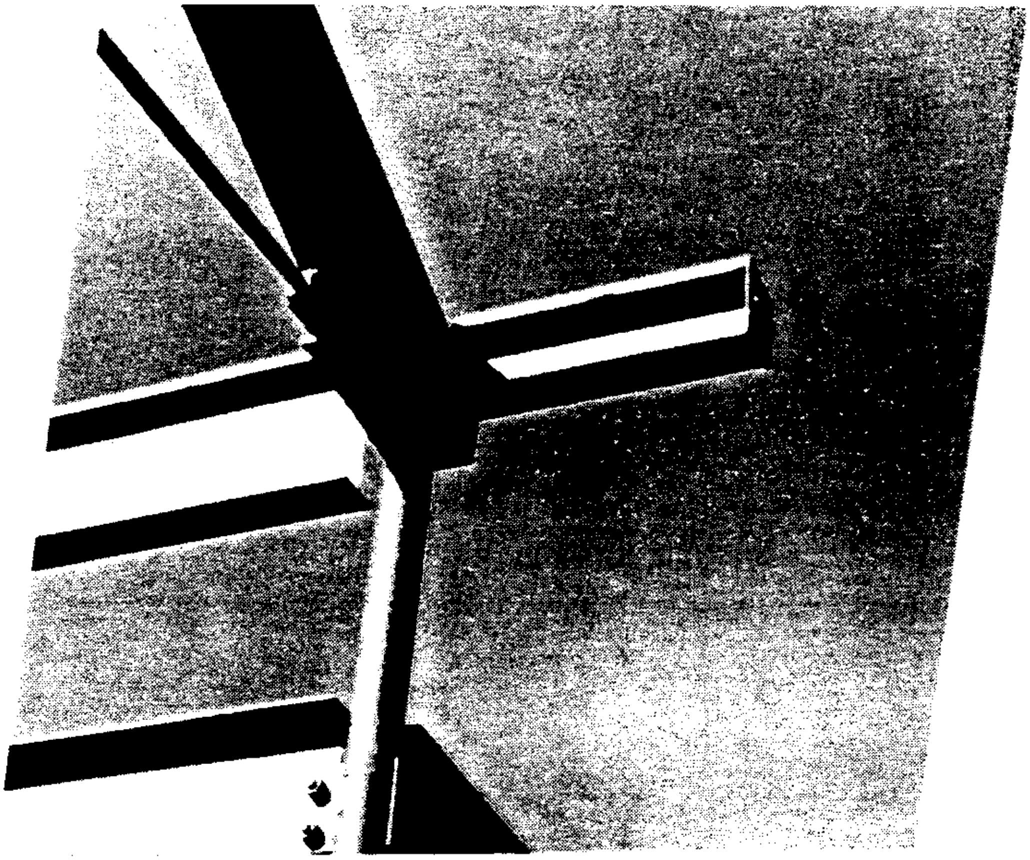
TECHNICAL PUBLICATION NO. 74

A STUDY OF MARCITE (PLASTER) DETERIORATION IN SWIMMING POOLS

Sponsored by the Building Construction Industry Advisory Committee under a grant from the State of Florida Department of Education, the Florida Region VII Council of the National Spa and Pool Institute, the University of Florida, and the National Spa and Pool Institute



Principal Investigator: E. Dow Whitney
Principal Investigator: Brisbane H. Brown, Jr.

M. E. Rinker, Sr., School of Building Construction
and
College of Engineering - Department of Materials Science and Engineering

1991

Executive Summary

Florida enjoys eighteen percent of the world swimming pool market, larger than California and Hawaii combined. Not surprising since a swimming pool is part of the "Florida life style" and is no longer considered a luxury item. However, over the past few years the pool industry has been plagued by a number of problems involving marcite (plaster) coated pools. These problems include all types of blemishes, etching, mottling and discoloration of marcite pool linings. Although these problems have been investigated for several years no single consensus has been developed as to their cause and consequently what preventative measures to take. Mechanisms responsible for the surface deterioration of marcite remained unknown.

Totally baffled and discouraged, the National Spa and Pool Institute Region VII (Florida) Council formed the Plaster/Marcite Committee in 1988 to seek out the problems that were besieging the industry and to come up with a solution. In the Spring of 1989 three research projects were started, funded by the Building Construction Industry Advisory Committee, a research grant committee operating under the Florida Department of Education, the National Spa and Pool Institute and the University of Florida.

The research program involved both mechanistic studies of marcite corrosion under controlled laboratory conditions as well as field diagnostic studies wherein petrographic, scanning electron microscopic (including energy dispersive X-ray spectroscopy) and X-ray diffraction phase analysis of healthy and deteriorated plaster from actual swimming pools were conducted.

From this study it was shown that deterioration of marcite (including both etching, pitting and staining) is chemically related and is primarily due to leaching of calcium hydroxide (portlandite) from the portland cement paste. The calcite aggregate in the cement does not appear to be particularly affected by the leaching process.

Water chemistry plays a major role in both leaching and staining of marcite. Aggressive pool water; i.e., water that has not been properly "balanced" chemically from the instant the freshly marcited pool is first filled can wreak havoc on marcite and pool plumbing resulting in etching and staining.

Recommendations are given for proper control of water chemistry as well as mitigating chemical attack by protecting the marcite surface with suitable chemical barrier coatings and the use of additives to the cement to chemically interact with the calcium hydroxide component of the cement paste in order to make it less reactive chemically and thus less susceptible to attack by pool water.

Copies of this report can requested from the Executive Secretary, Building Construction Industry Advisory Committee, Room 101 FAC, School of Building Construction, University of Florida, Gainesville, FL 32611 or by calling (904) 392-5965.

A Study of Marcite (Plaster) Deterioration in Swimming Pools

R 88-14

Grant Managed by:

Brisbane H. Brown, Jr.
M. E. Rinker, Sr. School of Building Construction

Research Conducted and Report Prepared by:

E. Dow Whitney
Department of Materials Science and Engineering

Sponsored by grants from:

The Building Construction Industry Advisory Committee

Florida Region VII Council - National Spa and Pool Institute

University of Florida

National Spa and Pool Institute

March 30, 1991

Table of Contents

Acknowledgements

The seemingly tireless efforts of the following young people without whose industry and enthusiasm this work would never have been accomplished is gratefully acknowledged.

Amy Bagwell
Dennis M. Gadonniex
Karen Anne Gurley
Sandra L. Guy
Sidney Lee Martin
Stephen J. Mitchell
Troy G. Morin

Financial support for this study was provided by the following organizations:

National Spa and Pool Institute (Region VII - Florida)

State of Florida Department of Education Building Construction Industry Advisory Committee (Grant 88-14)

National Spa and Pool Institute (National)

University of Florida

List of Tables

List of Figures

1. Background to the Problem

In Florida, swimming pools have almost become a necessity and are no longer a luxury item. They are a source of water storage, a place for family gatherings and entertainment, and the dream of millions of retirees who move to the sunny south to extend their golden years and utilize one of the best exercises known to mankind.

Florida enjoys eighteen percent of the world swimming pool market, larger than California and Hawaii combined. A pool is an affordable item for the retiree with an average income. Concrete technology has allowed swimming pool structure to be long lasting, durable, and a sound investment for the homeowner. With the coming of twenty-first century technology, new filter systems and improved disinfection techniques can assure crystal clear water - water so clear coins can be clearly seen even in deep pools.

However, over the past few years the pool industry has been plagued by a number of problems involving all types of blemishes, etching, mottling and discoloration of plaster pool linings. Most pool contractors feel that these problems did not exist beyond six or seven years ago. Initially, when the problems began, the pool contractor simply recoated the swimming pool and thus satisfied the home owner's complaint. Unfortunately, these complaints compounded and as the pressure increased, many contractors' businesses failed trying to do the "right thing".

The State of Florida has the most stringent licensing laws in the nation. The ultimate goal is to have full certification of all persons in the swimming pool industry from builders to service companies. To date, 30 percent of the pool and spa industry has fulfilled this requirement and the balance are duly registered with the state under the wing of state

SWIMMING SEASON ZONES...

MONTHS WITH AN AVERAGE DAYTIME AMBIENT TEMPERATURE OF 60°F OR HIGHER.

ZONE	SWIMMING SEASON
1	12 MONTHS
2	10-11 MONTHS
3	9-10 MONTHS
4	8-9 MONTHS
5	6-8 MONTHS
6	4-5 MONTHS
7	3-4 MONTHS

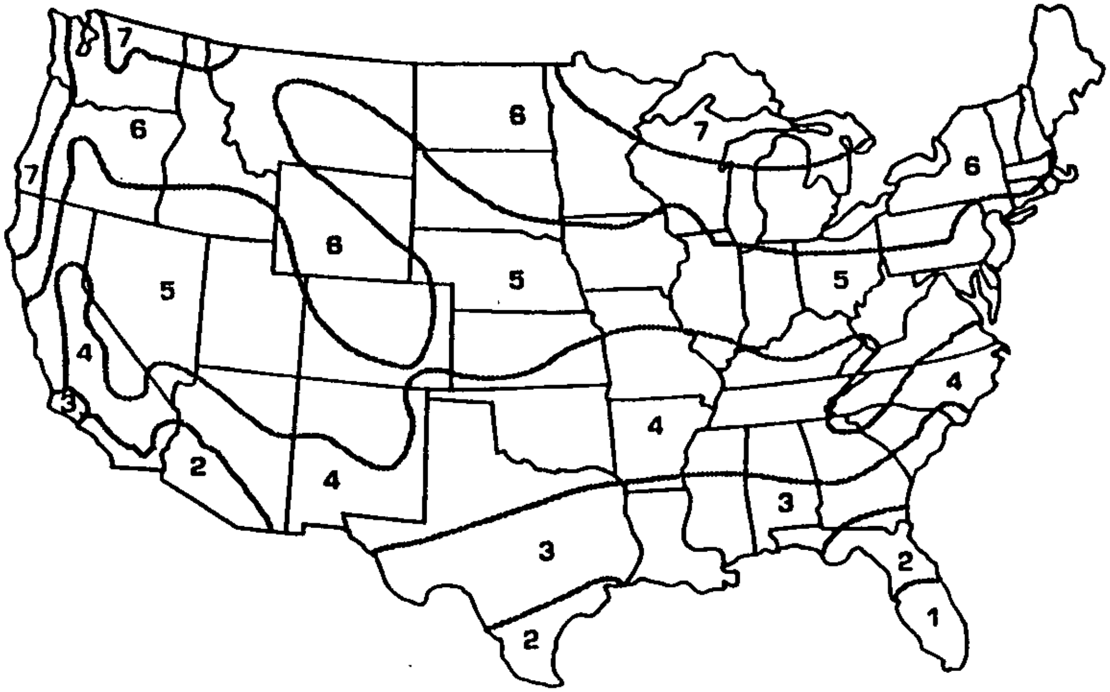


Figure 1. Swimming pool season zones. Months with an average daytime ambient temperature of 60° or higher.

legislation. Complaints to the state capital in Tallahassee have led to a number of license revocation, suspensions, and fines. It should be noted that the largest number of complaints relate to the plaster finish - commonly known as "marcite" in Florida.

Marcite (plaster), the interior finish applied to swimming pools, has been under considerable scrutiny in the last few years because of the problems of discoloration, mottling, and etching. Although these problems have been investigated for several years, there is as yet no single consensus as to what exactly is their cause, and consequently what preventive measures to take. To date, the exact nature of the chemical mechanism responsible for the surface deterioration of marcite is still not known.

Totally baffled and discouraged, the National Spa and Pool Institute Region VII (Florida) Council formed the Plaster/Marcite Committee in 1988 to seek out the problems that were besieging the industry and to come up with a solution. In the Spring of 1989 three research projects were started, funded by the Building Construction Industry Advisory Committee (BCIAC), a research grant committee operating under the Florida Department of Education, the National Spa and Pool Institute (NSPI) and the University of Florida. The material to be tested was plaster/marcite, generally composed of a two-to-one mix of marble aggregate to white portland cement or a pre-blend of similar ratio. The problems that needed to be checked were etching, staining and mottling.

Etching at times will occur within a few weeks to years after application of the marcite. Once the problem begins, a yellow, brown, or beige color settles in the damaged area(s). The addition of chelating agents, sequestering agents, vitamin C, etc., will sometimes remove the discoloration. Etching is frequently round in shape, dime sized and starts in the area of the steps and swimouts; as etching increases the damage works downward and the size of the etch "pit" increases. At other times the spots will be about the diameter of a pencil eraser and all over the marcite surface.

Mottling is a darker appearance on the marcite surface. Sometimes described as having the appearance of clouds of vertical development in the cumulus-type shape. These shadings are more prominent on shady days or at night with the pool light on. These areas can usually be made to disappear simply by draining the swimming pool and letting the sun dry out the spots. Some success has also been achieved by heating the areas with a torch or hair dryer.

Staining is generally caused by minerals in the water that precipitate out of suspension and adhere to the plaster. Usually calcium, copper, iron, manganese and other metallic impurities account for this phenomena.

2. Research Objectives

The purpose of this research effort was to investigate corrosion-related surface deterioration of swimming pool marcite. Marcite deterioration was investigated both from the standpoint of induced textural or compositional defects in the marcite itself and from the standpoint of water chemistry, since it is well known that pure water with low dissolved calcium bicarbonate content (a low temporary hardness) corrodes plaster. As is often the case with soft water, if the water also contains aggressive carbon dioxide this solvent action is increased.

Associated with laboratory studies of marcite corrosion under controlled conditions were field diagnostic studies wherein petrographic, scanning electron microscopic (including energy dispersive X-ray spectroscopy) and X-ray diffraction phase analysis studies of healthy and deteriorated plaster from actual swimming pools were conducted.

It was anticipated that, as a result of this study, information gained on those chemical processes occurring within the plaster-pool water environment scenario that resulting marcite breakdown might serve as the basis for the formulation of badly needed ASTM standards in swimming pool construction.

3. Experimental Procedures

3.1 Instrumentation

Three major analytical instruments were employed in this research, both for field diagnostic studies of pool plaster problems and in controlled laboratory etching and staining mechanism investigations. The analytical techniques were x-ray diffraction, scanning electron microscopy and energy dispersive x-ray spectroscopy.

The x-ray diffraction units used were a Philips Electronic Instruments APD3720 X-ray diffractometer and a APD3600 X-ray diffractometer. In this technique, X-rays are generated from a target tube and impinged on a sample which is moved through an arc at angles (2Θ) measured with respect to the incident X-rays. The target radiation is scattered by the sample and the X-rays are detected with a scintillation detector. The number of counts, or intensity, versus the degrees 2Θ is recorded on a paper strip chart and/or computer storage. The 2Θ values of the peaks are related to the d-spacings in the crystal lattice of the sample by Bragg's Law ($n\lambda = 2d\sin\Theta$). The intensity is related to the atoms making up the crystal lattice. Compound identification using the JCPDS files of d-spacings and intensities of known compounds is possible. Crystallographic information such as crystal structure, reflections and lattice parameters is also possible. In addition to identification of compounds in crystalline materials, quantitative phase analysis can be conducted.

In scanning electron microscopy a focused electron beam is scanned over the specimen. Backscattered electrons and secondary electrons are produced and detectors measure intensity versus position and display this on a CRT. Magnification is dependent on the size of the area sampled. The techniques can image topographical or microstructural features on polished or rough surfaces, provide qualitative or semiquantitative elemental analysis as well as crystallographic data from single crystals or large grains. The instrument is particularly useful for characterization of microstructures in metal, ceramic, geologic and biological materials, and in studying surface morphology.

In energy dispersive X-ray spectroscopy, high energy electrons excite atoms in a specimen. Atoms can de-excite by emitting an X-ray which has characteristic energy. The X-rays are detected by an Si (Li) detector. The number of counts vs. energy are displayed on a multi-channel analyzer. The technique is particularly useful for elemental identification, qualitative analysis and quantitative analysis. Applications include phase identification and elemental distribution in a material.

3.2 Etching and Staining Mechanistic Studies

An important aspect of this phase of the study was to duplicate typical swimming pool conditions in the laboratory. Several problems for which solutions were found are:

1. Determine a cement specimen surface area to water ratio that was as close as possible to the surface area to water ratio found in a typical swimming pool. Solution to the problem is given in Appendix A.

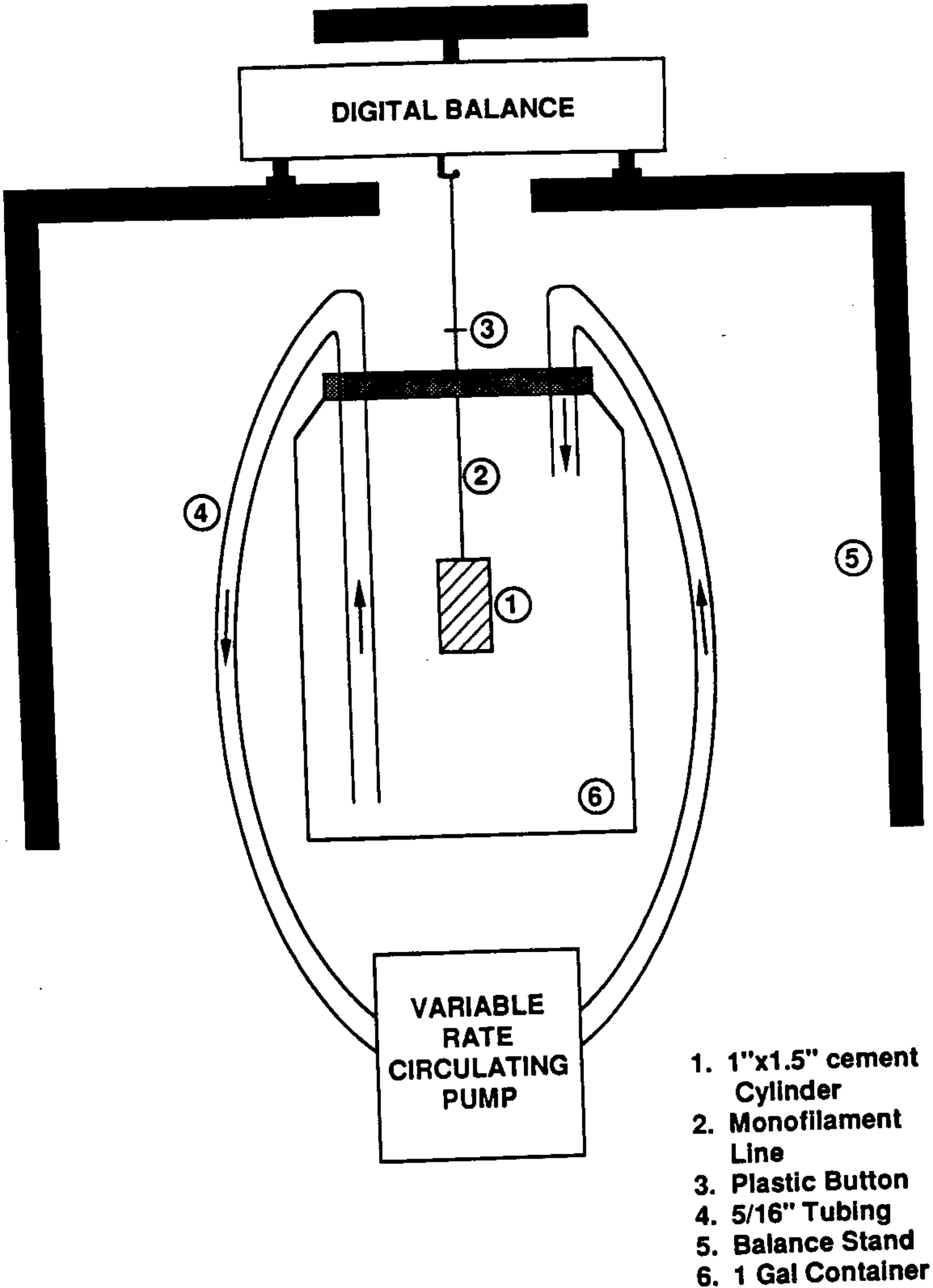
The radius of the cylinder was found to be equal to 1.27 cm (equivalent to one half inch). The length of the cylinder was 1.5 inches. One inch diameter PVC pipe cut in section was used as molds for the cement cylinders. Dried cement samples were separated from the PVC mold with a press.

2. Calculation of analogous circulation rates are also given in Appendix A. A flow rate of 1/8 gallon per hour, or 7.88 mL/min was determined.

   Pumps were chosen which had variable flow rates and had all plastic parts which would be in contact with the leaching solutions. The all plastic pumping mechanism was an important feature because at low pH values metal from the pump could contaminate the solution.

3. A diagram of the apparatus used in performing leaching rate experiments is shown in Figure 2. Cement specimens were suspended in the middle of the leaching solution in order to obtain uniform results. Samples could not rest on the bottom of the container or against the sides. Also, the area over which the string comes into contact with the sample had to be as small as possible so as to minimize the influence of the string upon the etching or staining process. This problem was solved by attaching a small plastic button to the end of a piece of monofilament fishing line. When the cement was placed into the molds the button was pushed into the cement where it became firmly anchored when the cement set. A small hole was drilled into the middle of the container cover and the fishing line was pulled through and tied to a paper clip.

4. The final problem was how to measure the weight loss of the specimen during the leaching process without removing the cement sample from the container which would disturb the etching of the sample. This problem was overcome by obtaining a balance which had provision for weighing from below. The



1. 1"x1.5" cement Cylinder
2. Monofilament Line
3. Plastic Button
4. 5/16" Tubing
5. Balance Stand
6. 1 Gal Container

Figure 2. Diagram of apparatus used in performing leaching rate experiments.

balance had a hook on the bottom where a string was attached. Tables were built that supported the balance over the containers so that the string could be attached from the bottom of the balance to the paper clip on top of the container. In this way the mass of the string, paper clip, button and cement sample was recorded. Since only the mass of the cement sample changed as a function of time, a rate of weight loss or leaching rate for any given leaching solution was readily obtained.

Leaching experiments were undertaken for three different water cement ratios (w/c) commonly used in the construction industry and in a pH range of 6.8-7.0. This pH range was chosen because it represents the lower end of the pH range commonly found in pool water. The experimental procedure was as follows:

1. 1" x 1.5" cement cylinders of 0.4 w/c and 0.5 w/c were dried at 100°F for 24 hours and weighed
2. The samples were then placed in the leaching solution (DI H_2O) an allowed to equilibrate.
3. After four days in solution, the pH was adjusted from the 10-10.5 natural pH of the solutions to the 6.8-7.0 pH range for the leaching experiments.
4. At first, pH was very unstable, climbing back toward the natural pH.
5. Daily adjustments were made back to the 6.8-7.0 range stabilized the leaching solutions after five days.
6. After stabilization, the pH was adjusted every 3 to 4 days.

4. Results

4.1 Field Diagnostic Studies of Swimming Pool Problems

Studies of etched and stained plaster obtained from swimming pools was a major part of this research effort. The goal was to determine the differences between healthy plaster and unhealthy plaster in an attempt to identify missing chemical species in etched plaster pits and new species present on the surface of stained plaster.

Analytical methods used to accomplish these tasks were x-ray diffraction and scanning electron microscopy, coupled with energy dispersive spectroscopy.

In this study, X-ray diffraction was used to compare which phases were present (or missing) in unhealthy plaster as opposed to healthy plaster.

With regard to chemical phases which are present in healthy cement, the majority of the material is composed of a matrix which is primarily complex hydrated calcium silicates. These silicates are predominantly amorphous, as opposed to crystalline and are thus difficult to detect with X-ray diffraction. In addition, several crystalline phases form from the hydration reaction (the reaction of calcined cement with water), such as calcium hydroxide (portlandite), magnesium hydroxide and calcium carbonate.

Experimental evidence from X-ray diffraction showed that calcium hydroxide was the predominant phase missing from pits in etched plaster. This is evident from an inspection of Tables 1 through 3 which show the results of X-ray diffraction analyses of etched and non-etched plaster samples taken from swimming pools at various Florida locations. In Appendix B is a listing of some of the more than fifty sources of marcite samples which were received and analyzed as part of the diagnostic studies. These sources included private individuals, condominium associations, hotel/motels, pool contractors and plastering companies, etc. Appendix C is the NSPI Plaster Sample Data Sheet which was requested

Cement Compound (Phase)	**Non-Etched**	**Etched**
Calcium Hydroxide $Ca(OH)_2$	●	○
Calcium Silicate Hydrate	●	●
Calcium Carbonate $CaCO_3$	●	●
Silica SiO_2	●	●

●	Phase Present
○	Phase not present

Table 1. X-ray Diffraction Analysis of Plaster from Pool in Gainesville, Florida

Cement Compound (Phase)	**Non-Etched**	**Etched**
Calcium Hydroxide $Ca(OH)_2$	●	○
Magnesium Hydroxide $Mg(OH)_2$	●	●
Ettringite	●	●
Calcium Carbonate $CaCO_3$	●	●

●	Phase Present
○	Phase not present

Table 2. X-ray Diffraction Analysis of Plaster from Pool in Sarasota, Florida

Cement Compound (Phase)	**Non-Etched**	**Etched**
Calcium Hydroxide $Ca(OH)_2$	●	○
Dolomite $CaMg(CO_3)_2$	●	●
Magnesium Aluminum Hydroxide Silicate	●	●
Calcium Carbonate $CaCO_3$	●	●
Silica SiO_2	●	●
Calcium Silicate Hydrate	●	●

●	Phase Present
○	Phase not present

<u>Table 3</u>. X-ray Diffraction Analysis of Plaster from Pool in Lutz, Florida

to be completed and returned with the plaster samples. This information often proved to be very helpful in the diagnosis of specific plaster problems.

Thermodynamic calculations confirmed that portlandite is the most chemically active component of cement. (See Section 5.3.2). Since cement is a basic material, portlandite would be especially susceptible to acidic water. The latter would thus be expected to exacerbate the preferential leaching of portlandite, which in turn results in etching. Experimental evidence showed that portlandite is preferentially leached out of the marcite matrix by aggressive pool water. Since portlandite comprises approximately 25% of portland cement by weight, its absence has deleterious effects upon the structural integrity of pool plaster; i.e., leading to surface degradation and etching.

The other analytical method employed in this phase of the work was scanning electron microscopy (SEM). Marcite was observed up to 15000x on the SEM. Also in conjunction with SEM, energy dispersive spectroscopy (EDS) was performed. While the sample is in the SEM, elemental analysis can be done using this technique. In Figure 3 are shown the results of EDS scans for the elements Ca, Si, Mg and Al while traversing a marcite sample from an existing swimming pool form a non-etched to a spot etched area. The sharp drop in relative concentration of calcium and corresponding relative increase in silicon concentration is evident in going from the non-etched to etched areas.

SEM studies showed that the appearance of the portlandite changes upon etching. Unetched portlandite crystals have smooth, regular faces. Portlandite crystals on etched surfaces are very sparse, as compared to portlandite crystals on unetched surfaces. Contrast in the portlandite morphology in etched and unetched samples lends credence to our conclusions.

In Table 4 are presented data showing relative concentrations of $Ca(OH)_2$

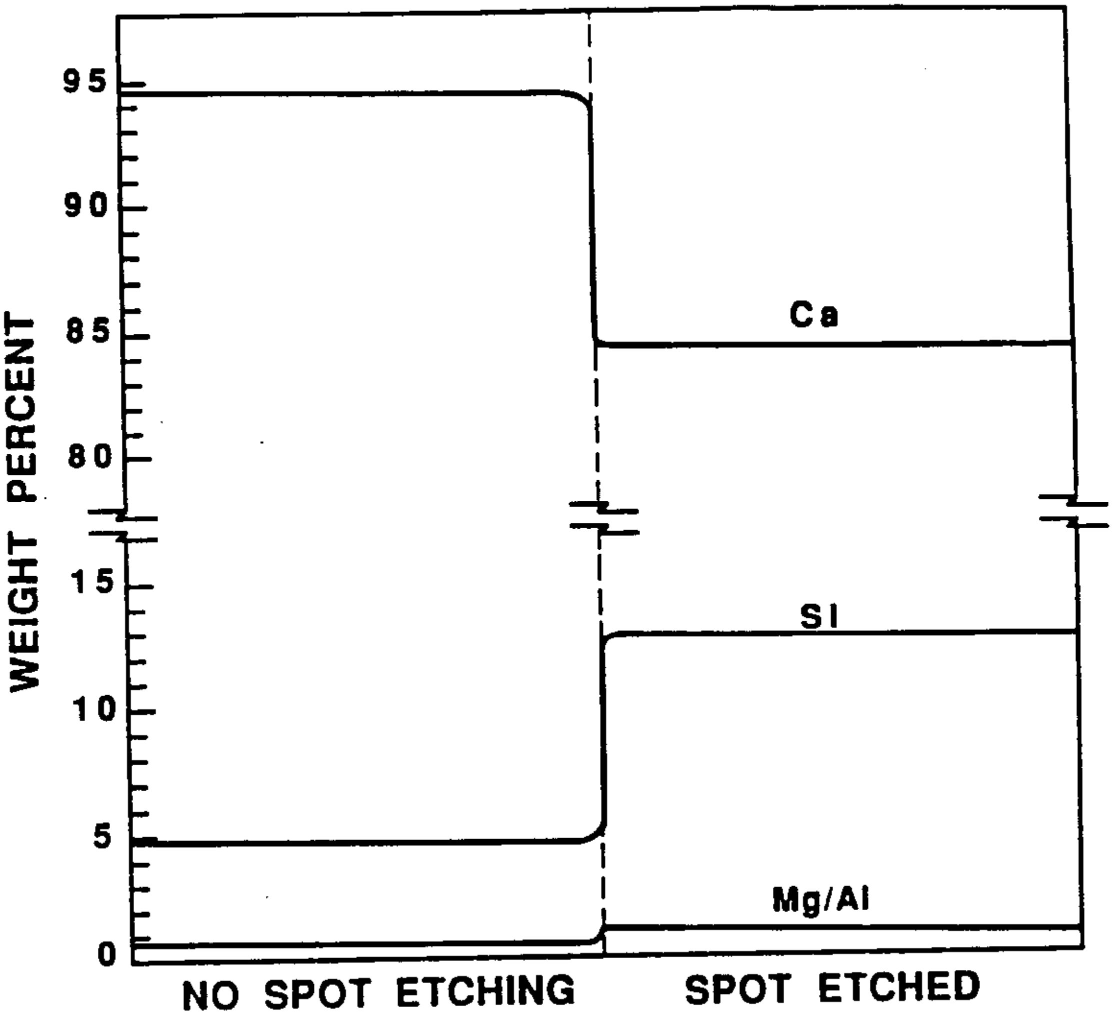


Figure 3. Calcium, silicon, magnesium and aluminum concentration profiles (EDS) in traversing from a non-etched to an etched area in marcite taken from a pool in Gainesville, Florida.

MATERIAL BALANCE
(Normalized to 100)

	TR-1	TR-2	TR-3
$Ca(OH)_2$	17	21	31
$CaCO_3$	42	40	12
SiO_2	41	39	57

Table 4. Relative concentrations of $Ca(OH)_2$ (portlandite) in marcite on a trowelled swimming pool surface.

(portlandite) in marcite on a trowelled swimming pool surface. In swimming pool construction, after the marcite layer is applied to the gunite shell wall the former is trowelled several times (usually three) so as to produce a very smooth surface. According to pool plastering professionals the attainment of a smooth surface involves the bringing of the "cream" or "fat" in the marcite to the surface which is accomplished by trowelling.

Since the trowelling operation is being conducted while chemical hydration reactions are simultaneously taking place in the cement the question was posed, "what effect does trowelling have, if any, on the distribution of developing hydrated phases in the marcite"? In Table 4, TR - 1, TR - 2 and TR - 3 identify samples of marcite removed from trowels during construction of a swimming pool after the first, second and third trowelling, respectively. Phase identification was performed by means of X-ray diffraction.

Although these results are preliminary, they do seem to indicate a preferential concentration of portlandite at the marcite surface as a result of the trowelling operation. Certainly this represents a very dynamic system, both chemically and mechanically, and involves complex morphology and rheology. However, it is interesting to note that the relative increase in phase concentrations with extent of trowelling, i.e., $Ca(OH)_2 > SiO_2 > CaCO_3$, has an inverse relationship with the phase densities, i.e., $CaCO_3 > SiO_2 > Ca(OH)_2$. In light of what will be discussed later in this report with regard to the susceptibility of portlandite to chemical attack by aggressive components in swimming pool water these preliminary observations should be pursued further.

SEM was also instrumental in studies of stained marcite surfaces obtained from the field. Elemental analysis via energy dispersive spectroscopy of stained plaster samples revealed the presence of copper on nearly every sample which was stained blue/green. The origins of the copper staining are either; 1) copper ions form unchelated copper algicides, or 2) copper ions from corroded bronze or brass plumbing. Once copper ions are in solution in pool water, they combine to form complex compounds on the surface of the plaster. In Figure 4 is shown an EDS scan on a sample of marcite with blue/green staining. In addition to the expected peaks for Ca, Mg, Si and O, a very distinct peak for Cu is noted. Figure 5 is a similar EDS scan on marcite from a swimming pool with distinctive yellow/brown staining. In this case the iron (Fe) peak is predominant.

4.2 Mechanisms of Etching and Staining

In conjunction with field diagnostic studies, laboratory studies were undertaken in an attempt to understand the mechanisms of etching and staining of pool plaster. Experiments were focussed on answering the following questions:

1. What factors do and do not cause etching?
2. What is the mechanism of staining of swimming pool plaster?
3. What can be done to alleviate the problem of etching and staining?

4.2.1 Leaching Experiments

Swimming pool literature suggests that the main causes of leaching are low pH, low calcium hardness and low total alkalinity with high cyanuric acid and high chlorine aspossible secondary effects. With these factors in mind a series of leaching experiments were conducted. Deionized (DI) water was used in all experiments which for the purposes of this work is the same as distilled water. DI water is very "soft" as it has no calcium hardness, no alkalinity and a pH of 6.9-7.0. Portland cement samples placed in DI water within a couple of days came to an equilibrium pH of approximately 11.0 with a very high calcium hardness and total alkalinity. Obviously, calcium carbonate had leached out of the

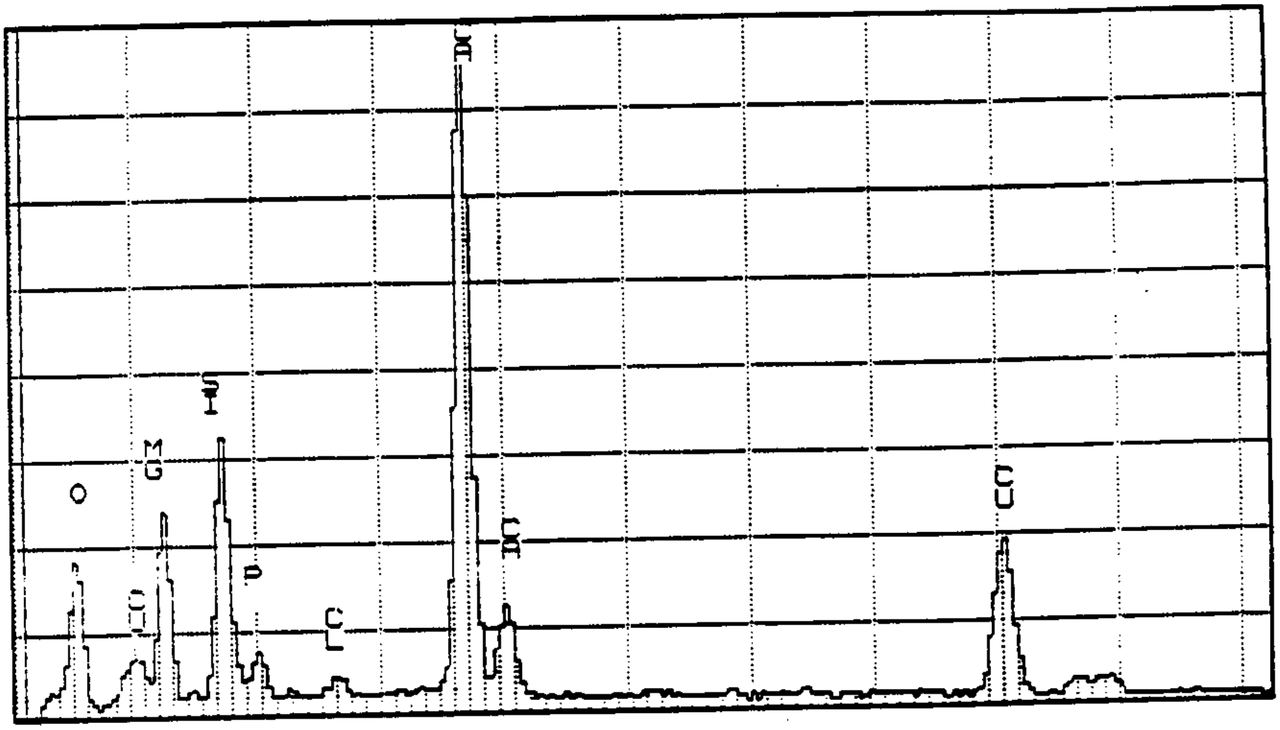


Figure 4. EDS Scan on marcite with blue/green staining.

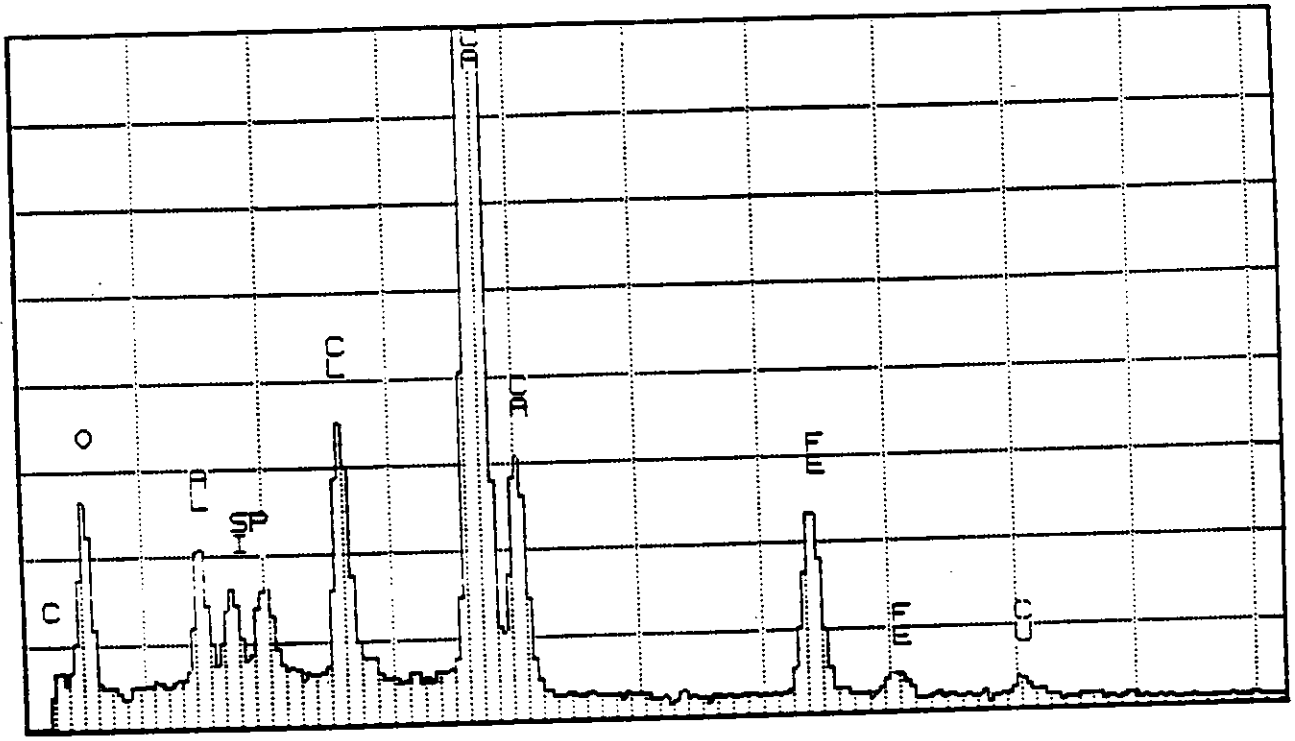


Figure 5. EDS Scan on marcite with yellow/brown staining.

sample which increased both the calcium hardness and alkalinity of the solution and also neutralized the H^+ ions in solution.

A solution of DI water with 500 ppm cyanuric acid was prepared. This amount of cyanuric acid is roughly ten times the normal recommended amount for stabilizing chlorine in a swimming pool. The initial pH of the solution was about 4.0. After the sample was placed in the solution the pH began increasing daily to an equilibrium pH of about 9.0 after a week. Calcium carbonate began precipitating out of solution. Cyanuric acid is a weak acid and even at a concentration of 500 ppm the cement was able to quickly increase the pH and avoid continued leaching. A very slight amount of cement was lost due to leaching, about 0.03 grams out of a 27 gram specimen. In a pool containing 2400 lbs of marcite this amounts to about 2.6 lbs lost. The only conceivable way to attain this high level of cyanuric acid in a pool would be to allow stabilized chlorine to dissolve in non-circulating water. A high local concentration of cyanuric acid would develop which could cause leaching. If solid cyanuric acid granules are permitted to remain in contact with marcite on the bottom of the pool, local pitting will occur.

A solution of DI water and 20 ppm liquid chlorine (NaOCl) was prepared. This solution was approximately ten times the normal chlorine concentration in a typical swimming pool. The pH of the solution was about 11.0. When the sample was introduced into the solution, the pH remained almost constant and the sample turned slightly whiter. No leaching occurred.

A solution of DI water and hydrochloric acid was prepared. The portland cement sample was introduced and the pH kept between 4.0 and 4.5 with additions of HCl every two to three days. At the end of the first week the sample had a distinct yellowish tint. It is believed that this yellow stain was caused by HCl coming into contact with iron oxides in the cement. It has been observed that when cement specimens are brought into contact with dilute HCl a yellowish stain found to be ferric chloride ($FeCl_3$) formed at the surface for the specimen in contact with the acid. Going deeper into the specimen the yellow stain turned to a dark brown or grey. The later color is due to ferric hydroxide. When the cement comes into contact with HCl the calcium forms soluble "salts" which are leached out of the cement matrix leaving the specimen very etched, porous and brittle. The remaining insoluble salts form what is called the "hydroxide mixture". This mixture largely composed of SiO_2 and ferric hydroxide forms a protective layer on the surface of the undamaged cement.

These observations indicate that yellowish stains found especially in newly filled swimming pools on the bottom of the pool could be caused by a low pH condition. Hydrochloric acid is much denser than water and when poured into a swimming pool will quickly settle to the bottom. pH measurements taken at the top surface of the pool may indicate a normal or even high pH condition while the bottom of the pool is experiencing a low pH condition.

In Figures 6a-c are given the results of the long term leaching experiments of portland cement at three different water/cement ratios. The first measurement of weight loss indicated in Figure 6 occurred after 1056 hours. Weight loss was measured as the change in weight divided by the initial weight.

$$\frac{\Delta W}{W} = \frac{\textit{initial weight} - \textit{weight measured at time } t}{\textit{initial weight}}$$

The initial weights of the samples were recorded between 240 and 288 hours into the experiment. During the "equilibration" period before 240 hours the mass of the samples changing due to tiny air bubbles escaping from the surface porosity and leaching solution

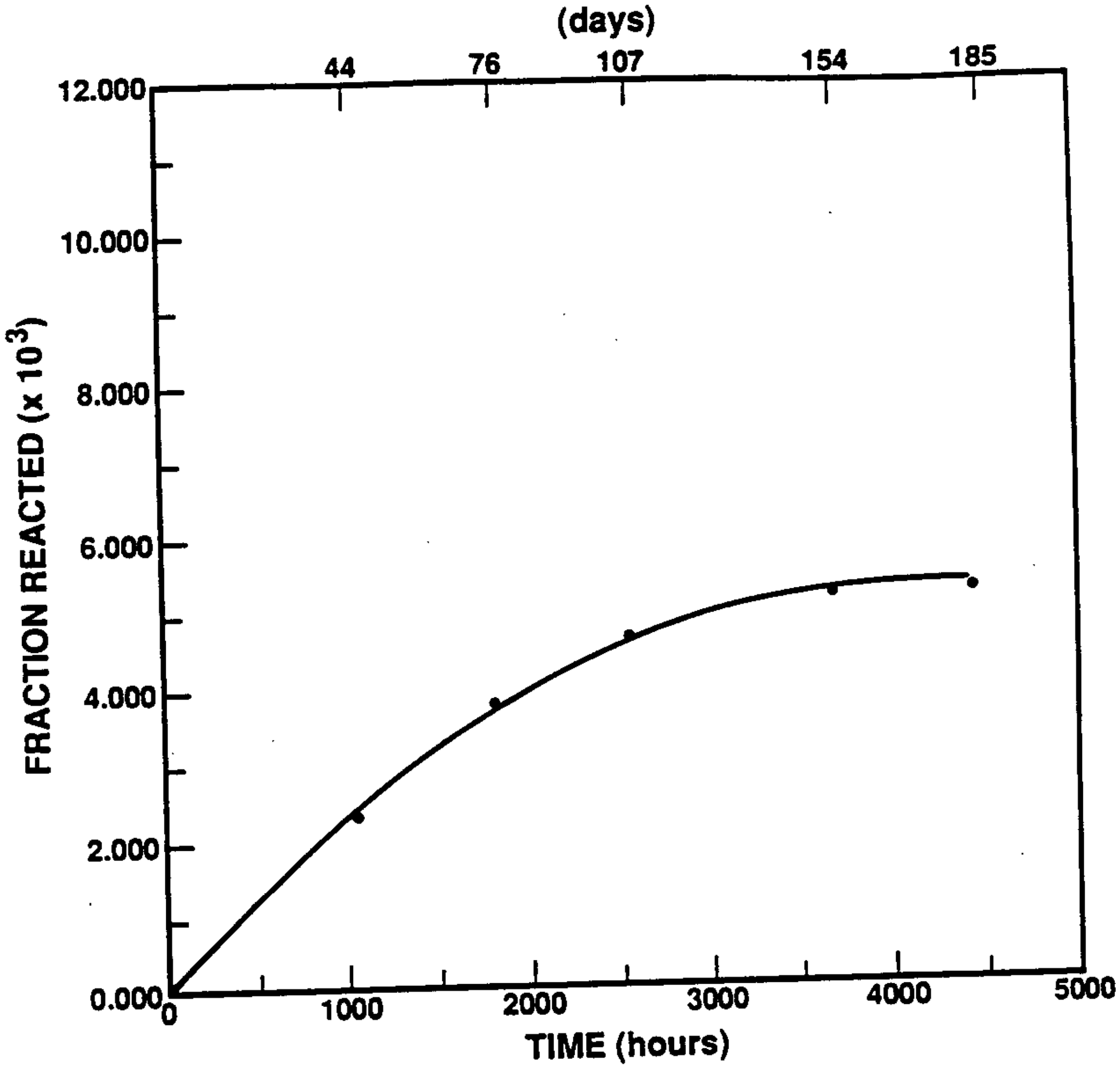


Figure 6a. Long term leaching rates of portland cement in DI water of pH 6.8-7.0. Water/cement ratio = 0.40

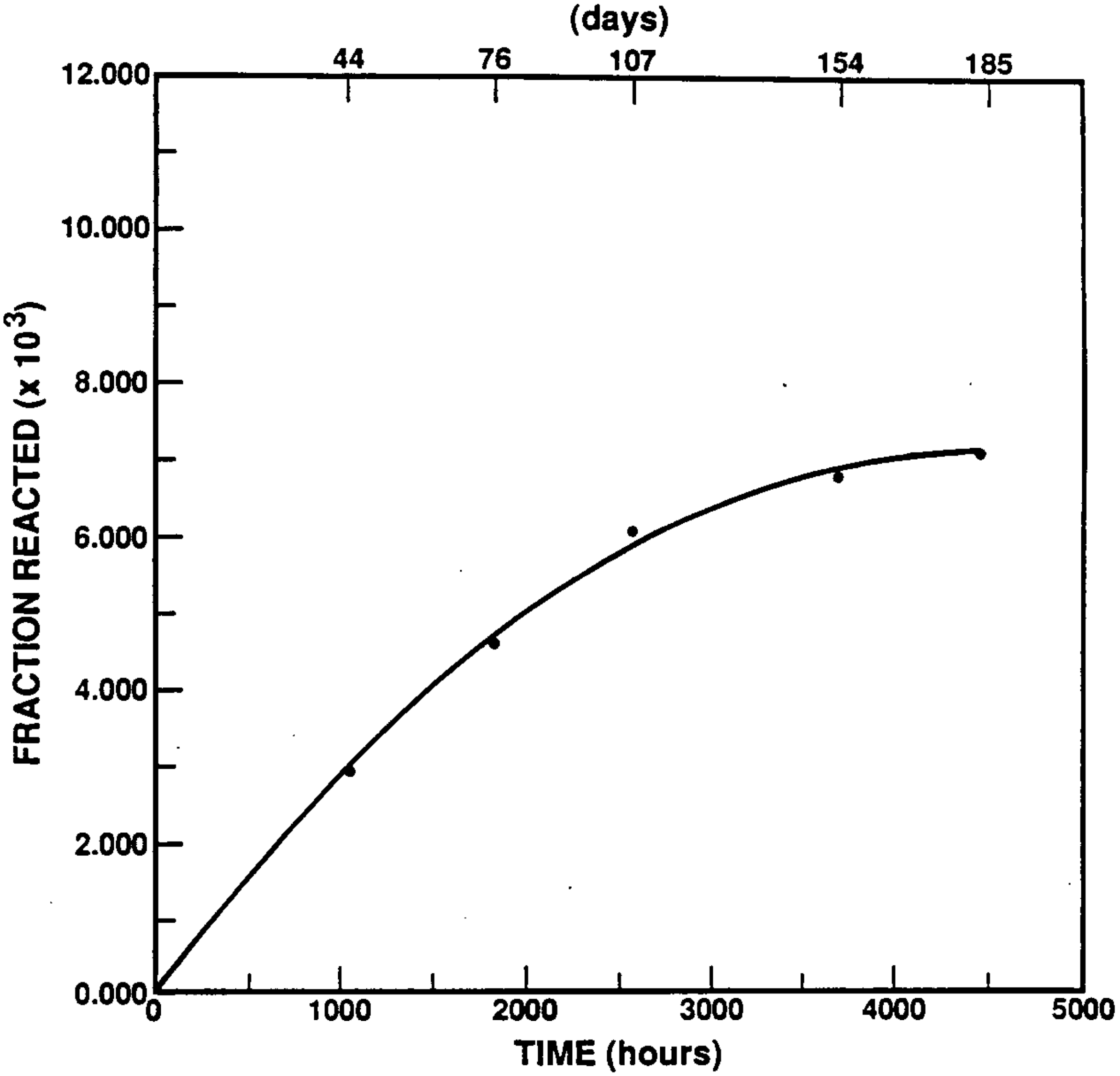


Figure 6b. Long term leaching rates of portland cement in DI water of pH 6.8-7.0. Water/cement ratio = 0.45

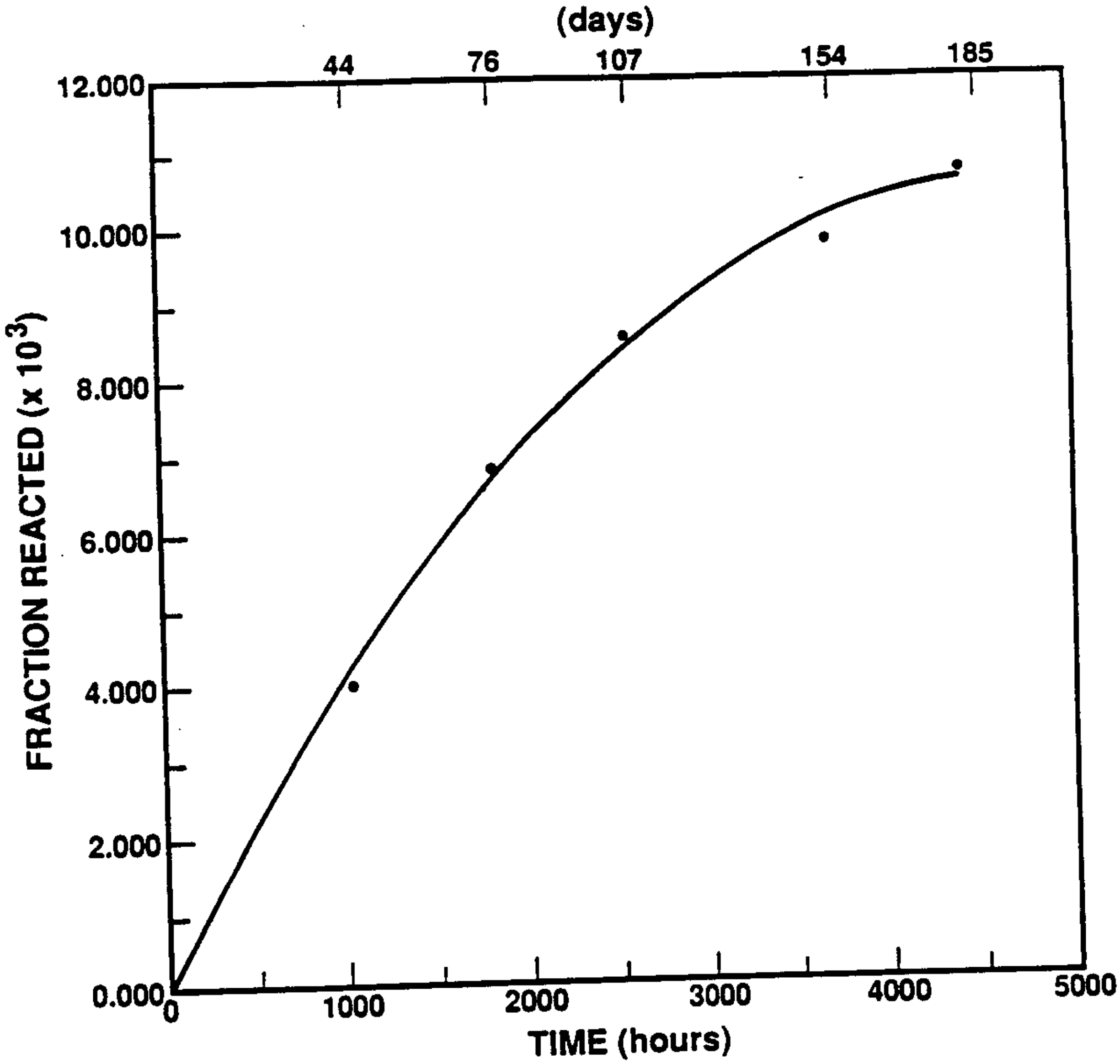


Figure 6c. Long term leaching rates of portland cement in DI water of pH 6.8-7.0. Water/cement ratio = 0.50

being absorbed into the samples. The leaching that occurred during this period was accounted for by extrapolating the graph back to zero, as is shown in Figure 6a-c.

4.2.2 Staining

The most common metals in contact with swimming pool water are copper, brass, aluminum and stainless steel. Diagnostic studies showed that of all the samples of pool staining studied as part of this research program, at least eighty percent were various shades of blue, green and aqua. This indicates that these stains were caused by copper. Various combinations of zinc and copper are the following metals: Muntz metal, 40% Zn-Cu; yellow brass, 30% Zn-Cu; and red brass, 15% Zn-Cu. Yellow and red brass are commonly used in manufacturing fittings, impeller blades and pump castings used for swimming pools.

Laboratory experiments consisted of exposing yellow brass, copper, aluminum and stainless steel samples to various corrosive solutions. The solutions were: (1) pure deionized water, (2) DI with HCl added to pH 5.0 and (3) DI water with HCl and 20 ppm chlorine added to pH 5.0.

Since deionized water is extremely "soft" it is very corrosive to all of the metals tested except aluminum and stainless steel. Solutions were prepared and the metal sample and a cement specimen introduced at the same time. Usually signs of corrosion were visible within 24 hours. The usual indication for copper and brass was a slight "greening" of the cement sample that became darker with continued exposure. The iron sample formed a light brown rust colored stain that also became darker with time. The addition of 20 ppm chlorine caused the corrosion rate of the copper and brass samples to increase with a resulting increased rate of cement sample staining. Samples that were introduced into the HCl and 20 ppm chlorine turned much darker than samples in HCl alone. This was probably due to the strong oxidizing nature of chlorine.

Rapid staining of the samples was indicative that once the metal cations are in solution they quickly attach themselves to the cement surface. The cations lower their free energy state by replacement of themselves with components of the cement surface. Once metal ions are in solution they will rapidly interact with the cement to cause staining. Therefore a drop in pH and an increase in chlorine for only a short time can cause staining in swimming pools, especially when the water hardness is low. This observation is important because in the normal maintenance of swimming pools the chlorine concentration can increase dramatically during the "shocking" process. Also the careless addition of HCl can cause a great drop in pH, especially at the bottom of the pool. The circulating pump picks up water from the drain at the bottom of the pool which is much more acidic than the rest of the pool water. If there are copper components anywhere in the pumping mechanism (and there almost always are) the combined effects of low pH and high chlorine will surely lead to corrosion and within a few hours stains will occur on the plaster surface.

Certainly one way to avoid staining is to remove all sources of copper and iron from contact with pool water. Unfortunately most of the sources of copper are impellers, fittings, gate and ball valves and pump castings, yet all of these parts are readily available in lexan fiberglass or PVC.

The aluminum specimen also showed signs of corrosion but apparently the aluminum cations in solution did not stain the cement. Stainless steels are in general susceptible to corrosion attack by any form of chlorine. Therefore high concentrations of HCl, NaOCl, LiOCl or $Ca(OCl)_2$ can cause corrosion of stainless steels. At high concentrations of Cl^- the passivating layer responsible for stainless steels corrosion resistance breaks down, and pitting corrosion occurs. Fortunately, the concentration of Cl^- ions in most swimming pools is not high enough to cause noticeable corrosion of the stainless steels used in ladders, light fixtures, railings, etc. It would appear that at the present time there are not enough problems with stainless steel corrosion to recommend that they be eliminated from swimming pool construction. However, if rust colored stains are noticed around any piece of stainless steel in contact with water, it is indicative that the passivity of the stainless steel has been destroyed and the part in question will continue to rust. The use of steel wool to clean stainless steels is also a big cause of corrosion. Steel wool will scratch the passivating layer on the stainless steel and leave tiny pieces of steel embedded in the stainless steel. These pieces become tiny anodes and will promote corrosion in the stainless steel at an incredibly fast rate. Steel wool should never be used to clean stainless steel in a pool or otherwise.

5. Discussion

5.1 The Corrosive Nature of Soft Water

Water is near to being a universal solvent and it can cause the dissolution of all but the most stable of materials. Very pure water with a low dissolved calcium bicarbonate content, i.e. of a low temporary hardness, will corrode concrete. If, as is often the case with soft waters, the water also contains aggressive carbon dioxide, the solvent action is increased. This action commences by leaching of the "free lime" or calcium oxides. Partial decomposition for the cement binder takes place when all the free lime is removed and thereafter, by successive leachings, practically all the cement can be decomposed. Under normal conditions, provided the concrete is dense, the action is only superficial and does not penetrate far into the mass of the structure. As a result of leaching of the cement matrix from the surface, the concrete will tend to assume a sandy appearance. On the other hand, pervious concrete is very susceptible to destruction by this action and deterioration to considerable depth can take place. The aggressiveness of a natural acidic soft water is dependent not only on its pH but also on the temporary hardness (bicarbonate content) and the free carbon dioxide content. Water from all common sources contains a variety of dissolved materials. Water and whatever else is present in the water will almost always have some effect on its container.

The composition of the container, in this case the marcite shell of the swimming pool, will be the determining factor in the nature and extent of these effects. To determine the effects of swimming pool water and the chemicals used in the water on white cement it is of importance to know the composition and properties of the various substituents which are present in portland cement.

5.2 Portland Cement and Marcite

Marcite is a mixture of limestone (sometimes lime) and white portland cement. The primary raw material for the manufacture of portland cement is calcium carbonate or limestone and clay containing silica, aluminum and ferric oxides in the proper proportions. The mixture is calcined in a rotary kiln at a temperature of about 1450°C to produce the desired product.

The primary compounds entering into the composition of finished portland cement are: tricalcium silicate, $3CaO{\cdot}SiO_2$ (54%); dicalcium silicate, $2CaO{\cdot}SiO_2$ (17%); tricalcium aluminate, $3CaO{\cdot}Al_2O_4$ (11%) and tetracalcium aluminoferrite, $4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$ (9%). White portland cement is richer in alumina and essentially free of ferric and magnesium oxides.

The setting of cement is essentially a hydration reaction to form calcium silicate hydrates. The hydrate forms a colloidal "mineral glue" which is called "tobermite", because it is practically identical with a rare, naturally occurring mineral of that name. The reactions which occur are given below.

$$3CaO \cdot SiO_2 + (X+1)H_2O \rightarrow Ca_2SiO_4 \cdot XH_2O + Ca(OH)_2 + Heat(500J/g) \qquad (1)$$

$$2CaO \cdot SiO_2 + XH_2O \rightarrow Ca_2SiO_4 \cdot XH_2O + Heat\,(260J/g) \qquad (2)$$

In reaction (1) about forty percent by weight of calcium hydroxide, $Ca(OH)_2$, or as it is sometimes called calcium hydrate, $CaO{\cdot}H_2O$, is formed. The hydration of the tricalcium aluminate is as follows:

$$3CaO \cdot Al_2O_3 + 6H_2O \rightarrow Ca_3Al_2(OH)_{12} + Heat(865J/g) \qquad (3)$$

As soon as the cement is mixed with water, a rapid reaction starts. In a few minutes, the gauging water becomes saturated with calcium hydroxide. The di- and tricalcium silicate is hydrated to a gel, releasing calcium hydroxide which slowly crystallizes from the solution. reactions (1) and (3) produce rapid setting but low strength in the cement. Reaction (2) is a slower setting reaction but produces higher strength. Microscopic examination of the hardened cement paste shows small amounts of unreacted calcined minerals and crystals of calcium hydroxide. The latter is a basic or alkaline material and is of considerable significance in connection with the resistance of cement to attack by aggressive agents as is discussed below.

5.3 Interaction of Swimming Pool Water and Marcite

In the process of cement hydration soluble calcium hydroxide is formed. This material is easily dissolved by water that is lime-free and that contains dissolved carbon dioxide. In addition, hydrated cement paste is an alkaline material and therefore pool water of pH less than 7.0 (acidic conditions) will readily attack a base material such as plaster.

The hydrogen ion will accelerate the leaching of calcium hydroxide:

$$Ca(OH)_2 + 2H^+ \rightarrow Ca^{2+} + 2H_2O \qquad (4)$$

The nature of the anion that accompanies the hydrogen ion may further aggravate the situation. Carbonic acid can also be very corrosive because of the formation of soluble calcium bicarbonate:

$$Ca(OH)_2 + H_2CO_3 \rightarrow Ca(HCO_3) + H_2O \qquad (5)$$

Adding water which has a high pH (basic) to a newly plastered pool which has an alkaline surface can further raise the pH of the water to a sufficient level to covert the bicarbonate ion (HCO_3^-) present in the water to carbonate ions ($CO_3^=$). This ion then combines with soluble magnesium and calcium ions in the water to precipitate insoluble magnesium and calcium carbonates.

$$HCO_3^- + OH^- \rightleftharpoons CO_3^- + H_2O \qquad (6)$$

$$Ca^{++} + CO_3^= \rightarrow CaCO_3(s) \qquad (7)$$

This is sometimes referred to as "plaster dust", although none of it comes from the plaster itself. With water as low as 25 ppm total hardness as much as four pounds of fine chalk dust can be precipitated from the water of a 20,000 gallon pool.

On the other hand, adding water which has a low pH (acidic), as the result of generating the disinfectant, hypochlorous aid (HOCl), via the reaction of chlorine gas with water,

$$Cl_2(g) + H_2O \rightleftharpoons HOCl + H^+ + Cl^- \qquad (8)$$

can result in chemical attack on the walls of the swimming pool resulting in the selective solvation or leaching out of mineral constituents from the plaster surface.

Figures 6a-c show that the largest leaching rate occurred at the beginning of the experiment. The 0.4 w/c ratio samples had a lower rate of leaching throughout the experiment and also an undetectable rate of leaching after five months. Since the 0.4 w/c ratio cylinders are denser and have less porosity than the 0.45 w/c and 0.5 w/c cylinders the ability of hydrogen ions to enter the structure and leach out calcium is decreased.

Mathematical modeling, curve fitting and additional research will be required to determine the diffusion kinetics responsible for leaching rates.

5.3.1 Etching of Marcite

Marcite, composed primarily of white portland cement, is a complex mixture of many different chemical compounds. The major elements in these compounds are calcium, oxygen, hydrogen, silicon and carbon. Results of this study show that a particular calcium compound may be selectively leached, or "dissolved" out of the plaster matrix by aggressive pool water. Calcium compounds are basic by nature, and therefore can be attacked by acids. Thermodynamic calculations (Section 5.3.2) and experimental evidence suggest that the most chemically active calcium compound in marcite is calcium hydroxide (portlandite), $Ca(OH)_2$. Thus, when plaster is exposed to acidic water, calcium hydroxide is preferentially leached out of the matrix. Since calcium hydroxide comprises about 25% by weight of portland cement, its absence weakens the structure and hastens its disintegration.

5.3.2. Thermodynamics of the Etching Process

In this section are presented the results of applying chemical thermodynamics to show quantitatively the effect of pool water pH on the stability of portlandite, or calcium hydroxide, $Ca(OH)_2$. This was done by calculating the Gibbs free energy change for the chemical reaction isotherm,

$$Ca(OH)_2(solid) + 2H^{+}(aq) \rightarrow Ca^{+2}(aq) + 2H_2O \tag{9}$$

The Gibbs free energy change (ΔG) accompanying the reaction depicted above, at constant temperature and pressure, is given by

$$\Delta G_{T,p} = G(products) - G(reactants) \tag{10}$$

From chemical thermodynamics it follows that for

$$\Delta G_{T,p} = \Delta G^{\circ}_{T} + RT\ln\left(\frac{a_{Ca^{2+}}}{a^{2}_{H^{+}}}\right)$$

$$\Delta G_{T,p} = \Delta G^{\circ}_{T} + 2.3RT\left[\log a_{Ca^{2+}} - 2\log a_{H^{+}}\right] \tag{11}$$

Where ΔG°_{T} is the standard free energy change for equation (9) at a specific temperature (T) expressed on the absolute scale (°K), R is the universal gas constant, p is the pressure, taken as 1 atm and $a_{Ca^{2+}}$ and $a_{H^{+}}$ the activities of calcium ions and hydrogen ions in solutions, respectively.

Since, by definition, $pH = -\log[H^{+}]$ and equating molar hydrogen ion concentrations $[H^{+}]$ to hydrogen ion activity ($a_{H^{+}}$) which is valid for low concentrations of hydrogen ions as found in swimming pools, one can write

$$\Delta G_{T,p} = \Delta G^{\circ}_{T} + 2.3RT\left[\log a_{Ca^{2+}} + 2pH\right] \tag{12}$$

Equation (12) was solved for a variety of pH values. Pressure was taken to be one atmosphere and temperature 25°C (77°F) which is assumed to be "typical" swimming pool water temperature. Finally, the activity of calcium ions in solution ($a_{Ca^{2+}}$) was taken to correspond to a calcium ion hardness of 250 ppm (as $CaCO_3$), a value well within the recommended range for well balanced swimming pool water.

Results of the above reaction isotherm calculations are shown in Figure 7. The significance of these results is in the fact that for portlandite in marcite to react spontaneously with hydrogen ions in solution, thus forming soluble calcium salts with resulting pitting and etching of the pool walls, the value of the Gibbs free energy change (ΔG) must be negative. If the value of ΔG is positive, the reaction cannot possibly take place, at least under the conditions specified.

As is seen from an inspection of Figure 7, ΔG is negative for all values below 13. This is indicative of the fact that calcium hydroxide is a strong base and will interact with hydrogen ions even when these ions are at the extremely low levels found in water whose pH is above 7.0.

In Table 5 are listed the Gibbs free energies of solution of the major constituents found in portland cement and consequently, marcite. These calculations were made following the general chemical thermodynamic guideline enumerated above.

The standard Gibbs free energy of solution, ΔG°, is given by the expression

$$\Delta G^\circ = -RT\ln K_{sp} \tag{13}$$

where R and T have been defined above and K_{sp} is solubility product in pure water for the substance in question. These values are known for $Ca(OH)_2$ and the two polymorphic forms of $CaCO_3$, argonite and calcite. For the silica (SiO_2) and wollastonite ($CaSiO_3$) phases, ΔG° was calculated from the expression for the work done by a representative voltaic cell, i.e.,

$$\Delta G^\circ = -nFE^\circ \tag{14}$$

where n represents the number of faradays of electricity possessed in the cell, F represents

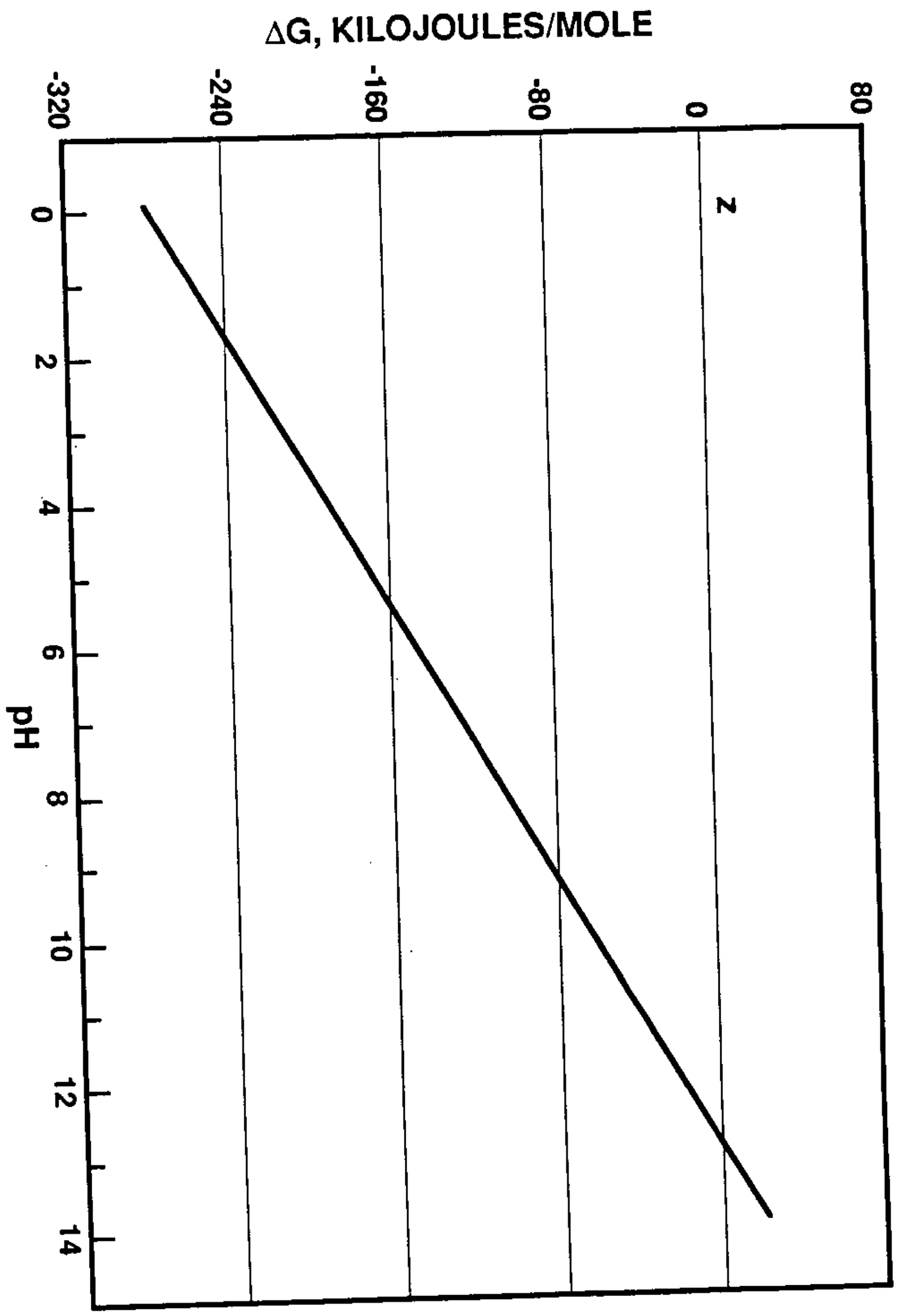


Figure 7. Gibbs free energy change for the reaction of $Ca(OH)_2$ (portlandite) with hydrogen ions in a solution as a function of pH.

Phase	**Gibbs Free Energy of Solution,** ΔG°_{298} (kilojoules/mole)
$CaSiO_3$ (wollanstonite)	+2881
SiO_2 (silica)	+949
$CaCO_3$ (calcite)	+47.7
$CaCO_3$ (aragonite)	+46.3
$Ca(OH)_2$ (portlandite)	+29

Table 5. Gibbs free energy of solution of major constituents of marcite

96,500 international coulombs and E° was calculated from standard (oxidation) potentials.

As can been seen from Table 5, the free energy of solution of portlandite is the least positive. Thus chemical thermodynamics predicts that even in pure water of pH 7.0 this constituent of marcite will be the phase most susceptible to dissolution with corresponding pitting and etching of pool walls.

5.4 Staining of Marcite

A major consideration in the maintenance of swimming pools is the prevention of copper staining. Although the occurrence of copper staining has diminished in recent years because of the use of plastics and other materials in place of copper it must still be considered because of the high costs involved in removing the stains. In this section the sources of copper ions in swimming pools, the formation of copper stains and methods of prevention and removal of copper stains will be discussed.

5.4.1 Sources of Copper in Swimming Pool Water

Copper may be introduced into swimming pool water in at least six different ways.

5.4.1.1 Fill Water

One source of copper in swimming pools is from the water used to initially fill thepool or the water used to periodically replace that which is lost by evaporation, splash-out, and filter backwashing. Copper may be present in both the municipal water supply and the water obtained from private wells. Many public water utilities use copper sulfate to limit the growth of aquatic plants in storage reservoirs [1]. Although the amount of copper in municipal water supplies is limited to meet health regulations, the copper concentration in swimming pools can become high enough to cause staining through repeated refilling of the pools. Water from private wells can contain copper in areas with copper deposits in the earth. Groundwater picks up copper from the earth through the natural processes of erosion and corrosion.

5.4.1.2 Erosion

Copper can enter the swimming pool by erosion of copper materials by circulating pool water. High velocity water can remove small pieces from tubing and other copper containing parts [2]. Erosion is most pronounced in areas with high turbulence such as "ell" and "tee" pipe fittings and pump impellers. These small particles of copper experience aqueous corrosion which eventually leads to copper staining. This source of copper in swimming pool water has been minimized by the use of PVC pipes and plastic parts in circulation pumps in place of copper containing materials [3].

5.4.1.3 Electrolysis

An extremely rare source of copper in swimming pool water is the process of electrolysis. Electrolysis occurs when an electric current carried by a low resistance metal is blocked by a material with a high resistance and the current is forced to leave the metal and be carried through an external path. As the current, or electrons, leave the metal, metal ions with an equal charge are also removed. Copper ions can enter the swimming pool water when an electric current, carried by copper water lines, meets a high resistance plastic or rubber fitting. The electric current is then carried by the flowing water, which in turn picks up copper ions from the pipe. This source of copper ions has been minimized by the use of PVC pipes in place of copper. Where copper pipes are used, they can be protected from electrolysis by electrically connecting them to a junk pipe or grounding rod which is buried in the ground. The current leaves the system at the junk pipe which is corroded instead of the copper pipes [4]. It is a good idea to always ground pool pumps with brass impellers, with a grounding rod to prevent electrolytic corrosion from occurring.

5.4.1.4 Aqueous Corrosion

A more common source of copper ions is the aqueous corrosion of copper materials in contact with the swimming pool water. The rate of corrosion of copper in swimming pool water is very low and nearly constant in the normal pH range of 7.2 to 7.8 [5]. As shown by the Pourbaix diagram in Figure 8, copper is observed to be stable in this region due to the formation of a passive film which impedes further corrosion. This passive film is stable only over intermediate pH values. At higher or lower pH values an ionic species is stable and corrosion is thermodynamically possible. Experiments have shown that the rate of corrosion of copper increases with decreasing pH over the pH range of 3.0 to 6.5 [6].

The presence of other chemical species can have a substantial effect on the corrosivity of swimming pool water to copper. Figure 9 shows that the presence of chlorine causes a large increase in the corrosion rate of copper in aqueous solutions, even at low concentrations. Another chemical which is often present in swimming pool water and which effects its corrosivity toward copper is ammonia. Ammonia may be introduced into swimming pool water via several mechanisms; one is through bather perspiration. An active swimmer can produce up to two pints of ammonia in one hour [7]. The Pourbaix diagram (Figure 10) indicates that the corrosion of copper becomes thermodynamically favorable in ammonia solutions when the pH exceeds an approximate value of 8.0 [8]. Another factor which effects the aqueous corrosion of copper is the alkalinity, measured as

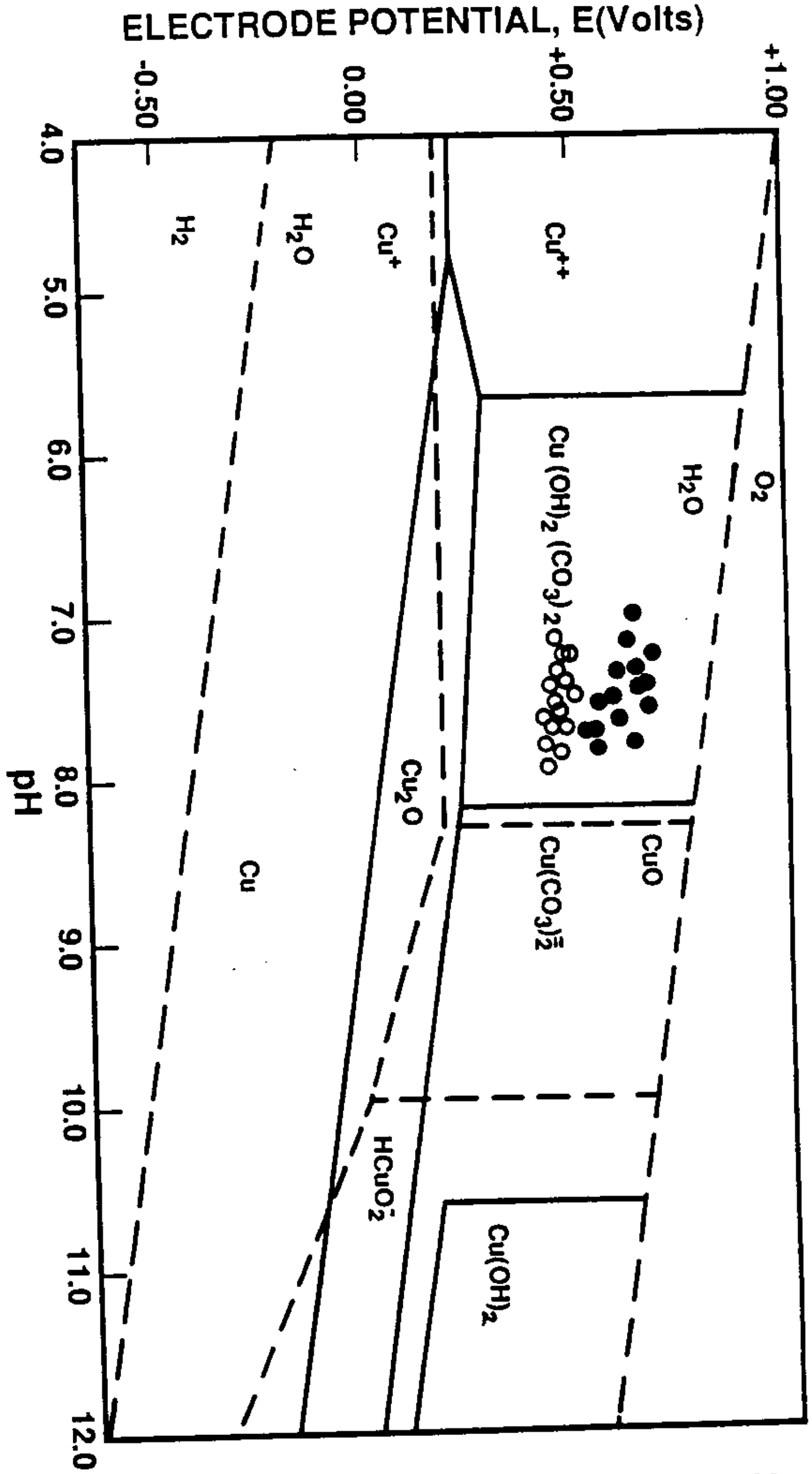


Figure 8. Pourbaix Diagram for 1.6×10^{-5} Cu in the presence of 100 mg/l alkalinity as $CaCO_3$. Close circles - aerated; open circles - deaerated.

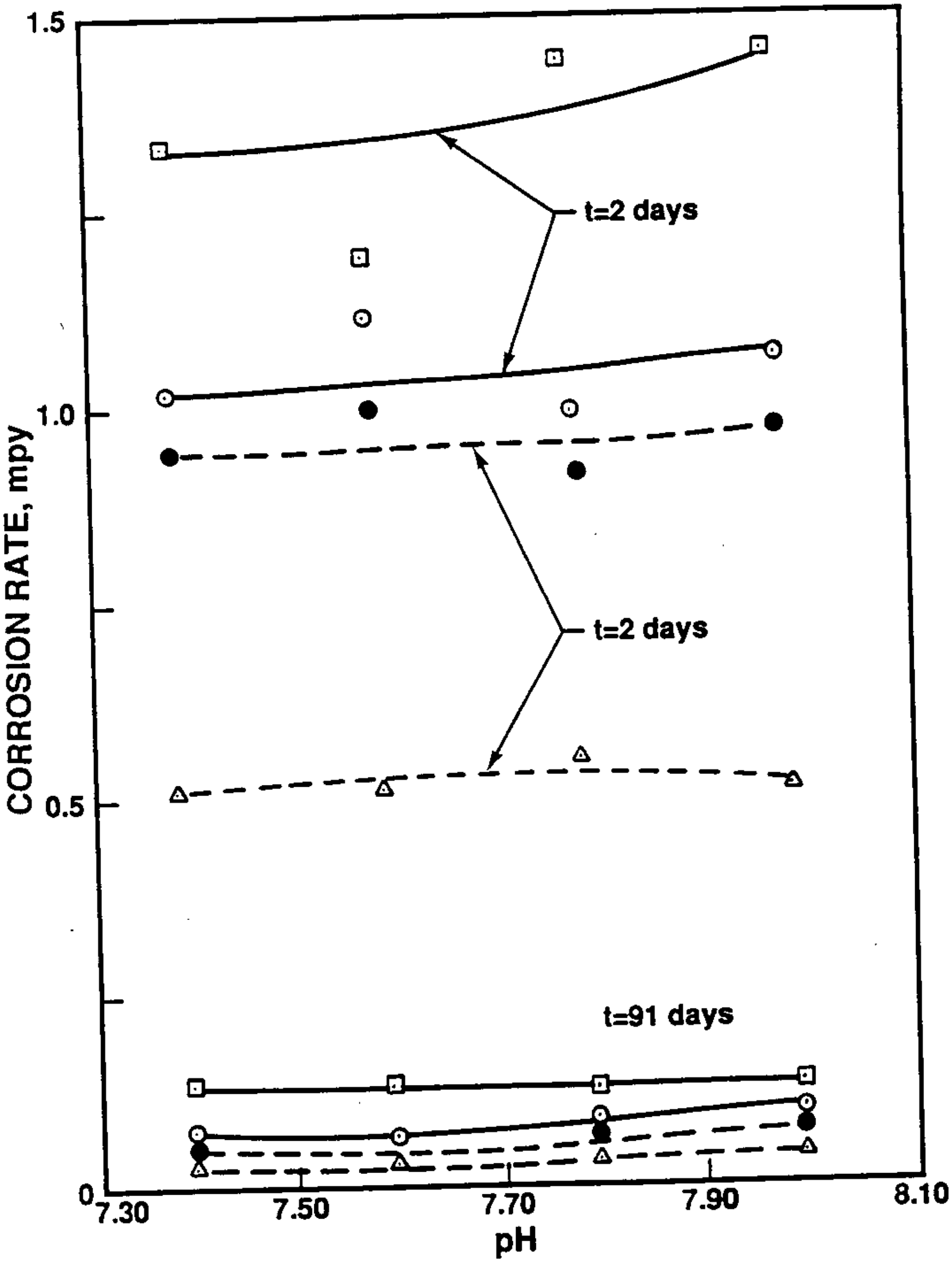


Figure 9. Corrosion rate of copper against pH at two exposure times via weight loss method. Open squares - aerated, chlorine = 1.0 mg/l; open circles - deaerated, chlorine = 1.0 mg/l; closed circles - aerated, no chlorine; open triangles - deaerated, no chlorine.

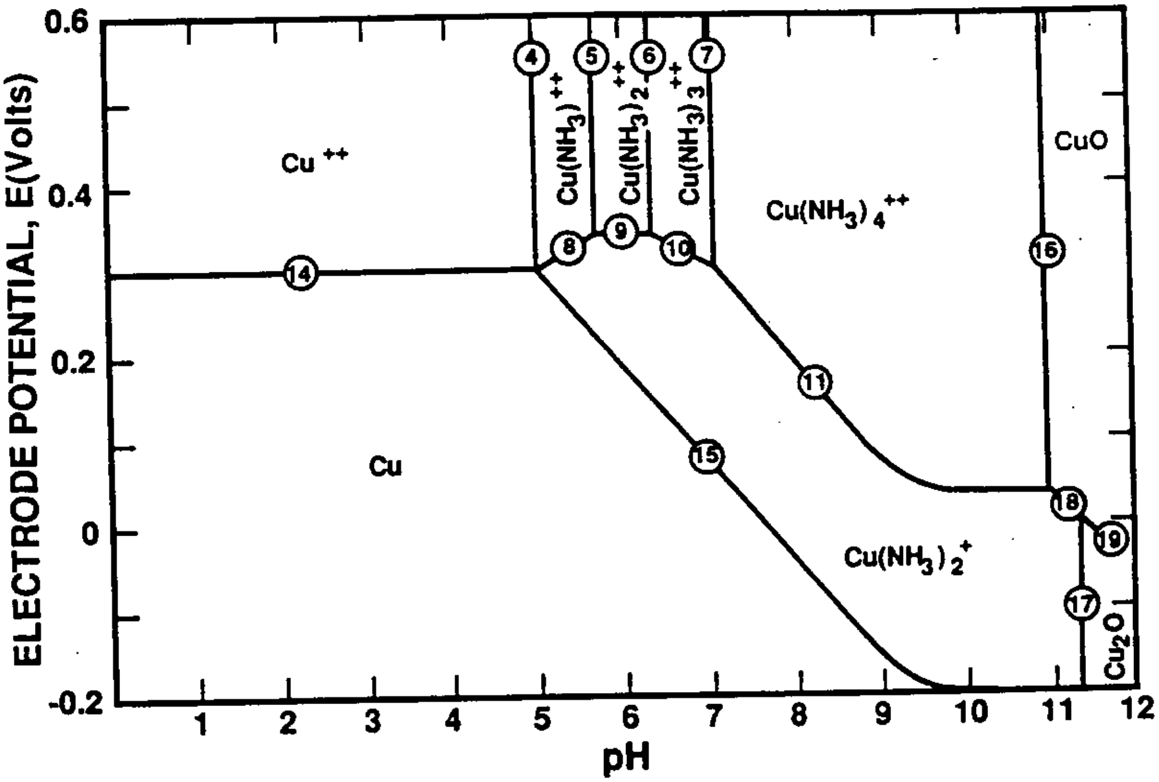


Figure 10. Pourbaix Diagram for H_2O - Cu - NH_3.

calcium carbonate. As Figure 11 shows, increasing alkalinity results in a decreased corrosion rate. This may be attributed to the role of carbonate ions in the formation of the passive films discussed previously.

The most important factor in controlling the corrosion of copper by swimming pool water is the proper maintenance of the pH value. Through the proper use of water test kits and careful attention to instructions for adjusting the pH, copper staining due to corrosion can be prevented. As has already been mentioned, copper staining has become less prevalent since copper pipes have been replaced by PVC, but there are still many sources of copper in the swimming pool system. Copper tubing in heaters, copper fittings, brass and bronze valves, bronze main drain covers, ladders, handrails and other chrome coated fixtures are all possible sources of copper in swimming pool water which can lead to staining [9]. Therefore, it is unwise to ignore the prevention of copper corrosion.

5.4.1.5 Acid Washing

Usually the only method of removing mineral stains, such as copper, iron or manganese, from the pool walls and floor is an acid wash. When the pool surface is acid washed, many of the metal fixtures are covered with acid, and acid enters into the water circulation lines. This acid removes the passive film on copper surfaces and promotes the corrosion of copper. Therefore, during acid washing, a substantial amount of copper is placed in solution. If the pool surface and the circulation lines are not completely cleansed with fresh water, the copper will remain in solution when the pool is refilled. The copper in solution will eventually lead to staining which may be worse than before the acid wash. Great care should be taken to completely flush out and neutralize all of the acid-wash solution [11]. In addition, the attack of marcite by hydrochloric acid as occurs in the acid

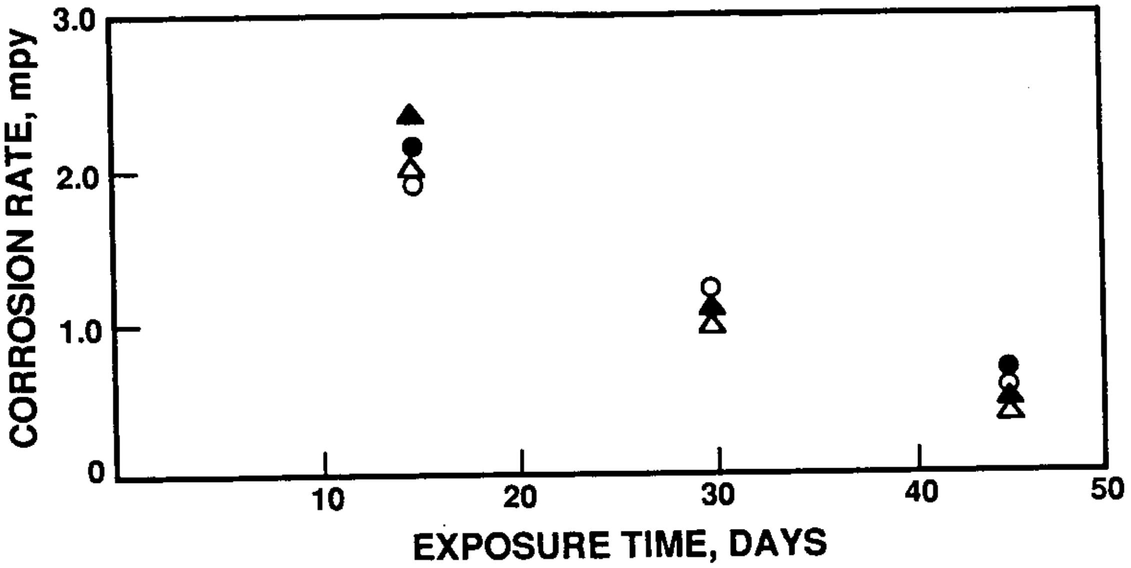


Figure 11. Effect of bicarbonate alkalinity on the rate of corrosion of copper in aerated solutions containing 5 mg/l of chloride and sulfate ions. Closed circles - no alkalinity; open circles - 25 mg/l alkalinity as $CaCO_3$; closed triangles - 100 mg/l alkalinity as $CaCO_3$; open triangles - 200 mg/l alkalinity as $CaCO_3$.

washing of pool walls can yield disastrous results. The attack is physico-chemical. The hydrochloric acid reacts with calcium compounds and forms soluble salts, which are subsequently leached out. Also, there are indications that the hydrochloric acid reacts with other compounds in the plaster to form insoluble salts which have larger volumes (and are less dense) then the material the acid reacted with. This marked increase in volume gives rise to stresses in the matrix which cause it to disintegrate. The appearance of the cement during hydrochloric acid attack changes - yellow stains appear on the surface along with pitting. The yellow stain is due to a compound called ferric chloride, $FeCl_3$, which is found as a result of hydrochloric acid reacting with iron oxides in the cement or in calcium chloride, if the latter has been mixed with the cement as an accelerator.

5.4.1.6 Chemical Additions

Copper can also be added to swimming pool water through chemical treatment. There are several commercial formulations which are designed to control the growth of algae, algaecides which contain copper compounds, usually copper sulfate. The effectiveness of these formulations in controlling algae growth is questionable, and they represent a possible source of copper staining [11]. Another source of copper is through the use of copper ionizers as a method of swimming pool water sanitation. These systems have proved to be effective in maintaining a sanitary swimming pool and they should not cause copper staining with proper maintenance and control. However, it is recommended to avoid adding copper to swimming pool water when there are suitable alternatives.

5.4.2 Formation of Copper Stains on Marcite

Copper stains consist of a precipitate of a copper salt. The two most common precipitates found on swimming pool surfaces are copper (II) oxide, CuO, and copper (II) carbonate, $CuCO_3$. These two precipitates can be distinguished by the different color stains they produce; a black stain is characteristic of copper (II) oxide, while copper (II) carbonate produces a blue-green stain [12]. The dissolution reactions of these compounds are given by the following equations:

$$CuO + H_2O \rightarrow Cu^{2+} + 2OH^- \tag{15}$$

$$CuCO_3 \rightarrow Cu^{2+} + CO_3^{2-} \tag{16}$$

The corresponding expressions for the solubility products are as follows:

$$for\ CuO: \qquad K_{sp} = [Cu^{2+}]\ [OH^-]^2 = 10^{-20.35} \tag{17}$$

$$for\ CuCO_3: \qquad K_{sp} = [Cu^{2+}]\ \left[CO_3^{2-}\right] = 10^{-9.63} \tag{18}$$

These expressions can be used to give a rough approximation of the copper (II) ion concentration required to produce copper stains. For example, at a pH value of 7.0, a copper (II) oxide precipitate would be in equilibrium with a copper (II) ion concentration of approximately 10^{-6} M. More precise calculations are much more complex because the presence of other ionic species disturbs the equilibrium. In the case of copper (II) carbonate precipitation, the concentration of carbonate ions, $[CO_3^{2-}]$, is strongly dependent on the pH of the water, as shown by the following reactions:

$$CO_2 + H_2O \rightarrow HCO_3^- + H^+ \tag{19}$$

$$HCO_3^- \rightarrow H^+ + CO_3^{2-} \tag{20}$$

The solubility product expressions provide general guidelines, but more accurate predictions require detailed knowledge of the specific solution in which precipitation takes place.

These copper compounds precipitate on the surface of pool plaster for several different reasons. The surface of swimming pool plaster contains hydrous calcium oxide, which has a high specific surface area which tends to absorb metal ions from solution. The absorbed ions lower the free energy of the solid-liquid interface. This results in a high concentration of copper (II) ions which forms precipitates. Precipitation involves the processes of nucleation and growth. Nucleation can be assisted by occurring on the plaster surface instead of in the bulk solution. Nucleation on a surface (heterogeneous nucleation) produces a lower interfacial energy between the precipitate and the liquid. Growth of the precipitate is assisted by the high concentration of copper (II) ions near the plaster surface.

In addition to the precipitation of copper salts causing staining of marcite, it is possible that staining can result from exchange of copper ions in the pool water with calcium ions from calcium hydroxide and/or calcium carbonate in the marcite. The resulting exchange products are colored. As has been mentioned above, copper (II) carbonate produces a blue-green stain. Copper (II) hydroxide is black. The exchange reactions are:

$$CaCO_3 + Cu^{2+} \rightarrow CuCO_3 + Ca^{2+} \tag{21}$$

and

$$Ca(OH)_2 + Cu^{2+} \rightarrow Cu(OH)_2 + Ca^{2+} \tag{22}$$

For reaction (21) the Gibbs free energy change is ΔG°_{298} = - 7.5 kilojoules/mole, whereas for reaction (22) the Gibbs free energy change is ΔG°_{298} = - 139.6 kilojoules/mole.

Thus, whereas chemical thermodynamics predicts that both exchange reactions will take place spontaneously, reaction (22) would be expected to dominate because of the more negative free energy change. This prediction is again in agreement with what has already been discussed in this report regarding the relative chemical activity of portlandite in marcite pool plaster.

5.4.3 Prevention and Removal of Copper Stains

As mentioned in the section on aqueous corrosion, copper staining can be prevented through careful control of swimming pool water chemistry and by using substitute materials in place of copper where they are available. Once copper ions are present in solution, sequestering agents can be used to prevent copper staining. Sequestering agents form inert chemical complexes with metal ions, which prevents them from precipitating out on the plaster surface [15]. Once copper stains appear on the plaster surface, they are usually removed by an acid wash. In an acid wash, the stains and some of the plaster are leached away by an acid solution.

6. Conclusions and Recommendations

6.1 Maintenance of Water Chemistry

As a result of studies and observations made during the course of this investigation, it is our opinion that the following guidelines set forth the suggested operation parameters for the proper chemical treatment and maintenance of swimming pool waters. Chemical treatment alone will not produce sanitary pool water. A filtration system in proper operational condition is also required to attain sparkling clear water.

	Minimum	Ideal	Maximum
A. Disinfectant Levels			
1. Free chlorine, ppm	1.0	1.0 - 3.0	3.0
2. Combined chlorine, ppm	None	None	0.2
3. Bromine, ppm	2.0	2 - 4	4.0
B. Chemical Values			
1. pH	7.2	7.4 - 7.6	7.8
2. Total alkalinity (buffering), ppm as $CaCO_3$[*]	60	80 - 140	180
3. Total dissolved solids, ppm	300	1000 - 2000	3000
4. Calcium hardness, ppm as $CaCO_3$	150	200 - 400	500 - 1000
5. Heavy metals	None	None	None

[*] Although reported as ppm $CaCO_3$, total alkalinity measures the combined influence of bicarbonates, carbonates and hydroxides in pool water; i.e., it would be possible to obtain a positive measurement of ppm "$CaCO_3$" with no carbonate in the water at all.

6.2 Prevention of Marcite Etching

From this study, the deterioration of marcite has been found to be chemically related and due primarily to leaching of calcium hydroxide (portlandite) from localized areas of pool plaster. Calcium hydroxide is the hydration product that is most readily leached from concrete.[*] The leaching is of portlandite from the portland cement paste. Unless the pool water is far out of balance the calcite marble aggregate in the cement is not particularly affected. Acidic pool water (pH less than 7.0) can wreak havoc on marcite and pool plumbing, resulting in etching and staining. Proposed solutions to control the damage aggressive water can produce include; (1) paying careful attention to water chemistry to avoid unbalanced water conditions and (2) providing a chemically inert barrier between the pool water and the marcite surface.

Experimental evidence supports the hypothesis that acidic pool water preferentially leaches the portlandite phase out of the marcite matrix, resulting in etching. The least expensive option is to monitor the pool water so as to avoid the occurrence of acidic or other marcite-corrosive conditions such as low water calcium content. This option, however, involves the education of pool owners and pool maintenance personnel concerning the importance of *regular* and *thorough* monitoring of pool chemistry. Pool owners must be knowledgeable about the pool chemicals they use as well as pool water chemistry in general.

From knowledge gained on this research program with regard to the swimming pool water - marcite system it is apparent that over time marcite will maintain its pristine and beautiful white surface only if swimming pool water chemistry is continuously and meticulously controlled. This control, i.e., maintaining pool water "balance" must be established from the very beginning and starts when the freshly marcited pool is first filled with water. However, field studies revealed that this is often not the case and that problems

---

[*] It should be noted that the temperature of the swimming pool water will also be a factor. Calcium hydroxide is more soluble in cold water than it is in warm water. This may explain observations communicated to us during the course of this investigation by several pool owners in the northern part of the country that extensive pitting and etching were observed in marcited swimming pools in the spring after having been covered over for the winter.

such as marcite pitting etching, mottling, staining and scaling are far too common.

It is our opinion that the "unforgiving" nature of marcite to poor control of water chemistry can be mitigated by protecting the marcite surface with suitable chemical barrier coatings. Suitable coatings would protect the marcite from aggressive water and therefore extend its useful life.

In a recent paper on coating concrete a simplified classification system for concrete exposure conditions is offered [20]. Coatings system recommendations are discussed generically within the context of the exposure classification. The authors of the above-referred paper do not address the problem of marcite deterioration in swimming pools directly. However, based upon their classification of substrates in terms of exposure potential - immersed (canals, pilings, tank linings); atmospheric (walls, low-stress pavement); atmospheric plus mechanical durability (decking, high stress pavement); industrial atmospheric (walls, pavement, floors in splash and spillage environments); and buried (pipelines, foundation slabs), the follow typical coating recommendations can be made as specifically regards marcite exposure conditions in swimming pools.

- High-performance epoxy; one or two coats, 10-12 mils.
- Elastomeric lining, usually polyurethane; 20-40 mils.
- Thermoplastic lining, usually vinyl.
- Polyester, glass filled; 20-60 mils.
- Epoxy, glass filled; 40-200 mils.
- Epoxy with polyurethane topcoat; 6+6 mils.
- Durable epoxy high build; 6-12 mils.
- Polyurethane sealer with polyurethane topcoats; 6-12 mils.
- Silicate or hydrophobic sealer.

- Polyurethane sealer.

Although coated marcite may be initially more expensive, it represents a promising alternative. The concept of coating a cement structure which is continuously immersed in water is not novel. Canals, waste water treatment process structures, tanks and pilings are concrete structures which are routinely coated with either epoxies, polyurethanes, vinyls, or polyesters. The coatings provide protection against reinforcement corrosion, chemical attack, frost damage, mechanical damage, water penetration and salt intrusion. Since selective leaching is involved in marcite deterioration and it is of primarily uncarbonated calcium hydroxide (portland cement hydration product), then precarbonation of the fresh marcite paste may be another method for restricting deterioration. This could be accomplished by initial use of "carbonated" water having a negative Langelier Saturation Index, or by creating a high carbon dioxide atmosphere (e.g. 5 to 7 percent carbon dioxide) and a relative humidity of about 50 percent inside a "tented" pool immediately after the marcite application [21].

Another possibility for eliminating or greatly reducing the leaching of calcium hydroxide from marcite comes from the construction industry [22,23]. The latest additive to strengthen concrete is silica fume. Silica fume, a by-product of silicon alloys and metals production, consists of particles 100 times smaller than portland cement grains. Silica fume improves the strength and durability of conventional concrete by filling voids, making the material extremely dense. It does this in two ways. In conventional concrete, about 25% of the cement paste is calcium hydroxide which does not contribute to concrete strength. Adding silica fume converts nearly all the calcium hydroxide to calcium silicate hydrate, which is the strength ingredient in cement paste. Microphotographs show that the silica fume partially fills the tiny voids between cement grains, and it apparently adds strength in this way. From the standpoint of plaster chemistry, conversion of calcium hydroxide to calcium silicate hydrate would make the pool plaster much less susceptible to chemical attack.

Copper staining in swimming pools is caused by the precipitation of copper (II) salts on plaster surfaces. These precipitates form from copper (II) ions which enter the swimming pool water through several different methods and common aqueous anions. The most common source of copper ions in solution is the aqueous corrosion of copper containing materials; therefore, the most effective method of preventing copper staining is the careful control of water chemistry. If copper ions enter into solution in the swimming pool, either through corrosion or any other source, a sequestering agent can prevent them from producing stains by blocking their chemical activity. Copper stains can usually be removed from swimming pool plaster by acid washing although this a method of "last resort".

Finally, a word about calcium chloride because of the role this additive can play in the overall integrity of marcite surface. The main benefit of calcium chloride is the acceleration of the hydration reaction of cement, which means it gets harder faster and this saves time and money for the pool contractor. However, care should be exercised when introducing calcium chloride into the cement. Calcium chloride *should not* be introduced into the cement mixture as a solid but only as a solution since the undissolved crystals can attract moisture and can deprive the cement of proper hydration. If the cement is not given the opportunity to hydrate sufficiently, flash setting can occur, which results in cracking. When using calcium chloride as an accelerator, no more than 2% as a solution to the cement should be added.

7. References

[1] Cardall, John T., Copper Staining, Pool 'N Patio (Spring 1973).

[2] Ibid.

[3] Girvan, John W., Presence of Copper in Swimming Pool Water (September 1981).

[4] Cardall, John T., Copper Staining, Pool 'N Patio (Spring 1973).

[5] Girvan, John W., Presence of Copper in Swimming Pool Water (September 1981).

[6] Ahmadi, Abdul B., Effect of Water Quality Parameters on Corrosion of Mild Steel, Copper, and Zinc, University of Florida Doctoral Dissertation (1981).

[7] Ingols, R.A., Iron, Copper and Manganese - A Technical Paper (1968).

[8] Ibid.

[9] Girvan, John W., Presence of Copper in Swimming Pool Water (September 1981).

[10] Cardall, John T., Copper Staining, Pool 'N Patio (Spring 1973).

[11] Girvan, John W., Mustard Algae Control in Swimming Pools (June 1985).

[12] Ingols, R.A., Iron, Copper and Manganese - A Technical Paper (1968).

[13] Pagenkopf, Gordon K., Introduction to Natural Water Chemistry, Environmental Science and Technology Series (1978).

[14] Levy, Barbara, Scale and Stains: It's What You Do When You Fill the Pool, Pool News (June 1975).

[15] Girvan, John W., Sequestering Agents (1985).

[16] Ahmadi, Abdul B, Effect of Water Quality Parameters on Corrosion of Mild Steel, Copper, and Zinc, University of Florida Doctoral Dissertation (1981).

[17] Ibid.

[18] Johnson, H.E. and Leja, J., Journal of the Electrochemical Society, 112 638 (1965).

[19] Ahmadi, Abdul B., Effect of Water Quality Parameters on Corrosion of Mild Steel, Copper, and Zinc, University of Florida Doctoral Dissertation (1981).

[20] Foscante, R.E. and Kline, H.H., Coating Concrete - An Overview, Materials Performance 34-36 (September 1988).

[21] Erlin, Hine, Associates Division, Wiss, Janney, Elstner Associates, Inc., Reconnaissance of Pools and Petrographic Studies of Pool Plasters for Artesian Pools, Inc. WJE No. 867746, March 17, 1987.

[22] Canfield, Doug, Seattle Leads Nation in the Art of High-Strength Concrete, Pacific Builder and Engineer (July 6, 1987).

[23] Godfrey, K.A., Concrete Strength Record Jumps 36%, Civil Engineering (October 1987).

Appendix A. Laboratory Simulation of Swimming Pool Parameters

An important aspect of this phase of the study was to duplicate typical swimming pool conditions in the laboratory. To determine a cement specimen surface area to water ratio that was as close as possible to the surface area to water ratio found in a typical swimming pool the following calculations were made.

Consider a swimming pool that is 30' long, 15' wide and an average of 8' deep:

$$volume = 30' x\,15' x\,8' = 360\ ft^3$$

$$3600\ ft^3\left(\frac{1\ m^3}{35.314\ ft^3}\right) = 101.94\ m^3$$

$$101.94\ m^3\left(\frac{100^3\ cm^3}{1\ m^3}\right) = 1.0195\,x\,10^8\ cm^3$$

$$1.0194\,x\,10^8\ mL\left(\frac{1\ \ell}{1000\ mL}\right) = 101{,}940\ liters$$

$$101{,}940\ liters\left(\frac{1\ gal}{3.7854\ liters}\right) = \mathbf{26{,}929\ gallons}$$

$$surface\ area\ of\ pool = 2ab + 2ac + bc$$

$$\begin{aligned}
&= 2(18)(15) + 2(8)(30) + 15(30)\\
&= 1170\ ft^2\\
&= 1170\ ft^2\left(\frac{1\ m^2}{10.763\ ft^2}\right) = 108.705\ m^2\\
&=108.705\ m^2\left(\frac{10{,}000\ cm^2}{m^2}\right) = 1{,}087{,}050\ cm^2
\end{aligned}$$

surface area cylinder

$$\begin{aligned} 2\pi rl + 2\pi r^2 &= 40.36 \\ 2\pi\left(rl + r^2\right) &= 40.36 \\ r(l + r) &= 6.42 \\ 1.27(l + 1.27) &= 5.05 \\ l + 1.27 &= 5.05 \end{aligned}$$

$$\begin{aligned} l &= 3.78\ cm \\ &\sim 1.5\ inches \end{aligned}$$

The radius of the cylinder was set equal to 1.27 cm (equivalent to one half inch). The length of the cylinder was 1.5 inches.

The problem of achieving analogous circulation rates was solved as follows:

> The pool industry recommends an eight hour turn over rate. Since one gallon containers were used in these investigations, a flow rate of 1/8 gallon per hour, or
>
> $$\frac{0.125\ gal}{hr}\left(\frac{1\ hr}{60\ \text{min}}\right)\left(\frac{3785\ mL}{gallon}\right) = \frac{7.88\ mL}{\text{min}}$$
>
> had to be achieved.

Appendix B. Sources of Marcite Samples for Diagnostic Studies

Aber Pools/Mr. Marcite

Acapulco Pool

Advanced Pool Design

Al Jackson Pools

Al Summers

Artesian Pools

Atlantis Condominium

Atlantis Pools

BioLab Inc.

Blue Image Pools

Bob Steelman Plaster

Bruce Steelman

C.F. Pools and Spas

C.L. Industries, Inc.

Cascade Pool and Spa, Inc.

Creative Custom Pools, Inc.

Dadeland Pools

Demar Baron Pool Plastering Co., Inc.

Eric Herman

Estate Pools

Estate Pools

Florida Pool Corporation

Florida Stucco Corp.

Gardner Pool Plastering

Gator Pool and Spa Service

Geo A. Brown and Son

George E. Linnert

Gerard Morrissey

Great Lakes Biochemical Co., Inc.

Guide Corporation

H_2O Chemists

Halifax Plantation Pool

Horner Equipment International, Inc.

Imperial Pools

J.J. Tepas

Jacks Magic

Kaplan Pools

Keith Payne Pools

Kelly

Lawden Pools

Longhammer Pool

Lotzkar Pool

Med's Pool Service

Ocean Palm Villa

Padgett Pool Plastering

Pensak Pool

Pools by John

Quality Pools

Riverside Cement Company

Rizzo Construction Pool Co., Inc.

Southern Vinyl Waterproofing

Starr-Lite Pools of Highlands County, Inc.

Tonoka Plaster

Town and Country Pools, Inc.

Treasure Coast Pool Service, Inc.

Village Condominium Pool

Village Pools

Wet World

Appendix C. NSPI Plaster Sample Data Sheet

(Please fill out what you can. If you kept a log other than what is listed below, please include a copy with this check list.)

NSPI PLASTER SAMPLE DATA SHEET

1. JOB ADDRESS____

City & State ____________________________ Zip Code __________

Your Name & Telephone________________________( )__________

2. PLASTERING

Plastering Company Name ______________________________

IS THIS AN NSPI ORIGINAL PLASTER SAMPLE? ☐ Yes ☐ No

☐ New Pool or ☐ Replaster? ☐ Commercial or ☐ Residential?

3. HOW SOON AFTER PLASTERING WAS THE POOL EQUIPMENT STARTED? *(please circle)* 1 Day 2 Days 3 Days Other_____

4. HOW MANY DAYS DID IT TAKE TO FILL THE POOL? *(please circle)* 1 Day 2 Days 3 Days Other_____

5. WHAT WERE THE WEATHER CONDITIONS AT START UP? *(Hot, cool, windy, rainy, etc.)* ____________________

6. CONDITION/BALANCE OF FILL WATER

A. Did you test the water before you began filling? ☐ Yes ☐ No

(Please list the measurements for the following, if known:) pH_____ Alkalinity_____ Hardness_____ Dissolved Solids_____

Chlorine_____ Iron_____ Copper_____ Temperature_____*(Specify Fahrenheit or Centigrade)*

B. Did you test the water when you finished the start up? ☐ Yes ☐ No

(Please list the measurements of the following, if known:) pH_____ Alkalinity_____ Hardness_____ Dissolved Solids_____

Chlorine_____ Iron_____ Copper_____ Temperature_____*(Specify Fahrenheit or Centigrade)*

C. Condition/balance of existing pool water. *(Please list the measurements of the following, if known:)* pH_____ Alkalinity_____

Hardness_____ Dissolved Solids_____ Chlorine_____ Iron_____ Copper_____ Stabilizer_____

Temperature_____*(Specify Fahrenheit or Centigrade)*

Type of Calcium Chloride Used: ☐ 77% ☐ 95% ☐ None Other_____

7. PLASTER/START UP

How much "plaster dust" was there when you started the pool up? *(please circle)* Heavy Medium Light

What method did you use to start up the pool? *(please circle appropriate response)*

Acid Start Up Light Acid *(raise pH and Alkalinity slowly)* Chlorine Shock Treatment Other *(please explain)*________________

How often was the pool brushed each day? *(please circle)* Once Twice Three Times Other_____

Was vacuum brush used? ☐ Yes ☐ No

How long did it take for "plaster dust" to disappear? ____________________

8. PHENOMENON FIRST APPEARED OR DISCOVERED

☐ Before Completely Full ☐ After First Filling ☐ Subsequent Fills ☐ Overnight Occurrence ☐ When First Heated

☐ Within One Month _____ Months After Plaster _____ Years After Plaster Other *(Explain)*:________________

9. APPEARANCE OR CHARACTERISTIC

☐ Spider Web Surface Marks ☐ Check Cracks ☐ Pimples/Eruptions ☐ Drip Marks Under Piping Outlets ☐ Discoloration

☐ Grey ☐ Blue/Green ☐ Pitting Holes ☐ Chalking ☐ Craters ☐ Localized Eroded Rough Areas ☐ Barnacles

☐ Localized Rough Buildup ☐ Delamination/Pop Offs ☐ Roughness on Tile/Light Lens Give Location:________________

10. CORRECTIVE/REMOVAL PROCEDURES ATTEMPTED WITH WATER IN POOL

☐ Chlorine Shocking ☐ Sequestering Agents ☐ Standing/No Drain Acid Wash ☐ Drain and Replace Water Immediately Without Acid Washing Is Condition Evolving/Worsening? ☐ Yes ☐ No or ☐ Static – No Change Since Discovery?

☐ Spot Acid Wash ☐ Sanding ☐ Other repair *(specify)* ______

11. EMPTY POOL PROCEDURES

☐ Chlorine Wash ☐ Acid Wash ☐ Power Sanding ☐ Hydrogen Peroxide Wash ☐ Application Heat

☐ Drain and Exposed for Additional Air Drying _____# Days *(please specify)*

12. COLOR OF PLASTER

Was the pool plaster *(circle)* WHITE or TINTED? *(If tinted, give color.)* ______

13. DID YOU USE SEQUESTERING AGENTS OR WATER CLARIFIERS? ☐ Yes ☐ No

If yes, please list which product(s) you used: ______

14. NORMAL CHEMICAL ADJUSTMENTS

☐ Daily ☐ Twice Weekly ☐ Weekly ☐ Continuously (feeder) ☐ Monthly

15. CHLORINATION/SANITIZER INTRODUCTION METHOD

☐ Floating/Wandering Trichlor Dispenser ☐ Tethered Trichlor Dispenser ☐ Trichlor Dispenser Anchored Deep End

☐ Trichlor Tablets in Skimmer ☐ In Line Trichlor Feeder Pressure Type ☐ Suction Type ☐ Liquid Chlorine

☐ Dichlor Granular Broadcast Over Surface ☐ Calcium Granular Broadcast ☐ Electrolytic Production Equipment Using Salt Type *(Specify)*______ ☐ Ion Transfer Copper/Silver ☐ Gaseous Chlorine Injections How Often? *(specify)*______

☐ Ozone ☐ Bromine ☐ Baquacil ☐ Other ______

16. pH CONTROL

☐ Muriatic Acid ☐ Dry Acid ☐ Soda Ash ☐ Bicarb ☐ Other______

17. ALGAE CONTROL

☐ Periodic Shocking Liquid ☐ Periodic Shocking Granular ☐ Quaternary Ammonia Algicide ☐ Elemental Copper Algicide

☐ Other ______

18. STABILIZER ADDITIONS

☐ Direct to Pool Granular ☐ Induced Through Skimmer ☐ Floater

19. MATERIALS OR PRODUCTS USED *(please specify)*

A. Factory Blended Material ______

B. Manufacturer/Vendor of Cement ______

C. Manufacturer of Aggregate ______

20. ADMIXTURES

☐ Troweling Agents ☐ Liquid ☐ Flake or ☐ Granular Calcium Chloride Accelerator ☐ 77% ☐ 95% ☐ Other______

☐ Pre Dissolve all Granulars ☐ Decanting Inert Ingredients ☐ Antihydro ☐ Retarding Agents

☐ Additional Cement Added to Factory Blend ☐ Dusting Dry Cement to Wet Surface ☐ Calcium Aluminate Cement

☐ Lime ☐ Other *(specify)*______

21. PRE-FILTRATION WATER CLARIFYING SCHEMES

☐ Activated Carbon ☐ D.E. ☐ Cartridge ☐ Sequestering Agents ☐ Oxidizers ☐ None ☐ Other______________

22. FILTERING TYPE/CONTAINER

☐ Non Corrosive (PVC/ABS/Plastic/Other)______________ ☐ Metallic ☐ D.E. ☐ Sand ☐ Cartridge ☐ Anthracite

23. TIMED CIRCULATION OPERATIONS PER DAY

☐ No Timer ☐ 2 Hours ☐ 4 Hours ☐ 6 Hours ☐ 12 Hours ☐ Other *(specify)* ______________

24. PUMP AND STRAINER

☐ Non Corrosive (PVC/ABS/Plastic/Other)______________ ☐ Metallic Bronze ☐ Cast Iron

25. VALVES (EXCEPT WASTE CONTROL)

☐ Non Corrosive (PVC/ABS/Plastic/Other)______________ ☐ Metallic Brass ☐ Cast Iron

26. PIPING AND MANIFOLDS

☐ Non Corrosive (PVC/ABS/Plastic/Other)______________ ☐ Copper ☐ Galvanized ☐ Heat Sinks Copper

27. PLUMBING BOTTOM DRAIN LINE

☐ Plumbed Directly to Pump ☐ To Skimmer ☐ Closed to Operate Suction Cleaner

28. HEATER

☐ Fossil ☐ Solar Metallic ☐ Solar Plastic ☐ Electric Resistance ☐ Heat Pump

*Please provide make and model number*______________

29. METALS IN CONTACT WITH WATER

☐ Skimmer Basket Weights/Handles ☐ Return and Hydrotherapy Outlets ☐ Chrome Plated Brass Lillypad Gooseneck

☐ Light Ring ☐ Handrails ☐ Ladders ☐ Bottom Drain Frames and Grate ☐ Hydrostatic Plugs

☐ Thermometer ☐ Vacuum Ports ☐ Rope Hooks ☐ Fountain/Spray Heads ☐ Copper Skimmer Tank

☐ Sacrificial Anode Current Collectors (Zinc Balls) Where located?______________ ☐ Electrical Powered Cleaning Robot

☐ Other ______________

30. GIVE POOL CAPACITY IN GALLONS

☐ Calculated______________ ☐ Owner/Service Co. Estimate______________ ☐ Meter Reading______________

31. SURFACE AREA ROUGHNESS COMPARED TO SANDPAPER GRIT

☐ 400 or Finer ☐ 220 ☐ 120 ☐ 80 ☐ 40 ☐ Rougher than 40

32. INFORMATION OBTAINED VIA

☐ Pool Owner ☐ Pool Contractor ☐ Start Up Personnel ☐ Plasterer ☐ Service or Retail Advisor

33. WINTERIZING

☐ Covered Full and Inoperative ☐ Completely Empty ☐ Anti Freeze in Piping ☐ Other________

Give Length of Swimming Season__________*(specify number of months)*

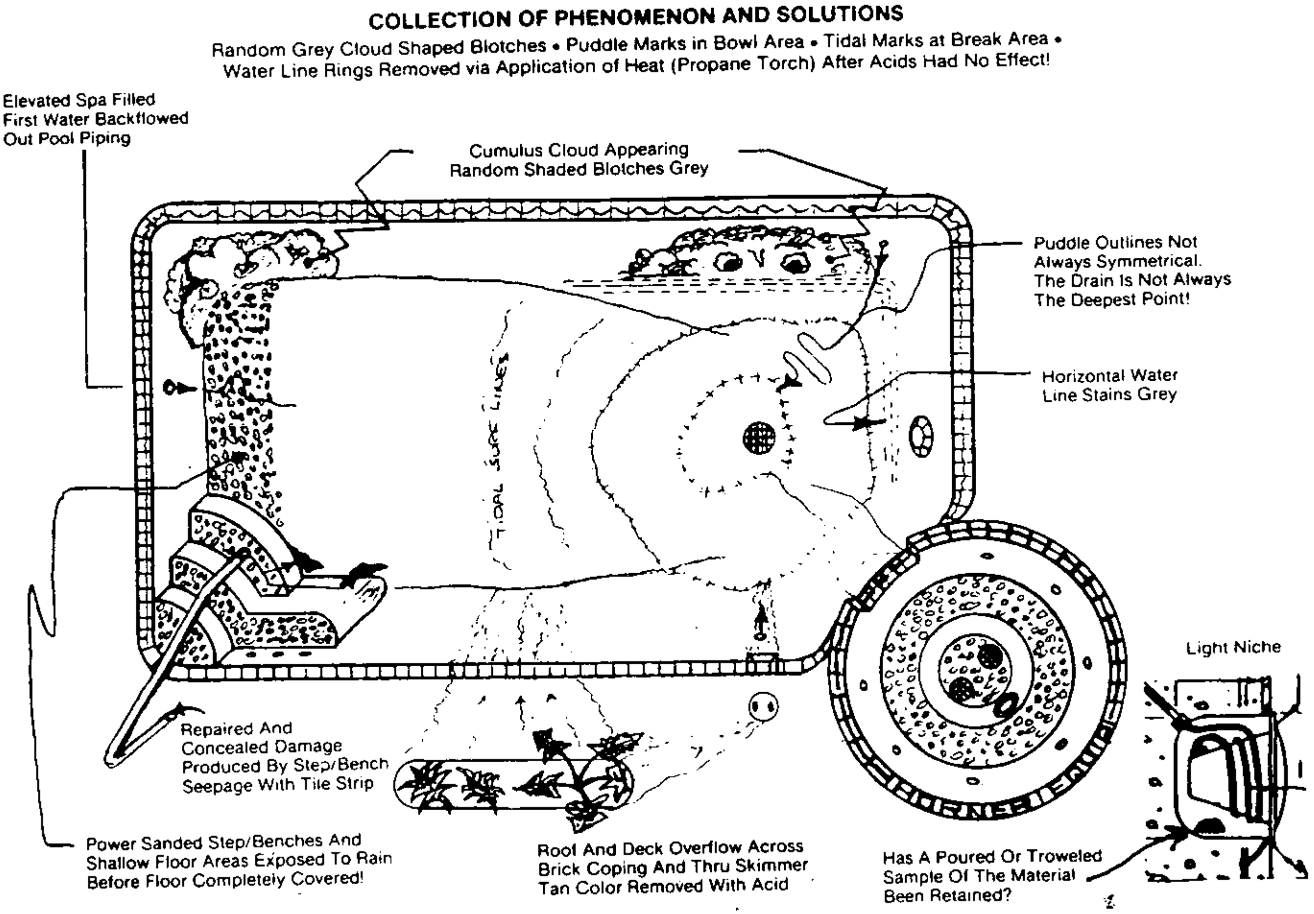
34. ARE THERE TRANSFORMER TYPE OR BURIED UTILITY LINES NEAR THE POOL? ☐ Yes ☐ No *How close?* ______________

35. RELATIVE SURFACE HARDNESS OF PLASTER

☐ Easily Scored With Pumice Stone ☐ Difficult to Score ☐ Some Areas Easily Scored ☐ Coin Used ☐ Credit Card Edge

36. COLLECTION OF PHENOMENON AND SOLUTIONS

This illustration shows common plaster finish deficiencies along with a brief description of the possible cause. Please indicate on the drawing the locations in the pool where the enclosed samples were taken and circle any characteristics below that are found in the pool. (If you wish you may attach a separate drawing of your pool and indicate the problem(s) found according to this example.)



(Diagram courtesy of Horner Equipment Of Florida)

37. TRANSMIT SAMPLES

Please send an NSPI disk (lid) *or* 2 x 2 inch sample of plaster deterioration problems (and a 2 x 2 inch sample of non-deteriorated plaster from the same pool, if possible), *in pool water*, along with this form and as much information concerning the history of the pool as you have available, to the address below. If you have questions concerning this data sheet, please contact:

PLASTER RESEARCH PROJECT
165A Rhines Hall
Dept. of Materials Science & Engineering
UNIVERSITY OF FLORIDA
Gainesville, Florida 32611

Standard BCIAC distribution list for all final reports

Julius Blum
American Plumbing
P.O. Box 1389
Orlando, FL 32802

Daniel Whiteman
Gulf Constructors Inc.
P.O. Drawer 4256
Sarasota, FL 33578

Hoyt G. Lowder
Fails Management Institute
5301 West Cypress Street
P.O. Box 22088
Tampa, FL 33622

Jim Falkner
Falkner, Inc.
P.O. Box 673
Orlando, FL 32802

Daniel O'Brien
FCILB
111 Coast Line Drive East
P.O. Box 2
Jacksonville, FL 32201

Susan J. Leigh
Fla. Housing Financing Agency
2740 Centerview Drive
Tallahassee. FL 32399-8244

William R. Conway
110 Orchard Lane
Ormond Beach, FL 32176

The Honorable Wm. Cecil Golden
Deputy Commissioner
Department of Education
FL Education Center
Tallahassee, FL 32399

Charles R. Perry
Perry Construction Inc.
2500 NE 18 Terrace
Gainesville. FL 32609

Brisbane H. Brown, Jr.
FAC 101
University of Florida
Gainesville. FL 32611

John C. Pistorino, President
Pistorino & Alam
7701 SW 62 Avenue - 2nd Floor
South Miami, FL 33143

J. R. "Jock" Crockett
Construction Complaints Study
Committee
2157 Coral Gardens Drive
Wilton Manors, FL 33306

Mr. Donald R. Dolan
Executive Vice President
MECH. CONTR. ASSOC. OF SO. FL.
99 N.W. 183rd Street, Suite 102
Miami, Florida 33169

Mr. Dean Ellis
802 Northwest First Avenue
Delray Beach, Florida 33444

Mr. Thomas Mack, State Director
FL. HOME BUILDERS ASSOCIATION
135 Young Place
Lakeland, Florida 33803

Mr. Russell P. Smith, Pres.
THE PLUMBING EXPERTS, INC.
303 Northwest First Avenue
Boca Raton, Florida 33431

Mr. Clifford I. Storm, Director
THE BROWARD CO. BOARD OF
RULES AND APPEALS
955 S. Federal Highway, Suite 401
Ft. Lauderdale, Florida 33316

Mr. Warren M. Sutton
UNIVERSAL DIVERS. ENT., INC.
1050 East 24th Street
Hialeah, Florida 33013

Ms. Celeste Kalemeris Valdez, Vice Pres.
KALEMERIS CONSTRUCTION, INC.
5010 North Cortez Avenue
Tampa, Florida 33684

Kinney S. Harley
P.O. Box 10428
Tallahassee, FL 32302

Joseph Holland
1225 N. Halifax Avenue
Daytona Beach, FL 32118

Paul Scheele
Paul Scheele & Associates
P.O. Box 24445
Jacksonville, FL 32241

R. Bruce Simpson
Crom Corporation
250 SW 36 Terrace
Gainesville, FL 32607

Michael Blankenship
1123 Woodville Hwy.
Tallahassee, FL 32301

T. Michael Kaney, Vice Pres.
FL. MINING AND MATERIALS CORP.
P.O. Box 31965
Tampa, FL 33631-3965

Richard Traynor
Executive Dir., Fla. AGC Council
P.O. Box 10569
Tallahassee, FL 32302

Clark Jennings
Department of Legal Affairs
Tallahassee, FL 32399-1050

Construction Engineering Tech. Dept.
Broward Community College
3501 S.W. Davie Rd.
Ft. Lauderdale, FL 33314

Building Construction Program
Central Fl. Community College
P.O. Box 1388
Ocala, FL 32678

Building Construction Program
Daytona Beach Community College
P.O. Box 1111
Daytona Beach, FL 32015

Building Construction Program
Edison Community College
8099 College Parkway S.W.
Fort Myers. FL 33919

Building Construction Program
Gulf Coast Community College
5230 W. Highway 98
Panama City, FL 32401

Building Construction Technology
Miami Dade Comm. College
11011 S.W. 104th Street
Miami, FL 33176

Vocational & Technical Programs
Pasco-Hernando Comm. College
2401 State Highway 41, North
Dade City, FL 33525

School of Bldg. Const.
University of Florida
FAC 101
Gainesville, FL 32611

Building Construction Technology
Fl. Jr. College/Jacksonville
501 W. State Street
Jacksonville, FL 32202

Construction Engineering Technology
Hillsborough Comm. College
P.O. Box 30030
Tampa, FL 33630-3030

Construction Engineering
Palm Beach Junior College
4200 Congress Avenue
Lake Worth, FL 33641

Engineering & Construction
Pensacola Junior College
1000 College Boulevard
Pensacola, Fl 32504

Building Construction Program
Indian River Comm. College
3209 Virginia Avenue
Fort Pierce, FL 33498

Building Arts Program
St. Petersburg Jr. College
2465 Drew Street
Clearwater, FL 33575

Building Construction Prog. I - 50
Santa Fe Community College
3000 N.W. 83rd Street
Gainesville, FL 32602

Construction Engineering Technology
Seminole Community College
100 Weldon Blvd.
Sanford, FL 32771-6199

Construction Technology
Valencia Community College
P.O. Box 3028 MC 4-23
Orlando, FL 32802

Construction Technology Dept.
Fl. Agr. & Mech. University
P.O. Box 164
Tallahassee, FL 32307

Construction Management Dept.
Florida Int'l University
V H 230
University Park - Tamiami Trail
Miami, FL 33199

University of North Florida
Div. of Tech. and Voc. Ed.
4567 St. Johns Bluff Road, South
Jacksonville, FL 32216

Building Construction Dept.
University of West Florida
Building 70
Pensacola, FL 32504

Technology
Manatee Junior College
5840 26th Street West
Brandenton, FL 34207

ABC Florida Gulf Coast Chapter
P.O. Box 152107
Tampa, Fl. 33684

ABC Florida Panhandle
7100 Plantation Rd.. Suite 21
Pensacola, FL 32504

ABC North Florida Chapter
1230 North Adams Street
Tallahassee, FL 32302

AGC Northwest Florida Chapter
P.O. Box 17108
Pensacola, FL 32501

AGC Mid-Florida Chapter
P.O. Box 22646
Tampa, FL 32622

ABC Central Florida Chapter
1260 Palmetto Avenue
Winter Park, FL 32789

ABC Florida Gold Coast Chapter
4700 N.W. 2nd Avenue, Suite 202
Boca Raton, FL 33431

ABC Florida Space Coast Chapter
P.O. Box 2296
Melbourne, FL 32902-2296

AGC Northeastern FLorida Chapter
P.O. Box 2519
Jacksonville, FL

AGC Florida East Coast Chapter
2617 Australian Avenue
West Palm Beach, FL 33407

Florida AGC Council
1363-A E. Lafayette Street
P.O. Box 10569
Tallahassee, FL 32302

AGC South Florida Chapter
15105 N.W. 77th Ave., Unit 150
Miami. FL 33015

DAYTONA BEACH HBA
2435 S. Ridgewood Avenue
South Daytona, FL 32119

Florida Home Builders Assoc.
P.O. Box 1259
Tallahassee, FL 32302

HBCA BREVARD
1500 A West Eau Gallie Blvd.
Melbourne, FL 32935

CHARLOTTE BCA
630 Woodbury Drive, Suite A
Port Charlotte, FL 33954

CHIPOLA FHBA
P.O. Drawer 728
Marianna. FL 32446

CITRUS CO. BA
1196 S. LeCanto Highway 491
LeCanto, FL 32661

COLLIER CO. BCA
3227 Horseshoe Drive, S.
Naples, FL 33942

FLAGLER CO./PALM COAST BA
1 Florida Park Drive, Suite 330
Palm Coast, FL 32137

FLA. ATLANTIC BA
3200 N. Military Trail
Boca Raton, FL 33431

HBA OF GAINESVILLE
2217 NW 66th Court
Gainesville, FL 32606

HERNANDO BA
7391 Sunshine Grove Road
Brooksville, FL 34613

HIGHLANDS CO. BA
363 U.S. 27 South
Sebring, FL 33870

HBA OF LAKE CO.
1102 N. Joanna Avenue
Tavares, FL 32778

BA OF MANATEE CO.
4835 27th Street W. #220
Bradenton, FL 34207

MARION CO. HBA
409 N.E. 36th Avenue
Ocala, FL 32671

HBA OF MID - FLORIDA
544 Mayo Avenue
Maitland, FL 32751

NORTHEAST FLA. BA
2002 Southside Blvd.
Jacksonville, FL 32216

HBA OF OKALOOSA/WALTON CO.S
1980 Lewis Turner Blvd.
Ft. Walton Beach, FL 32547

OKEECHOBEE BUILDERS CHAPT.
P.O. Box 1535
Okeechobee, FL 34973

CA OF FRANKLIN CO.
Box 150, St. George Island
Eastpoint, FL 32328

HBA OF GULF CO.
S.R. 1 - Box 750
Port St. Joe, FL 32456

LEE BIA
4571 Colonial Blvd.
Ft. Meyers, FL 33912

HBCA OF PALM BCH. CO.
5713 Corporate Way, Suite 200
West Palm Beach, FL 33407

HBA OF PANAMA CITY
P.O. Box 979
Panama City, FL 32402

PASCO BA
5852 Main Street
New Port Richie, FL 34652

CBA OF PINELLAS CO.
P.O. Box 2150
Pinellas Park, FL 34664

POLK COUNTY BA
2940 Winter Lake Road
Lakeland, FL 33803

CA OF SARASOTA COUNTY
3844 Bee Ridge Road, Suite 201
Sarasota, FL 34233

SOUTH FLORIDA BA
15225 N.W. 77th Avenue
Miami Lakes, FL 33014-6895

TALLAHASSEE BA
2522 Capital Circle, N.E. #3
Tallahassee, FL 32308

WEST VOLUSIA COUNTY
2435 S. Ridgewood Avenue
South Daytona, FL 32119

BA OF GREATER TAMPA
100 S. Ashley Street #290
Tampa, FL 33602

OKEECHOBEE BLD.S CHAP.
P.O. Box 1535
Okeechobee, FL 34973

TREASURE COAST BA
6560 South Federal Hwy.
Port St. Lucie, FL 34952

WASHINGTON/HOLMES CO.S HBA
P.O. Box 400
Chipley, FL 32428

WEST FLORIDA HBA
4400 Bayou Blvd. #45
Pensacola, FL 32503

Harold W. "Johnny" Johnson
P.O. Box 770771
Winter Garden, FL 34777-0771

National BCIAC distribution list for selected final reports

Mr. E. J. Jones
Assoc. of Gen. Contractors
of America
1975 "E" Street, N.W.
Washington, D.C. 20006

AGC Foundation
1957 "E" Street N.W.
Washington, D.C. 20006

Assoc. of Builders &
Contractors
729 15th Street, N.W.
Washington, D.C. 20005

National Assoc. of Home-
Builder Research Center
ATT: David McFadden
15th and M Street, N.W.

American Assoc. of Cost Eng.
ATT: Kenneth Humphries
308 Monongahela Building
Morgan town, WV 26505-5468

CII
ATT: Charles McGuiness
3208 Redrives, Ste. 300
Austin, TX 78705

Project Management Institute
Dir. of Educational Serv.
P.O. Box 43
Drexel Hill, PA 19026

The Business Roundtable
200 Park Avenue
New York, N.Y. 10166

American Inst. of
Construction
ATT: Mr. Ed Freeman
20 South Front Street
Columbus, OH 43215

Structures of Building
System Prog.
National Science Foundation
Washington, D.C. 20550

Professor Fred Moarenzadeh
Ctr. for Constr. Res. & Ed.
M.I.T.
77 Massachusetts Avenue
Cambridge, MA 02139

Mr. W.R. Jones
Nat. Constructors Assc.
1101 15th St,NW,Ste.1000
Washington, D.C. 20005

Mr. Ted Wilson
Professional Construction
Estimators Assoc. of America
P.O. Box 1107
Cornelius, N.C. 28031

Dept. of the Army Constr.
Eng. Research Laboratory
Corps of Engineers
P.O. Box 4005
Champaign, IL 61820
ATT: Dr. L. R. Shaffer

Frank Walker Company
ATT: Mr. Gene Callahan
Walkers Estimating and
Constr. Journal
5100 Academy Drive
Lisie, IL 60532

Special dissemination list for only this final report

Mr. Douglas A. Aber
Aber Pools, Inc.
23375 Janice Ave.
Port Charlotte, FL 33980

Aqua Magazine
Elene Davidson
P.O. Box 19531
Irvine, CA 92713

Mr. Jack Beane
Crystalene Products
Winco Center
4100 East Bay Dr.
Clearwater, FL 34624

Mr. Larry Bellinger
Executive Vice President Region VII N.S.P.I.
558 South Osprey Ave.
Sarasota, FL 33577

Booth B. Blakeman
Lehigh Portland Cement Co.
718 Hamilton Mall
P.O. Box 1882
Allentown, PA 18105-1882

Mr. George A. Brown
760 Santa Fe Ave.
Ormond Beach, FL 32174

Mr. Joel Caesar
Executive Director Region I N.S.P.I.
300 J. Campus Dr.
Morganville, N.J. 07751

Lester Cantrell
Georgia Marble
1201 Roberts Blvd., #100
Kennesaw, GA 30144

Jayne F. Carney
Olin Corporation
350 Knotter Dr.
P.O. Box 586
Cheshire, CT 06410

Dennis Chapman
National President N.S.P.I.
Bio-Lab, Inc.
P.O. Box 1489
Decatur, GA 30031-1489

Mr. Bill Conway
Chairman B.C.I.A.C.
110 Orchard Lane
Ormond Beach, FL 32176

Mr. Alan Cooper
Artesian Pools, Inc.
7347 East Colonial Dr.
Orlando, FL 32807

Mr. Glen Copponex
Georgia Marble Co.
1201 Roberts Blvd.
Building 100
Kennesaw, GA 30144-3619

Robert A. Crandall
8834 Hollowstone Way
Sacramento, CA 95828

Don Curts
Dolphin Fiberglass Technology, Inc.
3692 Beach Blvd.
P.O. Box 47586
Jacksonville, FL 32247-7586

Mr. Pat Delaney
P.A. Corporation
280 Cedar Grove Rd.
Conshohocken, PA 19428

Cal Eden
C.F. Pool Supplies, Inc.
702 Commercial Drive
Holly Hill, FL 32177

Mrs. Jeanne Anne Eden
President Region VII N.S.P.I.
C.F. Pools & Spas
702 Commercial Dr.
Holly Hill, FL 32117

Mr. Russell Flynn
LaFarge Corporation
P.O. Box 22348
Tampa, FL

Ms. Karen A. Force
Imagiforce Inc.
P.O. Box 340509
Tampa, FL 33695-0509

Ron Ford
1690 Country Lane
Dunedin, FL 34698

Mr. Chuck Foster
N.S.P.I. 1000 Club
Patio Pools, Inc.
4118 Gunn Hwy.
Tampa, FL 33624

Dr. Paul Fulmer
Chief Surgery - Horner Equipment
5755 North Powerline Rd.
Fort Lauderdale, FL 33309

Mr. Dan Gautier
Southern Grouts & Mortars Inc.
1502 S.W. 2nd Place
Pompano Beach, FL 33060

Steve H. Gebler
Chairman 506 Committee ACI
Construction Technology Labs, Inc.
5420 Old Orchard Rd.
Skokie, IL 60077

Carvin D. Giovanni
Technical Director N.S.P.I.
2111 Eisenhower Ave.
Alexandria, VA 22314-4698

Larry Golnick
Riverside Cement Co.
660 North Diamond Bar Blvd.
P.O. Box 4904
Diamond Bar, CA 91765

Mr. Fred Hanson
Gulf Solar
13650 North 12th St.
Tampa, FL 33613

Sally B. Heitanen
Special Projects Coordinator
National Spa and Pool Institute
2111 Eisenhower Ave.
Alexandria, VA 22314-4698

Bill Hoffman
Swimming Pool Spa Dealer News
P.O. Box 540622
Dallas, TX 75354

Mr. Lynn Howell
Florida Stucco Corp.
P.O. Box 1497
Boca Raton. FL 33429

Richard I. Hubbard
Pool & Spa Marketing
46 Crockford Blvd.
Scarborough, Ontario MIR-3C3
CANADA

Mr. Al Inglin
Aqua Pool Service & Supply Co.
892 Second St. Pk.
Richboro, PA 18954

Ron Jones
Senior Research Scientist
Bio-Lab, Inc.
P.O. Box 1489
Decalur, GA 30031-1489

Mr. Jeff Jordan
Jeff Jordan Pools
565 Jacobson Ave.
Holly Hill, FL 32117

Frank G. Katona
President
Leisure Life Products Corp.
7916 South Park Place
Orlando, FL 32819

George Kazdin
Retailers Council N.S.P.I.
Kazdin Pools
835 North Highway
Southampton, N.Y. 11968

Curt Kelsay
Vice-President, Engineering
Marshalltown Tools
P.O. Box 1684
Fayetteville, AK 72702

Tommy Kennon
Swimming Pool Age
6255 Barfield Rd.
Atlanta, GA 30328

John Kingston
Rinker Cement
1501 Belvedere Rd.
West Palm Beach, FL 33406

Mr. David Knoop
Chairman Education Committee N.S.P.I.
Olin Corporation
P.O. Box 586
350 Knotter Dr.
Cheshire, CT 06410

Les Kowalski
Chairman - National Swimming Pool Foundation
3012 Bond Dr.
Merrick, N.Y. 11566

Mr. Robert La Fleur
La Fleur Pool Builders
555 South River Street
Batavia, IL 60510

Ms. Barbara Langford
N.S.P.I. Education Committee
Gulfcoast Spa and Pool Keepers
P.O. Box 1245
Oldsmar, FL 33557

Mr. David G. Larsen
N.S.P.I. 500 Club
Pools By Larsen
2250 South Nova Rd.
South Daytona, FL 32110

Lehigh Portland Cement Co.
One Riverchase Office Plaza
Birmingham, AL 34244

Dan Leithauser
Bio-Lab, Inc.
P.O. Box 1489
Decatur, GA 30031-1489

Dr. R. Neil Lowry
Lowry & Associates
878 Dales Ave.
Box 335
Newmarket, Ontario L34 4X7
CANADA

Ms. Idelisa Martinez
Florida Engineer Magazine
325 Weil Hall
University of Florida
Campus

Mr. Jim McCloskey
Leisure Publications
3923 W. 6th St.
Los Angeles, CA 90020

Mr. Jeff McGalliard
J.M.K. Construction
751 Wambold Rd.
Souderton, PA 18964

David McPhillips
Hillsboro Gas Co.
5307 East Hanna
Tampa, FL 33610

P. Kirk Mitchell
Chairman - Chemical Treatment Subcommittee N.S.P.I.
Hydrotech Chemical Corp.
P.O. Box 6549
Marietta, GA 30065-0549

Mr. TImothy A. Nicastro
N.S.P.I. Marcite Consultant
Nation Chemical
492 South Beach St.
Ormond Beach, FL 32174

Mr. Larry Paulick
4504 Albion Rd.
College Park, Md 20740

Robert R. Peddie
Peddie Pools of Tallahassee
4911 Woodlane Circle
Tallahassee, FL 32303

Edward M. Pendleton
Estate Pools
4453 Ashton Rd.
Suite A
Sarasota, FL 33583

Ms. Paulette Pitrak
Director of Education N.S.P.I.
2111 Eisenhower Ave.
Alexandria, VA 22314-4698

Mr. William Poole
644 W. Colonial Dr.
Orlando, FL 32804

Mr. John Puetz
Chairman Tech Council N.S.P
Great Lakes Biochemical Co.
6120 W. Douglas Ave.
Milwaukee, WI 53218

Mr. Fritz Quednau
Sunshine Pools
P.O. Box 1348
Tampa, FL 33592

William F. Rahn
Executive Director N.S.P.I.
Florida WC Chapter
P.O. Box 9474
Treasure Island, FL 33740

Lawrence Rakestraw
Monsanto Company
800 N. Lindbergh Blvd., N3D
St. Louis, MO 63167

Randall Redd
DuPont Company
C & P Dept., B-12318
Wilmington, DE 19898

Dianne Rennell, Ph.D.
Artemis III Communications
283 Coreenridge Dr.
Dunkirk, MD 20754

Gordon C. Ripley
Pools By Ripley, Inc.
1703 Northeast 8th Ave.
Ocala, FL 32670

Mr. Lou Ritter
P.O. Box 10243
Tallahassee, FL 32302

Mr. Al Rizzo, Jr.
Rizzo Pools
3384 Berlin Turnpike
Newington, CT 06111

Mr. Tom G. Rosser
Designer Pools of Central Florida
P.O. Box 950760
Lake Mary, FL 32795

Mr. Wiliam W. Sadd
Executive Vice President N.S.P.I.
2111 Eisenhower Ave.
Alexandria, VA 22314-4698

David A. Saik
Saik Construction
2800 B. Northwest 74th Place
Gainesville, FL 32606

Bonnie Sandel
Olin Corporation
P.O. Box 586
Cheshire, CT 06410-0586

Dr. S. Sarkar
Faculty of Applied Science
University of Sherbrook
Quebec, Canada J1K2R1

Tom Seechuk
LaMotte Chemicals
P.O. Box 329
Chestertown, MD 21620

Bob Simmons
PPG Industries, Inc.
440 College Park Drive
Monroeville, PA 15146

Mr. Frederick A. Spies
3554 John Anderson Dr.
Ormond Beach, FL 32176

David R. Stevens
President Elect Region VII N.S.P.I.
Calorex Mfg. Co.
5826 Corporation Circle
Ft. Meyers, FL 33905

Neil W. Stillman
H2O Chemists, Inc.
1548 North Tech Blvd.
Suite 103
Gilbert, AZ 85234

Mr. Al Summers
Premix Marbletite
404 Ellendale Dr.
Winter Park, FL 32792

Mr. John Sutherland
Executive Director UPSA
P.O. Box 13223
Jacksonville, FL 32206

Dr. Arezki Tagnit-Hamou
Department of Civil Engineering
Universite De Sherbrooke
Sherbrooke (Quebec) J1K 2R1

Mrs. Barbara Tanner
Tampa Marcite
17004 Aspen Meadows Dr.
Lutz, FL 33549

Daniel E. Terlizzi, Ph.D.
Cooperative Extension Service - Univ. of MD
2335 Rock Spring Rd.
Forest Hill, MD 21050

Mr. John Thornett
Pools By John
P.O. Box 36-1193
Melbourne, FL 32936

Bill Tupper
Federal White Cement
P.O. Box 219
Vandalia, OH 45377

Mr. Albert Underwood
Chairman NSPI Builders Council
Aqua Blue Aquatech
1132 So. Patrick
Satellite Beach, FL 32937

Mr. Mike Unger
C.L. Industries
P.O. Box 13704
Orlando, FL 32859-3905

Brian Van Bower
Region VII N.S.P.I. N.V.P.
Van Bower Pool and Patio
823 N.E. 79th St.
Miami, FL 33138

Alfredo Vinci
Church & Dwight Co.
469 North Harrison St.
Princeton, N.J. 08543-5297

James W. Watson
Claims Representative
The Ohio Casualty Group
801-94th Ave. N.
P.O. Box 42048
St. Petersburg, FL 33742-2048

Mr. Skip West
Florida Solar
214 Hickman Dr.
Sanford, FL 32771

Don Wilson
Hasa, Inc.
23119 Drayton St.
Saugus, CA 91350

Mr. Andy Wolhuter
Topaz Pools
P.O. Box 39768
Bramley 2018
South Africa

C. Frank Wreath
Sophisticated Systems, Inc.
3785 U.S. Alt. 19 N.
Palm Harbor, FL 34683