Technical Report Documentation Page

1. Report No. FHWA-IP-82-14	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EPOXY THERMOPLASTIC TRAFFIC MARKING MATERIAL		5. Report Date July 1982
		6. Performing Organization Code
7. Author(s) Charles W. Niessner		8. Performing Organization Report No. FHWA-IP-82-14
9. Performing Organization Name and Address U.S. Department of Transportation Federal Highway Administration Office of Implementation Washington, D.C. 20590		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Highway Administration Office of Research Development and Technology Washington, D.C. 20590		13. Type of Report and Period Covered Final
		14. Sponsoring Agency Code

15. Supplementary Notes

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16. Abstract

This Implementation Package summarizes the result of an effort to develop a more durable traffic marking material-Epoxy Thermoplastic (ETP). The report includes background information on the development of ETP, a discussion of the field tests and evaluations, the material composition and equipment modifications for applying ETP. The package also includes material specifications for purchasing ETP and specifications for the application of ETP by contract.

17. Key Words Epoxy Thermoplastic, Traffic Markings, Striping Equipment	18. Distribution Statement No restriction. Available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 57	22. Price

Form DOT F 1700.7 (8-72)

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INTRODUCTION

Epoxy Thermoplastic (ETP) pavement marking material is a joint development of the Southwest Research Institute (SWRI) and the Federal Highway Administration (FHWA) research staff. It is generic material consisting of two epoxy resins, pigment, filler and glass beads.

Between 1975-79 two formulations were extensively field tested. These formulations differed only in the ratio of the two epoxy resins, one a liquid, the other a solid. The one formulation consisted of a 60:40 ratio of solid resin to liquid resin and the other was a 50:50 mixture. Based on the results of the field tests the 60:40 ratio was selected as the single formulation. ETP is applied as a hot spray at 450 F. It requires no primer and can be applied on either asphalt or portland cement concrete surfaces or over existing paint stripes with removal of the loose paint by brushing or other suitable methods. The recommended application thickness is 15 to 20 mils. Drop on glass beads are applied at the rate of 4-6 pounds per gallon.

ETP is a 100 percent solids formulation and contains no solvents or other volatile components. In field testing its no-track time is less than 5 seconds so that coning is not neccesary during application. When formulated according to specifications ETP has a pot life of at least four hours.

During the development phase of the SWRI study, numerous field test sections were placed in Texas and Colorado between 1974 and 1976. A program of large field installations was begun in 1978 to assess ETP durability and performance under extreme traffic loading and climatic conditions. This program was followed in 1979 by a series of smaller installations in other locations in connection with the demonstration of the ETP technology to interested State, municipal and private sector personnel. The details of the 1978 series of installations are presented in Table 1.

The evaluation of the performance of the field test installations (Table 1) was recently completed. In Minnesota,after 28 months exposure including two winters, the ETP on asphalt concrete (AC) surfaces continues to perform satisfactorily. Significant loss of the drop-on beads occurred, but adequate reflectivity is maintained by exposure of the premixed beads. The average material loss per stripe is 10 percent, due to abrasion rather than chipping. On the portland cement concrete (PCC) surface, more wear has taken place; on the average, material loss from each stripe is 50 percent, again through abrasion rather than chipping. Loss of drop-on beads has been severe, but premixed beads are providing adequate reflectivity.

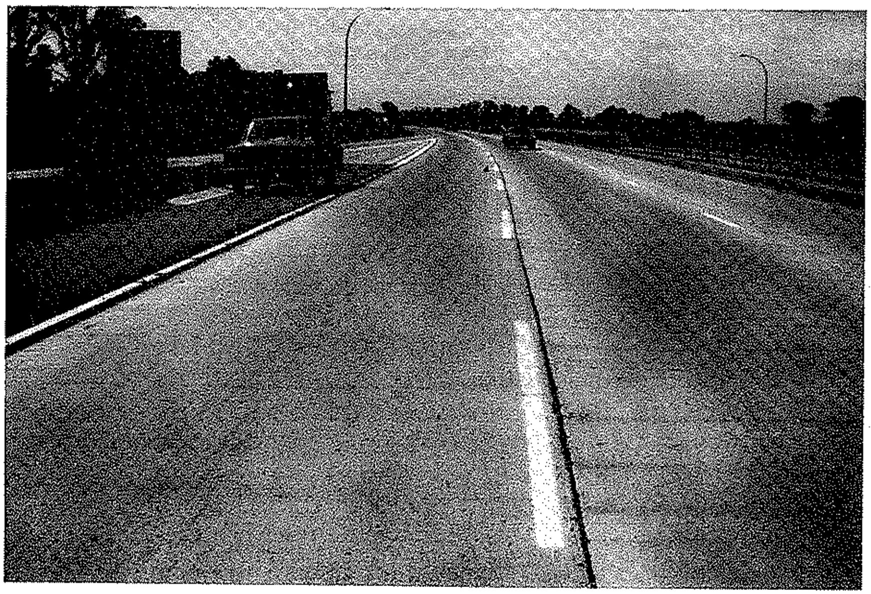


Figure 1. ETP on Portland Cement Concrete Pavement (I-35 Minnesota) in June 1978 (ETP Stripe in Foreground)

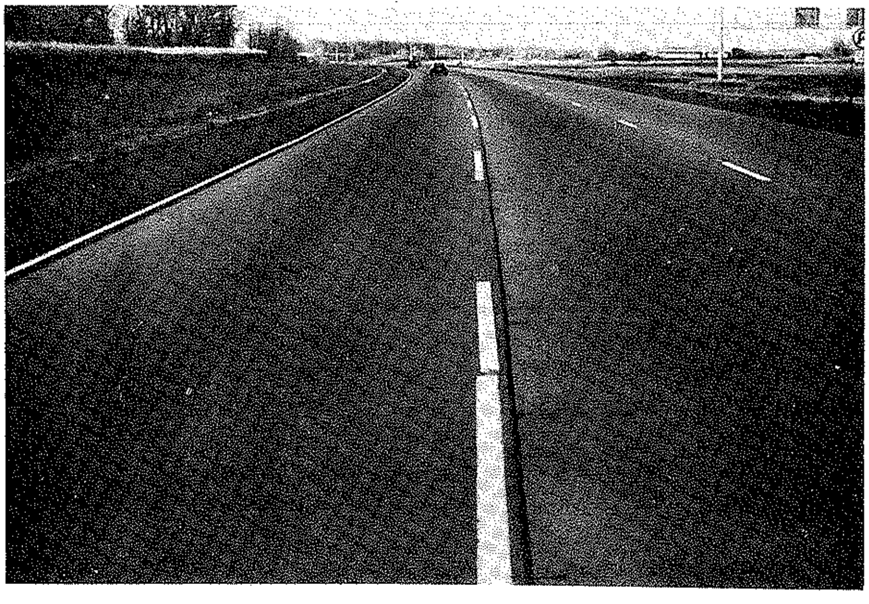


Figure 2. ETP on Portland Cement Concrete Pavement (I-35 Minnesota) After 28 Months (ETP Stripe in Background)

TABLE 1[1]

ETP Field Test Installations (1978 Series)

Date	State	Location	ADT	Details of Installation
June 1978	Minnesota	I-35, approximately 25 miles north of St. Paul	22,000	8.33 Lane miles of 10/40 skip stripes applied over bare pavement on both asphalt and portland cement concrete pavements.
June 1978	Colorado	I-70 westbound, approximately 10 miles west of Denver in Golden	27,000	6.33 Lane miles of 10/30 skip stripes applied over bare pavement on both asphalt and portland cement concrete pavements.
October 1978	California	Pacific Coast Highway between Hermosa Beach and Redondo Beach in Los Angeles County	42,000	4 Lane miles of 6/36 skip stripes applied one-half on and off existing paint stripes on both asphalt and portland cement concrete pavements.
October 1978	California	S.R. 99 northbound, 30 miles south of Fresno	28,000	6 miles of 6/36 skip stripes applied on bare pavement on both asphalt and portland cement concrete surfaces.
October 1978	California	I-80 westbound, west of Donner Pass	17,000	2.3 miles of 6.36 skip stripes applied one-half on and off existing paint stripes on portland cement concrete surface.

Table 1 (Cont.)

Date	State	Location	ADT	Details of Installation
November 1978	Texas	IH-35 southbound, approximately 20 miles south of San Antonio	12,500	3.06 Lane miles of 10/30 skip stripes applied over existing paint stripes on asphalt and portland cement concrete (bridge decks) surfaces.
February 1979	Colorado	U.S. 40, 12 miles east of Denver in Aurora	13,500	1.45 Lane miles, east and west bound, of 10/30 skip stripes on bare asphalt concrete pavement; applied at air temperature 31F, pavement temperature of 22F.

In California, the Los Angeles and Fresno sites, after 24 months exposure, show little evidence of loss of material through wear, and no evidence of chipping. The day and night appearance of stripes are completely satisfactory; although drop-on beads have been lost, adequate reflectivity is maintained by exposure of premixed beads. After 1.5 years, State personnel had noted that the Los Angeles test section was "in excellent condition, showing good wearability, bead retention, and nightime reflectance."

The Fresno test section also was noted as performing in a satisfactory manner. The Donner Pass site was virtually worn away within three months of installation by a combination of snow-plowing, abrasives, and tire chains. State personnel reported that the ETP was gone at the end of two snowstorms, versus one storm for the paint control section. (It is interesting to note that the PCC pavement at this site is heavily worn in the wheel-paths.)

The Texas site continues to provide excellent wear after 30 months' service. Some greater than expected drop-on bead loss was experienced early at this test section. It is thought that this loss is due to the use of State specification glass beads in lieu of treated beads that were used at the other sites. These beads are treated to harden their surface and make them resistant to chemical attack. In any event, adequate reflectivity has been maintained by exposure of premixed beads.

The Texas site is predominately AC surface, except for several PCC bridge decks. Some stripes on the bridge decks have experienced loss of material, presumably due to loss of adhesion of the underlying paint. Such losses however, have not been apparent in Los Angeles and Fresno where the ETP markings were applied one-half on and off existing paint stripes.

The I-70 site in Colorado experienced severe wear. This site receives a mixture of heavy truck and passenger car traffic with a high percentage of studded tire usage; it is on a curving roadway section with a sharp, climbing grade requiring heavy use of salt and abrasives during the winter. On an average for the entire section, State personnel estimated that the ETP provided twice the service life of traffic paint. On the AC section, the effective service life was longer than average. The best individual performance was experienced on the portland cement concrete section where stripe retention was 75 to 80 percent on the left lane line after ten months.

The U.S. 40 site in Colorado (Figure 3) was placed in late winter to determine whether ETP could be applied in below freezing weather. For this test only, the application temperature was elevated to 485 F, and successful application on a 22 F pavement was made. The application was completely satisfactory, and after 30 months the stripes continue to provide satisfactory delineation (Figure 4).

Figure 3. ETP Bituminous Concrete Pavement (US 40 Colorado) in March 1979.

Figure 4 ETP on Bituminous Concrete Pavement (US 40 Colorado) After 30 Months (ETP Stripes in Background).

The 1979 field test demonstration installations were not intended for frequent monitoring to determine trends in serviceability. However, recent, informal inspections of all these installations indicate continued good performance under day and night conditions. In each case, the demonstrated service life has far exceeded that of traffic paint in the same location. For example, the Illinois test section located at the junction of Wabash Street and MacArthur Boulevard is a 600 foot radius curve, four lanes with no divider, and 20,000 AADT. After one year's service, the ETP stripes were, on average, 40 percent intact. In contrast,traffic paint on this section historically has a service life of four to five weeks .

MATERIAL

Composition

ETP is a blend of two epoxy resins, pigment, filler and glass beads in the following proportions:

Solid resin:	30 parts by weight solid epoxy resin,
Liquid resin:	20 parts by weight liquid epoxy resin,
Pigment:	10 parts by weight titanium dioxide, (white formulation) or 9.26 parts by weight silica encapsulated lead chromate, medium yellow pigment (yellow formulation)
Filler:	10 parts by weight calcium carbonate
Beads:	14 parts by weight standard premixed glass beads

ETP weights approximately 13.1 pounds per gallon.

Listed below are potential suppliers of the raw materials required in the manufacture of ETP. These are not qualified product lists. The lists are based on information provided by the manufacturer in identifying possible materials for the ETP[2].

Additional information on the materials and suppliers may be found in National Paint and Coatings Association Raw Materials indexes, 1980 Edition, National Paint and Coatings Association, 1600 Rhode Island Avenue, Washington, D.C 20005.

Epoxy Resins	Solid	Liquid
Celanese Polymer Specialties Co., Louisville, Kentucky	EPI-REZ 54 OC	EPI-REZ 510
CIBA-GEIGY Corp., Ardsley, N.Y.	Araldite 7090	Araldite 6010
Dow Chemical Co., Midland, Michigan	DER 667	DER 331
Reichold Chemicals Co., White Plains, N.Y.	EPOTUF 37-006	EPOTUF 37-14
Shell Chemical Co., Houston, Texas	EPON 1007 F	EPON 828

Titanium Dioxide

American Cyanamid Co., Bound Brook, N.J
E.I. Dupont de Nemours & Co., Inc.,Wilmington, Delaware
G&W Natural Resources Group, Bethlehem, Pennsylvania
Glidden-Durkee, Division SCM Corp., Baltimore, Maryland
Ishihara Corp., San Franciso, California
Kerr-McGee Chemical Corp., Oklahoma City, Oklahoma
NL Chemicals, Hightstown, N.J.
Tioxide America, Inc., Columbia., Maryland

Calcium Carbonate[b]

Calcium Carbonate Co., Quincy, Illnois
Engelhard Minerals & Chemicals Corp., Edison, N.J.
Flintkote Stone Products Co., Hunt Valley, Maryland
Georgia Marble Co., Tate, Georgia
Hammill & Gillespie, Inc., Livingston, N.J.
OMYA, Inc., Proctor Vermont
Pfizer Corp., Easton, Pennsylvania
Smith Chem. & Color Co., Inc., Jamaica, L.I., N.Y.
Sylacauga Calcium Products, Sylacauga, Alabama
Thompson, Weinman & Co., Cartersville, Georgia
Whittaker, Clark & Daniels, Inc., South Plainfield, N.J.

Lead Chromate

CIBA-GEIGY Corp., Ardsley, N.Y.[a]
Rampart S-4075

E.I. Dupont de Nemours & Co., Inc., Wilmington, Delaware
Krolor KY-795-D

Beads

Cataphote Division, Ferro Corp., Jackson, Mississippi[a]
Flex-o-Lite St. Louis, Missouri
Pavemark Corp. Smyrna, Georgia
Potters Industries, Inc., Hasbrouk Heights, N.J.

[a] Supplier of material used in original ETP compounds.

[b] Because of the strong influence of this pigment upon ETP viscosity, it is recommended that the viscosity of the ETP formulation be used to determine acceptance. While materials not meeting the specification for the filler are known to be unacceptable there are no assurances, at present, that a material meeting the calcium carbonate specification will produce an acceptable ETP without checking it.

Specification

The specification covering white and yellow ETP hot spray pavement marking material is included in Appendix A. The specification includes various physical and chemical property requirements of the ETP and the individual components. It also contains all of the test procedures to measure these properties.

APPLICATION

Equipment

Epoxy Thermoplastic gains its outstanding adherence to different types of pavement surfaces by being applied at 450 F (232 C). To minimize cooling of ETP on application it is recommended that the atomizing air, if used, be heated to a minimum of 350 F.

The application equipment used by SWRI for the field evaluations is shown in Figure 5 and in schematic form in Figure 6. It consists of certain basic components: a pressure tank, a mixer, an oil jacketed discharge line, an oil pump to circulate the oil around the tank, an oil pump to circulate the oil around the tank and the discharge line, a flexible or rigid delivery line from the oil jacketed delivery line to a 90 full open -full closed ball valve, a fan spray nozzle screwed directly into the valve, and an electrical resistance heater wrapped around the delivery line, valve and fan spray nozzle. All of the above components are suitably shielded and insulated.

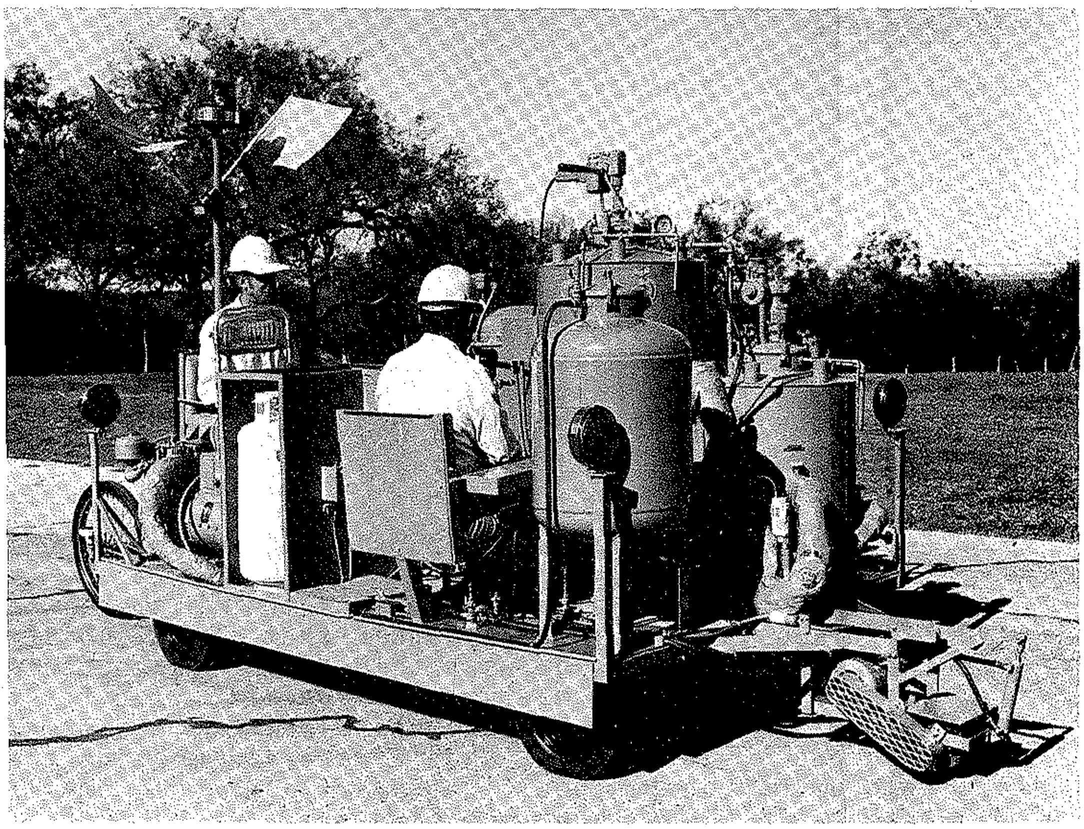
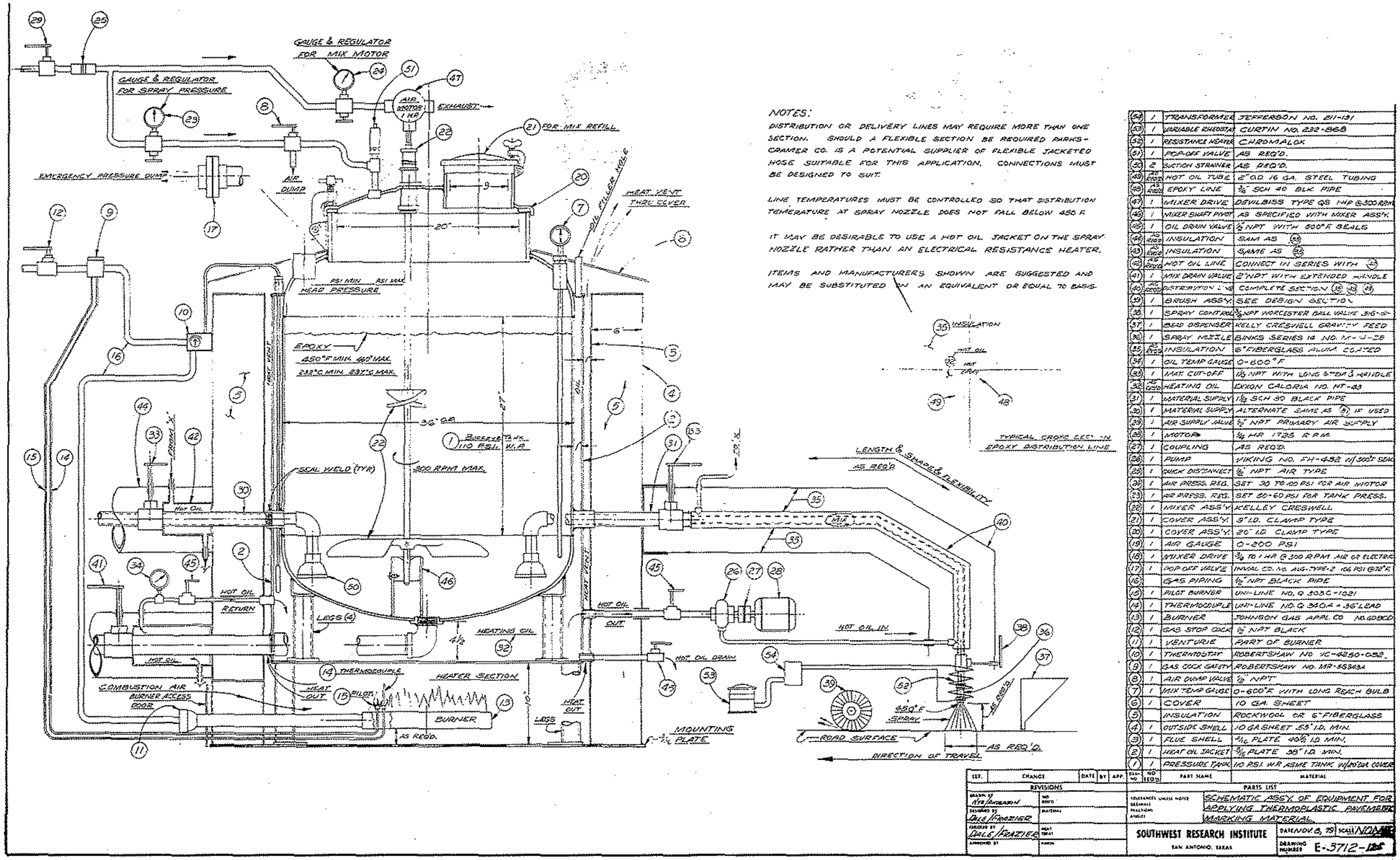


Figure 5. Application Equipment Used for the Field Evaluations



NOTES:

DISTRIBUTION OR DELIVERY LINES MAY REQUIRE MORE THAN ONE SECTION. SHOULD A FLEXIBLE SECTION BE REQUIRED PARKS-CRAMER CO. IS A POTENTIAL SUPPLIER OF FLEXIBLE JACKETED HOSE SUITABLE FOR THIS APPLICATION. CONNECTIONS MUST BE DESIGNED TO SUIT.

LINE TEMPERATURES MUST BE CONTROLLED SO THAT DISTRIBUTION TEMERATURE AT SPRAY NOZZLE DOES NOT FALL BELOW 450 F

IT MAY BE DESIRABLE TO USE A HOT OIL JACKET ON THE SPRAY NOZZLE RATHER THAN AN ELECTRICAL RESISTANCE HEATER.

ITEMS AND MANUFACTURERS SHOWN ARE SUGGESTED AND MAY BE SUBSTITUTED ON AN EQUIVALENT OR EQUAL TO BASIS.

DASH NO	NO REQ'D	PART NAME	MATERIAL
(54)	1	TRANSFORMER	JEFFERSON NO. 211-131
(53)	1	VARIABLE RHEOSTAT	CURTIN NO. 232-868
(52)	1	RESISTANCE HEATER	CHROMALOX
(51)	1	POP-OFF VALVE	AS REQ'D.
(50)	2	SUCTION STRAINER	AS REQ'D.
(49)	AS REQ'D	HOT OIL TUBE	2" O.D. 16 GA. STEEL TUBING
(48)	AS REQ'D	EPOXY LINE	3/4" SCH 40 BLK. PIPE
(47)	1	MIXER DRIVE	DEVILBISS TYPE QS 1-HP @300 RPM
(46)	1	MIXER SHAFT PIVOT	AS SPECIFIED WITH MIXER ASS'Y.
(45)	1	OIL DRAIN VALVE	1/2" NPT WITH 500°F SEALS
(44)	AS REQ'D	INSULATION	SAM AS (35)
(43)	AS REQ'D	INSULATION	SAME AS (35)
(42)	AS REQ'D	HOT OIL LINE	CONNECT IN SERIES WITH (2)
(41)	1	MIX DRAIN VALVE	2" NPT WITH EXTENDED HANDLE
(40)	AS REQ'D	DISTRIBUTION LINE	COMPLETE SECTION (35) (43) (48)
(39)	1	BRUSH ASSY.	SEE DESIGN SECTION
(38)	1	SPRAY CONTROL	3/8" NPT WORCESTER BALL VALVE 316-S-
(37)	1	BEAD DISPENSER	KELLY CRESWELL GRAVITY FEED
(36)	1	SPRAY NOZZLE	BINKS SERIES 14 NO. M-4-25
(35)	AS REQ'D	INSULATION	6" FIBERGLASS ALUM. COATED
(34)	1	OIL TEMP GAUGE	0-600°F
(33)	1	MAT. CUT-OFF	1½ NPT WITH LONG STEM & HANDLE
(32)	AS REQ'D	HEATING OIL	EXXON CALORIA NO. HT-43
(31)	1	MATERIAL SUPPLY	1½ SCH 80 BLACK PIPE
(30)	1	MATERIAL SUPPLY	ALTERNATE SAME AS (31) IF USED
(29)	1	AIR SUPPLY VALVE	1/2" NPT PRIMARY AIR SUPPLY
(28)	1	MOTOR	1/4 HP 1725 R.P.M.
(27)	1	COUPLING	AS REQ'D.
(26)	1	PUMP	VIKING NO. FH-432 W/500°F SEAL
(25)	1	QUICK DISCONNECT	1/2" NPT AIR TYPE
(24)	1	AIR PRESS. REG.	SET 30 TO 100 PSI FOR AIR MOTOR
(23)	1	AIR PRESS. REG.	SET 50-60 PSI FOR TANK PRESS.
(22)	1	MIXER ASS'Y.	KELLEY CRESWELL
(21)	1	COVER ASS'Y.	9" I.D. CLAMP TYPE
(20)	1	COVER ASS'Y.	20" I.D. CLAMP TYPE
(19)	1	AIR GAUGE	0-200 PSI
(18)	1	MIXER DRIVE	3/4 TO 1 HP @ 300 RPM AIR OR ELECTRIC
(17)	1	POP-OFF VALVE	INVAL CO. NO. A1G-TYPE-2 166 PSI @72°F.
(16)		GAS PIPING	1/2" NPT BLACK PIPE
(15)	1	PILOT BURNER	UNI-LINE NO. Q 305C-1021
(14)	1	THERMOCOUPLE	UNI-LINE NO. Q 340A - 36" LEAD
(13)	1	BURNER	JOHNSON GAS APPL. CO NO. 6050D
(12)	1	GAS STOP COCK	1/2" NPT BLACK
(11)	1	VENTURIE	PART OF BURNER
(10)	1	THERMOSTAT	ROBERTSHAW NO 1C-4250-052
(9)	1	GAS COCK SAFETY	ROBERTSHAW NO. MR-56543A
(8)	1	AIR DUMP VALVE	1/2" NPT
(7)	1	MIX TEMP GAUGE	0-600°F WITH LONG REACH BULB
(6)	1	COVER	10 GA. SHEET
(5)		INSULATION	ROCKWOOL OR 6" FIBERGLASS
(4)	1	OUTSIDE SHELL	10 GA SHEET 53" I.D. MIN.
(3)	1	FLUE SHELL	5/16 PLATE 40½" I.D. MIN.
(2)	1	HEAT OIL JACKET	3/16 PLATE 38" I.D. MIN.
(1)	1	PRESSURE TANK	110 PSI. W.P. ASME TANK W/20" DIA COVER

PARTS LIST

LET.	CHANGE	DATE	BY	APP.

REVISIONS

DRAWN BY NYE/ANDERSON
DESIGNED BY DALE/FRAZIER
CHECKED BY DALE/FRAZIER
APPROVED BY

NO. REQ'D
MATERIAL
HEAT TREAT
FINISH

TOLERANCES UNLESS NOTED
DECIMALS
FRACTIONS
ANGLES

SCHEMATIC ASSY. OF EQUIPMENT FOR APPLYING THERMOPLASTIC PAVEMENT MARKING MATERIAL

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO, TEXAS

DATE NOV. 6, 79
SCALE NONE
DRAWING NUMBER E-3712-125

Figure 6. Schematic of Application Equipment

Equipment Modification

The Illinois Department of Transportation has converted a conventional unheated paint striper to apply ETP.

The machine available for conversion was a conventional cold-paint PRISMO striper mounted on a 1972 INTERNATIONAL Model CO 1600, 22,000 GVW truck. It had been stripped of paint tanks, air compressor, guns, intercom system, and skip-timer. Available for reuse were the platform, bead tank, solvent tank, control console, various solenoid-controlled valves, and the two power-steered gun carriages, which were formerly powered by a hydraulic pump on the air compressor.

In a time of limited budgets and shrinking manpower, it was decided the machine should be capable of operation with a minimum of support equipment. This feature was also dictated by the intention of using the machine throughout the State rather than equipping each District with a similar machine. The decision was made, therefore, to incorporate the preheating or melting equipment on the striping vehicle itself rather than on a separate vehicle.

It was recognized the preheating (melting) function would consume a substantial amount of time and, on any start-up, would delay actual striping operations as long as it took to heat and transfer an initial batch of material. It was desirable to have the melting tank capacity somewhat greater than the application tank capacity so that succeeding batches, if any, could make use of a reservoir of heated liquid material into which the cold material could be introduced. The weight of the materials in both tanks, plus a reasonable bead supply, should not exceed the load capacity of the truck. Other significant weights going into this equation were those of the heating furnace and its fuel, the heat exchange medium (oil), pumps and plumbing, and the electrical generator. An application (pressure) tank size of approximately 90 useable gallons and a melter volume of approximately 140 gallons were selected. This application tank capacity is sufficient to apply approximately 20 miles of 1:3 skip-dash or 5 miles of solid 4-inch line on one charge. These productions can be accomplished in one to four hours. With preliminary heating and material transfer time,this should permit the application of approximately two full tanks (10 miles) of solid line or 1 1/4 tanks (25 miles) of skip-dash line in a ten-hour day.

The limited volume of compressed air required is within the capability of a standard truck air brake compressor driven by the truck engine. A furnace of suitable capacity was obtained commercially. Pumps, valves, agitator, controls, etc., were assumed to be adaptable from other striping applications. A commercially available small gasoline driven motor-generator was assumed to be sufficient.

The only items requiring custom building were the two jacketed tanks (melter and application) and the jacketed portions of the ETP lines.

Ease of maintenance was served by the generous use of unions and valves in the plumbing system and the decision to keep most of the plumbing on the top side of the truck platform. Maximum use of standard parts, as indicated in the previous objective, also served this purpose.

Since ETP is a thermoplastic material, purging of the machine for maintenance purposes can only be accomplished while it is hot, and conventional solvents cannot be used. Simply emptying the system of drainable material is assumed to be sufficient for normal shut-down purposes. More thorough purging, if necessary, will probably have to be accomplished by flushing with the liquid resin component of ETP under heated conditions.

Working an operating furnace and high-temperature pressurized materials on a moving vehicle in traffic carries with it a certain irreducible amount of inherent hazard. Some measures can be taken, however, such as providing insulation on heated surfaces, physically separating the furnace from the fuel supply as far as practicable, using a nonflashing heat transfer medium, protecting the operator's stations in so far as possible and providing highly visible rotating lights and a lighted arrow board to command the attention of other highway traffic. Limit controls on the heat and pressure systems, and various valves permitting the isolation of different parts of the plumbing system also serve in the interest of safety. Fire extinguishers are mounted on both sides of the platform.

The following is a description of the various system on the Illinois striper:

1 .<u>General Configuration</u> (Figures 7-13). The melter tank is mounted on the front center of, and elevated above, the truck platform. The expansion/reservoir tank for the heating oil is at the left forward corner with its upper end a little higher than the top of the melter tank. The furnace is located beneath the platform at the same corner. The gasoline-powered electrical generator is located on the right front corner with steps to a platform over the generator. This platform serves as a worker station in charging the melter tank. Furnace and truck/generator fuel tanks are mounted below the platform on the right side beneath the generator.

The pressurized application tank is set vertically into the platform between the frame rails of the truck and just aft of the melter tank. Directly behind the pressure tank is

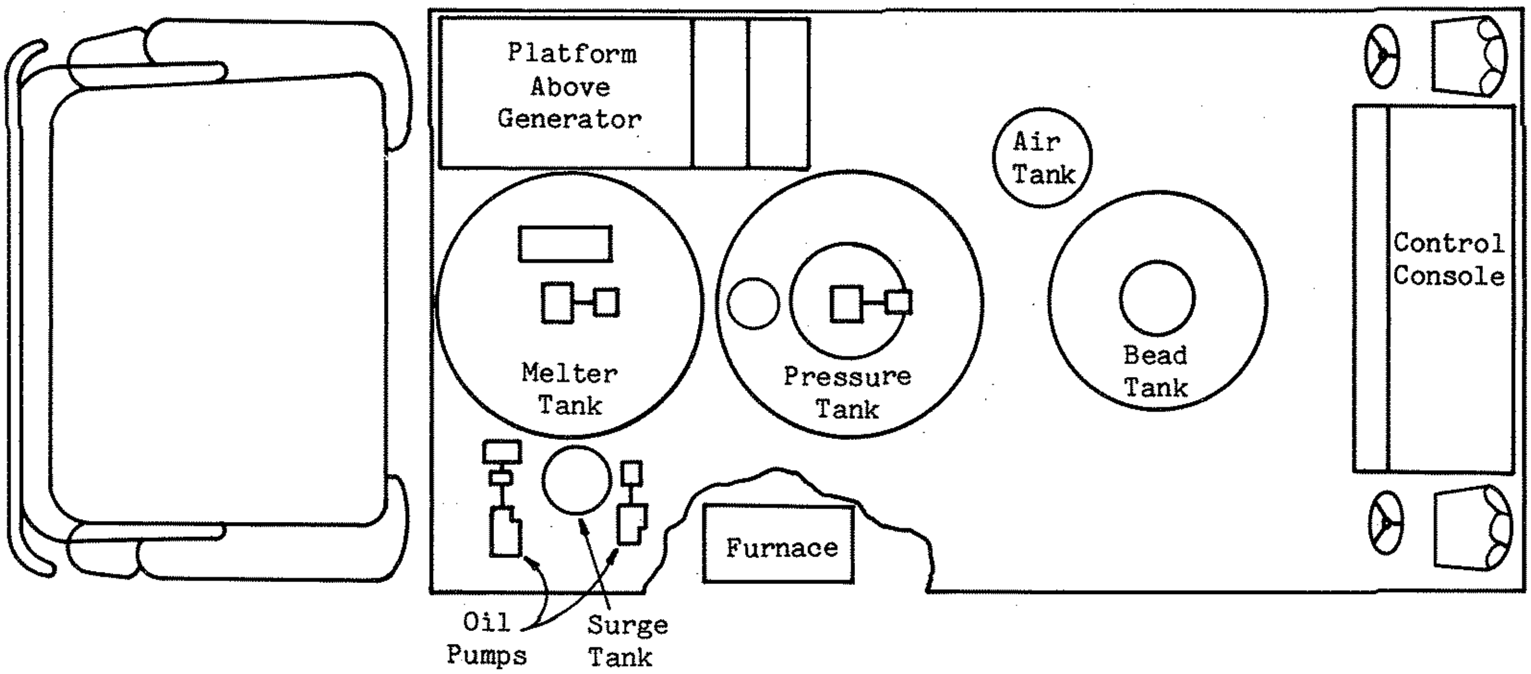


Figure 7 - Platform Layout

the bead tank and a vertically mounted compressed air receiver (formerly the 20 gallon solvent tank). Behind these components is a center control console, with carriage operator seats and steering wheels on either side. The vertically telescoping right and left gun carriages, power-steered horizontally, are just behind the rear truck wheels. A handrail is provided around the perimeter of the platform, and access steps are provided at the rear and on either side. A metal shade canopy covers the rear portion of the platform and carries a rear-facing lighted flashing arrow board controlled from the truck cab.

A collapsible "stinger" type pointer guide castoring wheel is attached to the front bumper of the truck.

A list of the major components and their manufacturers is included in Appendix C.

2. Materials Handling System. Cold, solid ETP material is introduced through a rectangular door in the top of the nonpressurized melter tank, which is 36 inches in diameter and equipped with a center-mounted vertical shaft agitator. The flat bottom of the tank is sloped downward toward the rear of the platform and has a 3-inch opening at the lowest point. A horizontal nipple, a slide-gate valve, and a swivelling elbow permit the heated ETP to flow by gravity into the application tank. The melter tank has a 1-inch oil jacket on the sides and bottom. All surfaces, except the access door, are insulated with 2 inches of high-temperature ceramic fiber insulation (KAOWOOL) with sheet metal sheathing.

   The pressurized application tank has a central 20-inch lid upon which is mounted a vertical shaft agitator. It also has a separate 8-inch lid on an elbow rising out of the front portion of the domed end, which is positioned directly below the swivel discharge from the melter tank. This tank is jacketed from the upper shoulder down, including the bottom, insulated, and sheathed all around. The 2-inch opening in the bottom of the tank is about 10 inches off center to avoid plumbing directly over the truck driveshaft.

   ETP material (under pressure) flows out the bottom of the tank (beneath the platform), through a plug valve and a jacketed/insulated steel pipe to a transverse jacketed pipe manifold at the rear of the platform. From each end of the manifold, it flows in jacketed flexible stainless steel lines (corrugated "bellows" type) to the guns on the steerable gun carriages. Manual valves control the flow to either or both carriages.

A. Melter Tank
B. Pressure Tank
C. Surge Tank
D. Large Pump
E. Furnace
F. Small Pump
G. (2) Heated Guns
H. (2) Heated ETP Pipes (Annular)
I. (2) Heated ETP Hoses
J. Oil Pressure Lines
K. Oil Return Lines
L. (2) Chromolox Air Operated Valves
M. Pressure Relief Valve ▨
N. Manual Shut Off Valve ⋈
O. Oil Diverter Circuit ▬

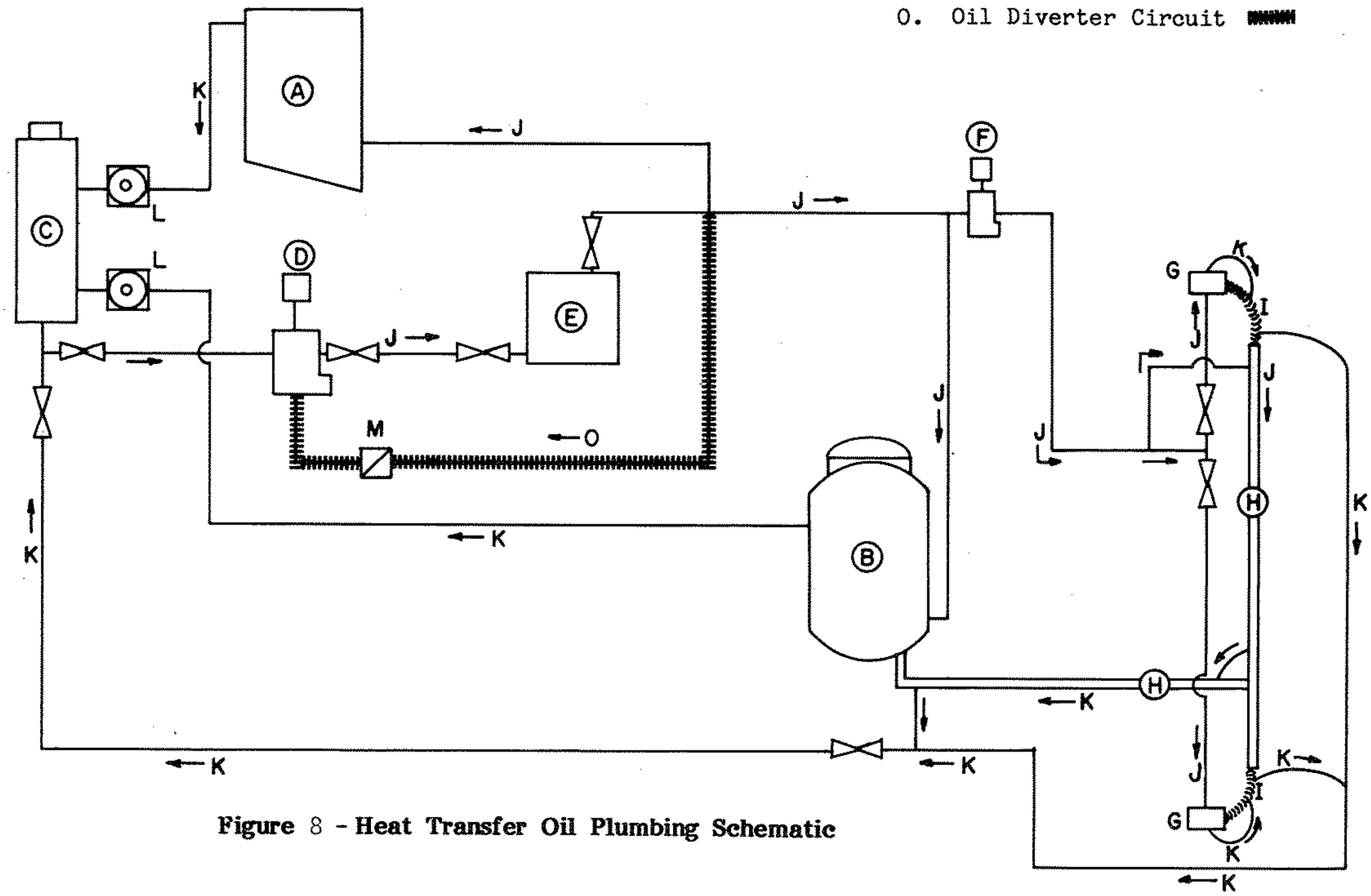


Figure 8 **- Heat Transfer Oil Plumbing Schematic**

3. HEATING SYSTEM. (See Figure 8) Heat is provided by an AXMAN-ANDERSON oil-fueled fire-tube furnace of approximately 285,000 BTU/hr. capacity. The heat exchange medium is MOBILTHERM 603 oil. Oil temperature is controlled by a PARTLOW thermostatic control which can be set to maintain the oil temperature within any selected range. This thermostat controls the burner, and its sensor is located in the furnace oil jacket.

Two pumps circulate the heating oil. One serves the melter and application tanks, and the other, smaller, pump serves the ETP lines and guns. Heated oil enters near the bottom of the tank jackets and exits near the top, and is returned to the oil expansion tank from which it is reintroduced into the furnace. Each tank is equipped with an adjustable thermostat, the sensor of which is located in the ETP material in the bottom of the tank. The thermostats control air-operated solenoid valves in the oil supply lines which interrupt the flow of oil to the tanks to maintain the selected ETP temperatures. When both valves are closed, a spring-loaded relief valve opens a loop that by-passes the tanks completely.

The smaller pump supplies oil directly to the guns and to the most remote ends of the hard jacketed ETP lines, which are heated as that portion of the oil returns to the "cool" side of the system. Probes located inside the guns monitor the ETP temperature as it leaves the guns.

The operator monitors the ETP temperatures by means of a four-circuit digital thermometer that may be switched to read either tank or either gun carriage. The operator controls the furnace oil thermostat, the tank ETP thermostats, and both pumps. Adjustment of ETP temperature at the guns is by manual switching of the small oil circulation pump. Manual oil valves permit the routing of oil to either or both gun carriages.

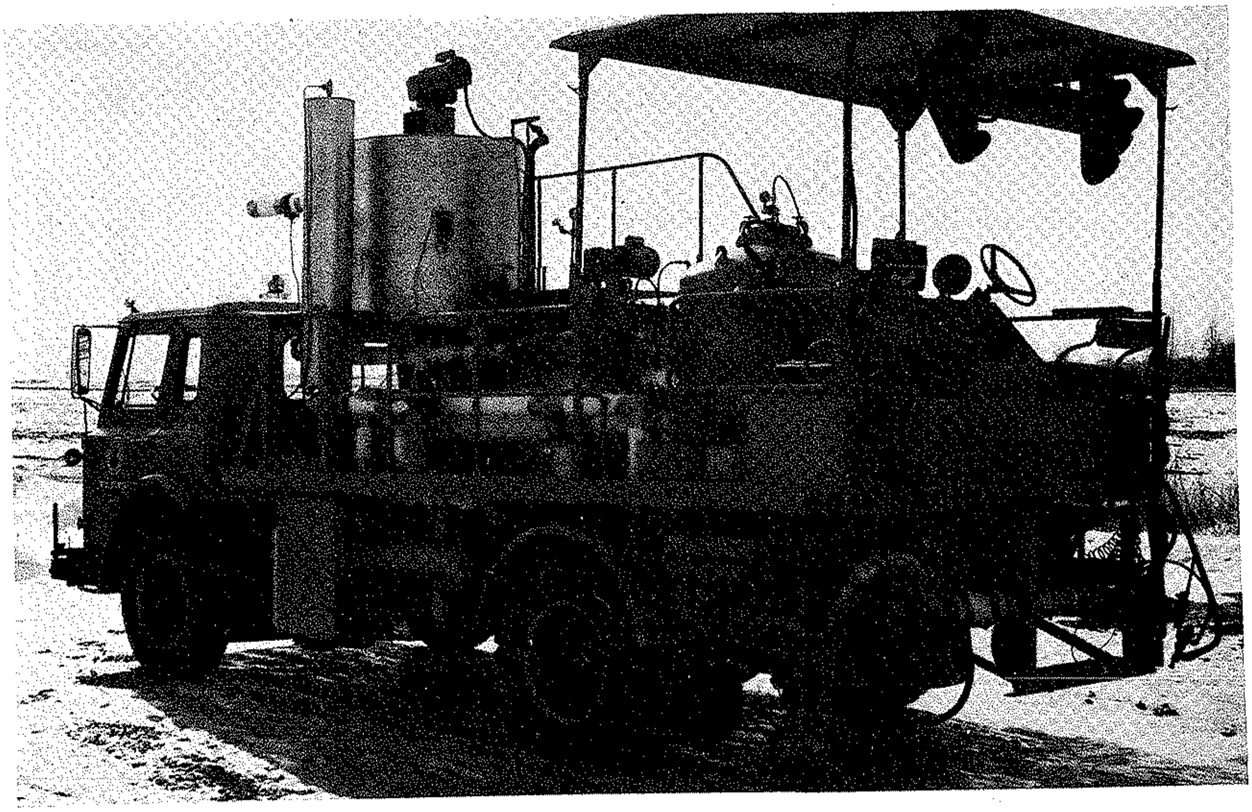
4. ELECTRICAL SYSTEM. Power to all 120-volt AC functions is provided by a four-cyclinder gasoline-powered motor-generator of 12.5 KW capacity. This is somewhat in excess of actual power requirements, but the generator was available as salvage from another application. The generator furnishes power to the furnace, tank agitators, oil pumps, and temperature control system. Power monitoring instruments and controls are on the motor-generator in view of the operator. All switches (except ETP tank thermostats mounted on the tank walls) are on the center console within operator reach.

5. COMPRESSED AIR SYSTEM. Compressed air at 120 psi is provided by a 13 CFM air-brake compressor on the truck engine to a receiver tank on the striper platform. Unregulated air operates the solenoid-controlled valves in the heating system and on the paint/bead guns. Individually regulated air pressurizes the ETP and bead tanks.

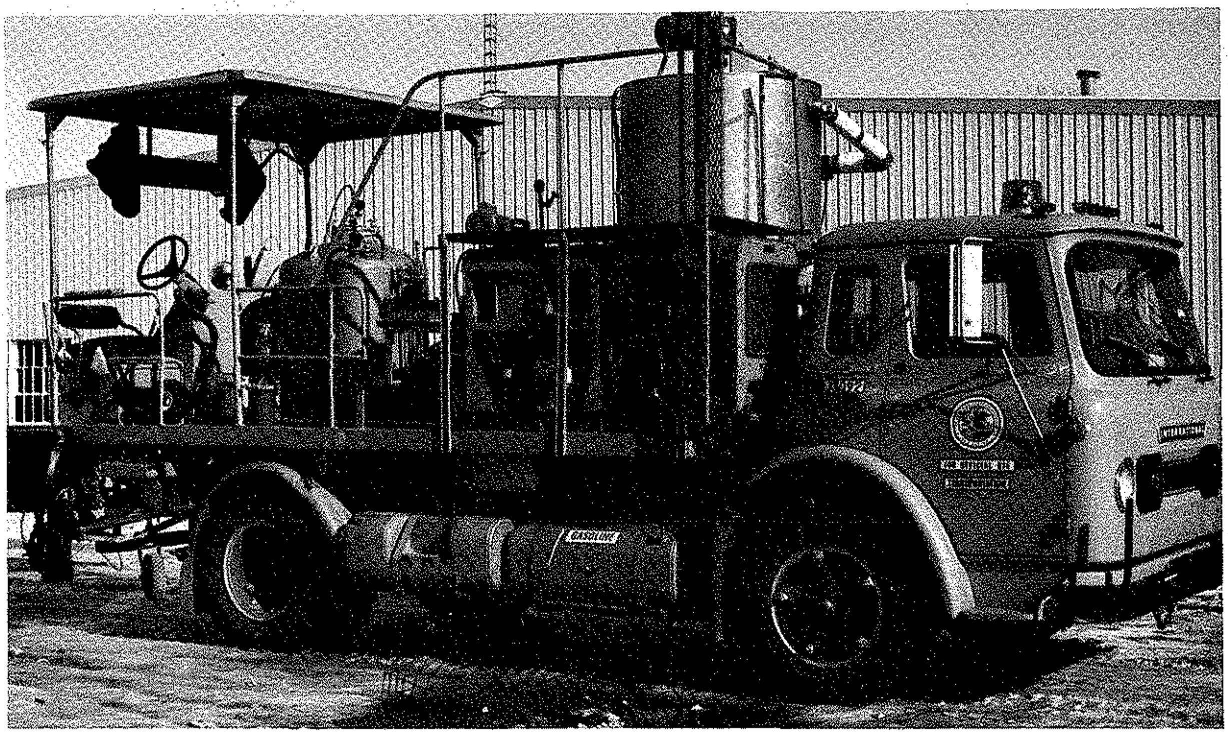
6. Application System The ETP application system is a low-pressure airless (nonatomized) spray. As indicated previously, the guns themselves (adapted from PRISMO atomizing heated guns) are oil-heated, as are all ETP conduits. There are, however, unavoidable gaps in the annular oil jacketing across valves and transitions from hard to flexible ETP conduits. These are connected by short loops of "flexible" grade copper tubing with mechanical joints. All hard jacketed lines are insulated with 1 1/2-inch thick fiber glass insulation. The principal flexible lines, from the rear manifold to the gun carriages, present an insulation problem because of the need to retain flexibility. They are simply wrapped with ribbon-type fiber glass secured with duct tape.

The gun nozzle presently being used is a BINKS No. F-14-20, and no heating, other than that provided by conduction from the gun body and from the ETP material itself, has been attempted.

The gun carriages, mounted directly behind the rear wheels, were utilized from the original paint machine and feature a scissors-type raising/lowering mechanism powered by an air cylinder. The carriages trail from the hydraulically extendible (power steered) roller/track outrigger and are supported by a single castoring wheel at the front. Height of the castor shaft is shim-adjustable, and additional height adjustment is provided on the gun mounts themselves. The spray fan from the airless nozzle is highly sensitive to wind,so a shroud is provided on the front and sides almost down to the payment surface. A BINKS Model 30 bead gun is adjusted to feed the applied line directly behind the ETP spray fan. Paint/bead gun control is through a RESEARCH DERIVATIVE skip-dash timer powered by the motor-generator 12-volt DC system and with a distance sensor on the truck speedometer drive. No distance recorder is incorporated.

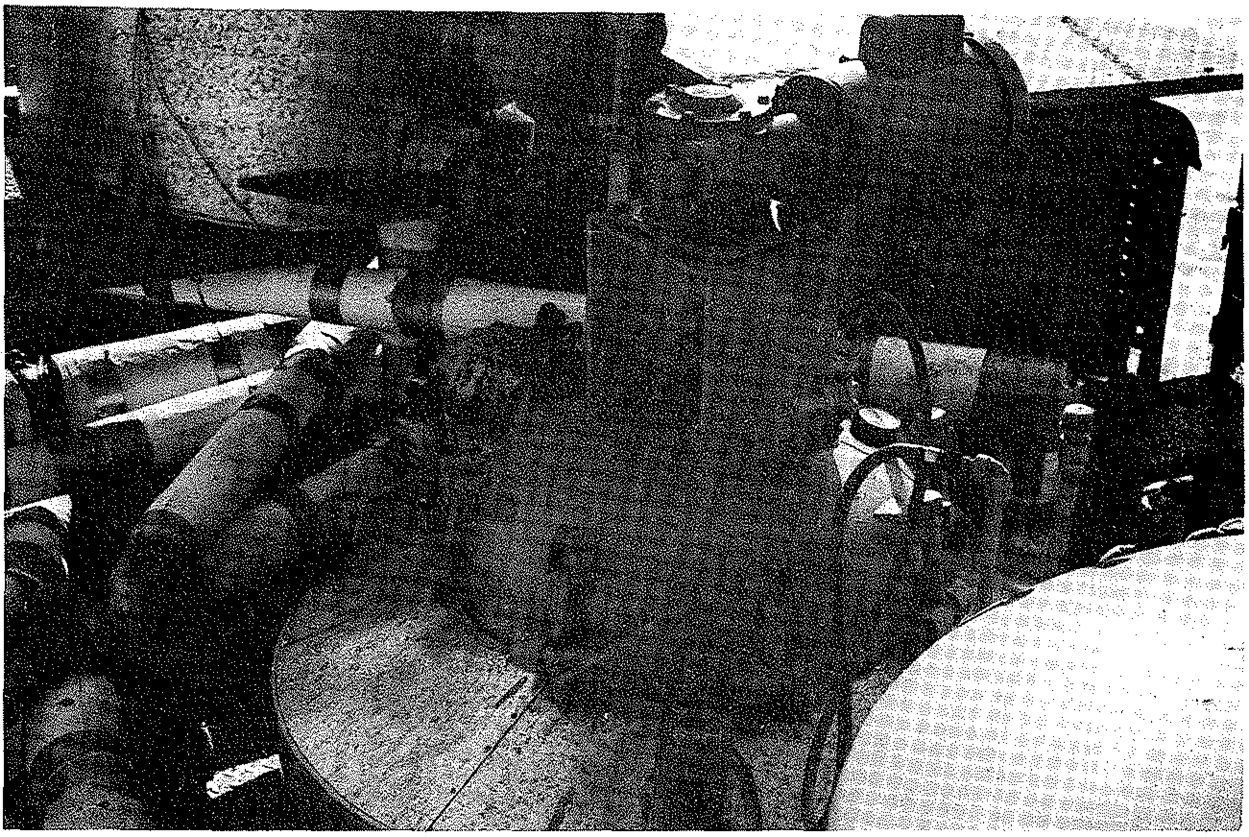


Left Side

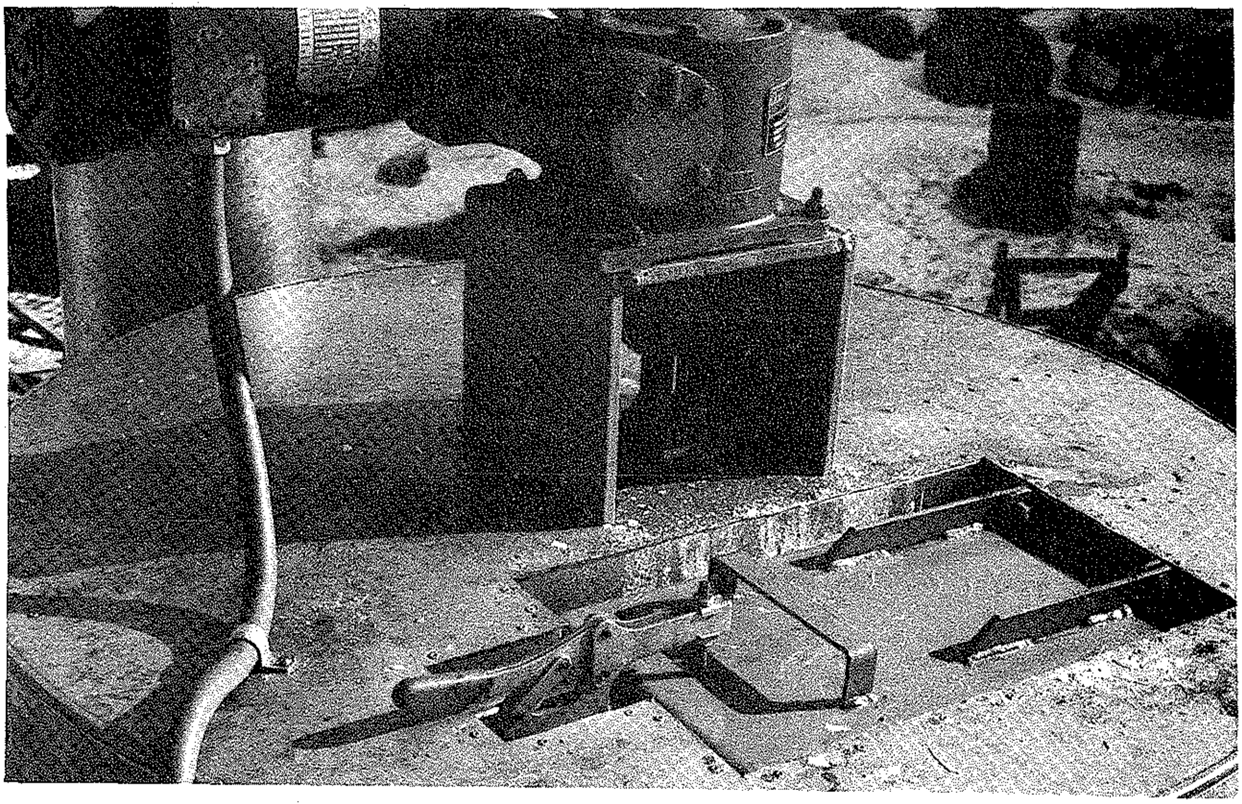


Right Side

Figure 9

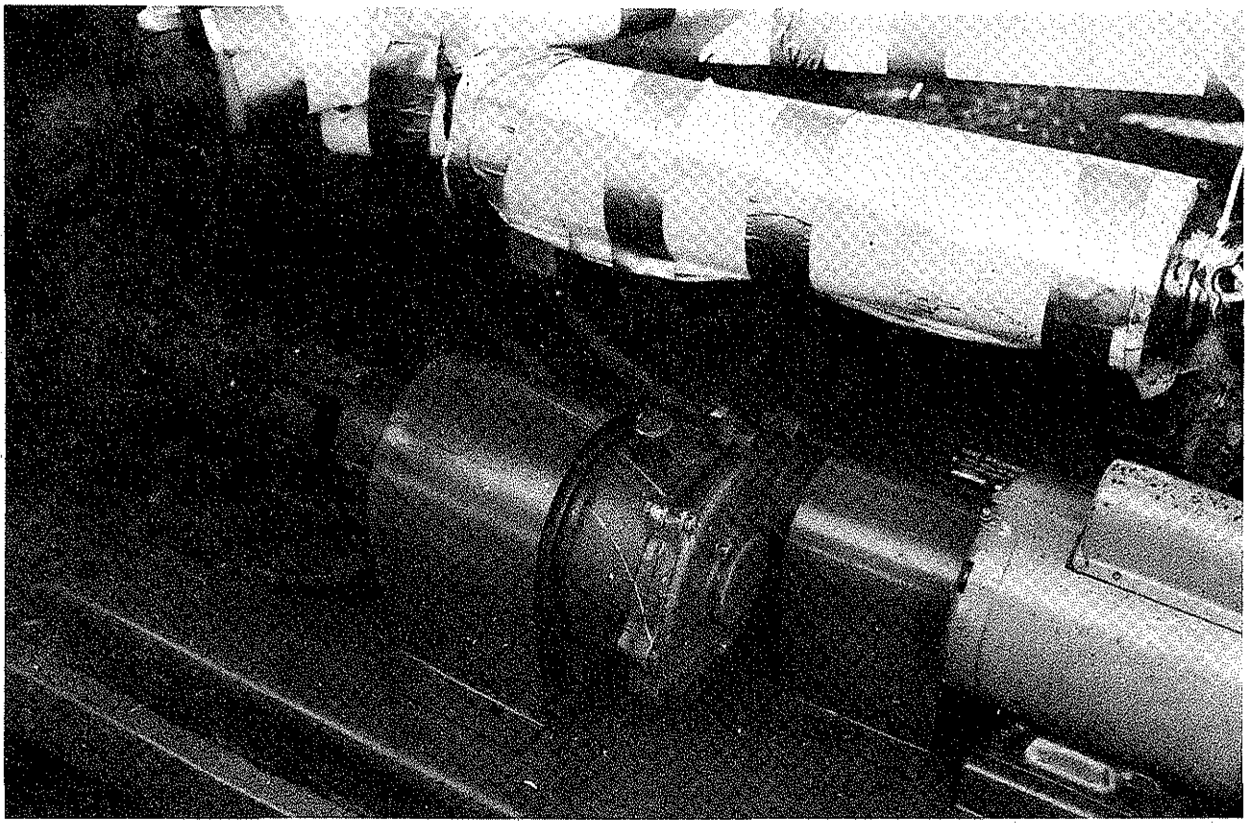


Application Tank

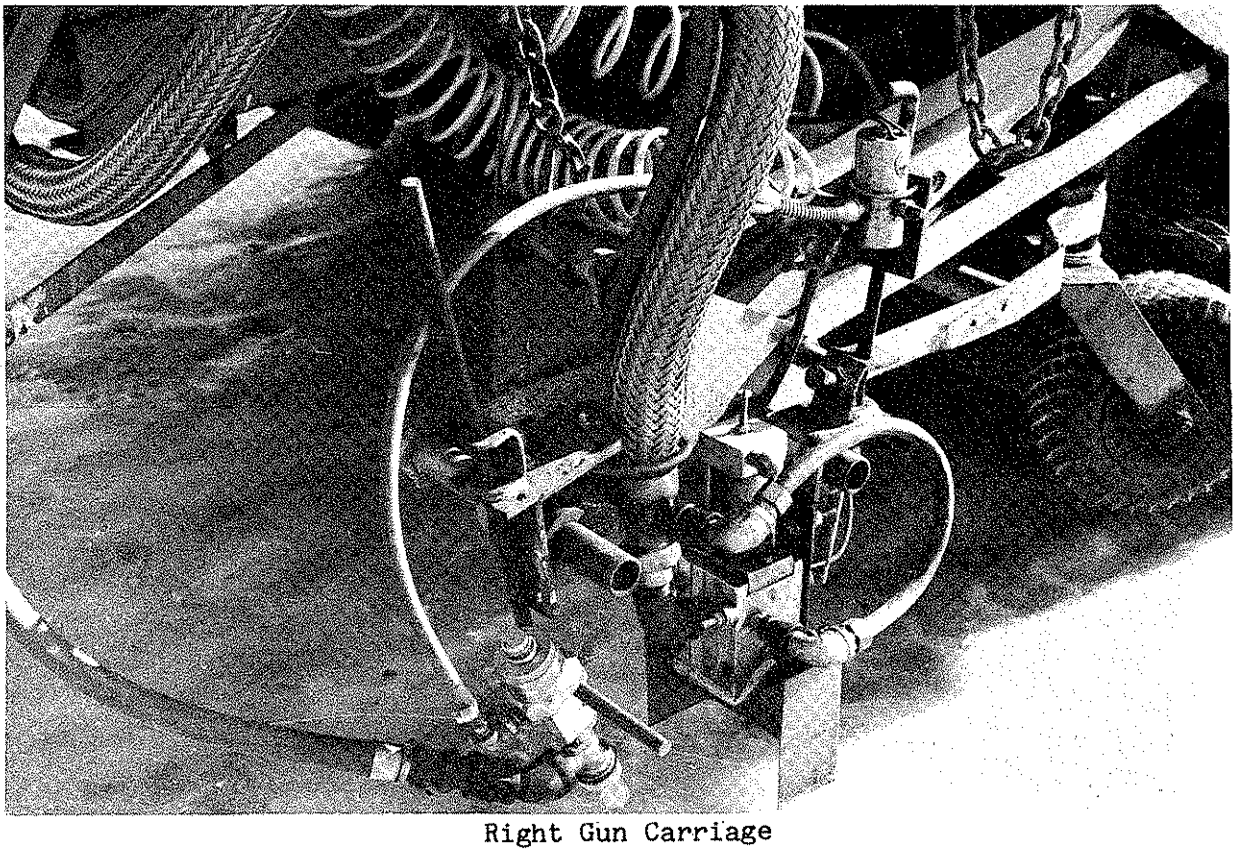


Top of Melter Tank

Figure 10

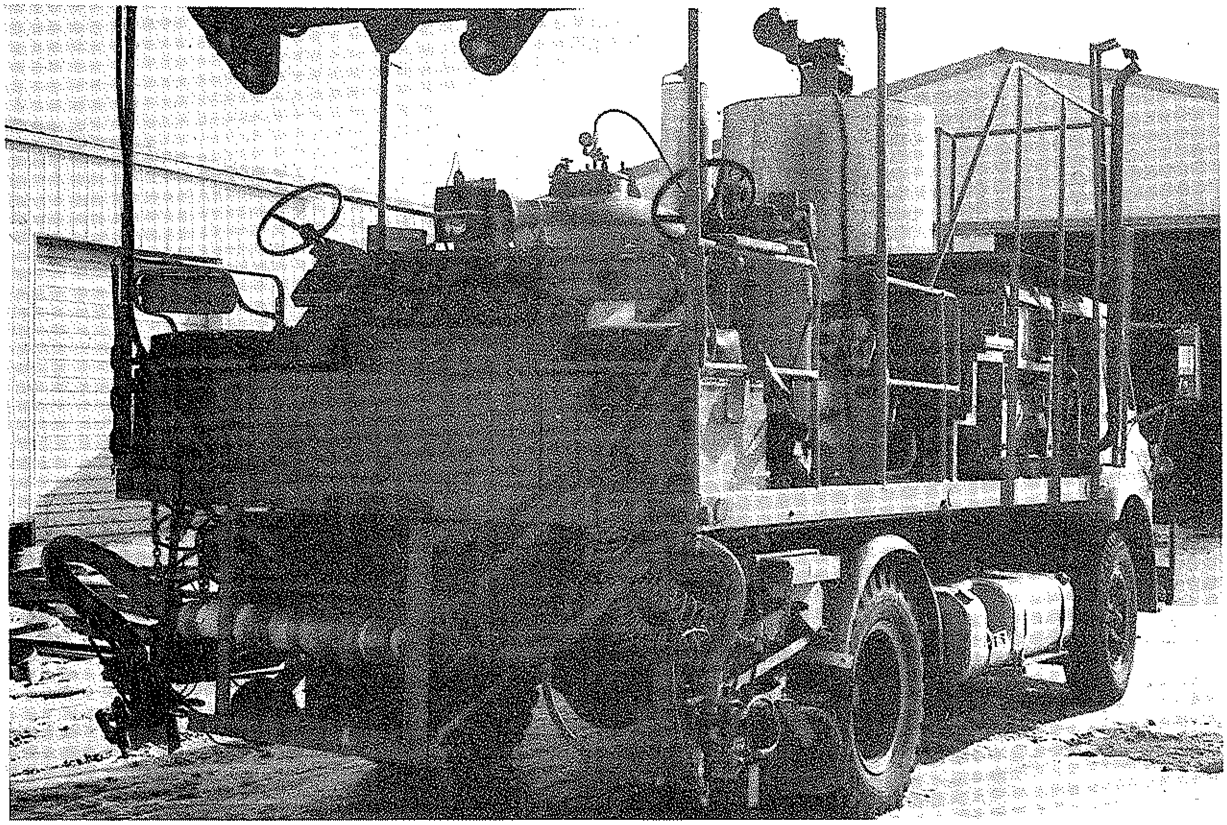


Large Oil Pump

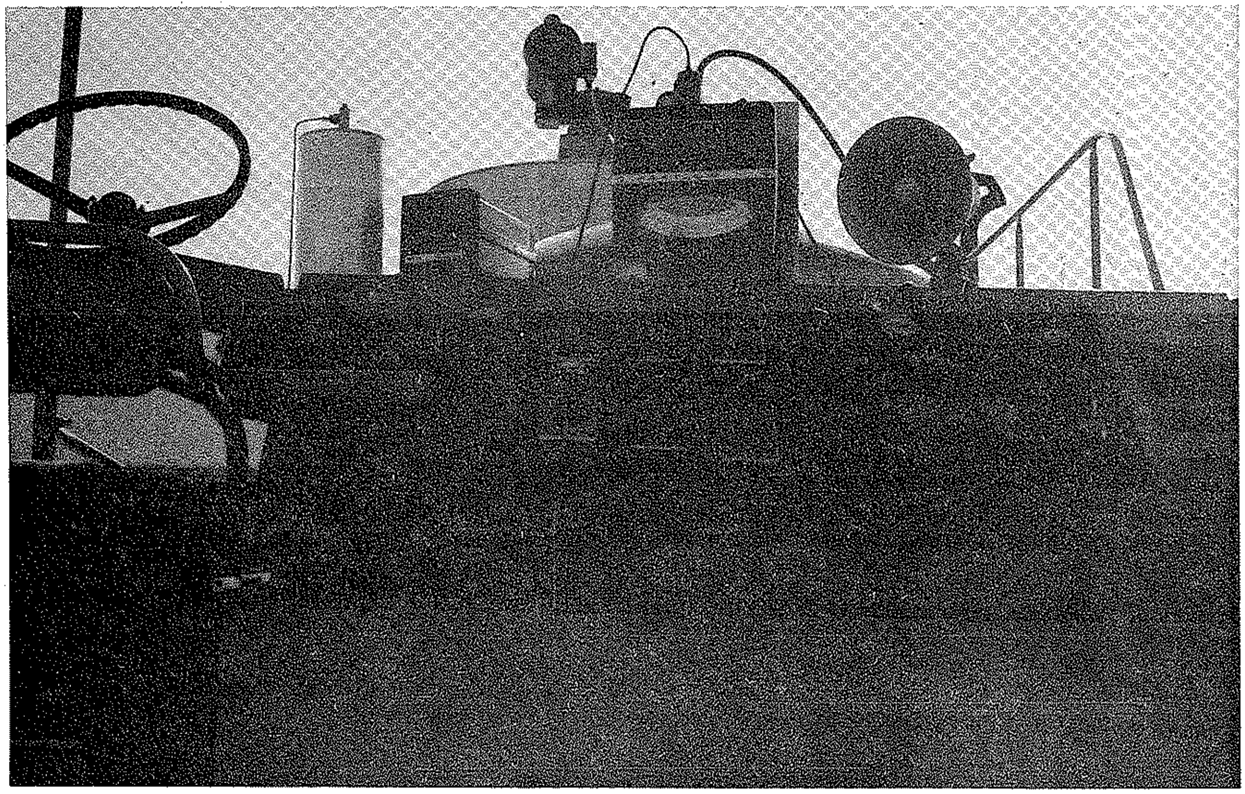


Right Gun Carriage

Figure 11

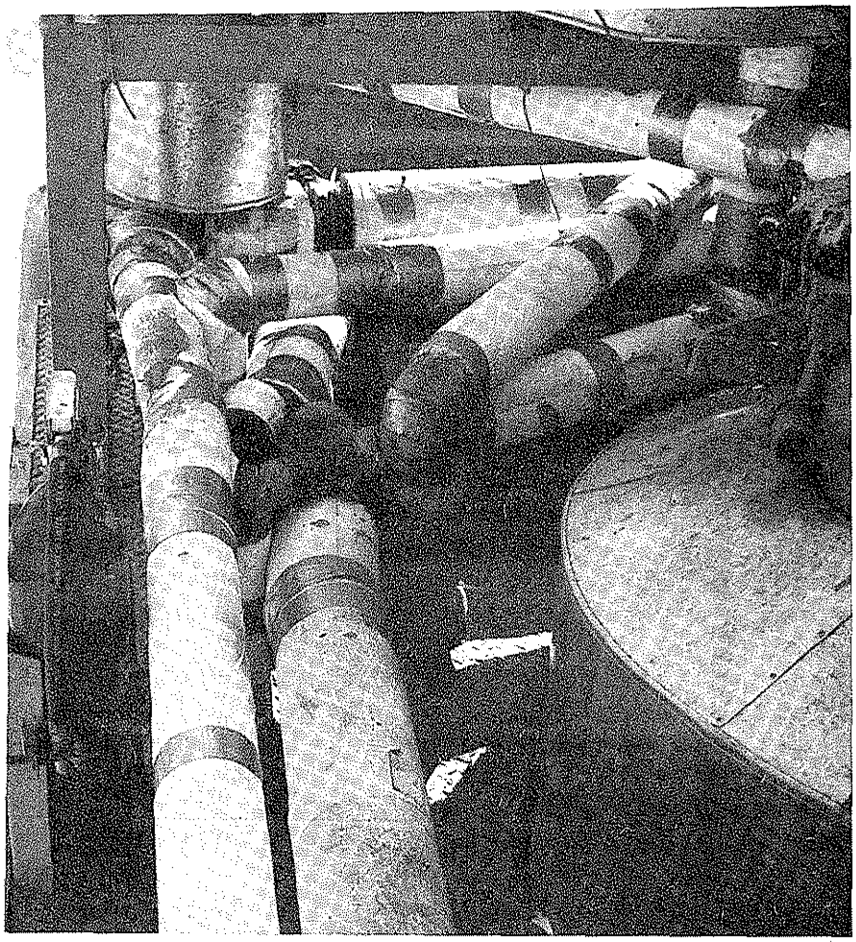


Rear View

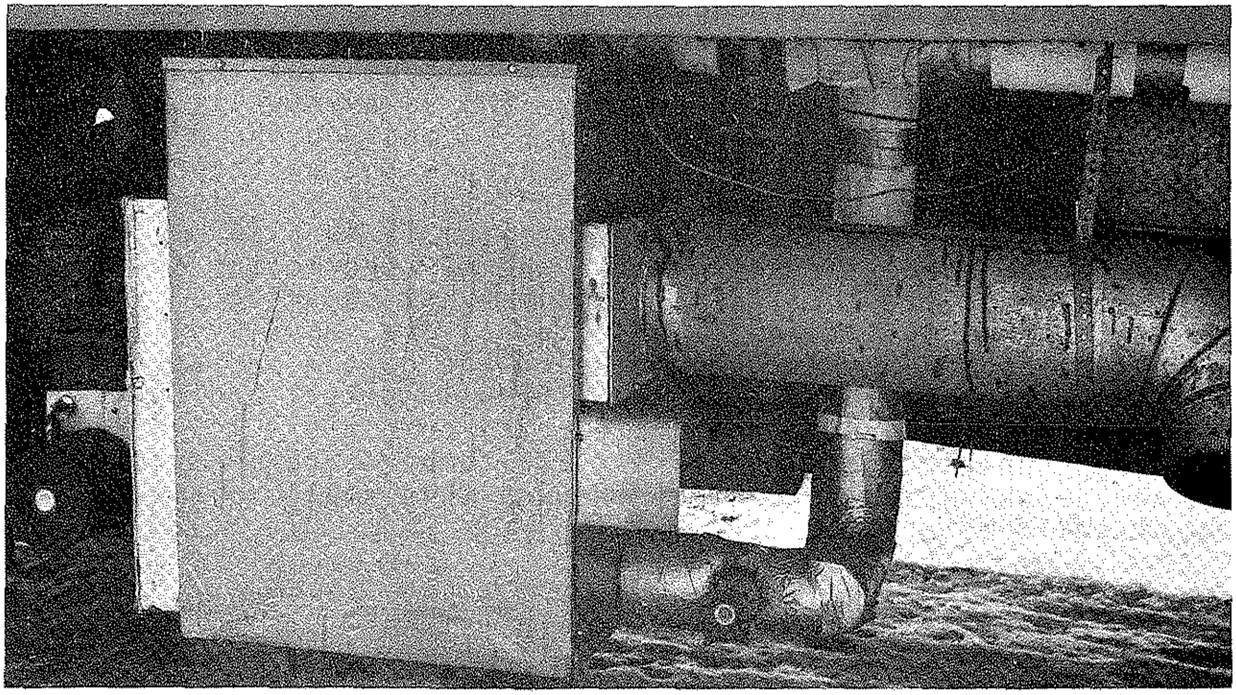


Control Console

Figure 12



Hot Oil Lines



Furnace

Figure 13

Several problems were encountered in modifying the paint striper:

1. Tanks. The tank arrangement works reasonably well, but experience has suggested some desirable changes that might be considered if the machine is duplicated.

   There are no baffles between the tank walls and the annular oil jacket walls. It would probably have been desirable to incorporate some that would guide the flow of the oil to all portions of the tanks rather than depend on convection for the uniform distribution of the heating oil.

   The sloping bottom of the melter tank aids in completely emptying the tank by gravity, but the slope also creates problems for the vertically mounted agitator. The lowest paddle, which just clears the high side of the bottom, leaves a considerable unswept volume on the low side. Mounting the agitator at an angle normal to the bottom surface would cure the problem, but would foreshorten the available length of the upper paddles. This is probably a tolerable situation. It is more important to get thorough agitation in the initial stages of the melt in the bottom of the melter than in the later stages (or in the application tank) when the bulk of the material is already highly liquid.

   The application tank has a deep bottom dome, and the drain from the tank should be nearer the low point than the 10 inches that was provided in this machine. The present arrangement leaves a significant volume of "dead" space which depends on the agitation of successive batches to completely purge the "undrainable" portion. Successive heatings of the <u>same</u> ETP material causes self-polymerization, and the material is eventually no longer thermoplastic in character. Locating the drain at the <u>lowest</u> point was avoided because the agitator carrier bearing fits over that spot (and it also is directly over the truck driveshaft). It is also the point where the sensors for the ETP thermostat and thermometer are located so as to prevent shearing damage from agitation. These probes are actually positioned in a short nipple below the bottom surface of the tank (but isolated from the oil jacket) and the material surrounding them is already completely polymerized (from repeated heating) making ETP temperature measurements now dependent on conduction through this small volume of solid material.

2. Heat-Susceptible Components. Oil circulation control valves from a standard hot-paint machine were used. These were equipped with bronze return (closing) springs and neoprene piston seals. Neither of these items is capable of operating in a 475-500°degree F. (246-260C.) environment. It was necessary to substitute stainless steel springs and TEFLON seals.

   The furance used was purported to be capable of handling the anticapted temperatures. It is of the fire-tube design, with the products of combustion moving through a battery of 2-inch tubes that are surrounded by the heating oil. However, the tubes leaked badly at the points where they were rolled into the jacket ends. It was necessary to weld them all around on both ends. It is not known what effect this will have on the life of the furnace.

3. Tank Agitators. The agitators originally installed were 1 HP gearhead motors with an output of 60 rpm. In the melter tank, this proved to be an insufficient gear reduction with a resulting stalling of the motor and damage to the agitator in the early melt stages when most of the ETP is still in the solid or semisolid state. A 15-rpm output gearhead was substituted in the melter tank and functions satisfactorily, although the initial melt stages must still be carefully monitored by visual observations and care taken in operating the agitator.

4. Electrical System The 5.3 -KW generator originally fitted was of insufficient capacity. Rather than purchase a new unit (about 8 KW is required) an old and much less compact 12.5-KW unit that happened to be available was substituted.

5. Compressed Air System Thermostatically controlled valves in the tank heating system are normally closed requiring air pressure for opening. This requires the truck engine to be operated (or a connection to a stationary air supply) during preliminary heating to obtain oil circulation to the tanks. Another approach would be to incorporate a small electrically (or gasoline) powered compressor on the platform. Space could undoubtedly be found if the motor-generator set were sized more nearly to actual requirements. Then, with the truck engine not required to drive the air compressor, the hydraulic steering pump, which is presently driven off the generator engine, could be driven off the truck engine. The volume of air used by the valves is very minor, and a compressor of 4 CFM capacity at 120 psi would probably be sufficient to provide make-up air in the application and bead tanks and to overcome system losses.

6. Nozzles. This problem has not as yet been satisfactorily resolved. The low- pressure airless system appears to be very sensitive to the combination of nozzle configuration, pressure, and ETP viscosity. With nozzles used so far, there is a good deal of splatter, the edges of the line are heavy compared to the center portion, and the line exhibits a "fluttery" pattern with void spots in the middle portion caused by the breakup of the spray fan before it reaches the pavement. This condition worsens as striper speeds get above 5-6 miles per-hour due to wind influence. ETP material cools and hardens within a very few seconds, and there is no"flow" of the material after it hits the pavement. This aspect of the machine is simply going to require more experimentation.

7. ETP Material Characteristics The epoxy components of ETP material exhibit an increase in viscosity with substained or repeated heating. The thermoplastic characteristics of the material make it unnecessary to add a "hardening" agent, as is normally done with epoxies. However, heat itself promotes polymerization (accounting for the viscosity change noted above), and if sustained long enough, high temperatures eventually transform the liquid to a solid that is no longer capable of being "melted." Limited experience indicates that even one heating-cooling cycle, plus a second heating, significantly changes the viscosity and thus affects the spraying characteristics. Repeated heat-cool cycles, probably about four, result in a complete solidification that cannot be reversed by any attainable amount of heat.

   This characteristic will dictate field procedures that minimize reheating of the same material and may eventually cause problems with the contamination of fresh material by old, fully polymerized deposits dislodged from various parts of the system.

Specification

The specifications included in this section were developed for use in applying ETP. These specifications while complete are not considered final and will be revised as the user agencies develop more expertise in working with ETP.

In the application of ETP there are two areas of concern that require the attention of the personnel applying this material.

Care should be taken to avoid overheating the ETP. The open cup flash point of this material is 485°F. Heating the material above 450°F and holding it at this temperature for long periods (in excess of 4 hours) is not recommended. Repeated heating and cooling (more than 2 cycles) of the same material and /or holding the ETP at elevated temperatures will cause the material to polimerize. If this occurs it is almost impossible to remove the material from the equipment.

The successful application and long term performance of ETP is directly dependent on the bond between the marking material and the pavement surface. The ETP may not adhere to built up deposits of painted or other types of pavement markings. The reason for the poor adherence is that these underlying deposits may delaminate from the pavement surface, resulting in the failure of the overlying ETP. The decision on whether or not to remove existing markings requires engineering judgement. It is recommanded that ETP not be applied over built up existing markings that show any indication of bond failure (delamination, chipping).

The specifications includes a section on "Surface Cleaning and Preparation of Pavement." The cost of this work is to be included in the bid price for the ETP markings. The removal of oil, dirt, grease, etc. is good practice for the proper application of pavement markings. If it is determined that the existing pavement markings should be removed the work should be included as a separate bid item. Appendix B is included as an optional specification for cleaning and preparation of pavement surfaces as a bid item.

Standard Specification for the Application of
EPOXY THERMOPLASTIC TRAFFIC MARKINGS

DESCRIPTION. Under this work, the contractor shall furnish and apply Epoxy-Thermoplastic (ETP) reflectorized traffic markings at the locations and in accordance with the patterns indicated on the plans, or as directed by the Engineer, and in accordance with these specifications.

The ETP traffic marking material shall be hot-applied, in a molten state by spray methods, on to bituminous and portland cement concrete pavement surfaces, with a surface dressing of glass beads. Upon cooling to normal pavement temperatures, the resultant ETP marking shall be a reflectorized stripe of the specified thickness and width that is capable of resisting deformation by traffic.

MATERIALS

A. White and Yellow Epoxy Thermoplastic (ETP). ETP composition shall be specifically formulated for use as a traffic marking material and for spray application at temperatures of 450 F. The ETP composition shall be formulated in accordance with the requirements of Appendix A. In addition the composition and individual components shall meet the physical and chemical property requirements of Appendix A when tested in accordance with the specified test procedures.

B. Reflective Glass Spheres for Drop-On. Drop-on reflective glass spheres shall conform to the following requirements:

The glass spheres shall be colorless, clean, transparent, free from milkiness or excessive air bubbles, and essentially clean from surface scarring or scratching. They shall be spherical in shape and at least 70% of ther glass beads shall be true spheres when tested in accordance with ASTM D1155.

The refractive index of the spheres shall be a minimum of 1.50 as determined by the liquid immersion method at 25 C.

The silica content of the glass spheres shall not be less than 60%.

The crushing resistance of the glass spheres shall be as follows: A forty (40) pound dead weight, for 20 to 30 mesh spheres, shall be the average resistance when tested in in accordance with ASTM D1213.

The glass spheres shall have the following gradation when tested in accordance ASTM D1214.

U.S. Standard Sieve	Mass % Passing*
No.20	100
No.30	79-100
No.50	15-60
No.80	0-15

*Some variation in this gradation, toward smaller sizes, may be appropriate.

Glass spheres for drop-on shall be treated with a moisture-proof coating.

C. Packaging and Shipment. The ETP composition shall be shipped and packaged in accordance with commercially accepted standards. (see note) The following information shall be plainly marked on each container or on the shipping invoice: the name of the product, the name and address of the manufacturer, the quantity of material, batch or lot number, the date of manufacture, and the date of expiration or shelf life.

Note: For maximum ease of handling a 2 inch maximum thickness for blocks of ETP has been found to be advantageous.

Reflective glass spheres for drop-on shall be shipped in moisture resistant bags. Each bag shall be marked with the name and address of the manufacturer and the name and net weight of the material.

D. Basis of Acceptance. White and yellow ETP traffic marking composition will be accepted at the job site on the basis of the Manufacturer's Certification. The manufacturer shall furnish the State a certified analysis showing that both the epoxy-thermoplastic composition and individual components meet the physical and chemical properties of this specification when tested in accordance with the requirements of Appendix A.

Reflective glass spheres for drop-on may be accepted at the job site on the basis of the Manufacturer's Certification; or they may be submitted to the State for testing.

EPOXY THERMOPLASTIC APPLICATION EQUIPMENT. Application equipment for the placement of ETP traffic markings shall be approved by the Engineer prior to the start of work.

A. In general the equipment shall be constructed to provide continuous mixing, agitation and indirect oil jacketed heating of the material. The equipment shall be constructed so that all mixing and conveying parts up to and including the spray nozzle maintain the material at a minimum temperature of 450° F. The equipment shall be designed to apply ETP marking material and reflective glass spheres in continuous and skip line patterns. In addition the equipment shall be provided with accessories to allow for the marking of legends, symbols, crosswalks, and other special patterns.

The applicator shall include the following minimum features:

1. The applicator shall be equipped with a pressure tank, mixer(s), and heating equipment of such capacity to maintain the ETP at a minimum temperature of 450° F. The heating equipment shall surround the pressure tank and consist of a direct thermostatically controlled heat transfer medium. Heating by direct flame shall not be allowed.
2. The applicator shall be equipped with a low pressure spray system. Atomizing air may be used provided it is heated to a minimum of 350° F. All spray lines and appurtenances leading from the heated pressure tank to the spray nozzle shall be fully insulated or suitably heated so as to allow the heated ETP material to leave the spray gun at a minimum temperature of 440 F.
3. The applicator shall be equipped with automatic glass bead dispensing equipment capable of applying surface glass spheres at the rate of six (6) pounds per gallon of ETP composition. The dispenser shall be located in such a manner that the beads are dispensed almost instantaneously upon the installed line. The glass sphere dispenser shall be equipped with an automatic cut off control synchronized with the cut off of the ETP material.

CONSTRUCTION DETAILS

A. General. All pavement markings and patterns shall be placed as shown on the plans and in accordance with the Manual of Uniform Traffic Control Devices.

Before any pavement marking work is begun, a schedule of operations shall be submitted for approval of the Engineer.

When pavement markings are applied under traffic, the contractor shall provide all necessary flags, markers, signs, etc. to maintain and protect traffic, and to protect marking operations and the markings until thoroughly set.

The application of pavement markings shall be done in the general direction of traffic. Striping against the direction of traffic flow shall not be allowed.

The Contractor shall be responsible for removing, to the satisfaction of the Engineer, tracking marks, spilled ETP or ETP markings applied in unauthorized areas.

When necessary, the Contractor shall establish marking line points at twenty-five (25) foot intervals throughout the length of pavement or as directed by the Engineer.

B Atmospheric Conditions. ETP traffic markings shall be placed upon dry pavement surfaces. At the time of installation the pavement surface temperature shall be a minimum of 35° F and the ambient temperature shall be a minimum of 35° F and rising. The Engineer shall be the sole determinor as to when atmospheric conditions are such as to produce satisfactory results.

C. Surface Cleaning and Preparation of Pavement. The Contractor shall be responsible for cleaning the pavement surface to the satisfaction of the Engineer.

Surface cleaning and preparation work shall be performed only in the area of the ETP markings application.

At the time of application all pavement surfaces shall be free of oil, dirt, dust, grease and similar foreign materials. The cost of cleaning these contaminants shall be included in the bid price of this item. (Optional specification for Cleaning and Preparation of Pavement Surfaces as a pay item, is included in Appendix B.)

D. Application of Epoxy Thermoplastic Traffic Markings. When surface preparation work is complete, ETP traffic markings shall be spray applied, using low pressure, spray equipment. The ETP shall be heated and sprayed at material temperatures no lower than 440° F, at the point of deposition- with the point of deposition being defined as at the spray nozzle. Applied markings shall have uniform width, true and smooth alignment and a minimum film thickness of 15 mil. Immediately after application drop-on reflective glass spheres shall be uniformly applied over and into the wet ETP at the rate of 6 lbs. per gallon of composition.

Method of Measurement Pavement striping will be measured by linear feet along the centerline of the pavement stripe, and will be based on a 4-inch stripe. Measurement for striping with a plan width greater or less than the basic 4 inches as shown on the plans or as directed by the Engineer, will be made by the following method:

$$\frac{\text{Plan Width of Striping (inches) X Linear Feet}}{\text{4 (inches)}}$$

No payment will be made for the number of linear feet of skips in the dashed line.

Letters and symbols will be measured by each unit applied. A unit will consist of one letter or one symbol. Example: 'SCHOOL' would be measured as six units.

BASIS OF PAYMENT. The accepted quantities of markings will be paid for at the contract unit price, which shall include the cost of furnishing all labor, materials and equipment to satisfactorily complete the work. The cost for maintaining and protecting traffic during the marking operations shall be included in the price bid. The cost of removal of concrete curing compounds and existing pavement markings will be paid under separate items and are not included in this item.

Payment will be made under:

Item	Pay Unit
White Epoxy Thermoplastic Pavement Stripes	Linear Feet
Yellow Epoxy Thermoplastic Pavement Stripes	Linear Feet
White Epoxy Thermoplastic Pavement Letters	Each
White Epoxy Thermoplastic Pavement Symbols	Each

APPENDIX A
STANDARD SPECIFICATION FOR
EPOXY THERMOPLASTIC (ETP) TRAFFIC MARKING MATERIAL

1. SCOPE

This specification covers white and yellow epoxy thermoplastic (ETP) hot spray traffic marking materials for use on bituminous and portland cement concrete pavements. The ETP is composed of two epoxy resins, calcium carbonate filler, glass beads, and either titanium dioxide pigment for the white formulation or silica-encapsulated lead chromate pigment for the yellow formulation. This specification includes acceptance criteria for production lots of ETP, for raw materials, and for laboratory prepared samples of the ETP. It describes various physical and chemical property requirements, and sampling, preparation, and test procedures to measure these properties.

2. APPLICABLE DOCUMENTS

ASTM D 153	"Specific Gravity of Pigments"
ASTM D 270	"Sampling Petroleum and Petroleum Products"
ASTM D 281	"Oil Absorption of Pigments by Spatula Rub-Out"
ASTM D 444	"Chemical Analysis of Zinc Yellow Pigment (Zinc Chromate Yellow)"
ASTM D 476	"Titanium Dioxide Pigments"
ASTM D 1199	"Calcium Carbonate Pigments"
ASTM D 1208	"Common Properties of Certain Pigments"
ASTM D 1394	"Chemical Analysis of White Titanium Pigments"
ASTM D 1652	"Epoxy Content of Epoxy Resins"
ASTM D 2205	"Traffic Paints"
ASTM E 97	"45-Deg, 0-Deg Directional Reflectance of Opaque Specimens by Filter Photometry"
ASTM E 313	"Indexes of Whiteness and Yellowness of Near-white, Opaque Materials"
AASHTO T-53	"Softening Point of Asphalt (Bitumen) and Tar in Ethylene Glycol (Ring and Ball)"
AASHTO T-250	"Thermoplastic Traffic Line Material"
Report No. FHWA/RD-80/069	"Epoxy Thermoplastic Pavement Marking Material: Specification and Testing"
Fed. Test Method Std. No. 141b, Method 1022,	"Sampling (General)"

3. REQUIREMENTS

3.1 Materials to be Submitted

The supplier of ETP shall submit samples of the following materials.

Production Batches of ETP (2 samples from each batch)

Raw Materials

- Solid epoxy resin (2 samples from each lot used)
- Liquid epoxy resin (2 samples from each lot used)
- Titanium dioxide pigment (for white ETP) (2 samples from each lot used)
- Lead chromate pigment (for yellow ETP) (2 samples from each lot used)
- Calcium carbonate (2 samples from each lot used)
- Beads (2 samples from each lot used)

Laboratory-prepared batches of ETP (2 replicates for each set of raw materials used in production)

The size and number of samples to be submitted are given in section 4. The above materials must satisfy the requirements of sections 3.2 to 3.4.

3.2 Production Batch Epoxy Thermoplastic Compound

3.2.1 Composition and Form of Materials - ETP's shall have the following compositions:

	White ETP		Yellow ETP	
	Parts by Wt.	% by Wt.	Parts by Wt.	% by Wt.
Solid epoxy resin	30.0	35.7 ± 0.5	30.0	36.0 ± 0.5
liquid epoxy resin	20.0	23.8 ± 0.5	20.0	24.0 ± 0.5
titanium dioxide	10.0	11.9 ± 0.3	-	-
lead chromate	-	-	9.3	11.1 ± 0.3
calcium carbonate	10.0	11.9 ± 0.3	10.0	12.0 ± 0.3
glass beads	14.0	16.7 ± 0.4	14.0	16.8 ± 0.4

The compound ETP shall be supplied in solid block form.

3.2.2 Test Requirements - The white and yellow production ETP's shall meet the requirements of Table 1. Two (2) samples shall be tested for each batch. The bulk ETP properties (before and after heating) will be determined for each sample tested. The frequency of the determination for the other properties (after separation) will be left to the discretion of the specifying agency but should be determined for at least one in each 10 batches tested. All experimental values used to calculate the quantities in Table 1 shall also be reported.

3.2.3 Application Requirements - ETP's are applied to the road surface at or near 232°C (450°F). The viscosity ranges specified in Table 1 are considered appropriate for most applications. However, before acceptance, it must be demonstrated that the ETP can be sprayed with the application equipment stipulated by the specifying agency below 247°C (475°F).

TABLE 1. REQUIREMENTS FOR ETP PRODUCTION BATCHES

ETP Property	Difference between 2 Samples[a]	Average of 2 Samples (white)	Average of 2 Samples (Yellow)	Test Procedure
Before Heating				
Viscosity, cps (20 RPM) 232°C (450°F)	$0.7\eta_{av}$[b]	200-1400	150-1300	4.3.1
Softening Point, $^{\circ}$C	4.0	71.0 - 83.0	71.0 - 83.0	4.3.2
Reflectance, %	7.0	≥ 74	≥ 38	4.3.3
Whiteness Index	7.0	≥ 42	-	4.3.3
Yellowness Index[c]	8.0	-	124 - 143	4.3.3
After Heating				
Viscosity Change, cps, 232°C (450°F)	250	-300 to +500[d]	-250 to +600[d]	4.3.4
Softening Point Change, $^{\circ}$C	4.0	-1.0 to +6.0[d]	+1.5 to +9.5	4.3.4
Reflectance, %	7.0	≥ 77	≥ 39	4.3.4
Whiteness Index	8.0	≥ 31	-	4.3.4
Yellowness Index	9.0	-	121 - 146	4.3.4
After Separation				
Total Organic, %	3.0	60.8 - 69.4	-	4.5.2
	3.7	-	57.9 - 61.2	4.5.6
Beads, %	3.2	14.0 - 16.9	-	4.5.3
	4.4	-	13.3 - 17.8	4.5.5
Titanium Dioxide, %	0.2	10.3 - 12.4	-	4.5.4
Chromate, %	0.4	-	2.4 - 2.5	4.5.7
Lead, %	5.0	-	4.6 - 6.7	4.5.6
Epoxy Equivalent Wt. (Gram/Equiv.)	100	410 - 510	340 - 460	4.4.3
Infrared Spectrum	-	Identical to Figure 1	Identical to Figure 2	4.4.4

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a. Two samples are required for each batch. This column gives maximum difference permitted between 2 samples. Columns 2 and 3 give permissible values for the average.

b. η_{av} = average viscosity of 2 samples.

c. Conform to Highway Yellow Color Tolerance Chart (PR Color #1) Federal Highway Administration, HTO-21, Washington, D.C. 20590.

d. E.g., $-300 \leq (\eta_a - \eta_b) \leq +500$ cps: η_b, η_a = viscosity before, after heating

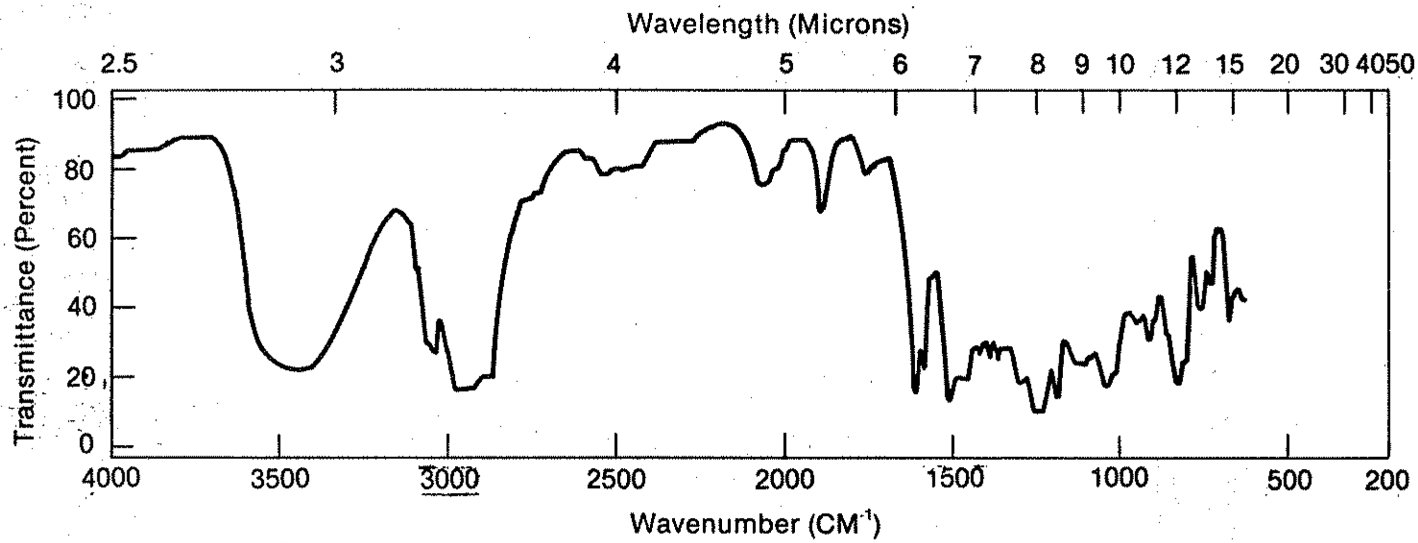

Figure 1. Infrared Spectrum of the Resin Extract of the White ETP.

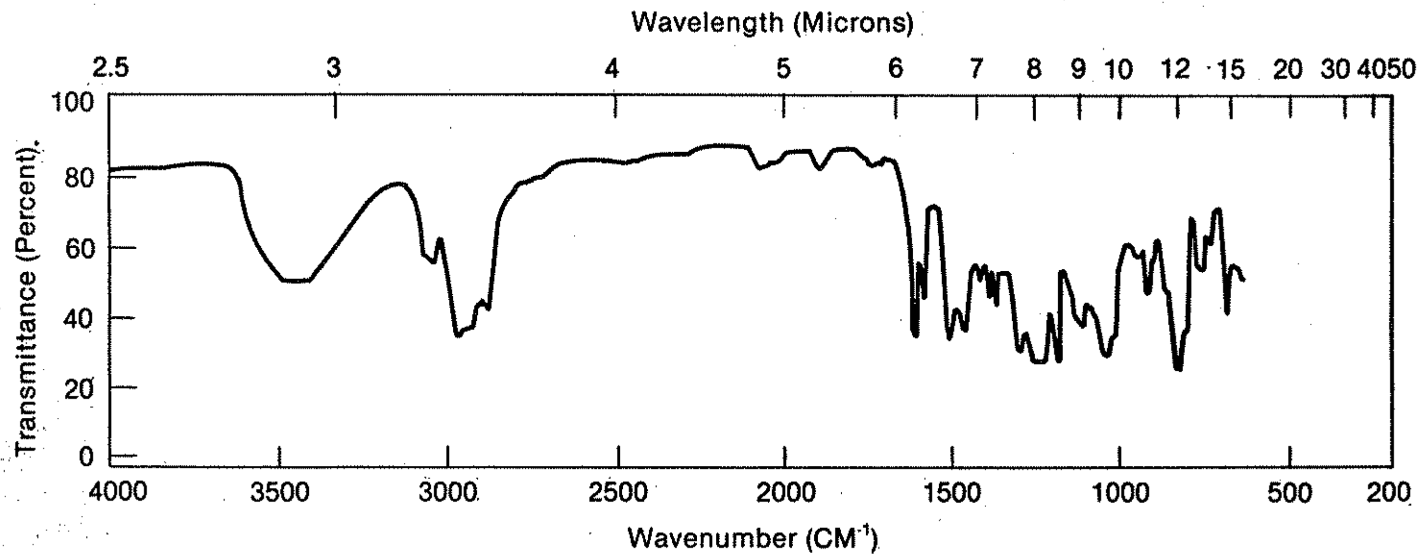

Figure 2. Infrared Spectrum of the Resin Extract of the Yellow ETP.

3.3 Components for Epoxy Thermoplastic Compound

3.3.1 Epoxy Resins - The liquid and solid resins shall be condensation products of bisphenol A and epichlorohydrin having the following properties:

	Liquid Epoxy Resin		Solid Epoxy Resin	
	Average	Difference[a]	Average	Difference[a]
Viscosity, cps 49°C, 20 RPM	680-810	10	-	-
232°C, 10 RPM	-	-	1300-2600	75
Epoxide Equiv. Wt. (g / equiv.)	180-196	10	1600-2300	50
Infrared Spectrum	Identical to Fig. 3		Identical to Fig. 4	

a. Between 2 replicates

3.3.2 Titanium Dioxide - The titanium dioxide shall conform to ASTM D 476, Type II. The oil absorption shall be between 13 and 30 grams oil/100 grams pigment with a maximum deviation between replicate samples of 1.0.

3.3.3 Calcium Carbonate - The calcium carbonate shall conform to ASTM D 1199, Type GC, Grade I with a dry brightness no less than 91 percent. The oil absorption shall be between 9 and 21 grams oil/100 grams pigment with a maximum deviation between replicate samples of 1.0.

3.3.4 Lead Chromate - The lead chromate shall be refractory type, silica-encapsulated, and with no additive surface treatment. When tested in accordance with section 4.6.4 it shall have the following properties:

	Min.	Max.	Max Deviation Between Replicates
pH in 5% water-slurry	7.0	9.0	0.2
Specific gravity	3.8	4.5	0.01
Lead,% by weight	44	50	0.5
Chromate, (CrO_4) % by Wt.	17	27	0.5
Chromium (Cr), % by Wt.	7.6	12.1	0.5

3.3.5 Glass Beads - The glass beads shall conform to ASTM D 2205, Type I.

3.4 Laboratory Batch Epoxy Thermoplastic Compound

3.4.1 Preparation - The laboratory scale batches of ETP shall be prepared as described in Appendix B of Report FHWA/RD-80/069 (See note below). Two (2) laboratory batches shall be prepared for each set of raw materials used in production. The compositional requirements are given in Section 3.2.1.

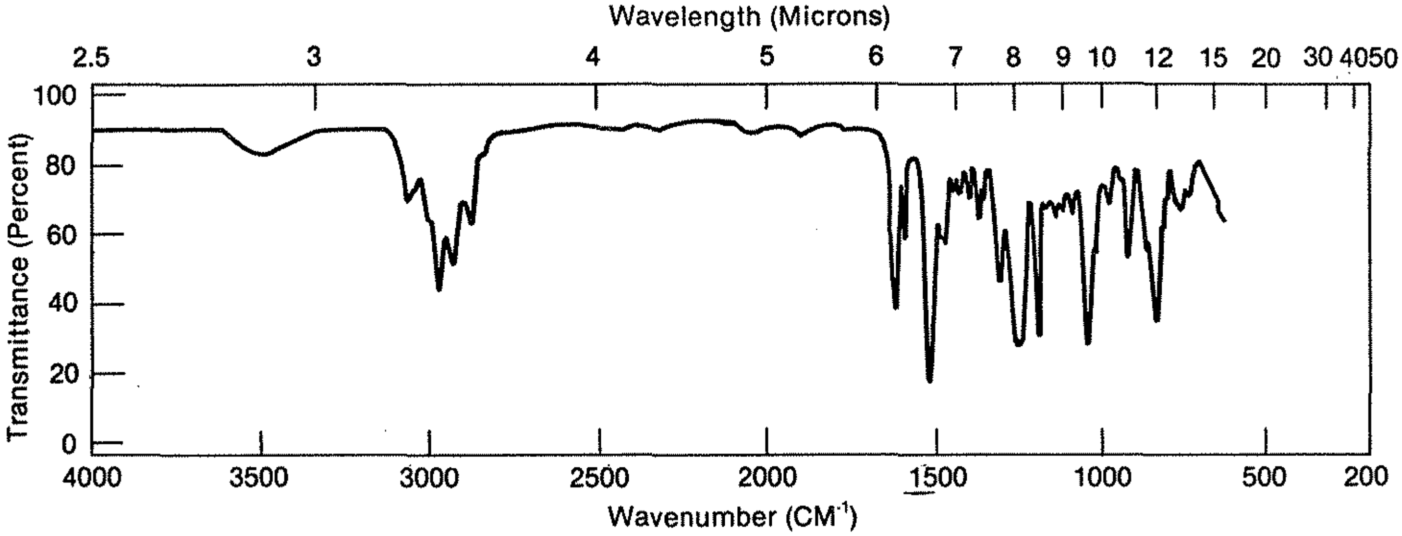

Figure 3. Infrared Spectrum of the Liquid Epoxy Resin.

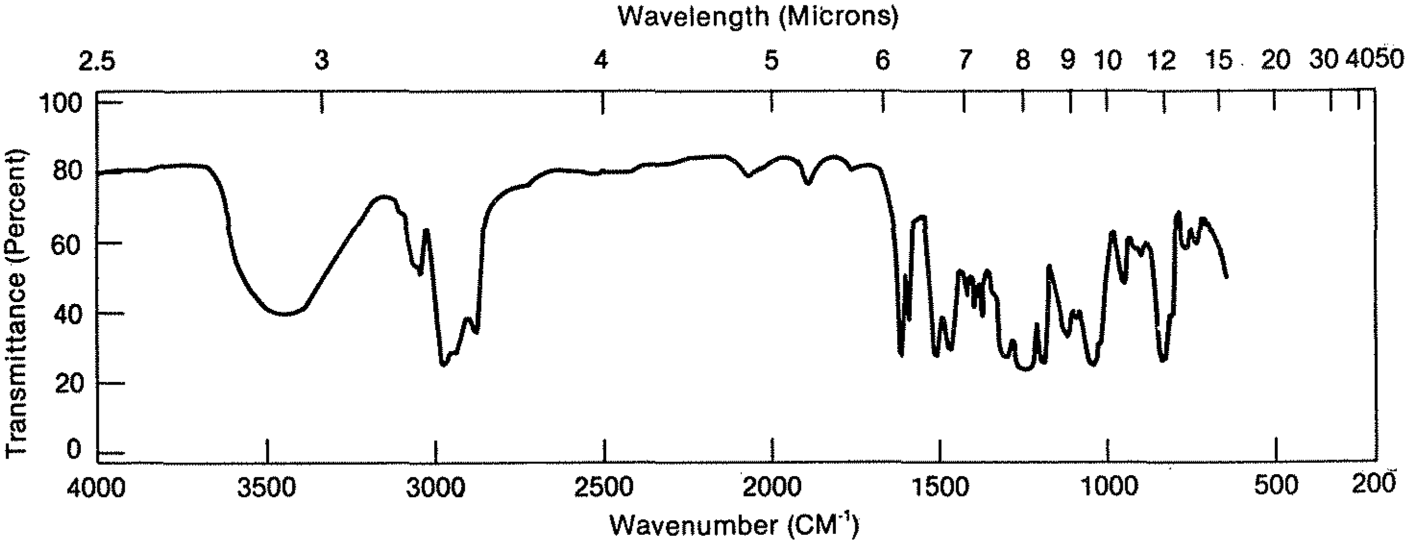

Figure 4. Infrared Spectrum of the Solid Epoxy Resin.

3.4.2 Test Requirements - The white and yellow ETP's shall meet the requirements of Table 2. For each set of raw materials, 2 replicate ETP batches shall be tested.

Note: The laboratory scale batches will be prepared by the ETP supplier unless agreed upon otherwise by the specifying agency.

4. TESTING PROCEDURES

4.1 Sampling

Production ETP Compound - The ETP will normally be supplied in disposable containers coated with a releasing agent for convenient removal. The containers shall consist of blocks whose size shall be mutually agreed upon by both the supplier and the user and shall weigh no more than 40 pounds. Take one (1) 350 g sample each from two (2) blocks selected at random from each batch.

NOTE: For maximum ease of handling, a 2 inch maximum thickness for these blocks has been found to be advantageous.

Solid Epoxy Resin, Pigments, Calcium Carbonate and Beads - Take two (2) samples from each batch in accordance with Federal Test Method Std. No. 141b, Method 1022.

Liquid Epoxy Resin - Take two (2) samples from each batch in accordance with ASTM D 270.

Laboratory-Scale ETP Compound - Two laboratory batches of ETP shall be prepared for each set of raw materials used in production. For each sample in a batch the number of repeated measurements of each property is given below:

ETP Property, Fresh and Heated (sec. 4.3)	Runs per sample
viscosity	1
softening point	2
reflectance	3
whiteness index	3
yellowness index	3
Solvent Extraction (sect. 4.4.)	1
epoxy equiv. wt.	3
infrared spectrum	1
Inorganic Analysis - White (sect. 4.5.)	3
% organic	3
% beads	3
% titanium dioxide	3
Inorganic Analysis - Yellow (sect. 4.5.)	1
% chromate	1
% lead	1
% organic	1
% beads	1
Component Property (sect. 4.6)	
resin: viscosity	1
resin: epoxy equiv. wt.	3
resin: infrared spectrum	1

TABLE 2. REQUIREMENTS FOR ETP LABORATORY BATCHES

ETP Property	Difference between 2 Samples[a]	Average of 2 Samples (white)	Average of 2 Samples (Yellow)	Test Procedure
Before Heating				
Viscosity, cps (20 RPM) 232°C (450°F)	$0.4\eta_{av}$[b]	See Fig. 5	See Fig. 6	4.3.1
Softening Point, °C	4.0	72.6 - 81.8	73.1 - 82.9	4.3.2
Reflectance, %	5.0	≥ 75.0	≥ 39.2	4.3.3
Whiteness Index	5.0	≥ 45.7	-	4.3.3
Yellowness Index[c]	5.0	-	126 - 141	4.3.3
After Heating				
Viscosity Change, cps, 232°C (450°F)	250	-350 to +200[d]	-150 to +500[d]	4.3.4
Softening Point Change, °C	4.0	0.0 to +5.3[d]	+2.0 to +9.0	4.3.4
Reflectance, %	5.0	≥ 77.7	≥ 39.5	4.3.4
Whiteness Index	5.0	≥ 34.8	-	4.3.4
Yellowness Index	5.0	-	126 - 141	4.3.4
After Separation				
Total Organic, %	0.9 3.7	60.8 - 69.4 -	- 57.9 - 61.2	4.5.2 4.5.6
Beads, %	3.2 4.4	14.0 - 16.9 -	- 13.3 - 17.8	4.5.3 4.5.5
Titanium Dioxide, %	0.2	10.3 - 12.4	-	4.5.4
Chromate, %	0.4	-	2.4 - 2.5	4.5.7
Lead, %	5.0	-	4.6 - 6.7	4.5.6
Epoxy Equivalent Wt. (Gram/Equiv.)	90	390 - 460	350 - 460	4.4.3
Infrared Spectrum	-	Identical to Figure 1	Identical to Figure 2	4.4.4

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a. Two samples are required for each batch. This column gives maximum difference permitted between 2 samples. Columns 2 and 3 give permissible values for the average.

b. η_{av} = average viscosity of 2 samples.

c. Conform to Highway Yellow Color Tolerance Chart (PR Color #1) Federal Highway Administration, HTO-21, Washington, D.C. 20590.

d. E.g., $-350 \leq (\eta_a - \eta_b) \leq +200$ cps; η_b, η_a = viscosity before, after heating

FIGURE 5

REQUIREMENT FOR VISCOSITY OF WHITE ETP

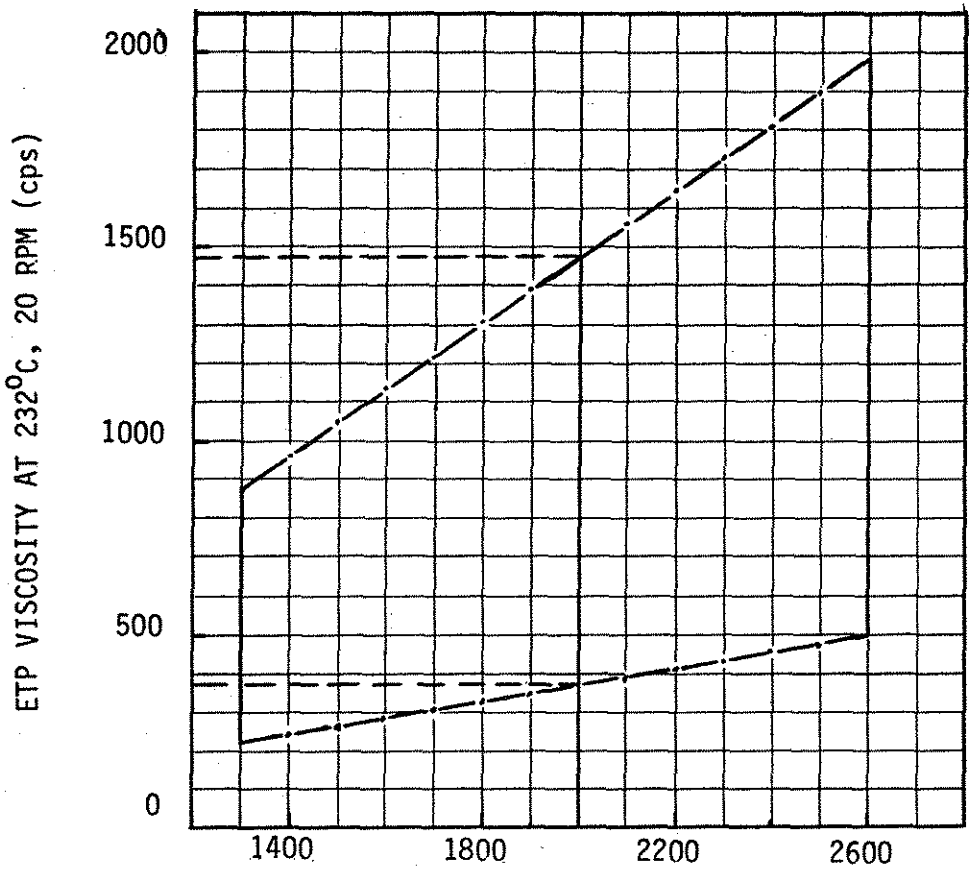
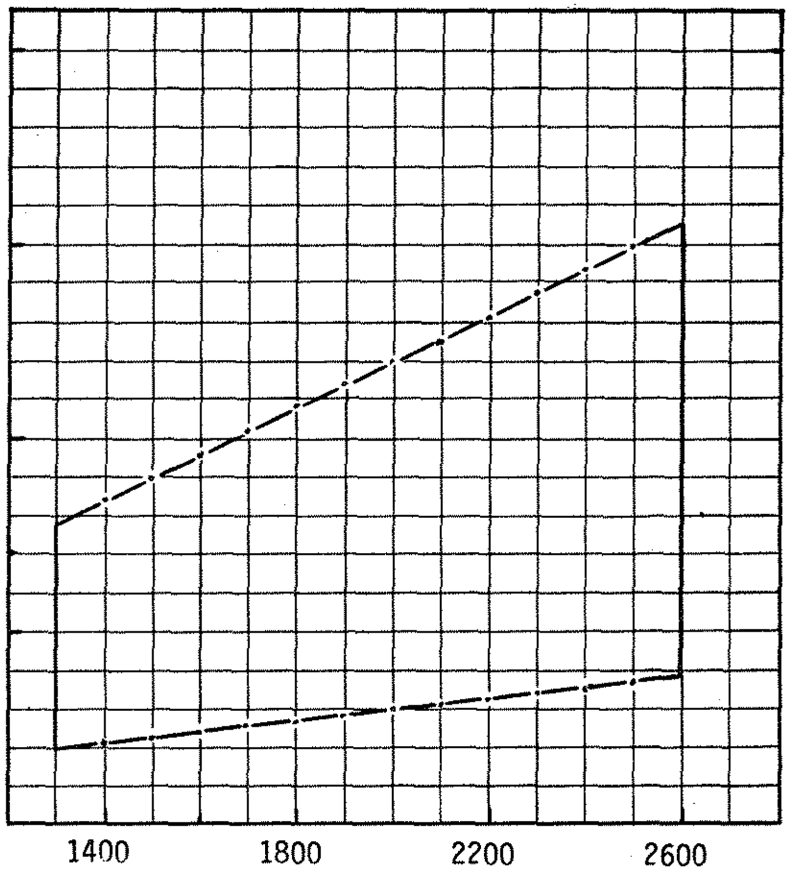


FIGURE 6

REQUIREMENT FOR VISCOSITY OF YELLOW ETP



These graphs are used to determine the acceptable range for ETP viscosity at 232°C. It is first necessary to determine the viscosity of the solid epoxy resin at 232°C. For example, for a solid epoxy resin viscosity of 2000 cps, the acceptable white ETP viscosity is between 375 and 1475 cps.

TiO_2: % titanium dioxide	3
TiO_2: oil absorption	2
$CaCO_3$: oil absorption	2
lead chromate: % lead, % chromate	1
lead chromate: pH, specific gravity	1

4.2 Preparation of Test Samples

4.2.1 Equipment

Paint film applicator.

Tooke paint thickness gauge or equivalent.

Softening point ring and ball apparatus as described in AASHTO T-53.

Stainless steel Brookfield viscosity sample chambers, 10 ml capacity, used with the Brookfield Thermosel system or equivalent.

Draw-down holder for glass plates.

Glass plates, 100 x 100 mm (4 x 4 in.).

4.2.2 Procedure - Equilibrate three glass plates in an oven set at 219°C (425°F). Heat the ETP (350 g) in a beaker (400 ml) in an oven set at 225°C (436°F) until the ETP is completely liquid (see Note). Remove the ETP from the oven and heat in an oil bath set at 240°C (465°F) while stirring with a thermometer until the ETP reaches 219°C (425°F). Remove the ETP from the bath, wipe off any excess oil from outside the beaker, and pour one viscosity sample in a viscosity chamber filling the chamber about three-fourths full. The sample will be used in section 4.3.1. Stirring with the thermometer is essential just before and after the pouring is conducted to make sure a representative sample of ETP is obtained.

Place the beaker in the oil bath to reheat the ETP to 219°C (425°F). Remove ETP from the bath, wipe off any excess oil as before, and pour samples into the two softening point rings, making sure that there are no air pockets left in the rings after pouring and that excess ETP is poured into each ring. These samples will be used in section 4.3.2.

While the softening point samples are being poured, retrieve the three glass plates from the oven and position them on the draw-down holder. Immediately pour the ETP over the top of each plate and slowly draw down a coating of 18 - 22 mil thickness (as measured by a Tooke gauge after cooling) on each plate using a paint film applicator. These samples will be used in section 4.3.3. This coating procedure should take no longer than 20 seconds per plate.

After preparing the plates, pour about 50 ml of ETP into a 100 ml beaker for the heat stability test (section 4.3.4). Pour an additional 5 g of the ETP into a weighed 400 ml beaker for the separation by extraction (section 4.4). Reweigh the beaker and contents after cooling. Finally pour three 1 g samples (approximate weight) of ETP into three aluminum dishes (6 cm diameter) for the separation by fusion (section 4.5). This entire procedure to prepare samples should take no longer than 20 minutes.

NOTE: Place the beaker on a heat resistant board to prevent breakage while oven heating.

4.3 Measurement of ETP Properties

4.3.1 Viscosity

Equipment - RVF Brookfield Thermosel system equipped with stainless steel viscosity sample chambers, spindle (SC4-27), Thermosel heating proportional container, SCR controls, and a Brookfield synchrolectric viscometer or equivalent. The system shall be capable of measuring viscosities at 37-260°C.

Procedure - Heat the ETP at 232°C (450°F) in the heating container and rotate the spindle in the ETP melt at 20 rpm until a constant shear reading is obtained. Record this value and convert the readings to cps values using the conversion table given with the instrument.

NOTE: The use of an alternative spindle (SC4-21) has been suggested for this test. The use of this spindle has not been validated.

4.3.2 Softening Point - Follow the procedure in AASHTO T-53.

NOTE: An alternative procedure based on ASTM E-28 using a hot plate, magnetic stirrer and glycerine has been suggested for this test. This procedure has not been validated.

4.3.3. Reflectance, Whiteness Index and Yellowness Index

Equipment - Multipurpose reflectometer

Procedure for Reflectance - Follow the procedure described in ASTM E 97. Results are considered suspect if the high and low reflectances obtained differ by more than 2.0 units.

Procedure for Whiteness and Yellowness Index - Follow the procedure described in ASTM E 313 for the Y, X and Z reflectance values for each of the three plates. Calculate whiteness index (W.I.) as follows:

$$\text{W. I.} = 3.387Z - 3Y$$

Calculate yellowness index (Y.I.) as follows:

$$\text{Y. I.} = \frac{127.7X - 106Z}{Y}$$

Results are considered suspect if the high and low W.I. or Y.I. differ by more than 1.5 units.

4.3.4. Heat Stability - Heat 50 ml of the ETP in a 100 ml beaker (section 4.2) in an oven set at 219°C (425°F) for fifteen (15) minutes. After heating, transfer the beaker to the oil bath set at 219°C (425°F), cover it with a watch glass, and heat the sample in the bath for 4 hours, stirring the mixture completely with a stirring rod every 15 minutes. Remove the beaker from the bath and determine viscosity, softening point, reflectance, whiteness index and yellowness index as described previously.

4.4 Separation and Characterization of the Organic Portion of ETP

4.4.1 Apparatus and Reagents

Centrifuge: speed of about 5,000 rpm and minimum tube capacity of 60 ml.

Perkin Elmer 621 Grating Infrared Spectrophotometer or equivalent.

Flash rotary vacuum evaporator.

Vacuum oven.

Solvent mixture: 70 parts toluene, 30 parts acetone.

4.4.2 Solvent Extraction Separation Procedure - Dissolve 5 g of ETP in 250 ml of solvent mixture in a 400 ml beaker (section 4.2). Centrifuge the mixture at about 2,000 rpm for 15 minutes. Carefully decant the supernatant from the solid residue into a round bottom flask without any solid being transferred into the flask. Wash the inorganic residue with fresh solvent (four-50 ml portions), separating by centrifugation each time as before and combining each wash supernatant with the original supernatant. Evaporate the solution to dryness under vacuum and heat (not over 60°C) using a flash rotary vacuum evaporator.

Finally evaporate the last remains of the solvent from the organic residue in a vacuum oven at 60°C (140°F) at least 16 hours. The material may froth at this point. Cool the organic residue and record the weight.

Wash the inorganic residue twice with acetone (2 ml), centrifuge as before, discard the supernatant, dry the residue at 110°C (230°F) for 16 hours, and save it for tests in section 4.5.5 (yellow ETP only).

4.4.3 Epoxy Equivalent Weight - Follow the procedure in ASTM D 1652 to determine the epoxy equivalent weight of the ETP resin portion using 1.0 g of the organic residue prepared above. The results are considered suspect if the high and low values of the epoxy equivalent weight differ by more than 20 units.

NOTE: An alternative procedure is given on page 49

4.4.4. Infrared Spectrum - Place approximately 5 mg of the residue obtained from section 4.4.2 on a sodium chloride infrared plate. Sandwich this residue between that plate and a second sodium chloride plate of the same size so that only a thin coating (about 5 mil) of material exists between the two plates. The plates may have to be heated (30°C) to melt and spread the sample. Mount the plates in an infrared cell holder and insert the holder into the infrared instrument. Position the pen between 90 and 95 percent transmittance at 2,200 cm^{-1} by adjusting the 100 percent dial of the instrument. Examine the spectrum of this film at 1,240 cm^{-1}. If the tip of the peak at 1,240 cm^{-1} is between 10 and 25 percent transmittance, run the complete spectrum of the film (4,000 to 650 cm^{-1}). If this peak extends to a lower transmittance percentage at this wavenumber, repeat the above procedure using less sample. Compare this spectrum with that of the reference resin spectrum (Figure 1 or 2).

4.5 Analysis of Inorganic Portion of White and Yellow ETP

4.5.1 Apparatus and Reagents

See ASTM D 1394 under Jones Reduction method for the determination of total titanium; and ASTM D 444, section II, thiosulfate method.

Porcelain crucibles, 1 inch (2.5 cm) diameter Whatman No. 40 ashless filter paper or equivalent.

Muffle furnace.

Dilute and concentrated sulfuric acid.

33% Potassium hydroxide in water (wt/vol.).

4.5.2 Percent Organic Material (White ETP) - Weigh to the nearest 0.0001 g approximately 1 g of white ETP in a porcelain crucible and heat the sample at 600°C (1112°F) for 16 hours (overnight). Let the sample cool in a dessicator, and weigh the residue. Calculate the percent organic material in the sample using the following formula:

$$\% \text{ organic} = (1 - r/w) \times 100$$

w = weight of white ETP

r = weight of ETP residue after heating

Results are considered suspect if the high and low percent organic obtained differ by more than 1.0 percent.

4.5.3 Percent Glass Beads (White ETP) - Using the inorganic residue from section 4.5.2 above for the white ETP sample, follow the procedure in ASTM D 1394 for determination of total titanium by the Jones Reduction method starting with section 11.3. After cooling the concentrated H_2SO_4 mixture, diluting carefully with 100 ml H_2O, and heating carefully to boiling while stirring (section 11.3), decant the solution from the beads into a 400 ml beaker. Residual calcium salts in suspension are allowed to be decanted at this point. Wash the residue beads twice with dilute sulfuric acid (1:19 in H_2O) and once with water, decanting the wash solution each time into the same 400 ml beaker of sample solution. Finally, wash the residue beads with acetone (discarding the acetone wash), dry at 110°C for 2 hours and weigh. Save the sample solution for use in section 4.5.4. Calculate the percent beads using the following formula:

$$\% \text{ beads} = (s/w) \times 100$$

w = weight of ETP (see section 4.5.2)

s = weight of residue beads

Results are considered suspect if the high and low percent beads differ by more than 1.0 percent.

NOTE: An alternative procedure is given on page 50.

4.5.4 Percent Titanium Dioxide (White ETP) - Using the sample solution in section 4.5.3, follow the procedure in ASTM D 1394 for the determination of total titanium by the Jones Reduction method starting with the second sentence in section 11.4. Calculate the percent titanium dioxide using the equation in section 12 of the ASTM procedure substituting the weight of ETP (see section 4.5.2) for s. Results are considered suspect if the high and low percent titanium dioxide differ by more than 0.5 percent.

NOTE: An alternative procedure is given on page 50.

4.5.5 Percent Glass Beads (Yellow ETP) - Dissolve the inorganic residue from section 4.4.2 in 20 ml of boiling concentrated potassium hydroxide solution (33% wt/vol) while stirring in a 250 ml Erlenmeyer flask. This should take approximately 15 minutes. Boil the mixture another 15 minutes while stirring, cool, and add 80 ml of distilled water. Filter the solid on medium ashless filter paper (Whatman No. 40 or equivalent). Wash the solid twice on the filter with distilled water. Add the wash water to the yellow basic filtrate. Save this yellow basic solution for section 4.5.6. Wash the wet solid from the filter paper into a 250 ml Erlenmeyer flask with dilute nitric acid (4 N, 20 ml). Add another 30 ml of this dilute nitric acid to the flask and stir this mixture for 5 minutes at room temperature. Decant the liquid and white precipitate from the beads onto a filter paper, collecting the colorless filtrate in a 250 ml flask. The white solid precipitate is allowed to be decanted onto the filter paper. Wash the residue beads twice with dilute nitric acid and once with distilled water, decanting each wash solution onto the filter and letting that wash filtrate be combined with the colorless dilute nitric acid filtrate. Discard the filter paper and save this colorless acidic solution for section 4.5.6. Finally, wash the residue beads with acetone (discarding the acetone wash), dry at 110^{o}C for 2 hours and weigh. Calculate the percent beads using the following formula:

$$\% \text{ beads} = (s/w) \times 100$$

w = weight of yellow ETP (see section 4.4.2)

s = weight of residue beads

4.5.6 Percent Lead (Yellow ETP) - Acidify the basic yellow solution from section 4.5.5 by adding concentrated sulfuric acid dropwise while stirring until the mixture is acidic to litmus paper. Boil the acidified mixture while stirring for 5 minutes and then cool for 15 minutes. The mixture should consist of an orange solution and a white precipitate (lead sulfate). Carefully decant the orange solution from the precipitate into a 500 ml volumetric flask and wash the precipitate with three 10 ml portions of water, decanting the wash water into the orange supernatant solution each time. Save the orange solution for section 4.5.7. Add more water (20 ml) to the precipitate and filter the white solid on medium ashless filter paper (Whatman No. 40 or equivalent). Wash the solid once on the filter. Add 2 ml of concentrated sulfuric acid to the colorless acidic solution from section 4.5.5. Boil this mixture for 5 minutes while stirring and then cool for 15 minutes. This mixture should consist of a white solid (lead sulfate) in a colorless solution. Filter this solid using the same ashless filter paper containing the other solid lead sulfate and let the colorless filtrate combine with the orange solution in the 500 ml flask. Wash the solid once on the filter with distilled water, fold the filter, place it in a weighed crucible, and heat the crucible and sample in a muffle furnace overnight at 600°C (1112°F) until it reaches a constant weight. Calculate percent lead as follows:

$$\% \text{ lead} = (c/y) \times 68.3$$

c = weight of lead sulfate

y = weight of yellow ETP (see section 4.4.2)

4.5.7 Percent Chromate (Yellow ETP) - Standardize a 0.IN solution of sodium thiosulfate against iodine and potassium chromate. Calculate the grams of potassium chromate titrated per milliliter of sodium thiosulfate used in this standardization (m). Dilute the acidic orange liquid from section 4.5.6 in a 500 ml volumetric flask to volume with water. Determine the percent chromate (CrO_4) in this solution by the thiosulfate method in section 11 of ASTM D 444. Use a 100 ml aliquot of the orange solution instead of the 25 ml called for in this procedure.

Calculate the percent chromate as follows:

$$\% \, CrO_4 = \frac{em}{y} \times 298.7$$

e = volume of std. sodium thiosulfate required for the titration (mls.)

m = weight of potassium chromate titrated per milliliter of sodium thiosulfate.

y = weight of yellow ETP (see section 4.4.2) calculate the percent chromium as follows:

$$\% \, Cr = \% \, CrO_4 \times 0.448$$

4.5.7 Percent Chromate (Yellow ETP) - Dilute the acidic orange liquid from section 4.5.6 in a 500 ml volumetric flask to volume with water. Determine the percent chromate in this solution by the thiosulfate method in section 11 of ASTM D 444. Use a 100 ml aliquot of the orange solution instead of the 25 ml called for in this procedure.

4.5.8 Percent Organic (Yellow ETP)

Calculate the percent organic material as follows:

% organic = (d/y) x 100

d = weight of organic extract (see section. 4.4.2, para. 2)

y = weight of yellow ETP (see section 4.4.2, para. 1)

4.6 Test Procedures for Components of ETP

4.6.1 Epoxy Resins

Viscosity - Obtain the viscosity of the solid (232°C, 10 rpm) and liquid (49°C, 20 rpm) resins using the procedure in section 4.3.1.

Epoxy Equivalent Weight (EEW) - Follow the procedure in section 4.4.3 to determine EEW of both the liquid and solid resins using 2.5 g of the solid resin and 0.5 g of the liquid resin.

Infrared Spectrum - Follow the procedure in section 4.4.4. to record the infrared spectra of the epoxy resins. The sodium chloride plates will have to be heated gently on a hot plate to melt the solid resin, using paper towels underneath the salt plates on the hot plate.

4.6.2 Titanium Dioxide - The pigment shall be tested in accordance with ASTM D 476. Follow the procedure in section 4.5.4 for the determination of total titanium dioxide in a 1.0.g sample of the pigment. Follow the procedure in ASTM D 281 for the determination of oil absorption using raw linseed oil. Results are considered suspect if the high and low percent titanium dioxide or grams of oil absorbed differ by more than 1.0 percent or 0.5 grams respectively.

4.6.3 Calcium Carbonate - The calcium carbonate shall be tested in accordance with ASTM D 1199. Determine the oil absorption according to ASTM D 281 using raw linseed oil. Results are considered suspect if the high and low grams of oil absorbed differ by more than 0.5 units.

4.6.4 Lead Chromate - Follow the procedure in ASTM D 1208 to determine the pH of this pigment using 2.5 g of pigment in 50 ml water. Follow the procedures listed in sections 4.5.6 and 4.5.7 using 1.0 g of pigment to determine the percentages of lead and chromate. Follow the procedure listed in ASTM D 153 to determine the specific gravity of this pigment.

4.6.5 Beads - Follow the procedure in AASHTO T-250 for the determination of bead grading.

ALTERNATE TEST PROCEDURES

1. INTRODUCTION

The following test procedures have been conducted by various manufacturers which participated in the interlaboratory study of ETP. While results using these procedures are very similar to those results using the procedures developed by the Federal Highway Administration, there were too few results to adequately make a statistical comparison.

2. EPOXY EQUIVALENT WEIGHT

Reagents

Chloroform.

Perchloric acid, 0.1 N in acetic acid, Fisher Scientific Co. So-P-339.

Tetrabutylammonium iodide, Eastman 4702.

Crystal violet indicator, 0.1% solution in acetic acid.

Standardization of Perchloric Acid

Dissolve by gentle heating 0.4 grams of potassium acid phthalate, weighed accurately to the nearest milligram, in 50 ml of glacial acetic acid. Add 6-8 drops of crystal violet indicator solution. Insert a clean stirring bar into the sample and adjust the magnetic stirrer to effect solution; continue agitation throughout the titration procedure. Titrate with perchloric acid reagent solution to the end point - sharp change in color from blue to green, stable for two minutes.

Test Procedure

Weigh accurately 0.80 - 1.20 g of sample into a 250 ml ground-glass stoppered Erlenmeyer flask. Add 20 ml of chloroform, stopper and stir until the sample is dissolved. Add 5 drops of crystal violet indicator, 20 ml of glacial acetic acid, and 2.0 - 2.5 g of tetrabutylammonium iodide.

Titrate immediately with 0.1 N perchloric acid to an aqua color which is stable for 5 seconds. The volume added is quantity "A".

Run a blank on 20 ml of chloroform, 20 ml of acetic acid and 2 g of tetrabutylammonium iodide, quantity "B".

Calculation

$$\text{Epoxy equivalent wt. (g/equivalent)} = \frac{G \times 1000}{(A-B) \times N}$$

where A = ml of titrant for sample
B = ml of titrant for blank
N = normality of titrant
G = grams of sample

NOTE: The titration can be performed potentiometrically, rather than visually, using an automatic titrator equipped with a glass electrode and a reference electrode filled with saturated methanolic KCl. The titrator is set on a 500 mv scale and very slow speed for titration of the blank.

3. PERCENT BEADS

Use the inorganic residue obtained (section 4.5.2) above. Add 1:1 sulfuric acid:water to the porcelain crucible. Transfer the slurry to a weighed 45 micron sieve, using water to complete the transfer. Trap the acid water solution in a 400 ml beaker. Wash the inorganic residue with water, catching the water in the same beaker, and brush gently with a rubber policeman to break up lumps of opaque white material. When only the glass beads remain in the sieve, rinse with acetone. Dry at 110°C for 30 min. and weigh.

Calculate the percent beads using the following formula:

% beads = $(s/w) \times 100$

w = weight of ETP (see section 4.5.2)

s = weight of residue beads

4. PERCENT TITANIUM DIOXIDE

Weigh 1 g of ETP into a platinum crucible and heat the sample at 600°C until all organic matter has been decomposed (16 hours).

Add lithium metaborate to the ash in the ratio of approximately 5/1 $LiBO_2$/ash. Add a few crystals of KI and fuse at 1000°C.

Cool the melt and dissolve it in dilute hydrochloric acid. Determine titanium content by Atomic Absorption Spectroscopy.

Appendix B
Standard Specification for Cleaning and Preparation of Pavement Surface

DESCRIPTION. This work shall consist of cleaning and preparing portland cement and bituminous pavement surfaces for the application of epoxy thermoplastic traffic markings.

MATERIALS Materials for cleaning and preparing pavement surfaces shall be as determined by the Contractor, except that they shall be approved by the Engineer and conform to any Local, State or Federal law, regulation or code.

CONSTRUCTION DETAILS

1. General. The work required to clean and prepare pavement surfaces shall be performed in accordance with these specifications and to the satisfaction of the Engineer. When no method of cleaning is specified the Contractor may complete the work in any manner, with the Engineer°s approval.

Whenever grinding, scraping , sandblasting or other operations are performed, the work must be conducted in such a manner that the finished pavement surface is not damaged or left in a pattern that will mislead or misdirect the motorist. When these operations are completed the pavement surface shall be blown-off with compressed air to remove residue and debris resulting from the cleaning work.

Unless otherwise specified in the Contract Documents the area(s) and quantity of cleaning work shall be determined by the Engineer at the job site when the Contract is in progress In addition the Engineer shall have the authority of increasing or decreasing the work area as the project continues.

2. Limits of Work. Cleaning and surface preparation work shall be confined to the surface area specified for application of epoxy thermoplastic marking materials; or the surface area of existing pavement markings that are specified for removal.

Surface preparation work shall include cleaning for lines or cleaning for letters and symbols. Lines shall be meant to include: broken line; dotted line; solid line; channelizing line; barrier lines; stop line; crosswalk line and crossbars.

When lines are cleaned, the area of preparation shall be at least the width of the new pavement marking, or existing line, plus one (1) inch on each side.

When letters and symbols are cleaned the area of preparation shall be sufficiently large to accommodate the new marking, or to remove the existing marking.

3. <u>Cleaning Existing Pavement Markings</u>. Existing pavement markings shall be cleaned for the purpose of:

    A. Preparing the pavement surface for the application of epoxy thermoplastic markings in the same location as the existing marking.

    B. To remove existing markings that are in good condition which, if allowed to remain, will interfere with or otherwise conflict with newly applied epoxy thermoplastic marking patterns.

It is not intended that all deteriorated or otherwise obscured existing pavement markings be removed. Example: If a new marking is applied to an unmarked 'skip' in a broken line, and the existing broken line pattern is worn or deteriorated to the extent that it is not misleading or confusing to the motorist, the existing markings do not require removal.

New epoxy thermoplastic traffic markings shall not be applied over existing epoxy or thermoplastic markings. Existing markings of these types shall be cleaned as directed by the Engineer and in accordance with the epoxy or thermoplastic manufacturer's recommendations for the proper adherence of his material.

New epoxy thermoplastic traffic markings may be applied over existing painted markings that are sufficiently deteriorated so as not to interfere with the adhesion of the new marking material. The determination of deteriorated markings shall be the sole judgement of the Engineer, and shall be guided by the following:

> A deteriorated painted marking shall be visibly abraded or chipped to the extent that the underlying pavement surface is exposed at the high points and only firmly adhered paint remains in the low areas of the substrate.

Heavy deposits of, or newly applied painted markings shall be cleaned to the extent that they meet the above criteria.

METHOD OF MEASUREMENT. Surface cleaning and preparation of pavement surfaces for lines will be measured in linear feet along the centerline of the prepared surface and will be based on a 4-inch wide line. Measurement for cleaning surfaces for,or with, a line of a width greater or less than the basic 4-inches will be made by the following method:

$$\frac{\text{Actual Width of Line (inches) x Linear Feet}}{\text{4 (inches)}}$$

No payment will be made for the additional 1-inch of cleaning on each side of the line.

Cleaning and preparation of letters and symbols on pavement surfaces will be measured by each unit cleaned. A unit will consist of one letter or one symbol. Example: 'STOP' would be measured as four letters.

The Engineer shall adjust the quantities of these items as required to meet field conditions. This may result in substantial increases or decreases of the proposal quantities.

BASIS OF PAYMENT. The accepted quantities of cleaned pavement surface will be paid for at the contract unit price, which shall include the cost of furnishing all labor, materials and equipment to satisfactorily complete the work. The cost for maintaining and protecting traffic during the cleaning work shall be included in the price bid.

Payment will be made under:

Item	Pay Item
Cleaning and Preparation of Pavement Surface-Lines	Linear Foot
Cleaning and Preparation of Pavement-Letters	Each
Cleaning and Preparation of Pavement-Symbols	Each

APPENDIX C

MAJOR COMPONENTS used in the Illinois Striper Modification

1. Melter Tank-Custom Built	Certified Tank Co. Springfield, IL.
2.Pressure (Application) Tank-Custom Built	Scherf Steel Co. Springfield, IL.
3. Air Compressor-IH Part No. 217877R93	International Harvester Trucks
4.Oil Transfer Pumps- VIKING 2-inch No. K412R with motor (Large) VIKING No.G125R with motor (Small)	Lane Machinery Co. St. Louis, MO
5.Flexible Metal Annular Hose-BRIGGS Stainless Steel Braided Hose	Briggs Rubber Co. Horsham, Penn.
6.Furnace-AXMAN-ANDERSON No. 48305	M-B of Wisconsin Chilton, Wisconsin
7.Agitator Drive (2)-WINSMITH No. R4643-84	State Electric St Louis, MO
8.Surge Tank-M-B No. 53786	M-B of Wisconsin Chilton, Wisconsin
9.Timing Mechanism-RESEARCH DERIVATIVES No. 304	Research Derivatives Sacramento, California
10. ETP Thermostats (2)-CHROMALOX No. AR7024	F.I. Tourtelot River Forest, IL
11. ETP Guns (2)-PRISMO No. 11222524	Prismo Unversal Montgomery, Penn.
12. Bead Guns (2)-BINKS No. 30	Binks Mfg. Co. Franklin Park, IL.
13 Temperature Indicator (4)- WEST No. 1669 Probes No. 1551	Premium Instruments Worth, IL
14. Tank Insulation-KOAWOOL (Babcock & Wilcox)	Sprinkmann & Sons Peoria, IL

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1. "Epoxy Thermoplastic Pavement Marking Material" Technical Note Dr. E.T. Harrigan July, 1981.

2. "Epoxy Thermoplastic Pavement Marking Material: Summary of Research Results and Revised Specification" Final Report Brian H. Choller and Bernard R. Appleman, December 1981. FHWA RD 81/144

3 "Development of Lane Delineation with Improved Durability" Final Report John M. Dale June 1981.FHWA RD-75-70

4. "Paint Striper Conversion to ETP Capability" Illinois Department of Transportation L.J. Weishaar and K.W. Lupton, February 1982.

* U. S. GOVERNMENT PRINTING OFFICE 1982 381-428/2367