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SUBJECT

Report of

Emulsion Formation of the "A" Series of Fuel Oils

by

O. I. Lewis
P. Borgstrom

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Public Release**

Naval Research Laboratory
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NAVY DEPARTMENT
BUREAU OF ENGINEERING

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ANACOSTIA STATION
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Prepared by:

O. I. Lewis, Contract Employee.

P. Borgstrom, Chemist, Superintendent,
Chemistry Division.

Reviewed by:

H. Ambrose, Lieutenant, U.S.N.

Approved by:

Hollis M. Cooley, Captain, USN, Director

Distribution:

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ABSTRACT

1. In this report it is shown that the stability of an emulsion can be affected by the method by which the emulsion is prepared and the type of water dispersed in the oil. Thus, emulsions formed by steam may show greater instability than emulsions formed from fresh water. Usually the emulsions formed from sea water show less stability than emulsions made from steam or the emulsions made from fresh water.

2. It is shown in this report that gravity is not the controlling factor in the stability of emulsions formed. In fact, oils studied in this report with a gravity lighter than 12° A.P.I. show a greater stability than those with a gravity heavier than 12° A.P.I.

3. The results show that viscosity is not a controlling factor in the stability of the emulsions formed. The fuels studied in this report having a viscosity that passes the present Navy specifications are slightly more unstable than the more viscous fuels, but the difference between the two varies from 1 to 10% only, the 10% difference occurring where steam was used for formation of the emulsion.

4. The data in this report show that the composition of the oil may have some influence in controlling the stability of the emulsion formed, but the type of the water dispersed and the method of dispersing may be as important as the nature of the oil itself.

EMULSION FORMATION OF THE "A" SERIES

INTRODUCTION

(a) Authorization

This problem was authorized by Bureau of Engineering Project Order 86/31 of 2 June 1931.

(b) Statement of Problem

The original problem given in the above reference dealt with the characteristics and supply of fuel oil for the Navy. The fuel oils dealt with in NRL Reports No. P-1012, No. P-1031 and No. P-1049 concerned tests of a group of cracked fuel oils that were reported as the "A" series. During the months of May and June 1934, emulsions were made of these 18 fuel oils of three types, (a) water steamed into the oil to make emulsions containing 2, 5 and 10% water; (b) water shaken into the oil to make emulsions containing 2, 5 and 10% water; and (c) sea water shaken in to make emulsions containing 2, 5 and 10% water. Method (a) is similar to the condition that exists when a steam line breaks in an oil tank; method (b), when harbor water or rain water gets into the bunkers and is shaken in, and method (c) is similar to a condition when sea water gets into the bunkers and is shaken in. Another sample was made that has 50% water and 50% oil, to note if such a sample would be stable. The concentration of water was determined on the emulsion when freshly made and again after it had stood for a period of approximately 3 months. In this report the data on these emulsions as to their stability and viscosity will be discussed.

(c) Facts Bearing on the Problem

In handling fuel oils aboard ship, three types of emulsions can be formed as shown in paragraph (b). Whether the three types are equally stable, or if one will form a stable emulsion while the others will not, is not known for cracked fuels. In the petroleum industry emulsions are often broken by the addition of salt or salt water, and if such information holds with emulsions of cracked fuels, then type (c) should not be as stable as type (a) or (b). The gravity of this dispersed water probably has some effect on its distribution when an emulsion breaks. If the water separating is heavier than the fuel oil there is a tendency for the water to settle, while if the water is lighter the tendency will be to rise. In some emulsions where the water and oil have the same density the water will separate into small globules throughout the oil. The effect on emulsions of the coefficient of expansion of water in comparison to that of fuel oils will be discussed in a future report.

(d) Theoretical Considerations

In the preparation of emulsions, and especially those dealing with these heavy fuels, the cause of the stability of the emulsions is not known.

Two oils very similar in behavior as to viscosity will form emulsions that are entirely different in stability. Whether the composition of the oil has any effect on the stability of the emulsions was discussed in NRL Report No. P-25-8 of 13 May 1933, which dealt with the stability of water in oil emulsions. In that report it is shown that the nitrogen content may have some effect in the formation of stable emulsions. Whether other organic compounds will also play a part in the formation of stable emulsions is not known now, but it is known that certain oxidation products such as naphthenic acids can form soaps that tend to stabilize emulsions. Whether some of these compounds are present in the fuel oil has not been determined. Another factor that may enter into the stability of the emulsion is the viscosity of the emulsion so formed.

(e) Original Work at this Laboratory

NRL Report No. P-25-8, of 13 May 1933, discusses the stability of water in oil emulsions. This report was written on the findings of the study of emulsions of the NRL series described in NRL Report No. P-25-9 of 25 July 1933 on the fuel oil samples in storage at the Naval Research Laboratory. This earlier work at this Laboratory was done on both the straight run residues and cracked fuels and the conclusions were based upon emulsions formed by steam distilled into the oil. In this report the conclusions state: (1) that certain fuel oils will form stable emulsions containing high percentages of water (up to 50%), (2) that certain fuel oils will not form stable emulsions under any condition, even though the water had been steamed in or shaken, (3) that the stability of the emulsions formed seems to be correlated with a percentage of nitrogen content present in the fuel oil, that is, with a nitrogen content of 0.15 molar (or 0.2%) or less the emulsions are not stable, while above that they are, (4) that whether the nitrogen content is the actual cause of stability or is present with certain other compounds to form stable emulsions is not known, (5) that sea water (shaken in), fresh water (shaken in), or fresh water (steamed in) form similar emulsions with four oils that were studied; the stability is the same for any of these emulsions just so the water is present, (6) that of the oils studied, those from California form stable emulsions while others, "except 36", form unstable emulsions. Whether this will hold for other samples cannot be predicted for this work. These conclusions will be discussed later in this report.

METHODS

(a) Preparation of Materials

In the preparation of the emulsions the oil was weighed in the container in which the emulsion was to be made and the desired amount of water to make a certain percentage of water in the emulsion was added. The container was then placed in a water bath and heated to a temperature at which the oil is fluid enough so that it can be shaken readily to bring the water into the oil. This method was used for formation of emulsions with sea

water and with fresh water. The shaking usually required 10 minutes, but for a viscous oil it was longer. The samples made up were shaken by hand, for in doing it in that manner, there was uneven shaking and the emulsions formed with greater rapidity. The emulsions made by the steaming in of water to form an emulsion similar to that which occurs when a steam line is broken, was made by passing in live steam into the sample to be emulsified. The weight before and after the steam was injected was noted and the percentage of water calculated from this gain in weight. The temperature of the oil at the end of the steaming process varied with the amount of water to be put into the oil and when a 10% emulsion was made the temperature at the end was approximately 90°C. Whether this temperature of 90°C had any effect on the oil to tend to make it a more or less stable emulsion is not known. With all the steamed-in samples, the sample was thoroughly shaken before putting away in storage.

After the samples had been in storage approximately one week, the water content was determined by the distillation method. The method used was that described as A.S.T.M. D95-30, except that benzol was used as a solvent instead of naphtha. Benzol was used throughout this work in the distillations because it is readily miscible with the fuels dealt with. Petroleum ether, with a boiling point of about 80°C to 110°C, can be used and it has the advantage that less water is found to be present in it. The amount of benzol used in the test may cause an error of approximately .05%. The distillation of water by this method usually took 12 hours, and many times it was allowed to run 24 hours, especially where the sample contained 50% to 60% water. The first samples taken, i.e. those which had stood for 7 to 8 days, were poured out of the container into the graduated cylinder to obtain the 100 cc, or the desired volume to be studied. This was then poured into the flask used for distillation and the graduated cylinder washed out with 100 cc of benzol. This method was entirely satisfactory for the first determination made on the emulsions. The water determinations made on the samples that had stood for 7 to 8 months had entirely different characteristics, for in some of these the water had coalesced to small bubbles that were disbursed throughout the oil and with some samples there were larger bubbles gathered on the outside surface next to the container. The containers for all of these samples were new glass jars. When 100 cc of this sample was poured, it was difficult to get a true sample. When the oil is moved these water bubbles may coalesce, and when it is poured these bubbles will come out of the body of the oil, and as a result, there are two separate phases present. One set of water determinations on the emulsions was made in this manner. To reduce this effect to the minimum, another set of determinations was made in which suction was applied to the flask in which the sample was to be run and a tube extended from the flask into the body of the oil itself was used to draw the sample from the center of the oil mass in the original container. This method would be fairly comparable to the suction that is taken when pumping fuel oils aboard ship. As a result, the percentage of water found in these samples is usually much higher than that found in the sample that was poured out when the oil has a tendency to separate into two phases. There were certain oils in which very stable emulsions were formed and these were not run by this second method. In the tabulated data which follows, as well as in Appendix I, the first method is called "Poured" and the second method "Drawn".

	% of Water put in	Steam				Shaken				Sea			
		Made	Poured	Drawn	Visc*	Made	Poured	Drawn	Visc*	Made	Poured	Drawn	Visc*
A-10	2	2.0	1.9	1.9	70	2.4	2.1	2.0	72	2.0	1.4	2.0	67
	5	4.4	4.5	3.9	66	4.7	4.7	5.1	69	4.7	4.1	5.1	68
	10	8.0	8.1	7.6	75	9.0	8.9	9.0	90	8.5	7.2	9.1	64
A-11	2	1.9	1.0	1.7	26	2.1	1.7	2.3	27	1.3	1.0	1.4	24
	5	3.6	2.3	4.1	31	4.5	4.4	4.8	28	2.3	0.5	2.1	25
	10	6.0	4.8	8.4	33	8.5	9.1	9.1	37	8.4	8.4	9.7	29
										8.4			
A-12	2	2.8	2.6	2.6	91	3.0	2.8	2.4	92	2.7	2.4	2.7	95
	5	5.4	4.5	4.7	93	6.0	5.6	4.7	95	5.3	4.9	6.0	97
	10	12.0	8.7	8.8	107	10.3	9.9	9.0	109	9.9	9.5	9.8	108
A-13	2	1.1	0.4	0.4	248	2.2	1.5	1.3	307	2.0	0.8	0.4	291
	5	4.6	3.6	3.7	279	4.6	1.6	2.3	308	3.0	1.2	0.8	297
	10	8.5	7.7	8.2	335	8.7	5.2	6.0	362	2.8	1.3	1.0	302
A-14	2	0.4	0.1	0.1	56	1.9	0.5	0.6	64	1.6	0.6	0.5	62
	5	0.4	0.2	1.0	58	2.4	1.3	1.3	65	2.2	0.4	0.5	63
	10	6.7	0.8	1.0	63	2.0	0.9	3.0	62	1.9	0.5	0.9	62
A-15	2	1.5	0.9	0.7	261	2.0	0.5	0.7	264	1.8	0.4	0.4	262
	5	4.0	2.5	2.9	286	4.5	3.0	2.4	278	2.6	0.8	0.6	254
	10	7.5	4.8	4.8	303	9.0	7.0	6.7	275	7.2	1.3	2.0	240
A-16	2	0.5	0.3	0.4	55	2.2	1.8	1.5	61	1.4	0.6	0.7	58
	5	0.1	0.2	1.4	56	1.2	0.6	0.4	56	1.7	0.8	0.9	55
	10	0.1	0.1	6.9	57	3.4	2.8	4.3	63	2.2	0.9	2.8	56
A-17	2	1.5	1.5	1.5	147	2.0	2.0	2.7	141	1.8	1.5	1.9	143
	5	3.5	2.6	2.4	155	4.5	4.6	4.7	158	4.3	4.3	4.7	155
			2.7										
	10	7.0	1.4	1.1	143	8.8	9.0	8.9	177	8.0	7.8	9.4	174
			1.6										
A-18	2	2.5	2.5	2.7	197	1.7	1.6	1.8	189	1.5	1.0	0.7	182
	5	1.3	0.3	1.4	187	4.2	3.4	3.8	207	3.3	1.9	1.7	185
	10	1.0	0.2	0.7	198	8.6	8.5	8.7	223	6.0	2.0	7.0	176

* Viscosity of poured sample.

A-1 is given in SSF; others in SSA.

The emulsions made by shaking equal volumes of fresh water and oil are given in Appendix I as the "J" samples. The water content was determined on this when freshly made and when eight months old. The viscosities at 77° and 122° were determined only on the aged samples using the Asphalt tip at 77° and the Furol tip at 122°F. The data found as well as the viscosities of the original oil at 77° and 122° are given below:

TABLE II

No.	PerCent Water			SSA at 77°F		SSF at 122°	
	Made	Poured	Drawn	Emulsion**	Orig. Note 1	Emulsion	Orig. Note 2
A-1	52	685		98*	91*	29	22
2	47	50		846 699	78	478	84
3	51	52		1521 1658	119	1359	123
4	51	51		986 990	153	1463	148
5	48	46		537 517	64	566	86
6	48	53		475 465	61	512	83
7	50	49		509 441	34	514	57
8	52	46		1562 1766	180	1132	149
9	51	56		233 218	24	348	38
10	50	51	51	475 404	31	472	50
11	52	49.5		172 189	14	238	29
12	68	60		143 158	64	176	79
13	53	50.5		2389 2352	163	1447	157
14	52	45°	48	430 454	39	635	59
15	41	28°	57	621 647	186	971	220
16	44	31°	56.5	260 295	43	545	64
17	48	50		984 900	110	619	89
18	49	51		1131 1208	116	1074	152

* Viscosity, SSF.

** Two determinations for all except A-1.

Note 1 - Minimum viscosity as given in NRL Report #1127, page 10.

Note 2 - Viscosity determinations made during March 1935 just after viscosities of emulsions had been determined at 122°F.

° A-14, 15, and 16 were rerun and the per cent water found was 56, 59 and 51%.

CONCLUSIONS AND RECOMMENDATIONS

In preparing emulsions, three sources of water must be considered: (1) steam from a broken steam line, (2) fresh water from rain, etc., and (3) sea water. Emulsions were prepared from the oils to contain 2, 5 and 10% water. For the determination of the water content of these emulsions, samples were poured out and when these determinations showed instability, other samples were drawn from the flask as would be done by the suction line in a tank. The first determination described above is called "poured" and the other "drawn" in the tabular data of this report.

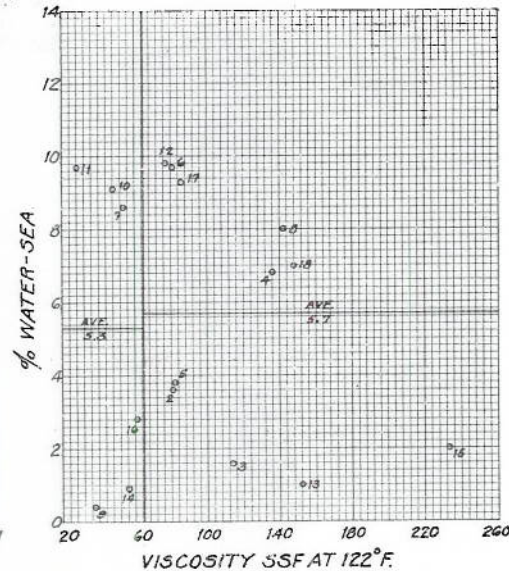
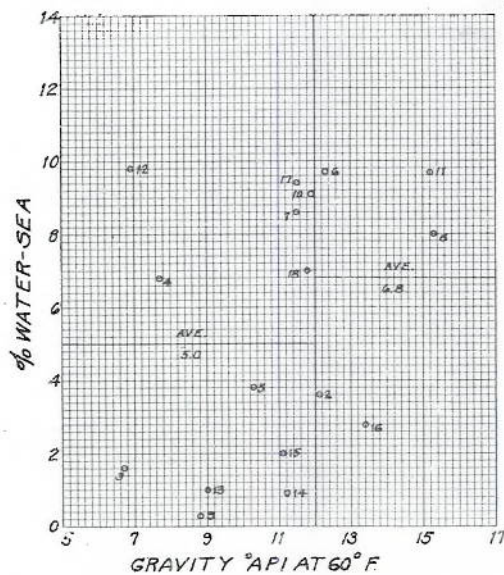
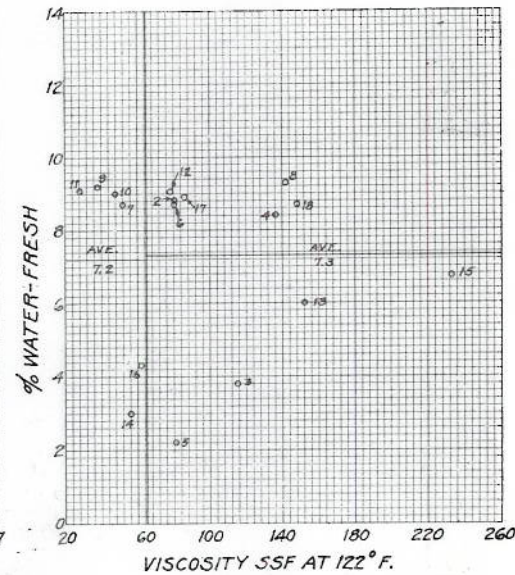
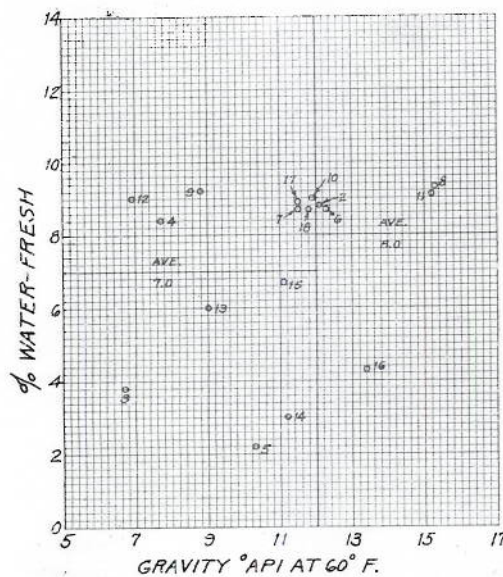
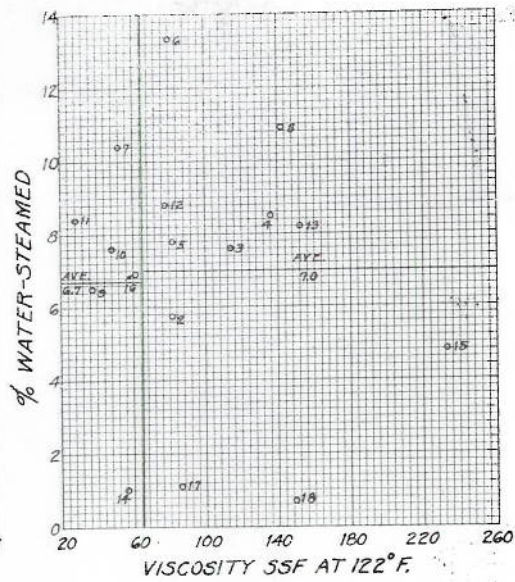
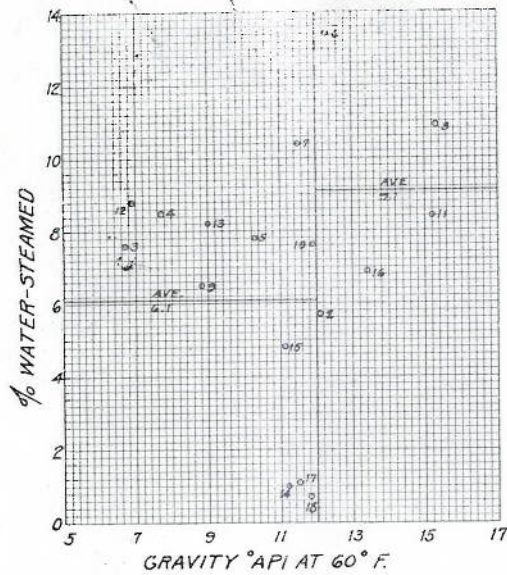
In comparing the stability of these emulsions, it is questionable whether one should consider the "drawn" or "poured" samples. The "drawn" samples are similar to the suction of the intake to the fuel system aboard ship, but one must remember that the ship is always moving and the fuel in the tank is moving. This movement can cause the water to be gradually worked out of the oil and as a result the emulsion remaining will have less water than a sample which had been stored on land when there was no movement.

Average Data on Oils A-2 to A-18

	Per Cent Water				Viscosity	
	Theoretical	Made	Aged		Emulsion	Original
			Poured	Drawn		
Steam	2	1.57	1.12	1.66	142	
	5	3.18	2.15	3.54	148	
	10	6.95	4.51	6.96	165	
Fresh	2	2.05	1.53	1.55	168	
	5	4.34	3.33	3.68	170	
	10	7.85	6.70	7.28	178	
Sea	2	1.76	1.06	1.14	153	
	5	3.80	2.29	2.72	175	
	10	6.66	4.34	5.54	171	87

It is interesting to note the average found for samples poured or drawn as given above. These values show that the emulsions steamed-in have less water when the sample is poured out and the water can separate from the oil than when the sample is drawn. The poured samples show 27% less water held than for the drawn samples with steam, 5% less with fresh water, and 8% less with sea water.

Whether the method by which the water was put in has an effect can be readily seen from the following comparison:



This shows that if the sample is drawn the stability ranks as follows: fresh and steam tied, and then salt water with percentages of 75, 75 and 55 remaining of that put in. If the sample is poured, the order is fresh, steam and salt water, and the percentages are 70, 48 and 47, showing that steamed emulsions and sea water emulsions have about the same stability with poured samples. This shows that steaming has some effect on the stability of the emulsion formed.

The emulsions having 50% water show a remarkable stability for all. The viscosity of these samples was greatly increased due to the emulsion formation as shown in the tabulated data on page 6 of this report.

The tentative Navy Department specifications for fuel oil of March 23, 1935, state under paragraph E-1, that the viscosity SSF at 122° maximum shall be 65 seconds and that the A.P.I. gravity shall have a numerical minimum of 12.0. The water content of the emulsions as shown on analysis of the drawn samples has been plotted against gravity and the type of emulsion formed in one series and viscosity at 122° in another series. On each of these plots is given the limiting value for the Navy specifications and another line shows the average per cent water found in the samples above or below the Navy specification limits. The values so found are summarized below:

		GRAVITY				VISCOSITY			
		up to 12° API		12° API+		65° SSF+		up to 65° SSF	
		%	% Ave Note 1	%	% Ave Note 1	%	% Ave Note 1	%	% Ave Note 1
Steam	2	1.70	85	1.58	79	1.75	88	1.52	76
	5	3.33	67	3.56	71	3.39	68	3.40	68
	10	6.08	61	9.08	91	7.05	71	6.70	67
Fresh	2	1.40	70	1.90	95	1.63	82	1.40	70
	5	3.72	74	3.60	72	3.64	73	3.77	75
	10	6.97	70	8.04	80	7.32	73	7.22	72
Sea	2	1.05	53	1.36	68	1.18	59	1.07	54
	5	2.53	51	3.20	64	2.99	60	2.23	45
	10	5.03	50	6.76	68	5.69	57	5.28	53
Average	2	1.38	69	1.61	81	1.52	76	1.33	67
	5	3.19	64	3.45	69	3.34	67	3.13	63
	10	6.03	60	7.96	80	6.69	67	6.40	64
Grand									
Average			64		77		70		65

Note 1 - Percentage given in this column is $\frac{\text{Ave. \% found}}{\% \text{ Put in}} \times 100$

APPENDIX I

1. The emulsions described in detail in this appendix were made as follows: A new two-quart Mason jar was weighed and to it was added the desired weight of fuel oil. With the fresh water and sea water emulsions of certain percentage, the water was poured into the oil and the jar and contents were heated to about 120°F. The jar was then shaken for ten minutes by hand. At the end of this shaking there was usually a uniform emulsion present. If it was necessary the samples were shaken longer. Steamed-in emulsions were made by passing steam into the fuel oil that had been previously warmed to about 120°F. The temperature was taken at the close of distillation as each desired emulsion was prepared. The temperatures at the end of distillation are given below:

	<u>Water Content</u>		
	<u>2%</u>	<u>5%</u>	<u>10%</u>
A-1	130°F	165°F	200°F
A-2	170	194	202
A-3	166	188	200
A-4	168	186	198
A-5	176	185	192
A-6	174	192	201
A-7	179	193	198
A-8	164	188	200
A-9	188	197	202
A-10	162	188	195
A-11	184	192	197
A-12	162	191	199
A-13	190	192	201
A-14	170	192	199
A-15	189	194	201
A-16	160	188	200
A-17	180	184	199
A-18	184	191	201

2. These temperature readings show that the oil had reached a temperature of approximately 200°F at the end of the distillation and a previous report states that the time required to reach this temperature is approximately 11 minutes to form the 2% emulsion, approximately 20 to 25 minutes to form the 5% emulsion, and from 30 to 60 minutes to form the 10% emulsion. During this steaming period, especially for the formation of the 10% emulsion, there may be a change in the fuel oil which is not known at the present time. It would be of interest to study further the behaviour of the fuel oil separating from these steamed-in emulsions, especially after the water has been completely separated. Under each of the oils will be found a short statement as to the source of the oil and a description of the oil in the jar just before the samples were taken for the water determinations on the aged samples. The hang-up on the glass above the emulsions gave a thin, smooth, black layer for some; others gave a granular layer. Whether this difference has any significance as to the change in characteristics of the fuel oil is not known. The data are

given in detail for each of the oils in connection with this work as follows:

A-1. The source of this fuel oil is Gulf Coast and East Texas; it has a gravity of 8.3° A.P.I. and a viscosity of 21.7 SSF at 122°F. The water determinations show that there is an increase in the upper layer when the sample is poured from the jar, especially with the steamed-in emulsions. The shaken-in emulsions show a tendency of separation. The sea water emulsions are unstable and separate on standing. The effect of the viscosity was from 10 to 30 seconds Furol at 77°F.

- A - Separated, with oil water scum on the walls of the jar.
- B - Separated, with oil water sediment on the walls of the jar.
- C - Separated, with oil water sediment on the walls of the jar.
- D - Oil water scum around walls of jar. No bubbles visible.
- E - Separated, with water bubbles on the walls of the jar.
- F - Water bubbles on the walls of the jar.
- G - No visible separation.
- H - No visible separation.
- I - No visible separation.
- J - Separated into three layers - 1-1/4" of black oil in bottom, a 2" brownish layer above, and a 3/4" lighter brown layer on top consisting largely of water.

Very little hang-up on the walls of the jars above the oil layer.

No.	% H ₂ O Put in	When Made		Aged Poured		Aged Drawn		Viscosity 77° SSF
		Age*	%	Age*	%	Age*	%	
A-1-A	2	12	3.6	247	5.5	253	2.3	101.3
A-1-B	5	12	9.7	247	1.6	253	1.5	107.2
A-1-C	10	12	12.7	247	15.0	351	2.9	118.0
A-1-D	2	7	2.0	248	0.5	360	0.3	103.4
A-1-E	5	7	5.6	248	3.7	360	1.6	108.6
A-1-F	10	7	10.2	248	12.1	360	2.1	122.6
A-1-G	2	7	1.4	248	T	270	0.1	101.9
A-1-H	5	7	1.8	248	T	270	0.1	101.7
A-1-I	10	7	4.0	248	T	270	0.1	101.0
A-1-J	50	7	52.0	248	68.5	268	6.2	98.4
Original								91/91

* Age given in days for all samples.

A-2. The source of this fuel oil is East Texas crude; it has a gravity of 12.1° A.P.I. and a viscosity of 80.2 SSF at 122°F. The emulsions formed from the shaken-in samples of ordinary water were fairly stable, while the emulsions made with steamed-in and sea water were not stable on standing. The viscosity effect at 77°F of the emulsions of 2 to 10% is not much different from the viscosity variations shown for this sample at 77° in the previous report.

- A - No visible separation.
- B - Small bubbles on the walls of the jar.
- C - Water bubbles on the walls of the jar.
- D - Very fine water bubbles on the walls of the jar.
- E - Water bubbles on the walls of the jar.
- F - Water bubbles on the walls of the jar.
- G - No visible water bubbles on the walls of the jar.
- H - Small water bubbles visible on the walls of the jar.
- I - Water bubbles visible.
- J - Water collected in areas on the walls of the jar between the oil and glass jar. Small bubbles visible throughout. Surface of oil foamy.

There is heavy hang-up on the walls above the oil layer, of the granular type.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-2-A	2	12	1.3	247	1.2	266	2.4	126.4
-B	5	12	0.6	247	0.4	349	6.3	111.2
-C	10	12	7.0	247	2.4	266	5.7	141.1
-D	2	7	1.7	248	1.6	358	1.9	140.1
-E	5	7	4.0	248	3.7	358	4.4	151.9
-F	10	8	3.9	248	8.1	358	8.8	168.8
-G	2	8	1.3	248	0.9	358	1.2	135.9
-H	5	8	2.9	248	1.5	358	3.7	134.2
-I	10	8	4.2	248	2.1	275	3.6	152.8
-J	50	8	47.0	249	50.0			846.0)
								699.0)
Original								146/78

Original * Age given in days for all samples.

A-3. The source of this fuel oil is California crude; it has a gravity of 6.7° A.P.I. and a viscosity of 115.6 SSF at 122°F. The emulsions formed with steamed-in water were fairly stable, while with sea water and fresh water shaken in about 25% remained at the end of 8 months. The viscosity of these emulsions at 77° showed an increase of 70 to 150 seconds over the original variation of this oil at 77°.

- A - No visible separation.
- B - No visible separation.
- C - A few small water bubbles visible.
- D - No visible bubbles.
- E - No visible separation.
- F - No visible separation. There seems to be a heavy scum on the surface of the oil.
- G - No visible separation.
- H - No visible separation.
- I - No visible separation. No appreciable scum on the surface.
- J - Small bubbles visible on the walls of the jar. Very viscous.

There are granules on the walls of the glass jars. In some jars there is a continuous black layer.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-3-A	2	11	1.1	246	0.5	348	0.3	209.9
-B	5	11	5.0	246	4.0	348	3.7	241.3
-C	10	11	8.9	246	8.1	348	7.6	301.6
-D	2	8	1.9	249	1.4	270	0.9	275.3
-E	5	8	5.7	249	4.2	270	3.6	304.9
-F	10	8	9.5	249	2.5	262)	4.5)	207.9
						270)	3.2)	
-G	2	8	1.5	249	0.5	270	0.5	281.7
-H	5	9	7.0	249	2.0	270	1.6	306.0
-I	10	9	9.1	249	1.7	270	1.6	295.2
-J	50	9	51.0	249	52.0			1521.0)
								1658.0)
Original								126/119

* Age given in days for all samples.

A-4. The source of this fuel oil is California crude; it has a gravity of 7.7° A.P.I. and a viscosity of 136.1 SSF at 122°. All the emulsions formed from this oil with either steamed-in or shaken-in water or sea water showed a stability of 70% and greater. The lowest values were found with sea water, even at the age of 8 months. The viscosity of the emulsions shows an increase of 150 to 200% over the viscosity as found at 77°.

A - No visible separation.

B - No visible separation.

C - Separation shows small bubbles on the glass jar. Surface of the oil shows bubbles - foamy.

D - No visible separation.

E - No visible separation.

F - Small bubbles on the walls of the jar. Surface clear. No foam.

G - No visible layering.

H - No visible layering.

I - No visible layering.

J - Large bubbles visible on the glass jar. No definite line of separation visible.

The drainage shows smooth, black inside coating on the jars.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSF
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-4-A	2	11	1.6	246	1.6	348	1.4	396.1
-B	5	10	4.8	235	4.4	348	4.1	425.9
-C	10	10	9.0	235	9.1	348	8.5	461.6
-D	2	9	2.2	249	1.8	358	1.4	457.7

(Continued)

No.	% H ₂ O Put in	When Made		Aged Poured		Aged Drawn		Viscosity 77° SSA
		Age*	%	Age*	%	Age*	%	
A-4-E	5	9	5.6	249	4.6	358	4.1	444.6
-F	10	9	9.2	249	8.6	358	8.4	443.6
-G	2	9	1.9	249	1.3	359	0.9	369.2
-H	5	9	4.8	249	3.5	359	3.1	381.8
-I	10	9	10.0	249	7.3	272	6.8	444.2
-J	50	9	51.0	250	51.0			986.0)
								990.0)
Original								163/153

* Age given in days for all samples.

A-5. The source of this fuel oil is mixed Texas and Venezuelan crude; it has a gravity of 10.3° A.P.I. and a viscosity of 81.2 SSF at 122°F. The emulsions formed with this fuel showed remarkable instability, especially on the aged samples. The increase in viscosity of the aged sample varied from 33 to 48% above the base at 77°, but the original oil itself showed a variation of 22% under different conditions at 77°F.

A - No separation.

B - Separated. Water layer on the bottom.

C - Separated. Water layer on the bottom.

D - No separation.

E - A few water bubbles on the walls of the glass jar. No layering shown.

F - Separated. A definite lower layer of 1" with a 2-1/4" oil layer above. This lower layer shows many bubbles of water.

G - No visible layering.

H - No visible layering.

I - No visible separation.

J - Layered. Top third shows no bubbles. Lower two-thirds shows bubbles. Surface, no bubbles. Granules in the drainage of the top of the jar.

No appreciable hang-up in the jar above the oil layer. Slight brownish coating with fine granules.

No.	% H ₂ O Put in	When Made		Aged Poured		Aged Drawn		Viscosity 77° SSA
		Age*	%	Age*	%	Age*	%	
A-5-A	2	10	0.3	235	0.1	338	0.8	85.5
-B	5	10	0.5	235	0.1	338	4.5	91.1
-C	10	10	0.5	235	0.1	338	7.8	88.6
-D	2	8	1.9	248	0.6	273	1.0	91.1
-E	5	9	2.5	248	1.4	273	1.6	92.9
-F	10	9	1.1	248	0.5	273	2.2	89.9
-G	2	9	1.6	248	0.9	273	0.8	89.3
-H	5	9	3.0	248	1.3	273	1.4	91.5
-I	10	9	2.1	248	0.8	272	3.8	95.0
-J	50	9	48.0	251	46.0			537.0)
								517.0)
Original								78/64

* Age given in days for all samples

A-6. The source of this fuel oil is West Texas crude; it has a gravity of 12.3° A.P.I. and a viscosity of 80.8 SSF at 122°F. The emulsions formed from this fuel showed good stability for the fresh water shaken in and fair stability for the sea water emulsions. When a sample is drawn from the center of the jar instead of pouring, it will be noted the emulsions are stable, while when a sample is poured from the jar there is separation of water and instability is reported. The increase in viscosity due to the emulsion formation varied from 50% to 113%, while the original oil itself showed as much as 59% increase in viscosity at 77° depending upon the age of the sample.

- A - The glass shows very little hang-up. No visible separation.
- B - No visible separation.
- C - No visible separation.
- D - No visible separation.
- E - Slight tendency toward separation on the glass. Bubbles very fine.
- F - Separation of bubbles on walls of jar larger than in "E".
No layer.
- G - No visible separation.
- H - No visible separation.
- I - No visible separation.
- J - Layered, but line of demarkation on the glass showing.

There is very little hang-up on the glass above the oil.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured Age*	%	Drawn Age*	%	
A-6-A	2	9	2.0	234	1.4	252	1.7	100.2
-B	5	9	3.1	234	0.6	252	3.4	92.1
-C	10	9	8.9	234	1.8	252	13.5	114.6
-D	2	9	1.8	248	1.9	349	1.7	115.6
-E	5	9	4.6	248	4.5	349	4.1	121.2
-F	10	9	9.1	248	8.5	349	8.7	131.2
-G	2	9	1.8	248	1.2	273	1.7	107.1
-H	5	10	4.7	248	3.4	273	4.7	116.7
-I	10	10	8.2	249	5.4	272	9.7	127.7
-J	50	10	48.0	253	53.0			475.0)
								465.0)
								97/61
Original								

* Age given in days for all samples.

A-7. The source of this fuel oil is East and West Texas crude; it has a gravity of 11.5° A.P.I. and a viscosity of 52.7 SSF at 122°F. The emulsions from this oil show a stability of 70% or greater on aged samples or the originals. The increase in viscosity varied from

65% to 120% with a corresponding increase in viscosity of the original fuel of 82%, depending upon the condition of the sample taken.

- A -- Small bubbles in oil and on glass surface.
- B -- Small bubbles in oil next to glass surface.
- C -- Bubbles between the oil and glass.
- D -- Small bubbles.
- E -- Many small bubbles.
- F -- Oil is separated from the glass by a film of water.
- G -- Small bubbles.
- H -- Small bubbles.
- I -- Small bubbles.
- J -- Water layer between oil and glass.

There is a heavy granular sediment on the glass surfaces about the oil.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured Age*	%	Drawn Age*	%	
A-7-A	2	9	2.3	234	1.5	336	2.6	56.2
-B	5	9	4.0	234	3.5	336	6.3	63.3
-C	10	10	8.0	234	8.5	336	10.4	73.6
-D	2	10	1.9	249	2.0	357	1.8	59.9
-E	5	10	5.1	249	4.4	357	4.4	61.5
-F	10	10	8.2	249	8.8	357	8.7	74.9
-G	2	10	1.9	249	1.6	357	1.7	62.8
-H	5	10	4.6	249	3.5	274	4.7	61.8
-I	10	10	8.9	249	8.4	357	8.6	70.6
-J	50	10	50.0	253	49.0			509.0)
								441.0)
								62/34
Original								

* Age given in days for all samples.

A-8. This fuel oil is from East Texas crude and has a gravity of 15.3° A.P.I. and a viscosity of 141.4 SSF at 122°F. The emulsions formed by shaking in fresh water and sea water are stable, while those formed from steam show instability after the sample is poured from the jar and fair stability with the 2% and 5% emulsions when the sample is drawn from the center of the jar. The 10% drawn in this way is stable. The gain in viscosity due to emulsion formation varied from 41% to 262% with the initial variation in viscosity of fuel oil itself 86%, depending upon the method in which the fuel oil is taken.

- A - No water.
- B - Thin layer of water separated on the bottom.
- C - No water.
- D - No water.
- E - No water.
- F - No water.
- G - No water.
- H - No water.
- I - No water.
- J - No visible water though the inside of the jar has a brown coating.

All of these samples have a very black granular deposit on the inside of the glass.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured Age*	%	Drawn Age*	%	
A-8-A	2	10	2.0	234	1.5	253	1.7	254.0) 271.0)
-B	5	10	4.2	234	2.6	253	2.6	257.0
-C	10	10	8.5	234	3.1	253	10.9	274.5
-D	2	9	2.0	252	2.2	273	2.1	477.5
-E	5	9	5.0	252	4.5	273	4.3	415.2
-F	10	9	9.6	252	8.3	274	9.3	473.2
-G	2	9	2.0	252	1.9	357	1.8	340.0
-H	5	9	4.7	252	4.7	357	4.6	652.2
-I	10	9	9.0	252	9.1	357	8.0	490.4
-J	50	9	52.0	252	46.0			1562.0) 1766.0) 335/180

Original

* Age given in days for all samples.

A-9. The source of this fuel oil is Coastal crude; it has a gravity of 8.8° A.P.I. and a viscosity of 37.7 SSF at 122°F. The emulsions formed with sea water showed instability on aging, while the other samples, if poured from the flask, showed poor stability, and if drawn from the center of the flask showed good stability. The increase in viscosity due to emulsion formation varied from 11% to 57%, while the original oil itself showed no increase in viscosity under different treatment.

- A - Some water, separated in spots.
- B - Some water, separated in spots.
- C - Water separated between glass and oil, or water toward top of layer.
- D - No separation.
- E - Separation between the oil and the glass; that is, a foam.
- F - Water foam between oil and glass.
- G - No separation.

H - No separation.

I - No separation visible. A dark brown layer 3/4" on the bottom, 2-3/4" of oil above.

J - One-half inch water layer between oil and glass on the top. Below that, only oil against the glass.

Between the glass and the oil body there is a thin foam of oil-water emulsion. This layer does not stick to the glass and therefore the oil floats independent of the glass surface. The glass itself above the oil is fairly clear with very little granular sediment.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-9-A	2	10	2.0	234	0.1	251	2.4	27.2
-B	5	10	4.5	234	0.3	251)	8.7)	26.8
						252)	3.7)	
-C	10	10	10.5	234	6.8	(251	(6.2	37.7
						(252	(6.7	
						(240	(8.0	
-D	2	9	2.0	248	T	267)	0.2)	28.0
						271)	1.1)	
-E	5	9	4.7	248	0.1	267	6.6	26.6
-F	10	9	9.5	248	6.2	257)	7.3)	34.0
						267)	9.2)	
-G	2	9	1.8	248	T	267	0.1	27.1
-H	5	9	3.5	248	0.1	267	0.1	26.9
-I	10	9	6.9	248	0.1	267	0.3	27.0
-J	50	9	51.0	253	56.0			233.0)
								218.0)
Original								24/24

* Age given in days for all samples.

A-10. The source of this fuel oil is East and West Texas crude; it has a gravity of 11.9° A.P.I. and a viscosity of 48.7 SSF at 122°F. The emulsions show a stability of 70% or greater on aging, independent of the type. The increase in viscosity at 77° varied from 108% to 191%, while the original oil itself showed an increase of 61%.

A - Water separated on the bottom. Small amount only.

B - Water separated on the bottom, about 1/4" layer.

C - Water separated on the bottom, about 1/4" layer.

D - Water bubbles throughout the oil.

E - Water bubbles throughout the oil; that is, on the glass oil surface.

F - Small bubbles on the surface; that is, under the glass.

G - No water.

H - No water.

I - No water.

J - Separated at the bottom. Granular sediment on the walls of the jar.

Granular sediment on the walls of all jars.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured Age*	%	Drawn Age*	%	
A-10-A	2	9	2.0	236	1.9	336	1.9	69.6
-B	5	9	4.4	236	4.5	336	3.9	65.9
-C	10	9	8.0	236	8.1	336	7.6	75.1
-D	2	9	2.4	248	2.1	357	2.0	72.3
-E	5	9	4.7	248	4.7	357	5.1	68.7
-F	10	9	9.0	248	8.9	357	9.0	90.2
-G	2	9	2.0	248	1.4	274	2.0	66.6
-H	5	9	4.7	248	4.1	274	5.1	68.2
-I	10	9	8.5	248	7.2	274	9.1	64.1
-J	50	12	50.0	253	51.0	260	51.0	475.0) 404.0)
Original								50/31

* Age given in days for all samples.

A-11. The source of this fuel oil is Louisiana and Texas crude; it has a gravity of 15.2° A.P.I. and a viscosity of 28.2 SSF at 122°F. The emulsions formed by shaking in fresh water show a stability of more than 80% on aging, while the emulsions formed from steam show a stability of 40% and higher. If the sample is drawn from the center of the flask, the stability is 80%. With sea water the emulsions formed from 2% and 5% are only fairly stable, while the 10% emulsion formed with sea water showed no change over a period of 8 months. The increase in viscosity due to emulsion formation varied from 74% to 162% with initial increase of as much as 64% of the original oil studied.

- A - No water.
- B - No water.
- C - A few bubbles along the walls of the jar.
- D - No water.
- E - No water.
- F - Small bubbles on the walls of the jar.
- G - No water.
- H - No water.
- I - No visible separation.
- J - Large water bubbles on walls of glass. No visible line.

Heavy sediment on the walls of the jars, granular in nature.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-11-A	2	9	1.9	236	1.0	253	1.7	26.3
-B	5	9	3.6	236	2.3	253	4.1	31.3
-C	10	9	6.0	236	4.8	253	8.4	32.5
-D	2	11	2.1	247	1.7	356	2.3	27.0
-E	5	11	4.5	247	4.4	356	4.8	28.0
-F	10	11	8.5	247	9.1	356	9.1	36.7
-G	2	11	1.3	251	1.0	273	1.4	24.3
-H	5	11	2.3	251	0.5	273	2.1	24.6
-I	10	11)	8.4)	251	8.4	356	9.7	28.6
		12)	8.4)					
-J	50	11	52.0	252	49.5			172.4)
								189.3)
Original								23/14

Original

* Age given in days for all samples.

A-12. The source of this fuel oil is Oklahoma and Texas crude; it has a gravity of 6.9° A.P.I. and a viscosity of 77.2 SSF at 122°F. All of the emulsions formed with this oil show remarkable stability on aging. There is probably some tendency of separation of water, or rather concentration of water, in the upper layers for the steamed-in samples. The increase in viscosity due to emulsion formation varied from 41% to 70% with a variation of 20% of the original fuel at 77°F.

A - No visible separation.

B - Separated. Water visible on the walls of the jar.

C - Water bubbles on the walls of the jar. Heavy sediment on the walls of the glass above oil layer.

D - No visible separation.

E - Separated. Water on the walls of the jar, not in bubbles, but in a continuous layer.

F - Two layers, but rather difficult to note line of demarkation. Top layer evidently less water than lower layer. Top layer about 40% of volume.

G - No visible separation.

H - No visible separation.

I - No visible separation.

J - Two layers; water layer on top of 1-1/2" and 3" of oil below.

There is a definite granular sediment on the walls of the jars.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-12-A	2	9	2.8	236	2.6	336	2.6	90.6
-B	5	9	5.4	236	4.5	336	4.7	92.9
-C	10	9	12.0	236	8.7	336	8.8	106.7
-D	2	11	3.0	251	2.8	357	2.4	91.8
-E	5	11	6.0	251	5.6	357	4.7	95.3
-F	10	12	10.3	251	9.9	357	9.0	108.5
-G	2	12	2.7	251	2.4	357	2.7	94.8
-H	5	12	5.3	251	4.9	357	6.0	97.4
-I	10	12	9.9	251	9.5	357	9.8	107.8
-J	50	12	68.0	253	60.0			143.4)
								158.3)
Original								81/64

* Age given in days for all samples.

A-13. The source of this fuel is California crude; it has a gravity of 9.0° A.P.I. and a viscosity of 151.9 SSF at 122°F. The emulsions formed by steam show a stability of 70% and higher for the 5% and 10% emulsions with only 20% stability for the 2% sample. The sample of shaken-in fresh water shows a stability of 50% and greater for the 2% and 10% emulsions with a tendency of separation for the 5%. The sea water samples were not stable, especially on aging. The per cent water varied from 0.4 to 1.3, depending upon the way the samples were taken. The increase in viscosity of the emulsions was from 52% to 122% with an original variation in the oil itself of 12%.

- A - No visible separation on the surface. Water bubbles visible on the top of the oil layer.
- B - Small bubbles visible, largely bubbles as in "A".
- C - Small and large bubbles visible on the walls of the jar, from the bottom to the top of the oil layer.
- D - Very fine water bubbles on the walls of the jar.
- E - Many fine water bubbles visible on the walls of the jar from the bottom to the top of the oil layer.
- F - Water bubbles visible in the oil layer. The top of the oil layer is rough, evidently water bubbles close to the surface.
- G - Very fine water bubbles visible. No water visible on the surface.
- H - Water bubbles over the walls of the glass. No large water bubbles visible on the surface, though surface is rather rough.
- I - Water bubbles visible on the walls of the glass. No bubbles visible on the surface.
- J - Oil fairly smooth. Very viscous. Water bubbles visible on the walls of the jar all the way around.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured Age*	%	Drawn Age*	%	
A-14-A	2	12	0.4	236	0.1	335	0.1	56.0
-B	5	11	0.4	235	0.2	335	1.0	57.7
-C	10	11	6.7	235	0.8	257	1.0	62.9
-D	2	12	1.9	250	0.5	277	0.6	64.4
-E	5	12	2.4	250	1.3	277	1.3	64.5
-F	10	12	2.0	250	0.9	277	3.0	62.4
-G	2	12	1.6	250	0.6	277	0.5	62.2
-H	5	12	2.2	250	0.4	277	0.5	63.1
-I	10	12	1.9	250	0.5	277	0.9	62.4
-J	50	12	52.0	252	45.0	264	48.0	429.5) 453.9) 43/39
Original								43/39

* Age given in days for all samples.

A-15. The source of this fuel oil is Venezuelan crude; it has a gravity of 11.1° A.P.I. and a viscosity of 233 SSF at 122°F. The emulsions formed by this oil show fair stability for the steamed-in samples, higher stability for the 10% shaken-in samples, and poor stability for the sea water emulsions. The increase in viscosity due to emulsion formation varied from 29% to 63% with the variation in the original fuel 8% at 77°F.

- A - Water and small bubbles on glass. A thin layer between oil and glass, not in bubble formation. The glass above the oil is clear.
- B - Water between the oil and glass, not in bubble formation. The glass above the oil is clear.
- C - Water between the oil and glass, not in bubble formation. The glass above the oil is clear.
- D - Bubble formation between oil and glass. The glass above the oil is clear.
- E - Small bubbles.
- F - Water bubbles between glass and oil, almost enough to form a continuous layer.
- G - No water.
- H - Small bubbles.
- I - Small bubbles.
- J - Water separated on the bottom, about 4-1/2" of oil and 1/2" of water.

Glass is comparatively clean. Very little sediment on the surface.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-15-A	2	11	1.5	235	0.9	257	0.7	260.8
-B	5	11	4.0	235	2.5	257	2.9	286.0
-C	10	11	7.5	235	4.8	257	4.8	303.5
-D	2	13	2.0	251	0.5	278	0.7	264.4
-E	5	13	4.5	251	3.0	278	2.4	277.5
-F	10	13	9.0	251	7.0	278	6.7	274.7
-G	2	13	1.8	251	0.4	278	0.4	262.2
-H	5	13	2.6	251	0.8	279	0.6	254.4
-I	10	13	7.2	251	1.3	279	2.0	239.9
-J	50	13	41.0	252	28.0	264	57.0	621.0)
								647.0)
Original								200/186

* Age given in days for all samples.

A-16. The source of this fuel oil is East Texas crude; it has a gravity of 13.4° A.P.I. and a viscosity of 60.9 SSF at 122°F. The emulsions formed from the steamed-in samples show very poor stability even when freshly made, while the samples shaken in show a stability from 10% to 43%, depending upon the original concentration of the water and the method of pouring the sample. The stability of the sea water emulsions varied depending upon the concentration of the emulsion formed, showing that the oil held about 0.9% water when the sample was poured or from 0.7% to 2.8% when the sample was drawn from the center of the flask. The increase in viscosity due to emulsion formation varied from 27% to 45% with an original variation of the viscosity of the oil itself at 77°F of 23%.

A - No water.

B - Water separated at the bottom. Fairly large bubbles.

C - Water separated in the bottom half and fairly large bubbles between the oil and glass.

D - No visible separation.

E - Brown layer on the bottom. No bubbles visible.

F - Water separated in bubbles on the bottom third. Small bubbles between glass and oil in upper layer.

G - No water.

H - No water.

I - No water.

J - No water.

The glass above the oil is fairly clear.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured Age*	%	Drawn Age*	%	
A-16-A	2	12	0.5	236	0.3	334	0.4	54.6
-B	5	12	0.1	236	0.2	334	1.4	55.9
-C	10	12	0.1	236	0.1	334	6.9	57.1
-D	2	13	2.2	251	1.8	279	1.5	61.1
-E	5	13	1.2	251	0.6	279	0.4	55.7
-F	10	13	3.4	251	2.8	279	4.3	62.6
-G	2	14	1.4	251	0.6	279	0.7	58.0
-H	5	14	1.7	251	0.8	279	0.9	55.1
-I	10	14	2.2	251	0.9	279	2.8	56.4
-J	50	14	44.0	252	31.0	265	56.5	260.0)
								295.0)
Original								53/43

* Age given in days for all samples.

A-17. The source of this fuel oil is East Texas crude; it has a specific gravity of 11.5° A.P.I. and a viscosity of 86.5 SSF at 122°F. The emulsions formed with fresh water shaken in and with sea water, show a stability of 75% and greater even on aging. The emulsions formed from steam show an instability and a resulting concentration of 1.1% to 2.7% water in the emulsions so formed. There may be some effect on the fuel oil itself due to the steam and this should be investigated further in connection with this oil. The increase in viscosity due to the formation of emulsions was from 28% to 61% with an original variation of 1% in the viscosity of the fuel studies at 77°.

- A - A few small bubbles.
- B - Small bubbles.
- C - Small bubbles.
- D - Small bubbles.
- E - Small bubbles.
- F - Medium bubbles in the lower third.
- G - Small bubbles.
- H - Small bubbles throughout on the glass.
- I - A few bubbles visible. Oil looks like a foamy emulsion.
- J - Bubbles all around between glass and oil.

The glass above the oil has a very heavy granular sediment on all the samples.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-18-A	2	12	2.5	236	2.5	336	2.7	197.1
-B	5	11	1.3	235	0.3	258	1.4	186.7
-C	10	11	1.0	235	0.2	258	0.7	197.9
-D	2	12	1.7	248	1.6	353	1.8	188.5
-E	5	12	4.2	248	3.4	276	3.8	207.2
-F	10	12	8.6	248	8.5	353	8.7	222.7
-G	2	12	1.5	248	1.0	280	0.7	182.4
-H	5	12	3.3	248	1.9	280	1.7	185.0
-I	10	12	6.0	248	2.0	280	7.0	175.7
-J	50	12	49.0	249	51.0			1131.0)
								1208.0)
Original								160/116

* Age given in days for all samples.

APPENDIX II

1. In the tabulations given below A-2 to A-18, inclusive, are considered. Oil A-1 is not compared with the others due to the fact that its viscosity is so low that almost any emulsion formed with it is unstable, and also it is much heavier than any oil that can be purchased by the Navy under the present specifications. As A-1 is made from cracking a gas oil, it is questionable if there will be a large source of this oil without increased cost to the Navy. The oils A-2 to A-18 are tabulated as to the hydrogen-carbon ratio, the per cent. nitrogen, the per cent. sulfur, the average molecular weight as determined by the freezing point method using naphthalene as a solvent, the per cent. carbon residue as determined by the Conradson method, and the per cent. insoluble in hexane as caught on a #4 sintered filter. In tabulating this data, only the 10% emulsions drawn as from a suction line are used. Other tables could be made using the 2% or the 5% emulsions or using the poured sample as has been discussed in this report previously. Of these comparisons, the one that shows the greatest interest is the one given for molecular weights, and why oils A-15, A-17 and A-18, and especially A-17 and A-18, should show the instability of the steamed emulsions in comparison with the fresh water and the sea water emulsions is not known.

2. In this appendix are also given the tabulated data for the per cent. water remaining in the aged sample for the steamed-in emulsion, fresh water emulsion, and sea water emulsion. Opposite each oil is given the ash, the density, the hexane insoluble, the Conradson carbon residue, the molecular weight, the per cent. sulfur, the per cent. nitrogen, and the hydrogen-carbon ratio.

Table 1

$\frac{H}{C}$	No.	10% Emulsion		
		Steam	Fresh	Sea
1.254	A-12	8.8	9.0	9.8
1.278	3	7.6	3.8	1.6
1.292	9	6.5	9.2	0.3
1.317	4	8.5	8.4	6.8
1.351	13	8.2	6.0	1.0
1.385	10	7.6	9.0	9.1
1.391	7	10.4	8.7	8.6
1.398	5	7.8	2.2	3.8
1.401	17	1.1	8.9	9.4
1.404	2	5.7	8.8	3.6
1.406	14	1.0	3.0	0.9
1.418	6	13.5	8.7	9.7
1.435	18	0.7	8.7	7.0
1.437	15	4.8	6.7	2.0
1.476	11	8.4	9.1	9.7
1.477	16	6.9	4.3	2.8
1.518	8	10.9	9.3	8.0

Table 2

$\frac{H}{N}$	No.	10% Emulsion		
		Steam	Fresh	Sea
0.19	A-6	13.5	8.7	9.7
0.30	9	6.5	9.2	0.3
0.33	18	0.7	8.7	7.0
0.34	11	8.4	9.1	9.7
0.38	12	8.8	9.0	9.8
0.41	16	6.9	4.3	2.8
0.42	17	1.1	8.9	9.4
0.43	8	10.9	9.3	8.0
0.44	10	7.6	9.0	9.1
0.45	5	7.8	2.2	3.8
0.48	7	10.4	8.7	8.6
0.50	15	4.8	6.7	2.0
0.53	2	5.7	8.8	3.6
0.71	3	7.6	3.8	1.6
0.87	14	1.0	3.0	0.9
1.00	13	8.2	6.0	1.0
1.12	4	8.5	8.4	6.8

Table 3

$\frac{H}{S}$	No.	10% Emulsion		
		Steam	Fresh	Sea
0.33	A-9	6.5	9.2	0.3
0.53	16	6.9	4.3	2.8
0.77	17	1.1	8.9	9.4
0.81	12	8.8	9.0	9.8
0.87	2	5.7	8.8	3.6
1.13	6	13.5	8.7	9.7
1.16	3	7.6	3.8	1.6
1.25	4	8.5	8.4	6.8
1.31	11	8.4	9.1	9.7
1.35	8	10.9	9.3	8.0
1.37	14	1.0	3.0	0.9
1.39	13	8.2	6.0	1.0
1.61	10	7.6	9.0	9.1
1.73	5	7.8	2.2	3.8
1.86	7	10.4	8.7	8.6
1.95	18	0.7	8.7	7.0
2.56	15	4.8	6.7	2.0

Table 4

Mol. Wgt.	No.	10% Emulsion		
		Steam	Fresh	Sea
297	A-9	6.5	9.2	0.3
306	12	8.8	9.0	9.8
310	3	7.6	3.8	1.6
320	4	8.5	8.4	6.8
321	14	1.0	3.0	0.9
332	11	8.4	9.1	9.7
334	10	7.6	9.0	9.1
341	7	10.4	8.7	8.6
346	13	8.2	6.0	1.0
355	16	6.9	4.3	2.8
361	6	13.5	8.7	9.7
365	5	7.8	2.2	3.8
365	2	5.7	8.8	3.6
374	17	1.1	8.9	9.4
410	18	0.7	8.7	7.0
415	15	4.8	6.7	2.0
443	8	10.9	9.3	8.0

Table 5

% Carbon Residue	No.	10% Emulsion		
		Steam	Fresh	Sea
7.1	A-16	6.9	4.3	2.8
8.4	11	8.4	9.1	8.4
8.7	17	1.1	8.9	9.4
8.8	2	5.7	8.8	3.6
9.3	9	6.5	9.2	0.3
9.3	6	13.5	8.7	9.7
9.4	8	10.9	9.3	8.0
10.4	5	7.8	2.2	3.8
10.5	10	7.6	9.0	9.1
11.0	7	10.4	8.7	8.6
11.9	14	1.0	3.0	0.9
12.0	15	4.8	6.7	2.0
12.4	18	0.7	8.7	7.0
13.3	12	8.8	9.0	9.8
13.6	13	8.2	9.0	0.9
17.3	3	7.6	6.0	2.0
17.6	4	3.8	1.0	1.6
		8.5	3.8	1.6
			8.4	6.8

Table 6

% Hexane Insol. #4 Filter	No.	10% Emulsion		
		Steam	Fresh	Sea
4.5	A-16	6.9	4.3	2.8
4.8	17	1.1	8.9	9.4
5.9	2	5.7	8.8	3.6
6.0	11	8.4	9.1	8.4
6.2	9	6.5	9.2	0.3
6.2	6	13.5	8.7	9.7
6.4	8	10.9	9.3	8.0
6.8	10	7.6	9.0	9.1
6.9	5	7.8	2.8	3.8
7.2	7	10.4	8.7	8.6
9.5	18	0.7	8.7	7.0
9.6	12	8.8	9.0	9.8
10.5	14	1.0	3.0	0.9
10.8	15	4.8	6.7	2.0
11.8	13	8.2	6.0	1.0
16.0	3	7.6	3.8	1.6
16.9	4	8.5	8.4	6.8

Table 7

10% Steam Emulsion Drawn

% Water	No.	Ash		Density	Hexane Insol.	Carbon Residue	Mol. Wgt.	% S	% N	H C Ratio
		NRL	NBL							
0.7	A-18	0.008	0.008	11.8	9.5	12.4	410	1.95	0.33	1.435
1.0	14	0.026	0.026	11.2	10.5	11.9	321	1.37	0.87	1.406
1.1	17	0.013	0.013	11.5	4.8	8.7	374	0.77	0.42	1.401
4.8	15	None	T	11.1	10.8	12.0	415	2.56	0.50	1.437
5.7	2	0.020	0.06	12.1	5.9	8.8	306	0.87	0.53	1.404
6.5	9	T	T	8.8	6.2	9.3	297	0.33	0.30	1.292
6.9	16	0.016	0.015	13.4	4.5	7.1	355	0.53	0.41	1.477
7.6	3	0.04	0.08	6.7	16.0	17.3	310	1.16	0.71	1.278
7.6	10	0.02	0.01	11.9	6.8	10.5	334	1.61	0.44	1.385
7.8	5	0.02	0.06	10.3	6.9	10.4	365	1.73	0.45	1.398
8.2	13	0.037	0.027	9.0	11.8	13.6	346	1.39	1.00	1.351
8.4	11	0.02	0.02	15.2	6.0	8.4	332	1.31	0.34	1.476
8.5	4	0.03	0.13	7.7	16.9	17.6	320	1.25	1.12	1.317
8.8	12	0.01	0.02	6.9	9.6	13.3	306	0.81	0.38	1.254
10.4	7	0.03	Lost	11.5	7.2	11.0	341	1.86	0.48	1.391
10.9	8	0.03	0.03	15.3	6.4	9.4	443	1.35	0.43	1.518
13.5	6	0.02	0.02	12.3	6.2	9.3	361	1.13	0.19	1.418

Table 8

10% Steam Emulsion Poured

% Water	No.	Ash		Density	Hexane Insol.	Carbon Residue	Mol. Wgt.	% S	% N	$\frac{H}{C}$ Ratio
		NRL	NBL							
0.1	A-5	0.02	0.06	10.3	6.9	10.4	365	1.73	0.45	1.398
0.1	16	0.016	0.015	13.4	4.5	7.1	355	0.53	0.41	1.477
0.2	18	0.008	0.008	11.8	9.5	12.4	410	1.95	0.33	1.435
0.8	14	0.026	0.026	11.2	10.5	11.9	321	1.37	0.87	1.406
1.5	17	0.013	0.013	11.5	4.8	8.7	374	0.77	0.42	1.401
1.8	6	0.02	0.02	12.3	6.2	9.3	361	1.13	0.19	1.418
2.4	2	0.02	0.06	12.1	5.9	8.8	306	0.87	0.53	1.404
3.1	8	0.03	0.03	15.3	6.4	9.4	443	1.35	0.43	1.518
4.8	11	0.02	0.02	15.2	6.0	8.4	332	1.31	0.34	1.476
4.8	15	None	T	11.1	10.8	12.0	415	2.56	0.50	1.437
6.8	9	T	T	8.8	6.2	9.3	297	0.33	0.30	1.292
7.7	13	0.037	0.037	9.0	11.8	13.6	346	1.39	1.00	1.351
8.1	3	0.04	0.08	6.7	16.0	17.3	310	1.16	0.71	1.278
8.1	10	0.02	0.01	11.9	6.8	10.5	334	1.61	0.44	1.385
8.5	7	0.03	Lost	11.5	7.2	11.0	341	1.86	0.48	1.391
8.7	12	0.01	0.02	6.9	9.6	13.3	306	0.81	0.38	1.254
9.1	4	0.03	0.13	7.7	16.9	17.6	320	1.25	1.12	1.317

Table 9

10% Fresh Emulsion Drawn

% Water	No.	Ash		Hexane Insol.	Carbon Residue	Mol. Wgt.	% S	% N	$\frac{H}{C}$ Ratio
		NRL	NBL						
2.2	A-5	0.02	0.06	6.9	10.4	365	1.73	0.45	1.398
3.0	14	0.026	0.026	10.5	11.9	321	1.37	0.87	1.406
3.8	3	0.04	0.08	16.0	17.3	310	1.16	0.71	1.278
4.3	16	0.016	0.015	4.5	7.1	355	0.53	0.41	1.477
6.0	13	0.037	0.037	11.8	13.6	346	1.39	1.00	1.351
6.7	15	None	T	10.8	12.0	415	2.56	0.50	1.437
8.4	4	0.03	0.13	16.9	17.6	320	1.25	1.12	1.317
8.7	6	0.02	0.02	6.2	9.3	361	1.13	0.19	1.418
8.7	7	0.03	Lost	7.2	11.0	341	1.86	0.48	1.391
8.7	18	0.008	0.008	9.5	12.4	410	1.95	0.33	1.435
8.8	2	0.02	0.06	5.9	8.8	306	0.87	0.53	1.404
8.9	17	0.013	0.013	4.8	8.7	374	0.77	0.42	1.401
9.0	10	0.02	0.01	6.8	10.5	334	1.61	0.44	1.385
9.0	12	0.01	0.02	9.6	13.3	306	0.81	0.38	1.254
9.1	11	0.02	0.02	6.0	8.4	332	1.31	0.34	1.476
9.2	9	T	T	6.2	9.3	297	0.33	0.30	1.292
9.3	8	0.03	0.03	6.4	9.4	443	1.35	0.43	1.518

Table 10

10% Sea Water Emulsion Drawn

% Water	No.	Ash		Hexane Insol.	Carbon Residue	Mol. Wgt.	% S	% N	$\frac{H}{C}$ Ratio
		NRL	NBL						
0.3	A-9	T	T	6.2	9.3	297	0.33	0.30	1.292
0.9	14	0.026	0.026	10.5	11.9	321	1.37	0.87	1.406
1.0	13	0.037	0.037	11.8	13.6	346	1.39	1.00	1.351
1.6	3	0.04	0.08	16.0	17.3	310	1.16	0.71	1.278
2.0	15	None	T	10.8	12.0	415	2.56	0.50	1.437
2.8	16	0.016	0.015	4.5	7.1	355	0.53	0.41	1.477
3.6	2	0.02	0.06	5.9	8.8	306	0.87	0.53	1.404
3.8	5	0.02	0.06	6.9	10.4	365	1.73	0.45	1.398
6.8	4	0.03	0.13	16.9	17.6	320	1.25	1.12	1.317
7.0	18	0.008	0.008	9.5	12.4	410	1.95	0.33	1.435
8.0	8	0.03	0.03	6.4	9.4	443	1.35	0.43	1.518
8.6	7	0.3	Lost	7.2	11.0	341	1.86	0.48	1.391
9.1	10	0.02	0.01	6.8	10.5	334	1.61	0.44	1.385
9.4	17	0.013	0.013	4.8	8.7	374	0.77	0.42	1.401
9.7	11	0.02	0.02	6.0	8.4	332	1.31	0.34	1.476
9.7	6	0.02	0.02	6.2	9.3	361	1.13	0.19	1.418
9.8	12	0.01	0.02	9.6	13.3	306	0.81	0.38	1.254

There is usually a black coating on the inside of the glass above the oil layer; especially, in the higher water content, there is granular formation.

No.	% H ₂ O Put in	When Made		Aged				Viscosity 77° SSA
		Age*	%	Poured		Drawn		
				Age*	%	Age*	%	
A-13-A	2	12	1.1	236	0.4	253	0.4	248.3
-B	5	12	4.6	236	3.6	253	3.7	279.0
-C	10	12	8.5	236	7.7	253	8.2	335.2
-D	2	12	2.2	251	1.5	273	1.3	306.6
-E	5	12	4.6	251	1.6	273	2.3	308.3
-F	10	12	8.7	251	5.2	273	6.0	361.5
-G	2	12	2.0	251	0.8	278	0.4	290.5
-H	5	13	3.0	251	1.2	278	0.8	297.1
-I	10	13	2.8	251	1.3	278	1.0	301.7
-J	50	13	53.0	252	50.5			2389.0)
								2352.0)
Original								184/163

* Age given in days for all samples.

A-14. The source of this fuel oil is California crude; it has a gravity of 11.2° A.P.I. and a viscosity of 56.2 SSF at 122°F. The emulsions formed from this oil show instability for the 2%, 5% and 10% whether it is steamed, fresh water, or sea water. The increase in viscosity at 77° varied from 43% to 65% with an original variation of the oil itself at 77° of 10%.

- A - No visible separation.
- B - Small bubbles visible.
- C - Small bubbles on the surface.
- D - No visible bubbles.
- E - No visible bubbles.
- F - No visible bubbles.
- G - No visible bubbles.
- H - No visible bubbles.
- I - A few small bubbles.
- J - Medium sized bubbles on the surface of the glass.

On the glass above the oil there is a small deposit with a few granules in it.