

ASPHALT - RUBBER STRESS ABSORBING MEMBRANES

Field Performance And State - Of - The - Art

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ABSTRACT

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Field Performance and State-of-the-Art

The maintenance of existing pavements is the foremost problem facing engineers today.

Paving cracking and subsequent reflection through overlays is directly associated with pavement deterioration and maintenance problems.

During the early 1960's a concept was developed utilizing a composition of 25 percent ground tire rubber reacted with 75 percent hot asphalt.

This process has been utilized in full scale field projects in the form of seal coats, stress absorbing interlayers, and as waterproof membranes.

Results from approximately 2000 lane miles of construction clearly show that this basic elastomeric material performs as a waterproof membrane with a high capacity to absorb direct tensile, flexural, and sheering stresses.

The paper reviews the performance of the asphalt-rubber seal coats placed since 1967 and will present the state-of-the-art of design and construction.

It further reviews test installations and results of stress absorbing membranes placed to (1) prevent reflective cracking of overlays placed over both flexible and rigid pavements; (2) provide bridge deck protection; (3) control differential movement of existing pavements constructed over expansive clays; (4) provide economical construction for low volume roadways; (5) provide improved sealing of cracks and joints.

Details of more than ten full-scale field trials of the above noted usages will be reviewed.

Ongoing formal and informal research will be reviewed and areas of needed research are suggested.

A pavement is no sooner built than deterioration begins and most pavements usually require several major corrective measures and possible complete reconstruction in a lifetime. We find that the combined action of traffic, sun, rain, frost and soil moisture all combine to create multiple problems. These problems are all associated with stresses and subsequent strains within the pavement structures that are manifestations of forces created by the major factors just noted.

The problems associated with these strains in pavements may be generally divided into the following three general categories:

1. Cracking of the pavement surface as a result of repeated flexural stresses.
2. Cracking of pavement surface by direct tensile stresses (normal jointing required in rigid pavements, thermal and shrinkage cracking in flexible pavements).
3. Differential vertical movement between directly adjacent independent (cracked) pavement sections.

A special problem is that of expansive clay subgrades. This problem will be discussed separately from "normal" failure modes.

Every pavement structure will eventually fail as the direct result of these stresses and strains and, in most cases, failure is preceded by a combination of two or more of the distress categories. To state the problem basically, the pavement structure is insufficient in either its elastic properties or its tensile strength to respond without fracture to the forces acting upon it.

All pavement types are affected and the problems peculiar to each will be discussed in the context of the use of the asphalt-rubber stress absorbing membrane as a corrective measure.

First let us take a look at the most common and costly problem of pavement distress that is worldwide (1) (5), that is fatigue cracking (9) (10) (15) of asphalt pavements. This type of cracking is due to repeated deflection of the pavement of as little as 0.010" (1) under wheel loads. In the advanced stage it is manifested by "alligator" or "chicken-wire" pattern cracking accompanied by the release of small pieces that later develop into potholes, particularly during wet weather. Since moving wheel loads actually function as strip loadings, as far as pavements are concerned, the initial phase of fatigue cracking appears as a longitudinal crack that appears in the wheelpath parallel to the direction of traffic. It is followed by a second crack, roughly parallel to the first; and transverse cracks start connecting the parallel cracks. This procedure progresses to the final state previously described, i.e., alligator pattern cracking (11).

Obviously, the problem here is due to a lack of flexibility (6) (13), or elasticity, in the asphalt pavement component required to respond without cracking to the resilient nature of the substructure under load. This resilience in the substructure is due to the entrapment of air within soil pores and held there by the capillary pressure of moisture between the soil grains. The effect is most pronounced in fine grained soils and results in a pneumatic, or "air mattress," effect under load.

The second type of pavement distress, that of direct tensile stresses occurs immediately after construction with rigid pavements and may be accentuated at later dates. In flexible pavements the problem manifests itself usually after some period of service although it may occur in as little as three months and in rare cases does occur during the normal design life of the pavement.

The compromise solution to this specific problem is to provide weakened planes in rigid pavement so that the cracks occur at designated intervals, in a straight line, eliminating potential spalling and providing a reservoir for sealant to prevent entry of moisture and incompressibles into the joint. While this solution delays the problem it is common knowledge that it does not eliminate it. The direct tensile failure in a flexible pavement system is of a different nature and generally the cause can be assigned to one of the following conditions:

1. The visco-elastic properties of the asphaltic concrete are such that at low temperatures its elastic limit is exceeded.
2. Oxidation and other chemical actions decrease the elastic limit of the asphaltic concrete and the pavements crack as a result of repeated temperature reversals in a fatigue mode of failure.
3. Subgrade and subbase material volume changes as a result of fluctuating moisture and temperature reflect stresses upon the asphaltic concrete in excess of its tensile strength.

Generally, the first two modes of stress, in conjunction with traffic induced stress, are involved in a tensile failure of flexible pavement. Solutions have been developed which can greatly delay the occurrence of tensile cracking and these should certainly not be ignored. However, once again, these solutions are delaying the actions and cannot be relied upon to eliminate completely the problem of tensile cracking.

The third category of pavement distress, that of differential vertical movement, comes into play after the pavement has cracked as a result of flexural or tensile failure modes. This type of distress is important in that it is the direct causal factor of poor riding qualities. It is also probably the critical factor in the initial reflection of existing cracks

through the overlays which must be later placed to restore the riding qualities. Efforts to solve these types of pavement destruction with the limited use of elastomers go back further than the memory of either one of the authors.

The direction of these efforts has been to modify the asphalt or the asphaltic concrete characteristics to reduce the affects of temperature change upon the stiffness and elasticity of the structure (2). Unfortunately, costs have usually limited the percentage of elastomer to asphalt to an inadequate amount to insure sufficient elastic protection, particularly in cold weather when the pavement is most brittle. However, the addition of elastomers should not be ignored. There is an abundance of evidence that long-term benefits may be achieved at a relatively low cost by the addition of a small quantity of elastomer to the asphaltic concrete mix.

Further, elastomeric products have been and are in broad use in sealing of joints and cracks in an effort to delay failure or to prevent the failure from occurring.

It is not within the scope of this paper to discuss the concept of modification of the asphaltic concrete mix or joint sealants for rigid pavement. To those interested, an excellent bibliography is provided in Ref. No. (6).

This paper instead will be limited to the development of a system which provides procedures for corrective action on a failed pavement.

In the early years of the 1960's a concept was developed for overcoming the problem of fatigue cracking. Field trials were initiated in the winter of 1964-65 and results reported to the Highway Research Board in January 1966 (8). The concept basically utilized a composition con-

sisting of 25 percent ground recycled tire rubber reacted with asphalt at high temperature to form a thick, jellied material with good elastic properties when cooled. In order to keep costs down and still get the benefit of a high rubber content, this material was spread in a thin membrane over a cracked surface, covered with chips to provide a wearing surface, and opened to traffic.

The first full-scale field trial of this material took place in January 1967 on the main taxiway of the City of Phoenix Sky Harbor Airport (7) which had been originally designed for DC-3 aircraft and was developing severe 'alligator' pattern fatigue cracking under Boeing 707 and similar aircraft. This application, though crude, served so well that by the spring of 1968 the equivalent of some 15-lane miles had been placed by the City at the airport and on streets.

The Arizona Department of Transportation became interested in this concept for prevention of reflection of "alligator pattern" cracking and in the summer of 1968 constructed an asphalt-rubber seal over 2-1/2_± miles of severely fatigue cracked pavements on frontage and access roads of the Black Canyon Freeway, I-17, Phoenix, Arizona (4).

The general appearance of the application at the completion of this contract was poor due to the fact that proper equipment and application techniques for this asphalt-rubber composition had not yet been developed. However, with the passage of time and traffic the unevenness of the application smoothed out until the appearance became reasonably acceptable. Most important, and in spite of construction difficulties, it proved the efficacy of the asphalt-rubber material in the prevention of "alligator" crack reflection. Today the surface is in excellent condition and shows only minor crack reflection after seven years of hard service. It should

be noted that it was the thermal or shrinkage cracking that reflected through the asphalt-rubber seal coat, but the cracks were narrow and have not spalled and the "alligator" crack reflection was not present (photo 1).

The Arizona Department of Transportation and other public agencies placed several other projects between 1968 and 1971 using the asphalt-rubber system with good success in controlling the fatigue cracking problem but with variable results in overcoming construction problems, as application techniques were gradually perfected. One of the most notable projects treated with asphalt-rubber during this period was the main Street of Tolleson, Arizona, (old U. S. 80) in the summer of 1969.

The street was in very poor condition with severe fatigue cracking and innumerable potholes. It actually appeared as though reconstruction would be imperative since a conventional overlay of sufficient thickness to control the cracking could not be used because of curb height restrictions and drainage conditions.

The town authorities decided to try an asphalt-rubber treatment, but first it was necessary to fill the numerous potholes and wider cracks. The necessary repair work was too extensive to be accomplished by hand patching so the contractor used a slurry seal operation to accomplish this over the entire street. The slurry seal was permitted to cure for a few days and the asphalt-rubber seal coat was placed. After six years of service, this project has required no maintenance and shows only a few minor reflective cracks with no evidence of spalling. See photo 2 for "before" condition and photo 3 for "present" condition.

A major improvement in the construction process which improved the reliability in obtaining good workmanship and appearance was introduced in the spring of 1971. This was the solvent dilution process whereby a

small quantity of kerosene was introduced into the viscous, reacted asphalt-rubber composition. This dilution temporarily reduces the viscosity of the composition and improves application uniformity and initial "wetting" of the chips. After a period not exceeding two hours, the viscosity of the composition increases to approximately its original high viscosity (2). This solvent dilution phenomenon is apparently the reaction of the mixture to selective absorption of solvent by the rubber particles. Figure 1 illustrates laboratory tests confirming this behavior in the viscosity of the material.

As a result of this development and the encouraging performances of the Tolleson and Black Canyon Freeway projects, the Arizona Department of Transportation decided to more fully evaluate the concept.

Other public agencies also increased the use of the asphalt rubber system.

Three projects placed by the Arizona Department of Transportation have played an important role in the development of the current specifications, procedures and the evaluation of the capabilities of the system. These projects are commonly known as the Aguila, the Flagstaff, and the Minnetonka.

Aguila Project: This project consisted of six miles on U. S. 60 and six miles on State Route 71 immediately east and north respectively from Aguila.

The pavements on these highways were in an advanced stage of fatigue and plans called for a six-inch overlay to restore the structural integrity. Typical condition of the pavement may be observed in Photo's 4 (foreground) and 5. Insufficient funds were available for an overlay and it was decided to place an asphalt-rubber seal coat. Because of the

heavy traffic volume, especially on U. S. 60 which temporarily carries Interstate 10 traffic, synthetic lightweight cover material was utilized to reduce windshield breakage (16).

The seal coat was placed during July, 1972, under extreme climatic conditions with ambient temperatures of 112° and 114°. In an effort to prevent aggregate roll-over and pickup under the heavy traffic and high temperature the asphalt-rubber was modified to use a harder asphalt (85-100) and five percent kerosene diluent. Traffic was held off the newly placed portions of the seal for as long as possible (at least two hours) and then piloted through at low speeds. In spite of these precautions some pickup occurred. The problem was finally corrected by applying a light application of sand (2-3 #/s.y.) before the final rolling. This procedure is included in the present specifications.

On this project the use of abutted longitudinal joints (as opposed to lapped joints) was also specified per normal seal coat procedures. It was determined that with the asphalt-rubber system there is insufficient flow of the binder materials and that longitudinal joints must be lapped. These laps iron out under traffic and pose no permanent problem. This procedure is also part of the current specification. This asphalt-rubber seal coat is serving extremely well, although the cracking in the pavement was so pronounced that the cracking pattern can be observed in the uncracked seal (see background, photo 4 and photo 6).

Flagstaff Project: Arizona is basically separated into two climatic zones by the high and cold Colorado plateau, which runs somewhat diagonally from northwest to southeast across the northern part of the State, and the largely semitropical Sonoran zone in the warm southern part. The major

cities of Phoenix and Tucson are situated in the southern part. Between the two zones is a mountainous transition zone. The major asphalt-rubber projects that we have discussed thus far have been in the warmer south although small test installations have been placed in the cold northern area and in other states as early as 1966 (14).

In August of 1973, the Arizona Department of Transportation placed its first major asphalt-rubber treatment in the northern part of the State, a 10+ mile project north of Flagstaff, Arizona (5). This project started approximately five miles northeast of Flagstaff and extended north on U.S. 89 for 10+ miles to the Townsend divide at an elevation of over 7,200 feet. The winters are cold with possible minimum temperatures as low as 40° below zero and frost depths of three feet in shady areas.

The existing surface was severely "alligatored" with fatigue cracking aggravated by a frost susceptible base course that caused severe breakup during thawing period. It was also very rough and almost impassable in the spring of 1973, so a thin skin patching course of cold mixed volcanic cinders was applied to most of the project as a leveling operation and to fill the many potholes (5). In August the asphalt-rubber treatment was placed using volcanic cinders as cover aggregate.

Some pickup was experienced on this project for a short time as the chip size was small and the asphalt-rubber application rate less than optimum. Normally, (3/8") nominal size is utilized and these chips were closer to a (1/4") nominal size. This project has performed excellently without reflection cracking to date and the photos 7 and 8 shows the present contrast between the treated and untreated surface at the north end of the project.

Minnetonka Project: In 1971 the ADOT participated in the National Experiment and Evaluation Program on Prevention of Reflective Cracking in in Overlays. A thirteen-mile section of Interstate 40 extending east from Winslow to Minnetonka was chosen for the studies. The project included some 26 different experimental sections, three of which utilized asphalt rubber - one placed as a seal coat and the other two placed between the overlay and the asphaltic concrete friction course as a stress absorbing membrane interlayer (SAMI).

The final inspection of the project was performed in the Spring of 1975 and the report is in preparation. Conclusions are that the asphalt-rubber stress absorbing membrane interlayer was effective in preventing reflection of all types of cracks - including fatigue, shrinkage and differential vertical strain while the asphalt-rubber seal coat was only effective in controlling fatigue cracking (see photos 9 through 12). As a result of this project and other evidence, ADOT implemented in 1975 the use of the stress absorbing membrane interlayer (SAMI) as standard procedure for all overlays under four inches in thickness that are placed over pavements where cracking is a problem. The cost of this inclusion is absorbed by reduction of overlay thickness.

To date virtually all of the knowledge of the asphalt-rubber systems has been developed by trial and error on numerous small scale experiments and full scale field installations. Although there has been only a limited amount of laboratory work, this work has given valuable insight into how and why the asphalt-rubber systems have performed in such an excellent fashion.

Previously, the phrase "asphalt reacted with the rubber" has been utilized, but it may be as accurate to this process as "rubber reacted

with the asphalt." Laboratory testing has shown that the minus #25 - plus #40 mesh crumb rubber when mixed with asphalt and held at a temperature of 375° for approximately 20 minutes, swells to approximately twice its original volume (see photos 13 and 14).

In addition to swelling, the rubber particles become much softer and more elastic. This phenomenon is the result of chemical and/or physical reaction between the resins (aromatic oils) in the asphalt and the rubber. The extent of this reaction can be modified by manipulating the composition of the asphalt (Fig. 1 and 2) and is also obviously subject to change by variations in the gradations and the amount of the crumb rubber combined with the asphalt (Fig. 3 through 6). Fig. 4 and 5 illustrate that gradations of rubber finer or coarser than #16 to #25 mesh do not react to produce desired characteristics. The effect of the percentage of rubber is demonstrated in Fig. 6 which charts the results of a simple low temperature fracture test. The graph shows an abrupt change in slope at a rubber/asphalt ratio of 1:5. Field experience has indicated that a 1:3 ratio is required to assure desired elastic qualities.

There is also a change that occurs with time wherein the individual rubber particles appear to coalesce and react in strain as continuous fibers. No attempt has been made to date to duplicate this long term behavior in the laboratory.

Considering these phenomena and the high percentage of rubber utilized in the system, it is postulated that the asphalt is serving to modify the elastic properties of the rubber rather than the rubber serving to modify the characteristics of the asphalt.

This difference from previous past research into the concept of asphalt and asphaltic concrete utilizing low percentages of rubber is

basic and one must recognize this basic change in concept to fully comprehend the behavior of the asphalt-rubber system.

It was previously noted that a major improvement in quality of construction was achieved by the addition of kerosene (or a high boiling point diluent) to the reacted asphalt-rubber mixture. The addition of the kerosene caused a sizeable reduction in viscosity which resulted in improved application and wetting of the cover material. Most important is that the decrease in viscosity is temporary and that in one to two hours the mixture regained its initial viscosity (see Fig.5). Since this increase in viscosity occurs long before evaporation of the diluent could occur, this reaction is puzzling and of interest. It is theorized, but not confirmed, that the increase in viscosity is the result of the diluent slowly penetrating the asphalt-rubber interface of the rubber particles and that the subsequent process of selective absorption by the rubber results in the increase in viscosity. Moreover, it should be noted that the viscosity characteristics of the initial mixture and the final mixture appears to be unchanged. It is emphasized that the final mixture is much less temperature susceptible than the original asphalt (Fig. 7), and it is also noted that the temperature susceptibility curve is flatter for the kerosene diluted mixture than for the asphalt-rubber alone.

The need and potential benefit of formal research of the asphalt-rubber systems is obvious. Procedures that provide major benefits have been developed, but we know little of the basic character of chemical and physical reactions occurring and even less of rational engineering procedures to optimally utilize the asphalt-rubber system. Some insight into the physical behavior of the system is illustrated in photo 15 which shows "stretch" marks or strain dispersal occurring at the pavement surface on

the Tolleson project. Parameters of elasticity and ductility need to be developed in reference to flexure and strain characteristics of the individual pavements. ADOT has initiated a research project in cooperation with the FHWA under the HPR to explore the basic chemical and physical processes.

A proposal is presently being prepared for another study to develop engineering criteria for the design of asphalt-rubber stress absorbing membranes in relation to pavement deflection, elastic modulus, overlay thickness, and other physical characteristics.

Thus far the discussion has concerned itself with the asphalt-rubber system placed to control reflective cracking. Results of full-scale projects of up to eight years in service have shown that when placed as a seal coat the system will effectively control the reflection of fatigue cracks and that when placed as an interlayer the system will effectively control the reflection of all types of cracking. These systems have been designated respectively as a Stress Absorbing Membrane (SAM) and a Stress Absorbing Membrane Interlayer (SAMI). The potential of the asphalt-rubber systems, however, extends far beyond that of reflective crack control.

During the course of developing the design and construction procedures for seal coat applications, the City of Phoenix and the ADOT constructed experimental projects containing over 200 experimental section.

This work led to consideration of other potential uses for this material. An interesting application (which led to later developments) was made directly on the subgrade of a street in Phoenix in April of 1971. The street (55th Avenue north of Clarendon Street) had previously been paved with a standard asphalt pavement of a half width on the west side. An irrigated alfalfa field, at a slightly higher elevation than the street, occupied the east half (Photo 16). The alfalfa field was bladed

back, the clay loam soil (which had a plasticity index of 18 with 80 percent passing the #200 sieve) was spongy, cloddy and difficult to compact; so approximately one inch of disintegrated granite was spread to smooth the surface. The surface was primed and allowed to cure for one week. Deflections were so high that at the end of the week, alligator cracking had developed in the primed surface (photo 17). Asphalt-rubber and chips were then applied to the surface and ditch slope next to the alfalfa field and it is serving well to this time with only minor maintenance (photo 18). This application is, of course, a modification of the membrane encapsulated pavement structure as developed by the Corps of Engineers. The performance of this project and discussions with Corps of Engineers research staff has indicated that the lower membrane is not necessary where adequate drainage of the subgrade exists. A ten-mile experimental project to develop reliable data concerning moisture contents, density and strength parameters of this concept is now in the planning stage by ADOT. The potential savings of this concept for low traffic volume roadways is obvious.

The use of hot asphalt-rubber has been employed and tested for application as a waterproof membrane on several bridge decks to date. ADOT performed standard wet condition resistivity tests and found substantially infinite resistivity through the surface of these decks even though they all consisted of a single application. A double application is recommended for this use, however, to eliminate the possibility of the occurrence of "holidays."

The realization that the system was also serving as a moisture barrier led to other applications. A major problem exists with high volume change clays and shales in northern Arizona. The montmorillonite clays derived from the Chinle formation shales are the principal offenders, although

there are some limited areas in the northeast of the Mancos formation that has also been troublesome to the states north and east of us. If subgrade moisture can be maintained in a uniform condition, volume change, of course, will not occur.

In these arid ranges it has been determined that the primary sources of moisture are surface run-off and moisture generated through the process of hydrogenesis in open-graded base course materials. It has been shown that, for new construction, a membrane placed over the subgrade effectively controls the moisture and subsequent expansion of the clay (17). Effective procedures have not been developed, however, for existing highways constructed over expansive clays. In 1975 major overlays were scheduled for 24 miles of Interstate 40 where expansive clays had caused serious heaving and cracking of the pavements. A SAMI was planned to control reflective cracking and it was decided to extend the membrane to cover the shoulders in an effort to reduce the problem of subgrade expansion. There is little question that this membrane will prevent entrance of surface moisture. It is unknown, however, if the membrane will prevent development of water through hydrogenesis or if redistribution of existing moisture will result in excessive differential swelling of the clay. This section of pavement has not been in service for a sufficient time to arrive at any conclusions.

The utilization of subgrade materials to provide structural base course led to a review of problems connected with stabilized subgrades. Virtually everyone in highway and street engineering is familiar with the normal shrinkage cracking inherent in soil cement and cement treated bases which reflect through thin bituminous surfaces (12). An asphalt-rubber treatment appears to be an answer to this crack reflection. There are a number of miles of pavement in the City of Phoenix where soil cement with a 1-1/2

inch bituminous surfacing and an asphalt-rubber treatment were placed at the time of construction. The earliest of these projects was placed in 1972 and in one case reflective cracking had already come through the 1-1/2 inch bituminous surface before the asphalt-rubber was applied. None of these projects show any reflective cracking to date (see photos 19 and 20).

The town of Paradise Valley cement-stabilized Doubletree Road in 1974 for a distance of approximately one-half mile. This project runs diagonally across the channel and overflow areas of Indian Bend Wash. The cement-stabilized material was primed and an asphalt-rubber treatment placed directly on that surface. The section is subject to submergence from periodic flooding but shows no reflection cracking to date although some breaks have occurred from slippage between lamination in the cement treatment.

Prior to the testing and development of the interlayer concept, one weakness of the seal coat type application was that rideability of the pavement was not significantly improved. Many distressed pavements are rough, as well as cracked, and in need of a leveling course. An effort was initiated in 1971 by the City of Phoenix to combine the asphalt-rubber in some form with a leveling course. The experiments were placed on the main taxiways at Sky Harbor International Airport and consisted of the following general concepts, the details of which are available upon request.

1. Three-fourths inch, of a lean (3% asphalt) open-graded mix flushed on the surface with .4 gallon per square yard, plus or minus, of hot asphalt-rubber composition and sanded.
2. Three-fourths inch of open-graded mix in which 10 percent of hot, fully reacted asphalt-rubber was used as the binder in lieu of the conventional 6-1/2 percent to 7 percent asphalt.

3. Three-fourths inch of standard open-graded mix plus ground tire tread rubber introduced at the pugmill.
4. Three-fourths inch of standard open-graded mix plus asbestos.
5. Three-fourths inch of standard open-graded mix plus whole ground tire carcass (including fiber) rubber.

After a few months it was apparent that the only test section controlling reflective cracking was No. 1 above consisting of the sanded asphalt-rubber flush coat over the lean open-graded mix (photo 21 in the appendix). This result interested the Arizona Department of Transportation in the possibility of using the process over rough concrete paving and a cooperative project was arranged with the City of Phoenix to place a test in the summer of 1973 over a very old, rough, cracked pavement two blocks long on Madison Street between 4th and 6th Streets which was subject to heavy industrial truck traffic. The basic elements of this test were essentially the same as the comparable one (#1 above) at Sky Harbor International Airport and after two winters has exhibited only minor hairline reflective cracking in isolated spots (see "before" and "after" photos 22 and 23.

The Arizona Department of Transportation extended the experiment to the concrete pavement of the Black Canyon Freeway (I-17-1-952) which runs through the City of Phoenix and over the years has developed considerable roughness and an undesirable level of skid resistance. A test section was placed in the Spring of 1974 and contained most of the elements involved in the 1971 Sky Harbor International Airport tests plus a control section consisting of standard open-graded asphalt concrete finishing course. All of the overlays averaged $3/4"$ ± in thickness, so that reflection cracks from the joints in the underlying concrete pavement, if they were going to occur, would occur quickly. Further, the section was located at the end of the concrete pavement where maximum movement occurs.

The opportunity was also taken to study the effect of various treatments of the joints, prior to overlay, as they might affect crack reflection.

The test section designed for the asphalt-rubber flush over the under-asphalted open-graded mix differed in one important detail from the one at the airport and the Madison Avenue project. Instead of using sand cover, 3/8" nominal sized chips were used in order to provide improved skid resistance.

An unplanned development occurred in connection with the application of the asphalt-rubber flush. Two parallel applications were made, one at 0.53 gsy and one at 0.85 gsy. The work was done at night under difficult visual conditions and when the distributor started the second application of 0.85 gsy it was inadvertently lapped over a foot onto the preceeding application for a distance of several hundred feet before a correction was made. This resulted in a total application of 1.38 gsy on the lap and 0.00 gsy on the outside edge. With ordinary asphalt this would have resulted in severe bleeding on the lap, but only blackening of the surface occurred. This confirms previous observations that this material is not critical on over-applications. On the edge that was skipped because of the lap, reflection cracks occurred within nine months at every joint but stopped where the flush began. The contrast was quite dramatic.

The end results of this experimental project were similar to those on the 1971 airport project in that the under-asphalted open-graded mix with the asphalt-rubber flush with chips is the only one that shows no reflective cracking to date (see before and after photos 24 and 25).

The soft, sticky, elastic properties of this material make it a natural for joint and crack filling use. Comparative experiments run for this purpose almost ten years ago indicated superior service and the Arizona

Department of Transportation is now using it on a regular basis for maintenance filling of concrete pavement joints, the longitudinal joint between concrete pavement and the asphalt shoulder, and all wide, shrinkage type, cracking.

The development of procedures which permit modification of mixture to achieve optimal characteristics has led to a large experimental program to further develop materials and procedures. Two districts have been supplied equipment and materials and are testing the various compositions and application techniques. From this work it is anticipated that several prepackaged mixtures will be developed for specific applications and that equipment, personnel and materials requirements will be determined.

SUMMARY

The beneficial use of recycled tires in an asphalt-rubber system has been demonstrated, as well as time tested. It has been shown that, when placed as a seal coat (SAM) the system will control reflection of fatigue cracks and is an effective alternate to a major overlay or reconstruction. When placed as interlayer (SAMI) the system will effectively control reflection of all cracks.

The performance of the system as a water barrier has been demonstrated on bridge decks. Potential applications and experimental projects have been described to evaluate its potential use:

1. For membrane encapsulated subgrades.
2. For control of expansive clay subgrades under existing highways.
3. To provide a thin overlay for renewing rideability and skid resistance on portland cement concrete pavement.
4. As an effective crack sealer for maintenance.

In this day of shortages of materials, energy, and money, the savings of scarce and expensive asphalt, supplementation of asphalt with rubber from recycling old tires (a problem waste material), scarce aggregates, and the cost of energy used in hauling and processing, all add up to a very attractive incentive for the use of this material as a proven maintenance and construction tool.

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Appendix A

SPECIFICATIONS
ASPHALT-RUBBER STRESS ABSORBING MEMBRANE (INTERLAYER) (SAMI)

The work under this item consists of placing an asphalt rubber stress absorbing interlayer across the full roadway width.

Asphalt Rubber Materials: The asphalt shall conform to the requirements of Table 705-1 of the Supplemental Specifications for Asphalt Cement AR-1000.

The granulated rubber shall meet the following requirements: When the mixing procedure involves the intimate contact between the hot asphalt and rubber for a period of five minutes or more, 95 percent of the granulated rubber shall pass the No. 16 mesh sieve and no more than 10 percent shall pass the No. 25 mesh sieve. Where the contact period is less than five minutes, 98 percent of the granulated rubber shall pass the No. 25 sieve. The sieves shall comply with AASHTO Designation M-92.

The specific gravity of the material shall be 1.15 ± 0.02 and shall be free of fabric, wire or other contaminating materials, except that up to 4 percent of calcium carbonate may be included to prevent the particles from sticking together.

Mixing Asphalt and Rubber: The material shall be intimately combined as rapidly as possible for such a time and at such a temperature that the consistency of the mix approaches that of a semi-fluid material. The temperature of the asphalt shall be between 350 degrees F. and 450 degrees F.

The method and equipment for combining the asphalt and rubber shall be so designed and accessible that the engineer can readily determine the percentage, by weight, of each of the two materials being incorporated into the mixture.

The proportions of the two materials, by weight, shall be 75 percent +2 percent asphalt and 25 percent +2 percent granulated rubber. After the full reaction described has occurred, the mix shall be cut back with Kerosene. The amount of Kerosene used shall be 5-1/2 percent to 7-1/2 percent, by volume, of the hot asphalt-rubber composition as required for adjusting the viscosity for spraying or better "wetting" of the cover material.

The Kerosene shall have a boiling point of not less than 350 degrees F. and the temperature of the hot asphalt-rubber shall not exceed 350 degrees F. at the time of adding the Kerosene.

After reaching the proper consistency, application of the material shall proceed immediately and in no case shall the material be held at a temperature over 330 degrees F. for more than one hour after reaching the proper consistency.

Construction Details: The existing pavement shall be cleaned in accordance with the requirements of subsection 404-3.01 of the Standard Specifications.

After cleaning and prior to the application of the membrane seal, the existing pavement surface shall be treated with a tack coat.

The hot asphalt-rubber mixture shall be applied at a minimum rate of .60 of a gallon per square yard. A rate of .75 of a gallon per square yard should be used for estimating purposes (based on 7-1/2 pounds per hot gallon). The distributor should be capable of spreading the asphalt rubber uniformly.

All transverse joints shall be made by placing building paper over the end of the previous application, and the joining application shall start on the building paper. Once the application process has progressed beyond the paper, the paper shall be disposed of as directed by the engineer.

All longitudinal joints shall be lapped approximately 4 inches.

Cover Material (Special): Immediately after the asphalt-rubber membrane has been placed Cover Material (Special) should be applied, primarily as a blotter. The rate of application should be only the amount necessary to protect the membrane from construction equipment required for placement of the asphaltic concrete. If traffic is to be carried over the membrane it will be necessary to increase the rate of application to maintain integrity of the asphalt rubber membrane.

For estimating purposes only, the rate of applications should be 25 pounds per square yard (dry weight). A sample of the cover material shall be submitted for approval at least two weeks before it is to be used and the engineer will then determine the exact rate of application.

The cover material should be at least as dry as material dried in accordance with the requirements of Section 4.2 of AASHTO T 85 at the time of application.

The cover material (Special) should comply with the following gradation:

<u>Sieve Size</u>	<u>% Passing</u>
3/8"	100
#4	30 - 60
#8	0 - 20
#200	0 - 4

At least 50 percent by weight of the material retained on the #4 sieve should have at least one rough angular surface produced by crushing.

Rolling: The cover material shall be rolled with pneumatic tired rollers carrying a minimum of 5,000 pounds on each wheel and minimum air pressure of 100 pounds per square inch in each tire.

Sufficient rollers shall be furnished to cover the width of the spread with one pass. It is imperative that the first pass be made immediately behind the spreader and if the spreading is stopped for any reason, the spreader shall be moved ahead so that all cover material spread may be immediately rolled. The rolling shall continue until four complete coverages have been made. Final rolling shall be completed within two hours after the application of the cover material.

Removing Loose Cover Material: The power broom used in removing loose cover material shall be a combination air jet and rotary sweeper type.

Excess loose cover material should be removed prior to placement of the asphaltic concrete. Care should be taken to maintain the broom pressure so that only the loose material will be removed and there will be a minimum dislodgement of embedded cover material.

Prior to placement of asphaltic concrete a tack coat should be applied if the asphalt-rubber membrane has been subjected to traffic.

Weather Limitations: Placement of the asphalt rubber stress absorbing membrane (1) shall not be made when the ambient air temperature is less than 50 degrees F, (2) shall not be placed on other than an absolutely dry pavement, and (3) material shall not be placed if wind conditions are such that a satisfactory membrane is not being achieved.

ASPHALT-RUBBER STRESS ABSORBING MEMBRANE (SEAL COAT) (SAMS)

The work under this item consists of placing an asphalt rubber stress absorbing interlayer across the full roadway width.

Asphalt Rubber Materials: The asphalt shall conform to the requirements of Table 705-1 of the Supplemental Specifications for Asphalt Cement AR-1000.

The granulated rubber shall meet the following requirements: When the mixing procedure involves the intimate contact between the hot asphalt and rubber for a period of five minutes or more, 95 percent of the granulated rubber shall pass the No. 16 mesh sieve and no more than 10 percent shall pass the No. 25 mesh sieve. Where the contact period is less than five minutes, 98 percent of the granulated rubber shall pass the No. 25 sieve. The sieves shall comply with AASHTO Designation M-92.

The specific gravity of the material shall be 1.15 ± 0.02 and shall be free of fabric, wire or other contaminating materials, except that up to

4 percent of calcium carbonate may be included to prevent the particles from sticking together.

Mixing Asphalt and Rubber: The material shall be intimately combined as rapidly as possible for such a time and at such a temperature that the consistency of the mix approaches that of a semi-fluid material. The temperature of the asphalt shall be between 350 degrees F. and 450 degrees F.

The method and equipment for combining the asphalt and rubber shall be so designed and accessible that the engineer can readily determine the percentage, by weight, of each of the two materials being incorporated into the mixture.

The proportions of the two materials, by weight, shall be 75 percent ± 2 percent asphalt and 25 percent ± 2 percent granulated rubber. After the full reaction described has occurred, the mix shall be cut back with Kerosene. The amount of Kerosene used shall be 5-1/2 percent to 7-1/2 percent, by volume, of the hot asphalt-rubber composition as required for adjusting the viscosity for spraying or better "wetting" of the cover material.

The Kerosene shall have a boiling point of not less than 350 degrees F. and the temperature of the hot asphalt-rubber shall not exceed 350 degrees F. at the time of adding the Kerosene.

After reaching the proper consistency, application of the material shall proceed immediately and in no case shall the material be held at a temperature over 330 degrees F. for more than one hour after reaching the proper consistency.

Construction Details: The existing pavement shall be cleaned in accordance with the requirements of subsection 404-1.01 of the Standard Specifications.

After cleaning and prior to the application of the membrane seal, the existing pavement surface shall be treated with a tack coat consisting of

.05 to .08 gallons per square yard of RC-250 or MC-250 liquid asphalt.

The hot asphalt-rubber mixture shall be applied at a minimum rate of .50 of a gallon per square yard. A rate of .60 of a gallon per square yard should be used for estimating purposes (based on 7-1/2 pounds per hot gallon). The distributor should be capable of spreading the asphalt rubber uniformly.

All transverse joints shall be made by placing building paper over the end of the previous application, and the joining application shall start on the building paper. Once the application process has progressed beyond the paper, the paper shall be disposed of as directed by the engineer.

All longitudinal joints shall be lapped approximately 4 inches.

Cover Material: Immediately after the asphalt-rubber membrane has been placed Cover Material Type CM-11 should be applied.

For estimating purposes only the rate of application should be 30 pounds per square yard (dry weight). A sample of the cover material shall be submitted for approval at least two weeks before it is to be used and the engineer will then determine the exact rate of application.

The cover material should be at least as dry as material dried in accordance with the requirements of Section 4.2 of AASHTO T 85 at the time of application.

No source of cover material is designated. Commercial sources or any source should be allowed, providing the finished product meets the requirements. For estimating purposes only, the source should be considered to be commercial sources in Bullhead City.

Rolling: The cover material shall be rolled with pneumatic tired rollers carrying a minimum of 5,000 pounds on each wheel and a minimum air pressure of 100 pounds per square inch in each tire.

Sufficient rollers shall be furnished to cover the width of the spread with one pass. It is imperative that the first pass be made immediately

behind the spreader and if the spreading is stopped for any reason, the spreader shall be moved ahead so that all cover material spread may be immediately rolled. The rolling shall continue until four complete coverages have been made. Final rolling shall be completed within two hours after the application of the cover material.

Blotter Material: After the initial pass of the rollers and before the final pass blotter material should be spread at the approximate rate of .5 pound per square yard. More than one application may be required.

Blotter material should conform to the requirements of Section 706(C)(2) of the Standard Specifications, except that the grading should be as follows:

Passing Sieve	Percent
3/8"	100
#4	80-100
#16	45- 80
#200	0- 15

Removing Loose Cover Material: The power broom used in removing loose cover material shall be a combination air jet and rotary sweeper type.

The initial sweeping shall begin at daybreak of the day following the placement and be completed not more than 24 hours after the application of the cover material.

If, because of temperatures or other causes, there is excessive displacement of embedded cover material, sweeping shall be discontinued until such time as there will be a satisfactory retention of cover material. Additional final sweeping shall be done and all excess cover material removed from three to five days after the roadway has been opened to traffic.

APPENDIX B

McDonald Method of Test for

LOW TEMPERATURE FRACTURE OF PAVING AND ROOFING
MATERIALS BY CONTROLLED DEFLECTIONScope:

1. This test method describes two procedures for determining a temperature at which plastic elastomer binder materials, such as asphalt and asphalt-rubber, used for paving and roofing purposes will fracture under specified deflection conditions.

Significance:

2. These methods establish the respective temperature at which 50 percent of the specimens tested would be expected to fail when subjected to the conditions herein specified. The bending strains under which these materials are subjected in the tests are much more severe than will be experienced in field service. Although the magnitude of the field service deflections are much less, they are subjected to multiple deflection repetitions under much lower strains. The test methods thus are intended to compensate for field service conditions and provide for a short cut procedure for comparative evaluation of plastic and elastomer paving and roofing materials. Resistance to bending fracture at low temperatures is an important factor in the service life of paving and roofing materials.

Definition:

3. Low Temperature Fracture: That temperature, estimated statistically, at which 50 percent of the specimens would fail by exhibiting cracking in a specified test.

Method A:

4. This method is designed to produce fractures at lower temperatures

than Method B. It is a deflection test, at a specific temperature, involving a 13-1/2° bend of the specimen over a 12" mandrel.

Apparatus:

5. (a) Specimen Fabricating Jig: The jig shall be designed to fabricate two or more specimens at the same time. The specimens shall be 16" plus or minus long by 1" wide by 1/8" thick. Welding rods, 1/8" X 18", positioned over strips of nonabsorbent paper serve very well (see sketch No. 1).

(b) Deflection Device: This arrangement shall provide for centering the specimens over a 12" cylindrical mandrel and permitting a deflection of 1-1/2" at a distance of 6-1/4" each side of the mandrel, thus producing a 13-1/2" deflection from a tangent to the mandrel, of two or more specimens simultaneously (see sketch No. 1).

Test Specimens:

6. The specimens shall be fabricated by placing the strips of non-absorbent paper on the jig and positioning the welding rods over the paper firmly in the jig. The 1" space between the rods shall be filled with the specimen material for a distance of approximately 8" each away from the center, making a specimen 16", plus or minus, in overall length. The material shall then be struck off level with the top of the rods, forming a specimen 1/8" in thickness.

Conditioning:

7. Test specimens shall be refrigerated at the starting temperature, and at each succeeding temperature, for not less than one hour prior to test. The starting temperature should be high enough that the specimens are reasonably certain to pass without failure.

Procedure:

8. (a) After conditioning, the specimen shall be quickly withdrawn from refrigeration and instantly and vigorously deflected over the mandrel to the stops on either side.

(b) Examine each specimen carefully after each test, and while the specimen is still in the fully deflected position, for cracks. Note and record the kind and extent of any crack visible to the naked eye and the identification of the specimen on which it occurred.

(c) Test a minimum of two specimens. In the event that all of the specimens fail or not fail, increase or decrease, respectively, the temperature of the test by approximately 3°C (approximately 5-1/2°F) and repeat the test. Any one specimen may be used for repeated tests only until it develops a crack visible to the naked eye. This constitutes a specimen failure. However, the degree of failure, such as multiple fractures, should also be noted as an aid in product evaluation. Test all specimens to failure.

Report:

9. The report shall include the following:

(1) The temperature at which the first crack visible to the naked eye occurred in each specimen.

(2) The average of the above individual temperatures for each specimen (obvious anomalies shall be rejected from the average). This is the failure temperature for material under test.

(3) Brief description of the type of cracking in each specimen--for example 2" transverse and 1" longitudinal.

(4) Complete identification of the material tested including type, source, manufacturer's name and code, and formula if available.

(5) Reference to test method.

- (6) Date of test.
- (7) Age of material in specimens.
- (8) Number of specimens tested.
- (9) Name and location of laboratory performing the test.
- (10) Any treatment to which the material has been subjected, in addition to the basic formulation, that could affect the physical properties (example: prolonged heating).

Method B:

10. This method is designed to produce fracture in a higher temperature range than Method A. It is an inverted deflection test, at a specific temperature, involving a $9^{\circ} 28'$ bend tangent to a $1/8''$ diameter mandrel. Slight, but insignificant impact is also present, amounting to only 2.25, plus or minus, feet per second ($1-1/2$, plus or minus, miles per hour).

Apparatus:

11. (a) Specimen Fabricating Jig: The jig shall be designed similar to that in Method A except that it shall accomodate four or more specimens $4-1/2''$, plus or minus, long by $1''$ wide by $1/8''$ thick, and the base paper for each specimen consists of $3'' \times 5''$ index cards inserted beneath the $1/8''$ welding rods (see sketch No. 2).

(b) Deflection Device: This arrangement shall provide for centering the specimen, index card side up, as a beam bridging a gap $1-1/2''$ wide by $1/8''$ deep. A mandrel, centered over the specimen "bridge", consisting of a striking edge, rounded to a $1/8''$ diameter, shall move relative to the specimen at a linear speed of 2.25' per second ($1-1/2$, plus or minus, miles per hour) at impact and during at least the following $1/8''$ of travel. In order to maintain this speed when testing a single specimen, a mechanically released freely falling mandrel weighted to 551.6 grams and released freely

falling mandrel weighted to 551.6 grams and released at a height 3 cm above the bottom of the gap beneath the specimen "bridge", has proven adequate. If multiple specimen testing or exceptionally rigid materials are involved, the acting forces would have to be increased accordingly to maintain the fracturing speed. See attached schematic sketch No. 2 for one version of a single specimen device that has been used for the purpose.

Test Specimens:

12. Except for the shorter length of the specimens, which are only 4-1/2", plus or minus, long and centered on the index cards, they are prepared the same as in Method A.

Conditioning:

13. This is the same as in Method A.

Procedure:

14. (a) This is the same as in Method A except that the specimen is placed index card up and centered over the gap as a bridge and the mandrel is mechanically or electrically released to deflect the specimen downward at the center.

(b) This is the same as in Method A.

(c) This is the same as in Method A except that a minimum of four specimens are tested.

Report:

15. This is the same as in Method A.

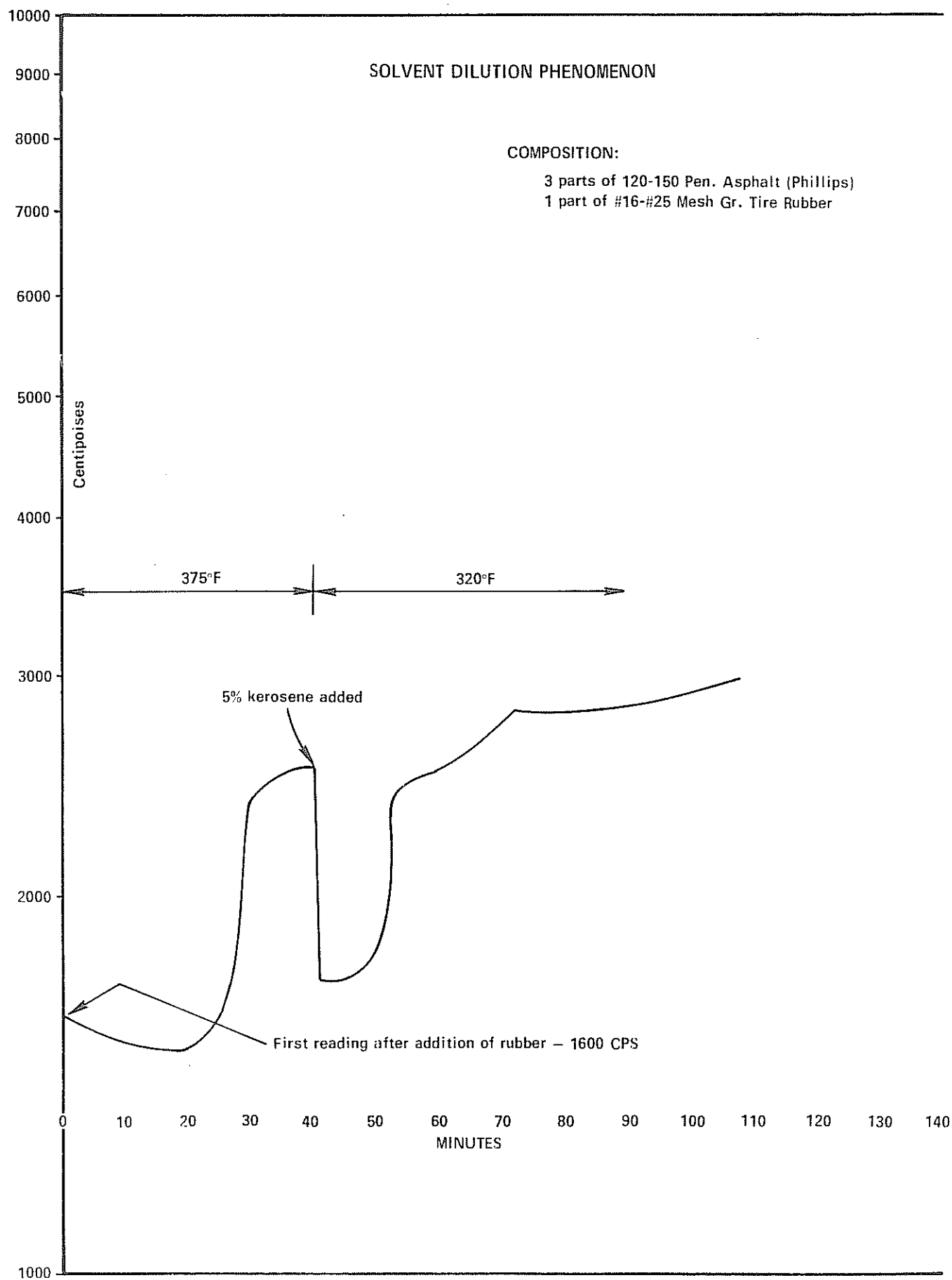
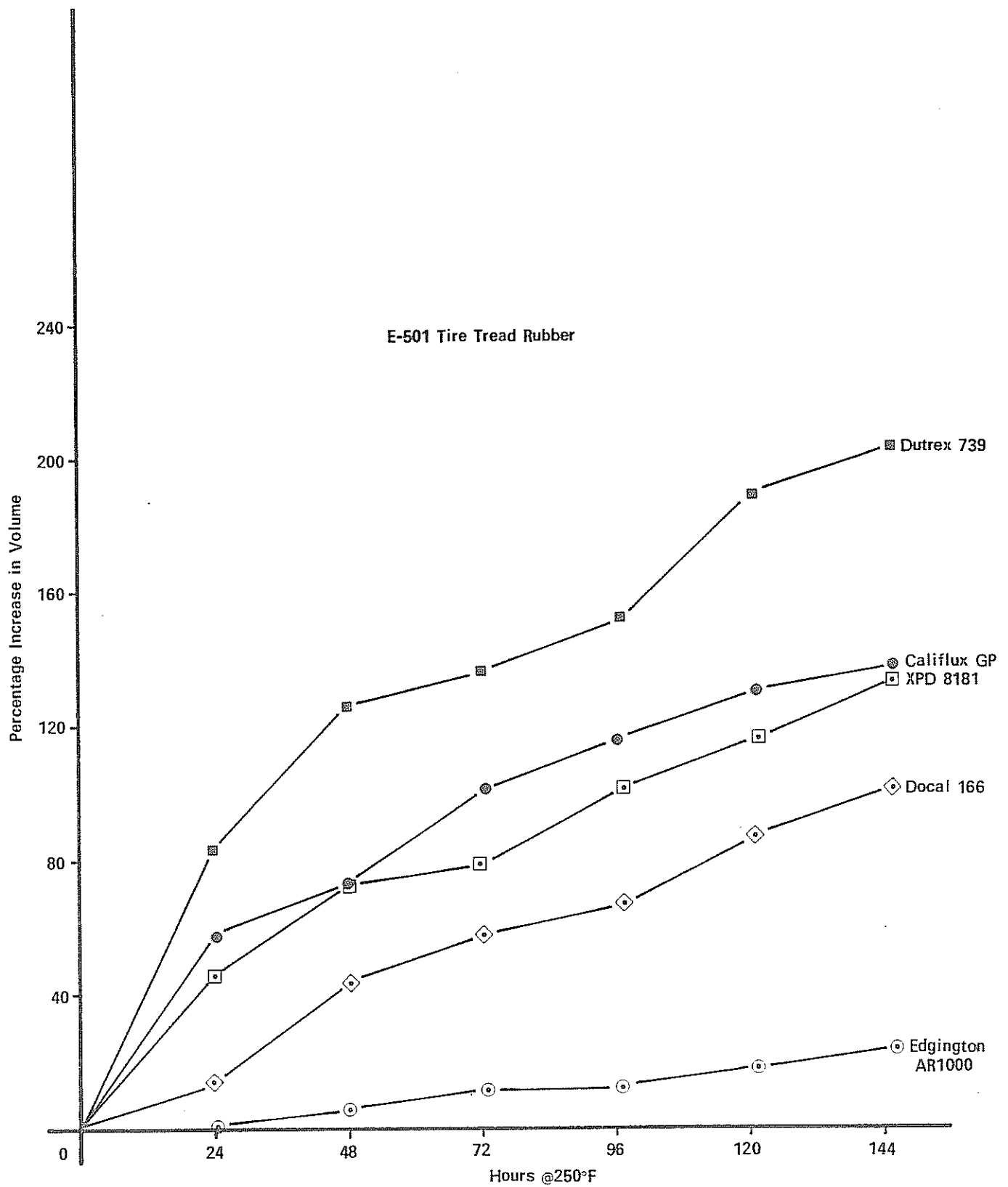


Fig. 1



INCREASE IN VOLUME OF RUBBER
By Extender Oils

Fig. 2

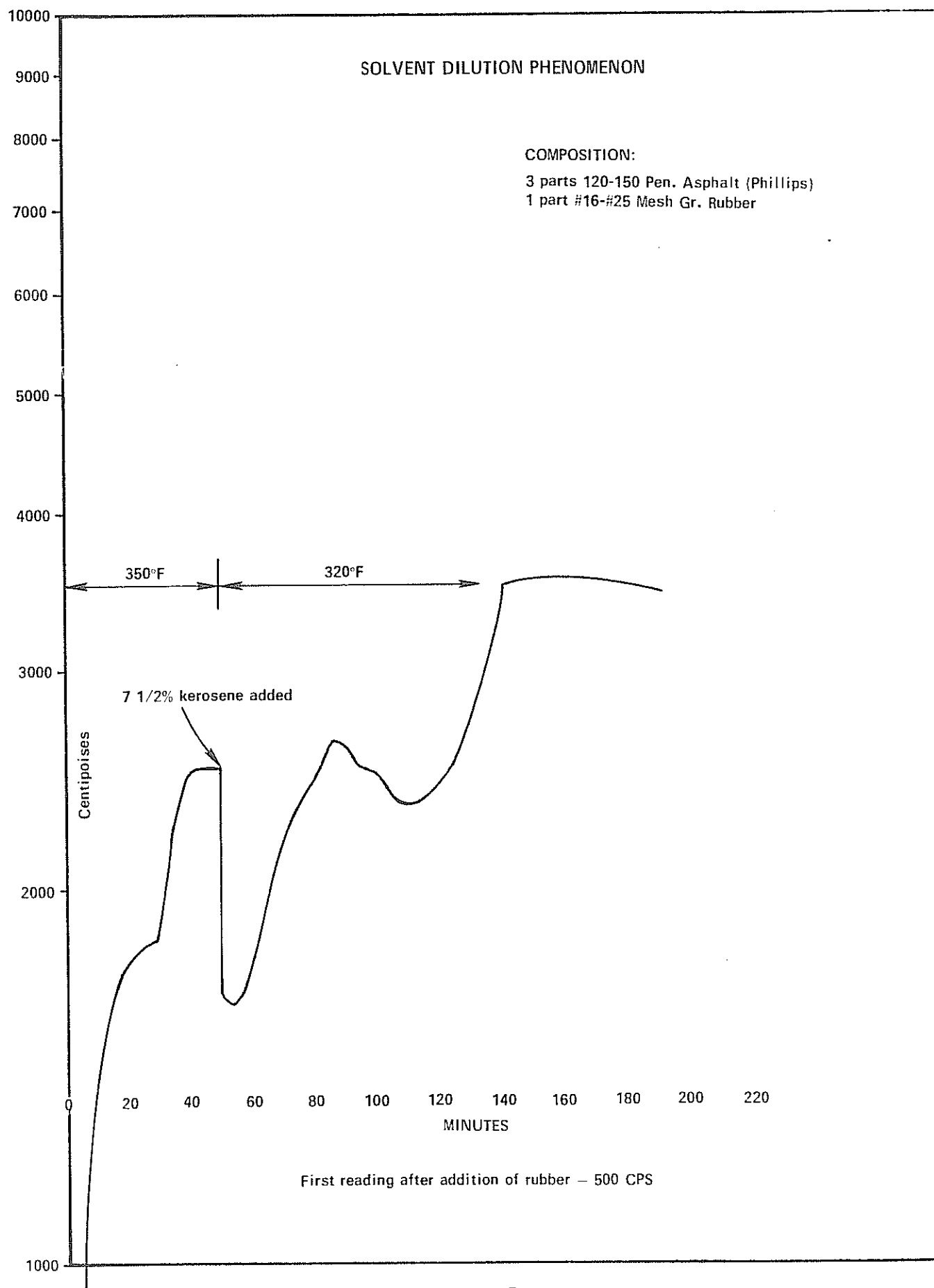


Fig. 3

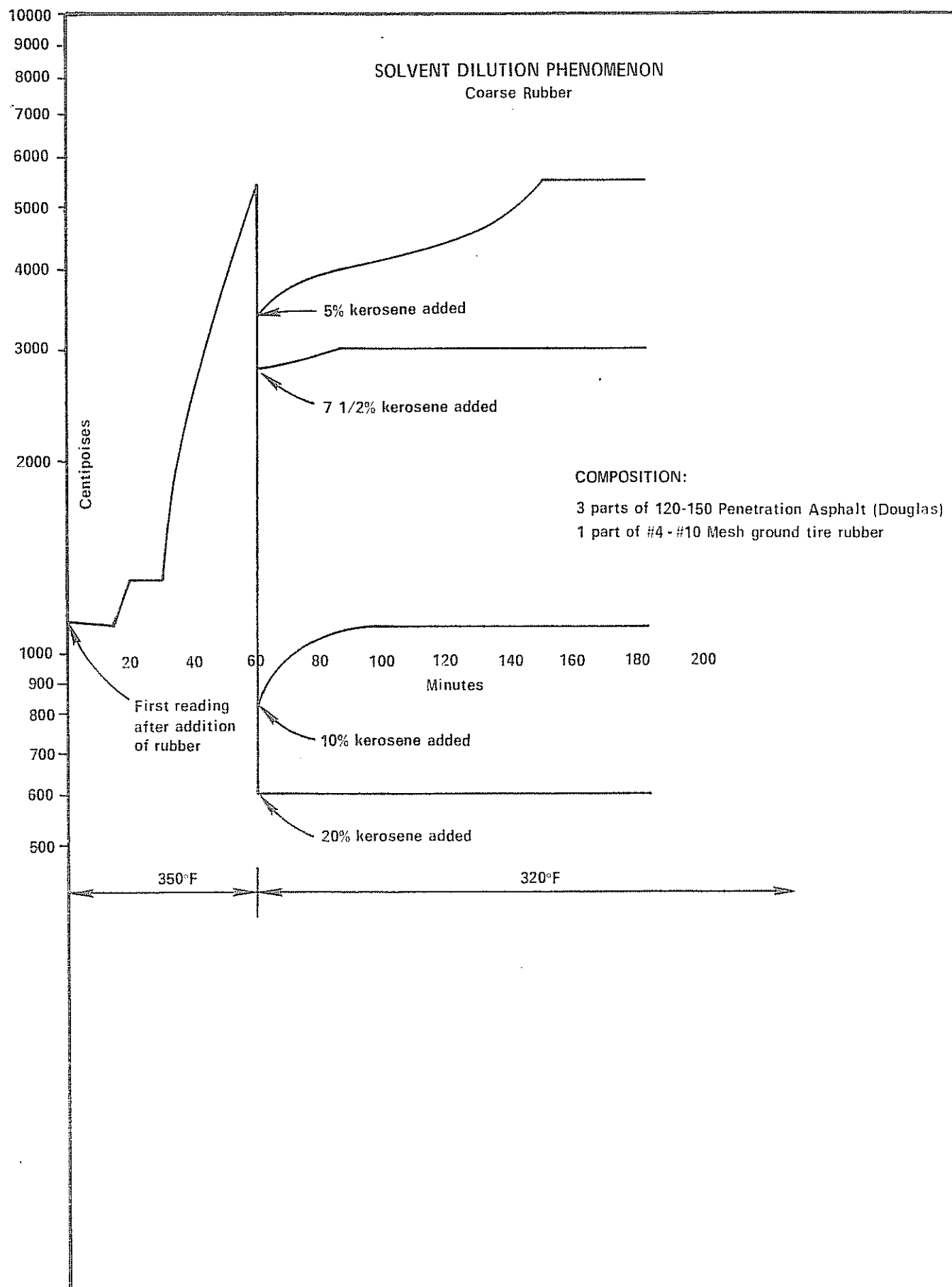


Fig. 4

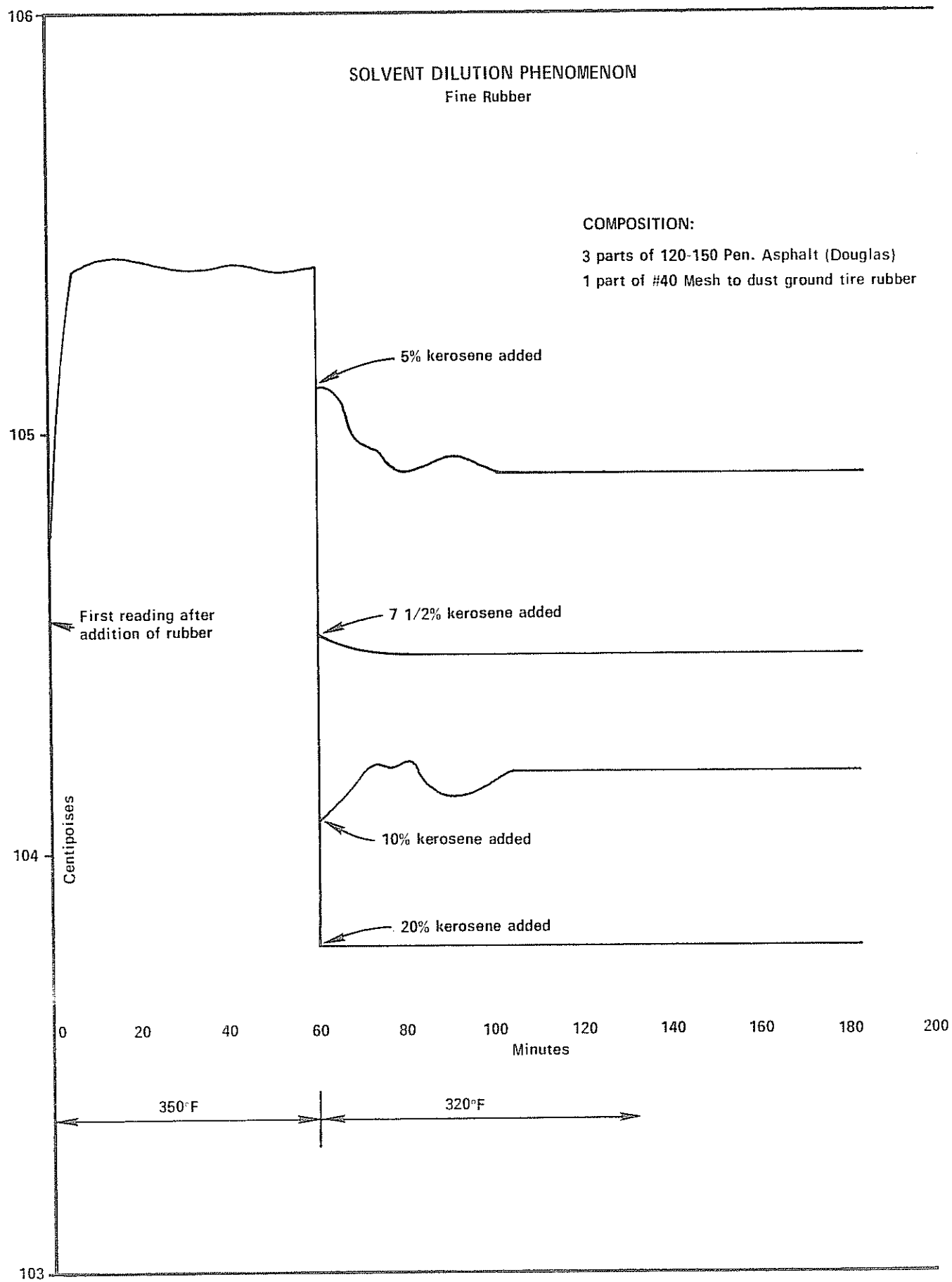
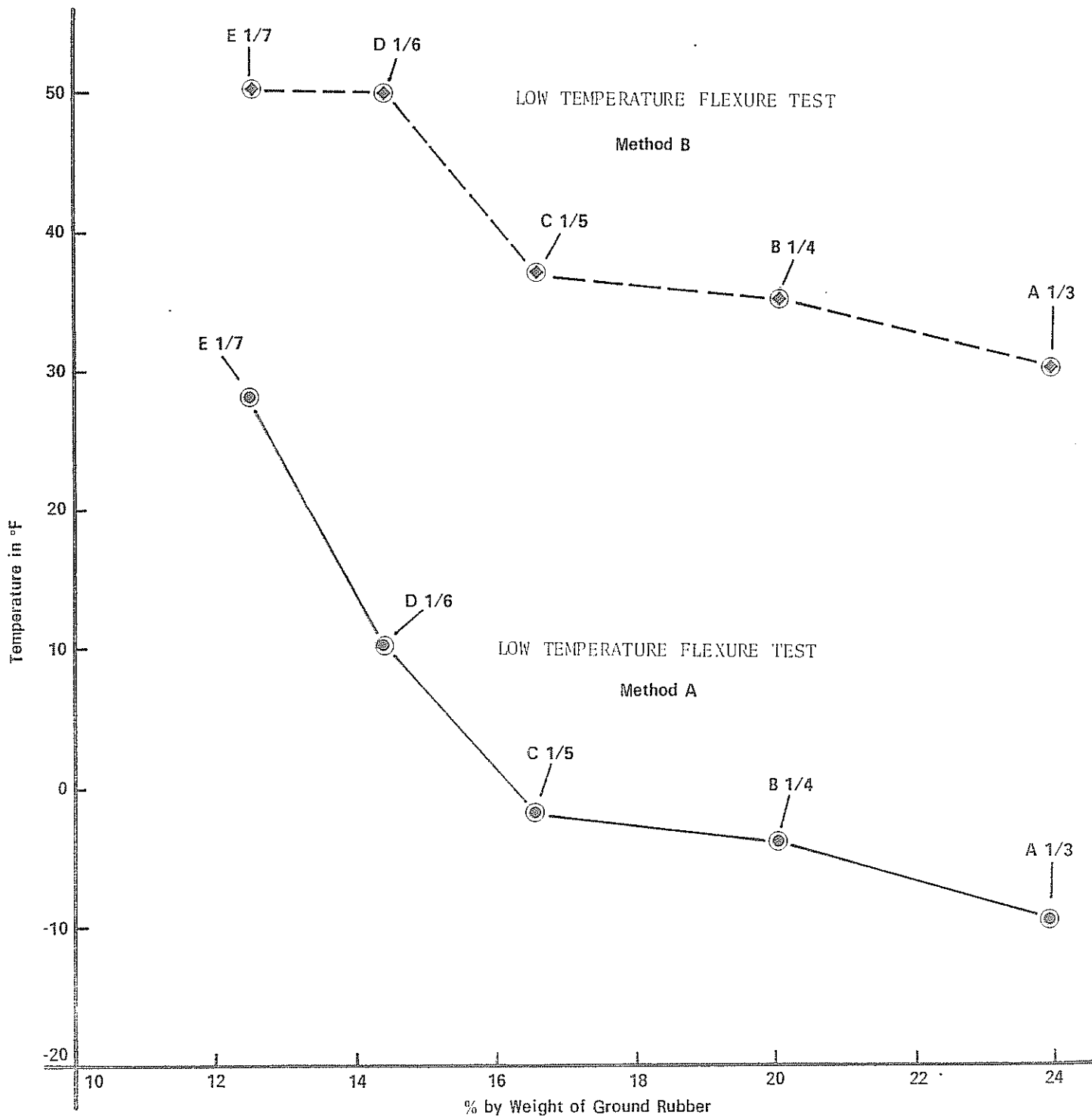


Fig. 5



EXAMPLE: D 1/6 = Sample "D" containing 1 part ground rubber to 5 parts of asphalt by weight, failed the test method at the indicated temperature.

LOW TEMPERATURE SUSCEPTIBILITY ANOMALIES TEST METHOD COMPARISON

Fig. 6

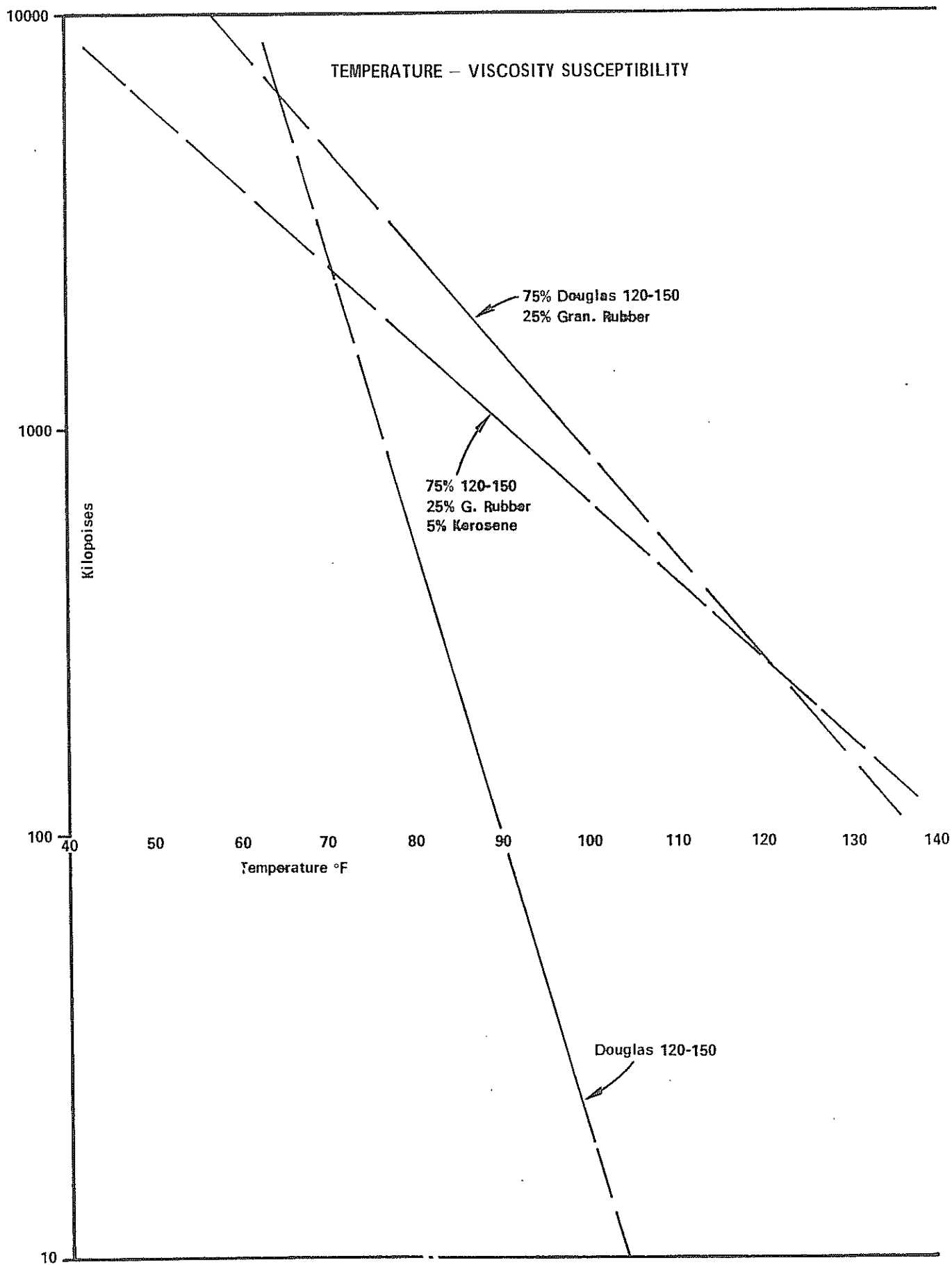


Fig. 7