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Approaches to the Conservation of Salt Deteriorated Brick

James M. Hewat
University of Pennsylvania

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APPROACHES TO THE CONSERVATION OF SALT DETERIORATED BRICK

James M. Hewat

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fg Matero

Frank G. Matero, Professor of Historic Preservation, Advisor

Samuel Y. Harris, Adjunct Associate Professor, Historic Preservation, Reader

David G. De Long, Professor of Architecture, Graduate Group Chairman

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Introduction

General

Fired clay brick has an excellent record as being a versatile, durable, and attractive building material. Like all materials, however, brick is subject to deterioration when exposed to adverse environments. Over the past century, a significant amount of research and writing has focused on the history, use, composition, deterioration, and conservation of the so-called "noble" building stones. However, surprisingly little work has dealt with these same issues as they relate to the commonest of all building materials; clay brick.

While intentionally broad and historically contextual in its scope, this thesis examines the major deterioration processes encountered with fired

brick. The study then narrows to focus on the most influential of damaging mechanisms (the crystallisation of soluble salts) and attempts to establish a laboratory approach to the conservation of salt-contaminated brick.

Scope of Work and Methodology

A general history of the manufacture of building brick is outlined in the first chapter of the thesis. The physical composition and major deterioration processes in fired brick is examined in Chapter Two. The first part of the Laboratory testing program is covered in Chapter Four and consists of :

- The characterization of eighteenth century hand moulded Pennsylvania brick used in testing program.
- Damage induced to brick samples through repeated cycles of sodium sulphate crystallisation .

The second part of the testing program is covered in Chapter Five and consists of:

- A review of current literature regarding conservation treatments for the treatment of fired bricks and porous building stones.
- Selection of two laboratory treatments for the conservation of deteriorated bricks.

Several tests to assess the relative success of the conservation approaches were designed and implemented at the Architectural Conservation Laboratory and at the Laboratory for the Research Into the Structure of Matter, both at the University of Pennsylvania. They are covered in Chapter six of this study.

Chapter 1

A Brief History of the Manufacture of Brick

> *"Go to, let us make brick, and burn them thoroughly . . . . Go to , let us build a city and a tower whose top may reach unto heaven."*
>
> *- Genesis Xi 3, 4.*

1.1 General

Clay brick (whether fired in a kiln or baked in the sun) has for thousands of years, been the principal building material in the world. The practice of brickmaking may be considered one of the earliest and rudimentary of crafts having had its beginnings in the Fertile Crescent over 10,000 years ago with the manufacture of crude hand-formed, sun dried mud blocks. The making of bricks is mentioned in the Old Testament in the book of Genesis and bricks dating back at least 5000 years have been found in Peru. For the craft of brickmaking to have developed independently in parallel ways around the world is quite remarkable. The unique properties of the clay used for brickmaking appears to have been apparent to the peoples of many early civilizations.[1]

1.2 Building Brick

An extremely durable and versatile building material, brick is literally moulded from the earth. It can be observed in the construction of the most rudimentary of shelters to the most magnificent examples of monumental architecture; from prehistory to the present; on all of the continents. It has been suggested that brickmaking is the second earliest industry practiced by

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[1] "Brick . . . Its History and How it is Made." General Shale Products Museum, Johnson City, Tenn.

mankind after agriculture and coincides with the transition from a nomadic to a more settled life in areas like the Fertile Crescent.[2] While the subsequent development of box moulded, fired, and machine produced brick to the present day represent improvements in the physical properties of the building material, its basic constituents of clay and water have changed little over the millenia.

Figure 1. Striking bricks in Maine c.1870

1.3 The Manufacture of Fired Brick

1.3.1 Raw Materials

Clay is basic raw material used in the manufacture of fired brick and a term which refers to the most widely distributed of the geological sediments. The sources of clay-forming minerals are aluminous rocks that most often

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[2] Brownell, "Structural Clay Products." New York: Springer-Verlag, 1976 p.1

contain feldspar. The erosion and chemical breakdown of these rocks result in the production of fine mineral particles smaller than 2μ. Most often, clay minerals are composed of kaolinite, illite, montmorillonite, and chlorite. The composition and structure of clays will be more thoroughly discussed in 2.2.1.

Clays are often catagorized into two major types; primary and secondary. Primary clays are produced when parent rocks are transformed under the earth's surface by the hydrothermal actions of gases and water. When the overburden is eroded and primary clays become exposed to the elements of weathering they are carried along rivers into lakes and eventually the sea. This process of transportation results in the heavier sediment settling out while the lighter particles are carried downstream to form deposits of sedimentary or secondary clays.[3]

Secondary clays are generally catagorized into four major sub-groups: river deposited (alluvial); glacial clays produced by the grinding action of glaciers; lacustrine and marine deposits which are formed by the setting out of clays in large bodies of water; and windborne deposits. The composition of these clays varies greatly according to their source, conditions during deposition, intermixture with other materials, and changes taking place after deposition.[4]

For thousands of years, the best clays for brickmaking were derived solely from secondary or superficial sources. These superficial deposits are generally, found just under the topsoil in low lying areas and are easily dug by hand or with simple tools. The superficial clays best suited for the manufacture of brick are the silty thin deposits formed during the Pleistocene epoch (1.8 - 10,000 years ago). Clays of this epoch often contain 30% sand or

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[3] Gurke's "Bricks and Brickmaking." p.3

[4] Shepard, Anna, "Ceramics for the Archæologist." p.11

more and can be taken straight from the ground to be moulded and fired into brick.[5] The fact that superficial clays occcur throughout the earth, no doubt, accounts for their widespread use over time.

Primary clays in the form of shales are commonly found in association with seams of coal. This source of clay seems not to have been exploited until the advent of mechanized mining in Europe and North America during the Industrial Revolution.

1.3.2 Winning and Preparing the Clay

The traditional method of removing clay from the earth for the manufacture of bricks is elemental and has occured for millenia. The first step in this process of making fired brick was to remove the overburden completely to ensure that none of it contaminated the clay below as this could result in defective bricks. This process is known as "encallowing" or removing the topsoil. In colder climates, the callow was removed in the fall to allow the clay to cure as it is exposed to frost and snow as a first step in the weathering phase.

Digging in shallow open pits appears to have been the most common and practical technique of excavating well into the nineteenth century. An 1813 account of excavating a pit in Philadelphia describes the clay being, "dug in spits , each spit being one foot deep, four feet wide, and 16 feet deep, which makes a mass for one thousand bricks."[6] Until the mid-nineteenth century, brickmaking was primarily a part-time activity and it was uncommon for a pit to produce more clay than was needed for local construction.

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[5] Davey' "History of Building Materials." p.64

[6] Foster, Joseph, "Accounts of Brickmaking in America Written Before 1850." p. 1

Horse drawn scrapers and later machine driven plows were used to remove the overburden and loosen the clay in open pit mines as the demand for brick increased. The increase in demand also led to the development of underground mining which exploited the deeper primary clays in areas where superficial deposits were scarce. This rather involved method of winning clay was not common and often took place in association with the mining of coal.

Once the clay was removed from the ground, it was heaped into piles several feet high and left to the effects of the weather. These piles would frequently be slashed and cut up in order to expose the clay to frost cycles which resulted in the breaking up and crumbling of the harder lumps of clay. Repeated rain washes acted to rinse the soluble salts from the clay. In some regions of England, fireclays were heaped for years to produce purer and more plastic clays in the belief that it would result in harder, more durable bricks as the finished product. [7]

After the clay had been left to weather for a sufficient time, the next step was to temper the clay. This normally consisted of water and other materials being added to the clay to achieve the desired plasticity, colour, and burn properties. The addition of various materials was added to the mix not only to increase workability, but to prevent cracking during drying, to lower the temperature at which vitrification took place, and to change the colour of the final product. Sand added to the mix was the primary constituent used to prevent shrinkage and cracking. However, during the late 1700's in England a substance known variously as "breeze", "sea coal ash", and "Spanish", began to be added to the clay mix in place of (or in addition to) sand. This fused coal ash (commonly known as clinker), was widely available, coal being the

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[7] "Bricks and Brickmaking." p.7

primary means of heating during the late eighteenth and nineteenth centuries. When added to the clay it made the bricks more porous, prevented shrinking and cracking, and assisted in achieving a consistent burn.[8] Breeze was apparently not used frequently in North America where it was considered to be a damaging additive if not properly mixed.[9]

Tempering very often included the addition of grog to reduce shrinkage during drying and firing. It was often obtained from old brick being crushed up and added to the mix. Grog has been described as acting as a skeleton that holds the brick together during firing when the other constituents of the clay are in a state of flux. Chalk is another material that was added to the clay during the tempering process in an attempt to reduce shrinkage and lighten the brick colour. Because of its high melting point, lime reduced the vitrification point and made firing of the brick more difficult. In addition, if there was too much lime in the mix or it was not ground finely enough, free or quicklime could result in areas of weakness that would fracture the brick.

The tempering process required that the entire clay mass be thoroughly mixed in order to achieve a consistant batch of brick in colour and physical properties. The most ancient method of combining the clay mixture, was to lay it out on a flat, confined surface and mix it by stomping until the desired consistency was achieved. Livestock such as oxen were often used to speed this process. Another traditional type of tempering which seems to have made its appearence in the eighteenth century is the soak-pit method in which the clay was shovelled into a pit with water and left to soak overnight. The following day, coal dust and sand was added to the clay mixture which

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[8] Foster, "Accounts of Brickmaking in America Written Before 1850." p. 39

[9] If coal dust is not thoroughly mixed in the clay it can result in hot spots which can crack or melt the brick.

was then placed in a ring-pit which utilized a manually driven iron ring to chop and mix .

During the early part of the nineteenth century, the first horse-driven and pug mills were introduced. The pug mill consisted of a bin containing a vertical shaft with extending knives to cut the clay and work a smooth consistency to it. Often there would be several horse drawn pug mills operating simultaneously at a single brick yard. The mechanized pug mill has been credited as having made possible the advent of evenly coloured and smooth-textured bricks of the mid-to-late nineteenth century.[10]

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[10] Eliot, "Techniques and Architecture - The Development of Materials and Systems." p.35

Figure 2. 1890 view of Fuller and Cony's Brickyard in Augusta, Maine. Note the horse powered pug mill and green bricks drying background.

The pug mill is credited by many historians to have facilitated the exponential explosion in brick production which occurred during the Industrial Revolution. Since the introduction of the pug mill, there have been a great many machines invented to aid the mixing of clay for brickmaking including roller mills used to crush and grind shale.

1.3.3 Moulding Bricks

Once the clay was tempered it was formed by hand or in a constructed formed in a wooden mould. The earliest bricks were formed by hand without the aid of moulds at least 10,000 years ago. It is known that as early as 4000 BCE, rectangular moulds were being used to form straw-filled bricks in

present day Syria. By 3000 BCE, the Egyptians had developed brick moulds very similar in size and design to those presently used on automatic machines for soft mud brick.

There are three main methods for moulding brick: soft-mud (water content of 20% to 30%), stiff-mud (water content of 12%-15%), and dry-pressed (up to 10% water content). For thousands of years, the most common method of forming bricks was a rudimentary soft-mud technique which consisted of hand-packing the wet clay mixture into single or double wooden, and later metal mould. The excess clay would be removed by the moulder by hand or with an instrument known as a strike and the brick(s) would be left to air-dry for a given period before firing. Bricks were produced by a "gang" that was usually comprised of family members or relatives. The head of the gang was the "stool" who supervised the "moulder" (who made bricks), the wheeler (who carried the tempered clay to the moulders table), and the "off bearer" (who carried the green bricks to the yard to dry). This cottage industry mode of production endured until well into the nineteenth century. Variations on this form of brick production included lubricants used to allow the green brick to slip free of the mould such as straw, sand, water, and later oil and soap.[11]

The first soft mud brick moulding machine was invented in the United States about 1830 and was in use in Perth Amboy, New Jersey for a number of years prior to 1850.[12] It was essentially an imitation of hand moulding methods that required manpower to remove the molds from the machine and the bricks from the moulds. It wasn't until the invention of the "Auto Brick" machine in 1920 that the human element was eliminated in the

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[11] For a more complete description of these variations see Gurke's "Bricks and Brickmaking."

[12] Brownell, "Structural Clay Products." p. 7

manufacture of soft-mud brick. Soft mud-brick bricks can be identified by their soft edges and non-uniform appearance.

The steam powered stiff-mud extruded brickmaking machine was invented in England in 1859 by John Craven. These machines were introduced to the United States soon after, but did not really gain in popularity until the late nineteenth century. A number of designs for such devices were exhibited in the Philadelphia Centenial Exposition of 1876. One such machine designed by the Chambers Brothers & Company of Philadelphia was constructed almost entirely of iron and could make 80 bricks per minute. What the Chambers Brothers machine made up for in in efficiency it lost in terms of brick quality. The extrusion of the clay through the die often led to the formation of laminations hidden inside the resulting brick. These laminations were considered to be planes of weakness and sites of premature deterioration if infiltrated by water, soluble salts, and other damaging substances. Subsequent designs for stiff-mud brick machines alleviated this problem with the addition of rollers which compressed the brick before being cutting it.[13] Stiff-mud extruded bricks are easily identified by the marks left behind from the cutting motion of the wires and by their uniform size. Both soft-mud and stiff-mud extruded bricks were frequently repressed in a hand operated device to increase the density and, often, to brand it with the manufacturer's name. There is no indication that repressing in any way increased the durability of the brick.

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[13] McKee, "Introduction to Early American Masonry." p. 45

JOHN WINSLOW'S PATENT

SELF-FEEDING BRICK PRESS.

The great inconvenience that has attended all machines that have hitherto been used for pressing Bricks, of putting the bricks into the mould by hand, and the slow progress made in pressing on that account, are entirely obviated in the *Self-Feeding Brick Press* now offered to the public. Each machine is furnished with three boards of a proper length to hold ten bricks, each setting up edgewise. To put the machine in operation, one of these boards is filled with unpressed bricks, and laid on one side of the machine, and an empty board on the other side; then by turning the crank moderately, the machine removes the bricks one at a time from the full board, presses them and places them on the other board all a quarter of an inch apart at the rate of fifteen in a minute. While one man is turning the crank, the third board should be filled with unpressed bricks and placed on the machine. As soon as the machine has filled one board with pressed bricks, the board is removed, (its place being supplied by the board that the machine has emptied,) and the bricks discharged from it on to the yard or boards for that purpose by turning the board up edgewise, steadying the bricks at the same time by a narrow board which leaves the bricks all a quarter of an inch apart standing on one end, giving them a very good opportunity to dry, without being handled while in a green state.

The machine is now in operation in PORTLAND, and will soon be exhibited and advertised in *Boston*, *New-York*, *Philadelphia*, and *Baltimore*, at all of which places the subscriber will probably be present, and be happy to wait on any that may wish to examine it, or purchase Machines, or the right of using them.

☞ *Any communication addressed to the subscriber at* Portland, *Maine, will receive due attention.*

JOHN WINSLOW.

Portland, 10th Mo. 4, 1826.

To John Winslow, Portland.

Yours Respectfully,

Figure 3. John Winslow's Patented Brick Press, Portland, Maine , 1826.

Dry press bricks began to be manufactured after the 1850's in England and the large cities of the north-eastern United States. The manufacturing process consisted of the clay mixture being dropped into iron moulds and then being subjected to pressures of up to 500 psi exerted from both the top and bottom of the mould. The earliest presses were hand operated screw devices and later hydraulic presses. Dry pressing with a mechanical toggle is currently the most common mode of brick moulding. It results in very durable, uniform bricks with sharp edges and low porosity. Its low density, low porosity, and resulting durability makes it an ideal facing material. In the 1870's Peerless Brick Company of Philadelphia was the leading manufacturer of dry-press brick in

America producing millions of facing bricks a year. By the turn of the century, its name had become synonymous throughout the country with that type of material.[14]

1.3.4 Drying

Bricks, typically, were left to air dry until their water content was approximately 10%.[15] The drying process in the manufacture was a crucial one; too much drying would result in too much dessication of the brick producing a friable final product. Not enough drying would result in the brick shrinking too much and cracking during the firing process. Drying needed to be done slowly enough so that the natural shrinkage would not damage the brick. Normally, hand moulded bricks required two to three weeks air drying time.

The earliest attempts at drying brick was rudimentary probably consisted of piling the partially dried green brick on the ground in "hacks", or piles, in such a way that afforded air flow through the pile. The drawback to this natural air-drying method was that the process was totally dependent on the weather. Rain and frosts could, and often did, destroy the vulnerable green bricks. For this reason, drying sheds (often with hinged roofs that could be opened on sunny days), were frequently constructed. During the nineteenth century when brickyards began to produce year round, various methods of heating the sheds were attempted.[16] Among the most successful of these methods was the Chamber's Brothers of Philadelphia tunnel dryer which consisted of a forty foot heated tunnel through which railway cars

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[14] Ibid., p.46

[15] Dry-press bricks do not need to be air dried as their water content is 10% or below.

[16] "Bricks and Brickmaking." p.26

hacked with brick would slowly pass. Total drying time in the tunnel dryer was reduced to under two days.

1.3.5 Firing.

The firing (or burning) of brick is perhaps the most critical stage in the manufacturing process as it, to a large extent, determines the shape, colour, and durability of the building unit. The first phase of the "burn" consists of water-smoking in which the physical water in the green brick is driven off. This is usually complete by about 100°C after which time the temperature should continue to rise until a "sintering" or vitrification of the brick takes place. Sintering usually commences at temperatures from between 871°C and 1204°C and results in a molecular melting of the clay platelets (described in more detail in 2.1.1). Finished bricks that have completed the sintering process are referred as "high-fired", while those that have not are "low-fired".

While the equipment and sequence of events involved in the burning of brick has evolved over time, the basic process remains relatively unchanged. The earliest method of firing bricks appears to have consisted of "clamp-burning" in which a foundation consisting of a layer or two of burnt brick was used to clamp (or stack), the unfired brick. Channels were arranged in the foundation so as to form a number of fire holes or flues running the throughout the clamp. The fireholes were then filled with fuel and the top of the clamp stacked with fired bricks and mud to help hold the heat in. The clamp was then set on fire and allowed to burn itself out; a process which could take several weeks. There is evidence to suggest that this firing technique was being used in Alāmadabad, India as early as 4000 BCE.[17] The main drawback to this method of firing seems to have been its inability to

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[17] "History of Building Materials." p.65

achieve temperatures of more than 600°C needed to achieve adequate vitrification. The result was a soft, low-fired brick lacking a protective "fireskin". Despite this, the clamp method of firing was still the favoured method of burning brick well into the eighteenth century. In 1684, clamps were operating in Philadelphia in which 40 to 50 thousand bricks were being fired at a time consuming half a cord of wood.[18]

A second early method of burning brick was in updraft kilns in which temperatures of 1000°C or more could be obtained. These kilns consisted of an upper and lower chamber in which fuel was burned in the lower chamber, while bricks were stacked for firing in the upper cell. The heat was drawn up through holes or grills in the floor by a chimney located on the roof of the structure. Kilns of this type dating from around 3500 BCE have been excavated in the Middle East, but it was the ancient Romans who most effectively exploited the technology with the large scale production of high-fired bricks and tiles in updraft kilns reaching its peak about 100 BP.[19]

The updraft kiln was the most common method to fire bricks in Britain and North America until the nineteenth century. Constructed of brick, these kilns were round or rectangular intermittent ovens that were, often built on site to fire hand moulded bricks for a particular job. In round scove kilns the raw bricks were stacked in a radial fashion, one end facing the center. These ends were exposed to the greatest heat and, as a result, were usually the most vitrified. Bricklayers recognized the more durable nature of this "glazed" and "stock" brick which was used for facing, and often to achieve patterned decorative effects. Though a generally effective firing device, the updraft kiln was inefficient in that heat was not uniform

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[18] "Introduction to Early American Brickmaking.' p.43

[19] Ibid., p.67

throughout the chamber, resulting in variations in hardness, texture, and colour.

During the early part of the nineteenth century, the more efficient intermittent down-draft kilns were adopted. In them, more consistent temperatures were achieved by bringing the gases from the firing chamber at the top and withdrawn through a flue at the bottom of the kiln. The introduction of the Hoffman kiln (which could produce continuously without cooling the kiln to remove the bricks), corresponded with the widespread mechanization of the moulding process during the 1850's. The Hoffman kiln was a sophisticated machine which consisted of a circular ring of kiln chambers connected by ducts. When one chamber's firing was complete, the heat would be transfered to an adjoining kiln resulting in a improved temperature control and energy efficiency. The high firing temperatures resulting in the uniform and highly durable red brick so often associated with Victorian era architecture. Another, less common, kind of continuous kiln used in the brick industry, was the tunnel kiln which was very similar in design to the tunnel dryer consisting of interconnecting compartments through which steel rail cars loaded with green brick passed. It is estimated that as late as 1950, 90% of common and face brick manufactured in Britain were fired in Hoffman kilns.[20] Tunnel kilns are presently the most common method of burning in the large scale manufacture of bricks.

1.4 Sorting and Classification

There are a number of ways to classify bricks according to method of manufacture, raw materials, and other characteristics such as age and

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[20] "Techniques and Architecture-..." p.43

provenance. For the purposes of this thesis, only methods of sorting and classifying North American bricks will be discussed.

The earliest classification of bricks appears to have been derived from the English method in which bricks were considered to be either the lower quality"place"(or "grizzle"), or better quality"stock". In the eighteenth century stock bricks were specially moulded and placed nearest the source of heat to promote a better firing.[21] The durabilty of stock brick was considered to be higher than the soft or cracked place brick and, as a result, their cost was considerably higher. During the nineteenth century numerous sub-categories for stock bricks were identified based on texture, colour, and shape. Among these were, "picked stocks"(best quality), "red stocks"(owing to colour), "shippers"(imperfect hard burned), "seconds", "shuffs"(defective), and "hard stocks" or "clinkers"(overburned bricks).

In 1913, the American Society for Testing Materials issued a standard for building bricks which divided the material into four categories; vitrified, hard, medium, and soft. A brick's classification was determined according to its, absorption properties, compressive strength, and other characteristics. The ASTM classification of brick probably evolved from the conventional wisdom of the time which stated that quality bricks should be, "hard, well-burnt, square, and regular in shape with clean sharp arrises. They should give a clear ring when struck; be free from lumps of lime or other impurities, and as non-absorbant as possible."[22] Research carried out by the Building Research Station in Great Britain in the late 1920's and 1930's did reveal that brick that was less porous was not always as durable as more porous brick.[23]

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[21] The source and meanings of place and common bricks seems to have become confused as the efficiency of kilns changed. See Gurke p.36

[22] Allen, John Parnell, "Practical Building Construction ..." p.5

[23] Butterworth, B., British Ceramics Society - Transactions. vol. 63 #11, 1964 p.615

The increasingly scientific approach to the characterization of structural clay products has given rise to a number of standard methods for the testing and classification of bricks. In North America, the ASTM C 67-81 - Standard Methods for the Testing of Brick and Structural Clay Products, is recognized as the most comprehensive of these testing schedules. Under classifications developed by the Brick Institute of America, all new brick is subdivided according to variations resulting from manufacturing methods, end use, or accepted terminology.[24] While these guides for the testing and classification of bricks are useful, they are primarily intended for new material. Standards for the testing and classification of historic bricks need to be developed before a truly comprehensive approach to this material can be effected.

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[24] Brownell, "Structural Clay Products.' p.19

Chapter 2

Physical and Chemical Composition of Fired Brick

2.1 General

As has already been discussed, the process of heating raw clay materials to temperatures in excess of 800-900°C results in certain unique structural features. The physical and chemical composition of a brick is dependent on a number of variables including raw materials, additives, moulding, and firing. Ultimately, the durability of a brick will vary greatly according to these variables.

2.1.1 Physical Structure of Fired Brick

The clays most often used in the manufacture of bricks are kaolinite, montmorillonite, illite, micas, chlorites, and quartz and often substantial amounts of calcium carbonate. These clays are often rich in fluxes (particularly iron and magnesium) which melt during firing to produce a durable glassy phase that acts to actually bind the brick matrix together. Iron often lends fired brick its characteristic red brown to bright red colour. It has been observed that while various components of the raw materials may differ with regard to their crystallographies and physical properties, they all share basic fundamental chemical and thermochemical properties.[25]

The minerals composing clay are predominantly layer silicates consisting of tiny, irregularly shaped platelets with hexagonal habits which are usually several tenths of a micrometer in diameter and several

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[25] Lewin and Charola, "The Physical Chemistry of Deteriorated Brick and its Impregnation Technique." p.190

hundredths of a micrometer in thickness.[26] The tendency is for these platelets to stack in piles was first observed by the German scientist E.E. Schmid in 1876 who likened the laminations of kaolin to "Geldröchen" (stack of coins) because of its structural resemblance to a pile of coins. Water molecules between the platelets act as a lubricant and give clay its characteristic plasticity. Montmorillonites are the most absorptive of the clays and, because of the thick water layers between the particles, are also the most plastic. When dehydrated, the stacks of clay particles flocculate to form a coherent mass which is largely crystalline in structure. The dried clay mass is soft enough to be scratched by a fingernail and subject to dissolution in the presence of water.[27] Because the platelets in unfired brick are not physically fused together, but rather linked in a crystalline-like structure, they are particularly susceptible to deterioration and erosion as a result of water and wind.

The crystalline structure of clays exist with either a double or triple layer lattice consisting of $Si0_4$ tetrahedra or Gibbsite. In the former, the units are linked together to form hexagonal networks of the overall composition Si_4O_{10}. In the latter, Al-O or Al-OH groups form two layers of tightly packed O atoms or OH groups, between which there are Al atoms equidistant from both types. Double layer lattices like kaolinite and halloysite are electrically neutral and chemically more stable, while the triple layer lattices are electrically negative and chemically more reactive. It has been postulated that the higher chemical reactivity of the triple layer lattices is the cause of cleavages often evident between layers in clays such as pyrophyllite and

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[26] Weir, Nixon, and Woods, "Measurement of Thickness of Dispersed Clay Flakes with the Electron Microscope." p.419

[27] Ibid., p.34

montmorillonite.[28] It is not known whether fired bricks containing triple lattice clays are more susceptible to deterioration.

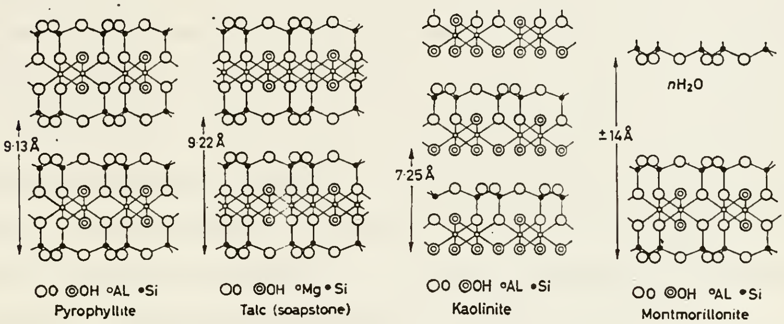

Figure 4. Layer-lattice structures of clay minerals.

During the process of firing, clays undergo a number of physical changes. The most common method to analyze high temperature reactions of clays is with Differential Thermal Analysis (DTA), which measures the exothermic and endothermic effects when heating a sample at a constant rate. Because of its purity and simple crystal form, kaolinite has received the most attention using this method of testing.[29] DTA measurements show that mechanical water in kaolinite is driven off completely at about 100°C while chemical water begins to dehydrate at about 500°C, changes to a spinel-type

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[28] Salmang, "Ceramics - Physical and Chemical Fundamentals." p.27
[29] Brownell, p.127

aluminosilicate at about 925°C, and decomposes into mullite plus cristobalite at temperatures above 1050°. During this process, the porosity of the brick continues to decrease until the sintering is complete. Amorphous silica is produced as a by-product of the dehydration and spinelization between 500°C and 900°C. The presence of other elements such as the alkalis and alkaline earths lowers the temperature at which thermal transitions occur while earth oxides released by these materials dissolve the silica to produce glasses.[30] It is this "glassy phase" which fuses the clay platelets together and, ultimately, increases the strength and durability of the brick matrix. The glassy phase is visually most evident by the thin "fireskin" that forms at the surface of a fired brick. It is generally accepted that the type of clay and amount of flux dictates the level of vitrification and resulting durability of the brick.[31]

Typically, the micro-morphology of a fired brick consists of a relatively open reticulation of fairly ordered stacks of platelets that are the remnants of the original clay particles. These stacks are embedded and fused together by the glassy matrix produced during the dehydration and spinelization phases. A great variety of internal pores, cracks, and channels are evident in fired bricks with pores ranging in size from 0.5mm down to 1μ.[32]

X-ray diffraction is often used as tool by which to identify the components of a selected brick. Lewin and Charola have demonstrated that the x-ray diffraction of a "common brick" shows a high predominance of alpha-quartz, with trace amounts of other high temperature-generated mineral phases. From these observations they also conclude that "brick may be considered to be composed of quartz grains in the shape of stacked platelets

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[30] Lewin & Charola, The Physical Chemistry of Deteriorated Brick and its Impregnation Technique." p.190

[31] University of Pennsylvania graduate student Ana Sanchez is presently investigating the properties and role of the fireskin in fired bricks.

[32] Brownell, p. 131

(i.e., psuedomorphs after the original clay particles), coated with alkali and alkaline earth/ferrous silicate glasses."[33] Clearly, the formation of the so-called glassy phase is largely responsible for increased strength of fired brick. The dissolution of this binding material will result in the breakdown of the brick matrix.

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[33] Lewin & Charola, "The Physical Chemistry ..." p.192

Chapter 3

The Deterioration of Fired Brick

3.1 General

As with most masonry materials, there are several processes which can act to change the physical and chemical properties of fired brick. The extent of these changes is normally dependent on surface exposure to weather, chemical attack, and improper structural design or execution. In general, the action of freeze-thaw action and the crystallisation of soluble salts are the processes most often responsible for the severe deterioration of bricks.

3.1.2 Chemical Reactivity.

The chemical inertness inherent to the constituents of most types of brick apparently accounts for their overall durability. However, bricks do exhibit significant chemical reactivities under certain conditions. The principal reactive species in fired brick appears to be the alkali and alkaline earth ferrous silicate glasses (silicate glasses) which, in the presence of H_2O, pollutants, and/or salts, can deteriorate rapidly.[34]

3.1.3 Effect of Water.

As with all masonry materials, even pure water with a neutral pH can play a crucial chemical role in the dissolution of a brick's matrix. As a solvent, water can act to dissolve and hydrolyze the alkali silicate glasses while as a hydrating agent it can convert hydraulic calcium silicates into their cement-type hydrates.

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[34] Ibid.

Lewin and Charola have identified sodium and potassium silicate as being the most soluble glasses in H_2O. From experimental data on the dissolution of glasses, they conclude that potassium silicates are ten times more soluble in water than sodium silicates. The introduction of even small amounts of calcium into either of these glasses reduces their solubilities markedly. On the basis of the alkali and alkaline contents of "common clays" and the thermal transformation that takes place during the firing, they estimate that the bricks with sodium, potassium, calcium, magnesium glassy phases with about 10-15% (Ca,Mg)O are among the most frequently encountered. They go on to calculate the leaching rate of such a brick by "atmospheric water" in a year would be between 500-200 angstroms per cm^2 per year. This translates to an estimated annual rate of platelet weathering of about 0.1 micrometers of surface per year, or about 0.01 millimeters per century.[35] Lewin and Charola point out that while this level of dissolution is relatively insignificant, if the clay employed in the brick is high in alkalis and low in calcium, the solvent effect of water may be many times greater resulting in the material being etched and eroded by rain with a neutral pH. In bricks with high porosity, such reactions will give some reduction in strength and can contribute to moisture expansion as a result of freeze-thaw action.

Excess lime in the brick matrix can combine with moisture to form $Ca(OH)_2$ resulting in significant increases in the volume which can cause fracturing and bursting in some bricks. In common clay-based bricks, lime and calcium silicates are normally cemented in the glassy matrix and, to an extent, are insulated from the hydrating action of H_2O.

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[35] Ibid., p.194

3.1.4 Effect of Pollutants.

In general, properly fired bricks have been shown to have an unusual resistance to attack by chemical agents.[36] Quartz (a major constituent in most bricks) is almost entirely immune against acid attack. However, as has already been discussed, the alkali and alkaline earth silicate glasses which bind the quartz and other mineral grains together can be susceptible to acids. The air pollutants of concern in the conservation of masonry are the acidic oxides produced by the combustion of fossil fuels.[37]

The most aggressive of these agents is sulfuric acid which results from the dissolution and catalytic oxidation of SO_2 in atmospheric water. It has been estimated that the development of sulfuric acid conditions from atmospheric conditions will increase the dissolution of the glassy phase in bricks by a factor of approximately ten times.[38] Lewin and Charola have shown that atmospheric sulfuric acid not only has an effect on the fireskin but, given sufficient time, can have access to the entire volume of ordinary bricks through capillarity resulting in eventual dissolution of the brick matrix.

3.1.5 Effect of Salts

The most common cause of deterioration of common masonry bricks is a result of the phenomenon termed "salt decay" in 1976 by the T. Stambolov.[39] The crystallisation of soluble salts within the pores of brick (sub florescence) is acknowledged as an important cause of decay. Soluble salts also

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[36] Gilberts C. Robinson, "Composition and Structure as Determinants of Brick/Mortar Durability." *Conservation of Historic Stone Buildings and Monuments.* , 1981

[37] Lewin & Charola, "The Physical Chemistry ..." p.197

[38] Robinson, p.12.

[39] Stambolov, "The Corrosive Action of Salts," *Lithoclastia,* 1976, p.3

frequently form on the exterior of brick masonry surfaces forming unsightly, though less damaging crystal formations known as efflorescence.

3.1.5.1 Efflorescence

When bricks are saturated with water in which there are appreciable amounts of soluble salts, the drying of the brick material will often result in the formation and growth of crystals at the surface. In order for efflorescence to occur, the rate of evaporation must be slower than the rate of migration of the solution from inside the brick to the surface. This phenomenon is most common during periods of low relative humidity.

3.1.5.2 Sub florescence

If the rate of evaporation of water vapour from the exposed brick surface is more rapid than the rate of new solution to that place by capillary migration, the surface will become dry. In this situation, a "dynamic balance" can occur where the rate of water vapour diffusion through a thin layer d of dry stone at the surface (Fick's Law) equals the rate of capillary migration of solution to the interface between the dry and wet zones (Poiseuille's Law). The result is subsurface crystallisation in the pores, channels, and crevices along the plane at distance d. This phenomenon is illustrated in the figure below.[40]

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[40] Lewin & Charola, "The Physical Chemistry ..." p.200

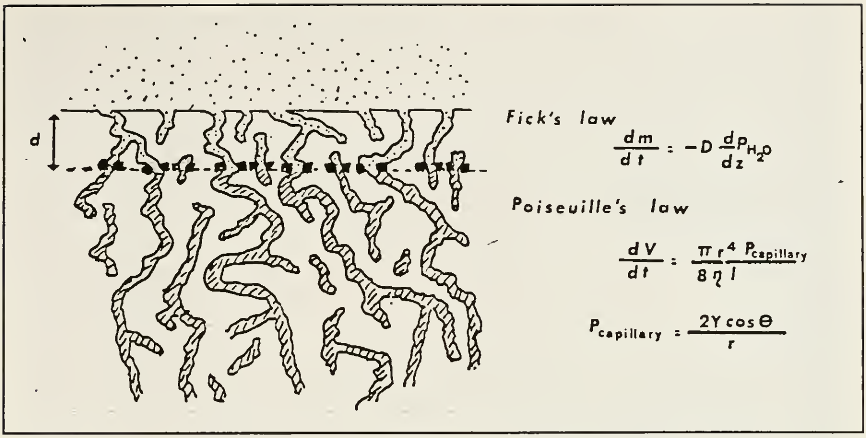

Figure 5. The mechanism of the formation of exfoliation flakes and blisters involves the illustrated escape of water vapour by diffusion. (from Lewin and Charola)

3.1.5.3 Sources of Soluble Salts in Brick Masonry

The source of water soluble salts in bricks is either *intrinsic* (introduced after the units are manufactured) or *Extrinsic.* (introduced to the brick by way of the environment). Alkali and alkaline earth sulfates are common intrinsic salts which usually result from the oxidization of sulfides present in clay that is being fired.

Extrinsic salts are transported into the brick from its surroundings. Gypsum is commonly encountered in bricks which have drawn the substance in solution into the brick from surrounding mortar and concrete. Found in areas adjacent to large bodies of salt water and in northern climates where it is widely used as a de-icing agent, sodium chloride is perhaps the most frequently encountered soluble salt to be introduced to brick masonry.

Figure 6 Efflorescence on nineteenth centuy hand moulded brick. Note the inappropriate repointing which can be a cause of extrinsic soluble salts.

3.2 Types of Soluble Salts

3.2.1 Chlorides

As has already been mentioned, chlorides are very common in northern climates and in coastal areas but also are present as additives in brick mortars. The most commonly encountered chlorides in brick masonry are halite (NaCl), sylvite (KCl), and antareticite ($CaCl_2 \cdot 6H_20$). The Chlorides are particularly destructive as they are soluble and hygroscopic. During condensation they quickly dissolve and once in solution are highly mobile penetrating deep into the masonry material. Because chloride crystals are able to adsorb moisture from humidity, small changes in the ambient moisture levels of the air causes renewed crystal growth and subsequently changing

pressure against pore walls. Sodium chloride usually penetrates into brick from the soil through rising damp and/or by way of salt spray.[41]

3.2.2 Nitrates

Often encountered in agricultural areas and in cemeteries, nitrates are borne of decomposing animal excrement although they can be distributed by way of atmospheric migration. The most common of the nitrates is niter (KNO_3) which forms needle shaped crystalline structures provided water supplied to the brick surface is constant and evaporation is slow. Because of the specific conditions need to form and the needle-like shape of the crystal, the disruptive effect of niter on the brick pore system is negligible.

3.2.3 Sulphates

Sulphates are somewhat less soluble and mobile in comparison with other salts. However because of the size and aggressiveness of their crystals, they can be extremely damaging when introduced to the internal pore network of bricks. When water evaporates they precipitate on the pore walls as hydrate salts which can then become anhydrous. If the humidity is low the anhydrous salts do not dissolve but hydrate and increase in volume which, in turn, exerts pressure on the walls of the pore.

In order for sulphates to hydrate an increase in temperature must be experienced. Sulphates require a slow hydration process to allow for the growth of the large, aggressive crystals for which they are noted. Warm surfaces with thick walls do not allow rhythmic hydration and dehydration which encourage such crystallisation.[42]

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[41] Giovanni Amoroso and Vasco Fassina, "Stone Decay and Conservation: Atmospheric Pollution, Cleaning and Consolidation." pp. 46-47.

[42] Ibid., p.44

3.3 Mechanical Effects of Salt Crystallisation on Bricks

Salt crystallisation within masonry materials is similar in action to that of freezing water in the pores of a solid where pressure is exerted as the volume of the water increases as it freezes. Lewin and Charola have demonstrated that in order for salt decay to occur in brick and stone, the solute must be deposited within the pores at a given distance below the external surface of the masonry. When conditions are such, crystals will form and grow in the pores and channels at the distance d below the exterior surface of the brick unit.[43] The growth of this sub florescence results in force being exerted on the surrounding brick material. The force exerted is strong enough to eventually cause a number of problems which can lead to the structural failure of the brick masonry unit. The following is a brief description of some of the most common manifestations of subsurface crystallisation in bricks.

3.3.1 Blistering

Swelling accompanied by rupturing of a thin uniform skin across and parallel to laminations off the brick's surface. Blistering commonly encountered in softer bricks which lie close to the ground, can lead to greater surface loss such as exfoliation or spalling as the laminar layers continue to separate from the sound brick.[44]

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[43] In "The Mechanism of Masonry Decay Through Salt Crystallisation",S.Z. Lewin points out that the pressure exerted by crystallizing salts is minor when compared with the expnasive force created when water freezes in masonry. See Page 2

[44] Anne Grimmer, "A Glossary of Historic Masonry Deterioration Problems and Preservation Treatments." p.10

3.3.2 Exfoliation/Flaking

A term often used to describe a symptom of deterioration encountered in natural stone, exfoliation can also be observed in brick where the surface of the material is peeling or flaking off on a plane parallel to the laminations of the unit. Bricks with high levels of soluble salts or those that a subject to repeated freeze-thaw cycles a prone to exfoliation.

3.3.3 Loss of Cohesion/Powdering

This condition of deterioration manifests itself by a marked brittleness and tendency of the brick to break up and dissolve. It is usually the result of a degradation of the glassy phase in bricks and often caused by sulfuric acid and/or salts dissolved and transported through the material. Bricks with lime or calcium silicates are most susceptible to this form of deterioration, however, repeated wettings of poorly fired bricks can eventually lead to the breakdown of the glassy phase and a resulting swelling of the non-vitrified clay.

Chapter 4

The Development of Part 1. of the Laboratory Testing Program - Inducing Salt Damage to Eighteenth Century American Brick

4.1 General

As has been already discussed, the primary cause of deterioration in fired brick is believed to be the result of sub florescent crystallisation of salts and freezing water. The most common manifestations of crystallisation are blistering, flaking, and powdering of the brick at or near its surface. While there has been a significant amount of research into the conservation of building stone, very little scientific attention has been devoted solely to the deterioration and development of conservation treatments for brick masonry.

A testing program developed at the Architectural Conservation Laboratory of the University of Pennsylvania was designed to simulate deterioration on hand moulded brick from a late eighteenth century farmhouse located in south-eastern Pennsylvania. The provenance of the bricks was identified and assessments made as to the type and condition of the units selected. The porosity of each of the brick types was determined using ASTM C67-81-7 standard test for determining absorption/porosity of brick. The laboratory simulated deterioration of the brick samples was undertaken according to a standard method developed by the Building Research Establishment. Quantitative and qualitative results from the simulated deterioration of brick samples were made.

4.1.1 Origin and Condition of Bricks

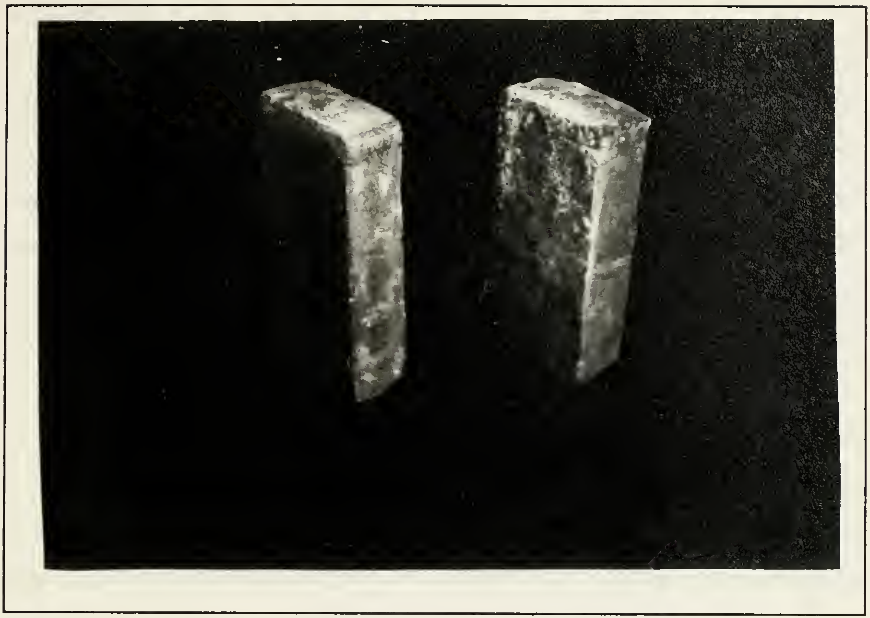

Figure 7 Two of the hand moulded bricks from a c.1785 farmhouse near Chadd's Ford Pennsylvania obtained for the laboratory testing program.

Approximately thirty hand moulded, fired bricks were obtained from a two and one half story late Federal (c.1785) farmhouse located near Chadd's Ford, Pennsylvania. All facing bricks, the units came from an exterior wall with a southwest orientation. In the early 1990's the bricks were removed from part of the wall when work was undertaken on this elevation.

The bricks were all in sound condition with only a few cracks observed. Fireskins on each of the bricks appeared relatively intact, however, some units exhibited areas of higher vitrification and some darkening on the surface as a result. No evidence of acid etching, efflorescence, or sub florescence was observed on any of the bricks.

4.1.2 Typology

The selected bricks ranged in size from 16cm. x 8cm. x 4cm to 19cm. x 9.5cm. x 5cm. They were identified as being of the soft mud, hand moulded variety by their soft edges, non-uniform appearance, and period of manufacture. Several finger prints were discernible on the surface of two of the bricks. The bricks were most probably manufactured in an updraft kiln, however, given the rural location of the building in which they were employed, they may have been fired in the more rudimentary clamp kiln method.

In terms of colour, the bricks fell into two categories. The first (Type 1) exhibited relatively bright reddish hue and partial vitrification characteristic of medium fired brick with a high iron oxide content. The second (Type 2) was a deeper brown red colour with a slight hue of purple indicating the presence of a higher proportion of another mineral in the clay. Both identified bricks appeared to be reasonably well "vitrified" or of "first" quality and appropriate units for use in the facing of a building.

Both grog and clinker were observed when the bricks were sliced with a diamond saw to reveal their interiors. In general, the brick matrix of all samples appeared homogeneous and few voids were observed. The black particles (ranging in size from 0.1cm. to 0.5cm.) were identified as being the clinker. Smaller red particles (between 0.05 and 0.2cm.) were identified as the grog. There was surprisingly little quartz visible, however, some large pieces of aggregate nearly 2cm. in length were encountered occasionally.

4.1.3 Porosity and Permeability

In order to more effectively characterize the bricks before treatment, a standard permeability/porosity test for brick was undertaken. Following the

procedure described in ASTM C67-81-7, five samples measuring approximately 9cm. x 6.75cm. 1.75cm. were selected and dried in an oven at 110°C for twenty four hours. Each sample was then submerged in clean distilled water with a temperature of 20°C for one hour and then weighed once again. Submersion was repeated and samples weighed after two hours and again after twenty four hours of soaking in the water. The percentage absorption for each sample was calculated using the equation $100(W_S-W_d)/W_d$.

4.1.3.1 Results and Discussion.

TYPE 1

Sample #	W_d (g)	W_s (g)	% = $100(W_S-W_d)/W_d$
A1.	1045.8g	1236.3g	17.2%
A2.	1017.8g	1210.4g	19.9%
A3.	1039.6g	1200.6g	15.4%
A4.	1006.1g	1175.2g	16.8%
A5.	1052.5g	1238.1g	17.6%
		Average	17.38%

TYPE 2

Sample #	W_d (g)	W_s (g)	% = $100(W_S-W_d)/W_d$
A6.	307.58g	337.63g	9.76%

Table A. Porosity and Permeabilty Data Tables for Type 1 and Type 2 Bricks.

The test revealed that the two identified brick types had significant differences in both their porosities and rates of absorption. The Type 1 samples averaged a 22.18% percent increase in sample weight after soaking for twenty four hours. After a one hour soak the weight increase averaged

17.38%. In contrast, the Type 2 samples averaged an average increase of 9.76% after twenty four hours of soaking. No increase in absorption was recorded for the Type 2 samples between the one hour soak and the twenty four hour soak. The test revealed that the Type 1 brick was a relatively porous material while the Type 2 brick had a relatively low rate of porosity. A boiling test was not undertaken to further determine the rates of absorption of the brick samples.

4.2 Accelerated Salt Crystallisation Procedure.

4.2.1 Preparation of Samples.

Samples from the thirty bricks were cut into tiles approximately 9cm. x 6.75cm. 1.75cm. in dimension with a fine diamond saw. Square cubes were not practical for the laboratory program developed. Tiles of approximately 4.5cm. in thickness were selected so that sufficiently large areas of fireskin could be analysed. An attempt was made to cut tiles parallel to observed laminations in the bricks in order that possible delaminations could be observed. Each brick tile was assigned a number which was recorded on a small plastic square fastened onto the sample with epoxy resin.

4.2.2 Description of Laboratory Procedure.

The Building Research Establishment 1989 method of salt crystallisation was selected to induce deterioration as it is considered to be the most effective way to reproduce the natural phenomenon.[45] It should be mentioned that this laboratory experiment produces conditions far worse than any that would be encountered under natural circumstances.

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[45] Luiga Bina & Giulia Baronio. "Measurement of the Resistance to Deterioration of Old and New Bricks by Means of Accelerated Aging Tests." *Durability of Building Materials.* , 1984 p.141

Thirty eight of the brick tiles were selected for the salt crystallisation test. A stock solution of sodium sulphate was prepared by dissolving 350 grams of anhydrous sodium sulphate (Na_2SO_4) in 2.15 litres of water. At 20°C the specific gravity of the solution was measured at 1.070 and the amount of sodium sulfate in solution was calculated to be just above sixteen percent as required. The samples were washed with water and dried for twelve hours at 103°C. After cooling to room temperature (20°C), the samples were weighed (W_1), and then placed into a non-reactive plastic basin containing fresh sodium sulphate solution to a depth of 5mm. The samples were supported on glass beads and left to soak for two hours then removed from the solution and transferred into the oven (pre-humidified and pre-heated to 103°C), where they were left to dry for sixteen hours. Each weighing, soaking, and heating cycle was repeated until the desired level of deterioration was achieved.

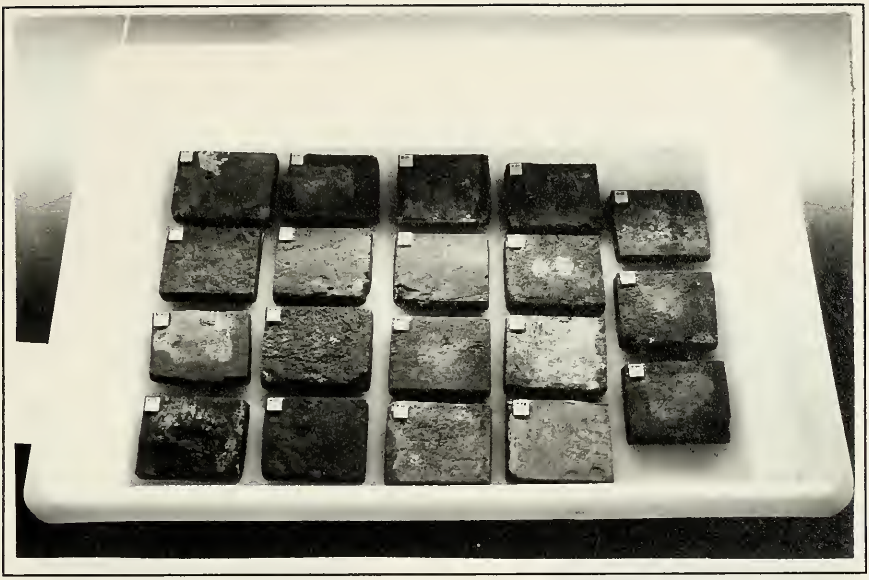

Figure 8. Initial Immersion of Brick Tiles in Sodium Sulphate Solution.

Visual observation of the soaking confirmed that the solution was migrating upward through the brick saturating each of the samples in a relatively short time. The Type 1 samples became fully saturated in a few minutes time while the Type 2 tiles took significantly longer for full saturation to occur. During the second immersion, superficial decohesion of submerged areas of some of the Type 1 samples was observed. Subsequent cycles confirmed that the Type 1 brick was apparently much more susceptible to sodium sulphate crystal rehydration than was the Type 2 brick samples.

After only two cycles several of the Type 1 samples exhibited superficial deterioration in the form of blistering and flaking and were removed from the testing sequence. After drying they showed an average weight increase of eighteen percent. Samples that were removed from the sequence after five cycles showed a weight gain of between nine and fourteen percent, with an

average increase in mass of twelve percent. Only five samples (all Type 2) continued to the tenth cycle without showing any significant signs of deterioration.

Figure 9 . Brick Samples After One Cycle of Sodium Sulphate Crystallisation. Note the formation of a Salt Crust on four of the eight samples shown.

The weight increase of the Type 2 samples was between four and eleven percent with an average gain calculated to be six percent. As expected, it was observed that the samples with lower porosities were more able to withstand the forces exerted by the crystallising sodium sulphate. Many of both the Type 1 and Type two samples exhibited efflorescence. All of the samples developed a hard crust-like sodium sulphate deposition on the .

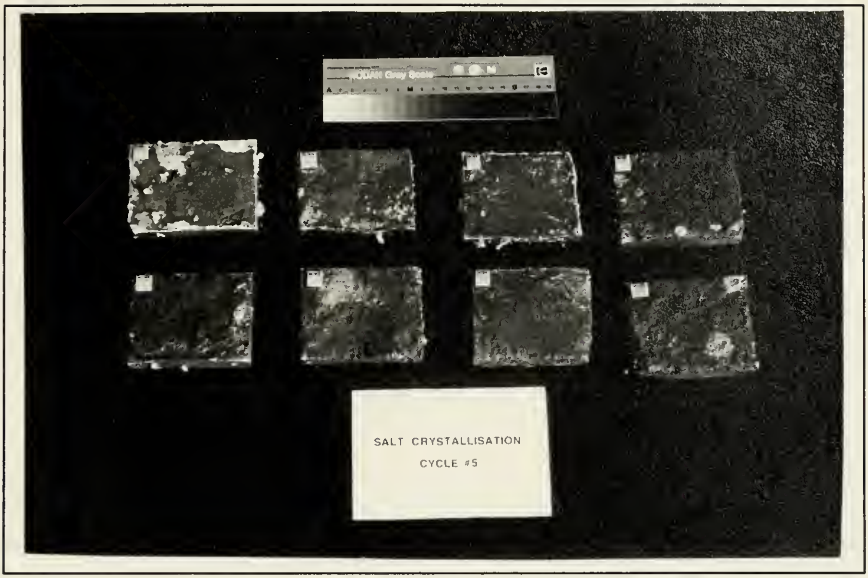

Figure 10 Brick Samples After Five Cycles of Sodium Sulphate Crystallisation. Note the blistering on the surface of the two bottom center Type 1 samples (samples SC45 and SC49.

Figure 11 Brick Samples After Eight Cycles . Note the blistering, cracking, and decohesion of the bottom center (Type 1 sample). Both top (Type 2) samples exhibit salt crusting .

4.2.3 Modification of Salt Crystallisation Test.

The sixteen percent solution of sodium sulphate appears to have been too concentrated for many of the brick samples tested. Approximately two-thirds of the brick tile were removed from the test sequence by the third cycle. Many of the samples exhibited crumbling and decohesion upon rehydration. This problem may have as much to do with the thin sample size as with the concentration of the solution. A more realistic way to induce superficial deterioration of relatively porous brick through salt crystallisation, may be to modify both the concentration of the sodium sulfate solution and increase the size of the sample to more closely match the actual dimensions of the brick unit. Such modifications to the test might result in more superficial blistering and flaking of the brick more akin to that encountered under natural weathering conditions in a saline environment.

Chapter 5

Part 2. of Laboratory Testing Program - The Comparative Evaluation of Two Treatments for Salt Damaged Brick

5.1 General

5.1.2 Fundamentals of Consolidation

Consolidation is a process by which the cohesion of a porous building material such as brick brick, is reestablished through the introduction of a substance to restore the intergranular bond of that material. Consolidation should impregnate sound material below the weathered zone and create a sound bond between the two. It is a radical measure and should only be applied when the survival of historic fabric is in serious jeopardy. In addition to strengthening the material, a successful consolidation should encapsulate/immobilize impurities in the brick matrix like soluble salts.

Good depth of penetration is one of the most important requirements of a consolidant. If good depth of penetration is not achieved, layers of consolidant will exist at the surface of the brick and may eventually lead to cracking and exfoliation as a result of differential thermal expansion, moisture movement, and freeze-thaw action.

It should be stressed that when consolidation is deemed appropriate, it will be necessary to determine the exact procedure(s) and materials needed through a complete program of pretreatment testing.

5.1.3 Review of the Literature

The blistering, flaking, and grain to grain decohesion of fired brick constitutes one of the most widespread and serious historic masonry problems encountered for the material. Literature describing research into the development of conservation treatments for brick masonry over the years is scarce. Lewin and Charola's work (1979) remains as one of the most comprehensive examinations into the deterioration processes of brick. Their preliminary investigations into impregnation techniques at that time suggested that alkoxysilane water repellents provided the most promise for the preservation of the historic bricks of Venice. The application of water repellents to brick has been explored to a certain extent by a number architectural conservators including Ashurst, Van Asperen, and Stambolov. Since the mid-1980's Luiga Binda and Giulia Baronio have published several articles dealing with the deterioration and conservation of bricks (1992). In 1988, Manganelli Del Fa (et al) published a work in which they outlined experiments with three types of perfluoropolyether. In all three cases, the treatments resulted in a net loss in porosity and permeability.[46]

Perhaps the boldest large-scale "conservation" treatment of brick thus far is that undertaken by K.L Gauri. In 1990, Gauri developed a treatment program for the Cathedral of the Assumption in Louisville, Kentucky in which dilute epoxy resin was applied to deteriorated brick areas on the cathedral. Pre-application testing consisted of a comparison with a mixture of ethyl silicate and an alkoxysilane water repellent. Gauri recommended the epoxy resin for the work on the grounds that it provided better grain to grain

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[46] C. Manganelli Del Fa et al, "The Protection of Building Materials: Bricks." *VI International Congress on Deterioration and Conservation of Stone*, Torun, 1988

adhesion, in comparison to the ethyl silicate/silane treatment, which he claimed formed a high concentration on the outer 0.3cm layer of the brick which significantly affected the material's normal vapour transmission. The method of application for Gauri's work is unclear although he reportedly achieved depth of penetrations of between three and four centimeters.[47]

While scientific literature dealing with the conservation of brick masonry is scarce, there is a significant body of research focusing on the conservation of building stones. Ottorino Nonfarmale's 1971 procedure for the consolidation of flaking yellow sandstone with a mixture of Paraloid B-72 and a silane was chosen as one model upon which to develop a laboratory program for the treatment of salt damaged brick samples.[48] Since Nonfarmale's early experiment, the so-called "Bologna cocktail" has been used in many subsequent applications and proven to be a successful treatment for the consolidation of porous stones.

Epoxy resins have also been used as consolidants for the treatment of porous stones. In Poland, epoxies were introduced to conservation work in the late 1950's. For years controversy has raged over the use of these compounds for conservation purposes. Opposition to the use of epoxies has come from the fact that these compounds are inherently non-reversible and, as such, do not meet a fundamental requirement of conservation standards. The reported breakdown of epoxies when subjected to ultraviolet light and certain microorganisms has further fueled the arguments of those opposed to the use of these compounds. Wieslaw Domaslowski has maintained that the use of epoxies for the conservation of stone is appropriate provided that

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[47] For a more complete discussion of Gauri's technique see Charles Selwitz's, "Epoxy Resins in Stone Consolidation." Santa Monica, CA: J. Paul Getty Trust, 1992 p.84

[48] Ottorino Nonfarmale, The Treatment of Stone Monuments: A Review of Principles and Processes," *The First International Conference on the Conservation of Stone Monuments*, Bologna, 1971 p.297

conditions are controlled and impregnation is properly performed.[49] It is now generally accepted that it is nearly impossible to remove even reversible consolidants from materials with grain to grain decohesion. Therefore, in many circumstances, reversibility is not a realistic expectation of a consolidation treatment. The new generation of cycloaliphatic and bisphenol epoxy resins are thought to be much more chemically stable than those utilizing traditional amine hardeners.[50] Use by Rossi-Manaresi, Domaslowski, and Gauri of epoxy resin for the consolidation and reattachment of deteriorating masonry materials were used as models upon which this laboratory program for the treatment of salt damaged brick samples was based.

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[49] Wieslaw Domaslowski and Alicja Strzelcyzyk, "Evaluation of Applicability of Epoxy Resins to Conservation of Stone Monuments." *Case Studies in the Conservation of Stone and Wall Paintings. Preprints of the Contributions to the Bologna Congress*, 21-26 Sept., 1986 p.130

[50] Charles Selwitz, "Epoxy resins in Stone Consolidation." p.17

5.2 Additional Criteria for Chosen Treatments

5.2.1 Viscosity

Lewin and Charola have observed that low viscosity, high surface tension, and a small contact angle are of prime importance for a successful impregnation with good depth of penetration. A consolidant which is too viscous will leave a high concentration of resin at the surface creating an impermeable barrier and causing colour problems. In general, a solution with a viscosity similar to that of water (one poise) or less is desirable for a consolidant. Normally, the consolidant will be diluted with a solvent to achieve a viscosity low enough to ensure good penetration and subsequent strengthening of the material's matrix. Both treatments were selected because of their reported abilities to meet these criteria.

5.2.2 Application Techniques

There are several application techniques which help increase the depth of consolidant penetration into masonry materials including total immersion of the object or treatment under vacuum pressure. Bladder bags which apply the consolidant to the surface in situ over an extended period of time have met with some success. The simplest and most effective way to apply consolidants appears to be the brushing or spraying of low viscosity consolidants. These forms of application have proved to be the most practical for buildings.

5.2.3 Toxicity and Reactivity

In selecting the conservation treatments, consideration was given to the toxicity and reactivity of the materials needed to provide a successful

consolidation. Material Safety Data Sheets (see appendices) were consulted regarding all of the materials used in the treatment processes. Wherever possible, less toxic/reactive materials were selected over more hazardous substances. In a controlled laboratory environment steps can more easily be taken to minimize the effects of toxic and reactive substances than treatments undertaken in situ. Because all epoxies (and many solvents) are flammable, corrosive, and potentially carcinogenic, proper equipment including respirators, gloves, eye wear etc., must be used at all times when handling these materials.

5.3 PreConsolidation and Desalination of the Salt Contaminated Brick Samples

5.3.1 Facing and PreConsolidation

An attempt was made to face and set down areas of flaking brick on the salt contaminated samples. The intent of such a preconsolidation is to fix and save rather than strengthen the material. Type 1 and Type 2 samples exhibiting blistering, flaking, and powdering were selected and delicately sponge cleaned with acetone and then sprayed with an acrylic resin (Acryloid B-72) diluted to 6.25% in a solvent containing equal proportions of toluene and xylenes. The samples were then each covered with wet strength Japanese paper torn into strips one inch wide and laid in place with overlapping edges. A 6.25% solution of Acryloid B-72 paper was then brushed onto the paper with a sable hair brush adhering the paper to the brick surface.

The treatment was left to cure then was again applied, this time with Acryloid B-72 at 30% in equal proportions of toluene and xylenes of which ten parts were mixed with ninety parts of 1,1,1 trichloroethane. The mixture was

applied with a brush until the brick no longer absorbed the liquid. After two days the samples were dabbed with tricloroethane in order to dilute the resin which had become deposited at the surface. The raised flakes were gently manipulated to their original surfaces. After 24 hours the brick samples were dabbed with the B-72 solution until saturation was achieved. The process was repeated twice. The samples were allowed to cure for a week before the Japanese paper was removed.

5.3.2 Desalination.

The preconsolidated samples were poulticed using a commercially available form of fibrous cotton marketed commercially under the name Aquasorb F.[51] This material was chosen for poulticing because of its great absorbency and drawing power. The material consists of partially water soluble and internally crosslinked cellulose esters. It has successfully been used in the laboratory and in situ for the desalination of contaminated of building stones.

The material was wetted to a paste-like consistency with filtered water and applied over Japanese paper onto the brick samples at a thickness of about 0.5cm. While the poulticing process did appear to draw some of the sodium sulphate out of the sample, the brick appeared to draw water out of the poultice resulting in an apparent rehydration of the sodium sulphate. When the poulticing material was removed, significant amounts of brick was also removed. Subsequent applications of the Aquasorb F resulted in dramatic decohesion in a majority of the Type 1 samples. Much of the brick surface was removed in all of the Type 2 samples.

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[51] Aquasorb F is the Registered Trademark of Aqualon Company of the Aqualon Group North Market Street, Wilmington, DE 19894; Phone. 302.594.5000.

The results of the poulticing procedure indicated that the rehydration of the sodium sulphate (between five and eighteen percent of total sample weight) was inducing decohesion of the preconsolidated surface (and unconsolidated subsurface material. Experiment modifications for the poulticing of brick samples might include changes to the concentration or type of consolidant and/or modification to the application techniques. Visual observations indicated that the pores of the samples were clogged with sodium sulphate and that the B-72 was unable to penetrate into the brick matrix. An initial gentle manual removal of dry salt on the surface of the brick samples may have aided the preconsolidation of the brick samples.

5.4 Acrylic Resin Consolidation of Brick Samples

5.4.1. Fundamentals of Acrylic Resin Consolidation

Synthetic acrylic resins are widely used as consolidants because they combine the desirable physical properties of organic resins yet exhibit a far higher chemical stability. The molecules of acrylic resins are built up out of repeating units (monomers) which are linked together (polymerized) to form molecular chain structures. In the presence of certain solvents, these polymers are separated in the form of a liquid solution.[52] This type of polymer chain is favoured by conservators because of its solubility and resultant reversibility. Among the most common acrylic resins for consolidation are Acryloid B-72™ and Acryloid B-67™. When correctly applied to porous masonry surfaces in dilute form (usually about 10% by weight), the acrylic consolidant will coat the inside of the pores and should only minimally affect the vapour transmission rate of the material. It has

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[52] Morgan Phillips, "Consolidation of Porous Materials: Problems and Possibilities of Acrylic Resin Techniques." *Technology and Conservation* ,Winter 1979.

demonstrated numerous times that using acrylic polymer resins to consolidate porous masonry can markedly increase the strength of the material without adversely affecting the rate of vapour transmission.[53]

5.4.2 Treatment of Samples

The acrylic resin Acryloid B-67™ was chosen to consolidate both salt damaged and non-salt damaged samples of Type 1 and Type 2 brick.[54] B-67 has been widely used as a consolidant by both fine arts and architectural conservators over the last several decades. It is a fast setting, medium hard acrylic ester resin with good water repellency. VM & P Naphtha was chosen as the solvent and a silicone (Dow Corning silane Z-6070) was added to the mixture to impart added hydrophobic properties to the brick samples.[55]

Solution A: Acryloid B-67 at 30% in VM & P Naphtha.
Solution B: Z-6070 at 20% in VM & P Naphtha.
Mixture: 10 parts. solution A, 10 parts. solution B, 80 parts. VM & P Naphtha to achieve 15% concentration of B-67 in solution.

The solution was poured into two non-reactive Pyrex glass dishes to a depth of 1cm. The brick samples were weighed and placed in the solution and the Pyrex dishes tented with plastic to slow the solution's rate of evaporation. The samples were removed from the solution after thirty minutes and excess consolidant was removed from the brick surface with a sable hair brush. The

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[53] Edward Merrill, "Acrylic Resin Consolidants - Feasibilty Study." p.31

[54] Acryliod B-67 is manufactured by Rohm and Haas Company, Independence Mall West, Philadelphia, PA 19105.

[55] Z-6070 is manufactured by Dow Corning Corporation, Midland, Michigan, tel. 1.800.252.9899

samples were weighed then covered and left to cure on a metal rack for two weeks. After curing, the consolidated samples were weighed once again.

5.4.3 Observations

The non-salt damaged samples appeared to become saturated by the acrylic solution in less than five minutes. The salt damaged samples achieved saturation after approximately fifteen minutes. The saturation of the samples with the consolidant solution resulted in a noticeable darkening of the brick material which disappeared upon curing.

5.5 Epoxy Resin Treatment

5.5.1 Fundamentals of Epoxy Resins

Epoxy resins are polymer-forming systems containing two principal components that interact to produce highly cross-linked products which have exceptional strength. Conservators are familiar with the two step process of epoxy resins in which a resin is mixed with a hardener to produce a strong, long lasting adhesive. The biggest problem encountered when using epoxies for consolidations is achieving adequate penetration.

Over the last two decades, industrial chemists have succeed in synthesizing and making commercially available a wide array of epoxies for a variety of applications. Because of their relatively low viscosities, the bisphenol A glycidal ether variety resins have been found to be the most appropriate epoxies for the consolidation of porous masonry materials.[56] When diluted with appropriate solvents, viscosities of 1.0 cP or lower can easily be achieved.

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[56] Charles Selwitz, "Epoxy Resins in Stone Conservation." p.16

The curing agent of an epoxy greatly affects the hardening time and chemical stability of the resin. The curing agents most commonly used for stone consolidation in the past have been the simple polyamines (like diethylenetriamine) which provide short curing times but often lead to yellowing, brittleness and discoloration when in the presence of ultraviolet light. Presently, the modified aliphatic amines (Isophorone diamines) are considered to be the most effective epoxy resin curing agents for stone consolidation. They combine a molecular weight of around 230, low viscosity, and can provide resins that will show no discoloration.[57]

5.5.2 Epoxy Resin Treatment

The epoxy resin system selected to consolidate both salted damaged and non-salt damaged samples of Type 1 and Type 2 brick was EPONEX 1510 resin and EPI-CURE 1618 curing agent.[58] EPONEX 1510 is a low viscosity hydrogenated Bisphenol A-Epichlorohydrin based epoxy resin described by the manufacturer "as a building block resin" for exterior applications.[59] EPI-Cure 3370 is a low viscosity modified aliphatic curing agent. The silane, Dow-Corning Z-6070, was added to the consolidant to impart added water repellency.

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[57] Ibid., p.18

[58] Both products manufactured by Shell Chemicals, One Shell Plaza, Houston, TX 77001 713.241.6161

[59] Ronald S. Bauer, "Formulating Weatherable Epoxy Resin for Maximum Performance." *Shell ChemicalTechnical Bulletin ,SC:729-83*

Figure 12. Mixing the Epoxy Resin /Silane Consolidant under a Fume Hood while wearing a respirator.

Because of the toxicity and flammability of the epoxy resin components and solvents used in this experiment a respirator, protective eye wear, gloves were used while carrying out the treatment process. All steps of the treatment were carried out under a fume hood.

Solution A:	Using the equation, mol. wt. amine/mol. resin x 100 the proportion of hardener to resin was established. Thirty two parts hardener were mixed with one hundred parts resin
Solution B:	Firty five parts ethanol, forty parts toluene.
Solution C:	Two parts z-6070, eight parts ethanol.
Mixture:	One part Solution A, two parts solution B.

An induction period specified in EPONEX 1510 product literature required that solution A be left to cure for one hour before treatment in order to prevent clouding of the cured resin.[60]

The mixture of A and B yielded a 33% percent solution of epoxy resin (considered optimum by Gauri for the consolidation of porous building materials). After mixing, the solution was transferred into two Pyrex glass dishes to a depth of approximately 1cm. The brick samples were weighed, placed into the solution (fireskin up) and tented with plastic to limit the amount of solvent evaporation. After thirty minutes the samples appeared fully saturated as a result of capillary rise; were removed from the solution and excess resin solution on sample surface was removed with a sable hair brush. Samples were weighed and transferred to a metal drying rack, tented and left to cure for two weeks as recommended. After curing the samples were weighed again.

5.5.3 Observations

All of the samples appeared saturated by solution after fifteen minutes. Surface darkening of all of the samples was observed upon saturation. The solution had thickened appreciably by the end of the thirty minute immersion period. Excess consolidant was gel-like in consistency and was easily removed with acetone. Some loss was observed on salt-treated samples upon removal from the solution. The darkening observed during immersion was not noticeable after curing. All of the salt treated samples exhibited a noticeable odor of toluene after curing indicating that the sulphates may have been preventing normal evaporation of the solvents from within the brick matrix. The untreated samples had no such odor. More research is required

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[60] If EPONEX 1510 is not properly inducted, epoxy will blush upon curing. See Bauer, p.5.

regarding the effect of sulphates on the evaporation rates of certain solvents.

Chapter 6

Part 3. of Laboratory Testing Program - Testing and Assessment of Consolidated Samples

6.1 General

There are no established criteria by which to evaluate the absolute success of a conservation treatment. A consolidation's success is often assessed according to results taken from the treated sample's resistance to laboratory induced deterioration. Mechanical tests to measure compressive and tensile strengths of treated samples are frequently undertaken as are measurements of water vapour transmission rates, absorption/porosity, and abrasion tests. Scanning electron microscopy is, increasingly, being used to make internal comparative assessments for various treatments in addition to analyzing the way that a consolidant modifies the grain cohesion and pore spaces of a material before and after treatment.

For this thesis, several tests were undertaken on each of the brick samples including an absorption test (ASTM C-67.7), a water vapour transmission test (ASTM E-96-80), and a three-point bending strength test with an INSTRON Tensile Testing Machine. Comparisons were made with untreated samples for each of the tests run. Because of time constraints, no procedures were undertaken to test the treated sample's resistance to deterioration or abrasion.

6.1.2 Absorption Test

The purpose of the after treatment absorption test was to determine to what extent the consolidation treatments affected the brick's ability to absorb water.

6.1.2.1 Procedure

Sixteen treated brick samples were selected for the Absorption test ASTM C67-81-7. Following the described procedure, the samples were dried at 110°C for twenty four hours and stored in a dessicator before weighing. Each sample was then submerged in clean distilled water with a temperature of 20°C for one hour and then weighed once again. Submersion was repeated and samples weighed after two hours and again after forty eight hours of soaking in the water. The percent absorption for each sample was calculated using the equation $100(W_s - W_d)/W_d$.

6.1.2.2 Observations

All of the sulphate damaged samples treated with the epoxy and acrylic resin consolidants exhibited significant decohesion and loss of material after the two hour soak. The epoxy consolidated salt damaged samples developed an opaque film on the surface after the two hour soak. All of the consolidated salt damaged samples exhibited extensive crumbling, cracking, and decohesion. All of these samples crumbled when removed wet from the soaking dishes.

The non-salt consolidated brick samples exhibited no decohesion after soakings. No formation of film on the surface of the non-salted epoxy resin treated samples was observed.

6.1.2.3 Results and Discussion

The results indicate that absorption rates for both the Type 1-B-67/Z-6070 and Type 1-Eponex/Z-6070 treated samples were significantly lower than untreated samples (see section 4.2.3.1). Type 1 samples treated with the acrylic resin solution showed an average absorption rate of 15.94%, while samples treated with the epoxy resin consolidant retained an absorption rate of 12.37% This compares with the untreated Type 1 samples which averaged a 17.36% weight gain after the forty eight hour soak. The only Type 2 sample tested (consolidated with epoxy resin), showed an absorption rate of 8.90%; essentially the same as the average 9.76% absorption rate recorded for the untreated Type 2 samples.

Sample #	W_d (g)	W_S (g)	$100(W_S - W_d) / W_d$
Type 1, B-67 A	110.30	129.17	17.10%
Type 1, B-67 B	91.00	102.94	13.12%
Type 1, B-67 C	80.24	92.34	15.07%
Type 1, B-67D	118.08	139.93	18.50%
Type 1, Eponex A	82.56	94.64	14.63%
Type 1, Eponex B	75.57	85.88	13.60%
Type 1, Eponex C	83.51	94.20	8.90%
Type 2, Eponex D	83.544	92.83	9.80%

Table B. Data recorded from Water Absorption/Porosity test of consolidated samples.

The net decrease in the treated samples ability to absorb water may be attributed to a modification of the brick's pore network as a result of the

consolidations. Ideally, the consolidant/water repellent should coat the inside of the pore networks, thereby, strengthening and also rendering the material somewhat hydrophobic. The decrease in absorption observed in the treated samples may be attributable to the space taken up by the cured consolidant in the pore network and/or by the water repellent properties of the silane. In the case of the epoxy resin, the decrease in absorption was three times that of the acrylic resin indicating that either the B-67 deposited less consolidant within the brick matrix, or the silane was more effective when used in combination with an acrylic resin. The former is probably a more reasonable postulation as the silane would probably be unable to effect water repellency under immersions of such a long duration. Scanning electron microscopy would be a useful method by which examine the deposition of the consolidant in the pore system.

Figure 13. Salt Damaged Brick Sample Treated With B-67/Silane Consolidant After Two Hour Soak. This degree of damage was typical of Type 1 salt damaged samples treated with both the acrylic and epoxy resin consolidants.

The dramatic decohesion observed in the consolidated salt damaged samples indicates that neither the acrylic resin or epoxy consolidant was able to effectively penetrate the brick and encapsulate the sodium sulphate depositions as intended. It appears that the crystallised sodium sulphate was acting as the binding material in all of four of these brick samples. When the samples were soaked in water, rehydration of the salt crystals occurred resulting in the observed decohesion. The opaque film observed on both samples treated with the Eponex indicates that the consolidate was unable to penetrate the salt laden material and formed a layer on the brick surface. It seems clear that the failure of these consolidations appears to be attributable to the extent of sodium sulphate and related damage that occurred in the brick samples during the crystallisation cycles (see section 4.3).

6.1.3 Measurement of Water Vapour Transmission Rates.

The purpose of this test was to determine the rate at which water vapour is able to pass through untreated, salt laden, consolidated non-salt laden, and consolidated salt laden brick samples. It generally acknowledged that measuring the vapour transmission rate of treated and untreated samples is one of the most important ways in which to assess the performance of a consolidation.

6.1.3.1 Procedure.

The test was conducted following ASTM E 96-80, "Standard Test Methods for Water Transmission of Materials". All of the sample disks were of the Type 1 brick and were cut to a diameter of 7cm from the brick tiles on with a coring bit affixed to a drill press. Ten samples (both salted and

unsalted) were treated with both the acrylic resin/silane and epoxy resin/silane consolidants as described in sections 5.4 and 5.5.

Figure 14. Samples Disks soaking in Epoxy Resin/Silane Consolidant in Preparation for Water Vapour Transmission Test.

After curing, electrical tape was wrapped twice around the edge of each disk. Tri-cornered polypropylene 250 ml beakers were used as test dishes. The beakers have an diameter of just slightly more than 7cm. All but one (the control) of the dishes was filled with 100ml of filtered water. The taped disks were pressed down until firmly wedged into the tapered beaker. The tops of the disks were flush with the rims of the containers in this position. To ensure an impermeable seal, melted paraffin was dripped with a pipette between the disk and container. Each disk assembly was marked with a sample number and weighed. All thirteen samples were then set into a sealed chamber containing desiccant and a hydro-thermograph. Typical

environmental conditions in the chamber were between 20-25°C with an average relative humidity of about 10%.

Each assembly was weighed every twenty four hours (plus or minus twenty minutes) for thirty eight days, as was the temperature and relative humidity in the chamber. The desiccant was changed three times during the experiment.

6.1.3.2 Observations

Five of the six salted samples began to spall after seven days in the desiccating chamber. An odor of toluene was discernible from the salted samples treated with the epoxy resin/silane consolidant. By the fourteenth day, significant decohesion was observed in the five of the salted samples.

Figure 15. Water Vapour Transmission Tank During Testing of Brick Disks.

6.1.3.3 Results and Discussion.

It should be noted that the number of samples tested is too low to achieve a low statistical rate of error. However, a number of preliminary conclusions may be drawn from the following results.

See Appendix 1 for the data recorded from the thirty eight day long experiment. The total daily weight loss of each sample type was added up and divided by the number of samples. Graphs were produced from the data with the average weights of each sample type assembly plotted as a function of time.[61]

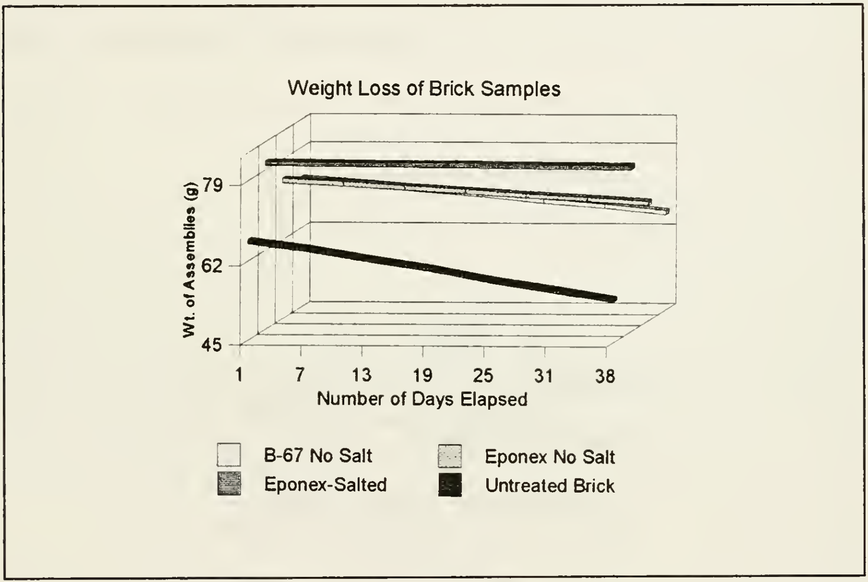

Table C. Graph Illustrating Weight Loss Averages of Each of the Sample Types during Thirty eight day water Vapour Transmission Test.

Except for the control, (sample 5.2) all of the sample types showed a marked loss of weight over the thirty eight day test period. The untreated,

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[61] Because of the dramatic decohesion observed in the salt laden samples during the vapour transmission test, data recorded from them was deemed unreliable and, therefore, not analysed.

unsalted sample showed the greatest weight loss with a decrease of 12.18 grams (18% of total assembly weight) while the salted, epoxy resin samples showed the smallest weight loss at 0.57 grams (less than 1% of total assembly weight). The non-salted samples treated with the B-67/silane mixture showed an average weight loss closest to that of the untreated sample with an average total weight loss over the thirty eight day period of 6.6 grams (9% of assembly weight). The non-salted samples treated with the epoxy/silane consolidants lost an average of 4.5 grams (6% of assembly weight). These figures indicate that the B-67/silane treatment resulted in a reduction of vapour transmission of roughly one-half, while the epoxy/silane consolidant decreased the rate by about two-thirds of untreated samples.

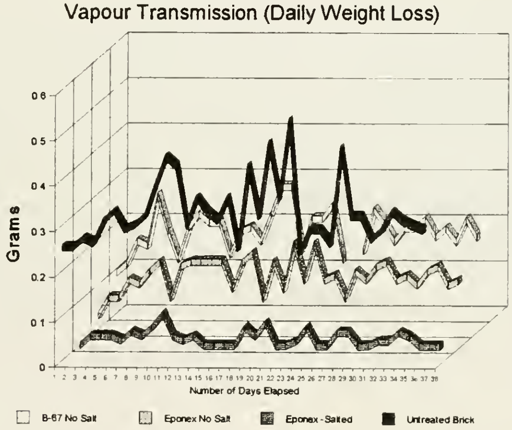


Table D. Graph Illustrating the Average Daily Fluctuations of each of the sample types during the Water Vapour Transmission Test.

Peak values for the average daily weight loss occurred on the twenty fifth day. The cumulative data chart graphically shows the average daily weight loss of each of the tested samples. The results indicate that the B-67/silane treated samples had a daily vapour transmission rate closest to that of the untreated brick. The low vapour transmission rate of the salt laden, epoxy resin consolidated sample may owe to the high concentration of sulphates deposited within the brick pore network and the resulting deposition of epoxy resin on the sample surface. The use of scanning electron microscopy would be useful to analyse the deposition of the sulphates and consolidants within the pore network of the brick samples. Because of time constraints, the water vapour transmission rate through a unit square meter of brick surface per hour was not calculated.

6.1.4 Three Point Bending Strength Test.

For a quantitative determination of the strengthening effect of the consolidants on the brick samples, a three point hardness test was undertaken at the Laboratory for the Research of the Structure of Matter (LRSM), at the University of Pennsylvania using an INSTRON Tensile Testing Machine (TTM). A total of twelve Type 1, non-salt damaged brick samples were tested. Of the twelve samples, four were consolidated with the B-67/silane mixture, four were treated with the epoxy/silane solution, and four were left untreated.

6.1.4.1 Procedure.

The INSTRON TTM requires a minimum sample preparation specific to the test. For the test, consolidated and unconsolidated brick tiles measuring 9cm x 6.75cm x 1.75cm were supported on two steel rollers placed

approximately 6cm apart. The mid-span contact line was engaged by a polished steel rod attached to a bar placed in a vertical track. The jig assembly is a standard device for such tests and has a scale for centered positioning of samples. The load was supplied by the TTM which was equipped with a 10,000 pound load cell and a strip chart recorder. The samples were positioned in the jig and pressure was loaded onto the sample at an undetermined rate.

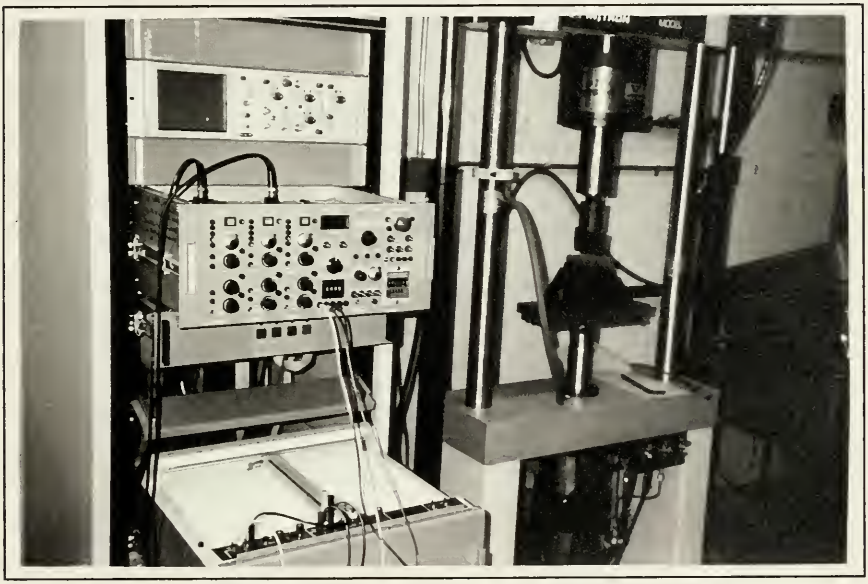


Figure 16. Brick Tile Loaded onto the Jig of the INSTRON Tensile Testing Machine.

6.1.4.2 Observations.

Samples exhibited no visible relaxation prior to fracture. Mechanical fracture occurred at the point of ultimate loading strength and was identified by an abrupt drop on the strip recorder.

6.1.4.3 Results and Discussion.

The results of each tested sample type was added up and divided by the number of samples to obtain an average. As Table indicates, significant strengthening of the untreated brick samples was obtained through consolidations with both the B-67/silane and Eponex/silane mixtures. Of the two treatments, the acrylic resin/silane consolidated samples showed the highest average point of rupture at 3920 pounds per square inch. This nearly represents a doubling of the strength of the untreated samples which averaged a 2180 pounds per square inch point of rupture. The increase in strength imparted by the Eponex treatment was close to that of the acrylic resin consolidation with an average point of rupture at 3483 pounds per square inch.

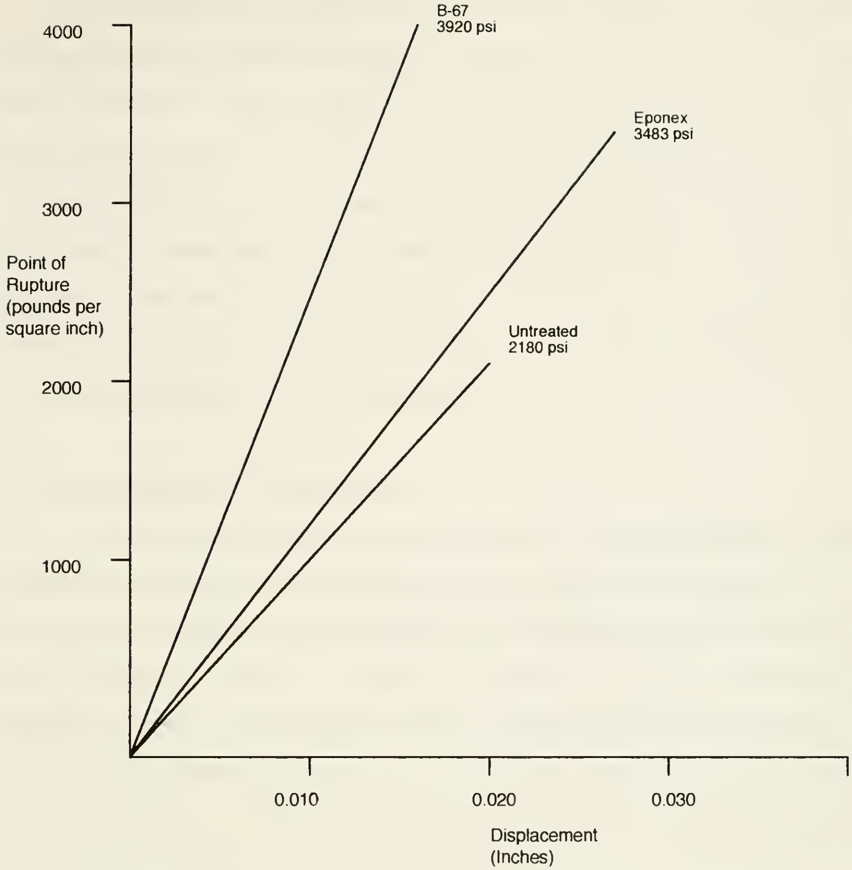


Table E. Graph showing the average Point of Rupture and Displacement of each of the sample types tested on the INSTRON (Tensile Testing Machine).

The results also indicate that the acrylic resin treated sample was considerably more brittle and fractured with less relaxation than the Epoxy treated sample which recorded the highest average displacement of 0.028 inches before rupturing. The untreated sample had an average displacement of 0.020 before rupturing while the acrylic resin treated sample recorded and average displacement of approximately 0.015 inches at rupture.

The INSTRON test clearly indicates that while both consolidation treatments impart significant tensile strengthening to the brick, the acrylic resin provided a higher average strength. The 30% increase in flexural strength of the epoxy resin consolidated sample is significant. In terms of flexural strength alone, both consolidants would appear to be appropriate consolidating materials for deteriorated brick. The increase in brittleness imparted to the brick by the acrylic resin (as indicated by the slight drop in displacement at rupture), is insignificant enough so as not to adversely affect the material or adjacent unconsolidated brick.

6.2 Evaluation of Treatments

As already described, an attempt was made to preconsolidate, face, and poultice the salt laden samples following Nonfarmale's method (see 5.3.1). It was presumed that rehydration of the sodium sulphate during the poulticing of the samples resulted in spalling, decohesion, and loss of structural integrity. It also appears that the sodium sulphate had become the binding vehicle within the brick matrix and that the superficial consolidation with the acrylic resin was unable achieve any real measure of grain to grain adhesion.

Unpoulticed, salt damaged brick samples that had been subjected to deep epoxy resin and acrylic consolidations exhibited similar massive decohesion and cracking during the water absorption test (6.1.2). This phenomenon also occurred in five of six of the salt damaged subjected to the water vapour transmission test after seven days. The results of these tests indicate that the consolidation treatments as carried out on the salt damaged brick samples was completely unsuccessful. More research is needed to

determine the effects of high concentrations of sodium sulphate on brick and ways to stabilize the resulting damage.

The consolidations of the non-salt damaged brick samples yielded some interesting results. Both of the acrylic and epoxy resin consolidants achieved good penetration when samples were immersed in them for a period of time. Of course, such immersions will usually not be practical for in situ applications and more work is required to determine the efficacy of alternate methods of applying these consolidants. The induction times and toxicity of the epoxy resin potentially makes field application more difficult than with the acrylic resin mixture.

The absorption rates of the samples treated with acrylic resin/silane treated samples were significantly closer to those of the untreated brick than were the epoxy/silane samples. These figures indicate that the B-67/silane consolidants result in less alteration of the pore network of the brick than does the Eponex/silane mixture. This conclusion is also borne out by the vapour transmission test which showed an average transmission rate for the B-67/silane treated samples about half that of the untreated sample, while the epoxy treated samples showed a vapour transmission of about one-third that of the untreated sample. Analysis of the samples by scanning electron microscope would prove useful in determining how the consolidants are distributed within the pore network of the brick material.

In terms of physical strength, the largest increase in tensile bending strength was achieved by the acrylic resin treated samples which showed a doubling in strength over the untreated brick. This increase in strength was accompanied by a slight decrease in the material's ability to bend under such force. The epoxy resin samples also showed a significant increase tensile strength over the untreated samples (though somewhat lower than the

acrylic resin). The epoxy resin treated showed a higher rate of flexing before rupture than either the untreated or acrylic resin treated samples.

These laboratory tests suggest that from the standpoints of ease of application, absorption, porosity, and tensile strength that the acrylic B-67/silane consolidant appears the compatible treatment for brick containing minimal levels of sodium sulphate contamination. Additional research work needs to be undertaken to determine the effects of the tested consolidants on damaged brick with low levels of soluble salts and accelerated decay to treated brick samples. Any additional experimentation with consolidating resins should include tests to determine their performance in a number of atmospheric conditions including ultraviolet light stability.

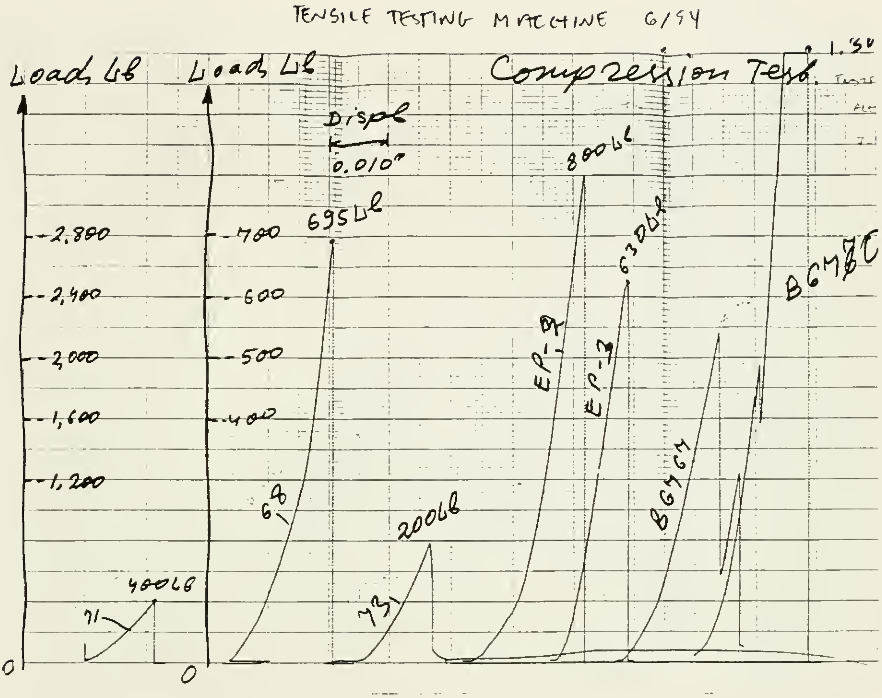
APPENDIX 1

Vapour Transmission Data of Treated and Untreated Brick Samples.

Day #	NS B67 1.0	NS B67 1.1	S B67 2.0	S B67 2.1	S B67 2.2	S EP 3.0	S EP 3.1	S EP 3.2	NS EP 4.0	NS EP4 4.1	NS NT 5.0	S NT 5.1	NT Ctl 6.0	Tmp C°	% hum	147. 5g. Wt.
1	69.55	75.32	72.46	72.31	77.18	75.10	75.09	80.49	73.30	75.71	66.27	72.85	50.43	25.0	4.o	147.37
2	69.40	75.29	72.31	73.25	77.51	75.13	75.15	80.54	73.18	75.73	66.02	72.88	50.48	21.5	5.0	147.54
3	69.25	75.23	72.28	73.26	77.54	75.09	75.12	80.52	73.05	75.72	65 77	72.83	50.48	21.0	4.0	147.63
4	69.05	75.12	72.12	73.20	77.51	75.00	75.10	80.48	72.87	75.66	65 50	72.77	50.48	22.0	4.5	147.57
5	68.86	75.02	71.95	73.13	77.49	74.93	75.06	80.46	72.71	75.62	65.24	72.70	50.47	23.0	4 0	147.49
6	68.60	74.87	71.74	73.01	77.39	74.85	75.03	80.45	72.52	75.56	64.93	72.66	50.48	24.5	3.5	147.56
7	68.37	74.75	71.55	72.91	77.30	74.71	74 14	80.42	72.31	75.48	64 60	72.56	50.47	25.0	3.5	147.45
8	68.19	73.69	71.44	72.86	77.28	74.59	73.97	80 40	72.17	75.47	64.31	72.50	50.47	23.0	3.5	147.59
9	67.94	74.56	71.28	72.75	77.17	74.46	73.80	80.36	71.97	75.40	64 01	72.41	50.44	23.0	4.0	147.46
10	67.69	74.41	71.12	72.63	77.06	74.30	73.65	80.29	71.77	75.30	63.69	72.30	50.43	24.0	4.0	147.38
11	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
12	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
13	66.78	74.05	70 68	72.38	76.85	73.77	73.36	80.24	71.05	75.16	62.40	72.00	50.46	24.5	6.0	147.57
14	66.58	73.99	70.58	72.34	76.81	73.64	73.30	80.24	70.90	75.13	62.11	71.93	50.45	23.0	6.0	147.56
15	66.34	73.87	70.46	71.92	76.74	73.29	73.11	80.29	70.70	75.05	61.75	71.85	50.46	25.0	6.0	147.57
16	66.07	73.75	70.34	71.26	76.66	72.87	72.86	80.24	70.49	74.98	61.42	71.75	50.45	24.0	6.0	147.60
17	65.86	73.65	70.25	70.60	76.63	72 49	72.65	80.24	70.31	74.93	61.11	71.68	50.45	26.5	6.5	147.58
18	65.58	73.50	70.11	69 91	76 54	72.04	72.37	80.24	70.09	74.86	60.75	71.57	50.44	26.5	9 0	147.53
19	66.34	73.43	70 .01	69 50	76.50	71.69	72.18	80.20	69 96	74 82	60.50	71.50	50 44	27.5	12.0	147.51
20	66.07	73.23	69 80	68.78	76.38	70.96	71.71	80.18	69.68	74 72	60.07	71.35	50.43	31.0	14.0	147.48
21	65.86	73.16	69 64	68.35	76.34	70 43	71.35	80.13	69.49	74 69	59.75	71.25	50.43	30.0	14.0	147.50
22	65.58	73.08	69 07	67 82	76.23	69 69	70 90	80.15	69.23	74 57	59.27	71.12	50 43	28.0	14 0	147.43

Day #	NS B67 1.0	NS B67 1.1	S B67 2.0	S B67 2.1	S B67 2.2	S EP 3.0	S EP 3.1	S EP 3.2	NS EP 4.0	NS EP4 4.1	NS NT 5.0	S NT 5.1	NT Ctl 6.0	Tmp C°	% hum	147. 5g. Wt.
23	65.40	72.83	68.34	67.43	76.19	69.09	70.55	80.13	69.07	74.52	58.91	71.04	50.45	28.0	16.0	147.52
24	65.04	72.67	67.34	66.95	76.08	68.34	70.14	80.12	68.82	74.44	58.38	70.90	50.44	28.5	17.0	147.50
25	64.82	72.60	66.78	66.69	76.06	67.98	69.89	80.08	68.71	74.42	58.14	70.82	50.45	28.0	18.0	147.47
26	64.49	72.46	66.23	66.35	75.96	67.57	69.58	80.10	68.51	74.36	57.85	70.75	50.44	25.0	19.0	147.54
27	64.24	72.36	65.67	65.63	75.92	67.20	69.25	80.08	68.32	74.33	57.56	70.69	50.47	25.0	22.0	147.46
28	63.93	72.21	65.13	64.96	75.84	66.84	68.98	80.10	68.15	74.22	57.25	70.55	50.45	26.0	23.0	147.49
29	63.77	72.06	64.47	64.14	75.76	66.41	68.63	80.05	67.94	74.16	56.78	70.44	50.43	29.0	15.5	147.51
30	63.55	71.95	63.94	63.46	75.72	66.06	68.32	80.02	67.75	74.13	56.46	70.37	50.44	29.0	18.0	147.51
31	63.38	71.80	63.42	62.84	75.66	65.72	68.04	80.03	67.58	74.07	56.14	70.25	50.45	27.0	21.0	147.53
32	63.08	71.65	62.97	62.36	75.62	65.40	67.80	80.01	67.41	74.04	55.87	79.09	50.45	27.0	20.0	147.54
33	62.83	71.47	62.48	61.83	75.53	65.08	67.52	79.99	67.23	73.96	55.58	69.90	50.44	27.0	18.0	147.54
34	62.62	71.27	61.95	61.29	75.44	64.72	67.23	79.96	67.03	73.88	55.25	69.70	50.43	27.0	17.0	147.53
35	61.71	71.11	61.51	60.79	75.37	64.43	66.98	79.94	66.87	73.83	54.94	69.53	50.44	26.0	17.0	147.55
36	61.50	70.99	61.11	60.33	75.31	64.13	66.73	79.32	66.70	73.78	54.64	69.39	50.45	25.5	18.0	147.45
37	61.30	70.80	60.69	59.88	75.22	65.82	66.48	79.92	66.53	73.74	54.35	69.23	50.45	26.0	20.0	147.52
38	60.87	70.66	60.30	59.47	75.18	66.55	66.26	79.92	66.38	73.68	54.09	69.11	50.46	26.0	21.0	147.52
Tot. Loss	8.68g	4.66g			2.0g			0.57g	6.92g	2.03g	12.18	3.74	0.03			
Av.g Los Per Day	0.228	0.122			0.05			0.015	0.182	0.053	0.32	0.098				

APPENDIX 2


TENSILE TESTING MACHINE 6/94
Load, Lb
Load, Lb
Compression Test
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Displ
0.010"
2,800
2,400
2,000
1,600
1,200
0
700
600
500
400
0
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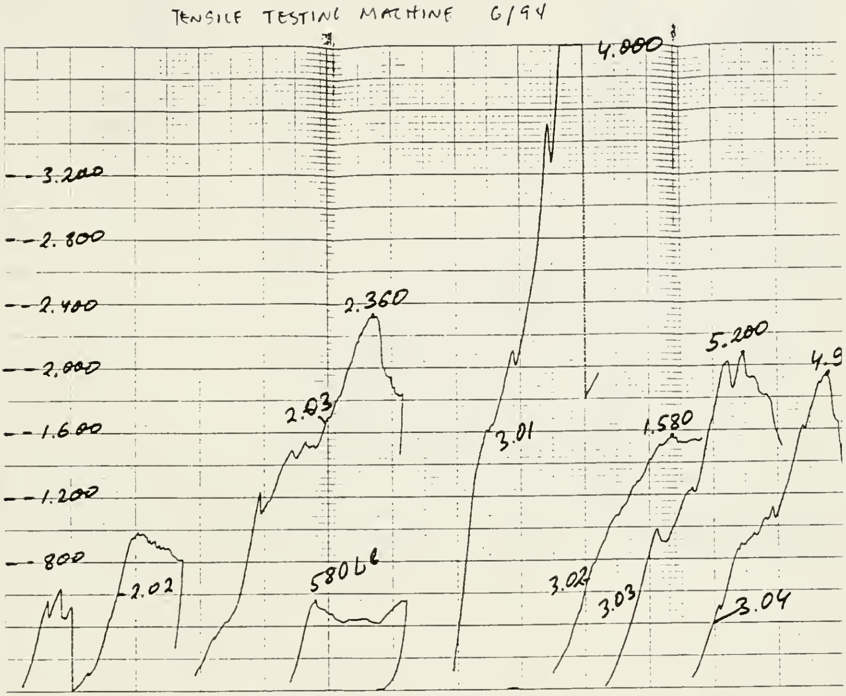
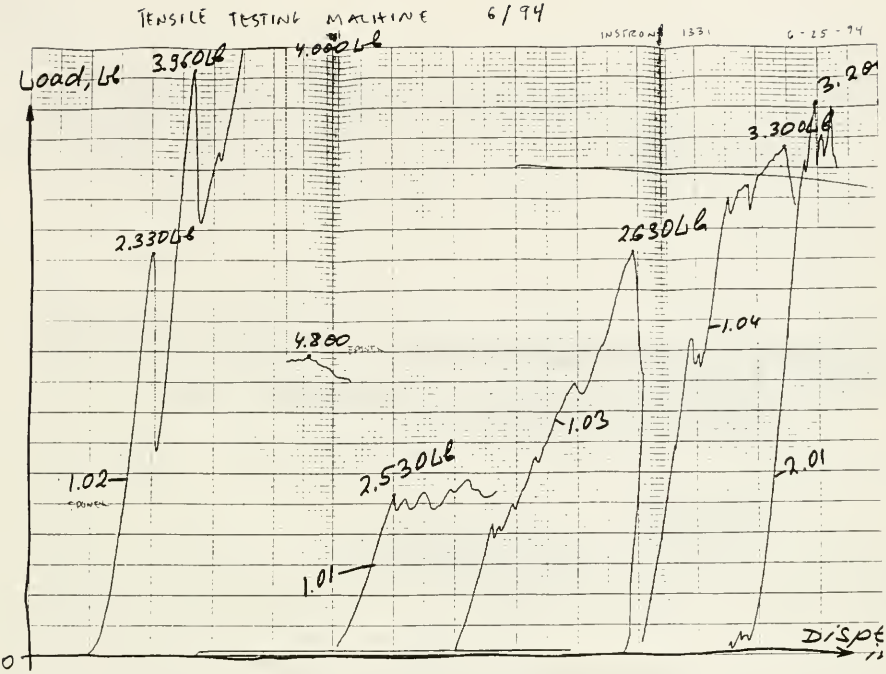
800Lb
630Lb
200Lb
400Lb
71
68
73
EP-2
EP-3
BG4GM
BGM7C

TENSILE TESTING MACHINE 6/94
3.200
2.800
2.400
2.000
1.600
1.200
800
2.02
2.03
2.360
580Lb
4.000
3.01
3.02
3.03
1.580
5.200
3.04
4.9


TENSILE TESTING MACHINE 6/94
INSTRON 1331
6-25-94
Load, lb
0
Disp
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4.000Lb
2.330Lb
1.02
DOWEL
4.800
2.530Lb
1.01
1.03
2630Lb
1.04
3.300Lb
3.20
2.01

APPENDIX 3

Text

Technical Bulletin
Shell Chemical Company

SC:729-83

Formulating weatherable epoxy resin for maximum performance

- VARIABLE WEATHERING EPOXY -

Ronald S. Bauer
Shell Development Company
Westhollow Research Center
Houston, Texas

Presented at the
Water-Borne and Higher Solids Coatings Symposium
February 17-19, 1982
New Orleans, Louisiana, USA

Symposium Sponsored by
University of Southern Mississippi
Department of Polymer Science
and
Southern Society for Coatings Technology

EPONEX™ 1510 Clear Ambient-Cured Coating Weathering Study

The purpose of this work was to evaluate the weatherability of EPONEX 1510 in several clear, ambient-cured, coating formulations using several curing agents, and an ultraviolet (UV) stabilizer additive package.

Three commercial curing agents from Pacific Anchor (Ancamine 1618 and 2050, and Ancamide 400) were evaluated. Another commercial polyamide curing agent (Versamid 1540 from Henkel) was evaluated alone, and with a UV stabilizer additive package from Ciba Geigy. One adduct of EPONEX 1510 and diethylenetriamine (DETA) was prepared as a curing agent. The formulation for this adduct, as well as the clear coating formulations, are attached.

A one-package commercial spar varnish and a commercial two-package clear urethane were evaluated as controls.

Wood test panels (6" X 12" X 25/32" solid mahogany) were coated by brushing on at least four coats of the coating to be evaluated. At least 24 hours dry time was allowed between coats. Test panels were exposed at 45 degrees South in South Florida for one year. Data summarizing the changes in 60 degree gloss are attached.

The commercial urethane clearly gave significantly better gloss retention than the commercial spar varnish. The EPONEX 1510 coating cured with the stripped DETA adduct gave gloss retention equivalent to the commercial urethane. Also, the EPONEX 1510 coating cured with Versamid 1540, which incorporated the Tinuvin 1130/Tinuvin 292 stabilizer package, gave excellent gloss retention as compared to the urethane system.

PREPARATION OF STRIPPED DETA ADDUCT

diethylenetriamine (DETA)	44.0
EPONEX™ Resin 1510	46.0
isopropyl alcohol	3.3
propylene glycol monomethyl ether	3.3
xylene	3.3

PROCEDURE

The EPONEX 1510 was combined with the solvents. The diethylenetriamine was charged in a reaction kettle equipped with a stirrer, nitrogen blanket, thermocouple, and heating mantle. The DETA was warmed to 49°C. The DETA was held under moderate agitation while the EPONEX 1510 solution was added dropwise. The exotherm was controlled below 93°C by regulating the addition rate of the EPONEX solution, and by cooling the reaction flask with an ice bath as necessary. After completing the addition of the EPONEX solution, the mixture was held at about 65°C for one hour to allow the reaction to go to completion.

In order to remove unreacted DETA, this product was stripped in a rotary evaporator. The mixture was heated to 58°C, and the temperature was raised slowly to 150°C over the period of one hour. Vacuum was controlled to maintain a hard boil, without flashing over the product. The mass was held at 1 mm Hg vacuum and 150°C for one hour after cessation of boiling. Some discoloration occurred during this step. The stripped adduct was then redissolved in OXITOL® to about 75% (wt.) solids.

EPONEX(R) 1510 CLEAR COATING FORMULATIONS

COATING:	A	B	C	D	E	F
EPONEX 1510	100	100	100	100	100	100
BEETLE 216-8	4	4	4	4	4	4
TINUVIN 292	--	--	--	--	1	--
TINUVIN 1130	--	--	--	--	2	--
ISOPROPANOL	36	36	46	30	30	22
XYLENE	36	36	46	30	30	22
PGME*	36	36	46	30	30	22
ANCAMIDE 400	50	--	--	--	--	--
ANCAMINE 1618	--	60	--	--	--	--
ANCAMINE 2050	--	--	85	--	--	--
VERSAMID 1540	--	--	--	55	55	--
DETA ADDUCT	--	--	--	--	--	62.7

* PGME - propylene glycol monomethyl ether

CLEAR COATING WEATHERING STUDY

SOUTH FLORIDA

(One Year, 45 Degrees South)

(Mahogany Panels, 60 Degree Gloss)

Coating	Initial Gloss	Unwashed Gloss	Washed Gloss	% Gloss Retained	Comments
A	40	17	29	72.5	very slight dirt pickup
B	78	6	6	7.4	heavy white haze
C	77	22	43	56.4	very slight dirt pickup
D	58	22	23	40.2	very slight dirt pickup
E	74	30	55	74.3	very slight dirt pickup
F	72	43	54	74.6	very slight dirt pickup
Spar Varnish	49	17	20	41.4	mildew and dirt
Urethane	75	43	57	75.7	very slight dirt pickup

Shell

ENVIRONMENTAL DATA SHEET

EDS NUMBER ▶ 1,476 PAGE

97449 (9-87)

PRODUCT ▶ EPI-CURE(R) CURING AGENT 3370 (FORMERLY CMD 832)

PRODUCT CODE ▶ 48466

SECTION I PRODUCT/COMPOSITION

NO.	COMPONENT	CAS NUMBER	PERCENT
P	EPI-CURE CURING AGENT 3370	MIXTURE	100
1	NONYL PHENOL	84852-15-3	*
2	M-XYLENE DIAMINE	1477-55-0	*
3	ISOPHORONE DIAMINE	2855-13-2	*
4	POLYGLYCOL	*	*

*THE SPECIFIC CHEMICAL IDENTITY AND/OR PROPORTION OF THIS COMPONENT IS CONSIDERED TRADE SECRET INFORMATION.

SECTION II SARA TITLE III INFORMATION

NO.	EHS RQ (LBS) (*1)	EHS TPQ (LBS) (*2)	SEC 313 (*3)	313 CATEGORY (*4)	311/312 CATEGORIES (*5)
P					H-1

FOOTNOTES

*1 = REPORTABLE QUANTITY OF EXTREMELY HAZARDOUS SUBSTANCE, SEC.302
*2 = THRESHOLD PLANNING QUANTITY, EXTREMELY HAZARDOUS SUBSTANCE, SEC 302
*3 = TOXIC CHEMICAL, SEC 313
*4 = CATEGORY AS REQUIRED BY SEC 313 (40 CFR 372.65 C), MUST BE USED ON TOXIC RELEASE INVENTORY FOR
*5 = HAZARD CATEGORY FOR SARA SEC. 311/312 REPORTING
HEALTH H-1 = IMMEDIATE (ACUTE) HEALTH HAZARD H-2 = DELAYED (CHRONIC) HEALTH HAZARD
PHYSICAL P-3 = FIRE HAZARD P-4 = SUDDEN RELEASE OF PRESSURE HAZARD
P-5 = REACTIVE HAZARD

SECTION III ENVIRONMENTAL RELEASE INFORMATION

EPA - COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT. UNDER EPA-CERCLA ("SUPERFUND") RELEASES TO AIR, LAND OR WATER WHICH EXCEED THE REPORTABLE QUANTITY MUST BE REPORTED TO THE NATIONAL RESPONSE CENTER, 800-424-8802.

KEEP OUT OF SURFACE WATERS, SEWERS, AND WATERWAYS ENTERING OR LEADING TO SURFACE WATERS. NOTIFY AUTHORITIES IF ANY EXPOSURE TO THE GENERAL PUBLIC OR ENVIRONMENT OCCURS OR IS LIKELY TO OCCUR.

SECTION IV RCRA INFORMATION

PLACE IN AN APPROPRIATE DISPOSAL FACILITY IN COMPLIANCE WITH LOCAL REGULATIONS.

Shell

ENVIRONMENTAL DATA SHEET

EDS NUMBER ▶ 1,476 PAGE

97449 (9-87)

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SECTION IV RCRA INFORMATION

PLACE IN AN APPROPRIATE DISPOSAL FACILITY IN COMPLIANCE WITH LOCAL REGULATIONS.

INGESTION
CORROSIVE AND MAY CAUSE SEVERE AND PERMANENT DAMAGE TO MOUTH, THROAT AND STOMACH.

SIGNS AND SYMPTOMS
IRRITATION AS NOTED ABOVE. LUNG DAMAGE (SCARRING, BRONCHITIS, EMPHYSEMA) MAY BE EVIDENCED BY SHORTNESS OF BREATH, ESPECIALLY ON EXERTION, AND MAY BE ACCOMPANIED BY CHRONIC COUGH. SKIN SENSITIZATION (ALLERGY) MAY BE EVIDENCED BY RASHES, ESPECIALLY HIVES. RESPIRATORY TRACT SENSITIZATION (E.G., ALLERGY, ASTHMA) MAY BE EVIDENCED BY WHEEZING WITH SHORTNESS OF BREATH AND COUGH.

AGGRAVATED MEDICAL CONDITIONS
PREEXISTING EYE, SKIN AND RESPIRATORY DISORDERS MAY BE AGGRAVATED BY EXPOSURE TO THIS PRODUCT. PREEXISTING SKIN OR RESPIRATORY TRACT ALLERGIES MAY INCREASE THE CHANCE OF DEVELOPING INCREASED ALLERGY SYMPTOMS FROM EXPOSURE TO THIS PRODUCT.

OTHER HEALTH EFFECTS
SEE SECTION VI FOR SUPPLEMENTAL HEALTH INFORMATION.

SECTION IV OCCUPATIONAL EXPOSURE LIMITS

	OSHA		ACGIH		OTHER
NO.	PEL/TWA	PEL/CEILING	TLV/TWA	TLV/STEL	
P	NONE ESTABLISHED				
1	NONE ESTABLISHED				
2		0.1 MG/M3 (SKIN)*	0.1 MG/M3 (SKIN)**		
3	NONE ESTABLISHED				
4	NONE ESTABLISHED				

* THE SKIN NOTATION INDICATES THE SUBSTANCE MAY BE ABSORBED THROUGH THE SKIN, MUCOUS MEMBRANES, OR EYES, BY DIRECT OR AIRBORNE EXPOSURE, AND SUGGESTS THAT APPROPRIATE MEASURES BE TAKEN TO PREVENT SUCH ABSORPTION SO THAT THE EXPOSURE LIMIT IS NOT INVALIDATED. ** CEILING LIMIT.

SECTION V EMERGENCY AND FIRST AID PROCEDURES

EYE CONTACT
IMMEDIATELY FLUSH EYES WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES WHILE HOLDING EYELIDS OPEN. RINSE CONTINUOUSLY WITH WATER WHILE ON WAY TO GET MEDICAL ATTENTION.

SKIN CONTACT
IMMEDIATELY REMOVE CONTAMINATED CLOTHING OR SHOES. WIPE EXCESS FROM SKIN AND FLUSH WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES. USE SOAP IF READILY AVAILABLE, OR FOLLOW BY THOROUGHLY WASHING WITH SOAP AND WATER. DO NOT REUSE CLOTHING UNTIL THOROUGHLY DECONTAMINATED. GET MEDICAL ATTENTION.

INHALATION
REMOVE VICTIM TO FRESH AIR AND PROVIDE OXYGEN IF BREATHING IS DIFFICULT. GIVE ARTIFICIAL RESPIRATION IF NOT BREATHING. GET MEDICAL ATTENTION.

INGESTION
DO NOT INDUCE VOMITING. GIVE ONE GLASS OF WATER UNLESS VICTIM IS DROWSY, CONVULSING, OR UNCONSCIOUS. SEEK MEDICAL ATTENTION IMMEDIATELY.

SECTION VI SUPPLEMENTAL HEALTH INFORMATION

COMPONENT 1: 4-NONYL PHENOL IS THE SUBJECT OF A TSCA CONSENT ORDER WHICH REQUIRES CERTAIN CHEMICAL FATE AND ENVIRONMENTAL EFFECTS TESTS.

COMPONENT 2: SOME AROMATIC AMINES ARE KNOWN TO PRODUCE METHEMOGLOBINEMIA AND CANCER OF THE URINARY TRACT. OTHER TOXIC EFFECTS INCLUDE HEMATURIA, CYSTITIS AND ANEMIA.

COMPONENT 3: IT HAS BEEN GENERALLY OBSERVED THAT ALIPHATIC AMINES CAN CAUSE CHANGES IN THE LUNGS, LIVER, KIDNEYS AND HEART.

SECTION VII PHYSICAL DATA

BOILING POINT: >477 (DEG F)

SPECIFIC GRAVITY: 1.0 (H2O=1)

VAPOR PRESSURE: 0.20 DEG C (MM HG)

MELTING POINT: NOT APPLICABLE (DEG F)

SOLUBILITY: (IN WATER) PARTIAL

VAPOR DENSITY: >1 (AIR=1)

EVAPORATION RATE (N-BUTYL ACETATE = 1): >1

APPEARANCE AND ODOR:
CLEAR, LIGHT MOBILE LIQUID WITH AMINE ODOR.

SECTION VIII FIRE AND EXPLOSION HAZARDS

FLASH POINT AND METHOD:
>200 DEG F (SETAFLASH)

FLAMMABLE LIMITS /% VOLUME IN AIR
LOWER: NA UPPER: NA

EXTINGUISHING MEDIA
USE WATER FOG, "ALCOHOL" FOAM, DRY CHEMICAL OR CO2. WATER OR FOG MAY CAUSE FROTHING WHICH CAN BE VIOLENT, ESPECIALLY IF SPRAYED INTO CONTAINERS OF HOT OR BURNING LIQUID.

SPECIAL FIRE FIGHTING PROCEDURES AND PRECAUTIONS
MATERIAL WILL NOT BURN UNLESS PREHEATED. DO NOT ENTER CONFINED FIRE SPACE WITHOUT FULL BUNKER GEAR (HELMET WITH FACE SHIELD, BUNKER COATS, GLOVES AND RUBBER BOOTS), INCLUDING A POSITIVE PRESSURE NIOSH APPROVED SELF-CONTAINED BREATHING APPARATUS. COOL FIRE EXPOSED CONTAINERS WITH WATER.

UNUSUAL FIRE AND EXPLOSION HAZARDS
DELAYED LUNG DAMAGE (PULMONARY EDEMA) CAN BE EXPERIENCED AFTER EXPOSURE TO COMBUSTION PRODUCTS, SOMETIMES HOURS AFTER THE EXPOSURE. NITROGEN OXIDES AND NITROGEN CONTAINING ORGANIC COMPOUNDS MAY BE RELEASED UPON COMBUSTION. SEE SECTION XII.

SECTION IX REACTIVITY

STABILITY: STABLE

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR

CONDITIONS AND MATERIALS TO AVOID:
AVOID HEAT, FLAME AND CONTACT WITH STRONG OXIDIZING AGENTS.

HAZARDOUS DECOMPOSITION PRODUCTS
NITROGEN OXIDES, CARBON MONOXIDE AND UNIDENTIFIED ORGANIC COMPOUNDS MAY BE FORMED DURING COMBUSTION

SECTION X EMPLOYEE PROTECTION

RESPIRATORY PROTECTION
DO NOT BREATHE VAPORS OR MISTS. IF EXPOSURE MAY OR DOES EXCEED OCCUPATIONAL EXPOSURE LIMITS (SEC. IV) USE A NIOSH-APPROVED RESPIRATOR TO PREVENT OVEREXPOSURE. IN ACCORD WITH 29 CFR 1910.134 USE EITHER A FULL-FACE, ATMOSPHERE-SUPPLYING RESPIRATOR OR AIR-PURIFYING RESPIRATOR FOR ORGANIC VAPORS.

PROTECTIVE CLOTHING
DO NOT GET IN EYES. WEAR CHEMICAL GOGGLES IF THERE IS POTENTIAL CONTACT WITH EYES. DO NOT GET ON SKIN, ON CLOTHING. WEAR CHEMICAL-RESISTANT PROTECTIVE CLOTHING SUCH AS GLOVES, OUTER CLOTHING OR APRON, OVERSHOES AND A FACE-SHIELD SUITABLE TO POTENTIAL EXPOSURE.

ADDITIONAL PROTECTIVE MEASURES

USE VENTILATION AS REQUIRED TO CONTROL VAPOR CONCENTRATIONS. EYE WASH FOUNTAINS AND SAFETY SHOWERS SHOULD BE AVAILABLE FOR EMERGENCY USE.

SECTION XI ENVIRONMENTAL PROTECTION

SPILL OR LEAK PROCEDURES

DANGER. CORROSIVE. PREVENT ALL BODILY CONTACT WITH SPILLED MATERIAL. WEAR APPROPRIATE RESPIRATOR AND FULL-BODY PROTECTIVE CLOTHING. *** LARGE SPILLS *** SHUT OFF LEAK ONLY IF SAFE TO DO SO. ELIMINATE POTENTIAL FIRE HAZARDS. DIKE AND CONTAIN. REMOVE WITH VACUUM TRUCK OR PUMP TO STORAGE/SALVAGE VESSELS. SOAK UP RESIDUE WITH AN ABSORBENT SUCH AS CLAY, SAND OR OTHER SUITABLE MATERIAL; PLACE IN NON-LEAKING CONTAINERS FOR PROPER DISPOSAL. FLUSH AREA WITH WATER TO REMOVE LAST TRACES OF RESIDUE; DISPOSE OF FLUSH SOLUTIONS BY ABSORPTION AS ABOVE. *** SMALL SPILLS *** TAKE UP WITH AN ABSORBENT MATERIAL AND PLACE IN NON-LEAKING CONTAINERS; SEAL TIGHTLY FOR PROPER DISPOSAL.

SECTION XII SPECIAL PRECAUTIONS

STORE IN A COOL, DRY PLACE WITH ADEQUATE VENTILATION. KEEP AWAY FROM OPEN FLAMES AND HIGH TEMPERATURES. DO NOT PRESSURIZE DRUM CONTAINERS TO EMPTY THEM.

HEATING THIS CURING AGENT IN THE PRESENCE OF AIR MAY CAUSE THERMAL AND OXIDATIVE DECOMPOSITION. WITH SOME EPOXY RESINS, IT MAY PRODUCE EXOTHERMIC REACTIONS WHICH IN LARGE MASSES CAN CAUSE RUNAWAY POLYMERIZATION AND CHARRING OF THE REACTANTS. FUMES AND VAPORS FROM THESE THERMAL AND CHEMICAL DECOMPOSITIONS VARY WIDELY IN COMPOSITION AND TOXICITY. DO NOT BREATHE FUMES. USE A NIOSH-APPROVED RESPIRATOR AS REQUIRED TO PREVENT OVER EXPOSURE. IN ACCORD WITH 29 CFR 1910.134, USE EITHER AN ATMOSPHERE-SUPPLYING RESPIRATOR OR AN AIR-PURIFYING RESPIRATOR FOR ORGANIC VAPORS.

DANGER! CORROSIVE. CAUSES BURNS TO EYE, SKIN AND RESPIRATORY TRACT. MAY CAUSE RESPIRATORY TRACT AND SKIN SENSITIZATION. DO NOT GET IN EYES, ON SKIN OR ON CLOTHING. DO NOT BREATHE VAPORS OR MISTS.

CONTAINERS, EVEN THOSE THAT HAVE BEEN EMPTIED, CAN CONTAIN HAZARDOUS PRODUCT RESIDUES. WASH WITH SOAP AND WATER BEFORE EATING, DRINKING, SMOKING, APPLYING COSMETICS, OR USING TOILET FACILITIES. LAUNDER CONTAMINATED CLOTHING BEFORE REUSE. CONTAMINATED LEATHER ARTICLES INCLUDING SHOES CANNOT BE DECONTAMINATED AND SHOULD BE DESTROYED TO PREVENT REUSE.

SECTION XIII TRANSPORTATION REQUIREMENTS

DEPARTMENT OF TRANSPORTATION CLASSIFICATION:

CLASS 8 (CORROSIVE MATERIAL), II

THE DOT INFORMATION IN THIS SECTION IS BASED UPON AN EVALUATION OF THE PRODUCT AGAINST THE REQUIREMENTS OF 49 CFR 172 AND 173 AS REVISED BY HM-181.

D.O.T. PROPER SHIPPING NAME:

POLYALKYLAMINES, N.O.S., (ALKYLAMINES)

OTHER REQUIREMENTS:

UN2735, GUIDE 60. THIS PRODUCT CONTAINS NONYL PHENOL WHICH IS A MARINE POLLUTANT UNDER 49 CFR 172.101, APPENDIX B.

SECTION XIV OTHER REGULATORY CONTROLS

THE COMPONENTS OF THIS PRODUCT ARE LISTED ON THE EPA/TSCA INVENTORY OF CHEMICAL SUBSTANCES.

PROTECTION OF STRATOSPHERIC OZONE (PURSUANT TO SECTION 611 OF THE CLEAN AIR ACT AMENDMENTS OF 1990): PER 40 CFR PART 82, THIS PRODUCT DOES NOT CONTAIN NOR WAS IT DIRECTLY MANUFACTURED WITH ANY CLASS I OR CLASS II OZONE DEPLETING SUBSTANCES.

IN ACCORDANCE WITH SARA TITLE III, SECTION 313, THE ENVIRONMENTAL DATA SHEET (EDS) SHOULD ALWAYS BE COPIED AND SENT WITH THE MSDS.

SECTION XV STATE REGULATORY INFORMATION

THE FOLLOWING CHEMICALS ARE SPECIFICALLY LISTED BY INDIVIDUAL STATES; OTHER PRODUCT SPECIFIC HEALTH AND SAFETY DATA IN OTHER SECTIONS OF THE MSDS MAY ALSO BE APPLICABLE FOR STATE REQUIREMENTS. FOR DETAILS ON YOUR REGULATORY REQUIREMENTS YOU SHOULD CONTACT THE APPROPRIATE AGENCY IN YOUR STATE.

STATE LISTED COMPONENT	PERCENT	STATE CODE
NONYL PHENOL (CAS NO: 84852-15-3)	*	CA, FL, MA, PA
M-XYLENE DIAMINE (CAS NO: 1477-55-0)	*	FL, IL, LA, MA, MN, NJ, PA, RI

CA = CALIFORNIA HAZ. SUBST. LIST; CA65 = CALIFORNIA SAFE DRINKING WATER AND TOXICS ENFORCEMENT ACT LIST; CT = CONNECTICUT TOX. SUBST. LIST; FL = FLORIDA SUBST. LIST; IL = ILLINOIS TOX. SUBST. LIST; LA = LOUISIANA HAZ. SUBST. LIST; MA = MASSACHUSETTS SUBST. LIST; ME = MAINE HAZ SUBST. LIST; MN = MINNESOTA HAZ. SUBST LIST; NJ = NEW JERSEY HAZ. SUBST. LIST; PA = PENNSYLVANIA HAZ. SUBST. LIST; RI = RHODE ISLAND HAZ. SUBST. LIST.

*THE SPECIFIC PROPORTION OF THIS COMPONENT IS CONSIDERED TRADE SECRET INFORMATION.

SECTION XVI SPECIAL NOTES

NEW MSDS.

THE INFORMATION CONTAINED HEREIN IS BASED ON THE DATA AVAILABLE TO US AND IS BELIEVED TO BE CORRECT HOWEVER, SHELL MAKES NO WARRANTY, EXPRESSED OR IMPLIED REGARDING THE ACCURACY OF THESE DATA OR THE RESULTS TO BE OBTAINED FROM THE USE THEREOF. SHELL ASSUMES NO RESPONSIBILITY FOR INJURY FROM THE USE OF THE PRODUCT DESCRIBED HEREIN.

DATE PREPARED: JANUARY 10, 1994

J. C. WILLETT

BE SAFE

READ OUR PRODUCT
SAFETY INFORMATION ...AND PASS IT ON
(PRODUCT LIABILITY LAW
REQUIRES IT)

SHELL OIL COMPANY
PRODUCT SAFETY AND COMPLIANCE
P. O. BOX 4320
HOUSTON, TX 77210

Shell

MATERIAL SAFETY DATA SHEET

MSDS NUMBER ▶ 1,476 PAGE

97387 (4-85)

24 HOUR EMERGENCY ASSISTANCE	GENERAL MSDS ASSISTANCE
SHELL: 713-473-9461 CHEMTREC: 800-424-9300	SHELL: 713-241-4819

ACUTE HEALTH *	FIRE	REACTIVITY	HAZARD RATING ▶
3	1	1	LEAST - 0 SLIGHT - 1 MODERATE - 2 HIGH - 3 EXTREME - 4

*For acute and chronic health effects refer to the discussion in Section III

BE SAFE
READ OUR PRODUCT SAFETY INFORMATION
. . . AND PASS IT ON
(PRODUCT LIABILITY LAW REQUIRES IT)

SECTION I — NAME

PRODUCT ▶	EPI-CURE(R) CURING AGENT 3370 (FORMERLY CMD 832)
CHEMICAL NAME ▶	MIXTURE
CHEMICAL FAMILY ▶	MODIFIED ALIPHATIC AMINE
SHELL CODE ▶	48466

SECTION II-A PRODUCT/INGREDIENT

NO.	COMPOSITION	CAS NUMBER	PERCENT
P	EPI-CURE CURING AGENT 3370	MIXTURE	100
1	NONYL PHENOL	84852-15-3	*
2	M-XYLENE DIAMINE	1477-55-0	*
3	ISOPHORONE DIAMINE	2855-13-2	*
4	POLYGLYCOL	*	*

* THE SPECIFIC CHEMICAL IDENTITY AND/OR PROPORTION OF THIS COMPONENT IS CONSIDERED TRADE SECRET INFORMATION.

SECTION II-B ACUTE TOXICITY DATA

NO.	ACUTE ORAL LD50	ACUTE DERMAL LD50	ACUTE INHALATION LC50
P	NO DATA AVAILABLE	NO DATA AVAILABLE	NO DATA AVAILABLE
1	1.3 G/KG (RAT)	2.0 G/KG (RABBIT)	>2 MG/L (RAT)
2	NO DATA AVAILABLE	NO DATA AVAILABLE	NO DATA AVAILABLE
3	1030 MG/KG (RAT)	NO DATA AVAILABLE	NO DATA AVAILABLE
4	28 G/KG (RAT)	NO DATA AVAILABLE	NO DATA AVAILABLE

SECTION III HEALTH INFORMATION

THE HEALTH EFFECTS NOTED BELOW ARE CONSISTENT WITH REQUIREMENTS UNDER THE OSHA HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200).

EYE CONTACT
CORROSIVE TO THE EYES AND MAY CAUSE SEVERE DAMAGE INCLUDING BLINDNESS. VAPORS MAY BE IRRITATING.

SKIN CONTACT
CORROSIVE TO THE SKIN. MAY CAUSE SKIN SENSITIZATION.

INHALATION
VAPORS/MISTS MAY BE CORROSIVE TO UPPER RESPIRATORY TRACT. REPEATED EXPOSURE MAY RESULT IN LUNG DAMAGE. MAY CAUSE RESPIRATORY TRACT SENSITIZATION.

PRODUCT NAME: EPONEX(R) RESIN 1510

EDS 173-2
PAGE : 2

[illegible]

DATE PREPARED: SEPTEMBER 01, 1992

SHELL OIL COMPANY
CORPORATE ENVIRONMENTAL AFFAIRS
P. O. BOX 4320
HOUSTON, TX 77210

FOR ADDITIONAL INFORMATION ON THIS ENVIRONMENTAL DATA PLEASE CALL
(713) 241-2252

FOR EMERGENCY ASSISTANCE PLEASE CALL
SHELL: (713) 473-9481
CHEMTREC: (800) 424-9300

SECTION VII PHYSICAL DATA

BOILING POINT: NOT AVAILABLE (DEG F)

SPECIFIC GRAVITY: 1.09 (H2O=1)

VAPOR PRESSURE: NOT AVAILABLE (MM HG)

MELTING POINT: <50 (DEG F)

SOLUBILITY: NEGLIGIBLE (IN WATER)

VAPOR DENSITY: >1 (AIR=1)

EVAPORATION RATE (N-BUTYL ACETATE = 1): NOT AVAILABLE

APPEARANCE AND ODOR:
COLORLESS, VISCOUS, ODORLESS LIQUID.

SECTION VIII FIRE AND EXPLOSION HAZARDS

FLASH POINT AND METHOD:
240 DEG F (PMCC)

FLAMMABLE LIMITS /% VOLUME IN AIR
LOWER: N/AV UPPER: N/AV

EXTINGUISHING MEDIA
USE WATER FOG, FOAM, DRY CHEMICAL OR CO2.

SPECIAL FIRE FIGHTING PROCEDURES AND PRECAUTIONS
MATERIAL WILL NOT BURN UNLESS PREHEATED. DO NOT ENTER CONFINED FIRE SPACE WITHOUT FULL BUNKER GEAR (HELMET WITH FACE SHIELD, BUNKER COATS, GLOVES AND RUBBER BOOTS), INCLUDING A POSITIVE PRESSURE NIOSH APPROVED SELF-CONTAINED BREATHING APPARATUS. COOL FIRE EXPOSED CONTAINERS WITH WATER.

UNUSUAL FIRE AND EXPLOSION HAZARDS
NO UNUSUAL HAZARDS.

SECTION IX REACTIVITY

STABILITY: STABLE

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR

CONDITIONS AND MATERIALS TO AVOID:
CAN REACT VIGOROUSLY WITH STRONG OXIDIZING AGENTS, STRONG LEWIS OR MINERAL ACIDS, AND STRONG MINERAL AND ORGANIC BASES/ESPECIALLY PRIMARY AND SECONDARY ALIPHATIC AMINES. REACTION WITH SOME CURING AGENTS MAY PRODUCE CONSIDERABLE HEAT.

HAZARDOUS DECOMPOSITION PRODUCTS
CARBON MONOXIDE, ALDEHYDES AND ACIDS MAY BE FORMED DURING COMBUSTION.

SECTION X EMPLOYEE PROTECTION

RESPIRATORY PROTECTION
AVOID BREATHING OF VAPOR OR MIST. IF EXPOSURE MAY OR DOES EXCEED OCCUPATIONAL EXPOSURE LIMITS (SEC. IV) USE A NIOSH-APPROVED RESPIRATOR TO PREVENT OVEREXPOSURE. IN ACCORD WITH 29 CFR 1910.134 USE EITHER AN ATMOSPHERE-SUPPLYING RESPIRATOR OR AN AIR-PURIFYING RESPIRATOR FOR ORGANIC VAPORS.

PROTECTIVE CLOTHING
AVOID CONTACT WITH EYES. WEAR SAFETY GLASSES OR GOGGLES AS APPROPRIATE. AVOID CONTACT WITH SKIN AND CLOTHING. WEAR CHEMICAL-RESISTANT GLOVES AND PROTECTIVE CLOTHING.

ADDITIONAL PROTECTIVE MEASURES
EYE WASH FOUNTAINS AND SAFETY SHOWERS SHOULD BE AVAILABLE FOR EMERGENCY USE.

SECTION XI ENVIRONMENTAL PROTECTION

SPILL OR LEAK PROCEDURES

MAY BURN ALTHOUGH NOT READILY IGNITABLE. USE CAUTIOUS JUDGMENT WHEN CLEANING UP LARGE SPILLS. *** LARGE SPILLS *** WEAR RESPIRATOR AND PROTECTIVE CLOTHING AS APPROPRIATE. SHUT OFF SOURCE OF LEAK IF SAFE TO DO SO. DIKE AND CONTAIN. REMOVE WITH VACUUM TRUCKS OR PUMP TO STORAGE/SALVAGE VESSELS. SOAK UP RESIDUE WITH AN ABSORBENT SUCH AS CLAY, SAND OR OTHER SUITABLE MATERIAL; DISPOSE OF PROPERLY. FLUSH AREA WITH WATER TO REMOVE TRACE RESIDUE. *** SMALL SPILLS *** TAKE UP WITH AN ABSORBENT MATERIAL AND DISPOSE OF PROPERLY.

SECTION XII SPECIAL PRECAUTIONS

STORE IN A COOL, DRY PLACE WITH ADEQUATE VENTILATION. KEEP AWAY FROM OPEN FLAMES AND HIGH TEMPERATURES.

CONTAINERS, EVEN THOSE THAT HAVE BEEN EMPTIED, CAN CONTAIN HAZARDOUS PRODUCT RESIDUES. WASH WITH SOAP AND WATER BEFORE EATING, DRINKING, SMOKING, APPLYING COSMETICS, OR USING TOILET FACILITIES. LAUNDER CONTAMINATED CLOTHING BEFORE REUSE. CONTAMINATED LEATHER ARTICLES INCLUDING SHOES CANNOT BE DECONTAMINATED AND SHOULD BE DESTROYED TO PREVENT REUSE.

SECTION XIII TRANSPORTATION REQUIREMENTS

DEPARTMENT OF TRANSPORTATION CLASSIFICATION:
NOT HAZARDOUS BY D.O.T. REGULATIONS

D.O.T. PROPER SHIPPING NAME:
NONE

OTHER REQUIREMENTS:
NOT REGULATED

SECTION XIV OTHER REGULATORY CONTROLS

THIS PRODUCT IS LISTED ON THE EPA/TSCA INVENTORY OF CHEMICAL SUBSTANCES.

PROTECTION OF STRATOSPHERIC OZONE (PURSUANT TO SECTION 611 OF THE CLEAN AIR ACT AMENDMENTS OF 1990): PER 40 CFR PART 82, THIS PRODUCT DOES NOT CONTAIN NOR WAS IT DIRECTLY MANUFACTURED WITH ANY CLASS I OR CLASS II OZONE DEPLETING SUBSTANCES.

IN ACCORDANCE WITH SARA TITLE III, SECTION 313, THE ENVIRONMENTAL DATA SHEET (EDS) SHOULD ALWAYS BE COPIED AND SENT WITH THE MSDS.

SECTION XV STATE REGULATORY INFORMATION

THE FOLLOWING CHEMICALS ARE SPECIFICALLY LISTED BY INDIVIDUAL STATES; OTHER PRODUCT SPECIFIC HEALTH AND SAFETY DATA IN OTHER SECTIONS OF THE MSDS MAY ALSO BE APPLICABLE FOR STATE REQUIREMENTS. FOR DETAILS ON YOUR REGULATORY REQUIREMENTS YOU SHOULD CONTACT THE APPROPRIATE AGENCY IN YOUR STATE.

STATE LISTED COMPONENT	PERCENT	STATE CODE
EPICHLOROHYDRIN (CAS NO: 106-89-8)	5-10 PPM	MA, CA65

DIGLYCIDYL ETHER (CAS NO: 2238-07-5)	130 PPM	MA

CA = CALIFORNIA HAZ. SUBST. LIST; CA65 = CALIFORNIA SAFE DRINKING WATER AND TOXICS ENFORCEMENT ACT LIST; FL = FLORIDA SUBST. LIST; IL = ILLINOIS TOX. SUBST. LIST; MA = MASSACHUSETTS SUBST. LIST; ME = MAINE HAZ SUBST. LIST; MN = MINNESOTA HAZ. SUBST. LIST; NJ = NEW JERSEY HAZ. SUBST. LIST; PA = PENNSYLVANIA HAZ. SUBST. LIST; RI = RHODE ISLAND HAZ. SUBST. LIST.

THIS PRODUCT CONTAINS A CHEMICAL OR CHEMICALS KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER AND/OR REPRODUCTIVE TOXICITY.

SECTION XVI SPECIAL NOTES

SEE ENVIRONMENTAL DATA SHEET FOR WASTE DISPOSAL AND OTHER ENVIRONMENTAL INFORMATION. THIS MSDS REVISION HAS CHANGES IN SECTION(S) VI AND XV AND EDS.

DATE PREPARED: SEPTEMBER 01, 1992

J. C. WILLETT

BE SAFE

READ OUR PRODUCT
SAFETY INFORMATION ...AND PASS IT ON
(PRODUCT LIABILITY LAW
REQUIRES IT)

SHELL OIL COMPANY
PRODUCT SAFETY AND COMPLIANCE
P. O. BOX 4320
HOUSTON, TX 77210

Shell

MATERIAL SAFETY DATA SHEET

MSDS NUMBER ▶ 173-11 PAGE. 1

97387 (4-85)

24 HOUR EMERGENCY ASSISTANCE	GENERAL MSDS ASSISTANCE
SHELL: 713-473-9461 CHEMTREC: 800-424-9300	SHELL: 713-241-4819

ACUTE HEALTH *	FIRE	REACTIVITY	HAZARD RATING ▶
2	1	0	LEAST - 0 SLIGHT - 1 MODERATE - 2 HIGH - 3 EXTREME - 4

*For acute and chronic health effects refer to the discussion in Section III

BE SAFE
READ OUR PRODUCT SAFETY INFORMATION ...AND PASS IT ON
(PRODUCT LIABILITY LAW REQUIRES IT)

SECTION I	NAME
PRODUCT ▶	EPONEX(R) RESIN 1510
CHEMICAL NAME ▶	HYDROGENATED BISPHENOL A-EPICHLOROHYDRIN BASED EPOXY RESIN
CHEMICAL FAMILY ▶	EPOXY RESIN
SHELL CODE ▶	43135

SECTION II-A PRODUCT/INGREDIENT

NO.	COMPOSITION	CAS NUMBER	PERCENT
P	EPONEX RESIN 1510	30583-72-3	100
.	TRACE COMPONENTS		
1	EPICHLOROHYDRIN	106-89-8	5-10 PPM
2	DIGLYCIDYL ETHER	2238-07-5	130 PPM

SECTION II-B ACUTE TOXICITY DATA

NO.	ACUTE ORAL LD50	ACUTE DERMAL LD50	ACUTE INHALATION LC50
P	5,300 MG/KG (RAT)	>2,000 MG/KG (RABBIT)	NO DATA AVAILABLE

SECTION III HEALTH INFORMATION

THE HEALTH EFFECTS NOTED BELOW ARE CONSISTENT WITH REQUIREMENTS UNDER THE OSHA HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200).

EYE CONTACT
BASED ON PRODUCT TESTING, PRODUCT IS IRRITATING TO THE EYES.

SKIN CONTACT
BASED ON PRODUCT TESTING, PRODUCT IS SLIGHTLY IRRITATING TO THE SKIN.

INHALATION
PRODUCT IS NOT EXPECTED TO CAUSE IRRITATION TO THE NOSE, THROAT OR RESPIRATORY TRACT BECAUSE OF ITS LOW VOLATILITY. IF MISTS ARE FORMED PRODUCT MAY PRESENT AN IRRITATION HAZARD VIA INHALATION.

INGESTION
BASED ON PRODUCT TESTING, PRODUCT IS SLIGHTLY TOXIC AND MAY BE HARMFUL IF SWALLOWED.

SIGNS AND SYMPTOMS
IRRITATION AS NOTED ABOVE.

AGGRAVATED MEDICAL CONDITIONS
PREEXISTING SKIN AND EYE DISORDERS MAY BE AGGRAVATED BY EXPOSURE TO THIS PRODUCT.

OTHER HEALTH EFFECTS
SEE SECTION VI FOR SUPPLEMENTAL HEALTH INFORMATION.

SECTION IV OCCUPATIONAL EXPOSURE LIMITS

	OSHA		ACGIH		OTHER
NO.	PEL/TWA	PEL/CEILING	TLV/TWA	TLV/STEL	
P	NONE ESTABLISHED				
1	2 PPM (SKIN)		2 PPM (SKIN)		
2	0.1 PPM		0.1 PPM		

SHELL INTERNAL STANDARDS - COMPONENT 1 - (TWA - 1 PPM; 15 MIN. PEAK - 3 PPM).

SECTION V EMERGENCY AND FIRST AID PROCEDURES

EYE CONTACT
FLUSH EYES WITH PLENTY OF WATER FOR 15 MINUTES WHILE HOLDING EYELIDS OPEN. GET MEDICAL ATTENTION.

SKIN CONTACT
REMOVE CONTAMINATED CLOTHING/SHOES AND WIPE EXCESS FROM SKIN. FLUSH SKIN WITH WATER. FOLLOW BY WASHING WITH SOAP AND WATER. IF IRRITATION OCCURS, GET MEDICAL ATTENTION. DO NOT REUSE CLOTHING UNTIL CLEANED.* *CONTAMINATED LEATHER ARTICLES, INCLUDING SHOES, CANNOT BE DECONTAMINATED AND SHOULD BE DESTROYED TO PREVENT REUSE.

INHALATION
REMOVE VICTIM TO FRESH AIR AND PROVIDE OXYGEN IF BREATHING IS DIFFICULT. GIVE ARTIFICIAL RESPIRATION IF NOT BREATHING. GET MEDICAL ATTENTION.

INGESTION
DO NOT INDUCE VOMITING. IF VOMITING OCCURS SPONTANEOUSLY, KEEP HEAD BELOW HIPS TO PREVENT ASPIRATION OF LIQUID INTO THE LUNGS. GET MEDICAL ATTENTION.*

NOTE TO PHYSICIAN
*IF MORE THAN 2.0 ML PER KG HAS BEEN INGESTED AND VOMITING HAS NOT OCCURRED, EMESIS SHOULD BE INDUCED WITH SUPERVISION. KEEP VICTIM'S HEAD BELOW HIPS TO PREVENT ASPIRATION. IF SYMPTOMS SUCH AS LOSS OF GAG REFLEX, CONVULSIONS OR UNCONSCIOUSNESS OCCUR BEFORE EMESIS, GASTRIC LAVAGE USING A CUFFED ENDOTRACHEAL TUBE SHOULD BE CONSIDERED.

SECTION VI SUPPLEMENTAL HEALTH INFORMATION

NOTE: THIS PRODUCT CONTAINS TRACE (5-10 PPM, TYPICAL) RESIDUAL QUANTITIES OF EPICHLOROHYDRIN (ECH), CAS NO. 106-89-8. IT IS VERY UNLIKELY THAT NORMAL WORK PRACTICES WITH THIS PRODUCT COULD RESULT IN MEASURABLE ECH CONCENTRATIONS IN THE WORKPLACE ATMOSPHERE. NEVERTHELESS, YOU SHOULD BE AWARE THAT ECH HAS BEEN REPORTED TO PRODUCE CANCER IN LABORATORY ANIMALS AND TO PRODUCE MUTAGENIC CHANGES IN BACTERIA AND CULTURED HUMAN CELLS. IT HAS BEEN CLASSIFIED BY THE INTERNATIONAL AGENCY FOR RESEARCH ON CANCER (IARC) AS A PROBABLE HUMAN CARCINOGEN (IARC GROUP 2A) BASED ON THE FOLLOWING CONCLUSIONS: HUMAN EVIDENCE - INADEQUATE; ANIMAL EVIDENCE - SUFFICIENT. IT HAS BEEN CLASSIFIED AS AN ANTICIPATED HUMAN CARCINOGEN BY THE NATIONAL TOXICOLOGY PROGRAM (NTP).

Rohm and Haas Company
100 Independence Mall West
Philadelphia, PA 19106-2399

HEALTH EMERGENCY : 215-592-3000
SPILL EMERGENCY : 215-592-3000
CHEMTREC : 800-424-9300

MATERIAL SAFETY DATA SHEET

PRODUCT IDENTIFICATION

ACRYLOID® B-67 100% Resin

Product code	:	66510
Key	:	905670-9
MSDS date	:	04/09/91
Supersedes	:	05/16/89

Rohm and Haas Hazard Rating		Scale
Toxicity	1	4=EXTREME
Fire	1	3=HIGH
Reactivity	0	2=MODERATE
Special	-	1=SLIGHT 0=INSIGNIFICANT

COMPONENT INFORMATION

No.		CAS REG NO.	AMT.(%)
1	Acrylic copolymer	Not Hazardous	98-100
2	Isobutyl methacrylate	97-86-9	<1.5
3	Toluene	108-88-3	<2.0

EMERGENCY RESPONSE INFORMATION

FIRST AID PROCEDURES

Inhalation

Move subject to fresh air.

Eye Contact

Flush eyes with a large amount of water for at least 15 minutes. Consult a physician if irritation persists.

Skin Contact

Wash affected skin areas thoroughly with soap and water. Consult a physician if irritation persists.

Ingestion

If swallowed, give 2 glasses of water to drink. Never give anything by mouth to an unconscious person.

FIRE FIGHTING INFORMATION

Unusual Hazards

Material as sold is combustible; burns vigorously with intense heat.

Extinguishing Agents

Use the following extinguishing media when fighting fires involving this material:
- carbon dioxide - dry chemical - water spray

Personal Protective Equipment

As in any fire, wear self-contained breathing apparatus (pressure-demand, MSHA/NIOSH approved or equivalent) and full protective gear.

Special Procedures

Use water spray to control heat.

SPILL OR LEAK HANDLING INFORMATION

Personal Protection

Appropriate protective equipment must be worn when handling a spill of this material. See the **PERSONAL PROTECTION MEASURES** Section for recommendations. If exposed to material during clean-up operations, see the **FIRST AID PROCEDURES** Section for actions to follow.

Procedures

Floor may be slippery; use care to avoid falling. Eliminate all ignition sources. Ventilate the spill area. Transfer spilled material to suitable containers for recovery or disposal.

HAZARD INFORMATION

HEALTH EFFECTS FROM OVEREXPOSURE

Primary Routes of Exposure

Inhalation
Eye Contact
Skin Contact

Inhalation

Inhalation of dust can cause the following:
- irritation of nose, throat, and lungs - nausea - headache - dizziness - nasal bleeding

CONTINUED

CONTINUATION

Eye Contact

Monomer vapors from heated product can cause the following:
- slight irritation

Skin Contact

Prolonged or repeated skin contact can cause the following:
- slight skin irritation

Delayed Effects

Prolonged or repeated overexposure to toluene can cause the following: - irritation of the respiratory tract - enlarged liver - kidney effects - cardiac sensitization - severe skin irritation

FIRE AND EXPLOSIVE PROPERTIES

Flash Point	Not Applicable
Lower explosive limit	No Data
Upper explosive limit	No Data

REACTIVITY INFORMATION

Instability

This material is considered stable. However, avoid temperatures above 260C/500F.

Hazardous Decomposition Products

Thermal decomposition may yield acrylic monomers.

Hazardous Polymerization

Product will not undergo polymerization.

Incompatibility

There are no known materials which are incompatible with this product.

ACCIDENT PREVENTION INFORMATION

COMPONENT EXPOSURE INFORMATION

Component Information

No.		CAS REG NO.	AMT.(%)
1	Acrylic copolymer	Not Hazardous	98-100
2	Isobutyl methacrylate	97-86-9	<1.5
3	Toluene	108-88-3	<2.0

Exposure Limit Information

Component		ROHM AND HAAS		OSHA		ACGIH	
No.	Units	TWA	STEL	TWA	STEL	TLV	STEL
1		None	None	None	None	None	None
2	ppm	50	75	None	None	None	None
3	ppm	50	75	100	150	100	150

PERSONAL PROTECTION MEASURES

Respiratory Protection

None required if airborne concentrations are maintained below the TWA/TLV's listed in the **COMPONENT EXPOSURE INFORMATION** Section. For airborne concentrations up to 10 times the TWA/TLV's listed in the **COMPONENT EXPOSURE INFORMATION** Section wear a MSHA/NIOSH approved (or equivalent) half-mask, air-purifying respirator. Air-purifying respirators should be equipped with organic vapor cartridges.

Eye Protection

Use safety glasses (ANSI Z87.1 or approved equivalent).

Hand Protection

Cotton or canvas gloves.

FACILITY CONTROL MEASURES

Ventilation

Use local exhaust ventilation with a minimum capture velocity of 100 ft/min. (30 m/min.) at the point of vapor evolution. Refer to the current edition of Industrial Ventilation: A Manual of Recommended Practice published by the American Conference of Governmental Industrial Hygienists for information on the design, installation, use, and maintenance of exhaust systems.

CONTINUED

CONTINUATION

Other Protective Equipment

Facilities storing or utilizing this material should be equipped with an eyewash facility.

STORAGE AND HANDLING INFORMATION

Storage Conditions

The maximum recommended storage temperature for this material is 60C/140F. Material can burn; limit indoor storage to approved areas equipped with automatic sprinklers. Avoid all ignition sources.

Handling Procedures

Monomer vapors can be evolved when material is heated during processing operations. See **FACILITY CONTROL MEASURES** Section for types of ventilation required. Ground all containers when transferring material.

SUPPLEMENTAL INFORMATION

TYPICAL PHYSICAL PROPERTIES

Appearance	Hazy
Color	White
State	Granular solid
Odor Characteristic	Acrylic odor
Viscosity	Not Applicable
Specific Gravity (Water = 1)	1.06
Vapor Density (Air = 1)	Not Applicable
Vapor Pressure	Not Applicable
Melting point	Not Applicable
Boiling point	Not Applicable
Solubility in water	Practically insoluble
Percent Volatility	2.7 Maximum
Evaporation rate (BAc = 1)	Not Applicable

TOXICITY INFORMATION

Acute Data

Oral LD50 - rat: >5000 mg/kg
Dermal LD50 - rabbit: >3000 mg/kg
Skin Irritation - rabbit: slight irritation
Eye Irritation - rabbit: slight irritation
Inhalation LC50 - rat: Dust generated at a maximum concentration of 3.4 mg/L for 4 hours was not fatal to any of 12 test animals.

CONTINUED

CONTINUATION

Reproductive/Teratology Data

Toluene has been demonstrated to be embryofetotoxic and teratogenic in laboratory animals.

WASTE DISPOSAL

Procedure

For disposal incinerate this material at a facility that complies with local, state, and federal regulations.

REGULATORY INFORMATION

WORKPLACE CLASSIFICATIONS

This product is considered hazardous under the OSHA Hazard Communication Standard (29CFR 1910.1200).

This product is a 'controlled product' under the Canadian Workplace Hazardous Materials Information System (WHMIS).

TRANSPORTATION CLASSIFICATIONS

US DOT Hazard Class . . . . . . NONREGULATED

EMERGENCY PLANNING & COMMUNITY RIGHT-TO-KNOW (SARA TITLE 3)

Section 311/312 Categorizations (40CFR 370)

This product is a hazardous chemical under 29CFR 1910.1200, and is categorized as an immediate and delayed health hazard.

Section 313 Information (40CFR 372)

This product contains a chemical which is listed in Section 313 above de minimis concentrations. The following listed chemicals are present: (Quantity present is found elsewhere on this MSDS.)
- Toluene (108-88-3)

CERCLA INFORMATION (40CFR 302.4)

This material has a component or components with a reportable quantity under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) Title III Section 304. The components, CAS numbers, and reportable quantities are listed below. Spills of a component in excess of its reportable quantity must be reported to the National Response Center (1-800-424-8802) and to the appropriate state and local emergency response organizations.

CONTINUED

CONTINUATION

Toluene (108-88-3) 1000lbs.

RCRA INFORMATION

When a decision is made to discard this material as supplied, it does not meet RCRA's characteristic definition of ignitability, corrosivity, or reactivity, and is not listed in 40 CFR 261.33. The toxicity characteristic (TC), however, has not been evaluated by the Toxicity Characteristic Leaching Procedure (TCLP).

CHEMICAL CONTROL LAW STATUS

All components of this product are listed or are excluded from listing on the U.S. Toxic Substances Control Act (TSCA) Chemical Substance Inventory.

STATE RIGHT-TO-KNOW LAWS

Any material listed as "Not Hazardous" in the CAS REG NO column of the **COMPONENT INFORMATION** Section of this MSDS is trade secret under the provisions of the Pennsylvania Worker and Community Right-to-Know Act.

ACRYLOID® is a trademark of Rohm and Haas Company or one of its subsidiaries or affiliates.

ABBREVIATIONS:
ACGIH = American Conference of Governmental Industrial Hygienists
OSHA = Occupational Safety and Health Administration
TLV = Threshold Limit Value
PEL = Permissible Exposure Limit
TWA = Time Weighted Average
STEL = Short-Term Exposure Limit
BAc = Butyl acetate
▌ Bar denotes a revision from previous MSDS in this area.

Rohm and Haas Company
100 Independence Mall West
Philadelphia, PA 19106-2399

HEALTH EMERGENCY : 215-592-3000
SPILL EMERGENCY : 215-592-3000
CHEMTREC : 800-424-9300

MATERIAL SAFETY DATA SHEET

PRODUCT IDENTIFICATION

ACRYLOID® B-72 100% Resin

Product Code : 65117
Key : 905259-8
MSDS Date : 08/27/92
Supersedes : 04/05/91

Rohm and Haas Hazard Rating		Scale
Toxicity	1	4 = EXTREME
Fire	1	3 = HIGH 2 = MODERATE
Reactivity	0	1 = SLIGHT
Special	-	0 = INSIGNIFICANT

COMPONENT INFORMATION

No.		CAS REG NO.	AMT.(%)
1	Acrylic polymer	Not Hazardous	98-100
2	Residual monomers	Not Required	0.15 MAX
3	Toluene	108-88-3	1.0 MAX

EMERGENCY RESPONSE INFORMATION

FIRST AID PROCEDURES

Inhalation

Move subject to fresh air.

Eye Contact

Flush eyes with a large amount of water for at least 15 minutes. Consult a phy cian if irritation persists.

Skin Contact

Wash affected skin areas thoroughly with soap and water. Consult a physician irritation persists.

Ingestion

If swallowed, give 2 glasses of water to drink. Consult a physician. Never gi anything by mouth to an unconscious person.

FIRE FIGHTING INFORMATION

Unusual Hazards

Material as sold is combustible; burns vigorously with intense heat.

CONTINUE

CONTINUATION

Extinguishing Agents

Use the following extinguishing media when fighting fires involving this material:
- carbon dioxide - dry chemical - water spray

Personal Protective Equipment

As in any fire, wear self-contained breathing apparatus (pressure-demand, MSHA/NIOSH approved or equivalent) and full protective gear.

Special Procedures

Use water spray to control heat.

SPILL OR LEAK HANDLING INFORMATION

Personal Protection

Appropriate protective equipment must be worn when handling a spill of this material. See the PERSONAL PROTECTION MEASURES Section for recommendations. If exposed to material during clean-up operations, see the FIRST AID PROCEDURES Section for actions to follow.

Procedures

Keep spectators away. Floor may be slippery; use care to avoid falling. Eliminate all ignition sources. Use water spray to keep dusting to a minimum. Transfer spilled material to suitable containers for recovery or disposal.
CAUTION: Keep spills and cleaning runoff out of municipal sewers and open bodies of water.

HAZARD INFORMATION

HEALTH EFFECTS FROM OVEREXPOSURE

Primary Routes of Exposure

Inhalation
Eye Contact
Skin Contact

Inhalation

Inhalation of monomer vapor from heated product can cause the following:
- irritation of nose, throat, and lungs - nausea - headache - dizziness

Eye Contact

Monomer vapors from heated product can cause the following:
- moderate irritation

CONTINUED

CONTINUATION

Skin Contact

Prolonged or repeated skin contact can cause the following:
- slight skin irritation

Delayed Effects

Repeated overexposure to the solvents in this product can cause the following:
- enlarged liver - kidney effects - cardiac sensitization - irritation of the respiratory tract

FIRE AND EXPLOSIVE PROPERTIES

Flash Point	Not Applicable
Auto-ignition Temperature	393°C/739°F Estimate
Lower Explosive Limit	No Data
Upper Explosive Limit	No Data

REACTIVITY INFORMATION

Instability

This material is considered stable. However, avoid temperatures above 260C/500F, the onset of polymer decomposition. Thermal decomposition is dependent on time and temperature.

Hazardous Decomposition Products

There are no known hazardous decomposition products for this material.

Hazardous Polymerization

Product will not undergo polymerization.

Incompatibility

There are no known materials which are incompatible with this product.

ACCIDENT PREVENTION INFORMATION

COMPONENT EXPOSURE INFORMATION

Component Information

No.		CAS REG NO.	AMT.(%)
1	Acrylic polymer	Not Hazardous	98-100
2	Residual monomers	Not Required	0.15 MAX
3	Toluene	108-88-3	1.0 MAX

Exposure Limit Information

Component		ROHM AND HAAS		OSHA		ACGIH	
No.	Units	TWA	STEL	TWA	STEL	TLV	STEL
1		None	None	None	None	None	None
2		a	a	a	a	a	a
3	ppm	50 Skin	75 Skin	100	150	50 Skin	None

a Not Required

PERSONAL PROTECTION MEASURES

Respiratory Protection

A respiratory protection program meeting OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. None required if airborne concentrations are maintained below the TWA/TLV's listed in the COMPONENT EXPOSURE INFORMATION Section.

Up to 10 times the TWA/TLV: Wear a MSHA/NIOSH approved (or equivalent) half-mask, air-purifying respirator.
Up to 1000 ppm organic vapor: Wear a MSHA/NIOSH approved (or equivalent) full-facepiece, air-purifying respirator.
Above 1000 ppm organic vapor or Unknown: Wear a MSHA/NIOSH approved (or equivalent) self-contained breathing apparatus in the positive pressure mode,
OR,
MSHA/NIOSH approved (or equivalent) full-facepiece airline respirator in the positive pressure mode with emergency escape provisions.

Air-purifying respirators should be equipped with organic vapor cartridges.

Eye Protection

Use safety glasses (ANSI Z87.1 or approved equivalent).

CONTINUED

CONTINUATION

Hand Protection

Cotton or canvas gloves.

FACILITY CONTROL MEASURES

Ventilation

Use local exhaust ventilation with a minimum capture velocity of 100 ft/min. (0.5 m/sec.) at the point of vapor evolution. Refer to the current edition of Industrial Ventilation: A Manual of Recommended Practice published by the American Conference of Governmental Industrial Hygienists for information on the design, installation, use, and maintenance of exhaust systems.

Other Protective Equipment

Facilities storing or utilizing this material should be equipped with an eyewash facility.

STORAGE AND HANDLING INFORMATION

Storage Conditions

Material can burn; limit indoor storage to approved areas equipped with automatic sprinklers. Avoid all ignition sources. The minimum recommended storage temperature for this material is -18C/0F. The maximum recommended storage temperature for this material is 49C/120F.

Handling Procedures

Monomer vapors can be evolved when material is heated during processing operations. See FACILITY CONTROL MEASURES Section for types of ventilation required.

SUPPLEMENTAL INFORMATION

TYPICAL PHYSICAL PROPERTIES

Appearance	Clear
State	Granular solid
Odor Characteristic	Acrylic odor
Viscosity	Not Applicable
Specific Gravity (Water = 1)	1.15
Vapor Density (Air = 1)	Not Applicable
Vapor Pressure	Not Applicable
Melting Point	No Data
Boiling Point	Not Applicable
Solubility in Water	Practically insoluble
Percent Volatility	1.15 Maximum
Evaporation Rate (BAc = 1)	Not Applicable

TOXICITY INFORMATION

Acute Data

Oral LD50 - rat: >5000 mg/kg
Dermal LD50 - rabbit: >3000 mg/kg
Eye Irritation - rabbit: moderate irritation
Skin Irritation - rabbit: slight irritation

Reproductive/Teratology Data

Toluene has been demonstrated to be embryofetotoxic and teratogenic in laboratory animals.

WASTE DISPOSAL

Procedure

For disposal, incinerate this material at a facility that complies with local, state, and federal regulations.

REGULATORY INFORMATION

WORKPLACE CLASSIFICATIONS

This product is considered hazardous under the OSHA Hazard Communication Standard (29CFR 1910.1200).

This product is a 'controlled product' under the Canadian Workplace Hazardous Materials Information System (WHMIS).

TRANSPORTATION CLASSIFICATIONS

US DOT Hazard Class . . . . NONREGULATED

EMERGENCY PLANNING & COMMUNITY RIGHT-TO-KNOW (SARA TITLE 3)

Section 311/312 Categorizations (40CFR 370)

This product is a hazardous chemical under 29CFR 1910.1200, and is categorized as an immediate and delayed health hazard.

Section 313 Information (40CFR 372)

This product contains a chemical which is listed in Section 313 above de minimis concentrations. The following listed chemicals are present: (Quantity present is found elsewhere on this MSDS.)
- Toluene (108-88-3)

CERCLA INFORMATION (40CFR 302.4)

This material has a component or components with a reportable quantity under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) Title III Section 304. The components, CAS numbers, and reportable quantities are listed below. Spills of a component in excess of its reportable quantity must be reported to the National Response Center (1-800-424-8802) and to the appropriate state and local emergency response organizations.
Toluene (108-88-3) 1000lbs.

RCRA INFORMATION

When a decision is made to discard this material as supplied, it does not meet RCRA's characteristic definition of ignitability, corrosivity, or reactivity, and is not listed in 40 CFR 261.33. The toxicity characteristic (TC), however, has not been evaluated by the Toxicity Characteristic Leaching Procedure (TCLP).

CHEMICAL CONTROL LAW STATUS

All components of this product are listed or are excluded from listing on the U.S. Toxic Substances Control Act (TSCA) Chemical Substance Inventory.

STATE RIGHT-TO-KNOW LAWS

Any material listed as "Not Hazardous" in the CAS REG NO column of the COMPONENT INFORMATION Section of this MSDS is trade secret under the provisions of the Pennsylvania Worker and Community Right-to-Know Act.

CALIFORNIA PROPOSITION 65

This product contains a component or components known to the state of California to cause birth defects or other reproductive harm:
- Toluene (108-88-3)

This product contains trace levels of a component or components known to the state of California to cause cancer:
- Benzene (71-43-2)

ACRYLOID® is a trademark of Rohm and Haas Company or one of its subsidiaries or affiliates.

Contents of this MSDS comply with the OSHA Hazard Communication Standard 29CFR 1910.1200

TSCA Status: All chemical substances found in this product comply with the Toxic Substances Control Act inventory reporting requirements.

EPA SARA Title III Chemical Listings:

Section 302 Extremely Hazardous Substances:
None

Section 304 CERCLA Hazardous Substances:

000067561	2	Methyl alcohol	5000.00 LB RQ

Section 312 Hazard Class:
Acute: Y
Chronic: Y
Fire: Y
Pressure: N
Reactive: N

Y = Yes N = No

Section 313 Toxic Chemicals:

000067561	2	METHYL ALCOHOL

Supplemental State Compliance Information

CAS Number	Wt%	Component
Massachusetts		
000067561	2	Methyl alcohol
New Jersey		
001185553	97	Methyltrimethoxysilane
001112396	1	Dimethyldimethoxysilane
000067561	2	METHYL ALCOHOL; #1222
Pennsylvania		
001185553	97	Methyltrimethoxysilane
000067561	2	Methyl alcohol

SECTION 16. OTHER INFORMATION

Prepared by: Dow Corning Corporation

This information is offered in good faith as typical values and not as a product specification. No warranty, expressed or implied, is hereby made. The recommended industrial hygiene and safe handling procedures are believed to be generally applicable. However, each user should review these recommendations in the specific context of the intended use and determine whether they are appropriate.

(R) indicates Registered or Trademark of the Dow Corning Corporation.

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