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16. Abstract

Increasingly, the corrosion of embedded reinforcing steel has been identified as a leading cause of structural damage and failure associated with bridges in Texas. In particular, bridge corrosion refers to the scaling, cracking, and delamination of the concrete. This document presents the results of a literature review conducted by the researchers to identify alternative methods by which to control bridge column corrosion among new and existing bridges. Specifically, the researchers investigated the literature on concrete modifications and reinforcement bar treatments. In terms of implementation, the findings of this review could be used to identify ways of reducing the corrosion of embedded reinforcing steel that can cause structural damage to Texas bridges.

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ALTERNATIVE METHODS BY WHICH TO CONTROL BRIDGE COLUMN CORROSION AMONG NEW AND EXISTING BRIDGES

by

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Jeff Morris
David W. Fowler

Research Report Number 1600-1F

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Alternative Methods by which to Control Bridge Column Corrosion among New and Existing Bridges

conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

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U.S. Department of Transportation
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by the

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May 1996

IMPLEMENTATION RECOMMENDATION

This document presents the literature review conducted by the researchers in order to recommend alternatives to the replacement of columns. Specifically, concrete modifications and reinforcement bar treatments were investigated as a way of reducing the corrosion of embedded reinforcing steel that can cause structural damage to Texas bridges.

This report was prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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SUMMARY

Increasingly, the corrosion of embedded reinforcing steel has been identified as a leading cause of structural damage and failure associated with bridges in Texas. In particular, bridge corrosion refers to the scaling, cracking, and delamination of the concrete. This document presents the results of a literature review conducted by the researchers to identify alternative methods by which to control bridge column corrosion among new and existing bridges. Specifically, the researchers investigated the literature on concrete modifications and reinforcement bar treatments. In terms of implementation, the findings of this review could be used to identify ways of reducing the corrosion of embedded reinforcing steel that can cause structural damage to Texas bridges.

ALTERNATIVE METHODS BY WHICH TO CONTROL BRIDGE COLUMN CORROSION AMONG NEW AND EXISTING BRIDGES

BACKGROUND

Over the past decade, corrosion has received increased attention as a cause of structural damage and failure. There are numerous concrete bridges in Texas that are currently suffering distress caused by corrosion of the embedded reinforcing steel. These distresses have been grouped into, but are not limited to, the following categories: scaling, cracking, and delamination of the concrete. The failure of reinforced concrete members caused by corrosion of embedded reinforcement is usually not attributed to the section loss of reinforcing steel, but rather to the concrete deterioration caused by the products of corrosion.

While efforts have been made to ensure the protection of the bridge deck surface, the current solutions may solve only 75 percent of bridge pier deterioration. In determining other factors in preventing corrosion, protection of the bridge pier columns is definitely an area of concern. And within an annual cycle, a bridge pier column is definitely an area of concern. During such an annual cycle, a bridge pier column endures extreme environmental conditions, including periods of submersion and drying, periods of exposure to the sun, drastic changes in water temperature, and concentrated penetration of chloride within the splash zone. In order to provide alternatives to column replacement, concrete modifications and reinforcement bar treatments were investigated in a literature review for this project.

During the initial stages of all construction, certain parameters must be established in order to optimize the specific project. Successfully constructed concrete columns within the marine environment should conform to the following characteristics: adequate cover, low water-cement ratio, low permeability, use of low-slump concrete, and maintenance of appropriate strength throughout all areas of the column.

Research has shown that the penetration rate of chloride ions into the concrete and the reaction time with the reinforcement bars are directly related to the depth of clearance cover for the underlying reinforcement bars. In evaluating existing concrete structures, the additional clearance cover allowance will not prevent corrosion. It will, however, increase the amount of time before the onset of corrosion in the embedded rebars becomes readily apparent. Low water-cement ratio is a quality of the concrete mix design that tends to give greater strength.

Also, reducing the number of voids that develop during the curing period of the concrete structure gives a denser concrete surface than may be manufactured and placed on construction sites. Other elements of good practice for concrete consists of the following: permeability, slump, workability, consistency, placing, and finishing. Concrete is seldom seen as a permeable surface, but "permeability of concrete depends not only on water-cement ratios and aggregate size, but also on consolidation, curing..." (Ref 1). Careful manipulation of these elements of design will facilitate good practice as well as provide a means for corrosion prevention in concrete structures. A distinct value may be achieved through the use of existing admixture and polymeric technologies

currently available. Although applications may differ, the central concepts developed in the mix designs may be incorporated to serve most, if not all, concrete structures.

SCOPE OF THE PROBLEM

Concrete structures within marine environments are synonymous with corrosion growth. Undoubtedly, the concrete surfaces of these marine structures will become exposed to the penetration of chloride ions, which will then lead to decay in the infrastructure. This phenomenon is frequently observed in those bridge pier columns that span waterways and sea shores.

Closer inspection reveals that the growth is concentrated within the area commonly referred to as the "splash zone." This area is normally an area 0.61 m to 0.91 m (2 or 3 feet) above and below the high and low tide marks of the body of water in question. This zone is further defined by naturally occurring events that allow for these pier columns to be the host for corrosion. Below the low tide marks, there is insufficient oxygen for ideal corrosion growth. Above the high tide mark, there is insufficient moisture available for ideal corrosion growth. Keeping these boundaries in mind, the cyclic motion of the waterbody provides the perfect mixture of moisture and oxygen blends for successful progression in most concrete pier columns in normal waterbodies. Recent polymeric technology developments and admixture enhancements made to portland cement concrete may provide a solution to the deterioration of the infrastructure of most concrete pier columns in the marine environment.

Admixtures are materials, other than cement, water, and aggregates, that are added before or during the mixing stage in order to obtain new or improved concrete properties. Desirable properties include low permeability, high strength, resistance to freezing, and good workability. Figure 1 shows a comprehensive classification of such admixtures (Ref 1). The main categories include those products that promote or are associated with:

- Accelerating
- Retarding
- Water-Reducing / Plasticizing
- Superplasticizers
- Air-Entraining
- Miscellaneous (corrosion inhibitors, finely divided minerals)

Table 1 lists the types of admixtures, the desired effect, and the materials used (Ref 2). The following section will briefly describe the major admixtures and their effects on concrete. Owing to the relevancy of finely divided minerals (mineral admixtures) and corrosion inhibitors, these will be discussed in detail.

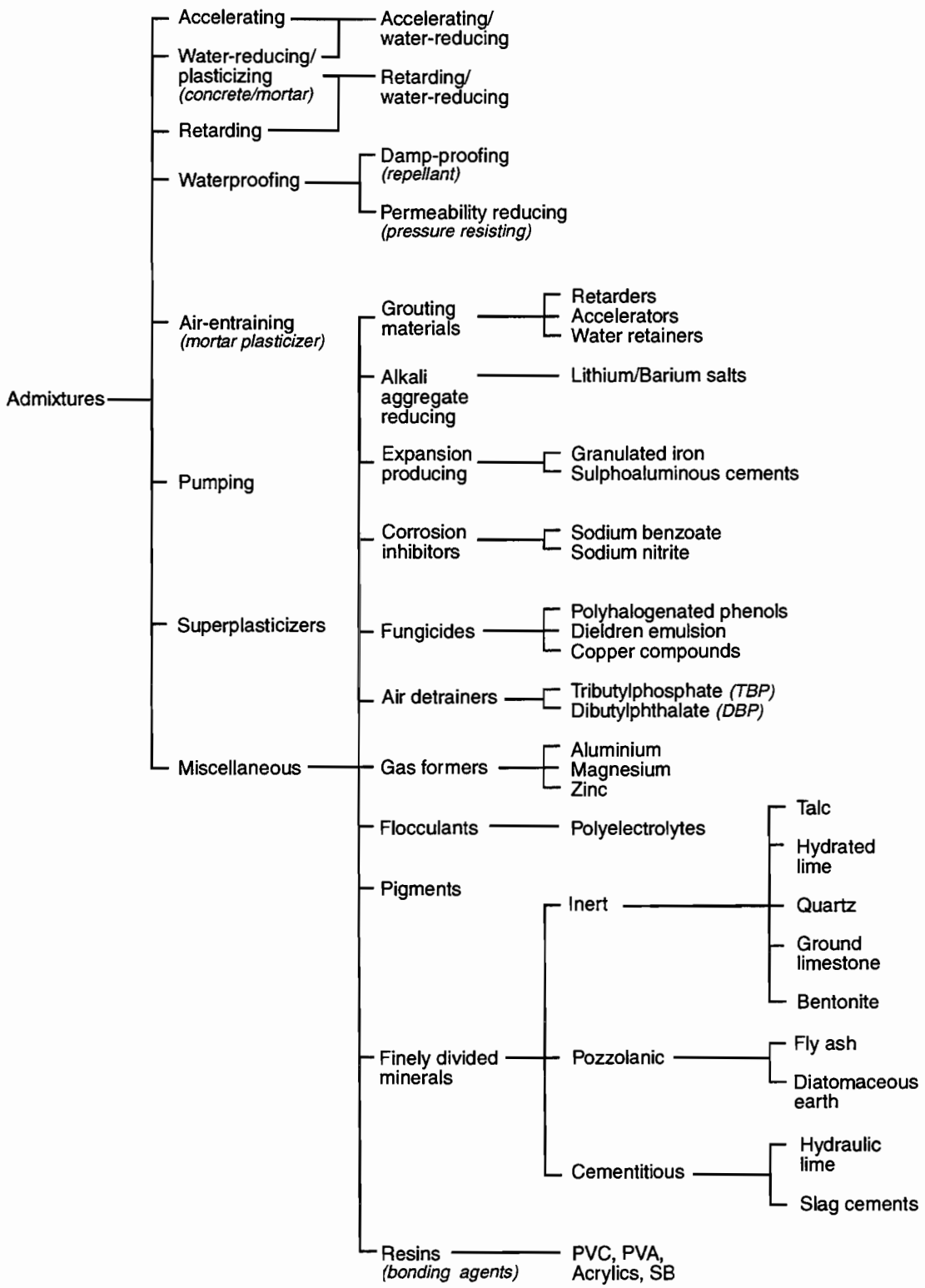

Figure 1. Admixture classifications (Ref 1)

Table 1. Concrete admixtures (Ref 2)

Type of Admixture	Desired Effect	Material
Accelerators (ASTM C 494, Type C)	Accelerate setting and early strength development	Calcium Chloride (ASTM D98) Triethanolamine, sodium thiocyanate, calcium formate, calcium nitrite, calcium nitrate
Air Detrainers	Decrease air content	Tributylphosphate, dibutylphthalate, octyl alcohol, water-insoluble esters of carbonic and boric acid, silicones
Air Detrainers (ASTM C 260)	Improve durability in environments of freeze-thaw, deicers, sulfate, and alkali reactivity Improve workability	Salts of wood resins (Vinsol resin) Some synthetic detergents Salts of sulfonated lignin Salts of petroleum acids Salts of proteinaceous material Fatty and resinous acids and their salts Alkylbenzene sulfonates Salts of sulfonated hydrocarbons
Alkali-reactivity Reducers	Reduce alkali-reactivity expansion	Pozzolans (fly ash, silica fume), blast-furnace slag, salts of lithium and barium, air-entraining agents
Bonding Admixtures	Increase bond strength	Rubber, polyvinyl chloride, polyvinyl acetate, acrylics, butadienestyrene copolymers
Coloring Agents	Colored concrete	Modified carbon black, iron oxide, phthalocyanine, umber, chromium oxide, titanium oxide, cobalt blue (ASTM C 979)
Corrosion Inhibitors	Reduce steel corrosion activity in a chloride environment	Calcium nitrite, sodium nitrite, sodium benzonate, certain phosphates or flousilicates, floualuminates
Damp-proofing Admixtures	Retard moisture penetration into dry concrete	Soaps of calcium or ammonium stearate or oleate Butyl stearate Petroleum products
Finely Divided Mineral Admixtures — Cementitious	Hydraulic properties Partial cement replacement	Ground granulated blast-furnace slag (ASTM C 989) Natural cement
— Pozzolans	Pozzolanic activity Improve workability, plasticity, sulfate resistance, reduce alkali-reactivity, permeability, heat of hydration Partial cement replacement Filler	Hydraulic hydrated lime (ASTM C 141) Diatomaceous earth, opaline cherts, clays, shales, volcanic tuffs, pumicities (ASTM C 618, Class N), fly ash (ASTM C 618, Classes F and C), silica fume
— Pozzolanic and cementitious	Same as cementitious and pozzolan categories Improve workability	High calcium fly ash (ASTM C 618, Class C) Ground granulated blast-furnace slag (ASTM C 989)
— Nominally inert	Filler	Marble, dolomite, quartz, granite
Fungicides, Germicides, and Insecticides	Inhibit or control bacterial and fungal growth	Polyhalogenated phenols Dieldrin emulsions Copper compounds
Gas Formers	Cause expansion before setting	Aluminum powder Resin soap and vegetable or animal glue Saponin Hydrolized protein
Permeability Reducers	Decrease permeability	Silica Fume Fly Ash (ASTM C 618) Ground Slag (ASTM C 989) Natural Pozzolans Water Reducers Latex

Table 1 (continued). Concrete admixtures (Ref 2)

Type of Admixture	Desired Effect	Material
Pumping Aids	Improve pumpability	Organic and synthetic polymers Organic flocculants Organic emulsions of paraffin, coal, tar, asphalt, acrylics Bentonite and pyrogenic silicas Natural pozzolans (ASTM C 618, Class N) Fly Ash (ASTM C 618, Classes F and C) Hydrated Lime (ASTM C 141)
Retarders (ASTM C 494, Type B)	Retard setting time	Lignin Borax Sugars Tartaric acid and salts
Superplasticizer (ASTM C 1017, Type 1)	Flowing concrete Reduce water-cement ratio	Sulfonated melamine formaldehyde condensates Sulfonated naphthalene formaldehyde condensates Lignosulfonates
Superplasticizers and Retarder (ASTM C 1017, Type 2)	Flowing concrete with retarded set Reduce water	See Superplasticizers and also Water Reducers
Water Reducer (ASTM C 494, Type A)	Reduce water demand at least 5%	Lignosulfonates Hydroxylated carboxylic acids Carbohydrates (Also tend to retard set so accelerator is often added)
Water Reducer and Accelerator (ASTM C 494, Type E)	Reduce water (minimum 5%) and accelerate set	See Water Reducer, Type A (Accelerator is added)
Water Reducer and Retarder (ASTM C 494, Type D)	Reduce water (minimum 5%) and retard set	See Water Reducer, Type A
Water Reducer — High Range (ASTM C 494, Type F)	Reduce water demand (minimum 12%)	See Superplasticizers
Water-Reducer—High Range—and Retarder (ASTM C 494, Type G)	Reduce water demand (minimum 12%) and retard set	See Superplasticizers and also Water Reducers
Workability Agents	Improve workability	Air-entraining admixtures Finely divided admixtures, except silica fume Water reducers

TYPES OF ADMIXTURES

Accelerating Admixtures

These admixtures are used to increase the rate of hydration, which reduces the setting time and accelerates strength development. Because of its availability and low cost, calcium chloride ($CaCl_2$) is the most commonly used accelerating admixture. $CaCl_2$ should conform to the ASTM D 98 and ASTM D 345 specifications. The advantages of $CaCl_2$ include:

- resistance to sulfate attack
- reduces setting time
- increase in compressive strength at an early age
- slight increase in workability

- reduces the bleeding rate
- more resistant to abrasive forces
- porosity decreases as hydration occurs

The disadvantages of $CaCl_2$ include:

- increases creep
- increases potential for chloride corrosion
- under longer curing times, flexural strength can be lower than that for portland cement
- must be handled with care in hot weather to be sure rapid setting and heat of hydration do not occur, causing an increase in shrinkage cracks

It is not recommended that one use calcium chloride in hot weather or for massive concrete placements, prestressed concrete, or in concrete containing embedded aluminum (Ref 2). Table 2 shows the maximum chloride-free content allowed in concrete.

Chloride-free accelerators (based on calcium formate) have been developed in response to the corrosion of the reinforcement caused by the calcium chloride. While calcium formate, $Ca(CHO_2)_2$, does not corrode the embedded reinforcement, it is not as effective as calcium chloride in accelerating the setting time. The main drawback of calcium formate is low solubility, which can cause dispensing problems.

Table 2. Maximum chloride-ion content for corrosion protection (Ref 2)

Type of member	Maximum water-soluble chloride ion (Cl-) in concrete, % by weight of cement
Prestressed concrete	0.06
Reinforced concrete exposed to chloride in service	0.15
Reinforced concrete that will be dry or protected from moisture in service	1
Other reinforced concrete construction	0.3

Retarding Admixtures

These admixtures are used to retard or delay the setting time and heat of hydration of concrete. Characteristics of retarding admixtures are:

- decreases the amount of mixing water
- improves workability
- reduces slump loss
- improves pumpability
- pore size is relatively unaffected
- reduces permeability

- does not affect drying shrinkage
- increases compressive strength at 28 days
- increases flexural strength
- increases tensile and shearing strength
- increases bond strength
- improves abrasion resistance
- not sufficient for frost resistant concretes
- entrains 2-3% air in the concrete

Water-Reducing / Plasticizing Admixtures

These admixtures are used to reduce the amount of water required in the mixing phase in order to produce a given slump or to modify the setting time. These admixtures must be in compliance with ASTM C 494 and ASTM C 1017. Water reducing/plasticizing admixtures are used to:

- increase the strength of concrete
- improve pumpability
- reduce water content by 5-10%
- some entrain air into concrete
- reduce shrinkage
- reduce permeability

Superplasticizers

High-range water reducers (HRWRs) serve the same purpose as regular plasticizing admixtures, but have improved properties. Characteristics of superplasticizing admixtures are:

- reduces water content by 12-30%
- some entrain air in the concrete
- generally retards the setting time
- can increase compressive strengths
- can reduce shrinkage
- high freeze/thaw resistance
- satisfactory resistance to salt scaling
- increases steel-concrete bond
- naphthalene-based HRWR does not lead to rust formation
- reduces permeability and chloride diffusion

Experiment: L. H. Currich and Fosroc International Ltd. performed experiments adding a superplasticizer (Conplast 430) to a portland cement mix (Ref 4). The tests determining water permeability used 150 mm cubes containing 0.25% (by weight) superplasticizer. Slump was

approximately 75 mm and the specimens were cured for 28 days. The permeability was reduced by 50% (from 1.6E-12 to 0.7E-12 m^2 /sec).

The chloride diffusion tests were conducted using 75 mm cubes containing 0.47% superplasticizer. The specimens were cured for 28 days at 20°C and cut into thin plates. One side was exposed to a 0.5N sodium chloride solution and the other side was exposed to a saturated lime solution. The rate of chloride intrusion into the lime solution was calculated using Fick's law. The measured depth of penetration under pressure was reduced from 27 mm to 17 mm, which represents a reduction in chloride diffusion.

Air-entraining Admixtures

These admixtures introduce microscopic air bubbles into the concrete. These tiny bubbles become part of the concrete matrix and bind the aggregates (Ref 3). Additions of air-entraining admixtures and applicable requirements must meet the requirements of ASTM C 226 and ASTM C 150, respectively. Air-entraining admixtures must also meet the specifications of ASTM C 260. The following characteristics are associated with air-entraining admixtures:

- dramatically increases resistance to freezing and thawing
- increases resistance to scaling (caused by deicing salts)
- improves workability
- usually involves a reduction in strength (for 1% of air, strength reduction of about 5%)
- minimizes segregation and bleeding
- produces a higher slump
- does not influence shrinkage or creep
- reduces permeability and rate of capillary absorption
- increases resistance to sulphate attack

Miscellaneous Admixtures

Corrosion Inhibitors: These admixtures chemically arrest the corrosion reaction by either providing a physical barrier that prevents the ingress of aggressive agents, or by chemically stabilizing the steel surface (Ref 5). They are generally grouped into three categories: anodic, cathodic, and mixed. Cathodic inhibitors usually slow the cathodic reaction. Anodic inhibitors stifle the reaction at the anode by their ability to accept protons. A mixed inhibitor affects both the cathode and anode processes. In order to be an effective inhibitor, Ramachandran says that the following requirements should be met:

1. Must be effective in the pH and environment in which it will be used.
2. Must be compatible with the system to ensure detrimental side effects do not occur.
3. Must be able to induce polarization of the electrodes at low current values.
4. Must be able to strongly accept electrons.
5. Must be soluble at a rate at which rapid saturation of the corroding surface does not allow for leaching to occur.

Characteristics of corrosion inhibitors include:

- generally an improved workability
- decrease in setting times (generally)
- produces slightly lower compressive strengths
- tensile strength varies with the type of admixture (-5% to 5%)
- increases potential for alkali-aggregate reaction
- decreases steel-concrete bond strength

Calcium nitrite is the most popular corrosion inhibitor admixture and is also considered to be a non-chloride accelerator. Calcium nitrite is an anodic inhibitor, minimizing the anodic reaction. This inhibitor is only effective in large quantities. Manufacturers claim that when the dosages of calcium nitrite are 10, 20, and 30 L/m3, they will protect against chloride levels of 3.6, 7.7, 9.5 kg/m^3, respectively. Calcium has been shown to increase the compressive and tensile strengths of concrete (Ref 3).

Experiment: Tests were conducted by Hope and Ip using sodium nitrite and stannous chloride as a chloride inhibitor (Ref 6). Calcium chloride was used to initiate corrosion. The experiment consisted of steel bars placed in a test cell containing oxygenated lime water, corrosion inhibitor, and calcium chloride. Table 3 shows the various tests and observations using stannous chloride and calcium nitrite. Calcium nitrite was found to suppress chloride-induced corrosion before and after the addition of calcium chloride. The corrosion threshold of calcium nitrite was found to be 0.07 and 0.09. Stannous chloride did not prove to be an effective corrosion inhibitor.

Experiment: OCIA (organic-based corrosion inhibiting admixture) is a combination of amines and esters in a water medium. OCIA forms a protective coating around the steel and reduces the susceptibility of concrete to chloride-ion penetration (Ref 5). The recommended dosage for concrete is 1 gal/yd^3 (5.0 l/m^3). Nmai, Farrington, and Bobrowski undertook an experiment to determine the effectiveness of OCIA in preventing corrosion of the embedded steel. The test specimens were 76 mm x 101 mm x 355 mm (3 in. x 4 in. x 14 in.) reinforced with sandblasted #4 reinforcing bars: Clear cover was 38 mm (1.5 in.). One gallon per cubic yard of OCIA was added. The specimens were cured for 14 days and then loaded flexurally to produce cracks through the concrete to the reinforcing bar. Ponding, subjecting the specimens to a sodium chloride solution, began at 28 days. Half-cell potentials of the reinforcing bars were measured using copper-copper sulfate electrodes. The effect of OCIA on plastic and hardened properties are:

- very little effect on slump
- may require the addition of an air-entraining mixture and extending mixing to give a given air content
- does not affect the peak exotherms or temperature development profile of the concrete
- slight decrease in compressive and tensile strength
- does not affect modulus of elasticity
- does not affect bond strength

- does not increase electrical resistivity of concrete
- decreases chloride ion content/decreases chloride-ion ingress
- does not affect freeze/thaw resistance
- does not affect the stability of the air voids during hardening
- does not affect abrasion resistance of concrete
- does not affect normal shrinkage of concrete
- longer time to corrosion in uncracked beams

Table 3. Summary of results for experiment by Hope and Ip (Ref 6)

Test No.	Test Solution	Visual Observations	Steel potential, mV SCE	AC impedance	Corrosion Rate, microamps/cm^2
Test Series 1					
1	Oxygenated lime water	No corrosion	-120 to -150		1.5 to 3.0
2	Oxygenated lime water 1% calcium chloride	Rust spots on steel surface	-480 to -520	Active corrosion of steel	
3	Oxygenated lime water 1% calcium chloride 0.1% calcium nitrite	Thin silvery white film on steel surface	-110 to -200	Formation of passive film on steel surface	0.1 to 0.4
4	Oxygenated lime water 1% calcium chloride 0.2-0.3% calcium nitrite	Silvery white film on steel surface	+ 10 to -50	Passive film on steel surface	Negligible
Test Series 2					
1	Oxygenated lime water 0.1% calcium nitrite	Silvery white film on steel surface	-10 to -40	Passive film on steel surface	–
2	Oxygenated lime water 0.1% calcium nitrite 0.5 to 1.5% calcium chloride	No rust spots on steel surface	-50 to -160	Passive film with film thickness reduced	–
3	Oxygenated lime water 0.1% calcium nitrite 2.0% calcium chloride	Rust spots on steel surface	-380 to -410	Active steel corrosion	0.9 to 1.7
Test Series 3					
1	Oxygenated lime water 1% calcium chloride 0.3% calcium nitrite 0.1% iron filings	No passive film visible; rust spots on steel surface	-380 to -420	Active steel corrosion	0.4 to 1.23

Finely Divided Minerals: Finely divided mineral admixtures are added to concrete in the hopes of changing the plastic or hardened properties of portland cement concrete (Ref 2). Most mineral admixtures increase the strength and durability and decrease the permeability. Finely divided minerals take the form of natural or by-product materials separated into four basic categories:

1. Cementitious materials
2. Pozzolans
3. Pozzolanic and cementitious materials
4. Nominally inert materials

Cementitious Materials (Blast-Furnace Slag): Cementitious materials are harden and set alone in the presence of water. The most common type of cementitious material is ground granulated blast-furnace slag, a by-product of iron manufacture. Granulated blast-furnace slag

must meet the standards in ASTM C 989. GBFS is made of silicates and aluminosilicates of calcium and other bases molted with iron in a furnace (Ref 2).

Fukudome, Miyano, Taniguchi, and Kita performed experiments on concrete containing blast furnace slag in a marine environment (Ref 7). Results show that BFS:

- decreases the compressive strength
- delays the strength development at earlier ages
- increases concrete's resistance to freezing and thawing.
- enlarges the air voids (contributes to freeze/thaw durability)
- reduces the effective diffusion coefficient of chloride

Philipose, Beaudonin, and Feldman have studied the effects of slag and silica fume mixed together in cement concrete on the degradation of normal portland cement due to reinforcement corrosion (Ref 8). BFS and silica fume were added to type 50 cement; 6.5 mm reinforcing bars were placed in the concrete, such that the reinforcement was both bonded and unbonded with the concrete. The concrete provided a cover of 1 2.7 mm and 25.4 mm. A vertical load was placed in the center of the beam and strain gauges were placed at the center, at quarter points, and at the supports. The beams were 76 mm wide, 102 mm deep, and 305 mm long. Figure 2 shows the cross section of the test set-up. The specimens were immersed in a 16.7 g/L chloride solution. The results are as follows:

- Unbonded bars were severely rusted and the bonded bars showed no sign of corrosion, except that which was outside of the concrete beam.
- The rate of chloride-ion intrusion is stress-dependent: the more the stress, the higher the rate of chloride intrusion.
- The admixture specimen provided superior resistance to chloride ingress.
- Microcracking is discontinuous at lower stress levels
- The admixture concrete showed that stressed and unstressed specimens showed similar initial reinforcement corrosion rates.
- Quality of concrete significantly affects corrosion rates at lower stress levels; these effects diminish at higher stress levels.

Pozzolanic Materials (Fly Ash and Silica Fume): Pozzolanic materials will chemically react with calcium hydroxide to form cementitious compounds (Ref 2). Many pozzolans are natural minerals like shales, volcanic tuffs, and clays. The most popular pozzolans are silica fume and fly ash. Owing to the popularity and overwhelming amount of information written on fly ash and silica fume, they will be discussed in detail. Pozzolans must comply with ASTM C 618 specifications. Silica fume must also comply with ASTM C 1240.

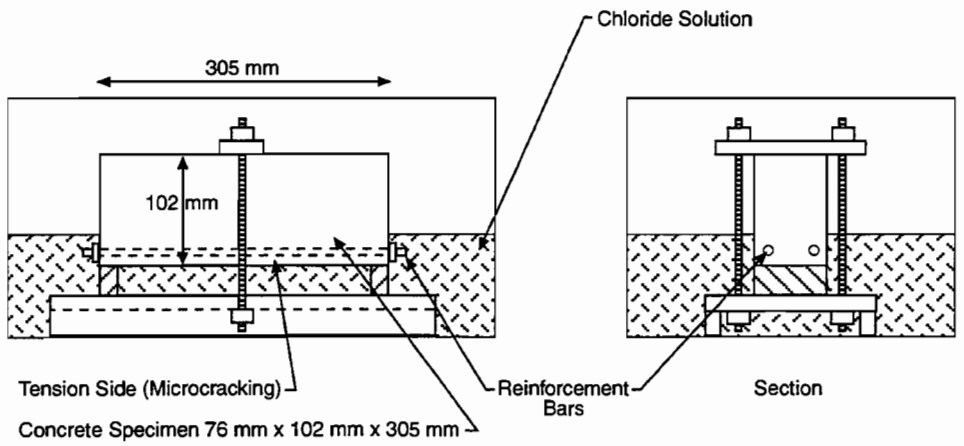

Figure 2. Cross section of Philipose, Beaudonin, and Feldman test set-up (Ref 8).

Fly Ash: Experiments show that there is little difference in compressive strength and elastic properties of fly ash concrete and non-fly-ash concrete (Ref 9). Experimental results on fly ash vary. A ten-year exposure test in China showed that fly ash concrete was more susceptible to corrosion and other experiments have shown that fly ash is durable in a marine environment. Strength development of concrete containing fly ash is slower than the control concrete and is very dependent upon the method of mix proportioning and on the type of fly ash used. Fly ash is used to make high strength concrete (60MPa) in 56 days.

Experiment: Nagataki and Ohga performed experiments in the hopes of determining the combined effects of carbonation and chloride corrosion of reinforcement in fly ash concrete (Ref 10). ASTM class F fly ash and Japanese standard sand were used and the reinforcement was polished round steel with a diameter of 9 mm and a length of 50 mm. The water-to-binder ratio was about 50%, the sand-to-binder ratio was 2.5, and the fly ash-to-binder ratio was varied between 0 and 30%. The specimens were cured for 7, 28, 56, 91 days in a chloride ion solution resembling that of sea water. After curing the specimens were placed in an accelerated carbonation chamber. The chloride ion concentration was determined using 1N silver nitrate solution as an indicator. The chloride penetration depths depended upon the curing period (in the NaCl solution), not on the amount of fly ash in the concrete.

Silica Fume: Silica fume (SF) is a very fine powder with particles 100 times finer than those of portland cement (Ref 12). The extreme fineness of silica fume increases the water demand of the concrete. This can be overcome with the addition of a superplasticizer or by simply adding more water. It is suggested that for every kg/m^3 of silica fume, 1 L/m^3 of water be added. Some characteristics of silica fume in concrete are the following:

- reduces segregation of concrete
- increases risk of plastic shrinkage
- reduces air loss resulting from vibration
- air-entraining admixtures are needed to keep desired air volume in fresh concrete

- longer setting time
- increase in compressive strength
- reduction in pore size
- tensile and flexural strength depends on amount of silica fume and the curing conditions

Moist-cured concrete with SF have higher bond strength with reinforcement.

- SF concrete has a modulus of elasticity similar to that of non-SF concrete
- reduces creep
- increases drying shrinkage
- decreases permeability
- increases resistance to aggressive chemicals
- reduces the alkali and hydroxide ions in pore solution
- increases electrical resistivity
- reduces diffusion coefficient of chlorides
- enhances abrasion resistance
- slightly increases the frost resistance in the presence of deicing salts

Experiment: Wolsiefer, Sivasundaram, Malhotra, and Carette examined the performance of various types of silica fume in concrete (Ref 13). Table 4 lists the 16 different types of silica fume used in this experiment. There were 34 concrete mixtures involving 16 different silica fume samples. Seventy-six batches were made in this experiment. All the concretes incorporated a superplasticizer, an ordinary water-reducer, and a air-entraining admixture (except the concretes with W/C+SF of 0.22). ASTM Type 1 concrete was used for the samples. Three batches were made and were prepared and cast differently. They concluded the following:

1. The mechanical properties and durability characteristics were comparable.
2. RCP values were 300 coulombs, indicating a low permeability.
3. Field-cured specimens showed that curing in cold weather did not prevent concrete from reaching its long-term strength potential.
4. The variation of bulk density of dry compacted silica fume did not affect the performance of SF concretes.
5. Low drying shrinkage strains for SF concretes.
6. Decreasing the w/c ratio and increasing the amount of SF decreased the RCP (rapid chloride penetration) values.
7. Variation in surface area of forms had no effect on SF concretes.
8. Concretes with 8.5, 12, and 15% silica fume had an air-void spacing of 0.2 (limiting value for excellent freeze-thaw durability).
9. There was virtually no sign of carbonation in the silica fume concretes.

Table 4. List of 16 silica fume samples used in experiment (Ref 13)

SF-1	Uncompacted silica fume from a Canadian silicon metal manufacturing source (SiO2 level 93.6%)
SF-2	Uncompacted silica fume from a concrete contracting source in the U.S. (SiO2 level 94.1%)
SF-3	Compacted air densified silica fume from a ready-mixed concrete source in the U.S. (SiO2 level 79.9%)
SF-4	Compacted air densified silica fume from a silicon metal manufacturing source in the U.S. (SiO2 level 89.6%)
SF-5	Compacted air densified silica fume from a shotcrete contracting source in the U.S. (SiO2 level 79.7%)
SF-6	Silica fume slurry from an admixture manufacturing source in the U.S. This slurry incorporated 50% water with dry uncompacted silica fume (SiO2 level 94.95%)
SF-7	The same silica fume slurry, as used in SF-6, at 6 months' age. After the first set of concrete mixtures, the remaining slurry was left before use in the concrete mixture.
SF-8	Sample A from the production plant of a silica fume blended cement manufacturer. This blended cement from a Canadian source is said to contain 8.5% uncompacted silica fume by weight.
SF-9	Sample B from the above blended cement, SF-8.
SF-10	Sample A from the production plant of another Canadian silica fume blended cement manufacturer. This blended cement is said to contain 7.5% interground pelletized silica fume by weight.
SF-11	Sample B from the above blended cement, SF-10.
SF-12	Compacted air densified silica fume from a contracting source in the U.S. (SiO2 level 95.35%)
SF-13	High density, compacted air densified silica fume from a shotcrete contracting source in the U.S. (SiO2 level 80.1%)
SF-14	Compacted, pressure densified silica fume from an admixture company in the U.S. (SiO2 level 94.3%)
SF-15	Sample A of blended, uncompacted silica fume cement from the manufacturer of SF-8 and SF-9; however, this sample was said to have been obtained from a field silo in a construction area.
SF-16	Sample B, taken at the same time from the source mentioned in SF-15 above.

Pozzolanic and Cementitious Materials: Certain materials exhibit both pozzolanic and cementitious properties. Various types of fly ash and granulated blast-furnace slags are pozzolanic and cementitious. The practice of placing both fly ash and granulated blast-furnace slag into portland cement mixes has been growing. Very little information was obtained regarding the incorporation of two or more of the mineral admixtures (silica fume, fly ash, and blast furnace slag). Here are the results of some experiments testing all three mineral admixtures.

Experiment: Sasatani, Torii, and Kawamura looked into the long-term properties of concrete containing blast-furnace slag, silica fume, and fly ash (Ref 14). These mineral admixtures were not mixed together in the concrete mix. Cylindrical specimens of 100 mm diameter and 200 m minimum height were examined. RCP tests were taken after 28 days of curing and the compressive strength and chloride ion penetration were measured after 1, 3, and 5 years. After initial curing the specimens were placed in four different environments: in water at 20°C (successive wet condition indoors), in a room at 20° C at 60% RH (successive dry conditions indoors), on the roof of a building 15 km from the sea (repeated wet and drying condition, outdoors), and on the tidal zone at Matsuto Beach (repeated wet and dry condition marine environment). Specimens contained either 30% FA or 50% BFS or 10% SF. The results were as follows:

1. Concrete with w/c ratio of 0.45 was better at prohibiting chloride intrusion versus concrete with a w/c of 0.55 and 0.65.
2. All the admixtures reduced the chloride ion penetration
3. Indoor curing environment affected the strength of the 50% BFS and 30% FA concrete.
4. 10% SF concrete showed a reduction in compressive strength for a curing of 7 days in water and air drying indoors.
5. 30% FA and 50% BFS had high coulomb ratings with respect to the ratings of the 10% SF concrete.

Experiment: Swamy and Laiw investigated the effectiveness of BFS, SF, and FA with regards to chloride penetration in concrete (Ref 15). In their experiment, 1000 x 500 x 150 mm slabs were reinforced with tensile steel. The slabs contained either 65% BFS, 30% FA, or 10% SF. These slabs were exposed to cyclic ponding for 7 days with 4% NaCl solution on the top surface and then dried for 3 days. The results were as follows:

1. BFS and FA enhance workability properties. SF resulted in a 70% decrease in slump.
2. At w/b ratios of 0.60 and 0.75, BFS concrete took 8 months to reach the same compressive strength as portland cement concrete.
3. FA reached about 80% of the compressive strength of PCC after 18 months.
4. After 7 days, SF had higher strengths than PCC.
5. After 10 cycles of exposure, all concrete with admixtures showed a reduction in chloride penetration depth.
6. After 20 cycles, the chloride penetration in FA concrete was the same as that for PCC.
7. After 50 cycles, the chloride penetration in BFS concrete was the same as that for PCC.
8. In SF concrete, after 50 cycles the chloride penetration depth was still very much less than that of the PCC.
9. The order of chloride resisting ability was SF, BFS, and FA.
10. FA concrete was susceptible to penetration just below the surface, but at a depth of 25 mm the chloride concentration was reduced.
11. 10% SF at w/b of 0.60 was far more resistant to chloride penetration than reducing the w/b ratio in PCC from 0.60 to 0.45.

Experiment: Torii and Kawamura investigated the pore structure and chloride permeability of concretes containing FA, BFS, and SF (Ref 16). Cubic concrete specimens were 210 mm x 240 mm x 240 mm, and were made with a coating of acrylic acid resin placed on three sides immediately after demoulding. The two initial curing conditions were continuous curing in water at 20°C or curing in water at 20°C for 7 days and then in a dry environment of 60% RH for 28 days. After initial curing, the specimens were exposed to three different exposure environments: in water at 20°C (wet condition), on a roof of a building (wet and drying condition), or in room at 20°C at 60% RH. The results are as follows:

1. All concretes with 7-day curing periods reached full compressive strength.
2. Greater compressive strength was observed in the specimens that had a curing period of 7-28 days.
3. Strength development in concrete with FA and BFS was more severely affected by initial curing period.
4. Porosity increased with the w/c ratio.
5. Porosity at the surface was much greater than that at a depth of 5 to 6 cm.
6. All admixtures were found to reduce chloride permeability.

Nominally Inert Minerals: Nominally inert minerals are finely divided quartz, marble, limestone, granite, and other materials. These materials have very little cementitious and pozzolanic properties. They are generally added to concrete as a partial replacement for sand. Very little information was found regarding these minerals. As an alternative method for producing improved mix designs for concrete, polymer concrete is becoming an accepted material for obtaining more durable and stronger concretes. The use of polymers has been defined by the manner and conditions of operations.

> Polymer impregnated concrete (PIC) is a hydrated portland cement concrete which has been impregnated with a monomer and subsequently polymerized in situ. Polymer-portland cement concrete (PPCC) is a premixed material in which either a monomer or polymer is added to a fresh concrete mixture in a liquid, powdery, or dispersed phase, and subsequently allowed to cure, and if needed, polymerized in place. Polymer Concrete (PC) uses a composite material formed by polymerizing a monomer and aggregate mixture. The polymerized monomer acts as the binder for the aggregate. (Ref 17)

These hybrid mixes have outperformed and outlasted many of the better conventional concrete cement design mixes in use today.

"Material Selection Criteria for Structural Concrete Repair," Research Project 0-1412 Draft Report, is a research study sponsored by the Federal Highway Administration (FHWA) and the Texas Department of Transportation (TxDOT). Within this study, a representative sample of polymeric materials currently in use by TxDOT was investigated. Increasing the strength of portland concrete cement has been a goal of various research and development efforts. The materials selected were the following: Patchroc 10-60, Burke Acrylic Patch, Renderoc HB, Emaco S88-CA, Set 45, Eva-Pox Epoxy Paste No. 22, and T 17 Polymer Concrete. Enclosed in the Appendix are Materials Safety Data Sheets on additional materials that were investigated in this study. The development and implementation of these products throughout current construction projects have established a precedent to be followed across the nation. Through laboratory testing, it has been determined that when producing polymer-modified concrete the strength of the mix does increase. The strength of this increase averages between 15-50%. In comparing the tensile strength vs. compression strength, tensile strength is greater by a ratio of 3 to 1 (Ref 18). Increasing the strength by such enormous projections will adhere to the theories in effectively

placing polymer-modified concrete in bridge decks and roadway surface applications. The tensile strength acquired by using polymer-modified concrete in bridge pier columns may not be as critical as initially perceived. The designs of previous concrete columns have survived their life-cycle design but have deteriorated as a result of concentrated chloride penetration, which in turn causes the decay of the infrastructure in the column. If the polymer-modified concrete can provide denser and less-permeable surfaces, the design life of the column can be realized, if not exceeded.

Application of polymeric materials will determine the effectiveness of the surface treatments. Techniques that may be investigated are: monomer saturation, encapsulation, and polymerization (Ref 19). Monomer saturation is governed by such parameters as degree of dryness and vacuum, soak pressure, and soak time. This process consists of soaking unevacuated samples at atmospheric pressure. This procedure results in partially saturated specimens and, therefore, somewhat lower strengths. Encapsulation methods require close care to minimize monomer evaporation and drainage losses from the concrete during the polymerization reaction. If the water is saturated with monomer prior to use, very little surface depletion is observed. Polymerization uses three general methods for the in-situ polymerization of monomers in concrete: radiation, thermal-catalytic, and promoter-catalytic. The thermal-catalytic polymerization method, which involves the use of chemical initiators and heat, appears to be the most practical for production-type operations.

Acknowledging the methods above and the ingenuity of the producers of polymeric materials, the factors that will affect the future designs of concrete columns in the marine environment will be cost and feasibility of the surface treatment system. The encapsulation method is a versatile method that may easily be modified for repair and new construction of concrete columns. The Pile Cap Corporation has developed an underwater application of polymeric material to pier columns, steel, and concrete. This system has been developed to reduce the rehabilitation costs of bridge pier columns in the marine environment. This system utilizes a self-contained mold that allows injection of material without adverse environmental effects. This process is completed in three phases. The initial phase entails preparing and securing the encapsulation vessel. Phase II entails the surface preparation. Acid is used to texture the surface and also to remove unwanted debris from the surface. A base coat is used to neutralize the surface treated by the acid. Phase III entails the application of the 25.4–37.6 mm (1–1.5 in.) of polymeric material that instantly adheres to the prepared surface. This coating will provide an impenetrable surface that will eliminate the ionic penetration into the surface of the column. Pile Cap has proven that polymeric material may be placed effectively in harsh marine environments. This will lead to the future development of hybrid concrete mixes that are equally applicable on vertical surfaces in adverse conditions. Bond strength will be the limiting factor in these designs, but the potential for future progress is encouraging. Although success has been seen in field applications, questions have arisen for alternate solutions to this growing problem in the coastal districts of the Texas Department of Transportation.

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APPENDIX:
MATERIAL SAFETY DATA SHEETS

DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

DOW CORNING(R) 902 RCS, PART A

SECTION 1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Dow Corning Corporation South Saginaw Road Midland, Michigan 48686	24 Hour Emergency Telephone: Product Information: Product Disposal Information: Transportation Information: CHEMTREC:	(517) 496-5900 (517) 496-6000 (517) 496-5813 (517) 496-8577 (800) 424-9300

MSDS No: 2120348 Print Date: 04/15/94 Last Revised: 02/16/94

Generic Description: Silicone elastomer
Physical Form: Liquid
Color: Charcoal
Odor: Amine-like odor
NFPA Profile: Health NA Flammability 1 Reactivity 0

Note: NFPA = National Fire Protection Association

SECTION 2. HAZARDOUS COMPONENTS

CAS Number	Wt%	Component	Exposure Limits
050791872	2	Methylvinyl bis(n-methylacetamido)- silane	Dow Corning guide: TWA 1 ppm, 5 ppm Excursion limit. See N-methyl acetamide co mments
None	37	Calcium carbonate treated with stearic acid	Observe CaCO3 limits. OSHA PEL: TWA 15 mg/m3 total dust, 5 mg/m3 respirable fr action. ACGIH TLV: TWA 10 mg/m3 total dust

Comments: N-methyl acetamide is formed on contact with water or humid air. Provide adequate ventilation to control exposures to within Dow Corning recommended exposure guidelines of 1 ppm (TWA) and 5 ppm (Excursion Limit). The effects of overexposure listed in Section 3 include health effects related to conversion of methoxysilanes to methyl alcohol upon exposure to moist or humid air.

SECTION 3. EFFECTS OF OVEREXPOSURE

Acute Effects

Eye: Direct contact irritates slightly with redness and swelling.

Skin: Repeated or prolonged contact may cause defatting of the skin leading to dermatitis.

Inhalation: Short vapor exposure may cause drowsiness, irritate nose and throat and cause injury to the following organ(s): Liver. Kidneys. Bone marrow. Testes. Immune system.

Oral: Small amounts transferred to the mouth by fingers during use, etc., should not injure. Swallowing large amounts may injure slightly.

Repeated Exposure Effects

Skin: None Known.

Inhalation: Short vapor exposure may cause drowsiness, irritate nose and throat and cause injury to the following organ(s): Liver. Kidneys. Bone marrow. Testes. Immune system.

Oral: Small amounts transferred to the mouth by fingers during use, etc., should not injure. Swallowing large amounts may injure slightly.

Special Hazards

This material contains the following components with the special hazards listed below.

Carcinogens

None Known

Teratogens

None Known

Mutagens

None Known

Reproductive Toxins

None Known

Sensitizers

None Known

Comments: Contains Bis(n-methylacetamido)silane which liberates N-Methylacetamido (NMA) during cure. NMA has been shown to cause birth defects in laboratory animals. Please read the additional information below.

The above listed potential effects of overexposure are based on actual data, results of studies performed upon similar compositions component data and/or expert review of the product.

SECTION 4. FIRST AID MEASURES

Eye: Immediately flush with water for 15 minutes.

Skin: Remove from skin and wash thoroughly with soap and water or waterless cleanser. Get medical attention if irritation or other ill effects develop or persist.

Inhalation: Remove to fresh air. Get medical attention if ill effects persist.

Oral: Get medical attention.

Comments: Treat according to person's condition and specifics of exposure.

SECTION 5. FIRE FIGHTING MEASURES

Flash Point (Method): > 213.98 DEGREE F / 101.10 DEGREE C
Autoignition Temperature: Not Determined

Flammability Limits in Air: Not Determined

Extingushing Media: Carbon dioxide (CO2). Water. Water fog (or spray). Dry chemical. Foam.

Unsuitable Extinguishing Media: None

Fire Fighting Procedures: Self-contained breathing apparatus and protective clothing should be worn in fighting fires involving chemicals. If large amount is involved, evacuate area.

Unusual Fire Hazards: None

Hazardous Decomposition Products: Silicon dioxide. Carbon oxides and traces of incompletely burned carbon compounds. Nitrogen oxides. Formaldehyde. Quartz.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Containment/Clean-up: Disposal of collected product, residues, and cleanup materials may be governmentally regulated. Observe all applicable local, state, and federal waste management regulations. Mop up, or wipe up, or soak up with absorbent and contain for salvage or disposal. For large spills, provide diking or other appropriate containment to keep material from spread-

ing. Clean any remaining slippery surfaces by appropriate techniques, such as: several moppings or swabbings with appropriate solvents; washing with mild, caustic detergents or solutions; or high pressure steam for large areas. For nonsilicones, use typical industrial cleaning materials. Observe any safety precautions applicable to the cleaning material being used. Observe all personal protection equipment recommendations described in Sections 5 and 8. Local, state, and federal reporting requirements may apply to spills or releases of this material into the environment. See applicable regulatory compliance information in Section 15.

NOTE: See Section 8 for Personal Protective Equipment for Spills

SECTION 7. HANDLING AND STORAGE

Handling: No special precautions.

Storage: Keep container closed and store away from water or moisture.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering Controls

Local exhaust: Recommended
General Ventilation: Recommended

Personal Protective Equipment For Routine Handling

Eyes: Use proper protection - safety glasses as a minimum.

Skin: Wash at mealtime and end of shift. Contaminated clothing and shoes should be removed as soon as practical and thoroughly cleaned before reuse. Chemical protective gloves are recommended.

Suitable Gloves: Eval/Unknown (Silver Shield(R), Barricade(R), Responder(R), Chemrel(R)) PE/Eval/PE (Safety4-4H(R)).

Inhalation: Use respiratory protection unless adequate local exhaust ventilation is provided or air sampling data show exposures are within recommended exposure guidelines. Industrial Hygiene Personnel can assist in judging the adequacy of existing engineering controls.

Suitable Respirator: Organic Vapor/Dust/Mist Type

Personal Protective Equipment For Spills

Eye: Use proper protection - safety glasses as a minimum.

Skin: Wash at mealtime and end of shift. Contaminated clothing and shoes should be removed as soon as practical and thoroughly cleaned before reuse. Chemical protective gloves are recommended.

Inhalation/
Suitable Respirator: Use respiratory protection unless adequate local exhaust ventilation is provided or air sampling data show exposures are within recommended exposure guidelines. Industrial Hygiene Personnel can assist in judging the adequacy of existing engineering controls.

Precautionary Measures: Avoid eye contact. Avoid skin contact. Avoid breathing vapor. Keep container closed. Do not take internally.

Comments: Product evolves N-methylacetamide when exposed to water or humid air. Provide ventilation during use to control N-methylacetamide within exposure guidelines (See Section 2) or use respiratory protection.

Note: These precautions are for room temperature handling. Use at elevated temperature, or aerosol/spray applications, may require added precautions.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Physical form:	Liquid
Color:	Charcoal
Odor:	Amine-like odor
Specific Gravity @ 25C:	1.30
Viscosity:	300000.00 CP
Freezing/Melting Point:	Not Applicable.
Boiling Point:	Not Determined.
Vapor Pressure @ 25C:	Not Determined.
Vapor Density:	Not Determined.
Solubility in Water:	None.
pH:	Not Applicable.
Volatile content (Wt%):	Not Determined.

Note: The above information is not intended for use in preparing product specifications. Contact Dow Corning before writing specifications.

SECTION 10. STABILITY AND REACTIVITY

Chemical Stability: Stable.

Hazardous Polymerization: Hazardous polymerization will not occur.

Conditions to Avoid: None.

Materials to Avoid: Oxidizing material can cause a reaction.

Comments: Water, moisture, or humid air - hazardous vapors form as described in Section 2.

SECTION 11. TOXICOLOGICAL INFORMATION

OPTIONAL SECTION - Complete information not yet available.

SECTION 12. ECOLOGICAL INFORMATION

OPTIONAL SECTION - Complete information not yet available.

SECTION 13. DISPOSAL CONSIDERATIONS

OPTIONAL SECTION - Complete information not yet available.

Call Dow Corning Environmental Mgmt. (517)496-6315, if more information is desired.

SECTION 14. TRANSPORT INFORMATION

DOT Information (49CFR 172.101)

Proper Shipping Name: Not Available

Hazard Technical Name: Not Available

Hazard Class: Not Available

UN/NA Number: Not Available

Packing Group: Not Available

Call Dow Corning Transportation, (517)496-8577, if additional information is required.

SECTION 15. REGULATORY INFORMATION

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:

001330207	2	Xylene	1000.00 LB RQ

Section 312 Hazard Class:

Acute:	Y
Chronic:	Y
Fire:	N
Pressure:	N
Reactive:	N

Y = Yes N = No

Section 313 Toxic Chemicals:
None present or none present in regulated quantities.

Supplemental State Compliance Information

CAS Number	Wt%	Component

California

Warning: This product contains the following chemical(s) listed by the State of California under the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) as being known to cause cancer.

None Known.

Warning: This product contains the following chemical(s) listed by the State of California under the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) as being known to cause birth defects or other reproductive harm.

None Known.

Massachusetts

No ingredient regulated by MA Right-to-Know Law present.

New Jersey

070131678	46	Dimethyl siloxane, hydroxy-terminated
050791872	2	Methylvinyl bis(n-methylacetamido)silane
063148629	11	Polydimethylsiloxane
068952534	2	Dimethyl, methylethyl-N-hydroxyethamine siloxane
None	37	Calcium carbonate treated with stearic acid

Pennsylvania

None	37	Calcium carbonate treated with stearic acid
070131678	46	Dimethyl siloxane, hydroxy-terminated
063148629	11	Polydimethylsiloxane

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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MATERIAL SAFETY DATA SHEET

Complies with OSHA's Hazard Communication Standard, 29 CFR 1910.1200

IDENTITY As Used on Label and List: SILSPEC 900 PNS COMP 'B'

SECTION I

Manufacturer's Name:	SSI	Emergency Telephone No.:	800-424-9300
	430 S. Rockford	Telephone No.:	918-587-5567
	Tulsa, OK 74120	Date Prepared:	01-20-95

Section II-Hazardous Ingredients/Identity Information:

PRODUCT CLASS: Epoxy Hardener

FORMULATION IDENTIFICATION: Adhesive ...

	OSHA PEL	...	ACGIH TLV	...	OTHER LIMITS	... %(OPTIONAL)
Trade Secret Amines						
CAS # NE	NE	...	NE	...	NA	...
Coal Tar Mixture						
CAS # 8007-45-2	.2 mg/cu m	...	.2 mg/cu m	...	NE	...

None of the remaining components considered a Hazardous Material or carcinogen (1910.1200 Hazard Communication (d)(4)).

TRANSPORTATION INFORMATION: DOT Classification: ALKYLAMINES, n.o.s.
DOT Shipping # : UN 2735

SECTION III - Physical/Chemical Characteristics:

Boiling Point: Degrees F.	>200°F	Specific Gravity (H2O = 1)	1.10
Autoignition Temperature:	NE	Melting Point:	NA
Vapor Pressure (mm Hg):	NE		
Vapor Density (Air = 1):	NE	Evaporation Rate:	NE
Appearance and Odor:	Black liquid, Tar odor.		

SECTION IV - Fire and Explosion Hazard Data:

Flash Point (Method Used): Tag Closed Cup 160°F.
Flammable Limits: LEL: NE UEL: NE
Extinguishing Media: Dry chemical, carbon dioxide or foam
Special Fire Fighting Procedures: Water stream may spread fire, use water spray only to cool containers exposed to fire. If leak or spill has not ignited, use water spray to disperse vapors. Wear self-contained breathing apparatus.
Unusual Fire and Explosion Hazards: Vapor heavier than air and may travel considerable distance to a source of ignition and flashback.

SECTION V - Reactivity Data:

Stability: Stable Conditions to Avoid: Heat & open flame.
Incompatibility (Materials to Avoid): Strong Oxidizers.
Hazardous Decomposition or Byproducts: Can form carbon dioxide and carbon monoxide.
Hazardous Polymerization: Cannot occur Conditions to Avoid: Heat & open flame.

SECTION VI - HEALTH HAZARD DATA:

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Not expected
Health Hazards:
Eyes: Can cause severe irritation, redness, tearing and blurred vision.
Skin: Prolonged or repeated contact can cause moderate irritation, defatting, dermatitis.
Inhalation: Excessive inhalation of vapors can cause nasal and respiratory irritation, dizziness, weakness, fatigue, nausea, headache, possible unconsciousness, and even asphyxiation.
Ingestion: Can cause gastrointestinal irritation, nausea, vomiting and diarrhea. Aspiration of material into the lungs can cause chemical pneumonitis which can be fatal.

Carcinogenicity: NPT? Yes IARC? No OSHA Regulated? No

SILSPEC 909 PNS COMP 'B'

Signs and Symptoms of Overexposure: Headache, drowsiness, nausea.
Medical Conditions Generally Aggravated by Exposure: None determined

Emergency and First Aid Procedures:

Skin:	Thoroughly wash exposed area with soap and water. Removed contaminated clothing. Launder contaminated clothing before re-use.
Eyes:	Flush with large amounts of water for 15 minutes lifting upper and lower lids occasionally. Get medical attention.
Ingestion:	Do not induce vomiting, keep person warm, quiet and get medical attention. Aspiration of material into the lungs due to vomiting can cause chemical pneumonitis which can be fatal.
Inhalation:	If affected, remove individual to fresh air. If breathing is difficult, administer oxygen. If breathing has stopped give artificial respiration. Keep person warm, quiet and get medical attention.

SECTION VII - Precautions for Safe Handling and Use:
Steps to be taken in case material is leaked or spilled:
Small Spill: Absorb liquid on paper, vermiculite, floor absorbent, or other absorbent material and transfer to hood.
Large Spill: Eliminate all ignition sources (flares, flames including pilot lights, electrical sparks). Persons not wearing protective equipment should be excluded from area of spill until clean-up has been completed. Stop spill at source. Dike area of spill to prevent spreading. Pump liquid to salvage tank. Remaining liquid may be taken up on sand, clay, earth, floor absorbent or other absorbent material and shoveled into containers. Prevent run-off to sewers, streams or other bodies of water. If run-off occurs, notify proper authorities as required, that a spill has occurred.
Waste Disposal Method:
Small Spill: Allow volatile portion to evaporate in hood. Allow sufficient time for vapors to completely clear hood duct work. Dispose of remaining material in accordance with applicable regulations.
Large Spill: Destroy by liquid incineration. Contaminated absorbent may be deposited in a landfill in accordance with local, state and federal regulations.
Other Precautions: Use only in well ventilated areas unless recommended respiratory protection is used. Keep body contact and splash to a minimum. Do not cut empty steel drums with a welding torch.

SECTION VIII - Control Measures:
Respiratory Protection: If TLV of the product or any component is exceeded, a NIOSH/MSHA jointly approved air supplied respirator is advised in absence of proper environmental control. OSHA regulations also permit other NIOSH/MSHA respirators under specified conditions. (See your safety equipment supplier). Engineering or administrative control should be implemented to reduce exposure.,
Ventilation: Provide sufficient mechanical (General and/or local exhaust) ventilation to maintain exposure below TLV(s).
Protective Gloves: Wear resistant gloves such as: Nitrile Rubber.
Eye Protection: Chemical splash goggles in compliance with OSHA regulations are advised. However, OSHA Regulations also per other type safety glasses (consult your safety equipment supplier).
Other Protective Equipment: To prevent repeated or prolonged skin contact, wear impervious clothing and boots.
Work/Hygienic Practices: Use only in well ventilated area unless recommended respiratory protection is used. Keep body contact and splash to a minimum.

Although the information and recommendations set forth herein (hereinafter "Information"_ are presented in good faith and believed to be correct as of the date hereof, Unitex makes no representations as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Unitex be responsible for damages of any nature whatsoever resulting from the use of or reliance upon information. No representations or warranties either express or implied of merchantability, fitness for a particular purpose or of any other nature are made hereunder with respect to information or the product to which information refers.

N/A: Not Available N/E: Not Established

MATERIAL SAFETY DATA SHEET

Complies with OSHA's Hazard Communication Standard, 29 CFR 1910,1200

IDENTITY As Used on Label and List: SILSPEC 900 PNS COMP 'A'

SECTION I

Manufacturer's Name:	SSI	Emergency Telephone No.:	800-424-9300
	430 S. Rockford	Telephone No.:	918-587-5567
	Tulsa, OK 74120	Date Prepared:	01-20-95

Section II-Hazardous Ingredients/Identity Information:

PRODUCT CLASS: Modified Epoxy

FORMULATION IDENTIFICATION: Adhesive

	OSHA PEL	...	ACGIH TLV	...	OTHER LIMITS	... %(OPTIONAL)
Epoxy Resin						
CAS # 25068-38-6	NE	...	NE	...	NA	...
Terpineol						
CAS # 8000-41-7	NE	...	NE	...	NA	...

None of the remaining components considered a Hazardous Material or carcinogen (1910.1200 Hazard Communication (d)(4)).

TRANSPORTATION INFORMATION: DOT Classification: Not Regulated
DOT Label: None

SECTION III - Physical/Chemical Characteristics:

Boiling Point: Degrees F.	>300°F	Specific Gravity (H2O = 1)	1.12
Autoignition Temperature:	NE	Melting Point:	NA
Vapor Pressure (mm Hg):	NE		
Vapor Density (Air = 1):	NE	Evaporation Rate:	NE
Appearance and Odor:	Clear liquid, pine odor.		

SECTION IV - Fire and Explosion Hazard Data:

Flash Point (Method Used): Tag Closed Cup 190°F.
Flammable Limits: LEL: NE UEL: NE
Extinguishing Media: Dry chemical, carbon dioxide or foam
Special Fire Fighting Procedures: Water stream may spread fire, use water spray only to cool containers exposed to fire. If leak or spill has not ignited, use water spray to disperse vapors. Wear self-contained breathing apparatus.
Unusual Fire and Explosion Hazards: Vapor heavier than air and may travel considerable distance to a source of ignition and flashback.

SECTION V - Reactivity Data:

Stability: Stable Conditions to Avoid: Heat & open flame.
Incompatibility (Materials to Avoid): Strong Oxidizers.
Hazardous Decomposition or Byproducts: Can form carbon dioxide and carbon monoxide.
Hazardous Polymerization: Cannot occur Conditions to Avoid: Heat & open flame.

SECTION VI - HEALTH HAZARD DATA:

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Not expected

Health Hazards:

Eyes: Can cause severe irritation, redness, tearing and blurred vision.
Skin: Prolonged or repeated contact can cause moderate irritation, defatting, dermatitis.
Inhalation: Excessive inhalation of vapors can cause nasal and respiratory irritation, dizziness, weakness, fatigue, nausea, headache, possible unconsciousness, and even asphyxiation.
Ingestion: Can cause gastrointestinal irritation, nausea, vomiting and diarrhea. Aspiration of material into the lungs can cause chemical pneumonitis which can be fatal.

Carcinogenicity: NPT? No IARC No OSHA Regulated? No

SILSPEC 900 PNS COMP 'A'

Signs and Symptoms of Overexposure: Headache, drowsiness, nausea.
Medical Conditions Generally Aggravated by Exposure: None determined

Emergency and First Aid Procedures:

Skin:	Thoroughly wash exposed area with soap and water. Removed contaminated clothing. Launder contaminated clothing before re-use.
Eyes:	Flush with large amounts of water for 15 minutes lifting upper and lower lids occasionally. Get medical attention.
Ingestion:	Do not induce vomiting, keep person warm, quiet and get medical attention. Aspiration of material into the lungs due to vomiting can cause chemical pneumonitis which can be fatal.
Inhalation:	If affected, remove individual to fresh air. If breathing is difficult, administer oxygen. If breathing has stopped give artificial respiration. Keep person warm, quiet and get medical attention.

SECTION VII - Precautions for Safe Handling and Use:
Steps to be taken in case material is leaked or spilled:
Small Spill: Absorb liquid on paper, vermiculite, floor absorbent, or other absorbent material and transfer to hood.
Large Spill: Eliminate all ignition sources (flares, flames including pilot lights, electrical sparks). Persons not wearing protective equipment should be excluded from area of spill until clean-up has been completed. Stop spill at source. Dike area of spill to prevent spreading. Pump liquid to salvage tank. Remaining liquid may be taken up on sand, clay, earth, floor absorbent or other absorbent material and shoveled into containers. Prevent run-off to sewers, streams or other bodies of water. If run-off occurs, notify proper authorities as required, that a spill has occurred.
Waste Disposal Method:
Small Spill: Allow volatile portion to evaporate in hood. Allow sufficient time for vapors to completely clear hood duct work. Dispose of remaining material in accordance with applicable regulations.
Large Spill: Destroy by liquid incineration. Contaminated absorbent may be deposited in a landfill in accordance with local, state and federal regulations.
Other Precautions: Use only in well ventilated areas unless recommended respiratory protection is used. Keep body contact and splash to a minimum. Do not cut empty steel drums with a welding torch.

SECTION VIII - Control Measures:
Respiratory Protection: If TLV of the product or any component is exceeded, a NIOSH/MSHA jointly approved air supplied respirator is advised in absence of proper environmental control. OSHA regulations also permit other NIOSH/MSHA respirators under specified conditions. (See your safety equipment supplier). Engineering or administrative control should be implemented to reduce exposure.,
Ventilation: Provide sufficient mechanical (General and/or local exhaust) ventilation to maintain exposure below TLV(s).
Protective Gloves: Wear resistant gloves such as: Nitrile Rubber.
Eye Protection: Chemical splash goggles in compliance with OSHA regulations are advised. However, OSHA Regulations also per other type safety glasses (consult your safety equipment supplier).
Other Protective Equipment: To prevent repeated or prolonged skin contact, wear impervious clothing and boots.
Work/Hygienic Practices: Use only in well ventilated area unless recommended respiratory protection is used. Keep body contact and splash to a minimum.

Although the information and recommendations set forth herein (hereinafter "Information"_ are presented in good faith and believed to be correct as of the date hereof, Unitex makes no representations as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Unitex be responsible for damages of any nature whatsoever resulting from the use of or reliance upon Information. No representations or warranties either express or implied of merchantability, fitness for a particular purpose or of any other nature are made hereunder with respect to Information or the product to which Information refers.

N/A: Not Available N/E: Not Established

DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

DOW CORNING(R) 902 RCS, PART B

SECTION 1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Dow Corning Corporation South Saginaw Road Midland, Michigan 48686	24 Hour Emergency Telephone: Product Information: Product Disposal Information: Transportation Information: CHEMTREC:	(517) 496-5900 (517) 496-6000 (517) 496-5813 (517) 496-8577 (800) 424-9300

MSDS No: 2165392 Print Date: 04/15/94 Last Revised: 02/16/94

Generic Description: Silicone elastomer
Physical Form: Viscous Liquid
Color: White
Odor: Amine-like odor
NFPA Profile: Health NA Flammability 1 Reactivity 0

Note: NFPA = National Fire Protection Association

SECTION 2. HAZARDOUS COMPONENTS

CAS Number	Wt%	Component	Exposure Limits
None	39	Calcium carbonate treated with stearic acid	Observe calcium carbonate limits. OSHA PEL: TWA 15 mg/m3 total dust, 5 mg/m3 r espirable fraction. ACGIH TLV: TWA 10 mg/m3 total dust

Comments: The above ingredients are hazardous as defined in 29 CFR 1910.1200.

SECTION 3. EFFECTS OF OVEREXPOSURE

Acute Effects

Eye: Direct eye contact may cause temporary discomfort with mild redness and dryness similar to windburn.

Skin: A single prolonged exposure (24 to 48 hours) causes no known adverse effect.

Inhalation: No irritation to eyes and respiratory passages. No injury is likely from relatively short exposures of less than 8 hours.

Oral: Small amounts transferred to the mouth by fingers during use, etc., should not injure. Swallowing large amounts may cause digestive discomfort.

Repeated Exposure Effects

Skin: None Known.

Inhalation: None Known.

Oral: None Known.

Special Hazards

This material contains the following components with the special hazards listed below.

Carcinogens

None Known

Teratogens

None Known

Mutagens

None Known

Reproductive Toxins

None Known

Sensitizers

None Known

Comments: Please read the additional information below.

The above listed potential effects of overexposure are based on actual data, results of studies performed upon similar compositions component data and/or expert review of the product.

SECTION 4. FIRST AID MEASURES

Eye: Immediately flush with water.

Skin: No first aid should be needed.

Inhalation: No first aid should be needed.

Oral: No first aid should be needed.

Comments: Treat symptomatically.

SECTION 5. FIRE FIGHTING MEASURES

Flash Point (Method): > 213.80 DEGREE F / 101.00 DEGREE C
Autoignition Temperature: Not Determined

Flammability Limits in Air: Not Determined

Extingushing Media: Carbon dioxide (CO2). Water. Water fog (or spray). Dry chemical. Foam.

Unsuitable Extinguishing Media: None known.

Fire Fighting Procedures: Self-contained breathing apparatus and protective clothing should be worn in fighting fires involving chemicals. If large amount is involved, evacuate area.

Unusual Fire Hazards: None

Hazardous Decomposition Products: Silicon dioxide. Carbon oxides and traces of incompletely burned carbon compounds. Formaldehyde. Quartz.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Containment/Clean-up: Disposal of collected product, residues, and cleanup materials may be governmentally regulated. Observe all applicable local, state, and federal waste management regulations. Mop up, or wipe up, or soak up with absorbent and contain for salvage or disposal. For large spills, provide diking or other appropriate containment to keep material from spreading. Clean any remaining slippery surfaces by appropriate techniques, such as: several moppings or swabbings with appropriate solvents; washing with mild, caustic detergents or solutions; or high pressure steam for large areas. For nonsilicones, use typical industrial cleaning materials. Observe any safety precautions applicable to the cleaning material being used. Observe all personal protection equipment recommendations described in Sections 5 and 8. Local, state, and federal reporting requirements may apply to spills or releases of this material into the environment. See applicable regulatory compliance information in Section 15.

NOTE: See Section 8 for Personal Protective Equipment for Spills

SECTION 7. HANDLING AND STORAGE

Handling: No special precautions.

Storage: No special precautions. Use reasonable care.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering Controls

Local exhaust: None should be needed
General Ventilation: Recommended

Personal Protective Equipment For Routine Handling

Eyes: Use proper protection - safety glasses as a minimum.

Skin: Washing at mealtime and end of shift is adequate.

Suitable Gloves: No special protection needed.

Inhalation: No respiratory protection should be needed.

Suitable Respirator: None should be needed. None should be needed.

Personal Protective Equipment For Spills

Eye: Use proper protection - safety glasses as a minimum.

Skin: Washing at mealtime and end of shift is adequate.

Inhalation/
Suitable Respirator: No respiratory protection should be needed.

Precautionary Measures: Avoid eye contact. Use reasonable care.

Comments: None

Note: These precautions are for room temperature handling. Use at elevated temperature, or aerosol/spray applications, may require added precautions.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Physical form:	Viscous Liquid
Color:	White
Odor:	Amine-like odor
Specific Gravity @ 25C:	1.30
Viscosity:	150000.00 CST
Freezing/Melting Point:	Not Applicable.
Boiling Point:	Not Determined.
Vapor Pressure @ 25C:	Not Determined.
Vapor Density:	Not Determined.
Solubility in Water:	None.
pH:	Not Applicable.
Volatile content (Wt%):	Not Determined.

Note: The above information is not intended for use in preparing product specifications. Contact Dow Corning before writing specifications.

SECTION 10. STABILITY AND REACTIVITY

Chemical Stability: Stable.

Hazardous Polymerization: Hazardous polymerization will not occur.

Conditions to Avoid: None.

Materials to Avoid: Oxidizing material can cause a reaction.

Comments: None

SECTION 11. TOXICOLOGICAL INFORMATION

OPTIONAL SECTION - Complete information not yet available.

SECTION 12. ECOLOGICAL INFORMATION

OPTIONAL SECTION - Complete information not yet available.

SECTION 13. DISPOSAL CONSIDERATIONS

OPTIONAL SECTION - Complete information not yet available.

Call Dow Corning Environmental Mgmt. (517)496-6315, if more information is desired.

SECTION 14. TRANSPORT INFORMATION

DOT Information (49CFR 172.101)

Proper Shipping Name: Not Available

Hazard Technical Name: Not Available

Hazard Class: Not Available

UN/NA Number: Not Available

Packing Group: Not Available

Call Dow Corning Transportation, (517)496-8577, if additional information is required.

SECTION 15. REGULATORY INFORMATION

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:
None

Section 312 Hazard Class:

Acute:	N
Chronic:	N
Fire:	N
Pressure:	N
Reactive:	N

Y = Yes N = No

Section 313 Toxic Chemicals:
None present or none present in regulated quantities.

Supplemental State Compliance Information

CAS Number	Wt%	Component

California

Warning: This product contains the following chemical(s) listed by the State of California under the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) as being known to cause cancer.

None Known.

Warning: This product contains the following chemical(s) listed by the State of California under the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) as being known to cause birth defects or other reproductive harm.

None Known.

Massachusetts

No ingredient regulated by MA Right-to-Know Law present.

New Jersey

070131678	49	Dimethyl siloxane, hydroxy-terminated
063148629	11	Polydimethylsiloxane
None	39	Calcium carbonate treated with stearic acid

Pennsylvania

None	39	Calcium carbonate treated with stearic acid
070131678	49	Dimethyl siloxane, hydroxy-terminated
063148629	11	Polydimethylsiloxane

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.

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