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AN EVALUATION OF A SULPHLEX SEAL COAT

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7. Author(s)
Richard L. Tyler

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State Department of Highways and Public Transportation
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Austin, Texas 78763

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16. Abstract

The Texas State Department of Highways and Public Transportation placed a short "unofficial" Sulphlex chip seal in August, 1980. The material was placed with a conventional, unaltered asphalt distributor. Placement went well and the job was considered to be a success.

Based on the experiences of the unofficial Sulphlex chip seal, as well as experiences with sulfur extended asphalt hot mix jobs, it was felt that a Sulphlex chip seal might be (1)more durable than a similar asphalt cement seal and (2)less likely to bleed or flush than a similar asphalt cement seal. Test sections for the official research study were selected in an effort to examine these potentials.

The Sulphlex chip seal was designed and placed similar to the way a typical asphalt seal coat would have been designed and placed. There were numerous viscosity related problems during the job, but a very good chip seal was placed despite the difficulties. Further, it was felt that the viscosity problems could be handled with relative ease in future jobs.

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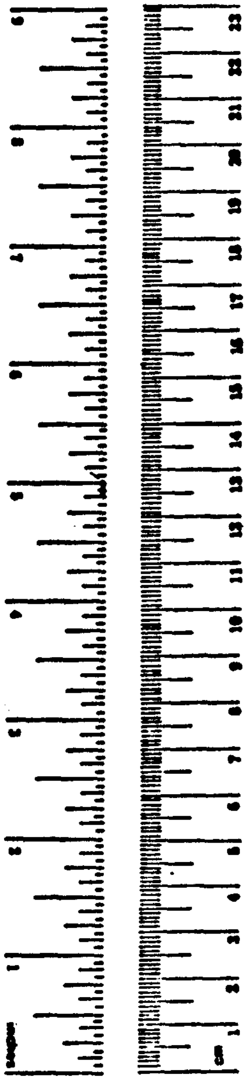
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

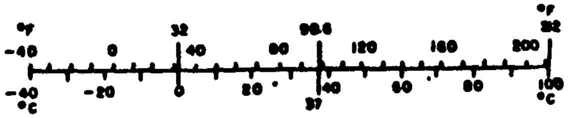


TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGEMENTS

Co-principal investigators Mr. Richard H. Magers, Supervising Laboratory Engineer, and Mr. Jon P. Underwood, Supervising Research Engineer, were responsible for the preliminary planning, site selection, and evaluation. Mr. Magers and his staff designed the chip seal and coordinated all construction activities. Special appreciation goes to Mr. M. Henry Hardy, District Geologist, who directed and coordinated the construction activities; to Mr. William Garbade, Supervising Resident Engineer, and to Mr. Melvin Maltsberger and his dedicated group of employees who placed the chip seal.

BACKGROUND

During the early 1970's the highway industry experienced an increased awareness of the limitations and finiteness of the world's oil supply, of ever increasing fuel prices, and of the economic motivation for refineries to squeeze more fuel and less asphalt from each barrel of oil. At the same time, the supply of sulfur was steadily increasing. The involuntary production of sulfur resulting from the processing of sour natural gas and from metallurgical operations, especially, was increasing.

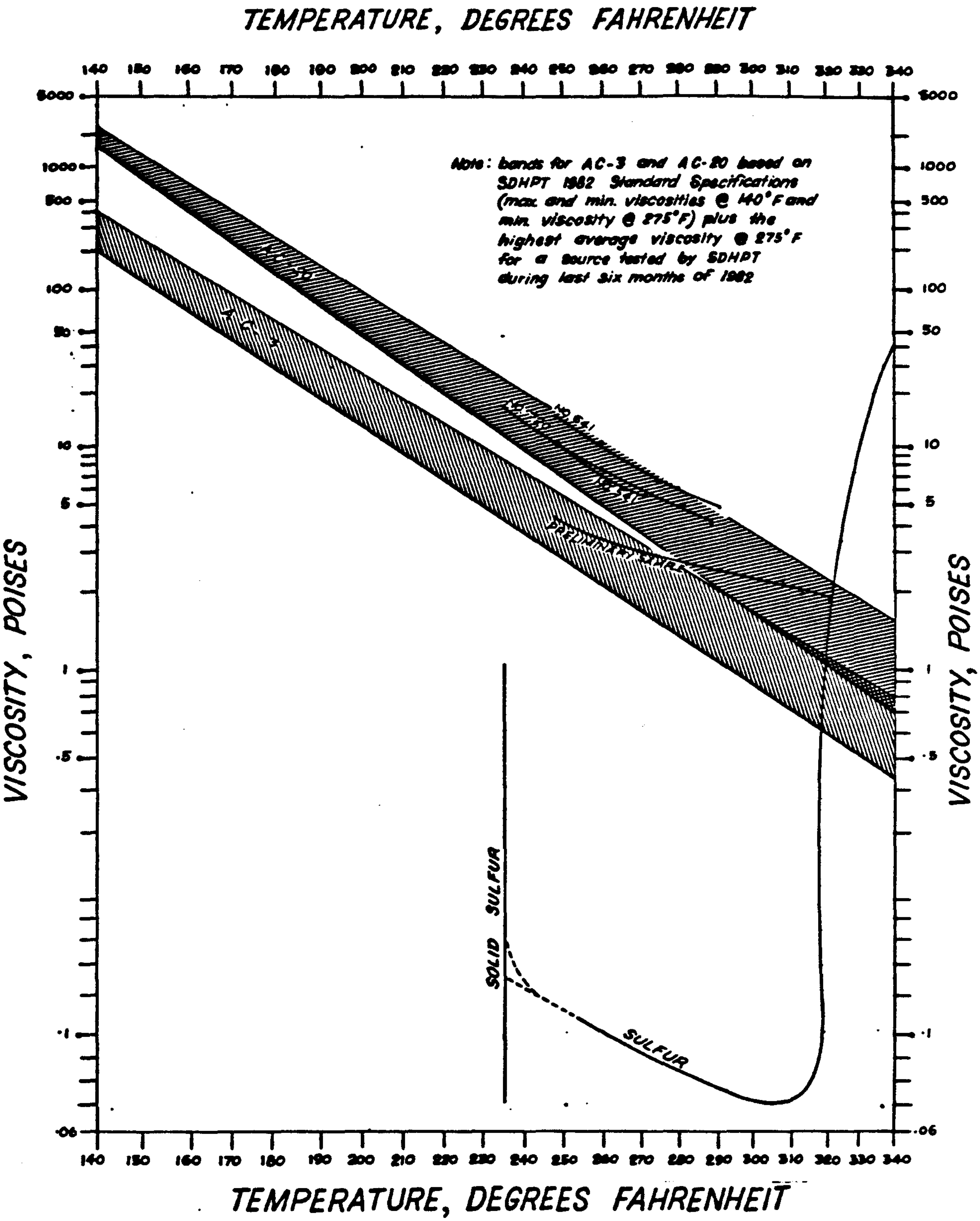
Southwest Research Institute (SwRI) in San Antonio, Texas had begun an active program in sulfur product development in 1959. And in the mid-seventies under the sponsorship of the Federal Highway Administration, they undertook a project to chemically modify elemental sulfur. Specifically, they sought to improve its engineering properties for the purpose of providing: (1) a binder to serve as a replacement for asphalt in flexible paving mixtures and (2) a binder to serve as a replacement for portland cement in rigid paving mixtures. The objective was to develop a system to modify sulfur so that it would serve as the total binder in paving mixes, not just as an additive or asphalt extender.

For flexible paving mixtures, the researchers at SwRI sought to chemically modify sulfur such that it would retain, indefinitely, some of the desirable characteristics of polymeric sulfur. The resultant plasticization process was one with which they could modify sulfur by reacting it with non-petroleum-derived chemical hydrocarbons. They called the products Sulphlex . The materials were formulated to have viscosity-temperature curves similar to those of asphalt cement but distinctly different from those of elemental sulfur (Fig. 1).

THE FIRST (UNOFFICIAL) SULPHLEX CHIP SEAL

Texas State Department of Highways and Public Transportation (SDHPT) placed 1.5 miles of Sulphlex hot-mix on August 26, 1980. The Sulphlex formulation which was selected for the test, No. 233A, consisted of 68% sulfur, 12% dicyclopentadiene, 10% vinyl toluene, and 10% Solvenol 2. Production and placement were accomplished using unaltered, conventional hot-mix paving equipment, and there were no significant problems.

After the hot-mix sections were placed, there were 1250 gallons of Sulphlex binder left in one transport; so district personnel decided to use this material to place an "unofficial" chip seal at the end of the



VISCOSITY- TEMPERATURE CHART:
COMPARISONS OF AC-20, AC-3, SULPHLEX & SULFUR

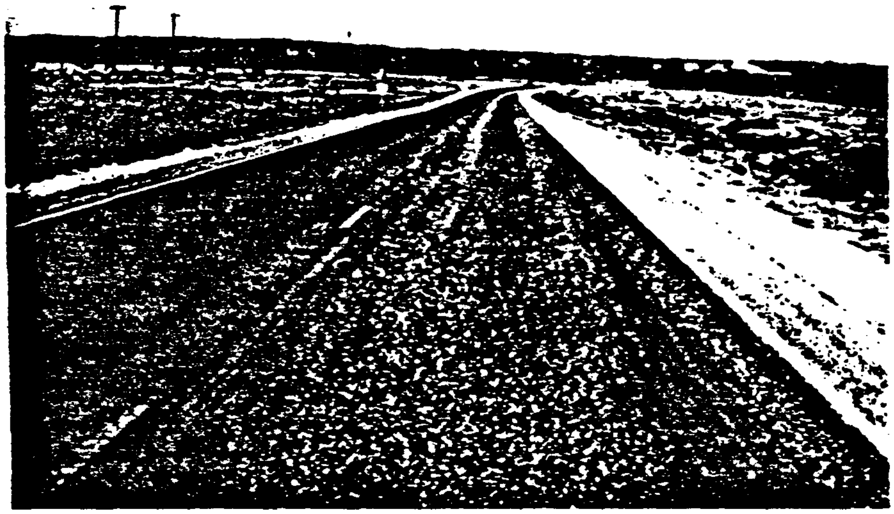
Figure 1

hot-mix test section. Total length of the chip seal was 3000 feet and the width was approximately 13 feet. Two types of aggregate were used: two loads of a precoated Grade 3 limestone rock asphalt which were spread at a rate of 1 cubic yard to 85 square yards and seven loads of Grade 4 (Delta) sandstone which were spread at a rate of 1 cubic yard to 100 square yards. An attempt was made to shoot 0.4 gallon of Sulphlex per square yard for the Grade 3 material, but since there was so little of it, it was estimated that something less was actually shot. Approximately 0.3 gallon of Sulphlex was shot for the Grade 4 material. An asphalt control section was placed adjacent to the Sulphlex chip seal; it consisted of AC-10 shot at approximately 0.3 gallon per square yard with a Grade 4 (Delta) sandstone spread at a rate of 1 cubic yard to 110 square yards.

UNOFFICIAL (1980) SULPHLEX SEAL COAT AND CONTROL

The site for both the Sulphlex hot-mix test sections and the unofficial seal coat section was northwest of San Antonio on Loop 1604, the outer loop around the city. The original roadway was constructed in 1961. It consisted of eight inches of flexible base and a two-course surface treatment. In 1970 this was overlaid with one inch of hot-mix asphalt concrete. Average daily traffic was 5600 with 9.3% trucks, and the average ten highest wheel loads (ATHWLD) was 12,300 with 60% tandem axles. The pavement had begun to flush and rut in some areas.

There were no major problems during placement of the unofficial chip seal, but the handling characteristics or workability of the Sulphlex was found to be different from that of AC-10. The Sulphlex was so viscous that the spray from the nozzles on the distributor bar did not fan out well; and after contacting the pavement, the Sulphlex didn't flow out evenly. Visible (but otherwise insignificant) ridges in the seal coat resulted from having had these longitudinal rows of binder. At one point the distributor inexplicably lost pressure and this caused more pronounced streaking for several yards. Further, the binder did not appear to adhere to the aggregate very well. Initially, it was felt that the material would have to be removed from the roadway; but within two to three hours the aggregate had seated and stuck very tightly.



PRONOUNCED STREAKING IN UNOFFICIAL (1980) SULPHLEX SEAL COAT

During the ensuing months, the control (AC-10) seal coat flushed very badly. On the other hand, the Sulphlex seal proved to be very durable and it did not bleed. The test was considered to be a success with most (if not all) of the problems being attributed to the higher viscosity. Notwithstanding the difficulties, a reasonably good seal coat had been placed with standard, unaltered equipment and with basically the same design which was used with AC-10.

SELECTION AND CONDITION OF THE TEST SITES

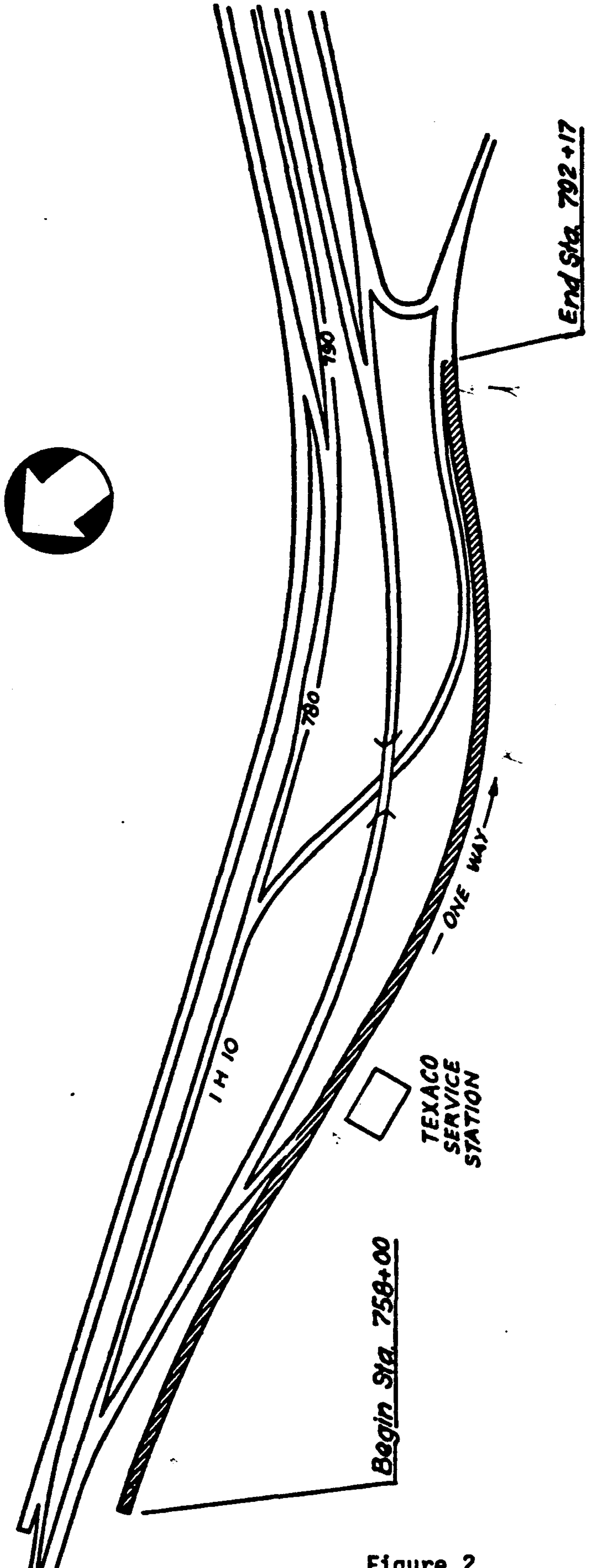
For purposes of this report, the terms "chip seal" and "seal coat" will be used interchangeably. The Texas State Department of Highways and Public Transportation 1982 Standard Specification describes a seal coat as "...a surface treatment composed of a single application of asphalt covered with aggregate for the sealing of existing pavements in accordance with these specifications," and it describes a surface treatment as "...a wearing surface composed of a single application of asphaltic material covered with aggregate, constructed on the prepared base course or surface in accordance with these specifications."

Seal coats can be used for reasons other than just sealing an existing surface, however. They can also be used for such things as to enrich an existing dry or raveled surface, to provide skid resistance, and with varying degrees of success, to try to stop pavements from bleeding.

While many have wanted and tried to control bleeding surfaces with the relatively inexpensive seal coat, its effectiveness has been dubious. Indeed, how appropriate could it be to spray a layer of asphalt on top of an already over-asphalted material? Further, the seal coat has shown a particular weakness where it was subjected to excessive stopping and turning maneuvers, such as at intersectons. The aggregate frequently shells out when the seal is placed in an area with such heavy scrubbing action.

Based on the performance of the initial test sections of Sulphlex, both the hot-mix and the unofficial chip seal, it was suggested that the material might perform well as a chip seal binder in two specific problem areas: the control of bleeding pavements and the control of shelling aggregates at intersections or other areas where there was excessive turning or stopping movements. It had been observed that the sulfur-asphalt type mixes in Texas had been dry and not prone to flushing or bleeding. This was also true of the previous Sulphlex jobs. And while Sulphlex and asphalt were obviously compatible, it was believed that excess asphalt would not bleed up through a Sulphlex chip seal. The Sulphlex pavements were more rigid than comparable pavements made of asphalt; so it seemed possible that a Sulphlex chip seal would be less susceptible to shelling than an asphalt seal.

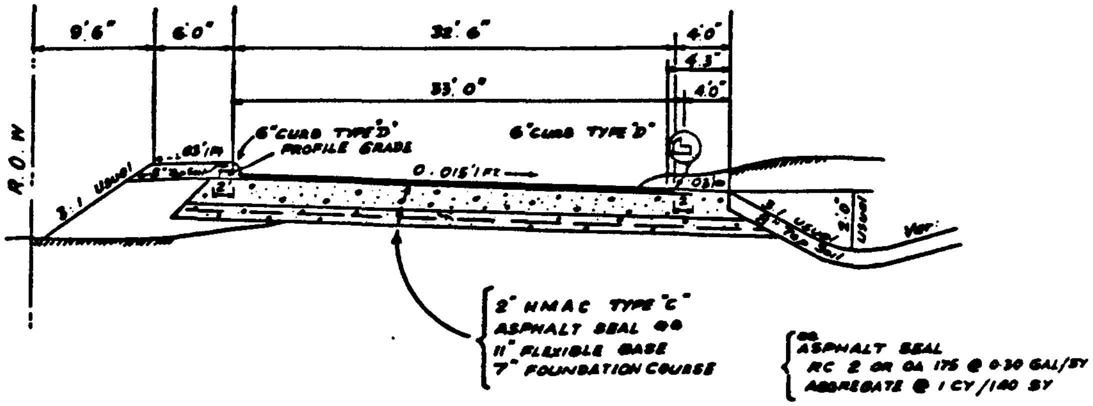
One of the sections which was chosen for the chip seal test was a (one way) section of IH 10 service road which had extensive flushing as well as excessive turning movements. It was a portion of the east/southeast bound frontage road between De Zavala Road on the upper end and Huebner Road on the lower end (Fig. 2). It was approximately three-quarters of a mile long.



PLAN VIEW OF SULPHLEX SEAL COAT TEST SECTION
IH 10, SAN ANTONIO, TEXAS

Figure 2

The original roadway was constructed in 1961. It consisted of approximately 11 inches of flexible base, a one course surface treatment, and two inches of Type C (Appendix A, Page 29) hot-mix asphalt concrete (Fig. 3). About five years after construction, a one course seal coat of AC-10 and Grade 4 precoated aggregate was placed.



TYPICAL SECTION-FRONTAGE ROAD

Figure 3

Standard SDHPT flexible pavement condition survey forms were used to comprehensively and objectively evaluate pavement distress throughout the section. The form requires an estimate of the percent of area which is affected by a particular type of distress, and then the distress is judged to be slight, moderate or severe. Following are the distress types or causes of distress which were considered: rutting, raveling, flushing, corrugations, alligator cracking, longitudinal cracking, transverse cracking, and patching.

In addition to extensive flushing, the section was found to have a few minor localized spots of raveling, which appeared to be the result of inadequate joint rolling. Of greater significance, however, was a sizeable area of unstable mix near the south end of the section where traffic slowed in order to turn onto an on-ramp to enter the freeway. The braking/turning maneuvers had caused moderate rutting and several spots of severe shoving. This area had been repaired at least once previously; and prior to the placement of the Sulphlex chip seal, the major shoved areas were cut out and backfilled with cold-mix. The average skid number was 25 as measured by the standard ASTM (40 mph) E 274 locked-wheel skid test.

SHOVED AREAS BEFORE REPAIRS

SHOVED AREAS AFTER REPAIRS

One particular portion of this roadway offered an even more severe test. A service station/truck stop was situated about midway through the section, just below an off-ramp. The flushed condition of the existing roadway clearly reflected the volume of trucks and severe turning maneuvers where vehicles entered and exited from the station. Additionally, it was suspected that the station operator had been cleaning the driveway with harsh solvents; and since typical petroleum solvents will not cut Sulphlex, this was considered to be another advantage to using this particular roadway for the test.

A 24-hour traffic count (which was made on a weekday in January 1982 and which was not seasonally adjusted) showed the traffic to be 2540 above the off-ramp with 2300 vehicles per day exiting from the freeway onto the service road just upstream from the station. Traffic downstream from the station was 4840, and the truck count was 4.1% (Fig. 4).

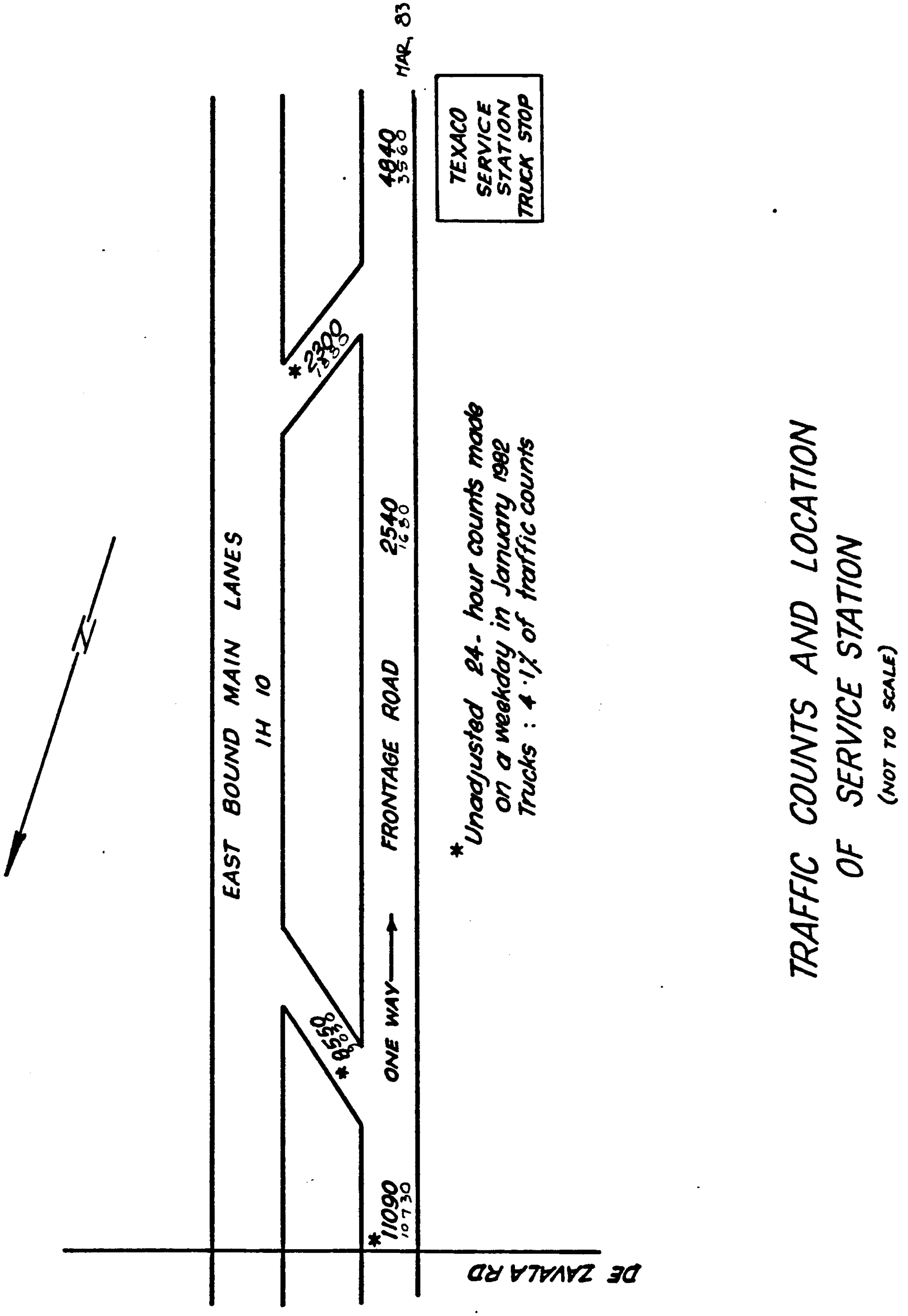
Another test site, the intersection of FM 1535 and Lp 1604, was selected because it offered a greater volume of traffic, traffic traveling at high speeds, and braking and turning maneuvers. However, due to construction problems, this site was not used.

Both sites were only a few miles from the original Sulphlex test sections, and they were reasonably close to the San Antonio District Office and Southwest Research Institute.

DESIGN CONSIDERATIONS AND TECHNIQUE

The San Antonio District uses a modified Kearby seal coat design method which is based on the SDHPT Manual of Testing Procedures Test Method Tex-216-F. Test Method Tex-216-F describes a "board" test for determining the adherent quality of aggregate proposed for use as surface treatment material. It provides the initial quantities to which adjustments are made, depending on the characteristics of the existing surface and the volume of traffic.

Assuming that District personnel had decided to seal the section and given that it had extensive bleeding with traffic approaching 5000 vehicles per day, a typical chip seal design would have called for a Grade 3 aggregate with approximately 0.38 gallon per square yard of



*Unadjusted 24-hour counts made on a weekday in January 1982
Trucks : 4·1% of traffic counts

TRAFFIC COUNTS AND LOCATION OF SERVICE STATION
(NOT TO SCALE)

Figure 4

AC-10 binder. It would provide for a very durable aggregate with a maximum size of $^5/_8$ inch; sufficient mat thickness to hold the rock; and an aggregate depth which would retard the flushing, provide good drainage, and skid resistance.

The actual selection of aggregate, rate of application of binder material, and aggregate distribution rate were arrived at through engineering judgement based on years of experience with the board test design method, years of field experience in placing seal coats, and the somewhat limited but valuable experience of having placed the unofficial chip seal in August of 1980. In other words, the Sulphlex chip seal was designed the way any other seal coat would have been designed, except with a great deal more scrutiny and the limited knowledge of how the material had handled before.

Two types of aggregates were selected for the test. One was a Grade 3 Modified, HVT (high volume traffic) limestone rock asphalt blended with traprock and precoated with flux oil. Approximately 20 cubic yards of this material were used on the inside lane at the lower end of the job. It complied with a special specification (Appendix B, Page 33). The aggregate which was used throughout most of the job was a Grade 3 limestone which was precoated with an anionic emulsion, EA-11M. This emulsion is something of a hybrid which is similar to an SS-1 (ASTM).

Since Sulphlex 233A was originally designed to be similar to AC-20, it was known that the viscosity would be somewhat higher than that of the AC-10 which the District's seal coat crew was accustomed to shooting. Even so, it was decided that the binder distribution rate should still be around 0.38 gallon per square yard.

Laboratory tests on a preliminary sample (submitted about 20 days prior to construction) showed that the material would start breaking down chemically and foaming excessively when it reached a temperature of about 300°F. Viscosity just prior to foaming was approximately 250 centipoises - considerably higher than ideal shooting viscosity. This confirmed that the distributor truck would be approaching its mechanical limits and that it was absolutely essential for the binder material to be delivered to the job site at no less than 260°F to 270°F. However, this material was supposed to be the same as that which had been used in 1980, so there was confidence that its handling characteristics and workability would be similar.

CONSTRUCTION OF THE SULPHLEX CHIP SEAL

The Sulphlex binder was manufactured by Chemical Enterprises at their Odessa, Texas plant. It is not known exactly when it was produced, but it was probably batched over a period of days during the first two weeks of August. The components were reacted and then pumped into three insulated chemical carriers (transports) to await shipment. It is also not known whether the material was maintained at elevated temperatures until shipment nor what the temperatures were when the three transports left the Odessa plant. However, maximum possible temperatures at departure were considered to be 280°F to 290°F, and the producer estimated that they would be 260°F to 270°F upon arrival at the job sites in San Antonio. Based on the viscosity-temperature test on the preliminary sample, this was considered to be the temperature which would produce the maximum usable viscosity.

The original plan was to have one transport arrive at an aggregate stockpile site on Fredericksburg Road (near the IH 10 frontage road test section) at 8:00 a.m. The Sulphlex was to be off-loaded to the distributor truck and the first shot was to be made by around 9:00 a.m. The second transport was scheduled to arrive at the second test section (intersection of Lp 1604 and FM 1535) around 10:00 a.m. and after the first section was completed, the second one would be begun. Depending on how well construction was going, the third transport could either be used or taken to a local trucking firm to be put on steam until it was needed. (The Sulphlex which was used in 1980 had been kept in the transport for several days; and the temperature had been maintained by connecting the tank's heating flues or coils to an equipment cleaner steam generator at the trucking firm.)

The first transport left Odessa at 12:30 a.m. on Wednesday, August 25, 1982. It made the 350-mile trip in just over seven hours, arriving in San Antonio at 7:40 a.m. This was Transport No. 720 (hereinafter referred to as Transport No. 1 or simply No. 1). Transport No. 1 went to the aggregate stockpile on Fredericksburg Road. Transport No. 641 (hereinafter referred to as Transport No. 2 or simply No. 2) arrived at about the same time at the Lp 1604-FM 1535 test site.

Samples were drawn from Transport No. 1, and the temperature was found to be about 206°F. The material was too viscous to shoot. Temperature of the material in the second transport was checked and found to be about the same, so it was taken to the trucking firm and put on steam. The Sulphlex in Transport No. 2 was down to 200°F by 11:15 a.m. when steam heating began. Transport No. 1 was also taken to the trucking firm to go on steam as soon as the material in Transport No. 2 was hot enough to use.

The third truck, No. 541 (hereinafter referred to as Transport No. 3 or simply No. 3), arrived at the Fredericksburg Rd. stockpile area at 10:00 a.m. Samples were drawn; the temperature was found to be 232°F and the viscosity was 1828 centipoise. Viscosities were measured with the Brookfield (rotating spindle) Viscometer which was powered by a portable generator.

BROOKFIELD VISCOMETER FIELD TESTS

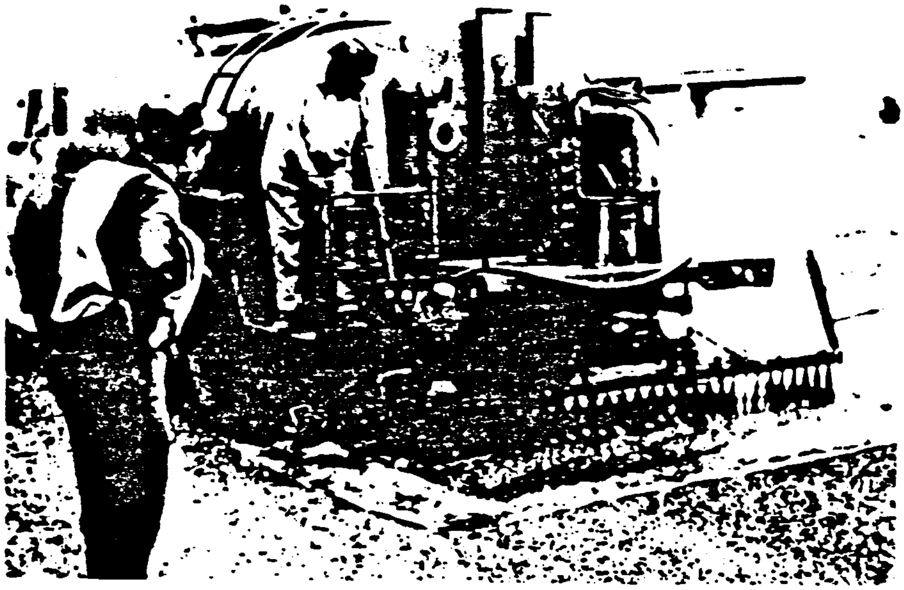
Even though it seemed apparent to some that the material couldn't be used at this viscosity, others (who were accustomed to working with asphalt, optimistic, and committed to the task) decided to try to pump a load into the distributor (Appendix C, Page 37). They found that it wasn't even possible to pump it through the three-inch diameter hose, much less through the spray bar and nozzles onto the roadway. A search was begun to find another trucking firm with an adequate steam generator to heat the material in Transport No. 3.

By early afternoon none had been found; however, a closer examination of the steam generator at the trucking firm revealed that it was similar to a (17-year old) steam cleaner (Appendix C, Page 37) which was located at the District shop area. So, in the absence of anything better, the proper fittings were made to input steam from the steam-cleaner nozzle into the heating flues of Transport No. 3. By 6:15 p.m. temperature of the Sulphlex was 210°F.

STEAM HEATING TRANSPORT AT DISTRICT OFFICE

The temperature climbed steadily throughout the night and by 6:00 a.m. the next day, Thursday, it was up to 280°F. The steam fittings were removed and the transport was taken to the Fredericksburg Rd. stockpile site for off-loading into the distributor. The distributor was loaded and ready to shoot by about 9:15 a.m. Temperature of the Sulphlex in the distributor was 260°F.

The transport contained enough Sulphlex for two distributor loads. The first shot began shortly after 9:15 a.m. and the second was completed by 10:30 a.m. The Sulphlex was considerably more viscous than desired (probably around 540 centipoises), but there were no serious problems. Application rate was estimated to be 0.36 gallon per square yard. The aggregate was applied with a self-propelled spreader (Appendix C, Page 37) at a rate of one cubic yard to 95 square yards. Rolling was accomplished with one steel flat-wheel roller and one nine-wheel pneumatic roller (Appendix C, Page 37).



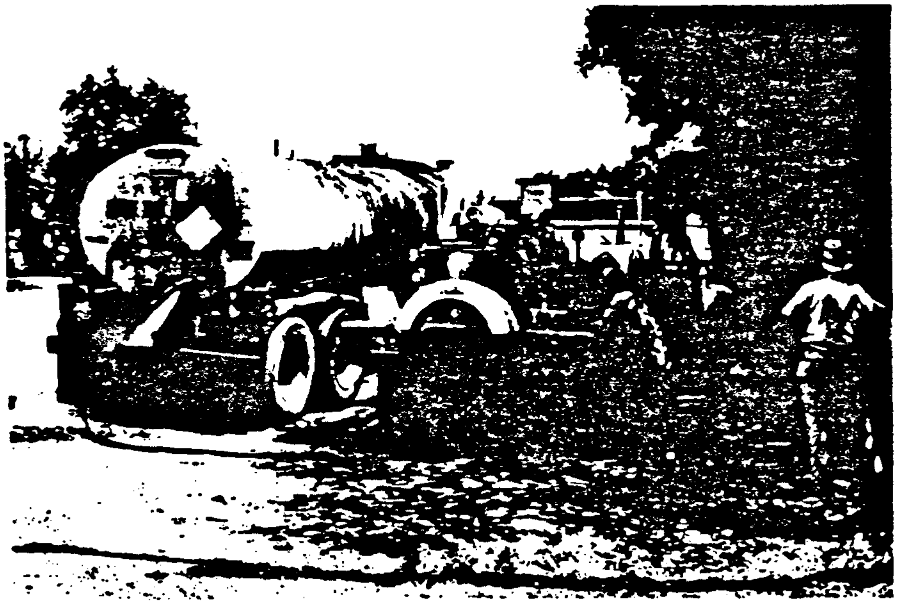
PLACING THE SULPHLEX SEAL COAT

Meanwhile, there were still two loaded transports: No. 2 had been taken off steam (Sulphlex temperature of 230°F) at 6:00 p.m. on Wednesday when the trucking firm closed for the night; and No. 1 had not been on steam at all.

By 6:00 a.m. on Thursday, No. 2 was put back on steam (down to 200°F), and for some reason it continued to lose heat. It was down to 180°F at 8:00 a.m. No. 1 was dispatched to the District shop to be connected to the steam generator which had worked so well the night before with No. 3. But the steam generator began to malfunction. It needed major repairs before it could be used. By 10:30 a.m. Transport No. 2 was up to only 220°F.

It was obvious that alternative heating equipment had to be found for both transports. After considerable searching, two portable oil field steam generating units were found. They were based in Luling, Texas, about 50 miles from San Antonio.

In the optimistic hope that the mobile steam generators would be effective, Transport No. 1 was dispatched to the Lp 1604-FM 1535 test site to be heated and Transport No. 2 was dispatched to the Fredericksburg Rd. stockpile area to be heated. By 3:00 p.m. both transports were connected and heating began: No. 1 began at 152°F and No. 2 began at 195° F. Temperatures climbed steadily through the afternoon, but it was soon realized that the material would not be hot enough to shoot before the previously agreed upon deadline of 5:00 to 5:30 p.m.



MOBILE STEAM GENERATOR

Both transports and steam generators were moved to the District maintenance yard to continue heating through the night. At 10:30 p.m. the heating tubes or flues in No. 1 ruptured, allowing steam to blow into the Sulphlex. The rupture was sudden. The steam generator was turned off immediately. Temperature of the Sulphlex was 230°F. There was no way to continue heating the material; further, there was no way to assess the extent and effects of the rupture until morning.

Upon examination the following morning (Friday), it could be seen that the Sulphlex was "...full of bubbles." A four to five foot-long sawn stick was pushed down into the Sulphlex (to the bottom of the tank). When it was pulled out it was just wet with a slight brownish discoloration ("...asphalt emulsion color"). The heavy, viscous Sulphlex had not adhered to the stick. By mutual agreement between the job supervisor and the Chemical Enterprises representative, it was decided that the material was suspect at best, that neither party could use the material, and that it should be removed from the transport while it was still liquid enough to flow out. It was taken to a dump site and wasted.

By 8:00 a.m. the material in Transport No. 2 had gotten up to 280°F to 290°F. The steam line was disconnected and the transport was moved to the Fredericksburg Rd. stockpile site. At about 9:00 a.m. as Sulphlex was being pumped into the distributor, a hydraulic hose on the distributor pump ruptured. By 10:30 a.m. it had been repaired, but then it was discovered that enough Sulphlex had solidified in the pump that it was inoperable - frozen. The distributor truck was driven back to the District shop where the pump and associated parts were heated with the (now repaired) steam cleaner. After about 15 minutes of heating, thickened Sulphlex oozed out of the spray bar. After the pump started working freely again, 50 gallons of diesel were pumped into the tank through the loading port in an effort to thin any remaining Sulphlex. The diesel was flushed out and the distributor returned to the Fredericksburg Rd. stockpile area.

By the time the hose was reconnected and off-loading begun, the pump was frozen again. This time (with several fire extinguishers on hand) an open flame pear-burner was used to free the pump. Then it was found that Sulphlex had thickened in the 3-inch diameter loading hose. The material just oozed out; it wouldn't pump. Another hose was obtained and the distributor was loaded. Temperature of the Sulphlex in the distributor tank was 250°F. With the pump in gear (circulating the material) the truck was driven slowly to the IH 10 frontage road test site and a successful shot was made.

The distributor truck operator left about 500 gallons of Sulphlex in the tank to circulate while returning for another load. The pump was straining and the hydraulic reservoir was hot and smoking. The spray bar nozzles were opened, one at a time, and each was clogged to some extent. The end plugs were removed from the spray bar and it was obvious that the Sulphlex was too viscous to shoot. If the pump had gone out at this point, the distributor would have had 500 gallons of solidifying Sulphlex in it. So it was decided to waste the 500 gallons, purge the distributor with hot AC-10, and send the remaining Sulphlex (part of one transport load) back to Odessa. The temperature of the material was 250°F to 255°F. It was 4:00 p.m.

The weather during the three days of this job was fairly typical for the latter part of August in the San Antonio area - hot, dry, and mostly clear. Air temperatures were 3 to 5 degrees higher than average with extremes of 76° to 97° on August 25th, 78° to 99° on the 26th, and 77° to 100° on the 27th. Wind direction for all three days was SSE with average speeds around 10 to 11 miles per hour. There was no precipitation during the job (Appendix D, Page 39).

It appeared that despite the difficulties, a very good Sulphlex chip seal test section had been placed. Standard ASTM (E 274) locked-wheel skid tests were run one month after placement. The section had a low SN_{40} of 47, a high SN_{40} of 70, and an average SN_{40} of 61. The average SN_{40} for the old surface (prior to placement of the seal) was 25 (Appendix E, Page 45).

NEW SULPHLEX CHIP SEAL

For the most part, conventional equipment had been used. It is not standard practice in Texas to use a steel flat-wheel roller on a chip seal because it tends to crush the aggregate; but for this job it was considered desirable because of the way the material had handled during the 1980 Sulphlex seal placement.

At first observers were not very optimistic about the rock sticking in the mat. It appeared that the Sulphlex was so viscous that it didn't really adhere to the aggregate. However, the material had performed the same way in the 1980 job. Observers of the 1980 Sulphlex seal said that "...it just laid there; it didn't look like it was going to stick. We expected to have to pick it all up, but after traffic had been on it a while, it settled in and looked like a regular seal coat."

A process of purging was used to clean the Sulphlex out of the distributor since there is no known solvent for Sulphlex for which there is a plentiful and inexpensive source. The distributor was first flushed by shooting about 50 gallons of hot AC-10 through it, and this was then followed by diesel to get the asphalt out.

EMISSIONS MONITORING

Heated Sulphlex emits very malodorous, greenish colored fumes; and knowing that these emissions can be toxic (in high concentrations), researchers monitored sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) during the job. Based on a toxicity chart (Figure 5) which was derived from references which were available to the Texas Air Control Board as of March 31, 1982, measured emissions were well below critical levels. Analysis for SO_2 by Ion Chromatography showed no detectable SO_2 in either the blank or in Sample 1. Sample 2 showed 0.02 ppm SO_2 at a minimum detectable level (MDL) of 0.003 ppm. Analysis for H_2S showed no detectable amounts for either the blank or Sample 1 and only 0.003 ppm for Sample 2 (Appendix F, Page 47).

Based on observations and discussions with those who were working on the job, there were no serious toxic reactions to the gases. However, the distributor truck operator experienced some temporary dizziness after standing over the open hatch of the distributor truck for a prolonged time while the tank was being filled. And those who sampled temperatures through the open hatches in the tops of the transports felt temporary eye irritation and even nose and throat irritation if they breathed the fumes for several minutes. The heated Sulphlex certainly

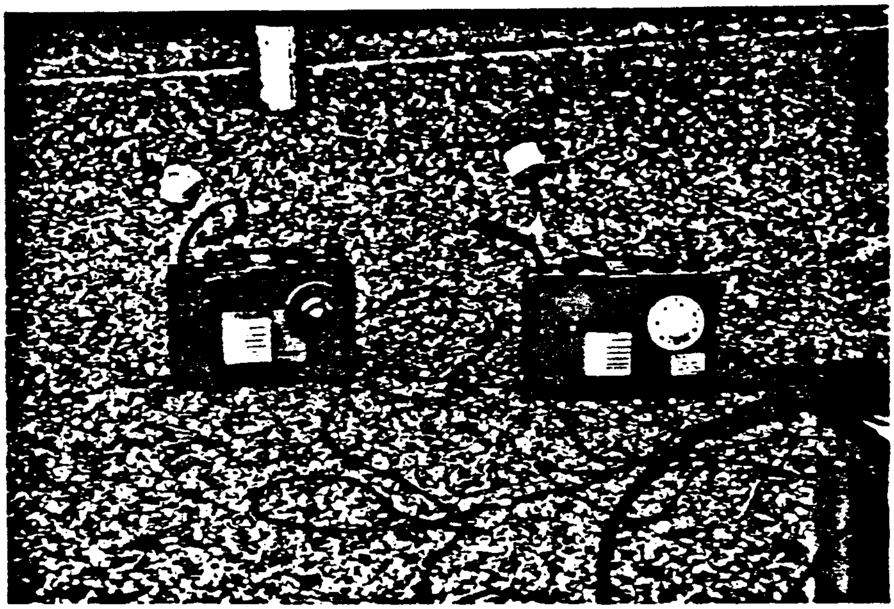
TOXICITY OF SO_2

Concentration (ppm)	Effect
0.3-1	Detected by taste (some people will notice odor and experience irritation at 0.5 to 0.7 ppm)
2	Threshold Limit Value (TLV) for 8 hours of exposure per day for 5 days
3	Noticeable odor
6-12	Immediate irritation of nose and throat
20	Irritation to eyes

TOXICITY OF H_2S

Concentration (ppm)	Effect
0.02	Odor threshold ("rotten egg" odor)
3-4	Eye irritation
10	Threshold Limit Value (TLV) for 8 hours of exposure per day for 5 days
20-50	Respiratory irritation, coughing
170-300	Maximum concentration which can be inhaled for one hour without serious consequences

Figure 5



EMISSIONS MONITORING BUBBLER SAMPLERS

had an objectionable odor, and it is likely that this caused workers to maintain a reasonable distance from the source. It should be noted that for most of the operations, the fumes were not terribly strong. It was not difficult to work with the Sulphlex, and no special breathing devices were required. In future jobs simple precautions could virtually eliminate any unpleasantness associated with the odors. Physical properties and safety data for vinyl toluene, dicyclopentadiene, and Solvenol 2 are contained in Appendix G, Page 51.

LABORATORY TESTS

The Sulphlex which was used in this chip seal was designed to be similar to asphalt cement, to have a viscosity similar to AC-20, and to be usable in conventional equipment. And the tests which the central (SDHPT) laboratory ran were the same tests which are typically run in acceptance testing of asphalt cements (with one adaptation). While these tests undoubtably have significance, caution is urged not to assign the exact same meaning to the results as would be assumed if asphalt were the material being tested. Through years of use, practitioners have developed a feel for how a particular penetration graded asphalt cement will behave. But will a Sulphlex of the same penetration behave the same way? Since Sulphlex foams excessively at about 300°F, the standard thin film oven test (5 hours at 325°F) was altered and run at 140°F for 14 days. What meaning can be assigned to the results of a test which was originally designed to simulate the accelerated aging of an asphalt cement in a drum plant and which was then adapted to another material? Figure 6 is a summary of the tests which were run on the samples and the resulting values.

When it was first discovered that the Sulphlex was too viscous to pump, it seemed obvious that the temperature had to be increased. This, of course, was consistent with previous laboratory tests and experiences with Sulphlex. However, the questions which followed were not so easily answered: (1) had the components of the Sulphlex been fully and properly reacted, (2) were the handling characteristics the same as those of the material which had been used two years earlier, and (3) had the Sulphlex deteriorated and/or become more viscous as a result of having been stored and (possibly) maintained at elevated temperatures for several days or weeks prior to delivery? There was no way to readily answer these questions in the field; and at best, only some indications were available from the test data which were obtained several weeks later.

Were the components fully reacted? There are no tests available to the State Department of Highways and Public Transportation which will clearly answer this question. However, data in Figure 6 indicate that the material which was contained in Transport No. 2 was quite different from the Sulphlex in either of the other two transports and in the preliminary sample. This is evidenced by higher viscosities, higher temperature for softening point, higher temperature for brittleness, and lower penetrations. Note also that Transport No. 2 contained the Sulphlex which was so viscous that approximately half of the load had to be returned to the chemical plant. Since material was used from both Transport Nos. 2 and 3 (after a high enough temperature was reached), and since a good seal coat was apparently achieved, the answer to the question of whether the components were fully reacted is not being pursued.

Were the handling characteristics the same? The Sulphlex in Transport No. 3 probably wasn't significantly different from that which had been used in 1980. As previously stated, the Sulphlex of the 1980 job didn't fan out well, it didn't flow after contacting the pavement, and at one point the distributor inexplicably lost pressure (perhaps due to a cool, thickened mass of Sulphlex). Also, the chip seal of 1980 was placed three days after the hot-mix job was completed, allowing the material to be heated for a considerably longer time.

SULPHLEX LABORATORY DATA SUMMARY

SAMPLE IDENTIFICATION	Lab #C82373527 Sampled 8-6-82 Submitted from Chemical Enterprises at plant in Odessa, soon after manufact.	Lab #C82374440 Sampled 8-25-82 by D. Hazlett at jobsite upon delivery. Truck No. 720 (No. 1)	Lab #C82374441 Sampled 8-25-82 by D. Hazlett at jobsite upon delivery. Truck No. 641 (No. 2)	Lab #C82374442 Sampled 8-25-82 by D. Hazlett at jobsite upon delivery. Truck No. 541 (No. 3)	Lab #C82374128 Sampled 8-27-82 by H. Hardy from distributor Truck No. 641 (No. 2)	Lab #C82374439 Sampled 8-80 by SwRI at completion of 1980 job
Viscosity @ 140 °F, Poise	1262	1579	3286	1287	2744	2432
Viscosity @ approx. 275 °F, Poise (Brookfield)	3.0 @ 270 °F	5.80 @ 273 °F	6.66 @ 274 °F	5.78 @ 272 °F	7.92 @ 275 °F	6.68 @ 275 °F
Penetration @ 77 °F	128	110	56	94	71	96
Specific Gravity @ 77 °F	1.559	1.553	1.553	1.566	1.547	1.505
Softening Point	111 °F	118 °F	120 °F	112 °F	123 °F	127 °F
Ductility on Original @ 77 °F, 5 cm/min	141	141	141	141	141	141
Ductility on Original @ 39.2 °F, 1 cm/min	4	0	0	0	0	0
Penetration, Original @ 39.2 °F, 100 g, 5 sec	3	0	0	2	1	0
Penetration, Original @ 39.2 °F, 200 g, 60 sec	38	15	10	33	6	17
Loss on Thin Film @ 140 °F, 14 days	.64%	.49%	.72%	.63%	.90%	1.203%
Viscosity on Residue @ 140 °F	2603	2256	5480	1408	4469	4255
Penetration on Residue @ 77 °F	90	86	48	105	49	57
Ductility on Residue @ 77 °F, 5 cm/min	141	141	141	141	141	141
Ductility on Residue @ 39.2 °F, 1 cm/min	0	0	0	0	0	0
Penetration TF @ 39.2 °F, 100 g, 5 sec	1	0	0	0	1	2
Penetration TF @ 39.2 °F, 200 g, 60 sec	16	15	3	16	8	16
Brittleness on Original	82 °F	79 °F	85 °F	80 °F	92 °F	87 °F

Had the Sulphlex deteriorated and/or become more viscous while in storage? Figure 1 clearly illustrates that the viscosities of the Sulphlex in the three transports were significantly higher than that of the preliminary sample which was taken at the plant only 19 days earlier. At 250°F this is approximately a six poises difference, and at 280°F it is approximately a 3 poises difference. Further, preliminary indications from research being performed at Texas Transportation Institute are that Sulphlex becomes significantly more viscous when stored for prolonged periods at elevated temperatures. Even so, Lab Sample #C82374441 (from Transport No. 2) is the only 1982 sample which had a viscosity higher than the maximum allowable viscosity for an AC-20 (Figure 6). The sample from Transport No. 1 had a measured viscosity slightly below the minimum allowable value for an AC-20, while the preliminary sample and the sample from Transport No. 3 had viscosities well below the minimum allowable value for an AC-20. Note that Lab Sample #C82374439, a sample of Sulphlex from August, 1980 which had been stored at ambient temperature, closed container conditions, was found to have a viscosity of 2432 poises at 140°F. This is only slightly higher than the maximum allowable viscosity for an AC-20.

EQUIPMENT CONSIDERATIONS

Clearly, it has been proven that Sulphlex can be applied with standard, unaltered paving equipment. Just as clear, however, is the fact that there is room for improvements, both in handling techniques and equipment. First, it is believed that the material could be at a higher temperature when it leaves the plant. Perhaps standard sulfur transports could be used to deliver the Sulphlex instead of chemical carriers. It is believed that sulfur transports are better designed and insulated to minimize heat loss during transit. Perhaps heating the transports with hot oil (as with asphalt cement transports) would be better than heating with steam. Additionally, modifications to the distributor should be considered. (Note that the distributor which was used was old and very worn.) Assuming that a Sulphlex with similar viscosity is to be used, it is felt that consideration should be given to using a distributor with a heavy-duty pump, perhaps larger or oversized nozzles, and an onboard heater which could be used. The heater on the SDHPT distributor was not used because it was felt that it might develop hot spots and cause the Sulphlex to foam.

PROBLEMS

From one perspective the hour by hour description of the construction activities makes the job seem almost calamitous - a new problem at every turn. But it should be kept in mind that (1) all of the problems (with one exception) were either directly or indirectly related to viscosity and (2) apparently an excellent chip seal was placed in spite of the difficulties.

At a post-construction conference which was held twelve days after the completion of the job, attendees identified two major problems - achieving a usable viscosity and cleaning the equipment. First, the Sulphlex was not delivered to the job at a usable viscosity; and in retrospect, it is very likely that both test sections could have been completed on the first day if the binder had been delivered to the job site at a usable viscosity. Problems with off-loading, clogged hoses, etc. were all considered to be results of trying to use too viscous a material. Second, the purging/flushing technique for cleaning the distributor was considered to be too time consuming and inefficient.

CONCLUSIONS

It is concluded that:

1. It is possible to construct a Sulphlex chip seal using conventional, unaltered paving equipment and typical chip seal designs.
2. There is evidence that a flushed pavement will not bleed up through a Sulphlex chip seal.
3. There is evidence that a Sulphlex binder will adhere to typical seal coat aggregates with a strong bond, creating a very durable pavement surface.
4. There is evidence that Sulphlex is resistant to gasoline, diesel fuel, and other typical petroleum solvents which dissolve asphalt cements.
5. The use of Sulphlex in chip seal paving operations presents no environmental or health hazzards due to emissions.
6. There is no known solvent for Sulphlex for which there is a plentiful and reasonably priced supply.
7. The workability and initial performance (aggregate retention) of Sulphlex are different from those of AC-10.

RECOMMENDATIONS

It is recommended that:

1. Qualitative tests and acceptance criteria be developed for Sulphlex.
2. Provisions be made to assure that the Sulphlex has a usable viscosity when it reaches the job site.
3. Adequate auxiliary heating equipment be available in the event that the job schedule is interrupted.
4. Prolonged exposure to concentrated Sulphlex fumes be avoided.
5. A better procedure/solvent be developed to clean the distributor.
6. If Sulphlex of a similar viscosity is to be used, consideration be given to making alterations to the distributor, such as larger nozzles, heavy duty pump, and on-board heater which provides even heating (no hot spots).
7. Consideration be given to using transports with well designed and insulated tanks to minimize heat loss.
8. The transport tanks have heating coils or flues which are in satisfactory condition and which are compatible with the heating devices to be used (such as steam or oil).
9. Additional Sulphlex formulations be developed which have viscosities comparable to AC-10 and for which there are substantial sources for the components.
10. Additional Sulphlex chip seal test sections be considered for areas where the conditions might further test the ability of Sulphlex to (1) prevent a surface from flushing and (2) withstand the scrubbing action of stopping and turning maneuvers.

APPENDIX A

Texas Highway Department
Type C Hot Mix Specification
1951 - 1961

ITEM 317

HOT MIX ASPHALTIC CONCRETE PAVEMENT

317.1. Description. This item shall consist of a base course, a leveling-up course, a surface course or any combination of these courses as shown on the plans, each to be composed of a compacted mixture of mineral aggregate and asphaltic material. It is the intent of this specification to produce a mixture which, when designed and tested in accordance with these specifications and methods outlined in T.H.D. Bulletin C-14, shall have the following laboratory density and stability:

Density %			Stability (%)
Min.	Max.	Optimum	Not less than 35 except
94	98	96	when otherwise shown on plans

If the mixture produced does not have the specified qualities, it shall be changed until it does. The pavement shall be constructed on the previously completed and approved subgrade, base, or in the case of a bridge, on the prepared floor slab, as herein specified and in accordance with the details shown on the plans.

317.2. Materials.

(1) Mineral Aggregate.

The mineral aggregate shall be composed of a coarse aggregate and a fine aggregate. Samples of coarse aggregate and fine aggregate shall be submitted in accordance with the methods prescribed in Item 6 of the Standard Specifications, and approval of both material and of the source of supply must be obtained from the Engineer prior to delivery.

(a) Coarse Aggregate.

The Coarse Aggregate shall be that part of the aggregate retained on a No. 10 mesh sieve; shall consist of clean, tough, durable fragments of stone, or gravel, as hereinafter specified, of uniform quality throughout; it shall be practically free from clay, organic or other injurious matter occurring either free or as coating on the aggregate. Material removed by decantation (T.H.D. Bulletin C-11) shall not be more than 2% except when the plasticity index of the removed material is less than 6, the amount may be as much as 4%. The coarse aggregate shall have an abrasion of not more than forty (40) when subjected to the Los Angeles Abrasion Test (A.A.S.H.O. T-96) for all types except Type "F" (Non-skid Surface Course), which shall have an abrasion of not more than thirty-five (35) when subjected to the same test. If gravel is used for Type "F", it shall be so crushed that ninety (90) per cent of the particles shall have more than one crushed face.

(b) Fine Aggregate.

The fine aggregate shall be that part of the aggregate passing the No. 10 mesh sieve and shall consist of sand or stone screenings for a combination of sand and stone screenings. Sand shall be composed of durable stone particles free from injurious foreign matter. Screenings shall be of the same or similar material as specified for coarse aggregate. The plasticity index of that part of the fine aggregate passing the No. 40 sieve shall be not more than 6 when tested by T.H.D.-53 procedure.

(c) Mineral Filler.

The mineral filler shall consist of thoroughly dry stone dust, slate dust, Portland cement, or other mineral dust approved by the Engineer. The mineral filler shall be free from foreign and other injurious matter. When tested by standard laboratory methods, it shall meet the following grading requirements:

Passing a 30 mesh sieve	100%
Passing a 200 mesh sieve, not less than	65%

(2) Asphaltic Material.

(a) Paving Mixture.

Asphalt for the paving mixture shall be of the types of Oil Asphalt as determined by the Engineer and shall meet the requirements of the Item "Asphalts, Oils, and Emul-

sions". The grade of asphalt used shall be as designated by the Engineer after design tests have been made using the mineral aggregates that are to be used in the project, and the various grades of asphalt. If more than one type of asphaltic concrete mixture is specified for the project, only one grade of asphalt will be required for all types of mixtures, unless otherwise shown on plans.

(b) Tack Coat.

The asphalt material for Tack Coat shall meet the requirements for Emulsified Asphalt, EA-11M; or Cut-Back Asphalt RC-2, or shall be a cut-back asphalt made by combining fifty to seventy (50-70) per cent of the asphaltic material as specified for the type of paving mixture with thirty to fifty (30-50) per cent of gasoline and/or kerosene; or if RC-2 Cut-Back Asphalt is used, it may, upon instructions from the Engineer, be diluted by the addition of not to exceed fifteen (15) per cent of an approved grade of gasoline and/or kerosene, by volume; the asphaltic materials shall meet the requirements of the Item "Asphalts, Oils, and Emulsions".

317.3. Paving Mixtures.

(1) Types.

The paving mixtures shall consist of a uniform mixture of coarse aggregate, fine aggregate and asphaltic material. The grading of each constituent of the mineral aggregate shall be such as to produce, when properly proportioned, a mixture, which, when tested in accordance with Bulletin C-14, will conform to the limitations for master grading given below for the type specified:

Type "C" (Coarse Graded Surface Course):

Passing 1" screen	100%
Passing ⅞" screen	97 to 100%
Passing ⅞" screen, retained on ½" screen	15 to 40%
Passing ½" screen, retained on ¼" screen	15 to 40%
Passing ¼" screen, retained on 10 mesh sieve	10 to 30%
Total retained on 10 mesh sieve	50 to 65%
Passing 10 mesh sieve, retained on 40 mesh sieve	0 to 25%
Passing 40 mesh sieve, retained on 80 mesh sieve	5 to 25%
Passing 80 mesh sieve, retained on 200 mesh sieve	5 to 25%
Passing 200 mesh sieve	1 to 10%

The asphaltic material shall form from 3.5 to 7% of the mixture by weight.

APPENDIX B

SPECIAL SPECIFICATION

ITEM 3155
AGGREGATE FOR SURFACE TREATMENTS
(For High Volume Traffic)

1. <u>Description</u>. This item establishes the requirements for aggregates to be used in the construction of surface treatments on roads with high volume traffic.

2. <u>Materials</u>. Aggregates shall be composed of clean, tough and durable particles of crushed trap rock, crushed flint rock, crushed limestone, crushed limestone rock asphalt, crushed sandstone, crushed rhyolite, crushed slag or lightweight aggregate. These aggregates may be furnished separately or as a blended combination thereof, except that limestone or limestone rock asphalt material may not be furnished separately or the two materials may not be blended together but may be furnished if blended with any of the other aggregates listed above. Any materials used, or a combination thereof, shall not contain more than a total of 5 percent by weight of soft particles and other deleterious material as determined by Test Method Tex-217-F, Part I, with respect to limestone rock asphalt, or as determined by Test Method Tex-413-A for all other materials. A minimum of 85% of the material retained on the No. 4 sieve shall have more than one crushed face.

   The aggregate shall not contain more than 1.0 percent by weight of fine dust, clay-like particles, and/or silt present when tested in accordance with Test Method Tex-217-F, Part II.

   The percent of wear, as determined by Test Method Tex-410-A, for each material used shall not exceed 35 percent.

   The maximum Flakiness Index shall not exceed 15 when tested in accordance with Tentative Test Method Tex-224-F.

   The aggregate will be subjected to 4 cycles of the Soundness Test in accordance with Test Method Tex-411-A. The loss shall not be greater than 30 when magnesium sulphate is used. This test will not apply to blends with crushed trap rock, crushed flint rock, crushed rhyolite or lightweight aggregate.

   Lightweight aggregate is herein defined as aggregates prepared by expanding, calcining, or sintering products such as blast furnace slag, clay, diatomite, fly ash, shale or slate. Lightweight aggregate is further defined so as to include aggregates prepared by processing natural materials, such as pumice, scoria, or tuff. Lightweight aggregates shall be composed predominately of cellular and granular inorganic material. The unit weight of successive shipments of lightweight aggregate shall not differ by more than 10% from that of the sample submitted for acceptance tests. The "Pressure Slaking Value" shall not exceed 4% when tested in accordance with Test Method Tex-431-A. The "Aggregate Freeze-thaw Loss" shall not exceed 7% when tested in accordance with Test Method Tex-432-A.

Aggregate used in this item shall have a "Polish Value" of not less than the value shown on the plans when tested in accordance with Test Method Tex-438-A, or, if the Contractor so elects, a uniformly blended mixture of aggregates may be used in this item. The mixture shall consist of non-polishing materials blended with other materials contained within paragraph 1 above. The Polish Value of the non-polishing material in the blend shall be not less than 41 when tested in accordance with Test Method Tex-438-A, except that when trap rock or flint rock is used, the polish value requirements are waived.

Aggregates from each different source shall be tested individually for compliance with all requirements. (Aggregates blended with non-polishing aggregates will not be required to meet polish value requirements). For blends with limestone or limestone rock asphalt, the amount of non-polishing aggregate included in the blended combination shall be a minimum of 30% by volume, as determined below, of the material passing the 3/4" sieve and retained on the 3/8" sieve for the Grade 3 Modified Aggregate; or of the material passing the 5/8" sieve and retained on the No. 4 sieve for the Grade 4 Modified or 4A Modified Aggregate. At the Contractor's option the non-polishing aggregate may be sized so as to include non-polishing particles within the other screen sizes of the particular Grade of blended aggregate. The non-polishing aggregate must be equal to or greater in wear resistance than the aggregate to be improved by blending when tested in accordance with Test Method Tex-438-A, Part III.

Specification compliance for proper proportion of the blended mixture of aggregates shall be from representative samples taken from the stockpiles after mixing is completed, but prior to precoating operations. Percent by volume may be determined by making a visual count of the materials as outlined in Test Method Tex-413-A, and converting weights to volumes by appropriate means.

3. Grades. When tested by Test Method Tex-200-F, Part I, the gradation requirements for the following grades of aggregate shall be as follows.

		Percent by Weight
Grade 3 Mod.	Retained on 3/4" sieve	0
	Retained on 5/8" sieve	0 - 5
	Retained on 1/2" sieve	20 - 45
	Retained on 3/8" sieve	85 - 100
	Retained on No. 4 sieve	95 - 100
	Retained on No. 10 sieve	98.5 - 100
Grade 4 Mod.	Retained on 5/8" sieve	0
	Retained on 1/2" sieve	0 - 5
	Retained on 3/8" sieve	15 - 35
	Retained on No. 4 sieve	85 - 100
	Retained on No. 10 sieve	98.5 - 100

Grade 4A Mod.	Retained on 5/8" sieve	0
	Retained on 1/2" sieve	0 - 5
	Retained on 3/8" sieve	20 - 45
	Retained on No. 4 sieve	85 - 100
	Retained on No. 10 sieve	98.5 - 100
Grade 5 Mod.	Retained on 1/2" sieve	0
	Retained on 3/8" sieve	0 - 5
	Retained on No. 4 sieve	50 - 70
	Retained on No. 10 sieve	98.5 - 100

4. <u>Precoated Aggregates</u>. The aggregates shall be precoated in accordance with the precoating methods outlined in Item 304 "Aggregate For Surface Treatments (Precoated)(Class B)",Article 304.5 thru 304.7, except that the allowable range in the percent of precoat material or flux oil shall be from 0.2 to 2.0 percent by weight. The type of precoating material shall be determined by the Engineer.

   Blended materials shall be blended prior to precoating.

5. <u>Measurement and Payment</u>. Aggregates will be measured and paid for in accordance with the governing specifications for the items of construction in which these materials are used.

APPENDIX C

EQUIPMENT

Binder Distributor: Etnyre-Model BTHS, 1750 gallon capacity

Aggregate Spreader: Rosco-Model SPKH, 14 ft.

Flat Wheel Roller: Ingram-3 wheel, 5-8 tons (used empty)

Pneumatic Roller: Ingram Model 9-2800P, 6 tons

District Steam Cleaner: Steam Heater by Malsbary, Model 327-GES

Mobile Steam Generators: Texsteam Steamer, Model P-4992-4BT

Emissions Samplers: Telematic Bubbler Samplers with dilute sodium carbonate/bicarbonate absorbing solution when testing for SO_2 and with alkaline cadmium sulfate absorbing solution when testing for H_2S

APPENDIX D

AUG 1982
SAN ANTONIO, TEXAS

AUG 1982 12921
SAN ANTONIO, TEXAS
INTERNATIONAL AIRPORT

ISSN 0198-5191

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

NAT WEATHER SERVICE FCST OFC

LATITUDE 29° 32' N LONGITUDE 98° 28' W ELEVATION (GROUND) 788 FEET TIME ZONE CENTRAL WBAN #12921

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 06AM INCHES	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 794 FEET ABOVE M.S.L.	WIND (M.P.H.)					SUNSHINE		SKY COVER TENTHS		
DATE	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)			WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)		RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	FASTEST MILE SPEED	FASTEST MILE DIRECTION	MINUTES	PERCENT OF TOTAL POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT	DATE
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	100	76	88	3	64	0	23		0	0	0	29.15	17	9.5	10.0	16	15	702	86	2	2	1
2	98	77	88	3	66	0	23	8	0	0	0	29.13	15	9.8	11.1	17	14	680	84	3	3	2
3	98	75	87	1	68	0	22		0	0	0	29.13	15	12.7	13.1	21	13	605	75	5	4	3
4	99	77	88	2	65	0	23	8	0	0	0	29.16	15	11.1	11.7	16	15	679	84	3	4	4
5	100	76	88	2	64	0	23	8	0	0	0	29.22	15	7.6	8.5	13	17	682	85	2	3	5
6	100	69*	85	-1	59	0	20		0	0	0	29.10	16	4.8	7.2	15	15	720	90	5	5	6
7	97	76	87	1	62	0	22	1 3 8	0	.19	0	29.11	16	7.9	9.4	15	15	483	60	8	8	7
8	96	72	84	-1	67	0	19	8	0	.19	0	29.10	16	4.7	6.8	14	16	415	52	7	8	8
9	87	71	79*	-6	70	0	14	1 3 8	0	.17	0	29.15	08	3.1	5.5	29	12	111	14	10	9	9
10	90	70	80	-5	69	0	15	1 8	0	T	0	29.21	14	4.4	6.0	16	12	392	49	8	7	10
11	95	77	86	1	70	0	21		0	0	0	29.22	14	8.5	9.5	16	11	632	79	7	7	11
12	96	77	87	2	68	0	22		0	0	0	29.21	16	10.0	10.0	16	14	662	83	4	4	12
13	99	75	87	2	66	0	22		0	0	0	29.15	16	9.6	10.4	14	14	725	91	6	4	13
14	99	75	87	2	68	0	22		0	0	0	29.11	15	8.8	9.5	14	14	695	87	5	4	14
15	98	76	87	2	66	0	22		0	0	0	29.11	16	8.0	9.1	13	14	670	84	5	5	15
16	100	71	86	1	63	0	21		0	0	0	29.15	12	6.1	7.1	13	10	740	94	3	3	16
17	102*	73	88	3	63	0	23		0	T	0	29.11	21	.7	6.3	12	12	582	74	6	5	17
18	98	77	88	3	67	0	23	3	0	0	0	29.12	10	4.6	6.6	13	07	427	54	9	8	18
19	95	73	84	-1	68	0	19	8	0	0	0	29.18	06	4.1	6.6	14	10	437	56	7	5	19
20	97	72	85	0	66	0	20	8	0	0	0	29.24	09	6.6	9.4	21	10	662	84	3	3	20
21	95	72	84	-1	66	0	19	8	0	0	0	29.24	09	5.6	7.2	16	13	613	78	4	4	21
22	95	70	83	-1	65	0	18		0	0	0	29.19	15	5.3	7.5	14	14	659	84	3	2	22
23	99	73	86	2	65	0	21		0	0	0	29.16	17	9.1	10.0	16	13	693	89	2	1	23
24	100	75	88	4	63	0	23		0	0	0	29.17	16	13.1	14.1	18	15	662	85	2	2	24
25	97	76	87	3	68	0	22		0	0	0	29.19	15	10.6	11.1	17	14	556	72	6	5	25
26	99	78	89	5	69	0	24		0	0	0	29.16	15	10.8	10.6	16	14	400	52	6	5	26
27	100	77	89*	5	66	0	24		0	0	0	29.11	17	10.3	11.1	16	14	686	89	1	2	27
28	98	77	88	5	67	0	23		0	0	0	29.18	15	9.2	9.8	13	14	688	79	3	3	28
29	96	77	87	4	67	0	22		0	0	0	29.21	16	7.4	8.2	14	15	553	72	5	3	29
30	98	75	87	4	67	0	22		0	0	0	29.20	15	8.8	9.9	18	13	610	79	6	5	30
31	97	76	87	4	67	0	22		0	0	0	29.21	14	10.3	10.8	14	12	543	71	6	5	31
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:						TOTAL	% OF POSSIBLE	SUM	SUM	
	3018	2311				0	655			.55	0	29.17	15	7.2	9.2	29	12	18300		152	138	
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION ≥ .01 INCH	3	DEP.						DATE: 09		POSSIBLE		AVG.	AVG.	
	97.4	74.5	86.0	1.3	66	0	48			-1.86								24520	75	4.9	4.5	

NUMBER OF DAYS				SEASON TO DATE			
				TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	0
MAXIMUM TEMP.		MINIMUM TEMP.		0	2307	THUNDERSTORMS	3
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0
30	0	0	0	0	53	CLEAR 11 PARTLY CLOUDY 16 CLOUDY 4	

GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
PRECIPITATION		SNOW, ICE PELLETS		
.36	8- 9	0	0	

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS AT 3-HOUR INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. ONE OF THREE WIND SPEEDS IS GIVEN UNDER FASTEST MILE: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED (A / APPEARS IN THE DIRECTION COLUMN). ERRORS WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL PUBLICATION.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC CENTER, ASHEVILLE, NORTH CAROLINA, 28801.

J. Ray Hunt
ACTING DIRECTOR
NATIONAL CLIMATIC CENTER

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA AND INFORMATION SERVICE / NATIONAL CLIMATIC CENTER ASHEVILLE, NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

AUG 1982 12921
SAN ANTONIO, TEXAS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL. HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL. HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL. HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					DAY 01											DAY 02											DAY 03						
00	0	UNL	10			81	71	66	60	15	10	0	UNL	12			81	70	64	56	14	10	0	UNL	10			80	72	69	69	15	10
03	0	UNL	10			78	71	68	71	15	9	7	14	8			77	72	69	76	14	9	0	14	10			77	72	70	79	15	9
06	9	14	10			77	72	70	79	21	7	7	14	6		R	77	72	70	79	19	7	0	12	10			76	72	70	82	13	5
09	3	UNL	10			83	73	69	63	19	9	4	UNL	7			84	74	69	61	21	10	4	UNL	7			84	74	69	61	18	11
12	0	UNL	15			92	74	65	41	23	7	2	UNL	8			91	74	66	44	14	9	3	UNL	8			91	73	65	42	15	12
15	0	UNL	15			99	72	58	26	16	9	1	UNL	8			96	74	63	34	14	8	4	UNL	10			96	73	62	32	15	11
18	0	UNL	15			98	71	56	25	14	10	1	UNL	12			97	72	60	29	12	10	5	UNL	12			92	74	66	42	13	10
21	0	UNL	12			89	72	63	42	15	14	0	UNL	10			87	72	65	48	14	14	2	UNL	10			85	74	69	59	14	15
					DAY 04											DAY 05											DAY 06						
00	0	UNL	10			80	72	69	69	14	10	0	UNL	12			79	72	68	69	12	7	2	UNL	10			83	67	57	41	17	5
03	9	13	10			78	73	71	79	14	8	9	10	10			76	72	70	82	16	7	0	UNL	10			77	67	62	60	15	5
06	9	13	10			78	72	70	77	17	8	9	10	6		R	76	72	70	82	16	7	4	UNL	7			78	63	59	68	32	3
09	5	UNL	7			83	74	70	65	10	10	5	UNL	6		R	81	73	69	67	18	6	0	UNL	8			83	68	60	46	23	9
12	3	UNL	8			92	73	64	40	16	12	0	UNL	8			91	75	68	47	15	7	0	UNL	10			93	71	60	33	19	8
15	2	UNL	10			97	73	61	30	13	10	0	UNL	10			99	72	58	26	18	9	9	UNL	10			98	71	57	26	12	6
18	0	UNL	12			97	70	55	24	14	11	2	UNL	10			98	69	52	21	12	10	10	UNL	12			98	71	57	26	14	7
21	0	UNL	12			87	71	62	43	13	10	0	UNL	10			90	67	54	29	11	6	0	UNL	10			92	70	58	32	12	7
					DAY 07											DAY 08											DAY 09						
00	10	300	7			84	69	60	44	17	7	10	110	8			76	69	66	71	19	9	10	110	7			75	72	71	87	01	3
03	6	UNL	6		R	79	68	62	56	20	7	10	100	6		R	74	69	66	76	00	0	8	UNL	4		F	73	71	70	98	02	3
06	9	100	4		R	77	67	62	60	22	4	8	100	4		R	73	69	67	82	00	0	10	7	3		F	73	72	71	93	02	5
09	9	100	4		R	83	70	64	53	20	5	4	UNL	5		R	81	71	66	60	19	6	10	9	3		F	78	73	71	79	06	6
12	10	100	5		R	93	72	61	34	16	8	4	UNL	10			89	73	65	45	22	6	9	100	5		R	87	75	69	55	11	6
15	9	100	5		R	96	72	60	30	12	10	8	90	12			95	74	64	36	13	10	10	5	5		RW	73	70	69	87	14	10
18	8	300	10			95	71	58	29	15	12	9	50	6		RW	81	73	70	69	13	12	10	100	6		R	75	70	67	76	14	2
21	10	45	7		TRW	77	70	67	71	12	12	10	100	7		R	74	72	71	90	03	4	10	120	7			73	70	68	84	34	3
					DAY 10											DAY 11											DAY 12						
00	9	UNL	7			71	69	68	90	00	0	1	UNL	12			77	73	71	82	11	6	9	UNL	12			79	72	71	77	13	7
03	9	11	7			72	69	68	87	05	3	10	12	8			78	74	73	85	18	9	9	14	10			77	73	72	85	17	8
06	7	7	5		F	72	70	69	90	09	3	8	11	8			77	74	73	88	14	5	10	14	8			77	73	72	85	18	6
09	9	7	5		F	77	74	73	88	12	7	5	UNL	8			82	74	71	69	17	8	5	UNL	10			80	72	69	69	19	10
12	8	20	8			88	74	68	52	21	9	5	UNL	15			90	74	66	45	15	9	3	UNL	15			91	74	67	45	18	10
15	8	250	15			84	74	69	61	13	8	8	300	15			93	74	65	40	14	6	2	UNL	15			96	75	65	36	14	10
18	8	250	15			85	73	67	55	16	7	10	300	15			90	75	69	50	11	14	6	UNL	15			95	73	62	34	14	10
21	2	UNL	12			78	71	68	71	11	5	0	UNL	15			82	75	72	72	11	9	0	UNL	15			86	72	65	50	14	14
					DAY 13											DAY 14											DAY 15						
00	0	UNL	12			79	72	69	72	14	9	0	UNL	12			80	72	69	69	13	9	0	UNL	15			81	72	67	63	13	7
03	1	UNL	12			77	73	71	82	18	7	0	14	10			77	72	70	79	16	6	6	14	12			77	73	71	82	17	6
06	4	UNL	10			75	72	70	85	14	4	4	UNL	12			75	72	70	85	15	5	6	13	10			76	72	70	82	16	7
09	4	UNL	10			81	73	69	67	17	10	4	UNL	10			80	73	70	72	20	8	4	UNL	10			82	73	69	65	20	10
12	2	UNL	15			91	73	65	42	17	9	7	UNL	12			91	76	69	49	17	7	6	UNL	12			89	74	68	50	18	6
15	0	UNL	15			97	72	59	28	19	9	4	UNL	15			98	74	62	31	13	10	6	UNL	15			98	73	61	29	19	9
18	7	UNL	15			97	71	58	27	14	12	3	UNL	20			97	72	60	29	16	9	3	UNL	20			98	72	58	26	13	10
21	2	UNL	15			87	73	67	52	13	12	6	UNL	15			88	75	70	55	14	12	3	UNL	15			88	71	63	43	13	8
					DAY 16											DAY 17											DAY 18						
00	0	UNL	15			80	70	65	60	13	8	3	UNL	15			84	71	64	51	18	8	5	UNL	15			85	72	66	53	13	7
03	0	UNL	10			76	71	69	79	16	6	3	UNL	15			80	70	65	60	00	0	8	300	15			82	72	68	63	18	4
06	4	UNL	12			71	68	66	84	01	3	4	UNL	15			74	68	64	71	32	4	9	UNL	15			78	71	68	71	05	3
09	6	UNL	12			82	72	68	63	13	4	6	UNL	15			87	72	65	48	28	7	10	100	12			86	72	66	51	01	4
12	3	UNL	15			93	71	59	32	12	4	9	UNL	15			96	74	64	35	29	6	9	350	12			93	74	65	40	16	5
15	2	UNL	15			99	71	56	24	12	7	6	250	15			100	74	60	27	32	4	10	350	12			95	74	65	37	11	5
18	0	UNL	20			98	71	57	26	18	11	4	UNL	20			99	73	60	20	13	8	10	350	8			86	74	68	55	07	11
21	3	UNL	15			90	70	60	37	11	6	8	50	15			90	72	63	41	09	8	8	300	8			81	72	67	63	07	7

WEATHER CODES

+	TORNADO	ZL	FREEZING DRIZZLE	IPW	ICE PELLET SHOWERS	BN	BLOWING SAND
T	THUNDERSTORM	S	SNOW	A	HAIL	BS	BLOWING SNOW
Q	SQUALL	SW	SNOW SHOWERS	F	FOG	BY	BLOWING SPRAY
R	RAIN	SG	SNOW GRAINS	IF	ICE FOG	K	SMOKE
RW	RAIN SHOWERS	SP	SNOW PELLETS	GF	GROUND FOG	H	HAZE
ZR	FREEZING RAIN	IC	ICE CRYSTALS	BD	BLOWING DUST	D	DUST
L	DRIZZLE	IP	ICE PELLETS				

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM
SPEED: THE FASTEST OBSERVED AVERAGE ONE-MINUTE VALUE, EXPRESSED IN KNOTS (MPH=KNOTS X 1.15).

PAGE 2

OBSERVATIONS AT 3-HOUR INTERVALS

AUG 1982 12921
SAN ANTONIO, TEXAS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
DAY 19											
00	7	UNL	10			78	71	67	69	01	5
03	5	UNL	10			75	70	67	76	00	0
06	9	300	7			74	69	67	79	33	4
09	6	UNL	10			83	74	70	65	06	5
12	10	40	10			81	76	74	79	36	7
15	6	300	8			94	75	67	41	13	8
18	2	UNL	8			94	75	66	40	10	12
21	0	UNL	7			83	70	63	51	06	5
DAY 20											
00	0	UNL	7			81	72	67	63	19	4
03	3	UNL	7			75	69	66	74	33	4
06	9	UNL	7			73	69	67	82	34	4
09	0	UNL	6		F	83	73	68	61	09	6
12	3	UNL	10			91	73	65	42	07	10
15	4	UNL	10			96	73	62	33	10	11
18	5	UNL	8			95	75	67	40	10	16
21	3	UNL	8			84	74	69	61	13	8
DAY 21											
00	0	UNL	8			79	73	70	74	09	4
03	3	UNL	10			75	71	69	82	05	4
06	5	UNL	7			73	70	68	84	36	4
09	0	300	10			81	74	71	72	11	4
12	4	UNL	15			89	73	66	47	09	6
15	4	UNL	12			94	72	61	33	07	9
18	2	UNL	10			93	70	58	31	11	10
21	3	UNL	10			83	70	64	53	15	9
DAY 22											
00	1	UNL	12			79	70	65	62	10	7
03	0	UNL	12			76	69	66	71	00	0
06	0	UNL	10			71	66	64	79	33	4
09	2	UNL	15			81	73	69	67	10	6
12	4	UNL	15			90	72	64	42	09	0
15	5	UNL	15			95	73	63	35	10	7
18	1	UNL	15			93	72	61	34	16	0
21	0	UNL	15			86	72	66	51	14	12
DAY 23											
00	0	UNL	15			80	71	67	65	15	8
03	1	UNL	15			77	72	69	76	10	7
06	0	UNL	10			75	72	70	85	11	6
09	6	17	10			81	73	70	69	16	8
12	3	UNL	12			92	75	67	44	20	9
15	0	UNL	12			99	71	56	24	22	13
18	0	UNL	12			97	69	53	23	16	12
21	0	UNL	12			86	74	69	57	13	14
DAY 24											
00	0	UNL	12			80	70	65	60	15	13
03	4	UNL	12			76	71	69	79	17	8
06	6	14	9			75	71	69	82	15	9
09	4	UNL	12			80	71	67	65	18	14
12	0	UNL	15			92	72	62	37	15	16
15	0	UNL	15			99	70	56	22	20	12
18	0	UNL	15			96	70	55	25	14	12
21	0	UNL	10			84	71	65	53	13	14
DAY 25											
00	0	UNL	10			79	72	69	72	15	8
03	6	14	10			77	72	70	79	16	7
06	6	13	8			76	73	71	85	10	5
09	6	17	10			81	73	69	67	17	10
12	6	45	15			90	74	67	47	14	10
15	4	UNL	20			94	75	67	41	10	10
18	6	350	20			95	74	64	36	14	12
21	0	UNL	20			85	74	69	59	14	15
DAY 26											
00	3	UNL	15			80	74	71	74	15	9
03	0	14	15			78	74	72	82	16	8
06	7	14	10			78	74	72	82	17	5
09	0	120	10			82	75	72	72	14	8
12	0	100	20			88	75	69	53	18	9
15	4	UNL	20			95	74	65	37	18	10
18	3	UNL	20			94	73	62	32	14	14
21	0	UNL	15			87	73	66	50	12	11
DAY 27											
00	1	UNL	15			80	72	69	69	16	10
03	0	15	12			78	73	71	79	17	9
06	9	17	12			78	72	70	77	17	8
09	3	UNL	15			83	74	70	65	17	10
12	0	UNL	20			93	73	64	38	22	9
15	0	UNL	25			98	73	61	29	19	8
18	1	UNL	25			97	70	56	25	15	11
21	0	UNL	20			87	72	65	48	15	12
DAY 28											
00	0	UNL	15			80	73	70	72	13	9
03	6	12	12			78	74	72	82	15	8
06	8	22	10			78	73	71	79	17	6
09	4	UNL	12			82	73	69	65	18	11
12	3	UNL	25			92	75	67	44	17	8
15	4	UNL	25			98	74	62	31	13	8
18	2	UNL	25			95	72	60	31	13	9
21	0	UNL	20			89	73	65	45	14	9
DAY 29											
00	0	UNL	15			82	72	68	63	16	9
03	0	UNL	15			78	72	70	77	17	4
06	6	14	10			77	73	71	82	10	6
09	5	UNL	20			82	73	69	65	22	6
12	6	300	25			90	74	66	45	17	7
15	7	300	20			93	73	64	38	10	6
18	2	UNL	20			94	72	61	33	13	9
21	0	UNL	20			88	71	63	43	14	10
DAY 30											
00	0	UNL	20			80	69	61	52	14	6
03	7	15	15			76	71	68	76	10	6
06	0	13	10			77	72	70	79	17	5
09	4	UNL	12			82	73	69	65	23	10
12	7	350	20			91	74	67	45	14	6
15	4	UNL	15			95	74	64	36	11	10
18	8	350	12			90	75	68	48	13	16
21	4	UNL	12			84	73	68	59	13	10
DAY 31											
00	0	UNL	12			80	73	70	72	13	9
03	9	11	12			78	74	72	82	15	8
06	8	14	10			77	73	72	85	17	8
09	7	20	15			82	74	70	67	13	10
12	6	40	15			90	73	65	44	16	10
15	5	UNL	15			95	73	62	34	16	9
18	4	UNL	15			94	73	62	35	14	9
21	2	UNL	15			88	73	66	48	12	12

SAN ANTONIO TEXAS 82 08

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES: SKY COVER (TENTHS)	AVERAGES: STATION PRESSURE (INCHES)	AVERAGES: TEMPERATURE: AIR TEMP °F	AVERAGES: TEMPERATURE: WET BULB °F	AVERAGES: TEMPERATURE: DEW POINT °F	AVERAGES: REL HUMIDITY %	AVERAGES: WIND SPEED (MPH)	RESULTANT WIND: DIRECTION	RESULTANT WIND: SPEED (MPH)
00	2	29.18	80	71	67	66	8.6	14	7.6
03	6	29.17	77	71	69	77	6.6	16	5.6
06	7	29.19	75	71	69	81	5.9	16	3.1
09	5	29.22	82	73	69	65	9.2	18	6.8
12	5	29.20	91	74	66	44	9.4	16	7.0
15	5	29.13	95	73	62	35	10.1	15	8.1
18	4	29.10	94	72	61	36	12.5	13	11.8
21	3	29.14	85	72	65	54	11.4	13	10.5

PAGE 3

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

AUG 1982 12921
SAN ANTONIO, TEXAS

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
1																									1
2																									2
3																									3
4																									4
5																									5
6																									6
7																					.10	.01			7
8																		.03	.10	.02	.02	.02			8
9														.12	.04	.01									9
10							T	T																	10
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29																									29
30																									30
31																									31

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	00.14	00.15	00.15	00.15	00.16	00.1[illegible]	00.19	00.19	00.19	00.19	00.19	00.19
ENDED: DATE	07	07	07	07	07	07	07	07	07	07	07	07
ENDED: TIME	1820	1825	1830	1835	1045	1900	1900	1900	1900	1900	1900	1900

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

SUBSCRIPTION PRICE AND ORDERING INFORMATION AVAILABLE FROM:
THE NATIONAL CLIMATIC CENTER, FEDERAL BUILDING, ASHEVILLE N.C. 28801
ATTN: PUBLICATIONS

SAN ANTONIO, TEXAS
USCOMM - NOAA - ASHEVILLE, NC

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COM 210

FIRST CLASS

State Dept. of Highways
P. O. Box 29928
San Antonio, TX 78284

Attn: Mr. John Kight

APPENDIX E

HIGHWAY: IH 10 EASTBOUND FRONTAGE ROAD
FROM: JCT. DE ZAVALA RD. TO: JCT. LP. 345 EXXON STA.
COMMENT: EBFR SULPHLEX SEAL
PLACED: 08/82
BINDER: SULPHLEX 233A
TESTED ON: 9/28/82
TRUCK NO.: 43
AIR TEMP.: 88 F

AVERAGE SKID NUMBER (OLD SURFACE) PRIOR TO PLACEMENT: 25

TEST & LANE	SPEED	CUMM. MILES	SKID NUMBER
1A	40	0.0	70
2B	40	0.1	62
3A	40	0.2	64
4B	40	0.2	47
5A	40	0.3	57
6B	40	0.4	60
7B	40	0.5	62
8B	40	0.5	62

SKID NUMBER - LO.... 47
SKID NUMBER - AVG... 61
SKID NUMBER - HI.... 70

APPENDIX F

TEXAS AIR CONTROL BOARD
LABORATORY
6330 Highway 290 East
Austin, Texas 78723

Sample: Special Study
I-10 at Old Fredericksburg Road
for Highway Department
City/County: San Antonio/Bexar
Description:
Impinger samples for SO_2

ACL Number: SS-20
Delivered By: Rod Moe
Date Sampled: 8-26-82

LABORATORY ANALYSIS

Analysis for SO_2 by Ion Chromatography shows no detectable SO_2 in either blank or in Sample 1. Sample 2 shows .02 ppm SO_2 at an MDL of .003 ppm.

8-30-82
Date Received

9-2-82
Date Reported

Analysis Performed By

TEXAS AIR CONTROL BOARD
LABORATORY
6330 Highway 290 East
Austin, Texas 78723

Sample:	I-10 at Old Fredericksburg Rd.	ACL Number:	Special Study 20
		Delivered By:	Highway Department
City/County:	San Antonio/Bexar	Date Sampled:	8 -26-82

Description:
H_2S

LABORATORY ANALYSIS

	ml	µg/ml	µg	M^3	µg/M^3	ppm
Blank	----	0.0	0.0	0.0	0.0	0.0
H_2S #1	20	0.0	0.0	0.0	0.0	0.0
H_2S #2	20	.012	0.240	.053	4.5	.003

8-26-82
Date Received

8-31-82
Date Reported

Juan J Rios
Analysis Performed By
Juan J. Rios

APPENDIX G

MATERIAL SAFETY DATA SHEET PAGE: 1

DOW CHEMICAL U.S.A. MIDLAND MICHIGAN 48640 EMERGENCY PHONE: 517-636-4400

EFFECTIVE DATE: 08 JUN 77 DATE PRINTED: 18 JUL 77 PRODUCT CODE: 91606

PRODUCT NAME: VINYL TOLUENE (12T AND 50T INHIBITOR GRADES) MSD: 0201

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS) : % :

VINYLTOLUENE, MINIMUM : 99.2 :

SECTION 1 PHYSICAL DATA

BOILING POINT: 333.9F : SOL. IN WATER: 0.0089%
VAP PRESS: 1.10 MMHG @ 20C : SP. GRAVITY: 0.9164 @ 60/60F
VAP DENSITY (AIR=1): 4.08 : % VOLATILE BY VOL: NOT APPL.
APPEARANCE AND ODOR: CLEAR LIQUID, DISAGREEABLE ODOR.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 127F : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: TAG CLOSED CUP : LFL: 0.8 UFL: 11
EXTINGUISHING MEDIA: WATER FOG, FOAM, ALCOHOL FOAM, CO2, DRY CHEMICAL.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: AT ELEVATED TEMPERATURES SUCH AS IN FIRE CONDITIONS, POLYMERIZATION MAY TAKE PLACE. IF IT TAKES PLACE IN A CLOSED CONTAINER, THERE IS A POSSIBILITY OF A VIOLENT RUPTURE. VAPORS FORM FLAMMABLE MIXTURE WITH AIR AT ELEVATED TEMPERATURES.

SECTION 3 REACTIVITY DATA

STABILITY: STABLE. POLYMERIZES SLOWLY AT ROOM TEMPERATURE; AVOID HEAT.
INCOMPATIBILITY: ACID, BASE, OXIDIZING MATERIAL.
HAZARDOUS DECOMPOSITION PRODUCTS: ----
HAZARDOUS POLYMERIZATION: MAY OCCUR. AVOID HEAT, METAL SALTS, SUCH AS FERRIC AND ALUMINUM CHLORIDES.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): SMALL SPILL OR LEAK: REMOVE FOR DISPOSAL BY COVERING WITH SUITABLE ABSORBING AGENT, SUCH AS SAND. IF SPILL OCCURS IN A CONFINED AREA, SUCH AS A DIKE, PUMP WATER INTO AREA; VINYLTOLUENE THEN CAN BE PUMPED OFF THE

(CONTINUED ON PAGE 2)

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES (CONTINUED)

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): (CONTINUED) WATER FOR RECOVERY.

DISPOSAL METHOD: INCINERATE IN PROPERLY DESIGNED FURNACE. COMPLY WITH FEDERAL, STATE AND LOCAL REGULATIONS.

SECTION 5 HEALTH HAZARD DATA

INGESTION: LOW SINGLE DOSE ORAL: LD50 (RATS) 4000 MG/KG.

EYE CONTACT: SLIGHT IRRITATION, BUT NO CORNEAL INJURY LIKELY.

SKIN CONTACT: SINGLE SHORT EXPOSURE -- NO IRRITATION LIKELY. PROLONGED OR REPEATED -- SLIGHT TO MODERATE IRRITATION EVEN A MINOR BURN POSSIBLE.

SKIN ABSORPTION: LOW TOXICITY: NO LD50 BECAUSE SKIN TESTS INDICATE NO ABSORPTION.

INHALATION: TLV: 100 PPM (1973).

EFFECTS OF OVEREXPOSURE: OBJECTIONABLE ODOR; EYE AND NASAL IRRITATION. HIGH LEVELS - ANESTHESIA. LOWER LEVELS - DIZZINESS AND DRUNKENNESS.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES: CAUTION - NEVER GIVE FLUIDS OR INDUCE VOMITING IF PATIENT IS UNCONSCIOUS OR HAVING CONVULSIONS.

EYES: FLUSH WITH PLENTY OF WATER, GET MEDICAL ATTENTION IF ILL EFFECTS DEVELOP.

SKIN: FLUSH WITH PLENTY OF WATER, GET MEDICAL ATTENTION IF ILL EFFECTS DEVELOP.

INHALATION: IF ILL EFFECTS OCCUR, PROMPTLY REMOVE PERSON TO FRESH AIR, KEEP HIM QUIET AND WARM AND GET MEDICAL ATTENTION. IF BREATHING STOPS, START ARTIFICIAL RESPIRATION.

INGESTION: CONTAINS PETROLEUM SOLVENT. ACTIVE INGREDIENT HAS A LOW ORAL TOXICITY. DO NOT INDUCE VOMITING. GIVE BLAND FLUIDS. IMMEDIATELY CONTACT A PHYSICIAN.

NOTE TO PHYSICIAN: THIS PRODUCT CONTAINS A PETROLEUM SOLVENT. A JUDGMENT AS TO THE ADVISABILITY OF GASTRIC LAVAGE MUST BE MADE BASED UPON THE TOXICITY OF THIS PRODUCT VERSUS THE HAZARD OF ASPIRATION. IF LAVAGE IS PERFORMED, THE USE OF A CUFFED ENDOTRACHEAL TUBE IS RECOMMENDED.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: NATURAL VENTILATION SUFFICIENT.

RESPIRATORY PROTECTION: UP TO 100 PPM -- NONE; 100 PPM AND ABOVE -- SELF CONTAINED BREATHING APPARATUS.

PROTECTIVE CLOTHING: CLEAN, BODY COVERING CLOTHING. PROVIDE WITH GLOVES MADE OF NEOPRENE OR NON-SOLUBLE PLASTIC.

(CONTINUED ON PAGE 3)

SECTION 7 SPECIAL HANDLING INFORMATION (CONTINUED)

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: AVOID BREATHING VAPORS IF GENERATED. AVOID SKIN AND EYE CONTACT. PRACTICE CARE AND CAUTION TO AVOID EXPLOSABILITY. MONITOR AND CONTROL INHIBITOR LEVEL AT >5 PPM. CONTROL TEMPERATURE IN STORAGE BELOW 90F. VAPOR IS 1.1 TIMES HEAVIER THAN AIR AT 100F AND HAS AN IGNITION TEMPERATURE OF 914F.

ADDITIONAL INFORMATION, IF ANY: ----

LAST PAGE

Specialty Chemicals

EXXON
CHEMICALS

Dicyclopentadiene 97

Specifications		Test Method	
		AMS	ASTM
Appearance	Clear and Free of Suspended Matter	80.65	
Color, Pt-Co	100 Max		D 1209
COMPOSITION — Avail. Monomers[1], Wt%		180.50	
Cyclopentadiene	97.0 Min		
Methylcyclopentadiene	2.5 Max		
Acyclic Dienes	2.5 Max		
Specific Gravity, 20/20 °C	0.97-0.985		D 1298
Inhibitor (p-Tertiary Butyl Catechol) ppm	100-200	as added	

[1] Cracked Analysis

Typical Analysis

		AMS	ASTM
Color Pt-Co	25		D 1290
Specific Gravity, 20/20 °C	.9765		D 1298
COMPOSITION — Avail. Monomers, Wt %		180.50	
C_5 Acyclics	1.4		
C_7 Cyclodienes	<.1		
Cyclopentadiene	98.3		
Methylcyclopentadiene	0.3		
DISTILLATION, °C			D 86
IBP	56		
10% Evaporated	157		
50% Evaporated	161		
95% Evaporated	169		
FPB	173		
Flash Point, (Tag Closed Cup) °F	66		D 56

Shipping Information

Shipping Weight (Approx) 60°F	8.17 lb/gal
Flash Point (Tag Closed Cup) °F	35

DANGER! EXTREMELY FLAMMABLE — MAY CAUSE FLASH FIRE
MAY CAUSE EYE IRRITATION — VAPORS IRRITANT

Refer to Material Safety Data Sheet
available from Exxon Chemical Company U.S.A. at address shown below.

EXXON CHEMICAL COMPANY U.S.A. • P.O. BOX 3272, HOUSTON, TEXAS 77001
An operating division of EXXON CHEMICAL COMPANY, a division of EXXON CORPORATION

SC-78-134

PRINTED IN U.S.A.

MSDS-07B
April 15, 1976
(Supersedes MSDS-07A
Page 1 of 2

HERCULES

MATERIAL SAFETY DATA SHEET

(Approved by U.S. Department of Labor as "Essentially Similar" to Form OSHA-20)

I. PRODUCT IDENTIFICATION

CHEMICAL NAME	Para-Menthadiene	**REGULAR TELEPHONE NO.** 302–575-5000 **EMERGENCY TELEPHONE NO.** 800–424-9300	
SYNONYMS:	Dipentene, phellandrene, terpinene, terpinolene (isomer names)	**CHEMICAL FAMILY:**	Terpene hydrocarbon
FORMULA:	$C_{10}H_{16}$	**MOLECULAR WEIGHT:**	136
TRADE NAME AND SYNONYMS:	Dipentene No. 122®, Dipentene No. 213™, Solvenol® 1, and Solvenol 2		

II. HAZARDOUS INGREDIENTS

MATERIAL	%	TLV (UNITS)
Not applicable		

III. PHYSICAL DATA

BOILING POINT, 760 mm Hg	174-187°C (281-305°F)	**FREEZING POINT:**	Below -40°C (-40°F)
SPECIFIC GRAVITY (H_2O = 1)	0.854	**VAPOR PRESSURE @**	22°C: 2 mm Hg
VAPOR DENSITY (AIR = 1)	4.9	**SOLUBILITY IN WATER, % BY WT. @**	20°C: Slight
PERCENT VOLATILES BY VOLUME	100	**EVAPORATION RATE (BUTYL ACETATE = 1)**	Less than 1; slower
APPEARANCE AND ODOR	Clear, colorless liquid; pleasant, pinelike odor		

IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (TEST METHOD)	115-120°F (46-49°C), TCC		**AUTOIGNITION TEMPERATURE**	458°F (237°C)	
FLAMMABLE LIMITS IN AIR, % BY VOLUME	**LOWER**	0.7	**UPPER**	6.1	
EXTINGUISHING MEDIA	Water fog, foam, carbon dioxide, dry chemical				
SPECIAL FIRE-FIGHTING PROCEDURES	Cool containers with water if exposed to fire.				
UNUSUAL FIRE AND EXPLOSION HAZARDS	Not applicable				

ORGANICS DEPARTMENT
HERCULES INCORPORATED
WILMINGTON, DELAWARE 19899

V. HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE	Not established
EFFECTS OF OVEREXPOSURE	Solvent action may defat skin
EMERGENCY AND FIRST-AID PROCEDURES	Eyes: Flush with water for 15 minutes, forcibly holding eyelids open. Call physician. Skin: Wash with soap and water. Remove contaminated clothing. Inhalation: Remove victim from contaminated area. Administer artificial respiration if necessary. Call physician.

VI. REACTIVITY DATA

STABILITY		CONDITIONS TO AVOID	
UNSTABLE	STABLE		Not applicable
	X		

INCOMPATIBILITY (MATERIALS TO AVOID)	Acid catalysts, strong oxidizers
HAZARDOUS DECOMPOSITION PRODUCTS	Burning liberates CO, CO_2, and smoke.

HAZARDOUS POLYMERIZATION		CONDITIONS TO AVOID	
MAY OCCUR	WILL NOT OCCUR		Not applicable
	X		

VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED	Salvage in metal container. Remove sources of ignition.
WASTE DISPOSAL METHOD	Incinerate. Waste disposal must be in accordance with local, state, and Federal regulations.

VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (SPECIFY TYPE)	Not applicable			
VENTILATION	LOCAL EXHAUST		SPECIAL	
	MECHANICAL (GENERAL)	X	OTHER	
PROTECTIVE GLOVES	Solvent-resistant rubber	EYE PROTECTION	Safety glasses	
OTHER PROTECTIVE EQUIPMENT	Not applicable			

IX. SPECIAL PRECAUTIONS

PRECAUTIONARY LABELING	Combustible – Keep Away From Open Flame.
OTHER HANDLING AND STORAGE CONDITIONS	Not applicable

HERCULES **PRODUCT data**

NUMBER 708-7

SOLVENOL® 2 Terpene Solvent

A High-Solvency Terpene Hydrocarbon

SOLVENOL® 2 is a pale yellow to near colorless liquid that has high solvency for resins, waxes, and greases. It is exceptionally effective as a softening and swelling agent for rubber. Of pinewood origin, it is a mixture of monocyclic terpenes similar to those comprising Solvenol 1, but in different proportions to one another and slightly broader in distillation range. It is comparable in solvent power with Solvenol 1 and, like the latter, is a stronger solvent than turpentine for waxes and resins.

Product Specification[1]

Specific gravity at 15.6/15.6°C	0.845-0.870
Distillation range, °C first cc	168 min
95%	195 max

---

[1] Hercules test methods used are available on request.

Typical Properties

Specific gravity at 15.6/15.6°C	0.860
Distillation range, °C, 5%	174
95%	183
Color, Hazen	45
Freezing point, °C	<-40
Flash point, Tag. closed cup, °F (°C)	115 (46)
Kauri-butanol value	80
Aniline point, °F (°C)	<23 (<-5)

Outstanding Characteristics

Clear, near colorless liquid; high solvent power; highly effective softening and swelling agent for natural and synthetic rubbers.

Typical Uses

Solvenol 2 is an excellent solvent for a wide variety of natural and synthetic resins, waxes, greases, and oils. Because of its softening and swelling action on rubber, Solvenol 2 is an outstanding reclaiming agent for natural and synthetic rubbers. In this application, it is generally used in conjunction with dark tackifier resins. Since Solvenol 2 does not migrate from reclaimed rubber, it contributes nonstaining properties to such compounds. Other applications for Solvenol 2 include its use as a modifier for protective coating solvents, and as a specialty solvent for a variety of uses that require a moderately volatile, high-solvent-power liquid with a pleasant odor.

(over)

ORGANICS DEPARTMENT

Available Forms: Liquid, in tank cars, tank trucks, and in 55-gallon (208-liter) drums (389 lbs, 177 kg, net wt).

FDA Status

Solvenol 2 is cleared by the U.S. Food and Drug Administration for use in food packaging as specified in the Code of Federal Regulations, Title 21, under Section 175.105, formerly Section 121.2520.

OSHA Status

As Hercules interprets the U.S. Occupational Safety and Health Act of 1970, Solvenol 2 is a hazardous material because it is combustible. It has a TCC flash point of 115°F (46°C). A Material Safety Data Sheet is available.

TABLE 1. PHYSICAL PROPERTIES

PROPERTY	Temp. °C	STYRENE	VINYL-TOLUENE	DIVINYLBENZENE DVB-55
1. Molecular Weight		104.153	118.180	130.191
2. Boiling Point, °C at 760 mm		145.15	167.7	195.
3. Critical Density, dc g/ml		0.297		
3a. Pseudocritical Density, dc g/ml			0.272	
4. Critical Pressure, Pc atm.		37.8		
4a. Pseudocritical Pressure, Pc atm.			32.5	24.3
5. Critical Temperature, tc °C		362.1		
5a. Pseudocritical Temperature, tc °C			395.	369.
6. Critical volume, vc ml/g		3.37		
6a. Pseudocritical Volume, vc ml/g			3.68	
7. Density, g/cc	0	0.92393		
	10	0.91506		
	20	0.90620	0.8973	0.9123
	25	0.90177	0.8930	0.9084
	30	0.89734	0.8889	0.9044
	40	0.88847	0.8805	
	50	0.87960		
	60	0.87074	0.8639	
	70	0.86188		
	80	0.85301	0.8469	
	90	0.84414		
	100	0.83528		
	110	0.82642		
	120	0.81755		
	130	0.80868		
	140	0.79982		
	150			
	160			

TABLE 1. PHYSICAL PROPERTIES—Continued

PROPERTY	Temp. °C	STYRENE	VINYL-TOLUENE	DIVINYLBENZENE DVB-55
8. Density, lb/gal	15	7.60	7.52	
	20	7.56	7.49	7.61
	25	7.53	7.45	7.58
	30	7.49	7.42	7.55
9. Flammable Limits	not obtainable below 100°F and at atmospheric pressure			
10. Flash Point, °F Tag Closed Cup		88 (31.1°C)	123 (50.5°C)	157 (69.4°C)
11. Auto Ignition Temp., °F		914 (490°C)	1067 (575°C)	941 (505°C)
12. Freezing Point, °C		−30.6	−77	−45
13. Heat of Combustion, Δ Hc, Kcal/mole at constant pressure. All reactants and products gases	25	−1018.83	−1162.98	
14. Heat of formation, Δ Ht, Kcal/mole—gas	25	35.22	27.52	
Liquid	25	24.72		
15. Heat of fusion, Δ Hm, cal/mole		2630.		
16. Heat of polymerization, Δ Hp. Kcal/mole	25	16.68	16.0±1.0	
17. Heat of vaporization, Δ Hv, cal/g	25	100.8	101.84	
	B. Pt	85.25	83.47	83.8
18. Refractive Index, D-Line	15	1.54969		
	20	1.54682	1.54220	
	25	1.54395	1.53951	1.5585
	30	1.54108	1.53415	
	35	1.53821	1.53437	

*For other operating conditions, the literature should be consulted.

3

TABLE 1. PHYSICAL PROPERTIES—Continued

PROPERTY	Temp, °C	STYRENE	VINYL-TOLUENE	DIVINYLBENZENE DVB-55
19. Solubility in Acetone	25	∞	∞	∞
Carbon Tetrachloride	25	∞	∞	∞
Benzene	25	∞	∞	∞
Ether	25	∞	∞	∞
n-Heptane	25	∞	∞	∞
Ethanol	25	∞	∞	∞
Water, %	25	0.032	0.0089	0.0052
Water in, %	25	0.070	0.047	0.054
20. Specific heat liquid, cp cal/g°C)	0	0.4004		
	20	0.4131	0.410	
	40	0.4269	0.428	
	50			
	60	0.4421		
	70			
	80	0.4590		
	90			
	100	0.4774		
	120	0.4969		
	140	0.5174		
21. Specific heat vapor, cp cal/g°C)	25	0.2802	0.2953 (27°C)	
22. Surface Tension dynes/cm	0	34.5		
	20	32.3	31.66	
	25	31.7	31.0	32.10
	30	31.2	30.52	
	40	30.0	29.52	
	60	27.8	28.7 (60°C)	
	80	25.6		
	100	23.5	23.0	
	120	21.5		
	140	19.4		
	160			

4

TABLE 1. PHYSICAL PROPERTIES—Continued

PROPERTY	Temp °C	STYRENE	VINYL-TOLUENE	DIVINYLBENZENE DVB-55
23. Vapor Pressure mm/Hg	0	1.15		
	10	2.34		
	20	4.50	1.10	
	30	8.21	2.22	
	40	14.30	4.23	
	50	23.87	7.64	
	60	38.41	13.23	
	70	59.78	22.00	
	80	90.31	35.32	
	90	132.82	54.92	
	100	190.63	82.98	
	110	267.62	122.15	
	120	368.22	175.61	
	130	497.39	247.08	
	140	660.64	340.87	
	150	864.00	461.86	
	160	1113.97	615.52	
24. Viscosity, cps	0	1.039		
	20	0.762	0.837	
	25			1.007
	40	0.588	0.644	
	60	0.469	0.518	
	80	0.385	0.428	
	100	0.324		
	120	0.279		
	140	0.243		
	160			
25. Cubical Coefficient Of Expansion	20	9.783×10^{-4}	9.361×10^{-4}	8.659×10^{-4}
	30	9.879×10^{-4}	9.450×10^{-4}	8.735×10^{-4}
	40	9.978×10^{-4}	9.540×10^{-4}	
26. Q Value		1.0	1.06	
27. E Value		−0.8	−0.78	
28. Volumetric Shrinkage upon Polymerization (Typical)		17.0%	12.6%	