9, one mg/l or above of free-residual chlorine is usually used. Factors that affect chlorine residuals are low pH, sunlight, number of bathers and the presence of debris.

Split chlorination is a method of chlorine application recently applied to swimming pools with recirculation and flow-through systems. It is now widely used particularly in large open air swimming pools where a heavy dose of chlorine is necessary to be injected into the incoming fresh water. The advantage of this method lies in the light application of chlorine in the incoming fresh water at the deep zone, and to "top up" with more chlorine at the beginning of the shallow zone. This is because the shallow zone supports the greatest number of bathers and is likely to be more contaminated than the deep zone which supports fewer bathers at any one time. Splitting of the chlorine dosage ensures comfort to swimmers by avoiding the irritation of their eyes and other mucous membrane; and also eliminating any objectionable smell due to heavy chlorine application.

It is important to keep in mind that the treatment of sea and fresh waters with respect to chlorination is exactly the same.

Algae exist in water in the form of free floating type or the attached type. Their survival and growth requires proper temperature and sunlight.

Open air pools are subject to algae growth and their problems to a greater extent than in the case of indoor pools. There is no way to keep algae out of a pool, but there are methods of checking their growth and spread. Both sea and fresh water can support algae growth, but the species will be different in each case.

Regular chlorine dosages to maintain a residual of at least 0.3 mg/l and correct maintenance of pH normally is all that is required to prevent the spread of algae[7,8]. After repeated exposures to a low dosage of chlorine, some algae may develop a resistence to chlorine. To counteract this superchlorination is used, where the pool is shocked every ten days during hot weather and non-swimming hours, and once every two or three weeks in the off season. The dosage should be four to five times the normal amount of one day, which breaks down any resistence the algae may have developed. In some cases the use of copper sulphate to supplement the use of chlorine proves effective in destroying certain types of algae. Continuous or occasional dosages from 0.12 mg/l up to a maximum of five mg/l of copper sulphate should be effective in destroying most kinds of algae[7,8].

Turbidity of swimming pool water can be attributed to faulty equipment, improper treatment, operation and overcrowding of the pool. The American Public Health Association[3] recommends that

> "at all times when pool is in use the water shall be sufficiently clear to permit a black disc of six inches (15 cm) in diameter on a white field, when placed on the bottom of the pool at the deepest point, to be clearly visible from the sidewalks of the pool at all distances up to 10 yards (9.15m) measured from a line drawn across the pool through the said disc".

In artificially heated swimming pools the water temperature should not be above 78°F (25.5°C). The air temperature must not be permitted to become more than 8°F (4.4°C) warmer nor than 2°F (1.1°C) colder than the water in the pool at any time when the pool is in use. For best results it is desirable that air temperature shall be about $5^{o}F$ ($2.8^{o}C$) warmer than pool temperature[9,3,5].

3- Bathing Load Limits

The maximum permissible bathing load in any swimming pool depends largely on its surface area, provided that its water is continuously changing. In this respect the swimming pool is divided into three zones with the number of swimmers attributed to each[3,1].

a) Diving Zone. A maximum of 12 persons are permitted in the area within 3 metres radius of each diving board or platform.

b) Swimming Zone. This zone is that part of the pool other than the area required for diving, and which is deeper than 1.5m. One person for each $2.5m^2$ of pool area is sufficient for swimming.

c) Non-swimming Zone. One square metre is required for each person in that part of the pool less than 1.5m deep.

For flow-through pools, bathing loads are formulated as follows[3,1]:

$$P_f = \frac{0.6\ C\ R}{T^3\ B} \qquad (1)$$

$$p_f = \frac{0.6\ C\ B}{T^3} \qquad (2)$$

$$Q = 24.75\ T^2 \qquad (3)$$

Where

- P_f is the maximum number of bathers per hour
- p_f is the maximum number of bathers that may be admitted to the pool during the hours that it is in use
- B is the number of hours in a day during which the pool is in use
- C is the pool capacity in litres
- R is the number of hours in a day during which pool water is added to the pool
- T is the turnover period in hours
- Q is the quantity of water required per bather in litres

B. Hydraulic Design Requirements

Compliance with public health requirements for water quality would provide safe water free from harmful bacteria, foreign matter, colour and odour. To provide and maintain water with such qualities the hydraulic design requirements have to be fulfilled as indicated below.

1- Inlets

The position of inlets in swimming pools is an important factor in minimizing stagnation areas, especially in the deeper section of the pool. Inlets are usually designed as orifices subject to adjustment, or provided with individual gate valves, and are so arranged as to offer the best circulation of water.

In swimming pools with a recirculation system the inlets are provided either on opposite sides or completely around the pool. On the other hand, in swimming pools using the flow-through method inlets are provided only at the deeper section of the pool, and may be installed at different depths.

In rectangular shaped pools the following number of inlets are recommended[9,10]:

Four inlets for pools not exceeding 10m in length.

Six inlets for pools from 10m to 14m long.

Eight pools should have inlets spaced not more than six metres on centres.

The inlet piping should be of such size as to provide a velocity in the neighbourhood of three metres per second, and it should discharge at a depth of 25 to 40 cms below pool overflow level. Moreover, inlets should not be placed further than 1.5m from every corner of the pool.

2- Outlets and Floor Drains

The position of outlets is as important as those of inlets. The dirty water should find its way out through the shortest possible path. For the circulating type of pools, outlets are usually placed at the deepest point. On the other hand, in pools of the flow-through method, multiple outlets are installed at the bottom of the shallow side because most bathers are to be found in this area, which makes the water dirtier than that in any other part of the pool.

Small pools with a recirculating system use the main floor drain opening as the outlet, but larger pools use multiple outlets at the deepest point spaced not more than six metres apart, nor more than three metres from the side walls. These outlets should be protected by a grating with openings to a total area of at least four times that of the main drain pipe. With this, excessive friction loss and suction currents at the outlet are prevented. The outlet piping should be of such size as to drain the pool in not more than five hours.

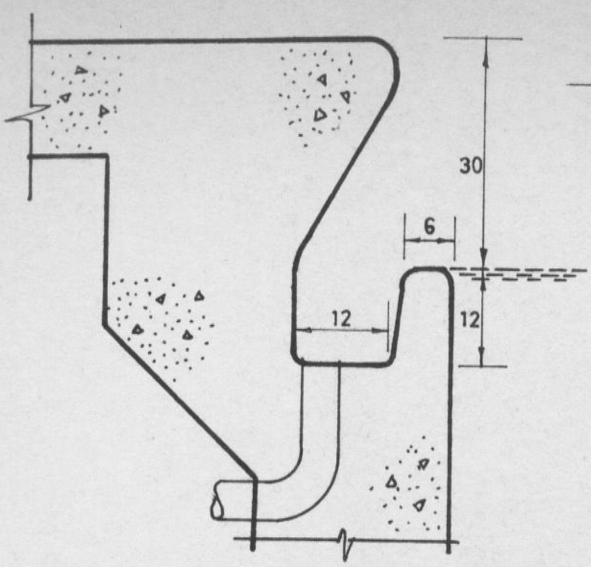
3- <u>Scum Removing Devices</u>

a) Scum gutters are usually located around the pool, and may sometimes be constructed only along their length. Their function is to remove the scum and floating material from the water by means of multiple outlets from which water flows either to a proper disposal area or back to the recirculating system.

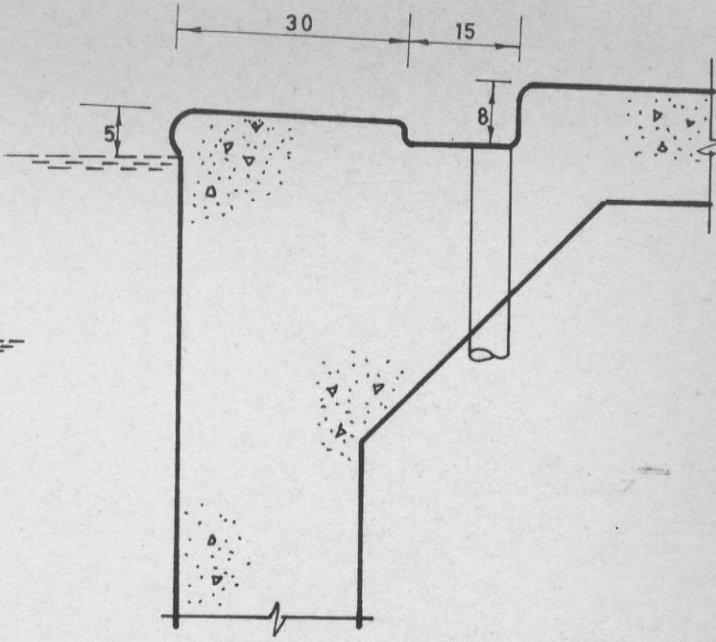
Pool water level should be maintained slightly below the gutters during the period of pool use, as wave action caused by bathers is sufficient to cause overflow. During daily pool cleaning the water should be allowed to flood the gutters so as to flush the debris.

Scum gutters can be either of the open, roll-over or semi-recessed type[3,1] as shown in Fig. 1(a), and should be easily accessible for cleaning and non-hazardous to swimmers. They should have a minimum depth of about 8cms with a 2% slope to gutter drains (2 inches in diameter) spaced at about three metres on centres[3].

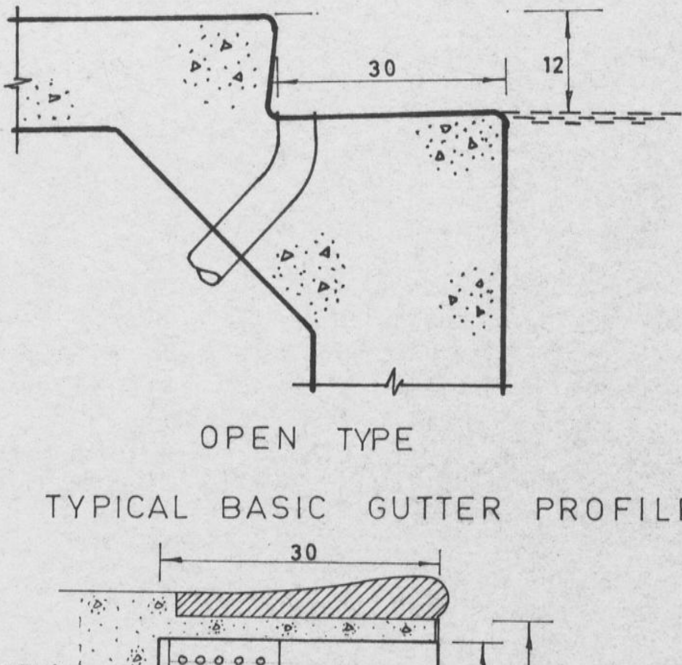
b) Surface skimmers are another alternative to scum gutters and where-ever used approved handholds are installed. Each skimming device is provided for at most $50m^2$ of pool surface area[11]. They are built into the pool wall as shown in Fig. 1(b), and in such position as to minimize interference with one another to ensure proper skimming of the entire pool surface.



SEMI - RECESSED TYPE



ROLL - OVER TYPE



OPEN TYPE

FIG 1(a) TYPICAL BASIC GUTTER PROFILES

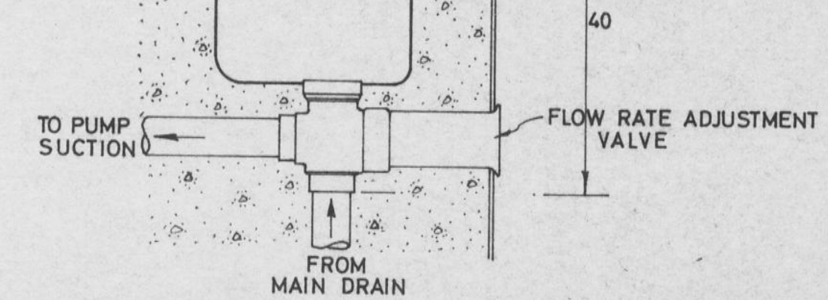


FIG 1(b) TYPICAL SECTION THROUGH SURFACE SKIMMER

Surface skimmers must meet the following specifications and the National Sanitation Foundation Standard[11]:

i) Skimmers should be provided with flow-rate adjustment valves to balance the system.

ii) Piping should be designed for a total capacity of not less than 80% of the required filter flow with a minimum flow-through rate of 115 litres per minute.

iii) Skimmer weir should be automatically adjustable with a variation in water level through a range of not less than 10 cms.

iv) Skimmer should contain an easily removable and cleanable basket or screen which serves as a trap for large particles or objects suspended in the overflow water.

v) An equalizer line is usually used in case the pool water level drops below the weir level. The function of this line is to protect the pump by preventing air-lock in the pump suction side. It is designed to meet the capacity requirements of the filter and pump, and it should be not less than two inches in diameter and providing a minimum quantity of 115 litres per minute. Its location should be at least 30 cms below the lowest overflow level of the skimmer and be provided with a valve which is to be closed during normal conditions but automatically opens when the pool water level drops below the weir level.

4- Walk Areas

Walk areas should be self draining away from the pool with a 2% slope to an adequate drain at which the water will flow freely to approved points of disposal. They should have a width of at least 1.2m and preferably 2.5m extending all around the pool. Walk areas should be of concrete, ceramic tile or other similar material, where the surface is sufficiently roughened to prevent slipping of bathers.

5- Pumps

Motor driven self priming centrifugal pumps are best suited for swimming pools. The motor should be capable of running continuously without over-heating and should be designed for long service in moist atmosphere. If electricity is not available gas or diesel engines or turbine can be used to run the pumps.

In selecting the pump the following factors should be considered: (a) initial and future operating efficiencies, and (b) initial cost.

Operating efficiencies should be the deciding factor since the higher priced, but more efficient, pump will usually prove to be the most economical.

The capacity of the pump is determined by the turnover period and the total available head.
For the recirculating system a total head of about 15m is assumed. Where three or more filter units are used the recirculation pump should deliver about 600 litres per minute per square metre of the filter area.

6- Piping

Water piping should be[3]: (a) properly designed so as to keep frictional losses to a minimum, which maintains the pumping cost at a reasonable figure - a velocity of about 2.5m per second is usually recommended; (b) easily accessible for rapid cleaning, inspection and repairs - this can be accomplished by providing unions wherever necessary; and (c) coloured for easy identification and differentiation.

Piping used for swimming pools can be of different materials depending on the availability, function and cost. For pressure lines cast iron, steel and asbestos-cement are the most popular. For simple drainage asbestos-cement, concrete and clay pipes are widely used. Wherever possible concrete channels should replace the drainage pipes as they are cheaper and easily accessible for cleaning.

7- Fresh Water Make-up Tank

This is used in connection with the recirculation system. The flow line in the tank has the same level as the water surface in the pool. Usually the outlet piping from the pool is connected to the tank from which the recirculating pump takes its function. It is recommended that the fresh water inlet pipe be at least two pipe diameters above the maximum water elevation in the pool. Make-up water can then be controlled by means of a float valve.

8- <u>Filters</u>

Filters may be of the pressure, gravity or vacuum type, and may employ sand or diatomaceous earth as the filtering media.

a) Sand Fillers. These can be either of the pressure or gravity types, both having the following specifications and requirements[10].

The filtration rate should be three gallons per minute per square foot of filter area.

A backwash rate of 15 gallons per minute per square foot of filter area should be adequate.

Air release valves are only required on pressure filters.

Chemical feeders are recommended to be on the suction side of the pump ahead of the sand filters.

A recent development on the pressure sand filters is the high rate ones where a filtration rate up to 20 gpm per square foot of filter area is used. These types of filters have several mechanical and media improvements, over the conventional ones.

b) Diatomite Filters. These can be either of the pressure or vacuum type with the following filtration rates[10] applied to both: (a) without slurry feed, two gallons per minute per square foot of filter area; and (b) with slurry feed, 2.5 gallons per minute per square foot of filter area.

It is recommended that slurry feed be used as it prolongs the length of filter runs.

c) Gauges. These are used on all types of filters to show the loss of head in the filter and to determine the need for backwashing. Gauges are usually installed on inlet and outlet piping.

III- TREATMENT AND PURIFICATION

A. Fill and Draw System

This system involves emptying and refilling the pool with fresh water periodically. The time lapse between two successive operations depends largely on the pool size and the number and the cleanliness of bathers. The pool fresh water which is drawn from the city water supply or any other approved source will remain in the pool until the cumulative pollution reaches a degree that requires the discharge of all the water to the sewers. Usually one or two days after refilling and usage of the pool the sanitary quality of the water will be doubtful.

The disadvantages of this system include:

1- Cost of Water

Due to the rapid frequency in changing completely pool water, the cost of such water creates an economic problem in pool operation, particularly in places where water is scarce.

2- Frequency of Shut-down

Pool draining, cleaning and refilling is a time consuming process, and necessitates frequent shut-down of pool thus ultimately increasing the operational costs.

3- <u>pH Control</u>

Constant addition of disinfectant to the water stagnating in the pool will make pH control difficult. This becomes prominent when the pool water pollution accumulates as the number of bathers increases and then large dosages of the disinfectant will be necessary. Most chlorine compounds are acidic in water and their continuous addition will lower the pH value, which consequently causes irritation of the eyes and other mucous membranes of bathers as well as attacking interior surfaces of the pool.

Briefly, the fill and draw system imposes a complete change of pool water instead of its treatment and purification, which will result in costly operation and maintenance. This fact rendered such a system unpopular and has become almost obsolete. The recirculation and the flow-through system, a more economical and efficient processes, is now used all over the world.

B. Recirculation System

This system is based on the recirculation of pool water through units for the purpose of purification and reuse. Where the water supplies are scarce and costly the recirculation system is economical in the long run. It is composed mainly of the following parts:

1- Hair Catcher

This device is a strainer installed ahead of the circulating pump to prevent foreign matter such as hair and lint in the circulating water to reach the pump and filter. Such materials clogg the pump and are rather difficult to wash from the filter medium.

The strainer, made of a non-corrosive material, is cylindrical in shape, and is easily removable from the casing.

The openings are not more than 3mm (1/8 inch) in size with a total area of opening at least ten times the area of the water inlets, or four times the area of the pump suction line[3]. The strainer should be cleaned as frequently as is necessary since its clogging will affect the pump efficiency.

2- Circulating Pumps

All pools should have a specified turn-over period which is directly related and proportional to the bathing load. It is defined as the number of hours needed for completely changing pool water. For public or semi-public pools this period should not exceed eight hours, while for private pools it should range from 12 to 24 hours[1,2]. The choice of the proper turn-over period directly determines the capacity of the pump. Then, knowing the available head (both static and dynamic), the pump can be easily selected from the manufacturer's charts. Under normal conditions the pump should ensure a recirculation rate of flow at a dynamic head of at least 15 metres (50 feet) for pressure sand filters or 18 metres (60 feet) for pressure diatomaceous earth filters[10]. In case less than three filters are used, a separate backwash pump should be required with a capacity of at least 15 gallons per minute per square foot of filter area.

Centrifugal pumps powered by electric motors are most commonly used. They should be located in such a way as to be always self-priming.

3- Chemical Feeders

This is a device installed for the purpose of applying chemicals such as alum and soda ash required for water conditioning. The use of such chemicals is mainly restricted to pressure sand filters. Sand beds are not effective in removing very fine suspended solids in the circulated water. Unless the water is coagulated then a gelatinous precipitate will form on the topmost layer of the sand bed that enmeshes the fine matter in suspension. Alum is widely used as the coagulant. The use of an alkali such as soda ash is simply to counteract the acidity due to added coagulant and, hence, controlling the pH at the desired level. The chemicals are usually applied as far ahead of the filter as possible in order to obtain maximum reaction time and thorough mixing. Fig. 2 illustrates the method commonly used for the installation of chemical feeders.

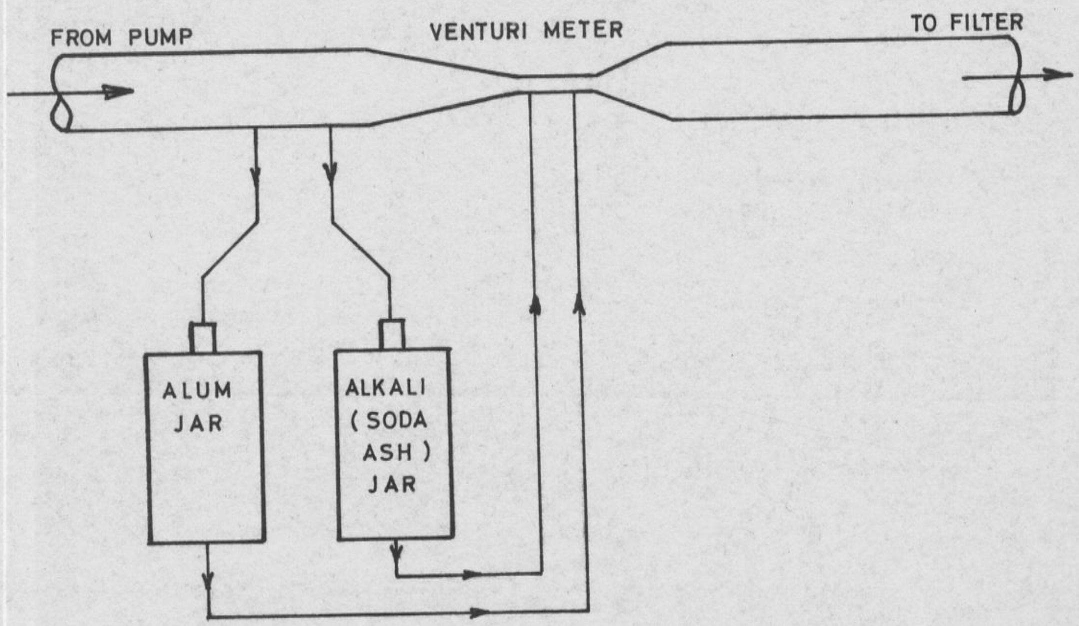


FIG 2 TYPICAL CHEMICAL FEEDING METHOD

A properly designed venturi meter, where a difference in pressure exists between the main pipe and the throat, serves to regulate the dosage of the chemicals to be fed.

Experience has shown that alum doses seldom need be greater than about 25 mg/l of water to be treated(7). The quantity of soda ash to be fed is about the same as that for alum.

4- Filters

As stated previously there are several types of filters. Gravity sand filters are used in large pools where ample land is available. They could be constructed with concrete similar to those of a municipal water supply. In case the available space is limited, rapid pressure filters (either the horizontal or the vertical type) are preferred for large capacity swimming pools. For medium or small pools the diatomaceous earth filter is used where no coagulant and alkali are required.

The following discussion pertains to the popular pressure sand filters which are used in batteries of three or four connected in series, except in the case of small private pools where one is only sufficient. Each one consists of a closed cylindrical steel shell containing a bed of granular filter medium carefully placed over a collector system. The water to be filtered enters at the top of the shell, percolates downward through the filter bed and is drawn off through the collector system at the bottom. Periodically, depending on the bathing load, this flow is reversed and the filter is backwashed to carry away the dirt which accumulates on the filter bed.

The filtering material should consist of at least 0.90 metres (36 inches) in depth of suitable grades of screened sharp filter sand or crushed quartz and filter gravel. The effective size of the sand should be 0.4 to 0.5mm with a uniformity coefficient of about 1.7. It should be washed free from clay, organic matter or soluble material. A minimum of 0.45 metres (18 inches) free-board to the overflow troughs or pipes is required to ensure proper washing without loss of filter sand(3). Fig. 3 illustrates a typical section through a pressure sand filter.

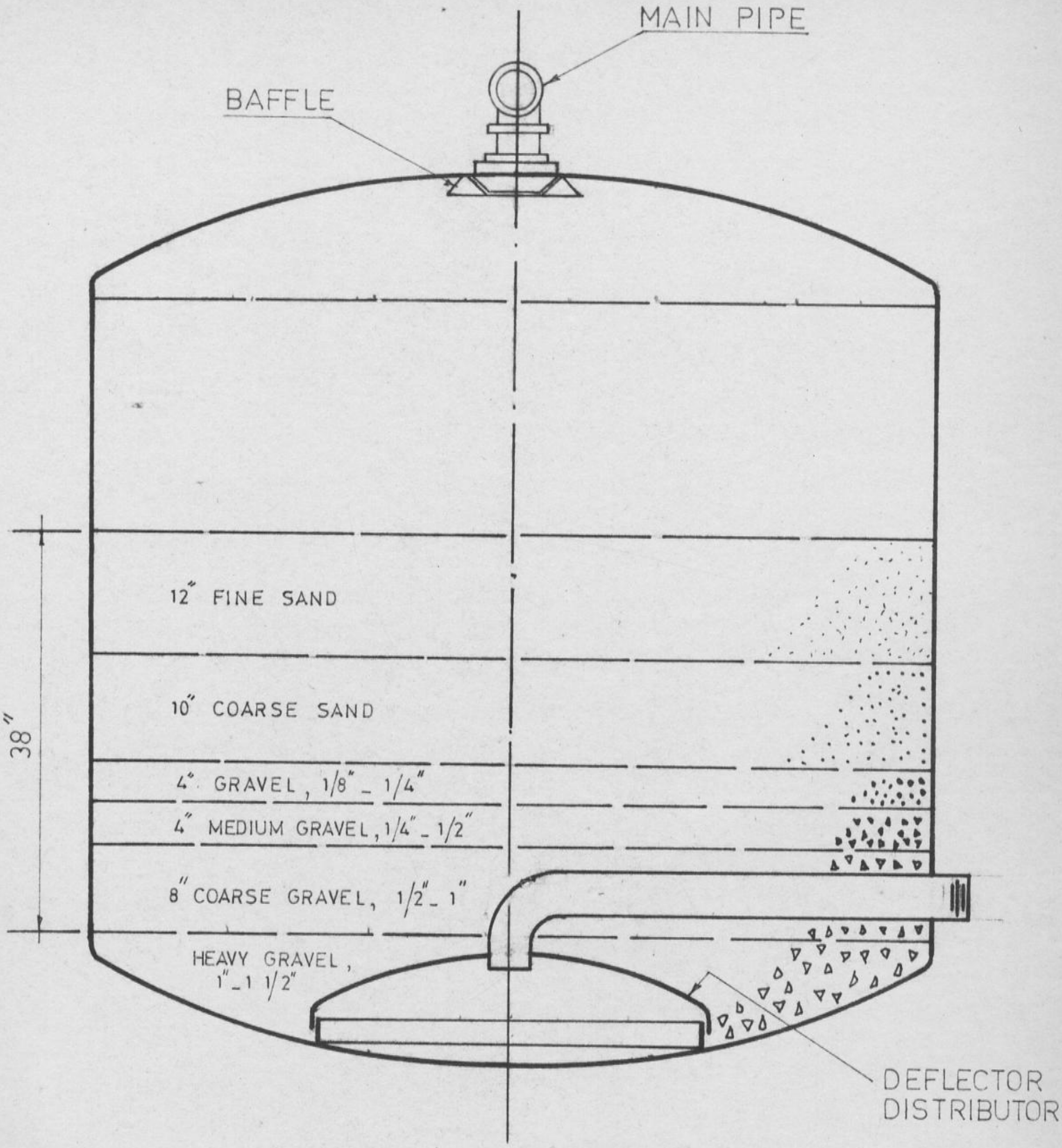


FIG. 3 TYPICAL SECTION THROUGH PRESSURE SAND FILTER

In designing the filter system a three gallons per minute per square foot of filter surface area should be considered[3,7]. Most manufacturers make vertical filters of three feet diameter as a minimum size.

Fig. 4, taken from Permutit bulletins number 2157-B and 2225-B, shows different sizes of filters and piping with pump power, and dimensions of equipment room[12].

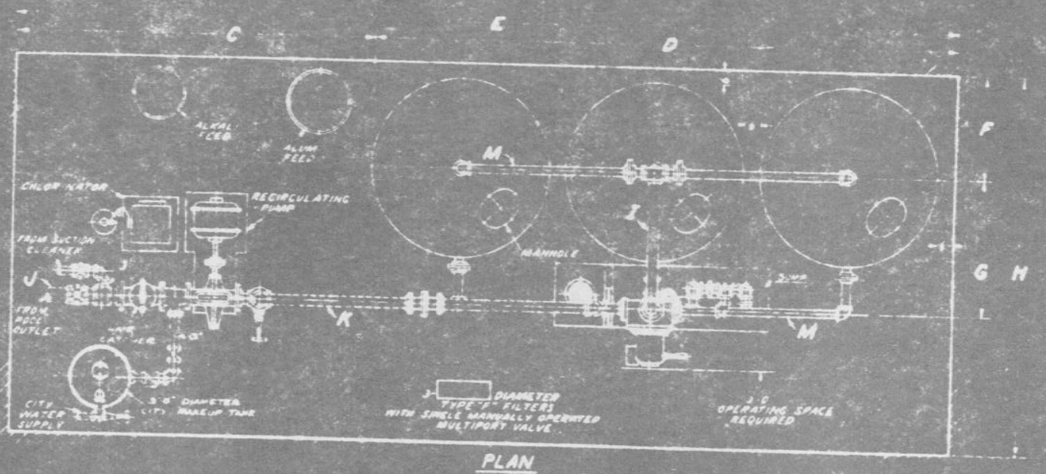
Both the vertical and horizontal type of pressure filters are commonly used. The advantage of the horizontal type is that it has a larger filtering area. Pressure filters are supplied with pressure gauges and usually the filter is backwashed when the loss of head is about 2.27 kg (5 lbs) and sometimes it may be desirable to wash at even lower losses of head[7]. The frequency of backwashing depends on the degree of turbidity of the circulated water which in turn depends upon the dirt contributed by bathers.

5- <u>Heater</u>

As previously stated, the water in a swimming pool should be maintained at a convenient temperature

OPERATING WEIGHTS

DIAMETER OF FILTERS	OPERATING WEIGHT EACH FILTER POUNDS
3'-0"	5,200
3'-6"	7,000
4'-0"	8,900
4'-6"	11,300
5'-0"	14,000
5'-6"	17,400
6'-0"	20,800
6'-6"	24,500
7'-0"	28,700
7'-6"	33,100
8'-0"	37,700
8'-6"	43,000
9'-0"	48,500
10'-0"	58,500



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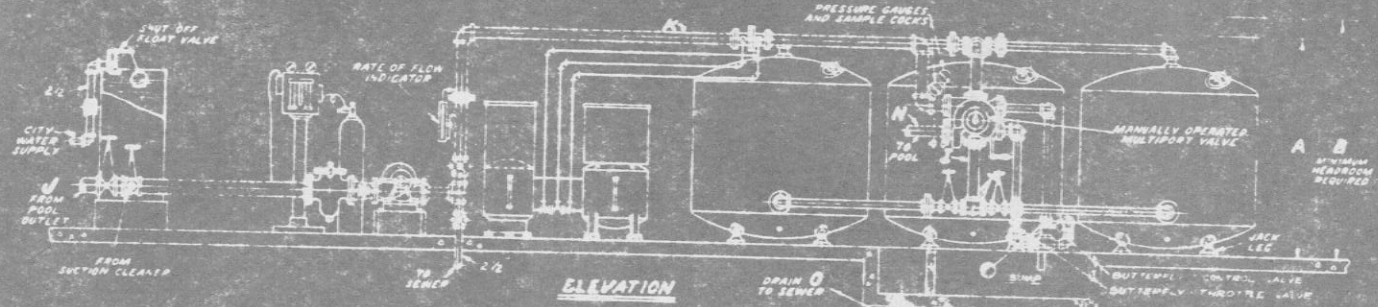


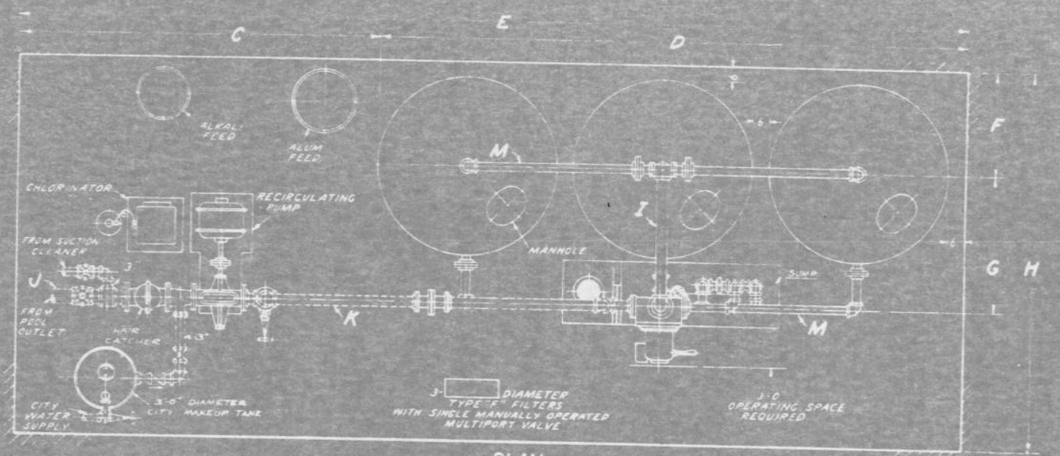
ELEVATION

DIMENSION TABLE AND SPACE REQUIREMENTS

POOL DATA 8 HOUR TURNOVER READ TO THE RIGHT: SIZE POOL FT.	CAPACITY GALLONS	DIA OF FILTERS	ALUM CHARGE POUNDS	ALKALI CHARGE POUNDS	HAIR CATCHER	PUMP G.P.M.	PUMP H.P.	A	B	C	D	E	F	APPROX. G	H	PIPE SIZES I	J	K	M	N	O	POOL DATA 12-HOUR TURNOVER READ TO THE LEFT: SIZE POOL FT.	CAPACITY GALLONS
15 × 45	30,000	3'-0"	10	10	3"	65	1½	6'-10"	7'-6"	10'-6"	10'-6"	21'-0	2'-0"	2'-6"	9'-0"	2"	3"	2"	1½	2"	4"	20 × 50	45,000
20 × 45	36,000	3'-6"	10	10	3"	75	2	7'-1"	7'-7"	10'-6"	12'-0	22'-6"	2'-3"	2'-10"	9'-6"	3"	3	3"	2	2½	4	20 × 60	55,000
20 × 60	55,000	4'-0"	20	10	3"	115	2	7'-4"	7'-8"	10'-6"	13'-6"	24'-0	2'-6"	3'-1"	10'-6"	3"	3	3"	2"	3	6"	25 × 75 / 30 × 60	80,000
25 × 60	68,000	4'-6"	20	10	4"	145	3	7'-6"	7'-11"	11'-0"	15'-0	26'-0"	2'-9"	3'-9"	11'-0	5"	4"	3"	3"	3"	6"	25 × 90	102,000
25 × 75 / 30 × 60	80,000	5'-0"	40	20	4"	170	3	7'-9"	7'-11"	11'-0"	16'-6	27'-6	3'-0"	4'-2"	11'-11"	4	4"	4"	3"	4	6	30 × 90	120,000
25 × 90	102,000	5'-6"	40	20	5	210	5	7'-11"	8'-1"	11'-0"	18'-0	29'-0"	3'-3"	4'-4"	12'-6"	4"	5	4"	3	4	6"	35 × 105	155,000
30 × 90	120,000	6'-0"	40	20	5"	250	5	8'-1"	8'-3"	11'-0"	19'-6"	30'-6"	3'-6	4'-7"	13'-0"	4	5	4	3	4	6	40 × 105 / 45 × 90	180,000
35 × 90	140,000	6'-6"	70	40	6"	300	7½	8'-4"	8'-9"	11'-0	21'-0	32'-0	3'-9	5'-1"	14'-0	6"	6	6"	4"	5	8	40 × 120	207,000
35 × 105 / 40 × 90	155,000	7'-0"	70	40	6	340	7½	8'-6"	9'-3"	11'-6	22'-6	34'-0"	4'-0	5'-4"	14'-6	6"	6	6	4	5"	8	45 × 135 / 50 × 120	248,000
40 × 105 / 45 × 90	180,000	7'-6"	100	70	8	390	7½	8'-9"	9'-10"	12'-0	24'-0	36'-0"	4'-3"	5'-9"	15'-2	6	8	6	5"	6	8	55 × 120 / 50 × 135	280,000
40 × 120	207,000	8'-0"	100	70	6	450	10	8'-11"	10'-2"	12'-0"	25'-6	3[illegible]'-6	4'-6	6'-0"	15'-8	6	8	6	5"	6"	8	50 × 150	310,000
50 × 120 / 45 × 135	248,000	8'-6	100	70	8"	510	10	9'-1"	10'-7"	12'-6"	27'-0	39'-6	4'-9	6'-3"	16'-2	6	8	6"	5	6"	8	60 × 150	372,000
55 × 120 / 50 × 135	280,000	9'-0"	160	70	10	570	10	9'-3"	11'-0"	13'-6"	28'-6	42'-0	5'-0"	6'-6"	17'-0	6	10	6"	5	6"	8	75 × 135 / 60 × 180	420,000
50 × 150	310,000	10'-0"	160	70	10	650	15	9'-6"	11'-9"	13'-6"	31'-6	45'-0	5'-6	7'-0"	18'-0"	6"	10"	6"	5"	6"	10"	75 × 150 / 70 × 180	465,000

OPERATING WEIGHTS

DIAMETER OF FILTERS	OPERATING WEIGHT EACH FILTER POUNDS
3'-0"	5,200
3'-6"	7,000
4'-0"	8,900
4'-6"	11,300
5'-0"	14,000
5'-6	17,400
6'-0"	20,800
6'-6"	24,500
7'-0	28,700
7'-6"	33,100
8'-0	37,700
8'-6"	43,000
9'-0	48,500
10'-0"	58,500



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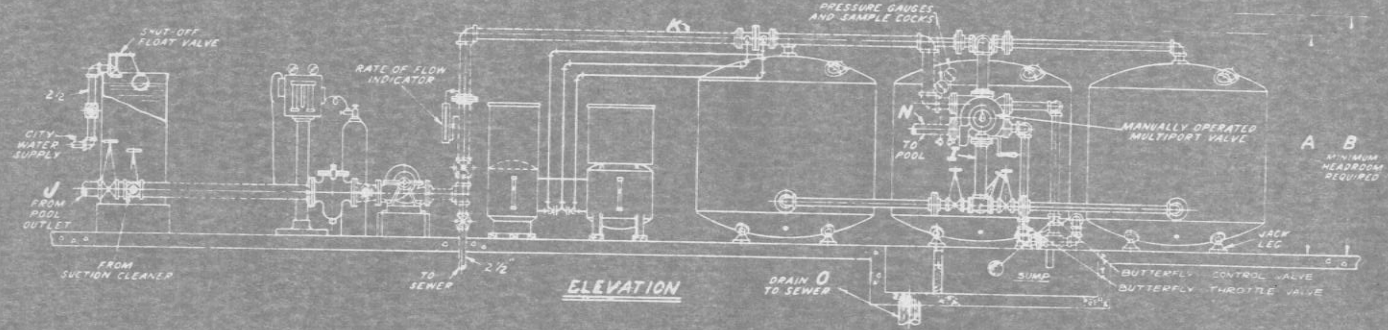


ELEVATION

DIMENSION TABLE AND SPACE REQUIREMENTS

POOL DATA 8 HOUR TURNOVER READ TO THE RIGHT: SIZE POOL FT	CAPACITY GALLONS	DIA OF FILTERS	ALUM CHARGE POUNDS	ALKALI CHARGE POUNDS	HAIR CATCHER	PUMP G.P.M	PUMP H.P	A	B	C	D	E	F	APPROX. G	H	PIPE SIZES I	J	K	M	N	O	POOL DATA 12 HOUR TURNOVER READ TO THE LEFT: SIZE POOL FT	CAPACITY GALLONS
15 × 45	30,000	3'-0"	10	10	3"	65	1½	6'-10"	7'-6"	10'-6"	10'-6"	21'-0	2'-0"	2'-6"	9'-0"	2"	3"	2"	1½"	2"	4"	20 × 50	45,000
20 × 45	36,000	3'-6"	10	10	3"	75	2	7'-1"	7'-7"	10'-6"	12'-0"	22'-6"	2'-3"	2'-10"	9'-6"	3"	3"	3"	2"	2½	4	20 × 60	55,000
20 × 60	55,000	4'-0"	20	10	3"	115	2	7'-4"	7'-8"	10'-6"	13'-6"	24'-0	2'-6"	3'-1"	10'-6"	3"	3	3"	2"	3	6"	25 × 75 30 × 60	80,000
25 × 60	68,000	4'-6"	20	10	4"	145	3	7'-6"	7'-11"	11'-0"	15'-0"	26'-0"	2'-9"	3'-9"	11'-0"	3"	4"	3"	3"	3"	6"	25 × 90	102,000
25 × 75 30 × 60	80,000	5'-0"	40	20	4"	170	3	7'-9"	7'-11"	11'-0"	16'-6"	27'-6"	3'-0"	4'-2"	11'-11"	4"	4"	4"	3"	4"	6	30 × 90	120,000
25 × 90	102,000	5'-6	40	20	5"	210	5	7'-11"	8'-1"	11'-0"	18'-0"	29'-0"	3'-3"	4'-4"	12'-6"	4"	5"	4"	3"	4	6"	35 × 105	155,000
30 × 90	120,000	6'-0"	40	20	5"	250	5	8'-1"	8'-3"	11'-0"	19'-6"	30'-6"	3'-6"	4'-7"	13'-0"	4"	5"	4"	3"	4"	6"	40 × 105 45 × 90	180,000
35 × 90	140,000	6'-6	70	40	6"	300	7½	8'-4"	8'-9"	11'-0"	21'-0"	32'-0"	3'-9	5'-1"	14'-0	6"	6	6"	4"	5"	8	40 × 120	207,000
35 × 105 40 × 90	155,000	7'-0"	70	40	6	340	7½	8'-6"	9'-3"	11'-6	22'-6	34'-0"	4'-0	5'-4"	14'-6"	6"	6"	6"	4"	5"	8"	45 × 135 50 × 120	248,000
40 × 105 45 × 90	180,000	7'-6"	100	70	8	390	7½	8'-9"	9'-10"	12'-0	24'-0"	36'-0"	4'-3"	5'-9"	15'-2	6"	8"	6	5"	6"	8	55 × 120 50 × 135	280,000
40 × 120	207,000	8'-0"	100	70	8"	450	10	8'-11"	10'-2"	12'-0"	25'-6"	37'-6	4'-6	6'-0"	15'-8	6	8"	6	5"	6"	8"	50 × 150	310,000
50 × 120 45 × 135	248,000	8'-6"	100	70	8"	510	10	9'-1"	10'-7"	12'-6"	27'-0"	39'-6"	4'-9	6'-3"	16'-2"	6	8"	6"	5"	6"	8"	60 × 150	372,000
55 × 120 50 × 135	280,000	9'-0"	160	70	10"	570	10	9'-3"	11'-0"	13'-6"	28'-6	42'-0	5'-0"	6'-6"	17'-0"	6	10"	6"	5"	6"	8	75 × 135 60 × 180	420,000
50 × 150	310,000	10'-0"	160	70	10"	650	15	9'-6"	11'-9"	13'-6"	31'-6"	45'-0	5'-6"	7'-0"	18'-0"	6"	10	6"	5"	6	10"	75 × 150 70 × 180	465,000

FIG. 4 Sizes of Equipment Room and All its Components

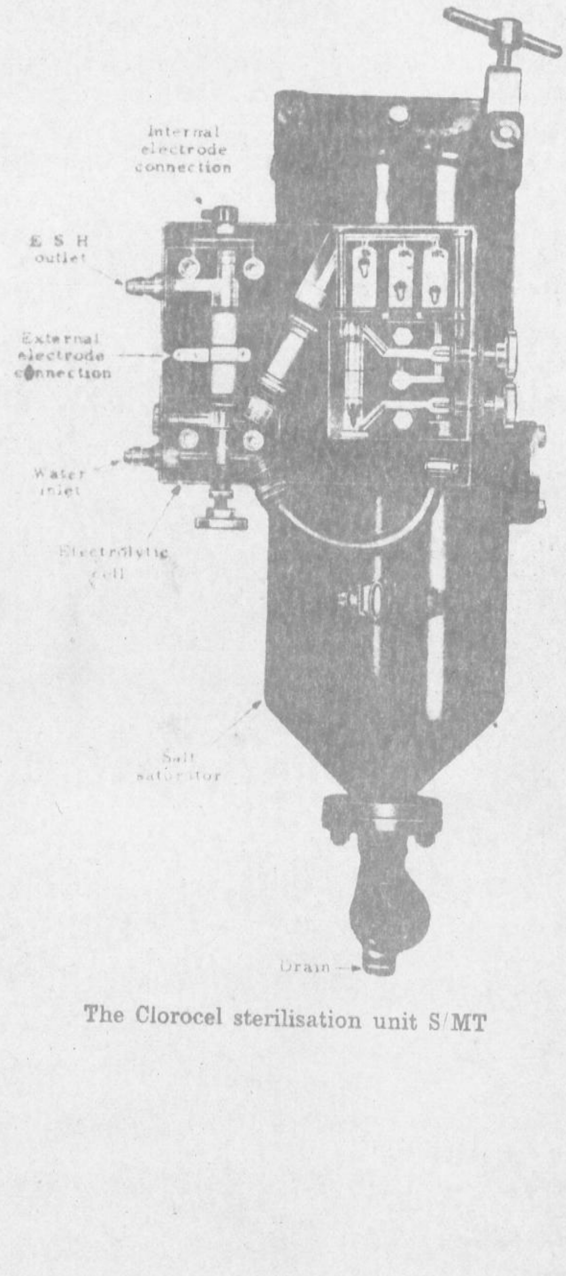
for the comfort of bathers without favouring the growth of bacteria. A temperature of 23°C (74°F) is desirable and for indoor swimming pools the air temperature should be maintained about 3°C (5°F) warmer than the water temperature[9,3,5].

The usual method of heating the water is by passing it through a heat exchanger, where hot water or steam from the boiler system is continuously circulating to the series of small section tubes of the heat exchanger. Electric heaters are sometimes preferred for small pools. The heater should be located after the filters, and as close as possible to the pool for conservation of heat in the water.

6- Chlorinator

For recirculation systems either gas chlorinators or hypochlorinators are used. The type of equipment that is needed depends on such factors as the size of the pool, the bathing load, and the recirculation rate. When fresh water is used with a pH range of 7.2-7.8 and volumes exceeding 100,000 gallons chlorination with chlorine gas proves to be economical[10]. Below this capacity hypochlorinators are recommended. For pools using water with high pH values ranging from 8.0-8.9 (such as sea water) special hypochlorinators are used. A hypochlorinator such as the "Clorocel", an equipment which is produced by the Paterson Engineering Company of London, England is widely used[13]. This equipment (Fig. 5), comparatively small in size, produces electrolytic sodium hypochlorite by the electrolysis of sodium chloride (common salt) or on occasion sea water. It is made in various sizes, giving outputs of 9-27 gm of chlorine per hour. When used for sea water pools it proves highly economical, since it draws its supply of salt from the sea water itself. It is adjustable to the exact strength and flow-rate needed, and the only running expense relates to the electric power consumption.

When a hypochlorinator is used, the chlorinating system consist of a storage crock for storage of chlorine solution and a feed pump which meters the solution to the circulating suction line. When a gas chlorinator is used it replaces the feed pump and a chlorine cylinder is used in



The Clorocel sterilisation unit S/MT

place of the chemical storage crock. Fig. 6(a) and Fig. 6(b) illustrate both systems.

Gas chlorinators should be located in a separate room accessable only from the outside and be well ventilated.

Chlorinators should be located close to pool inlets at which points the chlorine is applied.

7- <u>Suction Cleaner</u>

Suction cleaner should be used as an integral part of the recirculation systems wherever possible, otherwise a self-contained mobile pumping unit may be used. In the first case a steel suction main is run along-side the pool with outlets at a depth of 20 cms (8 inches) below water surface and at about five metres on centres[10]. On the other hand it is preferable to use a centrifugal pump, complete with electric motor and starter, mounted on a rubber wheeled trolley and fitted with a canvas delivery hose for discharge of waste water.

The suction cleaning apparatus works on the principle of creating high suctional velocity

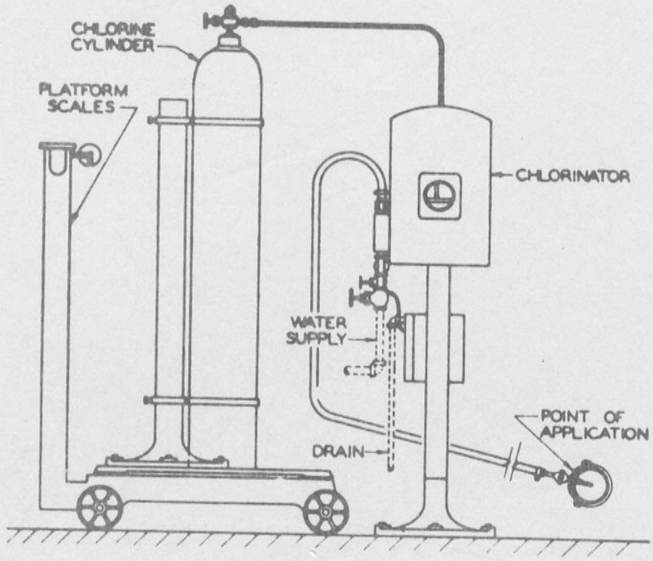


FIG 6(a) GAS CHLORINATOR

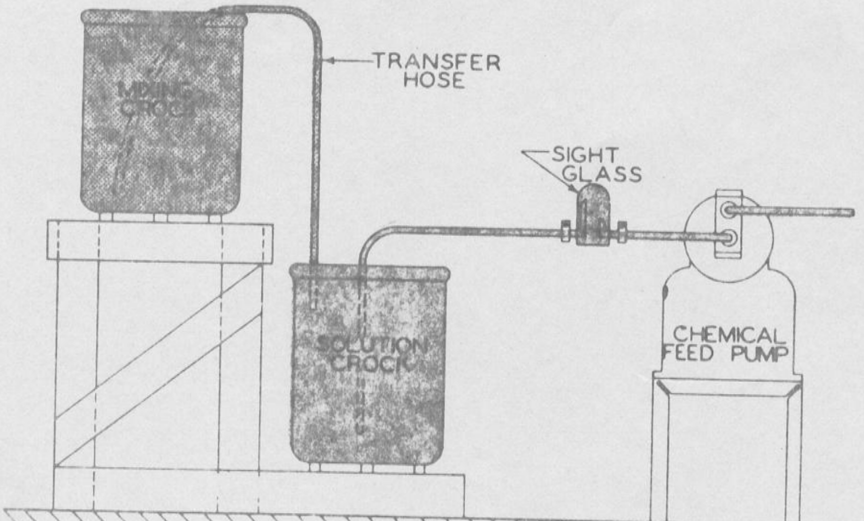


FIG 6 (b) HYPO-CHLORINATOR

capable of drawing off sediments collected on the pool bottom.

8- Piping

Pipes should be designed to reduce frictional losses to a minimum and to carry the required volume of water. Pipes smaller than three inches are undesirable for use. Union should be used where necessary to permit rapid cleaning, inspection and repairing of the pipes. The velocity should not exceed 2.5 mps (8 fps) at the discharge side of the pump, or 1.5 mps (5 fps) at the suction side[7,10]. The friction losses for the complete main suction line should not exceed 6 per cent.

C. Flow-through System

Sometimes swimming pools are constructed close to natural bodies of water such as sea, river or lake and, hence, water cost is reduced appreciably. In such a case, the flow-through system is preferred to the recirculation system because of the simplicity in operation and economy with respect to cost and maintenance.

The flow-through system includes:

1- Pumps

2- Heater

3- Chlorinator

4- Suction Cleaner

5- Piping and fittings

The design of the heater, chlorinator, suction cleaner and pipes are exactly the same as those discussed previously for the recirculation method. The design of pumps will depend on the difference between the water level of the natural body of water and that of the pool, plus the head due to the friction losses in pipes and fittings.

IV- THE DESIGN

A. The Long Beach Club

The Long Beach Club is one of the most frequented bathing beaches in Beirut. It has acquired this popularity by virtue of its proximity to residential areas, its cleanliness and the number of facilities and conveniences available to members.

To cope with the increasing clientele the Long Beach Administration decided to construct a new large swimming pool in 1963 to relieve the load on the existing ones. In addition, the beach coastline suffers a number of drawbacks, most important of which are (a) rock formation and deep shore water; (b) frequent roughness of sea, as the beach location is exposed to currents; (c) traces of oil and tar on the water surface that result from ship and refinery wastes.

The Long Beach site is divided into three zones as shown on the general layout plan drawing No. 1. The first zone is the waterfront that covers the new swimming pool under consideration, the children's pool and playground. The second is the general amenities zone that covers the entrance, the bar and the new changing cubicles. The third is the chalet zone that now includes the old changing cubicles, the dining terrace and the old swimming pool.

As the beach site is quite large and the present constructions as shown in drawing No. 1 are neither very well planned nor architecturally sound, the Long Beach Administration had decided to revise and re-develop the whole area.

B. Description of Long Beach Swimming Pool and Its Components

The Long Beach swimming pool was designed according to international requirements with regards to dimensions and shape as shown in drawing No. 2. Of the three possible systems, the flow-through system utilizing sea water was adopted to save on the cost of water and equipment. Clean water is admitted to the window tunnel leading to the two feed pump sumps through pipe intakes located at mid-sea water level, as shown in drawing Nos.3&4, in order to avoid surface floating matter and any bottom sediments. Fresh sea water will be constantly pumped in to feed the pool at the deep end during swimming hours through 16 inlets spaced equally in two rows symmetrical with the pool's longitudinal axis (see drawing No. 5). Outlets on the opposite shallow end discharge the used water to the sea at the same rate at which it is fed in. This flow is regulated by means of a gate valve placed in a manhole at the outlet side (see drawing No. 6). The used water flows freely back to the sea under gravity. In this respect, pool orientation was chosen to utilize the prevailing wind and shore currents so as to drive used water away from the intakes.

The inlet and outlet fittings are made of bronze with the dimensions shown in drawing No. 7. The total area of the holes in each fitting is made to be equal to twice the area of the pipe in order to reduce the inlet and discharge velocities. The shape of each hole is such that inlet or outlet losses are reduced and turbulence is minimized.

The open type gutters are adopted for this swimming pool and constructed only along its longer sides. The Eastern side gutter drains empty in a canal constructed along-side the projector's tunnel as shown in drawing No. 8. This canal also takes the walkway drainage and is finally joined to the beach surface drainage which is ultimately disposed of into the sea by means of a system of manholes.

The Western side gutter drains together with the walk-way drains on the same side pour into a 6 inch drain pipe installed in the projector's tunnel. This pipe is connected to the manhole that carries the used water from outlets (see drawing No. 8).

The under water lighting was provided by 32-1500 watt lamps which were installed equally on opposite sides facing one another along the pool's length. Access tunnels were constructed and made water tight to prevent moisture from reaching the projectors.

Pool draining was ultimately accomplished by the drainage pump shown in drawing No. 4.

Drained water discharges into the sea through a pipe that runs into the window tunnel leading to the sump of the feed pumps. This was found to be the most feasible way for installation. Water passes to the drainage pump through two floor drains made of bronze and installed at the deep end of the pool (see drawing No. 3). The total area of the openings in the floor drain is made equal to twice the area of the pipe in order to avoid high suction velocities and to reduce entrance losses.

The sanitary and hydraulic designs of all pool elements will be discussed subsequently.

C. Water Quality

The sanitary quality of sea water at the anticipated location of the intake was determined experimentally. The procedures followed for the tests involved are as described in Standard Methods for the Examination of Water and Wastewater[6].

The tests were limited to the raw feeding water and did not include the pool water or the effluent with the pool in operation in order to evaluate changes in water quality at the different stages resulting from the use of the pool. This was on the account of the fact that the pool was under construction at the time of testing. Furthermore, upon completion of the pool about a year later, the pool was not run by the proprietor on the flow-through system as designed, but rather on a fill and draw basis without chlorination, a practice which would not provide the information desired.

Several samples of sea water during the swimming season were taken at the proposed intake location (see drawing No. 3) at a depth of about two metres. Care was to obtain representative samples during both rough and calm seas to simulate actual operational conditions.

The figures shown in Table II represent mean values.

In general the results of the tests conducted compare very well with the accepted standards as discussed in Chapter II.

An MPN value of 38 classifies the bacteriological quality of the inlet water as excellent.

A pH value of 8.5 falls within the range of pH 8.0-8.9 which requires the application of a high chlorine residual, otherwise the pH value has to be lowered to a pH of 7.5-7.8 by the addition of an acid before applying a normal chlorine residual.

Table II - Laboratory Analysis of Sea Water* and Calculated Bathing Load

Coliform test		pH	Chlorine demand mg/l	Turbidity	Chlorides mg/l	Dissolved oxygen at 21°C mg/l	B.O.D. mg/l	No. of bathers	
Presumptive MPN	Confirmed MPN							P_f	p_f
240	38	8.5	0.3	None	14800	7.6	0.37	330	2220

* It is anticipated that the reported values may vary with season.

The fact that the samples tested showed no turbidity indicates that the sea water is expected to be clear and would not require treatment for turbidity removal.

The value of 7.6 mg/l for dissolved oxygen indicates that the sea water to be pumped is sufficiently aerated and furnishes a good aerobic medium for oxidation of organic matter under favourable conditions.

A value of 0.37 mg/l for B.O.D. indicates the presence of an insignificant organic load due to either sea water pollution or the presence of algae which contributes to the B.O.D. load because of their organic nature. This low B.O.D. value would not render the sea water in that locality unacceptable for bathing. Chlorination will further reduce the B.O.D. value.

Measures for algae control should be undertaken to avoid aesthetic and mechanical problems attributed to algae growth. An average dose of 0.5 mg/l of copper sulphate applied occasionally is recommended.

The existing pool space allows a maximum of 630 swimmers to be present in the pool during any one hour, according to accepted swimming pool space specifications, as per Chapter II.

The bathing load criteria allows a maximum number of bathers of 330 per hour. It also limits the number of bathers using the pool during the hours of its operation to 2220. Comparison between the space and bathing load criteria, as discussed in Chapter II, shows that the latter dominates. Hence admission into the pool should be restricted to a maximum bathing load of 2220 persons per day and 330 per hour.

D. Hydraulic Design

1- Design of Pumps, Motors and Pipe Sizes for Pool Inlets

$$\text{Pumping rate} = \frac{3000 \times 1000}{3.8 \times 8 \times 60} = 1650 \text{ gpm}$$

Using two pumps each of capacity 1000 gpm then the turn-over period would be:

$$\frac{3000 \times 1000}{2000 \times 3.8 \times 60} = 6.6 \text{ hours}$$

With recommended velocities, which are within the range of one to three metres per second, the sizes of inlet pipes have been picked up from the nomogram of Hazen and Williams formula with $C = 100$.

The static head on the pump is 11 feet. The dynamic head on the pump, which is the sum of all friction losses in the pipes and fittings plus the entrance and exit losses, is 13.74 feet.

Therefore, the total head on the pump is

$$11 + 13.74 = 24.74 \text{ feet say, } 25 \text{ feet}$$

Assuming a pump efficiency of 80% then motor horse-power

$$= \frac{1000 \times 25}{3960 \times 0.8} = 7.9$$

Therefore, use a 10 horse-power motor which is the nearest larger standard size.

2- Design of Pool Outlets

As the position of outlets are appreciably higher than the sea water level, gravity flow has to be made use of. The outflow water pours first freely into a manhole through a 12 inch gate valve, then flows by gravity through a 12 inch pipe back to sea. The main function of the gate valve is to regulate the flow so that the inflow rate would be equal to that of the outflow.

Inflow = Outflow = 2000 gpm

For the purpose of proper distribution and aesthetics, 12 - 3 inch diameter outlets connected by a 10 inch header is assumed.

The following basic assumptions were made

i) Pipes to flow full, whereby flow is controlled by the gate valve.

ii) Equal quantities flow through each outlet.

Hence the momentum equation[14,15] was used:

$$P_2 A_2 - P_1 A_1 = \rho q_1 V_1 - \rho q_2 V_2$$

Where

A = Cross sectional area of pipe

P = Pressure at the centre of pipe cross sectional area

ρ = Density of fluid

q = Quantity of flow passing through a section of a pipe

V = Velocity of flow

$$q = \frac{2000}{12} = 167 \text{ gpm} = 0.372 \text{ ft}^3/\text{sec}$$

$$\rho \text{ for sea water} = 64 \text{ lbs/ft}^3 = 2 \text{ slugs/ft}^3$$

$$A \text{ for } 10'' \text{ diam. pipe} = \frac{\pi \times 100}{144 \times 4} = 0.545 \text{ ft}^2$$

Applying the momentum equation on the 10 inch pipe sections between the three inch diameter outlets starting from the end outlet towards pool centre; considering the following values to exist at the end section of the header:

V_1 = point of stagnation

$P_1 = 3 \text{ ft} = 3 \times 64 = 192 \text{ lbs/ft}^2$ = static head

and at the next section:

$$V_2 = \frac{q_2}{A} = \frac{2 \times 0.372}{0.545} = 1.365 \text{ ft/sec}$$

Then

$$0.545 P_2 - 192 \times 0.545 = 0 - 2 \times 0.744 \times 1.365$$

$$P_2 = 188 \text{ lbs/ft}^2$$

Considering the rest of section on the same basis, the pressure at the last section at pool centre would be 160 lbs/ft^2. Therefore, the friction loss is

$$192 - 160 = 32 \ lbs/ft^2 = \frac{32}{64} = 0.5 \ ft = 15 \ cms$$

The other losses to be considered are 10 inch tee, 12 to 10 inch reducer, 12 inch gate valve and those of inlet and outlet. This value came to be about 2.47 ft (75 cms).

$$\text{Total loss of head} = 75 + 15 = 90 \ cms$$

which is slightly less than the available static head of about 91 cms (see drawings No. 2 and 7).

3- Design of Pump, Motor and Pipe Sizes for Pool Draining

Pool draining can be achieved in the best efficient manner by allowing the pool water to drain under gravity to the sea till the quantity flowing, which is a function of the static head, becomes nearly equal to the pumping rate. The pump then starts to remove the remaining volume at a constant pumping rate.

For gravity free flow from outlets[2,14,15]

$$Q = 0.62\ a\ \sqrt{2gh}$$

Where

Q = Quantity of flow in cfs

a = Section area of pipe in ft^2

g = Gravity force in $ft/sec^2 = 32\ ft/sec^2$

h = Head in ft

With a 12 inch diameter drain

$$Q = 0.62 \times \frac{\pi}{4} \times 1^2\ \sqrt{2gh}$$

$$= 3.95\ \sqrt{h}$$

which is an equation of a parabola.

For pressure flow from the bottom of the pool to the sea where the pipe is flowing full, Manning's formula[16,17] is used

$$Q = \frac{1.486}{n}\ a\ R^{2/3}\ S^{1/2}$$

Where

Q = Quantity of flow in cfs

n = Roughness coefficient[2,16]

a = Section area of pipe in ft^2

R = Hydraulic radius in ft

S = Slope of hydraulic gradient

And

$$R = \frac{A}{P}$$

$$S = \frac{H}{L}$$

Where

A = Wetted section area of the pipe in ft^2

P = Wetted perimeter in ft

H = Head in ft

L = Equivalent length of pipe in ft

Assume a pipe of 10 inch diameter

$$n = 0.013$$

$$R = \frac{\pi D^2}{4 \pi D} = \frac{D}{4}$$

$$Q = \frac{1.486}{0.013} \times \frac{100}{144} \times \frac{1}{4} \times \left(\frac{10}{12x4}\right)^{2/3} \times S^{1/2}$$

$$= 22 \ S^{1/2}$$

Total equivalent length = 300 ft

Then

$$S = \frac{H^{1/2}}{\sqrt{300}} = \frac{H^{1/2}}{17.4}$$

$$Q = \frac{22}{17.4} H^{1/2} = 1.25 \sqrt{H}$$

which is also an equation of a parabola.

Plotting the two equations on a graph as shown in Fig. 7 the most practical and convenient point for the limit of gravity flow appears to be at the outlets level.

The average gravity free flow from outlets is

$$2/3 \times 6.85 \times 3 \times 1/3 = 4.6 \text{ ft}^3/\text{sec}$$

The average gravity pressure flow from pool drain is

$$\frac{3.95 + 3.30}{2} = 3.62 \text{ ft}^3/\text{sec}$$

$$\text{Total gravity flow} = 4.6 + 3.62 = 8.22 \text{ ft}^3/\text{sec}$$

The volume of the pool water to be drained under gravity is

$$21.5 \times 50 \times 0.915 = 980 \text{ m}^3 \text{ say } 1000 \text{ m}^3$$

Then the time of gravity drainage is

$$\frac{1000000}{3.8 \times 8.22 \times 448.83} = 71 \text{ min}$$

$$\text{Total volume of pool} = 3000 \text{ m}^3$$

$$\text{Volume to be pumped} = 3000 - 1000 = 2000 \text{ m}^3$$

With a constant pumping rate of 2000 gpm

$$\text{pumping time} = \frac{2000000}{3.8 \times 2000} = 264 \text{ min}$$

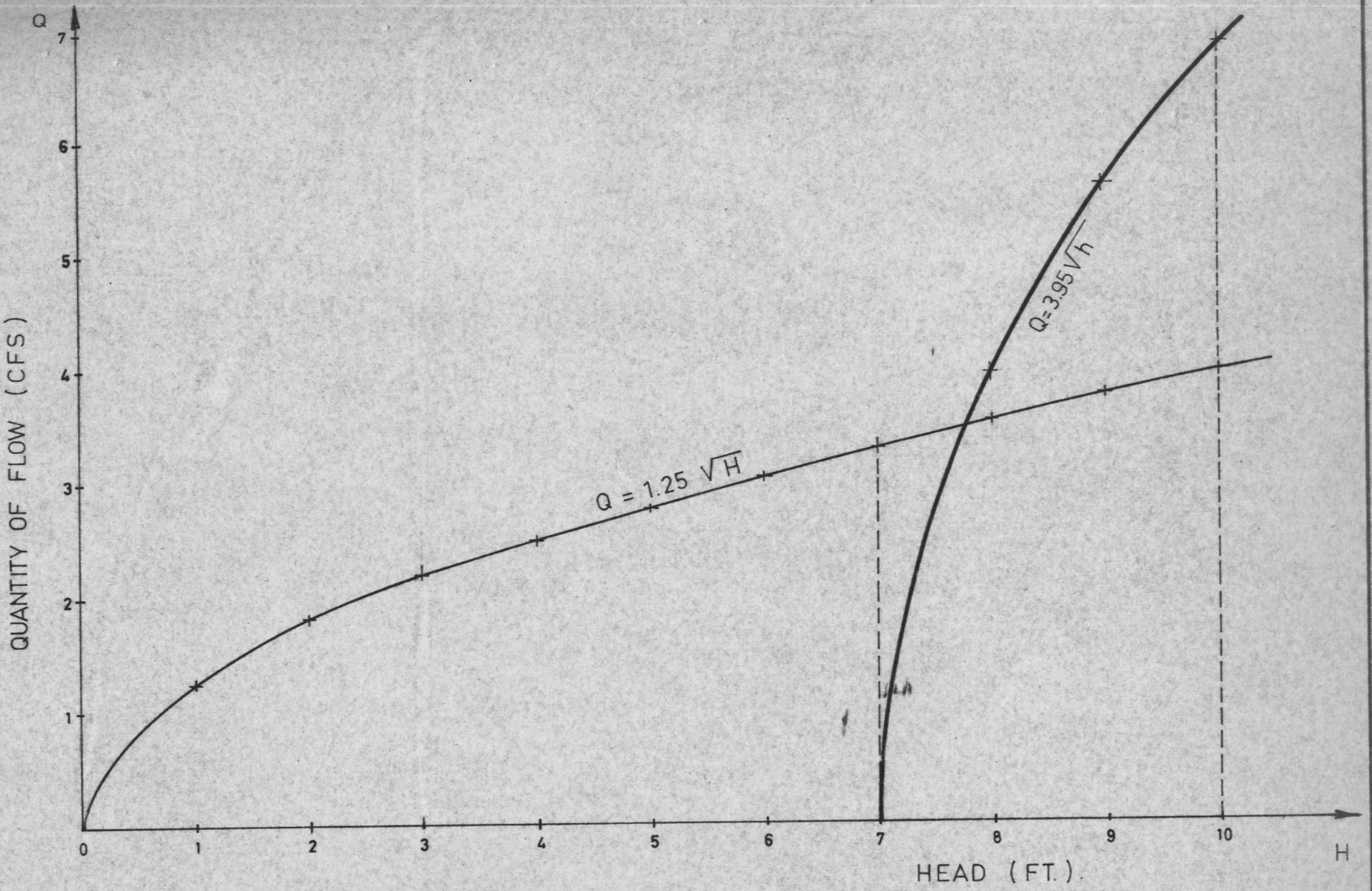


FIG. 7 PRESSURE FLOW UNDER VARIABLE HEAD

Total pool draining time = 264 + 71 = 335 min

= 5 hours and 30 min

Static head on pump = 5 ft

Friction losses in pipes and fittings including those of entrance and exit = 23 ft

Total head on pump = 23 + 5 = 28 ft

Assuming pump efficiency to be 80%

Then

$$\text{Motor horse-power} = \frac{2000 \times 28}{3960 \times 0.8} = 17.7$$

Therefore, use a 20 horse-power motor which is the nearest larger standard size.

4- <u>Design of Scum Gutter Outlets</u>

As shown on the drawings the scum gutter outlets used are 2 inch diameter pipes spaced at three metres interval (10 ft) along the length of the pool as recommended by the codes and standard(3).

The scum water is flushed back to the sea by either the canal that takes walkway drainage on one side of the pool or by a 6 inch diameter pipe that is laid in the projector's tunnel on the other side. This 6 inch diameter pipe also carries the walk-way drainage on that side of the pool where a 2-inch diameter pipes spaced at three metres interval (10 ft) are connected.

V- CONSTRUCTION PROBLEMS

Swimming pool construction normally requires special attention and careful levelling, pipe installations, water tightness and aesthetic considerations.

In the case of Long Beach swimming pool, the construction problems encountered were more than expected. Basically the reason for these problems was the fact that the management of the Long Beach decided to execute the work and do it in their own peculiar fashion, in order to acomplish some savings.

This swimming pool is so laid out that its walking area all around the pool is 15 cms below the general beach level which in its turn is 40 cms below the beach benchmark at the bar (see drawing No. 1). The walking area is 3.15 metres above the low tide sea water level. This means that the bottom of the pool at the deep end is about 1.50m below the sea water level.

Excavation of the large amount of material was particularly difficult because of the nature of the rock, hard sea bed-rock, and because of the mode chosen for its excavation (hand excavation using chisels and hammers). This method was used primarily so that the bathers using the beach would suffer the least disturbance, as the site of pool construction is located at the centre of the Beach Club area. Further, the management did not wish to invite the attention of the municipal police to the works by employing pneumatic jack hammers as they had decided to carry out the work without the necessary permits since the latter was extremely difficult to obtain. The excavation had thus to be carried out in silence and the spoil had to be removed from the job site inobstrusively.

The system of excavation adopted by the management retarted the progress of the work and added to the expense.

At times,and when the opportunity could be siezed, the owners managed to make use of explosives which is also illegal. Although the use of explosives helped in reducing the chisel and hammer work, it led to more serious problems. The rock became fissured, particularly at the deep end of the pool where the bottom is below sea water level. This resulted in sea water seepage. Successful attempts were made to stop the leaks by grouting, but the presence of the seepage water offset any saving that dynamiting may have brought about. It also complicated the casting of the concrete pool floor and walls.

Because of the frequent delays, the work was put off schedule, so much so that the excavation was still incomplete by the time when winter came. Rough sea played havoc with the progress of the work during this season as whenever the sea broke over the beach the pool excavations were filled. It took the only available four-inch pump two days to empty the filled excavation by the rough sea in a few minutes. The risk to the workers during periods of rough sea made the cessation of operations necessary. Any scaffolding that had been put up was naturally washed away. Plastering or tiling work recently completed was partially damaged. This could only further aggravate the work's program and increase cost beyond those anticipated. There was no way of protecting the swimming pool area from the rough sea for, as mentioned previously, the beach site is open to currents and its level is not sufficiently high above the sea level to render it safe from the destructive effects of the waves.

There is a general shortage of labour skilled in such work in the Lebanon. Most of the available skilled labourers are connected with contractors who specialize in this type of work. Unfortunately, the proprietors, in their efforts at saving money, decided to carry out the work themselves and refused to pay wages according to reasonable scales. This prevented them from hiring any reasonably skilled labour available for such work.

As a result of the fact that the proprietors undertook the construction of the pool without the services of a professional contractor, led to a number of problems which they have to face and additional expenses they have to incur unnecessarily. The proprietors learned to their detriment the high cost of their folly.

VI- COST ESTIMATE OF LONG BEACH POOL

Approximate cost estimates are presented here instead of actual construction costs as the latter are not available. The client did not maintain any proper records and employed very poor management in executing the works which resulted in higher costs than would have been met had the work been constructed in a professional manner. The following is a general resume of cost analysis.

Excavation

Rates Generally - The rates for excavation include labour work, removal of debris and carting away of the spoil.

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	Excavation in hard sea bedrock in:				
	1- pool	1520	20	m^3	30400
	2- pump house	50	20	m^3	1000
	3- projector tunnel	30	20	m^3	600
	Carried to collection on page 89				32000

Concrete Work

Rates Generally - The rates for concrete include the supply of ready-mix concrete and transportation to site and for placing, (including mechanically vibrating re-inforced concrete), protecting, curing and forming of construction joints.

The rates for steel reinforcement include the supply and clearing off scale, loose rust, cutting, fabricating and fixing rigidly in position; they also include the provision of all necessary stools, spacers, tying wire scaffolds, etc.

The rates for formwork include the supply, fabricating and fixing rigidly in position complete with all necessary bolting, strutting, striking to removal and cleaning before re-use.

The rates for construction and expansion-contraction joints include the supply of material, fixing in position, and the supply and installation of the sealing compounds for the expansion-contraction joint.

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
A.	Concrete of 3000 psi in:				
	1- pool				

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	a) floor	190	37	m^3	7030
	b) walls	76	40	m^3	3040
	2- projector's tunnels and canal				
	a) footing & floor	16	37	m^3	592
	b) walls	25	40	m^3	1000
	c) slabs	16	39	m^3	624
	3- the foundation of the diving tower	27	37	m^3	999
B.	Ordinary steel reinforcement in:				
	1- pool				
	a) 8m/m	11000	0.5	kgms	5500
	b) 10m/m	500	0.49	kgms	245
	c) 12m/m	3300	0.47	kgms	1541
	d) 16m/m	1000	0.46	kgms	460
	e) 22m/m	7900	0.46	kgms	3634
	2- projector's tunnel and canal				
	a) 6m/m	200	0.52	kgms	104
	b) 8m/m	2000	0.50	kgms	1000
	c) 10m/m	500	0.49	kgms	245
C.	Torsteel reinforcement in:				
	1- diving tower foundation				
	Carried to collection on page 89				26014

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	a) 10m/m	80	0.6	kgms	48
	b) 12m/m	60	0.6	kgms	36
	c) 14m/m	400	0.57	kgms	228
	d) 18m/m	200	0.55	kgms	110
D.	Formwork				
	1- sides of pool walls	409	3.0	m^2	1227
	2- slabs of projector's tunnel and canal	138	3.0	m^2	414
	3- walls of projector's tunnel and canal	260	3.0	m^2	780
E.	Sundries on structural concrete				
	1- form openings of 61 cm in diameter in walls for projectors	32	10.0	No.	320
	2- form openings of 25x25cm in walls for inlets and outlets	28	10.0	No.	280
	3- form openings of 20x40cm in floor of pool	2	10.0	No.	20
	4- cost of treatment of spring water by grouting and maintaining pool floor completely dry	-	-	-	2000
	Carried to collection on page 89				5463

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
F.	Construction and expansion-contraction joints				
	1- 15cm wide rubber for the construction joint	200	10.0	mr	2000
	2- 15cm wide p.v.c. for the expansion-contraction joint complete with the necessary filler and cellotex	26	46.0	mr	1196
G.	Provide the prime cost sum of Lebanese Pounds twelve thousand (L.L. 12000) for the construction of the diving tower complete with stainless steel ladders and hand-rails plus diving boards (provisional)	-	-	-	12000
	Carried to collection on page 89				15196

Blocklayer

Rates Generally - The rates include the supply, cutting, bending, wedging and pinning up.

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	Cement and sand vibrated hollow block-work in cement mortar in 20cm thick walling in projector's tunnel at pump house	92	7.0	m^2	644
	Carried to collection on page 89				644

Pavior

Rates Generally - The rates include the supply, laying to falls as required, cutting, fitting around pipes, projector's openings and at expension joint as well as intersection of planes. Also include executing work in narrow widths, edges and around corners.

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	Ceramic tiles				
	1- 10x10cm floor and wall tiles on and including 3cm cement and sand (1:4)	1422	21.0	m^2	29862
	2- 2x2cm ditto in gutters & walk area	492	21.0	m^2	10332
	Carried to collection on page 89				40194

Plasterer

Rates Generally - The rates for plastering, screeds, rendering, etc... include raking and joints, spraying slurry on new concrete surfaces, to form key, forming around holes and pipes.

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	15mm thick plain face cement and sand rendering in two coats as described on walls of swimming pool and existing tunnel blockwall	600	2.20	m^2	1320
	Carried to collection on page 89				1320

Electrical

Rates Generally - The rates include the supply and installation of 32 projectors each of 110 volts, 50 cycles and powered by 1500 watt lamp, complete with concentrating mirror glass reflector and diffusing front glass, with a separate cast bronze water-tight frame with toughened glass and a sealing compound. The rates also include all necessary wiring, junction boxes circuit brakers, etc.

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	1- projectors	32	680	No.	21760
	2- provide the prime cost sum of Lebanese Pounds seven thousand (L.L.7000) for the supply and installation of wiring, junction boxes circuit breakers, etc.. (provisional)	-	-	-	7000
	Carried to collection on page 89				28760

Mechanical

Rates Generally - The rates include the supply and installation of three vertical centrifugal pumps complete with their motors and fittings. The rates also include the supply, cutting, laying properly to falls as required, well supported and fixed in position of all piping and fittings.

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
A.	Vertical centrifugal pumps				
	1- circulating pumps				

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	each delivering 1000 gpm under a total dynamic head of 25ft with stainless steel impeller 10 hp electrical motor of 380 volts 3 phase, 50 cycles and including a space heater	2	4900	No.	9800
	2- pool emptying pump delivering 2000 gpm under a total dynamic head of 28ft. Ditto but 20 hp motor ditto	1	5950	No.	5950
B.	Pipes and fittings, of six atmospheres test pressure				
	1- from scum gutters to canal				
	a) 50mm diameter A.C. pipe 200 cm long	16	7.0	No.	112
	b) 50mm diameter C.I 90° bend	16	9.0	No.	144
	c) 50mm A.C. reka joints	48	1.25	No.	59
	Carried to collection on page 89				16065

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	2- from scum gutters to 150mm diameter drain in existing projector's tunnel				
	a) 150mm diameter A.C. pipes	40	9.0	mr	360
	b) 50mm ditto	13	4.0	mr	52
	c) 50mm ditto but 20cm long	16	1.50	No.	24
	d) 50mm ditto 25cm long	16	1.50	No.	24
	e) 50mm ditto 95cm long	16	4.0	No.	64
	f) 150mm A.C. reka joints	32	4.0	No.	128
	g) 50mm ditto	144	1.25	No.	180
	h) 150x150x50mm C.1 tee	16	35.0	No.	560
	i) 50x50x50mm ditto	16	12.0	No.	192
	j) 50mm diameter C.1 90° bend	32	9.0	No.	288
	k) 150mm diameter C.1 end plug	1	20.0	No.	20
	3- From pool outlets to sea				
	a) 300mm diameter A.C. pipe	10	28.4	mr	284
	b) 250mm diameter A.C. pipe 125cm long	10	25.5	No.	255
	Carried to collection on page 89				2431

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	c) 250mm ditto 35cm long	2	15.5	No.	31
	d) 75mm ditto 40cm long	12	2.0	No.	24
	e) 300mm A.C. reka joints	5	10.0	No.	50
	f) 250mm ditto	27	9.0	No.	243
	g) 75mm ditto	12	1.5	No.	18
	h) 300mm C.1 gate valve	1	468.0	No.	468
	i) 300x250mm C.1 reducer	1	80.0	No.	80
	j) 250x250x250mm C.1 tee	1	93.0	No.	93
	k) 250x250x75mm ditto	12	80.0	No.	960
	l) 250mm diameter C.1 end plug	2	42.0	No.	84
	4- From pumps to pool inlets				
	a) 250mm diameter A.C. pipe	22	20.0	mr	440
	b) 200mm diameter A.C. pipe 75cm long	2	11.0	No.	22
	c) 150mm diameter A.C. pipe 250cm long	12	22.0	No.	264
	d) ditto 100cm long	2	9.0	No.	18
	Carried to collection on page 89				2795

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	e) 75mm diameter A.C. pipe 40cm long	16	2.0	No.	32
	f) 250mm A.C. reka joints	9	9.0	No.	81
	g) 200mm ditto	5	6.8	No.	34
	h) 150mm ditto	38	4.0	No.	152
	i) 75mm ditto	16	1.5	No.	24
	j) 250x250x200mm C.I. wye with two flanges, one on main line and one on branch	1	118.0	No.	118
	k) 250x200m C.I. flanged reducer	1	50.0	No.	50
	l) 200mm C.I. flanged check valves	2	275.0	No.	550
	m) 250mm diameter C.I. flange pipe 46.5 cm long	1	60.0	No.	60
	n) 200 ditto 26.5cm long	1	50.0	No.	50
	o) 250mm diameter C.I. 45° bend	2	69.0	No.	138
	p) 250x200mm C.I. reducer	1	52.0	No.	52
	q) 200x150mm ditto	2	35.0	No.	70
	r) 200x200x200mm C.I. tee	1	70.0	No.	70
	Carried to collection on page 89				1481

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	s) 150x150x150mm ditto	2	44.0	No.	88
	t) 150x150x75mm ditto	16	37.0	No.	592
	u) 150mm diameter C.I. end plug	4	20.0	No.	80
	5- From pool floor drains to sea				
	a) 250mm diameter A.C. pipe	32	20.0	mr	640
	b) 150mm ditto 250cm long	2	22.0	No.	44
	c) 250mm A.C. reka joints	11	9.0	No.	99
	d) 150mm ditto	5	4.0	No.	20
	e) 250mm diameter C.I. 90° bend	1	90.0	No.	90
	f) 150mm ditto	2	38.0	No.	76
	g) 250x150mm C.I. reducer	1	42.0	No.	42
	h) 150x150x150mm C.I. tee	1	44.0	No.	44
	i) 250mm diameter C.I. 45° bend	2	69.0	No.	138
	j) 250x250x250mm C.I. tee, with two flanges, one on main line and one on branch	1	160.0	No.	160
	Carried to collection on page 89				2113

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	k) ditto but with three flanges	1	172.0	No.	172
	l) 250mm diameter C.I. flanged 90^{o} bend	1	120.0	No.	120
	m) 200mm ditto	1	95.0	No.	95
	n) 250mm C.I. flanged gate valve	1	325.0	No.	325
	o) 200mm C.I. flanged gate valve	1	230.0	No.	230
	p) 250x200mm C.I. flanged reducer	1	90.0	No.	90
	q) 250mm diameter C.I. pipe 15cm long, with one flange on one side and male thread on the other	1	155.0	No.	155
	r) 250mm diameter C.I. pipe 25cm long with one flange on one side and plain end at the other	1	63.0	No.	63
	s) 200mm diameter C.I. flanged pipe 93.5cm long	1	250.0	No.	250
	t) 200mm diameter C.I. flanged pipe 75cm long	1	80.0	No.	80
	Carried to collection on page 89				1580

Item No.	Description	Estimated quantity	Rate L.L.	Unit	Amount L.L.
	6- Miscellaneous				
	a) 300mm diameter C.I. flanged pipe 200cm long	3	750.0		2250
	b) stainless steel ladder for pool	6	800.0	No.	4800
	c) 75mm diameter special bronze pool inlets and outlets with face chrome finished	28	80.0	No.	2240
	d) 20x40cm bronze grille cover for pool floor drains	2	125.0	No.	250
	e) 10cm diameter bronze grille cover for scum gutter outlets with face chrome finished	32	8.0	No.	256
	Carried to collection on page 89				9796

COLLECTION

Page 74	....	L.L. 32000
Page 76	....	L.L. 26014
Page 77	....	L.L. 5463
Page 78	....	L.L. 15196
Page 79	....	L.L. 644
Page 79	....	L.L. 40194
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Page 81	....	L.L. 28760
Page 82	....	L.L. 16065
Page 83	....	L.L. 2431
Page 84	....	L.L. 2795
Page 85	....	L.L. 1481
Page 86	....	L.L. 2113
Page 87	....	L.L. 1580
Page 88	....	L.L. 9796
	Total:	L.L.185852

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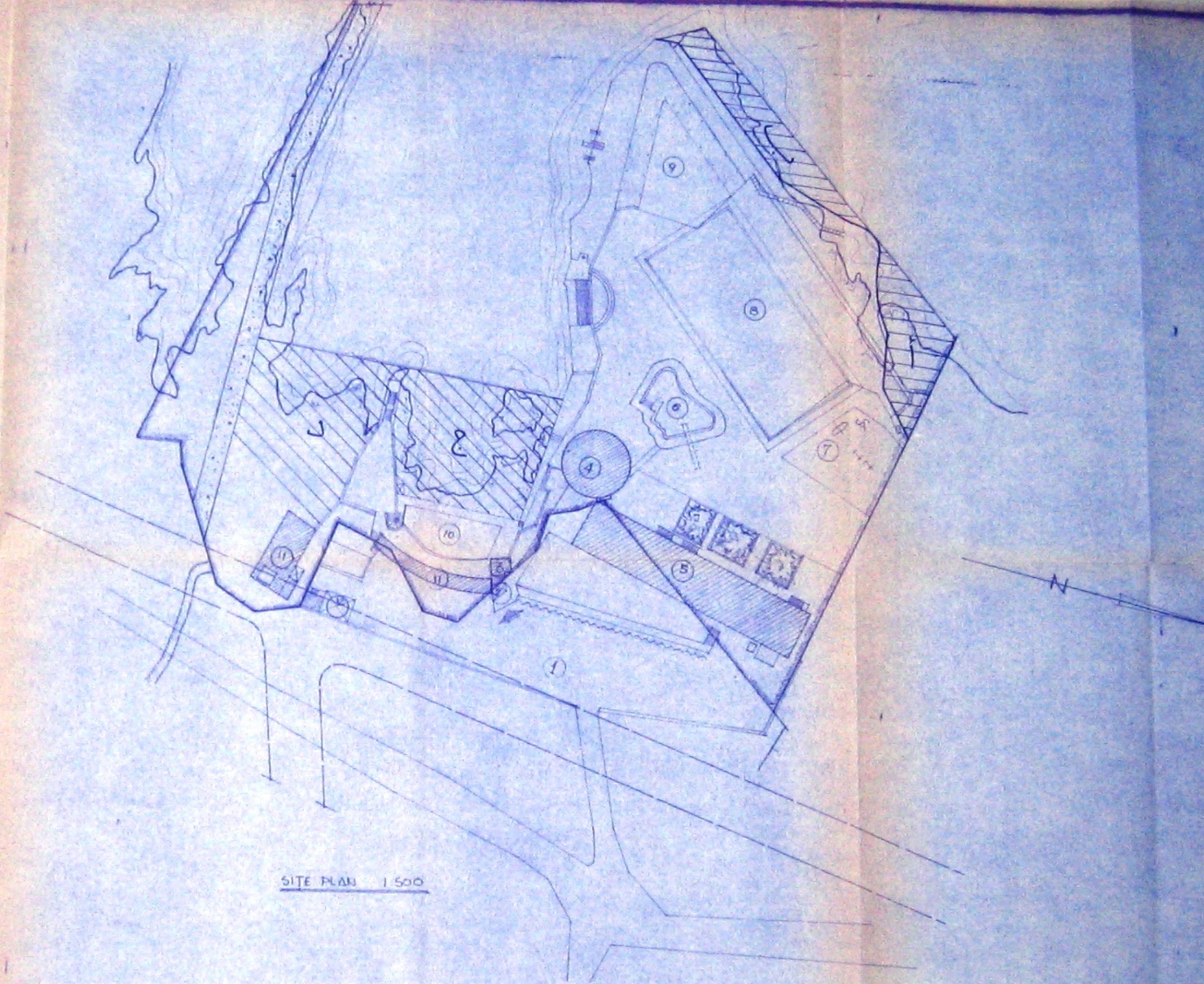
LOCATION PLAN 1:5000

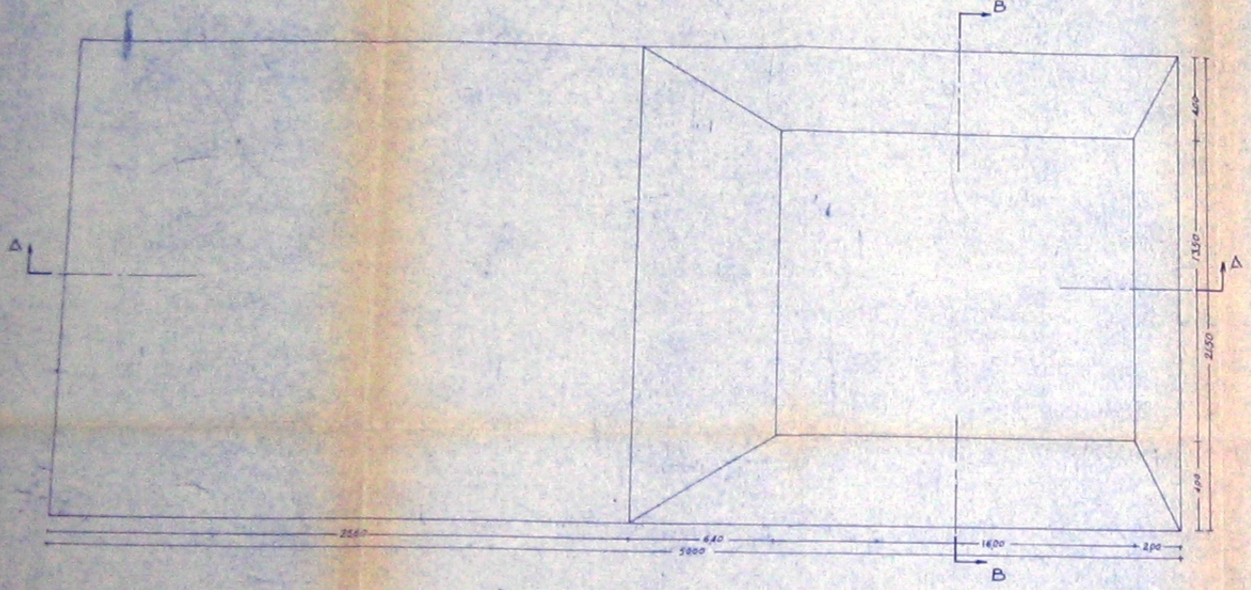


SITE PLAN 1:500

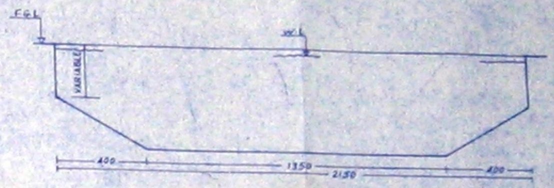
LEGEND.

1. ENTRANCE & PARKING.
2. TELEPHONE BOOTH
3. OFFICE
4. BAR
5. CABINS
6. SWIMMING POOL FOR CHILDREN.
7. CHILDRENS PLAY GROUND.
8. SWIMMING POOL (UNDER CONSTRUCTION).
9. TERRACE
10. SWIMMING POOL (EXISTING).
11. CABINS
12. KITCHEN.

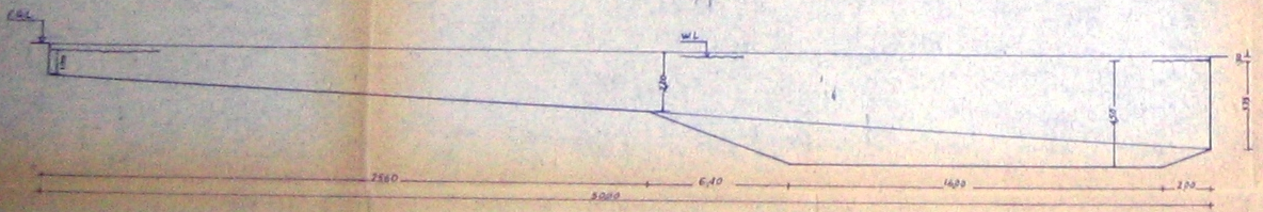
DRWG № 1



PLAN

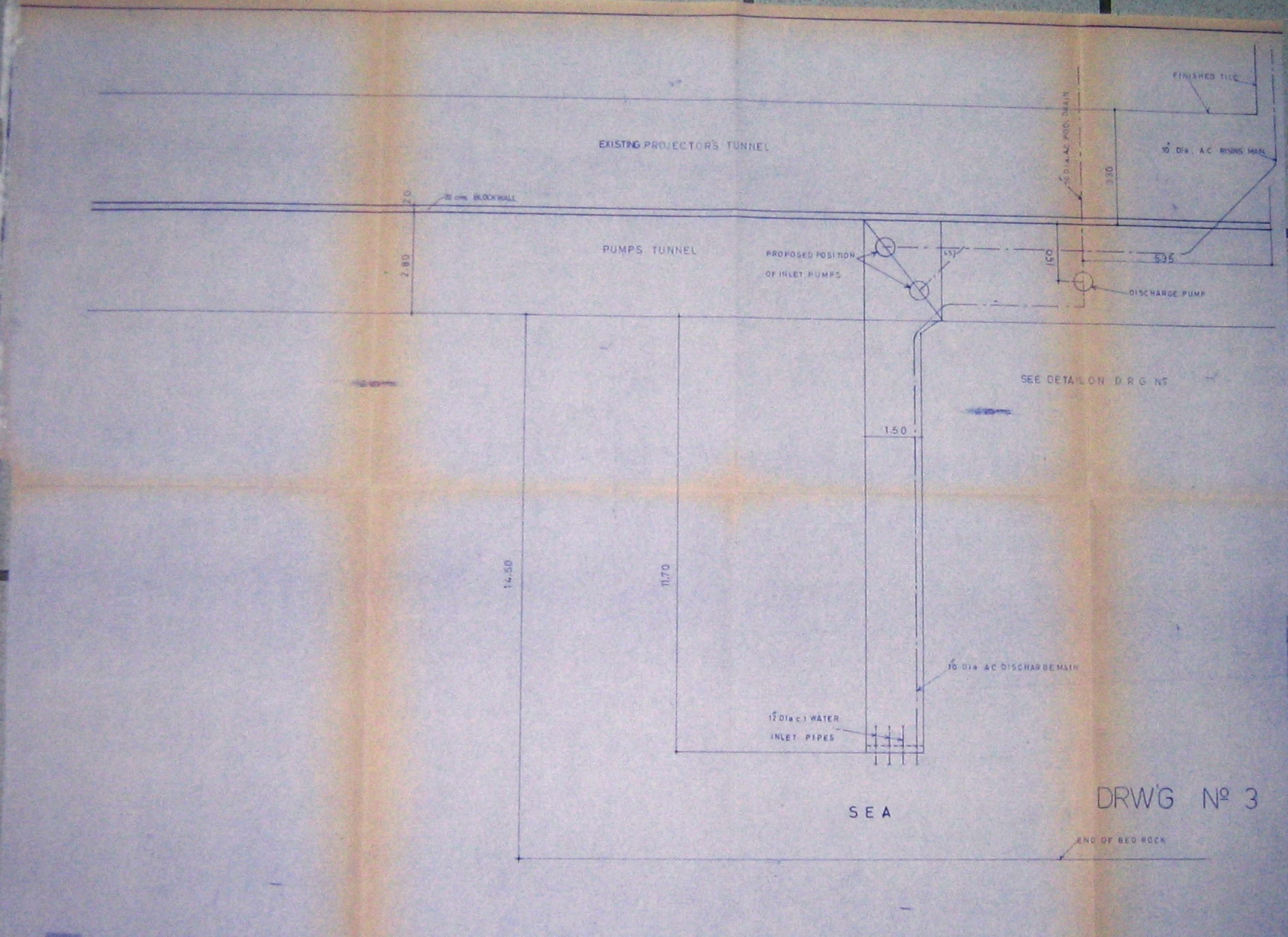


SECTION B.B

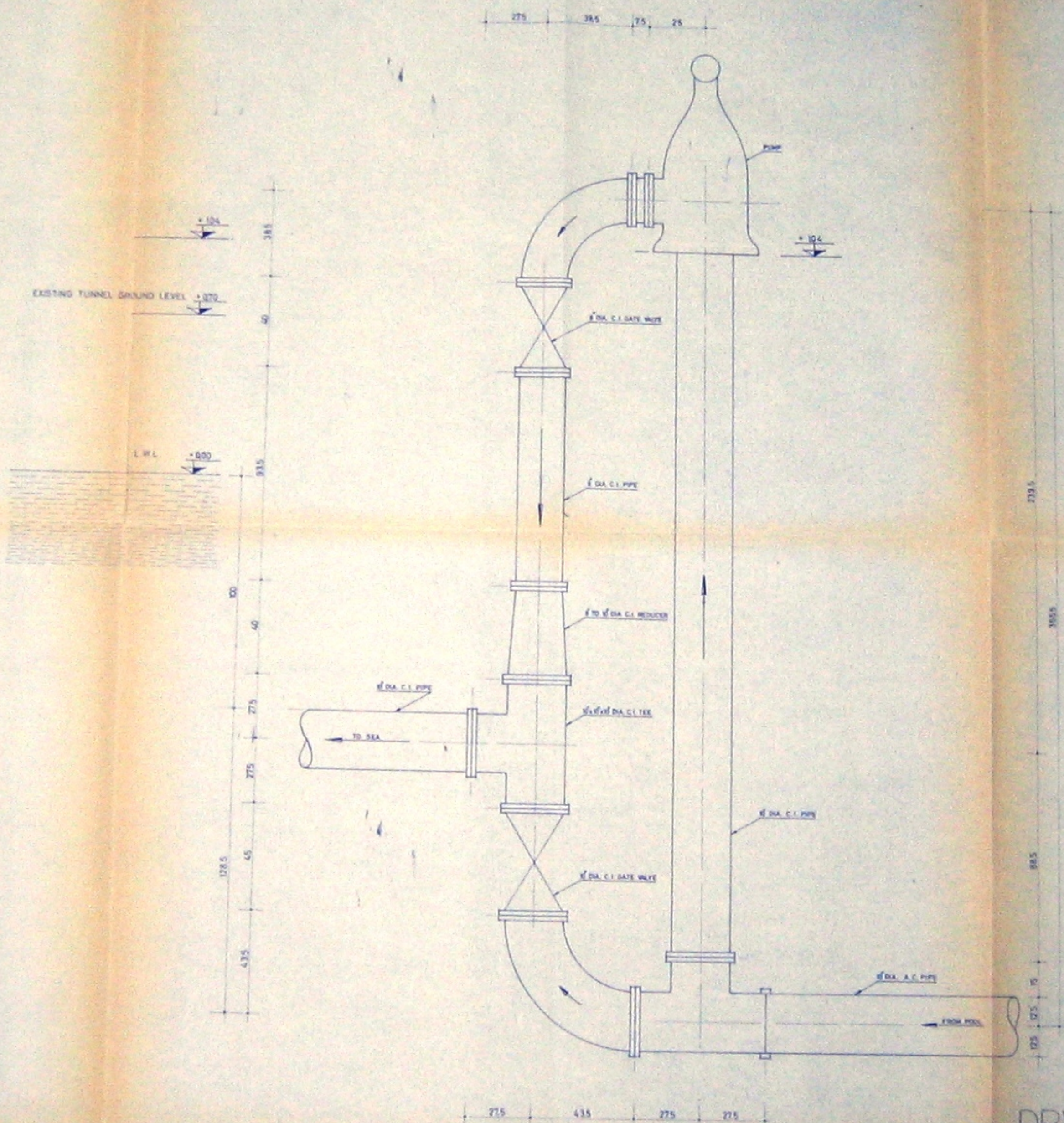


SECTION A.A

DRWG № 2

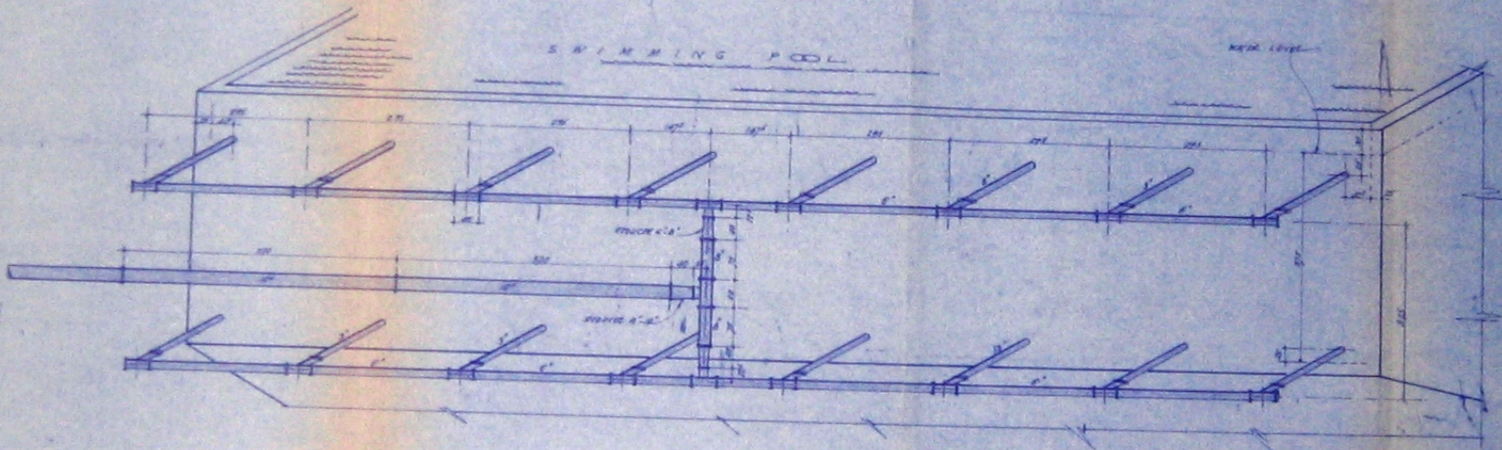

EXISTING PROJECTOR'S TUNNEL
FINISHED TILE
10" Dia. A.C. RISING MAIN
330
20 cms BLOCKWALL
20
PUMPS TUNNEL
2.80
PROPOSED POSITION
OF INLET PUMPS
45
160
535
DISCHARGE PUMP
SEE DETAIL ON D R G No.
1.50
14.50
11.70
10" Dia. AC DISCHARGE MAIN
12" Dia. c.i. WATER
INLET PIPES
SEA
END OF BED ROCK

DRW'G Nº 3

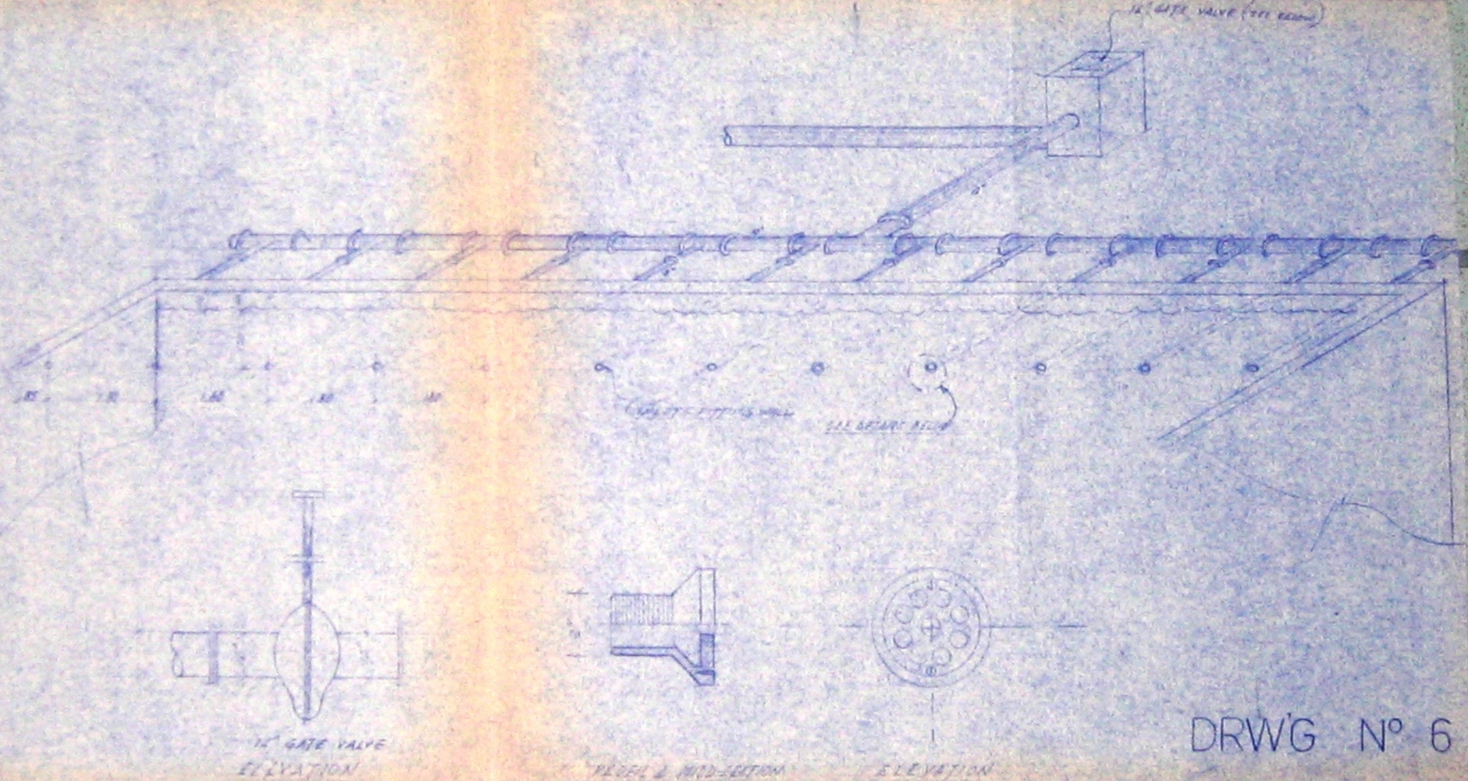


275
38.5
7.5
25
PUMP
+104
EXISTING TUNNEL GROUND LEVEL
L.W.L.
DIA. C.I. GATE VALVE
DIA. C.I. PIPE
DIA. C.I. REDUCER
DIA. C.I. TEE
TO SEA
FROM POOL
DIA. A.C. PIPE
38.5
93.5
100
50
27.5
27.5
128.5
45
43.5
273.5
355.5
88.5
15
17.5
17.5
12.5
27.5
43.5
27.5
27.5

DRW'G № 4

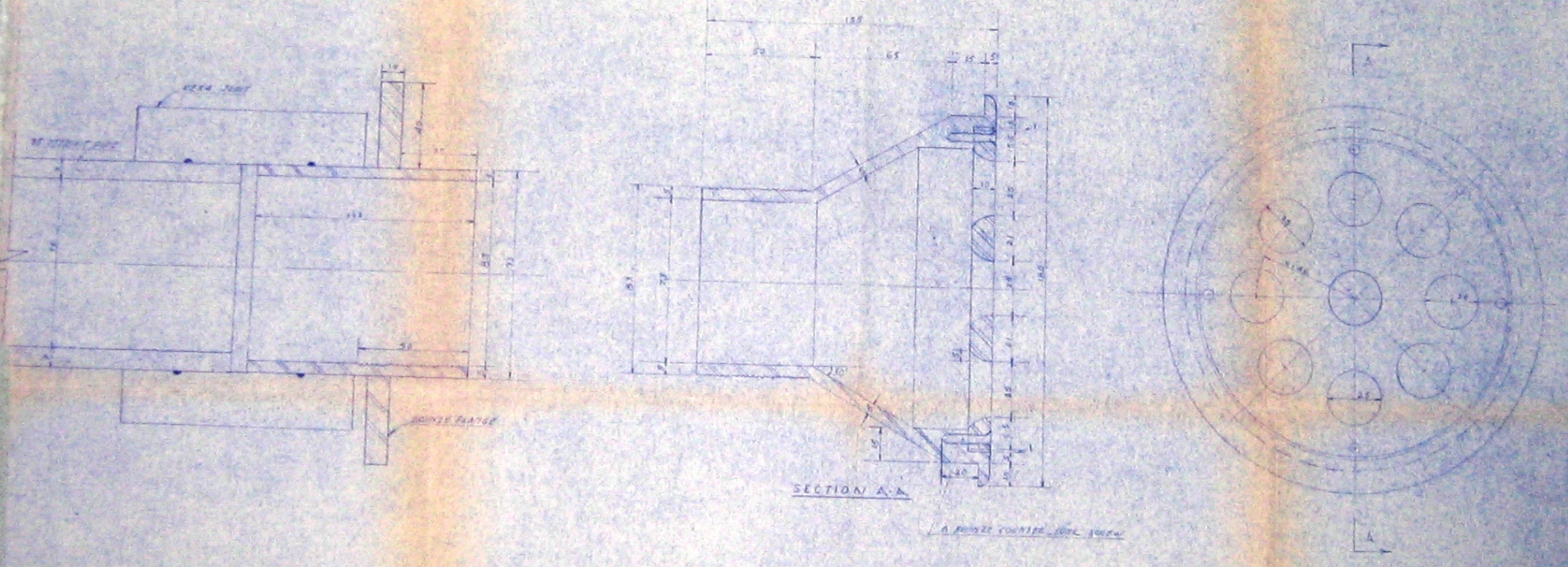


DRWG Nº 5

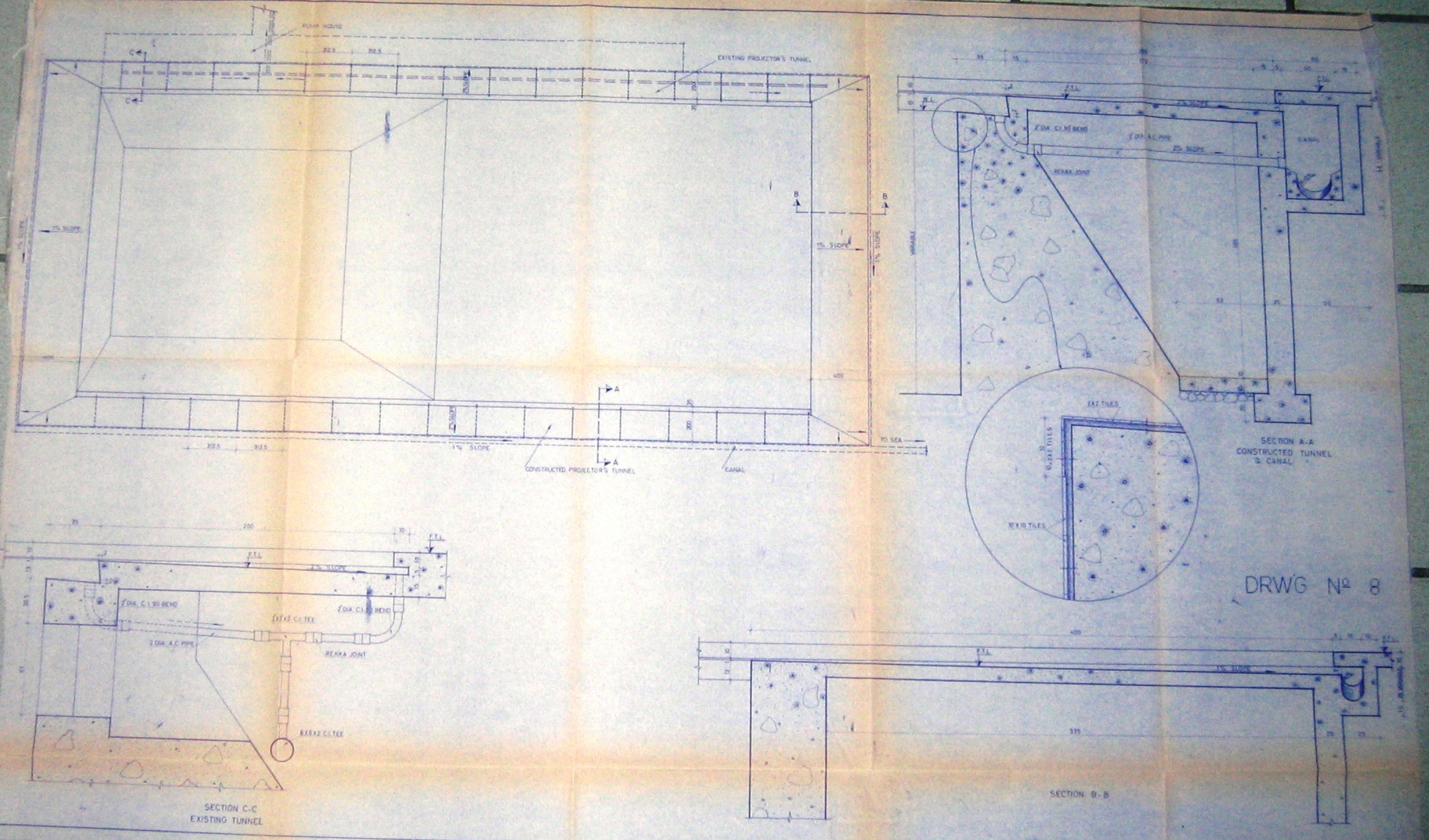


DRWG Nº 6

INLET FITTING WALL TYPE



DRWG Nº 7


PUMP HOUSE
EXISTING PROJECTOR'S TUNNEL
CONSTRUCTED PROJECTOR'S TUNNEL
CANAL
TO SEA
1% SLOPE
SECTION A-A
CONSTRUCTED TUNNEL
& CANAL
SECTION B-B
SECTION C-C
EXISTING TUNNEL
REKKA JOINT
F.T.L.
DRWG Nº 8