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JET REFERENCE FLUID STUDY FOR FUEL TANK SEALANTS

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1. SCOPE:

1.1 Background:

Standard reference fluids, or test fluids, have long been used to evaluate the effects of hydrocarbon fuels on various materials, such as integral fuel tank sealants. Standard fluids are required because hydrocarbon fuels, such as JP-4, vary widely in composition depending on crude source, refining techniques, and other factors. To ensure reliable and reproducible results when determining the fuel resistance of materials, reference fluids of known composition, using worst case fuel compositions, are used. The current Jet Reference Fluid (JRF) called out in military sealant specifications was developed in the mid-1950s specifically as a JP-4 type test fluid formulation to be used for the accelerated laboratory testing of integral fuel tank sealants.

In August 1978, chalking of the polysulfide sealant in integral fuel tanks of some new aircraft at Edwards Air Force Base in California was discovered after only 1 year of service. Although chalking of polysulfide sealants had been observed occasionally in the past, the rate of chalking was unprecedented. The results of an investigation showed that the rapid chalking of the polysulfide sealant was caused by a chemical reaction involving metal ions (copper, cadmium, lead, and iron) and mercaptan sulfur in the fuel. It was also noted that qualification testing of the sealant used had not predicted the chalking that occurred in service. Further investigation disclosed that the sealant had passed the chalking test in the military specification because the JRF used in the specifications chalking test did not contain trace metal ions as did the fuel removed from the tanks of the affected aircraft. The special Air Force investigating team included in its final report a recommendation that the JRF specification be reviewed and revised.

The above chalking incident coupled with concerns resulting from deficiencies observed with the current JRF, and from changing sources of JP-4 indicated that an update of the JRF formulation in the sealant specifications was needed. A proposal was made to the SAE Aerospace Sealing Committee (G-9) which then formed a subcommittee for the development of a new Jet Reference Fluid (JRF) for evaluation of integral fuel tank sealants with Mr. W. F. Anspach as its chairman. The subcommittee members were:

W. F. Anspach, Chairman	Wright Patterson AFB Materials Lab, AFWAL/MLBT
P. A. House	Wright Patterson AFB Materials Lab, AFWAL/MLSE
C. R. Martel	AFWAL/POSF
C. Nadler	Naval Air Development Center
R. E. Meyer	Products Research & Chemical Formerly of Essex Chemical
R. N. Gilliland	Products Research & Chemical (since retired)
H. Weltman	General Dynamics Fort Worth, Texas
K. Q. Lovinggood	McDonnell Douglas Long Beach, CA

1.2 Program Organization:

The organization of the committee and its functions were discussed at a meeting in Long Beach, CA on 23 May 1979. The prime purpose of this meeting was to define objectives, establish the scope of effort, and to develop a program plan so that it could get started on the technical effort. Simply stated, the objective of this committee was to develop a new JRF for sealant evaluation which would reasonably reflect the worst to be expected from fuels derived from existing and expected sources, provide reliable sealant differentiation, and have none of the known deficiencies of the current JRF.

1.3 Approach:

The current JRF called out in MIL-S-8802 and MIL-S-83430 sealant specifications was selected as a suitable starting point for discussion and planning. Knowledge of the rationale used for the development of the current JRF and the selection of its components coupled with the problems encountered with its use was considered essential to the development of a new replacement fluid. Establishing the scope of effort proved to be difficult. However, there was general agreement that a broad, two-level program to define the requirements for, develop the composition of, and fully evaluate a new JRF was needed. It consisted of a short-term effort addressing current, urgent problems and a long-term effort to address the full spectrum of fuels, seal and sealant materials, and potential environments. As a minimum, the new JRF should address the following:

a. Both military and commercial requirements with emphasis on the military
b. Composition of JRF to simulate existing fuels (i.e., JP-4, JP-5, JP-8, and Jet A) and future alternate fuels as developed
c. The effects of JRF on the following classes of materials: polysulfides, fluorosilicones, fluorocarbons, and nitriles
d. Problems experienced with the current JRF
e. Analytical techniques and handling/storage requirements to ensure adequate quality control of the JRF
f. The potential requirement for more than one JRF (i.e., high and low aromatics content) for different applications
g. An appropriate method for governing the new JRF with provisions for future review and revisions
h. Appropriate and adequate testing

Although a detailed program plan was not accomplished at that time, the following considerations for the Short-Term Program and the Long-Term Program were initially identified:

a. Short-Term Program:
   (1) Consider polysulfide sealants only
   (2) Concentrate on reliable sealant differentiation
   (3) Establish a common source
   (4) Establish analytical techniques for quality control
   (5) Establish problem contaminant content (i.e., metal ions and mercaptan sulfur)

1.3 (Continued):

(6) Revise current chalking test
(7) Formulate to better represent the worst to be expected from fuels derived from existing and expected sources

b. Long-Term Program
(1) Evaluate mercaptan content
(a) kind
(b) level
(2) Formulate to represent future fuel compositions
(3) Evaluate potential problem fuel components
(a) sulfur compounds
(b) additives
(c) aromatics composition and content
(d) nitrogen compounds
(4) Consider other sealant materials (i.e., fluorosilicones, fluorocarbons, and nitriles)

It was later decided that the mercaptan study as well as aromatics, nitrogen compounds, and other sulfur compounds and additives needed to be addressed in the short-term program in order to properly formulate a new JRF.

2. BASIC CONSIDERATIONS:

2.1 Historical:

The history/background of the current JRF was traced to determine the basic factors considered by the formulating committee (ARTC Panel W-83, 1955 to 1956) in determining its composition. A fairly complete picture was pieced together from information obtained from the files of former members of the W-83 Panel and from the microfilm files of the Aircraft Industries Association (AIA) in Washington, D.C.

As early as 1953 concern was expressed by the Aircraft Industry that the reference fluid Type III called out in MIL-H-3136 for testing rubber and sealants for acceptability with 115/145 octane aviation gasoline might not be appropriate as a screening fluid for rubbers and sealants to be used with JP-4. It was suspected that the composition of JP-4 would vary widely due to different sources of crude oil and due to differences in refining techniques. The unknown variety of as yet unidentified contaminants might well introduce new deleterious effect.

This was brought to the attention of the Coordinating Research Council (CRC) Inc., an organization to which the aircraft industry and the oil industry belonged. They failed to act, prompting the formation of a W-83 subcommittee of the Aerospace Research and Testing Committee of AIAA (ARTC) in July 1955. Subsequently CRC recommended several consultants from the oil companies to assist in the study to establish an appropriate JRF composition to screen rubber and sealants to be exposed to JP-4.

2.1 (Continued):

The ARTC Plan was as follows:

a. Learn from the oil companies the variability in composition of JP-4 to be expected from different sources of crude oil and different refining methods.

b. Establish a base fluid, then add various aromatics, mercaptans, olefins, and other types of compounds (such as sulfides, sulfones, nitrogen bearing compounds, oxygenated materials (peroxides), and organometallic compounds). These compositions would be evaluated on the basis of their effects on EC-801 (a lead catalyzed polysulfide sealant) then qualified to the MIL-S-7502 specification.

A detailed set of experiments was then conducted to establish the composition of a representative JRF. The composition selected was:

Toluene (TT-T-548)	30 Volumes
Cyclohexane (95 MOL% min)	60 Volumes
Iso Octane (MIL-S-3136 TYPE I)	10 Volumes
Tert-Dibutyl Disulfide (Phillips)	1 Volume
Tert-Butyl Mercaptan (Phillips)	0.015 ± percent by weight of the other components

The total sulfur content of this JRF composition is 0.4% and the mercaptan sulfur is 0.0045%.

Recommendations were also made to limit the test temperature to 160°F due to volatility and to set a maximum shelf life of 90 days on the mixed JRF. The data found in the documents did not give a complete basis for the composition selected for the JRF. Whether additional data were available and not presented or whether some of the selection of elements of composition were arbitrarily selected is not known. The following "gaps" of information were noted:

a. No data were available to support the selection of 0.4% sulfide sulfur as an upper limit.
b. No mention was made of any implementation of plans to evaluate the effects of organometallic compounds.
c. No data were available to show the variability in composition of production JP-4, thus no direct data could be reviewed on the concentrations of organic materials.

2.1 (Continued):

The current JRF is called out in the MIL-S-8802 and MIL-S-83430 sealant specifications and in general has served well since its development. As one might expect, however, some problems, deficiencies, and concerns have been identified. Some of the major problems are listed below:

a. The JRF is inadequate for use in the MIL-S-8802 chalk tests because it lacks controlled metal ion content.
b. It has been difficult to establish a reliable common source.
c. The composition relative to the composition of current fuels (i.e., JP-4, JP-5, and JP-8) is questionable (see Table 1).
d. Analysis for quality control purposes is difficult.
e. The aromatics components and content may not be appropriate.
f. It does not contain common fuel additives or suitable simulants.
g. The sulfur compounds may not be appropriate or adequate.

It was clear that the time had come to upgrade the current JRF or develop a new one.

2.2 Composition of Fuels From Existing and Expected Sources:

Mr. C. R. Martel of the Air Force Wright Aeronautical Laboratories Aeropropulsion Laboratory searched the literature for information on the hydrocarbon composition and nitrogen content of jet fuels produced from various sources. He compiled data showing typical compositions for JP-4, JP-5, and JP-8 and Jet A fuels from three different sources; petroleum, shale, and coal (see Table 1). The data included percentage ranges for paraffins, cycloparaffins, alkyl benzenes, naphthalenes, and sulfur. He also tabulated concentration ranges for the following impurities: mercaptan sulfur, total sulfur, total nitrogen, and trace metals (see Table 2).

It was observed that jet fuel derived from shale presented a less severe environment than that derived from petroleum because the aromatic content is considerably lower (6 to 13% versus 9 to 19% for JP-4). Nitrogen is higher (0.01% versus 0.0027%); present jet fuel specifications, however, limit nitrogen to 0.01% maximum to maintain fuel stability.

JP-4 from coal could contain higher concentrations of aromatics (19 to 30%); however, all present jet fuel specifications limit the aromatic content to 25% maximum since higher concentrations greatly reduce engine life. JP-4 from coal will contain twice the concentrations of cycloparaffins (62 to 73%) compared with present JP-4 from petroleum (27 to 40%). This is not expected to be more detrimental since tests with 100% cycloparaffins produced sealant changes (volume swell) which were less significant than a model jet fuel mix containing 20% aromatics. (Current original JRF composition contains 30% aromatics).

A comparison of anticipated compositions of jet fuel made from petroleum, shale oil, and coal is given in Appendix A. Additional information concerning the composition of JP-4, -5 and -8 are given in Appendices B, C, and D.

TABLE 1 - Composition of Fuels

Fuel Type	Source	Paraffins (%)	Cyclo-Paraffins (%)	Alkyl Benzenes (%)	Naphthalenes (%)	Sulfur (%)
JP-4	Petroleum	39-64	27-40	9-19	0-1	0-0.15
	Shale	49-67	20-45	6-13	0	0.006
	Coal	5-11	62-73	19-30	0	0.0003
						0.002
JP-5	Petroleum	31-51	21-50	11-27	1-4	0-0.23
JP-8	Shale	44-51	30-40	8-22	0-2	0.002
Jet A	Coal	5-13	53-66	20-41	0	0.003
						0.0005

NOTE: Oil shale fuels are quite similar to petroleum. Aromatics content is dependent upon degree of hydrotreatment required to remove nitrogen.

Coal fuels are quite different with low paraffins content. Cycloparaffin and aromatics content will depend upon degree of hydrotreatment used.

TABLE 2 - Fuel Impurities

Fuel Type	Source	Mercaptan Sulfur (wt %)	Total Sulfur (wt %)	Total Nitrogen (wt %)
JP-4	Petroleum	0-0.001	Unknown	Unknown
	Oil Shale	Unknown	Unknown	0-0.01
	Coal	Unknown	0-0.001	0-0.002
JP-5, 8	Petroleum	0-0.002	0-0.16	Unknown
Jet A	Petroleum	0-0.005	0-0.23	Unknown
Kerosene	Oil Shale	Unknown	0-0.001	0-0.24
Kerosene	Coal	Unknown	0-0.003	0-0.005

NOTE: Expect N_2 must be held to <100 ppm for fuel stability. Sulfur tends to be removed along with N_2.

2.3 Possible Relaxation of Restrictions on Jet Fuel Compositions for Greater Availability:

Relaxation of freezing and boiling point limitations would permit the use of high boiling fractions.

Fuels from coal would contain a significantly higher content of cycloparaffins. Fuel specification limits might be raised.

The higher nitrogen of shale oil fuels could be reduced by hydrotreating. Nitrogen levels are kept low for acceptable jet fuel storage stability.

Fuel icing inhibitors and fuel biocides at the current 0.2 to 0.5% levels in jet fuels have no detrimental effects on sealants (Navy study per NADC). These limits are not expected to change.

3. TESTS PERFORMED DURING THE COMMITTEE'S INVESTIGATION:

Special tests were run by AFML, NADC, and General Dynamics, Fort Worth Division. These laboratories, along with McDonnell Douglas Long Beach and two sealant suppliers, Essex Chemical Corporation and Products Research and Chemical Corporation, also participated in a round robin test program.

3.1 Effects of Metal Ions:

Exploratory tests with metal ions at 10, 5, and 1 ppm indicated that copper ions and cadmium ions caused rapid chalking of sealant in the JRF solution. Calcium, iron, lead, magnesium, manganese, and nickel ions also caused chalking, but at a much slower rate. Metallic naphthanates were found by NADC to be the most stable organometallic vehicle for the introduction of metal ions into a JRF formulation.

Initial round robin tests utilized the original JRF composition but modified it to include 0.10 ppm by weight of copper ions and 0.10 ppm by weight of cadmium ions. This "first fix" recognized the effects of cadmium fasteners on sealant in F-16 fuel tanks where chalking had been observed.

Specimens of sealant (1/8 in x 1/8 in x 5 in) cut from cured sheets were suspended totally immersed in a closed glass container containing 900 cc of the test fluid at 140°F. The fluid was changed twice per week (Mondays and Thursdays) and was examined for chalking daily and rated as no chalk, slight chalk, moderate chalk, or heavy chalk. This was continued until all samples exhibited heavy chalk. The sealants used were:

PR-1422	A polysulfide, dichromate cured system qualified to MIL-S-8802
PROSEAL 890	A manganese dioxide cured polysulfide qualified to MIL-S-8802
PROSEAL 899	A manganese dioxide cured polysulfide qualified to MIL-S-83430

RESULTS: The samples showed a slight chalk in 1 to 2 weeks and a heavy chalk in 3 to 4 weeks.

3.1 (Continued):

A modified procedure was evaluated in which the concentration of copper and cadmium ions was increased to 0.5 ppm each and the immersion conducted at 77°F. Under these conditions, no significant chalking was observed until after six or seven days. It was decided that this was a satisfactory procedure and should be incorporated into MIL-S-8802. The detailed test procedure is shown in Section 5 of this report.

3.2 Effects of Aromatic Compounds:

The results showed that test fluids composed of 40% cyclohexane, 35% iso-octane, and 25% aromatic, the bicylic aromatic compounds (and alkyl derivatives) caused much greater swell (22 to 35%) than the alkyl benzenes (7 to 14%); however, bicyclic compounds occur in jet fuels only in low concentrations (less than 1%). Only indene and tetralin chemically degraded the sealants, but this occurred at a concentration of 5% or greater. No degradation was apparent at concentrations less than 1% (swell and weight loss data shown in Appendix E).

3.3 Effects of Paraffins and Cycloparaffins:

Regarding the effects of paraffins and cycloparaffins, sealant properties were observed before and after immersion in various fluids for 266 h at 140°F. The study included alkanes, alkenes, and cycloalkanes in the C_6 to C_{16} range. Results were compared with control samples of JP-4, -5, and -8 (from petroleum) and a sample of JP-4 derived from shale oil. The results showed that the effects of alkanes, alkenes, cycloalkanes, and mixtures on sealant properties were roughly equivalent to that of the control samples. When blends were prepared containing 20% toluene in addition, the volume swell was 2 to 3 times greater than the same blends without toluene added. Alkanes as pure compounds affected the sealant less than cycloalkanes. Within any given class of compound (alkanes, alkenes, cycloalkanes) there was little variation in results over the range of carbon numbers studies. It was, therefore, concluded that a single alkane and a single cycloalkane should be adequate for representing these classes in the JRF formulation and should be present in proportions representative of current jet fuel compositions. Iso-octane and cyclohexane were selected considering purity and availability as well as low cost. (Data shown in Appendix F).

3.4 Effects of Sulfur Compounds:

Mercaptan sulfur appears to react with certain elemental metals. In the cases of copper and cadmium, the ions thus produced can cause chalking of sealants. It is important to note that if metal is present only in ionic form, the chalking rate is independent of mercaptan concentration. Mercaptans appear to have no effect on sealant volume or weight. Chalking tests were run with JRF containing metal ions both with and without mercaptans present. When mercaptans were absent no chalking occurred. The conclusion was drawn that both metal ion and mercaptan must be present in order to produce chalking.

3.4 (Continued):

Regarding disulfides, similar tests were run with and without disulfides being present. Although there was some indication that the presence of disulfides intensifies volume swell, it has little effect on chalking.

The concentration limits of total sulfur in jet fuels is not expected to change. As refineries switch to the use of higher sulfur crude oils, they will be forced to use hydrodesulfurization. This could result in a reduction in the average sulfur content of jet fuels in the future. A decision was made to maintain the total sulfur concentration in the new JRF at 0.4% by weight and to adjust to that level through the use of tertiary butyl disulfide as was done in the past with the original JRF.

3.5 Miscellaneous:

Conclusions concerning other potential deleterious contaminates are as follows:

a. Peroxides - Current fuel specifications are adequate to prevent the formation of peroxides in jet fuels, thus no test of the effects of peroxides on sealant is necessary.

b. Acidity - Fuel specifications control the acidity of fuels to acceptable levels.

c. Thiophenes (Aromatic Sulfur Compounds) - No information is available regarding the current levels of thiophenes in jet fuels. They are easily removed by hydrotreating. There is no evidence that these materials currently present a problem.

4. JRF-2 FORMULATION:

4.1 Composition:

Based on the preceding surveys and laboratory tests, a formulation was established that represents the worst to be expected from fuels derived from existing and expected sources. Furthermore, the formulation provides reliable sealant differentiation and has none of the known deficiencies of the current JRF. The fluid was designated JRF-2. The composition is shown below along with the current JRF and typical JP-4 fuel. The toluene level was reduced from 30 volumes to 25 volumes to better simulate the highest level to be expected in typical fuels. Current JP-4, -5, -8, and Jet A fuel specifications limit the aromatics to 25%; consequently, testing at higher levels was considered to be unrealistic. The cyclohexane level was reduced from 60 to 35 volumes and the iso-octane was increased from 10 to 40 volumes. This was to better represent the ranges of paraffins and cycloparaffins actually found in typical fuels. Tertiary dibutyl disulfide and tertiary butyl mercaptan were retained at their previous levels and trace amounts of copper and cadmium ions (0.5 ppm each) have been added for

4.1 (Continued):

fluids to be used for chalking tests. Since the presence of trace amounts of metal ions has no apparent affect on sealant properties other than chalking, they may be omitted for all other tests.

TABLE 3 - JRF-2 Formulation

	JRF-2	ORIG. JRF	JP-4
Toluene (TT-T-548)	25 Vol	30	10-20%
Cyclohexane (Tech Grade)	35	60	27-40%
Iso-Octane (TT-S-735 TY I)	40	10	39-64%
Tertiary Dibutyl Disulfide[1]	1	1	(Total Sulfur 0.03% wt)
Tertiary Butyl Mercaptan[2]	0.015+0.0015 wt%		(Mercaptan Sulfur 0.0004% wt)
Copper Ions[3,4]	0.50 ppm by wt	0	0-0.025 ppm
Cadmium Ions[5]	0.50 ppm by wt	0	0-0.014 ppm

[1]Total sulfur content: 0.400 ± 0.005 wt%
[2]Mercaptan sulfur content: 0.0050 ± 0.0005 wt%
[3]To be added as soluble naphthalenate with final concentration of 0.50 ± .05 ppm by wt.
[4]Metal ions added to JRF-2 composition for chalking tests only.
[5]See Footnote 4.

4.2 Preparation of the New JRF-2 Formulation:

Omitting the metal ions, mix the ingredients in the proportions given in the JRF-2 composition shown above. If the solution is to be used either immediately or at a later date for chalking tests with metal ions added, store the mixture from the start in amber glass containers.

Analyze for total sulfur and mercaptan sulfur.

The procedure for adding metal ions for chalking tests is described in 5.1.

4.3 Comparison of JRF-2 and Original JRF:

Tests were conducted by subcommittee members to compare the old and new formulations. Tensile strength, elongation, hardness, and volume change of three sealant samples were measured following 7- and 14-day immersion in the two fluids. Data are shown in Appendix G.

5. IMPROVED CHALKING TEST:

5.1 Fluid Makeup:

Combine the five individual components of JRF-2. (NOTE: Do not use commercial JRF-2 unless analysis shows the mixture to contain less than 0.05 ppm copper or cadmium ions).

Add copper and cadmium ions from a standard reference concentrate of copper and cadmium naphthanates certified to contain 500 ppm copper and 500 ppm cadmium. Add 1.0 mL of this concentrate to 999 mL of the other 5 components. This will result in a final copper and cadmium concentration of 0.5 ppm ± 0.05 ppm each. Store fluid in amber-glass (avoid contact with any metals).

There is currently no suitable quantitative analysis available for metal ion concentration. The desired method of preparing the JRF-2 with metal ions, therefore, must be done carefully.

5.2 Procedure:

Cut four 1/8 in x 1/8 in x 5 in specimens from a sheet of the sealing compound that has been cured for 14 days at 77°F+ 2° and 50% RH ± 2%. The specimens shall be suspended on nylon cord in a closed glass container with 900 mL of test fluid so that the specimens are totally immersed in the fluid. Aluminum foil shall be used to seal the lids of the containers. No metal items shall be allowed to be in contact with the fluid or specimens during the immersion period. The specimens shall not touch each other, so that all sides are exposed to the fluid. The immersion temperature shall be 77°F ± 2°. The tests will be started on a Wednesday and the fluid changed on the following Friday. The specimens shall be examined for chalking on the following Monday. Remove specimens from the fluid and allow the fluid to evaporate. The specimens are not to be blotted or wiped.

Examine strips in well lighted area. Use an original specimen for comparison with the specimens under test to detect chalking.

5.2.1 Rating Criteria:

SLIGHT CHALK - Initial observation of white or light gray formation, usually starting at edges of the sealant.

MODERATE CHALK - The white or light gray formation has spread to about one-quarter to one-half of the surface area.

HEAVY CHALK - The white or light gray formation has spread to about three-quarters or more of the surface.

Observations of chalking greater than moderate after 5 days of immersion shall be cause for rejection of the test sealant.

6. COMMERCIAL SOURCES OF SUPPLY FOR JRF-2 AND METAL IONS:

Phillips Petroleum, Borger, Texas, will manufacture and sell the JRF-2 composition (without metal ion added). It will be available in drums and in smaller containers. The amount of metal ion that might be imposed upon the solution from the container itself is not considered to be significant in affecting sealant properties for any immersion tests except the chalking test. It is strongly recommended that JRF-2 solutions to be used for chalking tests be made up directly in the laboratory of the using facility and that the resultant solution be stored in amber glass containers.

Metal ions (copper and cadmium) as the naphthanates can be purchased as primary standards in Drakeol #9 oil from National Spectrographic Labs., Inc., 7650 Hub Parkway, Cleveland, OH 44125; telephone number (216) 447-1550.

7. LONG TERM TASKS:

After completing all of the short term tasks, the subcommittee evaluated the remaining tasks that were a part of the long-term program. These tasks included consideration of formulations to represent future fuel compositions and consideration of other sealant materials such as fluorosilicones, fluorocarbons, and nitriles. Regarding future fuels, it was decided to delay their consideration until their compositions are known. It was also decided that the JRF subcommittee would not study other sealing materials. A new subcommittee could be formed if such additional studies become warranted.

8. CONCLUSIONS:

The efforts of the jet reference fluid subcommittee may be summarized as follows:

a. Conducted surveys to determine compositions of jet fuels derived from current and expected sources
b. Conducted laboratory tests to determine the effects of fuel constituents on polysulfide sealants
c. Conducted laboratory tests to determine the effects of fuel contaminants, including sulfur compounds and metal ions, on polysulfide sealants
d. Based on the preceeding studies a new JRF formulation (JRF-2) was devised and recommended for committee approval; the new fluid reasonably reflects the worst to be expected from fuels from existing and expected sources, provides reliable sealant differentiation and has none of the known deficiencies of the current JRF
e. A test fluid formulation was devised for testing for chalking of polysulfide sealants (JRF-2 plus metal ions)
f. A test procedure for chalking was established
g. Sources were identified for JRF-2 fluid and for metal ion concentrates
h. Consideration of future fuels and sealants other than polysulfides was postponed to a later date

PREPARED BY SAE AMS COMMITTEE D

APPENDIX A

COMPOSITION, YESTERDAY - TODAY - TOMORROW

TABLE A1 - JP-4 Composition, JP-5, 8, Jet A Yesterday-Today-Tomorrow

				Aromatics		Sulfur		
Fuel Type	Source	Paraffins (%)	Cyclo Paraffins	Alkyl Benzenes	Naphthalenes	Mercaptan	Total	Total Nitrogen[1]
	Petroleum	39-64	27-40	9-19	0-1	0-0.001	0-0.2	0-0.002
JP-4	Shale	49-67	20-45	6-13	0	?	0.006	0-0.01
	Coal	5-11	62-73	19-30	0		0-0.002	0-0.002
JP-5	Petroleum	31-51	21-50	11-27	1-4		0-0.23	
JP-8	Shale	44-51	30-40	8-22	0-2		0.002	
Jet A	Coal	5-13	53-66	20-41	0		0.003	

[1]Nitrogen will be held to 0.01% max for fuel stability.

APPENDIX B

CORRELATION OF AVIATION TURBINE FUEL PROPERTIES[1]

B.1 Some of the important properties of aviation turbine fuels produced from petroleum were correlated with density and aromatic content in order to provide a framework for estimating the properties of aviation turbine fuels produced from synthetic fuels.

B.2 COMPOSITION:

The composition of various jet fuels was evaluated by Kearns (36). JP-4 and JP-5 differ in the molecular weight of their aromatic components. JP-5 also has a lower concentration of paraffins. Table B1 lists the composition of these fuels as determined by Kearns. Those compositions are compared with a straight run kerosene.

Table B2 illustrates the effects of molecular structure on the physical properties of jet fuel hydrocarbon components. Paraffins have the lowest density, melting point, boiling point, and highest heating value per carbon atom. Aromatics have the highest density, melting point, boiling point, and lowest heating values. Naphthenes fall between aromatics and paraffins in properties but resemble aromatics more closely.

A correlation based on Siemssen's (35) work is presented in Figure B1. The calculations are based on a naphthene density of 0.8233 g/cm^3, an aromatic density of 0.9195 g/cm^3, and a paraffin density of 0.7487 g/cm^3. Note that these densities were obtained from a regression of the composition presented by Armstrong et al., (33). Eisen's results (15) do not fall on the triangular graph probably because the COED based jet fuel contains higher molecular weight naphthenes than are present in petroleum based fuel. The naphthene density seems to be on the order of 0.85 g/cm^3 as compared with the correlation number of 0.8233 g/cm^3. Also, the product from Western Kentucky coal appears to have higher molecular weight cyclic compounds than the Utah coal jet fuel product.

[1]Prepared by Exxon Research and Engineering Company, Government Research Laboratory, Linden, New Jersey 07036. March 1975. Section VI.

TABLE B1 - Composition of Jet Fuels in Volume Percent (36)

	JP 4	JP 5	Kerosene
Benzenes			
C 9	13.1	1.7	0.3
C10	4.1	4.6	1.4
C11	1.1	2.5	1.6
C12	0.5	1.0	1.0
C13	0.3	0.7	0.8
C14		0.2	0.5
C15		0.1	0.3
C16			0.2
Indanes			
C10	0.1	0.3	0.2
C11	0.1	1.0	1.0
C12	0.1	1.0	1.5
C13		0.4	1.2
C14		0.1	0.7
C15			0.3
C16			0.1
Indenes			
C11		0.1	
C12		0.1	0.1
C13		0.1	0.2
C14			0.2
C15			0.1
Naphthalenes			
C10	0.1	0.4	0.1
C11	0.2	1.5	0.6
C12	0.2	1.7	1.5
C13		0.4	1.0
C14		0.1	0.3
C15			0.1
Totals			
Alkanes	38.7	30.8	41.7
Non Condensed Cycloalkanes	32.1	34.4	27.2
Condensed Cycloalkanes	7.4	16.8	12.9
Olefins	1.9	0.0	2.8
Aromatics	19.9	18.0	15.4

TABLE B2 - Properties of Hydrocarbons in the Jet Fuel Range

Name	Formula	Hydrogen % (w)	MW	Density g/cm^3	MP °C	BP °C	LHV kJ/g
Aromatics							
Benzene	C_6H_6	7.74	78.11	0.879	5.5	80.1	40.1
Naphthalene	$C_{10}H_8$	6.29	128.16	1.025	80.2	217.9	40.2
Toluene	$C_6H_5CH_3$	8.75	92.13	0.866	-95	110.8	40.5
Xylene o	$C_6H_4(CH_3)_2$	9.50	106.16	0.881	-25	144	40.8
m	$C_6H_4(CH_3)_2$	9.50	106.16	0.867	-47.4	139.3	40.8
p	$C_6H_4(CH_3)_2$	9.50	106.16	0.861	13.2	138.5	40.8
Naphthenes							
Cyclohexane	C_6H_{12}	14.37	84.16	0.779	6.5	80	43.4
Decalin cis	$C_{10}H_{18}$	13.13	138.24	0.895	-51	193	42.8
trans	$C_{10}H_{18}$	13.13	138.24	0.872	-32	185	42.8
Methyl Cyclohexane	C_7H_{14}	14.37	98.18	0.769	-126.3	101	43.4
Dimethyl Cyclohexane							
cis 1,2	C_8H_{16}	14.38	112.13	0.796	-50.1	129.7	43.4
trans 1,2	C_8H_{16}	14.38	112.13	0.776	-89.2	123.4	43.4
cis 1,3	C_8H_{16}	14.38	112.13	0.776	-75.6	120.1	43.4
trans 1,3	C_8H_{16}	14.38	112.13	0.784	-90.1	124.5	43.4
cis 1,4	C_8H_{16}	14.38	112.13	0.783	-87.4	124.3	43.4
trans 1,4	C_8H_{16}	14.38	112.13	0.763	-37.0	119.4	43.4
Paraffins							
h-hexane	$CH_3(CH_2)_4CH_3$	16.38	86.17	0.659	-94	69	44.7
i-hexane		16.38	86.17	0.654	-153.7	60.2	44.6
neo-hexane	$(CH_3)_3C\ C_2H_5$	16.38	86.17	0.649	-98.2	49.7	44.6
	$(CH_3)_2CHCH(CH_3)_2$	16.38	86.17	0.662	-129.8	58.0	44.6
n-heptane	C_7H_{16}	16.09	100.21	0.684	-90.61	98.4	44.6
n-octane	C_8H_{18}	15.88	114.23	0.703	-56.8	125.7	44.4
n-decane	$C_{10}H_{22}$	15.59	142.28	0.730	-29.7	174.0	44.2

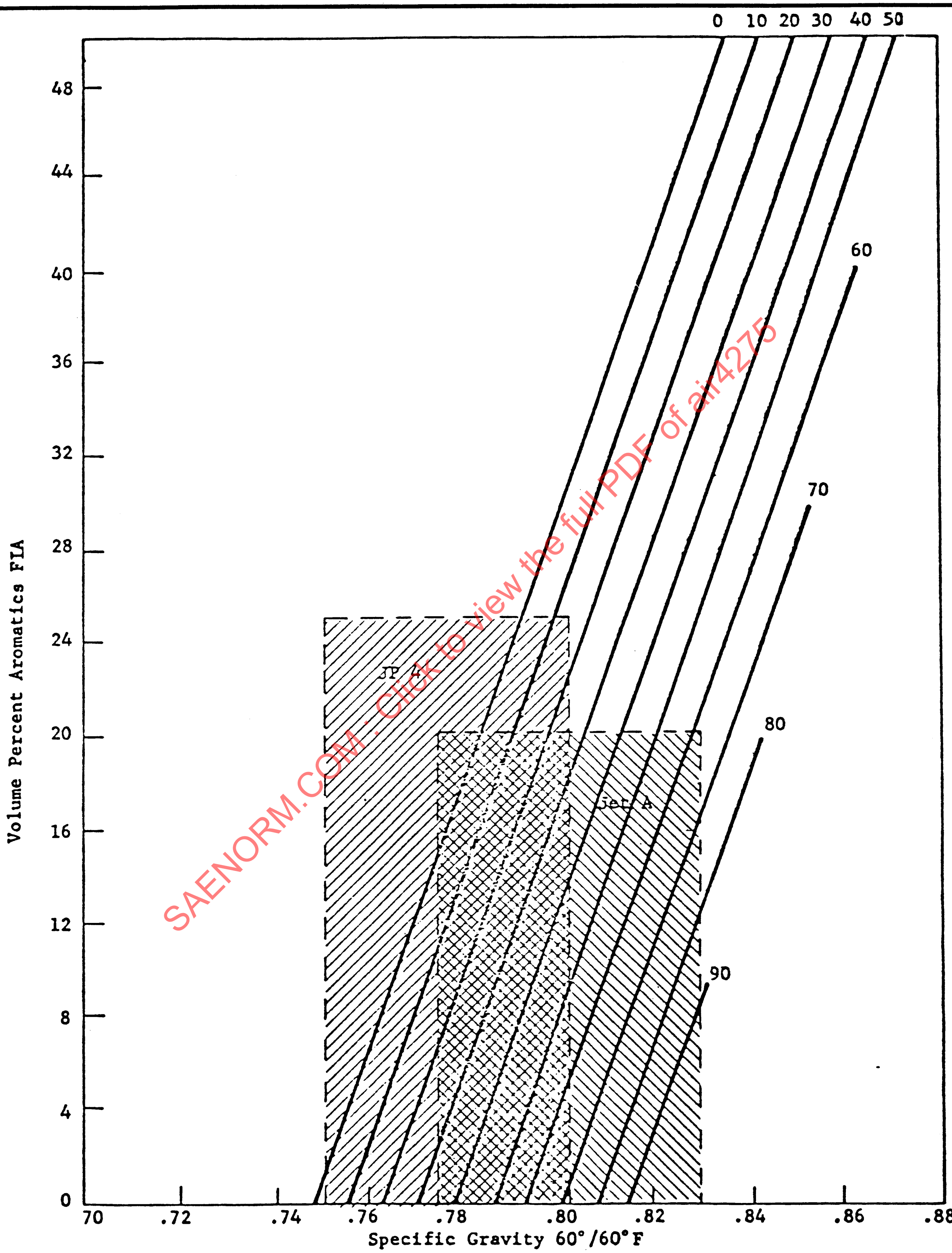


FIGURE B1 - Volume Percent Naphthenes

APPENDIX C[2]

AIR FORCE AERO PROPULSION LABORATORY TECHNICAL REPORT, "ANALYSIS OF AIRCRAFT FUELS AND RELATED MATERIAL, TABLES 64, 77, 78, 79

TABLE C1 - Hydrocarbon-Type Analysis

	JP-8		Xylene Composite		2040 Solvent	
	Weight, %	Average Carbon No.	Weight, %	Average Carbon No.	Weight, %	Average Carbon No.
Paraffins	41.8	12.1	-	-	-	-
Cycloparaffins	37.5	12.0	-	-	-	-
Dicycloparaffins	6.1		-	-	-	-
Tricycloparaffins	1.1		-	-	-	-
Alkylbenzenes	7.5	10.9	100.0	8.9	35.5	10.5
Indanes/Tetralins	3.8		-	-	6.8	11.0
Indenes	0.7		-	-	0.09	11.0
Naphthalene[1]	-[2]		-	-	18.6	10.0
Naphthalenes	1.5	11.6	-	-	39.0	11.2
Acenaphthenes	-		-	-	-	-
Acenaphthylenes	-		-	-	-	-
Tricyclic aromatics	-		-	-	-	-
Analytical Method	ASTM D 2549 and ASTM D 2425		ASTM D 2789		ASTM D 2425	

[1]Refers to the unsubstituted compound.
[2]Dash indicates none was detected.

[2]From Hodgson, F.N. and Tobias, J.D., Analysis of Aircraft Fuels and Related Materials, Monsanto Research Corp., Dayton, OH 45407. March 1979.

TABLE C2 - Boiling Point Distribution
(ASTM D 2887)

Percent Recovered	JP-4, Tank B-11 (Temperature) °C	°F	JP-4, (Temperature) °C	°F
0.5 (initial boiling point)	26	78.8		
5.0	69	156	61	
10.0	89	192	75	
20.0	103	217	98	
30.0	119	246	117	
40.0	134	273	127	
50.0	153	307	151	
60.0	178	352	170	
70.0	199	390	189	
80.0	218	424	211	
90.0	237.5	459	235	
95.0	252	485	252	
99.5 (end point)	279	534	275	

TABLE C3 - Heat of Combustion

	Gross, BTU/lb	Net, BTU/lb
JP-4, Tank B-11	20 046	
	20 031	
	Average 20 039	18 717
JP-4, 8-24-77	20 092	
	20 089	
	Average 20 091	18 767

TABLE C4 - Hydrocarbon-Type Distribution

Compound Type	Volume Percent JP-4, 8-24-77	Volume Percent JP-4, Tank
Paraffins	60.5	62.1
Monocycloparaffins	24.6	21.4
Dicycloparaffins	4.3	5.3
Alkylbenzenes	8.5	8.7
Indanes & Tetralins	1.6	1.5
Naphthalenes	0.5	1.0
Average Carbon Number	8.7	9.5

APPENDIX D

MERCAPTANS IN JET FUELS

Mercaptan sulfur compounds found in aviation turbine fuels (jet fuels) tend to have the same chemical types as found in the fuel. Thus, fuels composed predominately of paraffinic molecules would tend to have primarily paraffin-derived mercaptans, while fuels having a high concentration of aromatics would tend to have mercaptans of the mercapto-benzene (thiophenol) type.

The specification limit for military aviation turbine fuels is 0.001% mercaptan sulfur by weight. However, if the fuel is determined to be "Doctor Sweet" by ASTM D 484, the fuel is normally acceptable. For the Doctor test to be negative (i.e., sweet) the mercaptan present must not exceed the following concentration:

Methanethiol (Methyl mercaptan)	0.002%
Ethanethiol (Ethyl mercaptan)	0.0006%
Propanethiol (Propyl mercaptan)	0.0009%
2-methyl-2 propanethiol (tert-butyl mercaptan)	0.0004%
3-methyl-1 butanethiol (i-amyl mercaptan)	0.0003%
Heptanethiol (n-heptyl mercaptan)	0.0001%
Mercapto benzene (thiophenol)	0.002%[3]

Thus, an acceptable jet fuel by the Doctor test may have less than 0.0001% by weight mercaptan sulfur (if the only mercaptan present is heptanethiol) or as much as 0.002% mercaptan sulfur (if the mercaptan present is either methanethiol or mercapto benzene).

An analysis of the mercaptan sulfur compounds found in jet fuel kerosene distillates could not be found. However, for straight run gasolines from mid-continent crude oils the mercaptans usually consisted of methanethiol, ethanethiol, propanethiol, butanethiols, and pentanethiols with hexyl mercaptans and heavier mercaptans occasionally present. Mercapto benzene was present in some cases.[4]

In Table D1 the boiling range of typical jet fuels, the boiling points for the jet referee fuel constituents, and the boiling points for various mercaptan sulfur compounds typically found in gasoline and heavier distillate fuels are listed. As the mercaptans present in a distillate fuel will have the same boiling range as the fuel, a JP-4 fuel would be expected to contain ethanethiol, propanethiols, butanethiols, and higher molecular weight mercaptans. JP-5 and JP-8 fuels, which have a significantly higher initial boiling point than JP-4, would have hexanethiol and heavier mercaptans. Mercapto benzene, which has a boiling point within the boiling ranges of JP-4, JP-5, and JP-8, would be expected to be found in all three fuels.

[3] "Jet Fuel Treatment," by K. M. Brown, UOP Process Division, Universal Oil Products Company, presented at the South East Fuel Quality Assn., Jet Fuel Quality Protection Group, Memphis, TN, 23 Sept. 71.
[4] "Petroleum Refinery Engineering," W. L. Nelson, 4th Edition, McGraw-Hill Book Company, New York, NY.

Shell Research Limited[5] noted that mercapto benzene was more severe than tert-octyl mercaptan in its attack on Thiokol type (polysulfide) rubbers. As it is known that mercapto benzene may be present in JP-4, JP-5, and JP-8 in concentrations as high as 0.002% by weight, the Jet Reference Fuels should possibly contain mercapto benzene as the primary mercaptan sulfur compound to generate a worst-case fuel for elastomer testing.

A series of tests is recommended to compare the rate of attack of various mercaptan compounds on polysulfide sealants of the MIL-S-8802 variety. The mercaptans to be tested should include tert-octyl mercaptan, mercapto benzene, and butanethiol. These tests should help to determine the choice of mercaptan compound(s) to be used in future jet reference fuels. Concentrations of the mercaptans should range between 0.001 and 0.005% by weight.

[5]"The Corrosion of Certain Aero-Gas Turbine Fuel System Components by Mercaptans and the Effect of the Latter on Synthetic Rubbers", Shell Research Limited, Thornton Research Centre Report K. 127, March 1955.

TABLE D1 - Boiling Points of Mercaptan Compounds and Fuels

Product	Boiling Point, °C
JP-4 (Distillation range)	0-320
JP-5 (Distillation range)	115-320
JP-8 (Distillation range)	100-320
Jet Reference Fuel Constituents	
Toluene	111
Cyclohexane	81
Isooctane	100
Mercaptans	
Ethanethiol	37
n-Propanethiol	67-68
2-Propanethiol	57-60
2-Methyl-2-propanethiol (tert butyl mercaptan)	64.2
1-Butanethiol (n-butyl mercaptan)	97-98
2-Butanethiol	85-95
1-Hexanethiol	151
2-Hexanethiol	140
Cyclohexanethiol	158-160
1-Heptanethiol	177
1-Octanethiol	199
2-Octanethiol	186
1-Nonanethiol	220
Mercapto benzene (thiophenol)	170
Mercapto toluene (toluenethiol)	194-195

APPENDIX E

EFFECT OF AROMATIC FUEL COMPONENTS ON POLYSULFIDE FUEL TANK SEALANTS

TABLE E1 - Effect of Aromatics on Polysulfide Sealants

Fluid Immersion

Fluid	500 mL	
Temp	140°F &	158°F ± 1.8
Time	266 h	(266 h ± 0.25)

Specimens

1 in x 2 in x 0.075 in ± 0.005 in
4 per jar

Sealants

MIL-S-8802	Chromate cure - RTV for 14 days
MIL-S-8802	MnO_2 cure - RTV for 14 days
MIL-S-83430	MnO_2 cure - RTV for 14 days

Data

Volume change	Swollen & dried
Weight change	Swollen & dried
Hardness change (Dry)	
Tensile strength change (Dry)	
Elongation at break change (Dry)	

TABLE E2 - Composition of Jet Fuels in Volume Percent

	JP-4	JP-5	Kerosene
Alkanes	38.7	30.8	41.7
Cycloalkanes	39.5	51.2	40.1
Olefins	1.9	0	2.8
Aromatics	19.9	18.0	15.4

TABLE E3 - Composition of Jet Fuels in Volume Percent

	JP-4	JP-5	Kerosene
Benzenes			
C9	13.1	1.7	0.3
C10	4.1	4.6	1.4
C11	1.1	2.5	1.6
C12	0.5	1.0	1.0
C13	0.3	0.7	0.8
C14		0.2	0.5
C15		0.1	0.3
C16			0.2
Indanes			
C10	0.1	0.3	0.2
C11	0.1	1.0	1.0
C12	0.1	1.0	1.5
C13		0.4	1.2
C14		0.1	0.7
C15			0.3
C16			0.1
Indenes			
C11		0.1	
C12		0.1	0.1
C13		0.1	0.2
C14			0.2
C15			0.1
Naphthalenes			
C10	0.1	0.4	0.1
C11	0.2	1.5	0.6
C12	0.2	1.7	1.5
C13		0.4	1.0
C14		0.1	0.3
C15			0.1
Totals			
Alkanes	38.7	30.8	41.7
Noncondensed Cycloalkanes	32.1	34.4	27.2
Condensed Cycloalkanes	7.4	16.8	12.9
Olefins	1.9	0.0	2.8
Aromatics	19.9	18.0	15.4

TABLE E4 - Hydrocarbon-Type Analysis

	JP-8		Xylene Composite		2040 Solvent	
	Wt. %	Average Carbon No.	Wt. %	Average Carbon No.	Wt. %	Average Carbon No.
Paraffin	37.5	12.1	-	-	-	-
Cycloparaffins	41.8	12.0	-	-	-	-
Dicycloparaffins	6.1		-	-	-	-
Tricycloparaffins	1.1		-	8.9	15.5	18.8
Alkylbenzenes	7.5	10.9	100.0	8.9	35.5	10.5
Indanes/Tetrolins	3.8		-	-	6.8	11.0
Indenes	0.7		-	-	10.09	11.0
Naphthalene[1]	-[2]		-	-	18.6	10.0
Naphthalenes	1.5	11.6	-	-	39.0	11.2
Acenaphthenes	-		-	-	-	
Acenaphthylenes	-		-	-	-	-
Tricyclic aromatics	-		-	-	-	-
Analytical Method	ASTM D 2549 and D 2425		ASTM D 2789		ASTM D 2425	

[1]Refers to the unsubstituted compound.
[2]Dash indicates none was detected.

TABLE E5 - Identification of "Xylene Bottoms" by Kouats Indices on a 117 m OU17 Column

Compound	K.I. Sample	K.I. Library	K.I.	Area %
Ethyl Benzene	944.17	944.10	+0.07	0.45
P-Xylene	948.53	948.44	+0.09	0.87
M-Xylene	949.96	950.03	-0.07	2.68
O-Xylene	981.50	981.56	-0.06	3.63
Cumene	1006.04	1006.06	-0.02	10.29
N-Propyl Benzene	1035.57	1035.65	-0.08	8.65
1 Ethyl 3 Methyl Benzene	1046.45	1046.12	+0.33	33.03
1,3,5 Trimethyl Benzene	1051.49	1051.36	+0.13	7.89
1 Ethyl 2 Methyl Benzene	1070.54	1070.46	+0.12	6.93
1,2,4 Trimethyl Benzene	1081.29	1080.84	+0.45	19.63
Iso-Butyl Benzene	1083.01	1082.90	+0.11	0.18
Sec-Butyl Benzene	1090.44	1090.33	+0.11	0.36
1 Methyl 3 Isopropyl Benzene	1104.02	1103.84	+0.18	0.45
1,2,3 Trimethyl Benzene	1120.47	1120.33	+0.14	1.89
1 Methyl 3 Propyl Benzene	1134.72	1134.57	+0.15	0.50
Indane	1147.67	1147.39	+0.28	0.53
Total				97.96

TABLE E6 - Aromatic Solvents

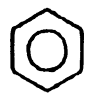
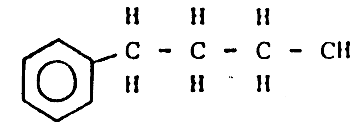
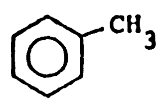
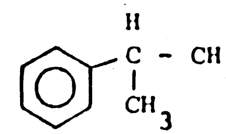
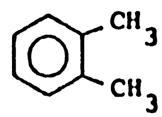
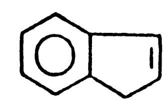
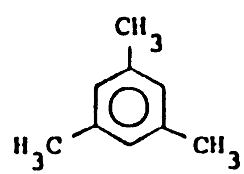
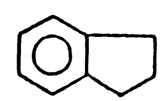
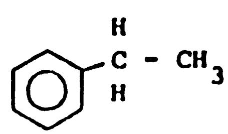
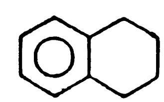
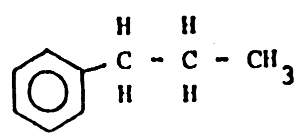
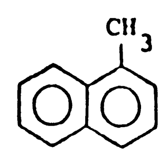
Solvent	Structure	Solvent	Structure
Benzene		Butylbenzene	
Toluene		Cumene	
Xylene	 ortho, meta and para	Indene	
Mesitylene		Indane	
Ethylbenzene		Tetralin	
Propylbenzene		1-Methylnaphthalene	

TABLE E7

Aromatic Compound	Fluid Compositions To Be Run			
	A	B	C	D
Indene	X	X		X
Phenanthrene (solid)	X			
Benzene	X	X		
Toluene	X	X	X	
Xylene ortho	X	X		X
meta	X	X		
para	X	X		
Ethyl benzene	X	X		
Cumene (isopropyl benzene)	X	X		X
1,3,5 Trimethylbenzene (mesitylane)	X	X		X
Acenaphthene (solid)	X			
Tetralin	X	X		X
Indane				X
Propylbenzene	X			X
Butylbenzene	X			
Xylene bottoms	X	X	X	
2040 Solvent	X	X	X	
1-Methylnaphthalene	X			X

TABLE E8 - Aromatic Test Fluids

JP-4 spec simulation with max aromatic and max cycloparaffin

Cyclohexane	40%
Iso-octane	35
Aromatic	25

Aromatic compound 100

Cyclohexane	40
Iso-octane	45
Aromatic	15

Cyclohexane	40
Iso-octane	35
Toluene	20
Aromatic	5

TABLE E9 - MIL-S-83430

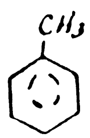
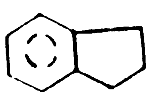
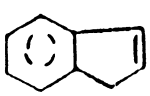
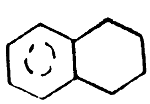
Cycloaromatics	25% Aromatic				20% Toluene, 5% Aromatic			
	Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.	Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.
 Toluene	+12.4	-6.6	+33	-28	+12.4	-6.6	+33	-28
 Indane	+22.2	-6.1	+11	-11	+15.0	-6.3	+19	-21
 Indene	Reverted				Reverted			
 Tetralin	Reverted				+13.3	-6.3	+16	-19

TABLE E9 (Continued)

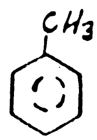
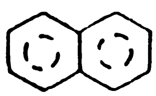
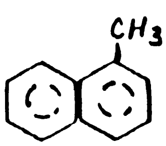
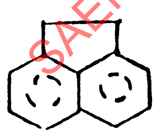
Naphthalenes	25% Aromatic			
	Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.
 Toluene	+12.4	-6.6	+33	-28
 Naphthalene				
 1-Methylnaphthalene	+22.9	-6.3	+15	-26
 Acenaphthene	+35.0	-1.3	+25	+33
2040 Fluid	+16	+7	+17	-26

TABLE E10 - MIL-S-83430 (Pro Seal 899)

Aromatic Compound		Original			After Fluid Immersion						
								Swollen		Dry	
		Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
Toluene	100%	49	391	360	72	613	230	+142	+74	-25	-17
	25	49	391	360	66	519	260	+12.4	+5.6	-11.4	-6.6
	5	49	391	360	67	448	300	+8.1	+3.2	-11.6	-6.7
	0	49	391	360	64	458	335	+2.2	+0.1	-10.8	-6.0
Xylene Bottoms	100%	49	391	360	69	530	280	+38	+20	-17.5	-11.0
	25	49	391	360	65	470	300	+10.1	+4.3	-11.3	-6.6
	5	49	391	360	67	490	280	+6.6	+2.5	-11.7	-6.7
	0	49	391	360	64	458	335	+2.2	+0.1	-10.8	-6.0
2040 Fluid	100%	49	391	360	68	470	315	+330	+200	-14.7	-10.9
	25	49	391	360	68	458	265	+15.9	+8.4	-12.2	-7.1
	5	49	391	360	67	489	310	+11.0	+5.4	-11.9	-6.8
	0	49	391	360	64	458	335	+2.2	+0.1	-10.8	-6.0

TABLE E11 - Effect of Aromatics on Polysulfide Sealants - 100% Aromatics

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
<u>Pro Seal 899</u>										
Benzene	49	390	360	77	560	140	+600	+200	-26.0	-18.1
Toluene				72	615	230	+140	+74	-25	-17
Xylene, ortho				74	585	205	+95	+50	-21.3	-14.7
Xylene, meta				71	585	220	+44	+22	-17.9	-11.5
Xylene, para				70	580	250	+39	+20	-17.5	-11.0
Ethyl Benzene				73	590	235	+48	+24	-18.1	-11.7
Cumene				70	475	255	+19	+9.5	-16.8	-10.3
1,3,5 Trimethyl Benzene				71	540	255	+20	+10	-14.7	-8.9
1-Methylnaphthalene				63	525	290	+960	+515	-25.4	-18.3

TABLE E11 (Continued)

Aromatic Compound	Original Hard.	Original Tensile Strength	Original % Elong.	After Fluid Immersion (266 h @ 140°F) Swollen Hard.	Swollen Tensile Strength	Swollen % Elong.	Swollen Vol. Ch.	Swollen Wt. Ch.	Dry Vol. Ch.	Dry Wt. Ch.
Pro Seal 899 (Continued)										
Indane										
n, Propylbenzene										
Xylene Bottoms				69	530	280	+39	+20	-17.5	-11.0
2040 Fluid				-	365	355	+330	+200	-14.7	-10.9
None				64	460	335	+2.2	+0.1	-10.8	-6.0
PR 1422										
Benzene	74	465	155	83	735	145	+232	+137	-15.8	-10.0
Toluene				80	650	140	+186	+106	-23	-17
Xylene, ortho				80	595	130	+92	+53	-17.0	-11.3

TABLE E11 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
PR 1422 (Continued)										
Xylene, meta				80	640	165	+59	+35	-12.8	-7.5
Xylene, para				80	625	160	+54	+32	-11.6	-6.7
Ethyl Benzene				83	570	120	+52	+29	-20.0	-13.5
Cumene				77	355	75	+19	+10	-21.6	-14.0
1,3,5 Trimethyl Benzene				79	575	185	+28	+17	-10.6	-5.7
1-Methylnaphthalene										
Indane										
n, Propylbenzene										
Xylene Bottoms				76	595	200	+53	+30	-12.6	-7.7

TABLE E11 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
PR 1422 (Continued)										
2040 Fluid				76	505	250	+197	+127	-14.9	-10.2
None				77	535	185	+1.7	+0.7	-2.1	-1.2
Pro Seal 890										
Benzene	46	370	415	77	570	120	+655	+245	-30.3	-22.4
Toluene				75	620	220	+130	+66	-28	-20
Xylene, ortho				76	600	190	+84	+42	-23.0	-16.2
Xylene, meta				74	590	215	+39	+19	-18.6	-12.6
Xylene, para				73	560	115	+35	+17	-18.1	-12.3
Ethyl Benzene				73	565	225	+43	+21	-18.8	-12.8

TABLE E11 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
Pro Seal 890 (Continued)										
Cumene				70	500	245	+16	+6.5	-17.4	-11.5
1,3,5 Trimethyl Benzene				70	535	245	+17	+7.6	-14.9	-9.7
1-Methylnaphthalene										
Indane										
n, Propylbenzene										
Xylene Bottoms				72	540	255	+34	+16	-18.0	-12.2
2040 Fluid				74	470	260	+337	+200	-26.5	-19.6
None				66	480	300	+3.5	+0.2	-10.0	-5.9

TABLE E12 - Effect of Aromatics on Polysulfides - Fluid Blend (25% Aromatics)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
Pro Seal 899										
Benzene	49	391	360	66	515	250	+14.7	+7.0	-11.8	-6.8
Toluene	49	391	360	66	519	260	+12.4	+5.6	-11.4	-6.6
Xylene, ortho	49	391	360	67	534	270	+11.1	+5.1	-11.6	-6.6
Xylene, meta	49	391	360	66	505	270	+9.5	+4.1	-11.5	-6.7
Xylene, para	49	391	360	66	530	255	+9.3	+4.1	-11.5	-6.6
Ethyl Benzene	49	391	360	67	522	250	+9.9	+4.3	-11.6	-6.7
Cumene	49	391	360	65	497	255	+10.1	+4.4	-11.2	-6.5
1,3,5 Trimethyl Benzene (Mesitylene)	49	391	360	67	518	265	+7.4	+3.0	-11.1	-6.4

TABLE E12 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
Pro Seal 899 (Continued)										
Indene	49	391	360	Too soft and sticky to determine						est. +3
Tetralin	49	391	360	Very soft and sticky						est. -5.1
Acenaphthene	49	391	360	56	490	480	+35.0	+22.6	-5.6	-1.3
Phenanthrene	49	391	360							
1-Methylnaphthalene	49	391	360	65	450	265	+22.9	+13.0	-11.2	-6.3
Indane	49	391	360	61	435	320	+22.2	+11.7	-11.3	-6.1
n, Propylbenzene	49	391	360	66	491	270	+8.6	+3.5	-11.9	-6.8

TABLE E12 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
PR 1422										
Benzene	74	464	155	79	575	155	+14.4	+8.2	-6.6	-4.1
Toluene	74	464	155	79	575	145	+10.8	+6.1	-6.2	-3.9
Xylene, ortho	74	464	155	79	593	155	+10.2	+5.7	-6.0	-3.8
Xylene, meta	74	464	155	79	587	155	+8.0	+4.3	-6.1	-4.0
Xylene, para	74	464	155	79	566	145	+8.1	+4.3	-5.9	-3.9
Ethyl Benzene	74	464	155	78	550	160	+8.1	+4.7	-6.1	-3.8
Cumene	74	464	155	76	503	140	+5.0	+2.6	-7.3	-4.5
1,3,5 Trimethyl Benzene	74	464	155	79	575	150	+6.1	+3.4	-5.9	-3.7

TABLE E12 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
				Swollen					Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
PR 1422 (Continued)										
Indene	74	464	155	Too soft and sticky to determine						est. +4
Tetralin	74	464	155	Very soft and sticky						est. -3.4
Acenaphthene	74	464	155							
Phenanthrene	74	464	155							
1-Methylnaphthalene	74	464	155	77	560	170	+26.5	+17.3	-5.7	-3.0
Indane	74	464	155	67	216	85	+10.6	+8.3	-8.7	-3.5
Propylbenzene	74	464	155	77	531	140	+7.0	+3.8	-5.6	-3.4

TABLE E13 - Effect of Aromatics on Polysulfide Sealants - Fluid D: 20% Toluene, 5% Aromatic

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
				Swollen					Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
<u>Pro Seal 899</u>										
Benzene	49	390	360							
Toluene	49	390	360	66	520	260	+12.4	+5.6	-11.4	-6.6
Xylene, ortho	49	390	360	65	480	300	+13.2	+5.8	-10.8	-6.5
Xylene, meta	49	390	360							
Xylene, para	49	390	360							
Ethyl Benzene	49	390	360							
Cumene	49	390	360	66	465	300	+13.1	+5.9	-11.1	-6.6
1,3,5 Trimethyl Benzene	49	390	360	66	460	285	+12.1	+5.3	-11.1	-6.5
1-Methylnaphthalene	49	390	360	66	465	300	+17.4	+8.6	-9.8	-5.6

TABLE E13 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
Pro Seal 899 (Continued)										
Indane	49	390	360	67	465	285	+15.0	+7.1	-11.0	-6.3
n, Propylbenzene	49	390	360	66	475	270	+12.6	+5.6	-11.0	-6.5
Xylene Bottoms	49	390	360							
2040 Fluid	49	390	360							
Indene	49	390	360	Reverted						
Tetralin	49	390	360	66	455	290	+13.3	+6.0	-10.8	-6.3

TABLE E14 - Effect of Aromatics on Polysulfides - Fluid Blend (25% Aromatics)

	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
Aromatic Compound	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
<u>Pro Seal 890</u>										
Benzene	46	370	415	66	459	260	+17.0	+7.1	-12.5	-8.9
Toluene	46	370	415	66	493	275	+14.8	+5.9	-12.2	-7.7
Xylene, ortho	46	370	415	66	519	265	+13.8	+5.4	-12.4	-7.8
Xylene, meta	46	370	415	65	492	270	+11.8	+4.3	-12.4	-7.8
Xylene, para	46	370	415	65	513	270	+12.2	+4.5	-12.3	-7.7
Ethyl Benzene	46	370	415	66	485	260	+12.6	+4.7	-12.2	-7.7
Cumene	46	370	415	67	484	290	+11.8	+4.3	-12.1	-7.5
1,3,5 Trimethyl Benzene	46	370	415	67	496	250	+10.1	+3.5	-12.1	-7.6

TABLE E14 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
Pro Seal 890 (Continued)										
Indene	46	370	415	Reverted - glob on bottom of jar						
Tetralin	46	370	415	Very soft and sticky						est. -1.1
Acenaphthene	46	370	415							
Phenanthrene	46	370	415							
1-Methylnaphthalene	46	370	415	65	470	245	+25.3	+13.4	-11.7	-7.2
Indane	46	370	415							
Propylbenzene	46	370	415							

TABLE E14 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
				Swollen					Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
PR 1422										
Benzene	74	465	155							
Toluene	74	465	155	79	575	145	+10.8	+6.1	-6.2	-3.9
Xylene, ortho	74	465	155	76	520	210	+10.4	+6.0	-6.2	-3.9
Xylene, meta	74	465	155							
Xylene, para	74	465	155							
Ethyl Benzene	74	465	155							
Cumene	74	465	155	75	505	225	+9.6	+5.2	-6.3	-4.2
1,3,5 Trimethyl Benzene	74	465	155	76	560	210	+10.2	+5.9	-5.6	-3.5

TABLE E14 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
PR 1422 (Continued)										
1-Methylnaphthalene	74	465	155	76	530	165	+15.6	+9.4	-5.0	-2.9
Indane	74	465	155	73	435	200	+12.0	+7.2	-6.4	-3.5
n, Propylbenzene	74	465	155	76	555	200	+13.1	+7.7	-5.7	-3.3
Xylene Bottoms	74	465	155							
2040 Fluid	74	465	155							
Indene	74	465	155	40	57	260	+37.8	+27.7	+19.0	+10.5
Tetralin	74	465	155	76	520	200	+11.5	+6.5	-5.7	-3.7

TABLE E14 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)			Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
Pro Seal 890										
Benzene	46	370	415							
Toluene	46	370	415	66	495	275	+14.8	+5.9	-12.2	-7.7
Xylene, ortho	46	370	415	67	480	290	+12.8	+5.3	-11.6	-7.3
Xylene, meta	46	370	415							
Xylene, para	46	370	415							
Ethyl Benzene	46	370	415							
Cumene	46	370	415	67	460	290	+13.9	+5.7	-11.4	-7.2
1,3,5 Trimethyl Benzene	46	370	415	68	500	270	+12.2	+4.8	-11.3	-7.0
1-Methylnaphthalene	46	370	415	68	495	280	+17.5	+7.9	-11.1	-6.9

TABLE E14 (Continued)

Aromatic Compound	Original			After Fluid Immersion (266 h @ 140°F)			Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
Pro Seal 890 (Continued)										
Indane	46	370	415	67	490	280	+15.5	+6.7	-11.3	-7.0
n, Propylbenzene	46	370	415	67	510	260	+12.5	+4.9	-11.4	-7.2
Xylene Bottoms	46	370	415							
2040 Fluid	46	370	415							
Indene	46	370	415	Reverted						
Tetralin	46	370	415	67	485	300	+13.0	+5.4	-11.4	-7.0

TABLE E15 - Toluene

Aromatic Content	Original			After Fluid Immersion						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
100%	49	391	360	72	613	230	+142	+74	-25	-17
25%	49	391	360	66	519	260	+12.4	+5.6	-11.4	-6.6
15%	49	391	360	67	448	300	+8.1	+3.2	-11.6	-6.7
0%	49	391	360	64	458	335	+2.2	+0.1	-10.8	-6.0
100%	74	464	155	80	651	140	+186	+106	-23	-17
25%	74	464	155	79	575	145	+10.8	+6.1	-6.2	-3.9
15%	74	464	155	78	577	170	+7.5	+4.1	-5.2	-3.1
0%	74	464	155	77	533	185	+1.7*	+0.7*	-2.1*	-1.2*

*Some fluid lost.

TABLE E15 (Continued)

Aromatic Content	Original			After Fluid Immersion						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
100%	46	370	415	75	618	220	+130	+66	-28	-20
25%	46	370	415	66	493	275	+14.8	+5.9	-12.2	-7.7
15%	46	370	415	67	460	330	+9.7	+3.3	-11.5	-7.0
0%	46	370	415	66	480	300	+3.5*	+0.2*	-10.0*	-5.9*

*Some fluid lost.

TABLE E16 - Xylene Bottoms

	Original			After Fluid Immersion						
							Swollen		Dry	
Aromatic Content	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
100%	49	391	360	69	530	280	+38.8	+20.0	-17.5	-11.0
25%	49	391	360	65	470	300	+10.1	+4.3	-11.3	-6.6
15%	49	391	360	67	490	280	+6.6	+2.5	-11.7	-6.7
0%	49	391	360	64	458	335	+2.2	+0.1	-10.8	-6.0
100%	74	464	155	76	597	200	+52.9	+30.3	-12.6	-7.7
25%	74	464	155	78	544	200	+8.6	+5.1	-6.0	-3.3
15%	74	464	155	78	548	190	+6.1	+3.4	-5.7	-3.3
0%	74	464	155	77	533	185	+1.7*	+0.7*	-2.1*	-1.2*

*Some fluid lost.

TABLE E16 (Continued)

	Original			After Fluid Immersion						
							Swollen		Dry	
Aromatic Content	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
100%	46	370	415	72	542	255	+34.1	+16.1	-18.0	-12.2
25%	46	370	415	66	449	295	+11.8	+4.2	-11.8	-7.4
15%	46	370	415	67	475	280	+8.4	+2.6	-11.6	-7.2
0%	46	370	415	66	418	300	+3.5	+0.2	-10.0	-5.9

*Some fluid lost.

TABLE E17 - 2040 Fluid

Aromatic Content	Original			After Fluid Immersion						
						Swollen			Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
100%	49	391	360	68	470	315	+330.5	+199.7	-14.7	-10.9
25%	49	391	360	68	458	265	+15.9	+8.4	-12.2	-7.1
15%	49	391	360	67	489	310	+11.0	+5.4	-11.9	-6.8
0%	49	391	360	64	458	335	+2.2	+0.1	-10.8	-6.0
100%	74	464	155	76	507	250	+197.1	+127.4	-14.9	-10.2
25%	74	464	155	79	527	185	+17.5	+11.3	-6.6	-3.4
15%	74	464	155	77	499	165	+11.4	+7.0	-5.3	-3.1
0%	74	464	155	77	533	185	+2.2	+0.1	-10.8	-6.0

TABLE E17 (Continued)

	Original			After Fluid Immersion						
				Swollen					Dry	
Aromatic Content	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
100%	46	370	415	74	471	260	+336.6	+199.9	-26.5	-19.6
25%	46	370	415	68	455	285	+16.5	+8.0	-12.4	-7.8
15%	46	370	415	66	480	300	+12.2	+5.2	-11.7	-7.2
0%	46	370	415	66	418	300	+3.5	+0.2	-10.0	-5.9

TABLE E18 - Effect of Aromatics on Polysulfide Sealants

Fluid Immersion

Fluid	500 cc	
Temp	140°F &	158°F ± 1.8
Time	266 h	(266 h ± 0.25)

Specimens

1 in x 2 in x 0.075 in ± 0.005 in
4 per jar

Sealants

MIL-S-8802	Chromate cure - RTV for 14 days
MIL-S-8802	MnO_2 cure - RTV for 14 days
MIL-S-83430	MnO_2 cure - RTV for 14 days

Data

Volume change	Swollen & dried
Weight change	Swollen & dried
Hardness change (Dry)	
Tensile strength change (Dry)	
Elongation at break change (Dry)	

TABLE E19 - Effect of Naphthalenes on MIL-S-83430

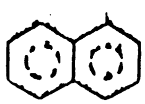
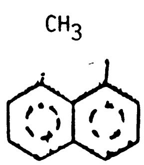
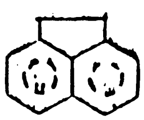
	25% Naphthalene				20% Toluene, 5% Naphthalene			
	Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.	Vol. Ch.	Wt. Ch.	T.S. Ch.	% E. Ch.
 Toluene	+12.4	-6.6	+33	-28	+12.4	-6.6	+33	-28
 Naphthalene	+24.1	-6.6	+22	-22	+21.2	-6.4	+17	-34
 1,Methylnaphthalene	+22.9	-6.3	+15	-26	+17.4	-5.6	+19	-17
 Acenaphthalene	+35.0	-1.3	+25	+33				
"2040 Fluid"	+16	-7	+17	-26	+16	-7	+17	-26

TABLE E20 - Effect of Cycloaromatics on MIL-S-83430

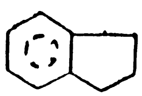
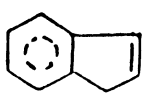
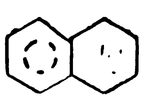
	25% Cycloaromatic				20% Toluene 5% Cycloaromatic				24% Toluene 1% Cycloaromatic			
	Vol. Ch.	Wt. Ch.	T.S. Ch.	% E. Ch.	Vol. Ch.	Wt. Ch.	T.S. Ch.	% E. Ch.	Vol. Ch.	Wt. Ch.	T.S. Ch.	% E. Ch.
 Toluene	+12.4	-6.6	+33	-28	+12.4	-6.6	+33	-28				
 Indane	+22.2	-6.1	+11	-11	+15	-6.3	+19	-21				
 Indene	REVERTED				REVERTED				+17.5	-6.1	+13	-28
 Tetralin	REVERTED				+13.3	-6.3	+16	-19	+26.4	-5.9	+18	-38

TABLE E21

Aromatic Compound	Original			After Fluid Immersion						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
<u>Pro Seal 899</u>										
Naphthalene @ 25%	57	410	400	72	500	310	+24.1	-13.5	-10.4	-6.6
Naphthalene @ 5% with 20% Toluene	57	410	400	72	480	265	+21.2	+10.0	-10.1	-6.4
Indene @ 1% with 24% Toluene	57	410	400	72	465	290	+17.5	+7.5	-9.7	-6.1
Tetralin @ 1% with 24% Toluene	57	410	400	72	485	250	+26.4	+12.1	-9.4	-5.9

TABLE E21 (Continued)

Aromatic Compound	Original			After Fluid Immersion						
							Swollen		Dry	
	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
PR 1422										
Naphthalene @ 25%										
Naphthalene @ 5% with 20% Toluene										
Indene @ 1% with 24% Toluene	78	515	170	75	485	200	+15.9	+9.6	-3.9	-2.0
Tetralin @ 1% with 24% Toluene										

APPENDIX F

EFFECT OF ALKANE AND CYCLOHEXAND FUEL COMPONENTS ON POLYSULFIDE FUEL TANK SEALANTS

TABLE F1 - Analysis of Control Fuels

Composition	JP-4 Pet. (%)	JP-4 Shale (%)	JP-5 Pet. (%)	JP-8 Pet. (%)
Paraffins	61.4	45.6	45.4	43.2
Monocycloparaffins	23.6	43.4	38.9	39.9
Dicycloparaffins	5.0	--	2.8	3.7
Alkylbenzenes	8.5	7.4	7.5	7.4
Indanes & Tetralins	1.0	3.6	3.0	3.9
Indenes & Dihydro-naphthalenes	--	--	--	--
Naphthalenes	0.5	TRACE	2.4	1.9
Total Paraffins	90.0	89.0	87.1	86.8
Total Aromatics	10.0	11.0	12.9	13.2
Olefins	1.5	1.0	1.7	2.1
Hydrogen (wt %)	14.5	14.3	13.8	13.9
Sulfur:				
Mercaptan (wt %)	0.0004	0.0005	--	0.0004
Total (wt %)	0.03	0.03	--	0.11
Additives (anti-icing)	0.07	0.10	--	0.14

TABLE F2 - Effect of Alkanes/Cycloalkanes on Polysulfide Sealants

Fluid Immersion

Fluid	500 mL
Temp	140°F
Time	266 h

Specimens

1 in x 2 in x 0.075 in ± 0.005 in
4 per jar

Sealants

MIL-S-8802	Chromate cure - RTV for 14 days
MIL-S-8802	MnO_2 cure - RTV for 14 days
MIL-S-83430	MnO_2 cure - RTV for 14 days

Data

Volume change	Swollen & dried
Weight change	Swollen & dried
Hardness change (Dry)	
Tensile strength change (Dry)	
Elongation at break change (Dry)	

TABLE F3 - Test Matrix

Test Fluid		A	B	C	D	E
Hexane	C_6	X	X	X		X
Heptane	C_7	X	X			
N - Octane	C_8	X	X			
N - Nonane	C_9	X	X			
N - Decane	C_{10}	X	X	X		X
N - Undecane	C_{11}	X	X			
N - Dodecane	C_{12}	X	X			
N - Hexadecane	C_{16}	X	X	X		X
I - Hexene	C_6	X	X	X		X
I - Octene	C_8	X	X			
Iso-Octane	C_8	X	X	X		X
Cyclohexane	C_6	X	X		X	X
Decalin	C_{10}	X	X		X	X
Methylcyclohexane	C_7	X	X			
JP-4, Petroleum						X
JP-4, Shale						X
JP-5, Pet.						X
JP-8, Pet.						X

TABLE F4 - Fluid Blends

Blend A	Iso-Octane	45
	Cyclohexane	45
	Paraffin/Cycloparaffin	10
Blend B	Iso-Octane	35
	Cyclohexane	35
	Toluene	20
	Paraffin/Cycloparaffin	10
Blend C	Cyclohexane	50
	Paraffin	50
Blend D	Iso-Octane	50
	Cycloparaffin	50
Blend E	Paraffin/Cycloparaffin	100

TABLE F5

MIL-S-8802 - Chromate Core Alkane	Alkane 10%		45 Iso-Octane 45 Cyclohexane	
	Vol. Ch.	Wt. Ch.	T.S. Ch.	% E. Ch.
c-c-c-c-c-c Hexane	+3.0	-2.0	+9.7	+8.8
c-c-c-c-c-c-c Heptane	+2.7	-1.9	+10.7	+2.9
c-c-c-c-c-c-c-c n-Octane	+2.9	-2.0	+14.6	0
c-c-c-c-c-c-c-c-c n-Nonane	+2.7	-2.1	+15.5	+2.9
c-c-c-c-c-c-c-c-c-c n-Decane	+2.7	-2.0	+12.6	-2.9

TABLE F5 (Continued)

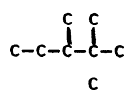
MIL-S-8802 - Chromate Core Alkane	Alkane 10%		45 Iso-Octane 45 Cyclohexane	
	Vol. Ch.	Wt. Ch.	T.S. Ch.	% E. Ch.
 Iso-Octane	+2.6	-2.0	+18.4	+5.9
c=c-c-c-c-c Hexene	+3.0	-2.1	+17.5	-2.9
JP-4, Petroleum	+4.2	-1.9	+5.8	+5.9
JP-4, Shale	+3.0	-2.0	+9.7	+8.8

TABLE F5 (Continued)

MIL-S-8802 - Chromate Core Alkane	Alkane 10%		45 Iso-Octane 45 Cyclohexane	
	Vol. Ch.	Wt. Ch.	T.S. Ch.	% E. Ch.
JP-5, Pet.	+2.9	-1.9	+6.8	+8.8
JP-8, Pet.	+3.0	-2.0	+8.7	+11.8

TABLE F6

MIL-S-83430 Alkane	Alkane 10% Vol. (Wet)	Alkane 10% Wt.	Alkane 10% T.S.	Alkane 10% % E.	Toluene 20%, Alkane 10% Vol. (Wet)	Toluene 20%, Alkane 10% Wt.	Toluene 20%, Alkane 10% T.S.	Toluene 20%, Alkane 10% % E.
c-c-c-c-c-c Hexane	+5.7	-5.3	+15	-30	+15.3	-6.0	+21	-34
c-c-c-c-c-c-c Heptane	+5.7	-5.3	+20	-33	+14.7	-6.0	+17	-35
c-c-c-c-c-c-c-c n-Octane	+5.4	-5.4	+17	-26	+14.4	-6.0	+20	-33
c-c-c-c-c-c-c-c-c n-Nonane	+5.0	-5.4	+17	-33	+14.5	-6.0	+18	-31
c-c-c-c-c-c-c-c-c-c n-Decane	+4.7	-5.2	+17	-30	+14.2	-5.9	+21	-33

TABLE F6 (Continued)

MIL-S-83430 Alkane	Alkane 10% Vol. (Wet)	Alkane 10% Wt.	Alkane 10% T.S.	Alkane 10% % E.	Toluene 20%, Alkane 10% Vol. (Wet)	Toluene 20%, Alkane 10% Wt.	Toluene 20%, Alkane 10% T.S.	Toluene 20%, Alkane 10% % E.
c-c-c(c)-c(c)(c)-c Iso-Octane	+5.0	-5.3	+17	-30	+14.1	-5.9	+20	-33
c=c-c-c-c-c Hexene	+6.2	-5.4	+20	-31	+15.4	-6.0	+23	-34
JP-4, Pet.	+5.6	-5.1	+18	-28	+5.6	-5.1	+18	-28
JP-4, Shale	+3.3	-5.2	+18	-33	+3.3	-5.2	+18	-33
JP-5, Pet.	+1.6	-5.2	+17	-28	+1.6	-5.2	+17	-28

TABLE F6 (Continued)

MIL-S-83430 Alkane	Alkane 10%				Toluene 20%, Alkane 10%			
	Vol. (Wet)	Wt.	T.S.	% E.	Vol. (Wet)	Wt.	T.S.	% E.
JP-8, Pet.	+1.8	-5.2	+20	-28	+1.8	-5.2	+20	-28

TABLE F7

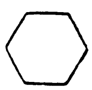
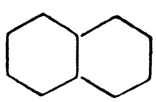
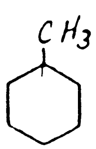
MIL-S-83430 Cycloalkanes	Iso-Octane 45%, Cyclohexane 45% 10% Cycloalkane				Iso-Octane 35%, Cyclohexane 35% 20% Toluene, 10% Cycloalkane			
	Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.	Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.
 Cyclohexane	+6.3	-5.4	+23	-30	+15.8	-5.9	+26	-30
 Decalin	+7.1	-5.5	+16	-36	+15.8	-6.2	+18	-35
 Methylcyclohexane	+6.5	-5.2	+18	-31	+15.6	-5.8	+21	-33
JP-4, Petroleum	+5.6	-5.1	+18	-28	+5.6	-5.1	+18	-28
JP-4, Shale	+3.3	-5.2	+18	-33	+3.3	-5.2	+18	-33

TABLE F7 (Continued)

MIL-S-83430 Cycloalkanes	Iso-Octane 45%, Cyclohexane 45% 10% Cycloalkane				Iso-Octane 35%, Cyclohexane 35% 20% Toluene, 10% Cycloalkane			
	Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.	Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.
JP-5, Petroleum	+1.6	-5.2	+17	-28	+1.6	-5.2	+17	-28
JP-8, Petroleum	+1.8	-5.2	+20	-28	+1.8	-5.2	+20	-28

TABLE F8

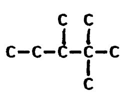
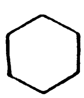
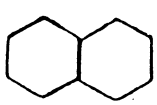
MIL-S-83430 Alkane/Cycloalkane	100% Alkane/Cycloalkane Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.	50% Alkane, 50% Cyclohexane 50% Iso-Octane, 50% Cycloalkane Vol. Ch. (Wet)	Wt. Ch.	T.S. Ch.	% E. Ch.
c-c-c-c-c-c Hexane	+0.6	-5.1	+21	-29	+12.3	-5.3	+15	-35
 Iso-Octane	-0.5	-4.9	+18	-33	+5.6	-5.3	+17	-34
 Cyclohexane	+14.6	-5.6	+20	-33	+5.6	-5.3	+20	-33
 Decalin					+6.7	-5.7	+12	-36
JP-4, Petroleum	+5.6	-5.1	+18	-28	+5.6	-5.1	+18	-28

TABLE F9 - Analysis of Control Fuels

Composition	JP-4 Pet.	JP-4 Shale	JP-5 Pet.	JP-8 Pet.	JRF
Paraffins	61	46	45	43	10
Cycloparaffins	29	43	42	44	60
Aromatics	10	11	13	13	30
Mercaptan Sulfur	0.0004	0.0005	--	0.0004	0.005
Total Sulfur	0.03	0.03	--	0.11	0.40
Hydrogen	14.5	14.3	13.8	13.9	--

TABLE F10 - Effect on Polysulfide Sealants - Mix A
(Iso-Octane 45, Cyclohexane 45, Paraffin/Cycloparaffin 10)

	Original			After Fluid Immersion						
							Swollen		Dry	
Paraffin/ Cycloparaffin	Hard.	Tensile Strength	% Elong.	Hard.	Tensile Strength	% Elong.	Vol. Ch.	Wt. Ch.	Vol. Ch.	Wt. Ch.
PR 1422										
Hexane	78	515	170	78	565	185	+3.0	+1.4	-2.9	-2.0
Heptane	78	515	170	78	570	175	+2.7	+1.3	-3.0	-1.9
n-Octane	78	515	170	78	590	170	+2.9	+1.4	-3.0	-2.0
n-Nonane	78	515	170	78	595	175	+2.7	+1.3	-3.1	-2.1
n-Decane	78	515	170	78	580	165	+2.7	+1.3	-3.0	-2.0
Iso-Octane	78	515	170	78	610	180	+2.6	+1.3	-2.9	-2.0
Hexene	78	515	170	78	605	165	+3.0	+1.5	-3.0	-2.1