DIATOMACEOUS EARTH FILTERS FOR SWIMMING POOLS

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Before the adaptation of diatomaceous earth filters to the field of water filtration, they had been used quite widely in various industrial processes. The petroleum and cloth-cleaning industries were using diatomite successfully in removing difficultly separable solids from process liquids, and the beverage industry recognized that a diatomite filter could put a very high polish and sparkle on water used in its products. During World War II, the Army undertook to extend the usefulness of the tiny prehistoric skeletons to aid in the preparation of drinking water from questionable sources for troops in the field. Contrary to most industrial uses, where diatomaceous earth was placed between elements of cloth filter presses, the Army directed its efforts toward the use of a steel-shell, pressure-type filter in order to allow greater filtration rates and more rugged use. Near the end of the war the Army let its "skeletons" out of the closet of secrecy and opened the way for commercial development of diatomite filters in the water treatment field.

Filter companies eagerly seized upon the opportunity thus offered and, with little or no further refinement, promptly announced to the swimming pool world that a new star was in its sky. The considerable advantages of the new filter's ability to produce a clearer effluent than sand filters and the small space required for an installation were cited Many of the filter companies sought even an additional advantage over the sand filter by increasing the filtration rates. Several types of elements, adaptations of those developed by the Army for other purposes, were offered the swimming public. These included wire-wound plastic cores, wire-wound steel cores, screen-mesh cylinders, sintered stone, sintered brass and all-plastic elements.

During the winter of 1946, the first diatomaceous earth filter to be used for swimming pool water filtration in the District of Columbia was installed in an indoor pool used throughout the year. There are now six installations of diatomite filters of the wire wound and wire mesh element types in both indoor and outdoor pools in the District. Three of these are in federally owned pools whose health jurisdiction lies with the U. S. Public Health Service. Due to the very close liaison between the U. S. Public Health Service and the District Health Department, the operation of the pools has been treated as a mutual problem with decisions being made jointly. In the seven years of experience with these filters some major difficulties have developed. It is the purpose of this paper to indicate weaknesses in design and operation of diatomaceous earth filters within the authors' personal experience. Nothing contained herein should be construed as a reflection on the ability of a properly designed and constructed diatomaceous earth filter to produce, under good operational control, a highly desirable effluent, nor the ability of the manufacturers to produce such equipment. In the following paragraphs the difficulties experienced with diatomite filters in the District of Columbia will be discussed. The various failures and troubles will be considered in order of the resultant seriousness of consequences.

During the middle of last summer it was noticed that the filtered water in one of the large outdoor pools was turbid. The pool was in its third year of using diatomaceous earth filters having elements made

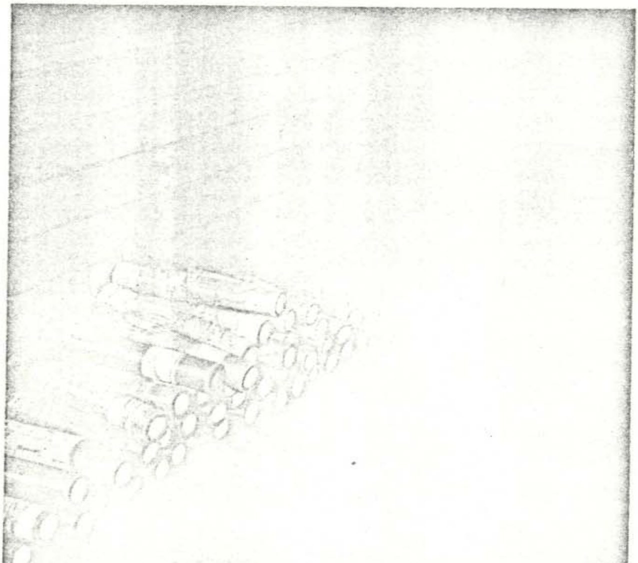

FIGURE 1

of plastic cores wound with monel wire. An inspection of the filters through the sight glasses revealed pieces of wire against the glass of one of the filters. The filters were torn down and examined. A great many of the elements showed broken wire, and large amounts of wire were found on the bottom of the filter shells. Failure of the elements had allowed diatomite to carry over into the pool resulting in the high turbidity. Inspection revealed that approximately 100 of the total of 300 elements in the three filters has failed in this manner, Figure 1.

Concern immediately arose over the condition of an identical installation in a pool across town. An inspection was made, and the similar type and degree of element deterioration was found. The Public Health Service submitted sample elements from both installations to the National Bureau of Standards for study. Despite the non-corrosive characteristic of monel, microscopic examination of the wire revealed countless cases of monocellular, or "pinpoint," corrosion. In each case, the corrosion started as a dot on the surface of the wire in contact with the element core. The corrosive action, galvanic in nature, continued until a tiny hole was made severing the wire which then unwound from the core and failure occurred.

Samples of the elements were also taken to the Engineer Research and Development Laboratories at Fort Belvoir where pioneer work on the diatomite filter had been and still is being conducted. The examination concurred in the findings of the Bureau of Standards. Some limited laboratory studies were conducted and it was found that dirty elements corroded more rapidly than clean ones. The corrosion appeared to be caused by the moisture retained by the foreign matter on the elements rather than by the foreign matter itself. The release of gases from the water during filtration was found to stimulate corrosion as did the presence of "excessive" chlorine residuals.

Additional corrosion had occurred when some of the elements had come in contact with the filter shells. This was due to poor design which placed the elements in the filters in vertical columns of three elements each. The ratio of length to the radius of gyration thus created was so great that the elements were in constant vibration when in use. Either the original alignment was poor or the vibration altered it until some of the elements came in contact with the shells. The vibration may also have advanced the time of failure by inducing fatigue in the metal at stress points provided by the corrosion.

The element cores were plastic cylinders milled parallel to the diameter and fluted lengthwise. The wire is wrapped around the cylinder in the milled grooves and crimped into brass collars at both ends of the core. The dimensions of the fluted grooves, although critical for proper filtration, varied considerably apparently due to the method of production. In numerous cases the wire had torn loose from the crimping at the collar and spalled off the core. Even a high percentage of new elements shipped by the filter company to replace the broken ones arrived in this condition, Figure 2.

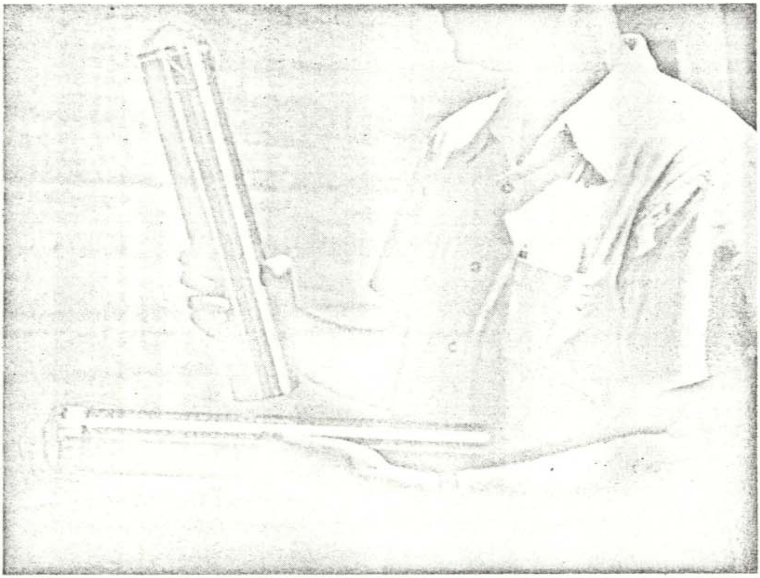

FIGURE 2

Not all of the difficulties are inherent in the filters themselves. Some are built into the job. Straining to put the filters back in operation in answer to silent throngs of saddened neighborhood children, workmen soon discovered that the ceiling slab, poured after the filters were installed, was too low to permit removing the elements through the top of the shell. The access manhole in the tank sheet was too small and it was only with great difficulty and working in cramped positions that the workmen maneuvered the elements through this portal.

Failure also occurred last summer at one of the outdoor pools using the wire-mesh screen element. Very short filter runs were experienced. The filters were disassembled and examined. These elements consist of two concentric cylinders of wire mesh. Water is filtered through both cylinders toward the space between them. In this way almost double the filter area is obtained per element. It was found that the inside cylinder was packed solid with dirt and diatomite for the entire length of the element. The compaction was so tight that the blade of a penknife could not be pushed into it manually. Obviously no water was being filtered by the inner screen. The outer screen was also badly clogged resulting in a considerable reduction of effective filter area. Each element had to be removed and hand cleaned. The elements were fragile and many dents were made in them. The construction was not rugged enough to permit even careful cleaning.

The diatomite elements used in the first installation in 1946 have performed satisfactorily under conditions of year-round swimming pool use. They are stainless-steel wire on stainless-steel cores. The original filter shells were of stainless steel also. The shells, however, failed at the welds due to bi-metal corrosion and had to be replaced. Steel was substituted due to the scarcity of stainless steel at the time. These shells, too, corroded and were subsequently replaced with new stainless ones.

Corrosion is one of the primary difficulties associated with the failure of diatomite filters. This is not due to any accelerated rate of corrosion peculiar to diatomite filters, but to the structural characteristics of the design. While other types of filter equipment will also corrode, this condition will not cause early failure due to the greater thickness of metals used. For example, an amount of corrosion inconsequential to other types of filter equipment will be sufficient to sever the thin wire or mesh in a diatomite element. Additional corrosion occurred whenever dissimilar metals were joined. The fact that diatomite filters have been assembled of many finely-machined parts, provided many opportunities for this to occur. Even with carefully designed diatomite filters it has always been necessary to join dissimilar metals. This generally occurred at the point where the relatively corrosion-resistant metal used in the filter elements met the baser metal of the filter header or circulation system plumbing. The two metals exert different electric potentials which give rise to minute but persistent currents. Preventing corrosion at these points is a difficult matter.

Filter rooms are generally cellar rooms or dark underground pits, the walls, ceilings and piping of which are covered with condensation. This constantly moist condition is a catalyst to the ever-present corrosive action. Of particular importance in this connection is the off-season storage preparation or "winterizing" of filters. In pools that shut down seasonally, it is undoubtedly true that much of the corrosive damage occurs during the dormant period when filter shells and elements are drained and in moist contact with air.

Equally important is the problem of obtaining adequate backwash. Experience with and close examination of the wire-wound and screen-mesh installations described above, shows definitely that such elements cannot be properly cleaned by the usual backwash procedures but must be disassembled and scrubbed by hand. Experience and experiment had shown that a backwash rate of 5 to 10 times the filter rate, depending on temperature conditions, was satisfactory for sand filters. For no logical reason this ratio, and less, was used for diatomite filters. The washing problems of the diatomite filter are entirely different from those of the sand filter. There is no "schmutzedecke" formed by a coagulant to entrap the solids on the filter surface. Instead, except for a thin pre-coat, the filter media is completely mixed with the dirt and grease it is removing. In swimming pools this grease, coming from cosmetics and body oils, acts as a binder, penetrates the pre-coat and very tenaceously holds moisture and foreign material to the filter elements. At swimming pools used seasonally the stage is thus set for corrosion due to the presence of moisture and air during "out-of-service" periods. In addition the adhering foreign matter clogs the elements, reducing the effective filter area, increasing the head loss and further hindering backwash. This cycle thus aggravates itself.

Because of the difficulties with backwash problems, the Army has experimented with compressed air. Propelled by air compressed inside the filter shell, a small amount of water is forced through the elements at high backwash rates. A quick-opening valve suddenly releases the pressure on the influent side of the filter elements with the result that the air compressed in the effluent side forces water through the elements. The high backwash rate exists for only a fraction of a second and is then followed by conventional washing. Momentary peak backwash rates as high as 4000 gpm per square foot have been induced. There is some evidence that satisfactory backwash rates for diatomaceous earth swimming pool filters may be obtained at 100 or 200 times the filter rate—a far cry from 5 or 10 times the rate! The elements must be sturdily built to withstand the shock but experimental ones have done so satisfactorily at even the 4000 gpm per square foot rate. One of the commercial filter companies now has on the market a diatomite filter utilizing a mechanical compressor to produce an air-bump backwash. Such an installation is being completed in the District of Columbia at the present time.

The operation of a diatomaceous earth filter depends on constant body feed of diatomite slurry. Experience in the District of Columbia has shown that true diatomaceous earth is the only satisfactory material available for this use. During the shortage of that material last year several substitute types of filter-aid materials were used. Such products are usually fines which are by-products of the manufacture of construction materials. As available they have no uniformity of particle size and a high proportion of the material is finer than useful diatomite. Much difficulty was encountered due to the fact that these fines carried through to the pool and produced dangerous turbidities. Several times pools had to be shut down until the condition could be corrected by continuous circulation of the pool water through the filters.

Until now all of the evils discussed have been mechanical in nature. There is one other factor whose importance cannot be overemphasized, the pool operator. A good operator can make a very inferior pool perform superbly, while an unskilled operator can be handed the finest installation that can be designed and still not produce satisfactory results. Under his "care" the installation may deteriorate in a season or two. No amount of mechanical ingenuity can substitute for a well-trained operator who wants to make his pool work. This is equally true of sand filters or any type of installation in the water or sewage works field.

Surely there must be some cures for the failings discussed. The approaches to many of the problems are now readily discernable. Filter elements should be designed from the point of view that they are to be used in swimming pools and to meet specific problems thus posed. Elements should be carefully manufactured and each filter installation should be specifically tailored to the local conditions. Specifications should be rigidly written for each installation.

Backwash rates must be greatly increased. The air-bump backwash holds promise of meeting this need. The possibility of the use of spray jets as a cleaning mechanism should be thoroughly explored.

Corrosion problems can be better controlled by reducing to a minimum the use of dissimilar metals. It may be possible to join dissimilar metals, where necessary, by means of a union made of a non-conductor. Wherever practicable filter rooms should be built above ground and well ventilated to prevent continual dampness. For seasonally operated pools it may be desirable to disassemble diatomaceous earth filters at the end of each season, manually clean the elements, wrap them protectively and store them in a dry place. The possibility of maintaining the filter in a flooded condition might be investigated as an alternate. Certainly all filters should be opened and carefully inspected at least once a year. The installation should be designed to make this an easy task.

Operators must be thoroughly trained in the operation and care of their equipment. Through routine inspection and maintenance many troubles can be detected and corrected at their onset.

A recent development in diatomite filters may go far towards solving both the backwash and corrosion problems. This is the so-called "tray filter". The tray filter is basically different from other diatomite filters in that it utilizes sand as the filter element. The filter consists of three or more shallow horizontal trays aligned vertically inside a conventional steel shell. The trays contain approximately one inch of sand which leaves a freeboard of slightly more than one-half an inch. In operation the sand is pre-coated with diatomite and a slurry is continuously fed. Each tray has an underdrain system below it which collects filtered water. The trays are washed one at a time through the individual underdrain systems. The sand expands and dislodges the diatomite which is wasted, but the sand is retained. Thus there are no metal or plastic elements to clog, break or corrode. The need for very high backwash rates is eliminated. At the present time there is only one commercial installation of this type in the country. It is hoped, however, that one will soon be installed at a pool in the District of Columbia so that it can be closely observed.

Many extremely pertinent questions still remain unanswered. One of these is of fundamental importance to all installations. What should be the allowable design rate of filtration? Experts differ sharply on this issue. Although much work has been done more is needed before agreement can be reached. The rates variously accepted range from 2 gpm per square foot up to 5 or more gpm per square foot of filter surface. There is difference of opinion concerning what are the health and mechanical significance of filtration rates. Part of the answer certainly lies in the economic considerations of pumping costs versus installation and amortization costs.

Summary

In our experience with diatomaceous earth filters in the District of Columbia we have encountered failure due to: corrosion of elements; poor installation; poor design and manufacture of elements; insufficient cleaning during backwash; corrosion of filter shells; lack of proper filter aid material; and lack of good operation. These factors may act singly or in combination to produce faulty operation or complete shutdown. When first installed the filters have generally given satisfactory service. Difficulties have been experienced in the con-

tinuity of service. In many instances the "good-service life" has been entirely too short. At the first sign of trouble it is usually too late to correct the condition by a change in operation as structural damage has resulted. Some of these ills can be solved by present knowledge. Further study is required for other problems. In seasonal pools the filters should be carefully winterized to afford protection. It is good practice to open the filters and make a careful inspection at least once a year. Good operation by trained personnel is essential for maximum filter life and satisfactory results.