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Aviation Gasoline Storage at Naval Air Station Pensacola, Florida

NAVAL RESEARCH LABORATORY

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NAVY DEPARTMENT
BUREAU OF ENGINEERING

Report On

Aviation Gasoline Storage at Naval Air Station, Pensacola, Florida

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
Washington, D. C.

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Authorization: BuAer letter Aer-E-46-KM F38-4 F21(R790) of 27 July 1936

Date of Test: September - December 1936.

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APPENDICES

INTRODUCTION

(a) Authorization

1. This problem was authorized by Bureau of Aeronautics' letter, reference (a), and other data pertinent to this problem are contained in reference (b).

Reference: (a) BuAero let. Aer-E-46-KM F38-4 F21(R790) of 27 July 1936.
(b) Navy Yard, New York, Test No. 3676 of 20 Oct. 1936.

(b) Statement of Problem

2. During the overhaul of engines from airplanes attached to the Naval Air Station, Pensacola, gummy deposits have been found in the carburetor induction systems. The problem considered in this report is to determine the cause and, if possible, suggest methods for the prevention of this deposit.

(c) Known Facts Bearing on Problem

3. Two grades of gasoline are in use at Pensacola:

(a) A leaded gasoline of about 87 octane rating.
(b) Non-leaded gasoline of 73 octane rating.

A separate storage and delivery system is used for each. The 73 octane gasoline delivered by the present contractor beginning 14 April 1936, contained a small percentage of di-isobutylene and tri-isobutylene. Other naval establishments have been supplied by the same vendor but no trouble, or very little trouble, has been reported from these other stations. The major difficulty at Pensacola has been with engines using the 73 octane grade. The trouble is noticed during the routine overhaul of engines. A gummy deposit was found in all parts of the carburetor induction system between the butterfly valves to the intake valves with a maximum deposit occurring in the intake valves, valve stems and intake parts.

4. Gasoline is stored at Pensacola in:

(a) The main storage tank of the contractor who supplies the station.
(b) The station storage tanks.
(c) The hose used to deliver the gasoline to the various planes.

5. The gasoline filling hose used in servicing the engines in which trouble was experienced are constructed as follows: An outer cover of ordinary vulcanized rubber is separated by a binder of 3 ply cotton cord from a liner composed of a chlorinated polymerized hydrocarbon, probably duprene (now known as neoprene); the liner contains about 3 to 3-1/2 percent sulphur. This sulphur is extracted by gasoline in contact with the liner as a result of which the sulphur content of the liner may decrease by as much as 1 percent in service.

(d) Theoretical Considerations

6. Aviation gasoline, whether of the 87 or 73 octane grade, is carefully tested for conformity to the gum specifications by the contractor before it is shipped to the Naval Air Station, Pensacola, and a sample is taken at the station for control. The specification limit for gum is 10 milligrams of gum per 100 c.c. of gasoline. Any increase in the gum content of the gasoline may be due to: (a) reaction occurring with the gasoline itself in storage, (b) absorption of heavy hydrocarbon from deposits in the storage tanks and lines, or (c) absorption from the hose used to fuel the plane. The presence of an excessive amount of gum in the gasoline results in a gradual accumulation of sticky deposits in the carburetor induction system. Evaporation of this material which would take place when the engine becomes heated would lead to the formation of heavy tars and similar products.

(e) Narrative of Original Work Done at this Laboratory

7. This Laboratory has previously worked on problems which have a bearing on the present one. This work has been reported in Report No. P-1224 on "The Storage of Aviation Gasoline in Metal Containers", and in Report No. P-1280 on "Study of the Effect on Gasoline Stored in Duprene-lined Hose". At the present time this Laboratory is working on the problem of the composition of gasoline and its stability in storage. In the present work samples of both 73 and 87 octane gasoline were obtained from the several storage points at Pensacola by a representative of the contractor and brought to the Laboratory for study. Analyses for gum content were run on all these samples to determine where gum formation occurred in the storage systems and supply lines of the contractor and of the Air Station. Typical examples of gum coated inlet valves and parts of the intake manifold were supplied by the Air Station and the deposits thereon were analyzed. Lastly, an investigation of the gasoline hose used in fueling the planes was made to determine if this was in any way responsible.

METHODS

8. The gum content of the gasoline was determined by evaporation of a 100 c.c. sample of the gasoline on a steam bath followed by drying in an oven at 110° C for one hour. If the weight was above 10 milligrams, the drying was continued for a second hour and until the weight became constant. This method differs somewhat from the official methods of the A.S.T.M. and probably gives values somewhat higher than the official method. The analysis of the deposits included determination of oily matter, asphaltic material, and highly polymerised material. In studying the effect of the gasoline hose, gasoline was stored in the hose for varying periods and then analyzed for its gum content. Details of all these analyses and the methods employed are given in Appendix A.

CONCLUSIONS AND RECOMMENDATIONS

(a) Facts Established

9. The quantity of pre-formed gum in the 73 octane gasoline from the Marine Terminal storage tanks of the contractor was rather high, although it was less than the Government specification limit. Since the gum content

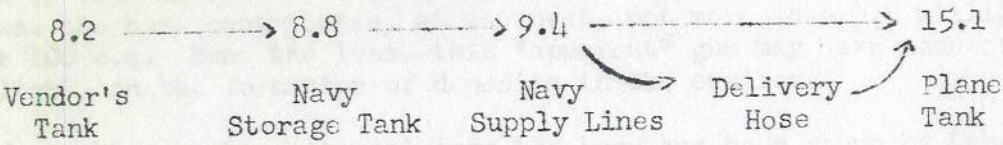
of this gasoline was higher than it was when it left the refinery, it must have picked up some contamination after leaving the refinery. The gum content of the 87 octane gasoline in the contractor's storage tanks was quite low.

10. The gummy residue found in the plane's induction system was found by analysis to contain 25 to 63% of insoluble material. The gummy residue was found to contain lead, sulphur, and a trace of halogens. The sulphur content is approximately the same as reported in the literature for ordinary gum from gasoline. Gasoline which has remained in contact with the rubber filling hose for any length of time was found to have a markedly increased gum content with both the straight run 73 octane stock and the iso-butylene blended fuel; this increase is probably due to the extraction of heavy hydrocarbons from the synthetic rubber liner and not to polymerization reactions within the gasoline. The complete hose is soluble in gasoline to the extent of 2.1 - 2.7 percent, while the liner alone is soluble to about 5.4 percent (ref. (b)). Irrespective of the type of gasoline, prolonged contact with the filling hose dangerously increased the gum content.

(b) Opinions

11. Reports from the Naval Air Station, Pensacola, agree that the chief trouble was experienced with the planes using 73 octane gasoline. It is believed that the data accumulated for this grade of gasoline are of more significance.

12. It is understood that the 73 octane gasoline shipped from the vendor's refinery has a gum content of less than one milligram per c.c. Yet in the contractor's Terminal Marine tanks many times that quantity was found. Further, the gum content increases on transfer to and passage through the storage and supply lines of the Air Station. This is shown in the data of Table 5, and is particularly evident for Squadrons One and Four where the gum increase is as follows:



Considering these facts, and bearing in mind that no trouble has been experienced at other Naval stations (*) or by commercial planes using the same type of equipment and gasoline as is used at Pensacola, it is evident

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(*) Note: Ref.(a) , paragra phs 3 and 4). Some difficulty with residues in the blower chambers of certain engines was experienced at the Pearl Harbor Base. These deposits resembled, superficially, those from the induction systems of the affected engines at Pensacola. However, it is believed that the trouble at Pearl Harbor arose from causes other than those encountered at the former station. In the first place, the deposits are not the same chemically. Secondly, the affected engines were of different types and were supplied with fuel originating from different sources. While no information is available concerning the condition of the storage facilities at Pearl Harbor, it is known that the gasoline stocks there came from West Coast rather than Texas refineries, and were probably free of iso-butylene polymers. In light of these facts, it is impossible to correlate the trouble at Pearl Harbor with that at Pensacola as to causative factors.

that some peculiar condition conducive to gum formation is present in the Pensacola storage system. That condition may very well be simply dirty equipment. Gasoline storage tanks and pipe lines tend to accumulate a residuum as storage is continued from year to year, each fresh lot of gasoline contributing to the deposit. In this residuum occur a variety of substances, among which are partially oxygenated hydrocarbons, probably peroxides. These peroxides are generally considered to catalyze gum formation so that gasolines, otherwise stable, when standing in contact with such substances rapidly show a marked increase in gum content. That a dirty storage system is responsible for the gum formation seems to be confirmed by the data on the gum content of the gasoline samples from the two automobile filling stations at Corry Field. The tanks and lines of these stations have probably received less care than any other part of the storage and supply system and hence are proportionally dirtier. Gasoline from these has a gum content of upwards of 15 mg/100 c.c.

13. Although unclean storage is believed to be the primary cause of gum formation and the resulting troubles, it is not believed to be the sole factor. The gasoline hose employed in transferring the fuel undoubtedly contributes something to the "apparent" gum through absorption of heavy hydrocarbons. It has been observed in this Laboratory that the hose does exhibit a decided solubility in gasoline. The amount extracted in the course of 24 hours may increase the gum content as much as 34 milligrams. It must be borne in mind, however, that this excessively high figure will not represent the gum content of the gasoline after delivery to the plane. Fuel is usually stored aboard planes in 50 or 100 gallon tanks. If all the gasoline contained in a 50-foot length of hose (approximately 5 gallons) is emptied into a plane tank, it will be diluted subsequently with 45 to 95 gallons of fresh gasoline which has not remained in contact with the hose long enough to absorb any appreciable amount of heavy matter. This represents a dilution factor of 1:9 to 1:19. The final concentration of gum derived from the hose in the tank will be from 2 to 5 mg/100 c.c.

14. The illustration cited is an exaggerated condition probably never achieved in actual refueling operations. If gasoline which has stood any length of time in the hose is discarded just prior to replenishing the plane tanks, the hose contributes, at the most, not more than 0.5 milligram of gum per 100 c.c. None the less, this "apparent" gum may have some effect, however slight, on the formation of deposits in the engines.

15. The soluble material from the hose has been shown by Laboratory tests to have no accelerating or catalytic action toward further gum formation. Moreover, the small amount of sulphur which is extracted from the hose has little bearing on the formation of deposits on the valves and valve pipes. Analysis of these deposits shows no increase of sulphur content over that generally found in such cases.

16. While the observed material from the hose was found to have no catalytic influence on the stability of gasoline containing 1 to 2 percent di- and tri-isobutylenes, the oxidized hydrocarbons in the storage system at Pensacola do seem to have that effect. No trouble was experienced until the iso-butylene blended gasoline commenced to be used. It would be advantageous to omit these unsaturates from all gasolines furnished the Navy in the future. Even when the storage system is periodically cleaned, enough catalytic matter may accumulate between times to accelerate the polymerization of these seemingly unstable hydrocarbons.

17. The above opinions may be summarized briefly as follows:

The storage tanks of both the vendor and the Navy and the servicing hoses in use at the Naval Air Station are fruitful sources of contamination. Gasoline with two or less milligrams of gum may dissolve oxidized hydrocarbons or "gum" and as a result of this dissolved material the gum formation of an otherwise stable gasoline is accelerated. This may have happened at Pensacola in the vendor's tanks as well as the Navy's if the tanks have not been carefully cleaned. Gasoline which has stood for any length of time in the filling hose should be discarded , otherwise the "apparent" gum content of the gasoline in the airplane tanks will increase and possibly cause further trouble in operation.

(c) Recommendations

18. The following recommendations are made:

(a) Unsaturated hydrocarbons such as di- and tri-isobutylene should be omitted in blending the 73 octane stock.

(b) The gum content of the aviation gasoline should be kept rigorously low by the manufacturer.

(c) The storage and delivery equipment of the Naval Air Station should be thoroughly cleaned and renovated. Effort should be made to obtain hose having a minimum gasoline solubility.

(d) Gasoline which has stood in the servicing hose must not be allowed to pass to the plane tanks.

(e) A study should be made of the gum content as determined by the A.S.T.M. method D-381-34T in reference to intake manifold deposition under operating conditions.

SUMMARY

19. Contamination of gasoline can occur readily in dirty storage tanks and this contamination may accelerate gum formation or engine trouble with an otherwise stable gasoline.

20. The tanks of the vendor and the Navy should be periodically cleaned.

21. Gasoline hose can be a source of "apparent" gum in gasoline and may aid in formation of engine deposits.

22. The contents of the gasoline hose should be discarded if it has been in contact with the hose for any appreciable time.

APPENDIX A

ANALYTICAL METHODS

MATERIALS

(1) History and Nature of the Problem

A detailed review of the nature and history of the trouble in connection with the fouling of engines at the Pensacola Air Station is given in Appendix B, a report filed by Mr. R. C. Rich of the Shell Petroleum Corporation from the Houston Refinery Laboratory of that company.

(2) Description of Materials

(a) Gasoline Samples from Pensacola. Samples were taken of the two types of gasoline used at the Naval Air Station by Mr. Rich on August 27 and 28. The points at which they were obtained along the delivery system from the main storage tanks to the planes are listed in Table V. The samples arrived in metal cans of quart to gallon capacity, labeled in duplicate, and in good condition. Gum tests were run immediately on receipt of the specimens.

(b) Deposits. Several samples of material from the valve stems and induction pipes of typical engines were obtained from Pensacola. The material from the pipes was generally more tacky and gummy than that from the valves. Three specimens from the valve stems, one fresh and rather damp and two which had been air-dried for a number of days, were available. One of the latter was brought personally by Mr. Rich. The deposits were solids, dark in color varying from brown to black, sticky though rather friable in texture, rather homogeneous in appearance, and possessing the characteristic odor of cracked hydrocarbons.

(c) Hose. Several samples of hose were available; the source and history of them is given in Table III. All were blackrubber with the exception of the hose from the Gates Rubber Company. The hoses measured 11/16" I.D. and 1-5/16" O.D. They consist of a cover of ordinary vulcanized rubber separated by a braided 3-ply cotton reinforcement from the tube. The latter appear to be a Duprene composition.

(d) 73 Octane Gasoline for Test Purposes. Five gallons of this gasoline were obtained about 1 September from the Naval Air Station, Anacostia, and stored in a tinned container until used. Later, about 15 September, two gallons additional were obtained and stored in a glass bottle.

METHODS

(1) Halogens and Sulphur

Analysis for these elements was done by the well known Parr bomb method. The results are given in Tables IIa and III.

(2) Sulfated Ash and Lead.

A 0.2 gram sample was decomposed by fuming down with H_2SO_4 - HNO_3 in a tared 250 c.c. beaker. When oxidation was complete, as evidenced by the disappearance of charred organic matter, the beaker was washed down with a little water, and 3 c.c. of H_2SO_4 added. After cautious evaporation of the acid, the beaker was flamed to remove all traces of volatile material and weighed. The residue so obtained is reported as "sulfated ash". This residue was carefully transferred to a weighed Gooch crucible with the aid of a small amount of water containing a few drops of ethyl alcohol, dried at 100°C for one hour and the weight taken as lead sulfate (Table IIb).

(3) Extraction of Deposits.

The percentage of oily matter in the deposits was found by continuously extracting with naphtha a three or four gram sample in a weighed alundum thimble, drying at 100° C, weighing, and continued extraction until no further loss was noted. In like fashion, by extraction with chloroform the quantity of asphaltic material was found. The residue consisting of carbonaceous matter and high molecular weight polymers was analyzed only for sulphur, since the halogen content of the original material was low.

(4) Effect of Extractable Material from Hose on Gum Content.

An experiment was undertaken to discover the influence of extractable material from the hose on the gum content of straight run 73 octane stock and on iso-butylene blend prepared at the Laboratory which approximated that in use at the Pensacola Air Station. Three 1000 c.c. portions of 73 octane gasoline which was obtained from the Naval Air Station, Anacostia, about 1 September, were placed in liter Erlenmeyer flasks equipped with cork stoppers. To the gasoline in flasks 2 and 3 1% each of di- and tri-isobutylene was added. Gum tests were then run on the contents of each vessel. In flask 3 a section of hose was immersed, the three containers placed in a dark locker, allowed to remain 72 hours, the hose removed, and gum determinations made immediately on each sample. Thereafter, at periods of approximately 48 hours, the gum determinations were repeated. A similar procedure was carried out with gasoline of the same origin obtained September 15, save that no isobutylene was added.

DATA OBTAINED

TABLE I

EXTRACTION OF DEPOSITS

	Valve Stem damp	Intake Pipe
Original Sample, Grams Weight	3.6068	4.3003
Extraction with Precipitation Naphtha (Removal of Oily Matter)		
Hours	50	75
Weight extracted	0.6464	1.8570
% Removed	17.4	42.3
Extraction with Chloroform (Removal of Asphaltic Material)		
Hours	64	60
Weight extracted	0.6964	1.2281
% Removed	19.3	28.6
Residue from Extractions (Insoluble Polymeric Substances)		
Weight of Oil and Asphaltenes extracted	1.3428	3.0851
Weight Residue	2.2640	1.1152
% Residue	62.9	25.8

TABLE II

ANALYSIS OF DEPOSITS

(a)

	Original Sample Before Extraction		Residue Left After Extraction	
	Halogens %	Sulphur %	Halogens %	Sulphur %
Valve Stems				
Damp	0.033	1.60	trace	1.47
Dry	0.044	2.90	"	-
Dry, brought from Pensacola by Mr. Rich	0.150	1.97	-	-
Intake Pipe	0.050	1.50	trace	1.85

(b)

Sulfated Ash and Lead

	Weight Sample	Weight Ash	Ash %	Weight $PbSO_4$	% Pb
Valve Stems					
Pensacola, damp	0.2295			0.0116	3.45
Dry, brought from Pensacola by Mr. Rich	0.2366			0.0055	1.59
	0.2188	0.0105	4.8	0.0051	1.56
Intake Pipe	0.2057	0.0124	6.03	0.0118	3.92

TABLE III

ANALYSIS OF HOSES

	% Sulphur	% Halogens
Hose No. 1		
Inside	2.26	14.39
Inside, next to cloth	2.84	15.96
Outside	1.35	0.33
Hose No. 2		
Inside	3.49	14.86
Outside	1.30	trace
Hose No. 3		
Inside	3.60	14.55
Outside	1.46	trace
Hose No. 4		
Inside	3.12	16.07
Outside	1.68	trace
Hose No. 5		
Inside	2.63	10.91
Outside	1.86	trace

Hose No. 1, U. S. Rubber Products, used from Naval Air Station, Anacostia.
Hose No. 2, U. S. Rubber Products, unused, from first delivery to Pensacola about December 1935.
Hose No. 3, U. S. Rubber Products, unused, from second delivery to Pensacola about July 1936.
Hose No. 4, Same as lot 2, used approximately 7 months.
Hose No. 5, Gates Rubber Company, 1-1/4" hose, unused, delivered through Naval Aircraft Factory.

TABLE IV

EFFECT OF EXTRACTABLE MATERIAL FROM HOSE ON GUM CONTENT

Gum = mg./100 c.c.

(a)

Hours	I Gasoline*	II Gasoline* + 2% Isobutylenes	III Gasoline* + 2% Isobutylenes + Hose	
0	0.6	1.85	1.85	0.0 corr.
48 (1)	0.4	1.60	16.30	14.7 corr.
72	0.6	2.00	16.6	14.6 corr.
96	1.1	2.90	17.6	14.7 corr.
288	0.8	2.00	16.5	14.5 corr.

(b)

Hours	I Gasoline**	II Gasoline + Hose	
0	1.2	1.2	0.0 corr.
72 (1)	1.1	19.8	18.7 corr.
96	1.1	22.3	21.1 corr.
144	1.0	21.4	20.3 corr.
168	1.1	19.6	18.6 corr.
312		20.8	19.7 corr.

* Gasoline from Naval Air Station, Anacostia, 1 September.
** Gasoline from Naval Air Station, Anacostia, 15 September
(1) Hose removed from gasoline.
The figures marked "corr." indicate the amount of gum derived from the rubber tube corrected for the gum in the control. See Appendix A for details.

(c) Sections of hose were extracted with samples of 73 grade aviation gasoline. One sample was obtained from the Air Station at Pensacola; the other, from the Naval Air Station, Anacostia. The extractions were continued 7 hours and the hose air-dried for 48 hours to a constant weight.

73 Octane from Shell Terminal Marine Tanks at Pensacola.

Hours	Original Weight	Total Loss	% Loss
7	6.7994	.1427	2.1

Gasoline from NAS, Anacostia, 73 Octane for Tests.

Hours	Original Weight	Total Loss	% Loss
7	6.9435	.1855	2.7

TABLE V

GUM TESTS ON SAMPLES FROM NAS, PENSACOLA
SAMPLES AUGUST 27 and 28, 1936

(a) 73 Octane Grade.

Description of Sample	Gum Content - mg./100 c.c. Glass Dish Gum, NRL Data Dried 1 hr.	Dried 2 hrs.	Vendor's Data
Shell Terminal Marine Tank	8.2	--	6
Squadron 2, Corry Field			
Bulk storage tank	5.8	--	5
Servicing hose, usual operating conditions.	6.2	--	4
Servicing hose for 24 hrs. Exposed to sunlight during day.	24.6	23.4	24
From tank of Plane No. 9713 (sample blue; evidently not 73 octane).	3.9	--	6
Automobile Station, C.F.	15.4	11.0	6
Squadrons 1 and 4			
Bulk storage tank 356	8.8	7.2	7
Pump House 407, end of line	9.4	--	8
Hose, Squadron 1 (sample yellowish)	34.7	29.2	24
Plane No. 8190 NY-2, Squadron 1.	15.1	11.5	10
Automobile Station, Yard.	14.0	9.3	7

(b) 87 Octane Grade.

Shell Terminal Marine Tank	0.2	--	2
Squadron 5			
Tank car PPX 2666.	2.2	--	4
Bulk storage tank.	1.8	--	2
Servicing hose, usual operating conditions.	4.0	--	1
From tank of Plane 8621 F4B-2.	4.7	--	2
Squadron 3			
From tank.	0.4	--	2
From servicing hose under usual conditions (sample greenish).	26.2	24.4	22
From Plane No. 8252 02U3.	1.1	--	3
Squadrons 1 and 4			
Storage tank No. 402.	3.5	--	3
Pump House No. 405.	2.5	--	5
From hose, Squadron 4.	6.2	--	6
Tank of Plane No. 8312 PM-1, Squadron 4.	3.5	--	4

The 73 Grade of Aviation Gasoline is dispensed to automobiles at two stations at the airport. Trouble is reported here with gum deposits in the bowl of the carburetor and gumming of the carburetor jets. Many carburetors have been reported fouled recently due to gum. The main difference between the automobile carburetors and the airplane carburetors is that the former are down-draft and the latter up-draft carburetors.

In order to locate where the trouble may be, samples were taken in duplicate on August 27 and 28 for both the 73 and 87 Grades from Shell Terminal storage tanks, tank cars, Naval Air Station tanks, from servicing hose, and from planes. One set of samples was forwarded to the Houston Refinery Laboratory and the other set to the Naval Research Laboratory at Anacostia, D.C. The writer witnessed the testing of the samples at Anacostia. The preformed or glass dish gum was the only test made at Anacostia. The preformed gum, color, gum after accelerated aging, copper dish corrosion, copper dish gum, and the octane number of a few samples were determined at Houston. These results are tabulated in the attached Appendices I and II, one covering the 73 Grade and the other the 87 Grade samples.

In Appendix III, full properties are given of the samples obtained from Shell Terminal tanks on August 27. In addition, full properties are also listed of samples from two Navy storage tanks for 73 grade which were obtained on September 18. The Navy specifications are listed for comparison.

The analysis of a sample of deposit taken from an engine which used 73 Grade of gasoline is also given in this memorandum.

On September 17 and 18, the writer again visited the Naval Air Port at Pensacola. Mr. C. E. Ekstrom, Lt. U.S.N. and Mr. C. E. Earle of the Navy Department were also there from Washington, D. C. The trouble was still persisting and it was desired to take definite steps toward remedying the condition. The steps taken are included in the next heading, "Results, Conclusions, and Progress."

RESULTS, CONCLUSIONS, AND PROGRESS

1. The results of the samples which were taken on August 27 and 28 and which are reported in the attached Appendices I and II, show definitely that there is some contamination at the Naval Air Station. This is more pronounced for the 73 Grade than for the 87 Grade; although, one sample from the servicing hose of the 87 Grade is high in gum. Garlock No. 237 packing is used for pumps and valves and no contamination is likely from this source. In view of the contamination, all the Navy storage tanks will be cleaned and the service hose will be tested to determine if they meet Navy specifications.

2. The gum after the accelerated aging test in most cases is pretty much on the same order as theinitial preformed gum (Appendices I and II). In other words, the gasoline is quite gum stable to the accelerated aging test. This applies to both grades of gasoline and especially to that in the Shell Marine storage (see Appendices I, II, & III). The preformed gum in the Shell Terminal tanks is 6 to 8 milligrams for the 73 Grade, which has increased since being delivered to this tank; and, 0.2 to 2 milligrams for the 87 Grade. The preformed gum for the 73 Grade is higher than for the 87 Grade. Even though with 6 to 8 milligrams of gum, from information available, trouble would ordinarily not be expected, especially in motor cars. A peculiar

situation appears to exist at the Naval Airport. This condition is all the more unusual because no complaints have been received from other points of outlet using identically the same type of gasoline.

Both gasolines in Shell Terminal storage on August 27 met all of the Navy specifications M-222 (see Appendix III).

3. On the writer's second visit to Pensacola on September 17 and 18 it was definitely stated by Navy officials that no trouble was experienced with the 87 Grade of Gasoline and that it was satisfactory. The trouble previously reported was attributed to some engines in which 73 Grade Gasoline had been used prior to changing to 87 Grade.

4. In order to determine if the gasoline supplied by Shell is at least partially at fault, a test was started on September 17 using a plane with a newly overhauled engine and 73 Grade of Gasoline which was delivered in drums directly from Shell Marine Storage. The gasoline was supplied to the plane by means of pails to avoid the use of hose.

The writer did not witness the inspections after this test, but it was reported that after about 26 hours a trace of gum in the intake system was indicated and after 43 hours a definite indication of the usual trouble was evident.

Based upon this test, the 73 Grade Gasoline in the Navy storage amounting to roughly 60,000 gallons will be returned to Shell Marine storage and, beginning September 28 this grade will be supplied directly from the Houston Refinery. Four 10,000 gallon cars are to be on hand in Pensacola on September 28 and two cars each week thereafter. This procedure will be followed until the 73 Grade can be moved from Shell Marine storage and a new supply delivered. These cars will be connected directly to the servicing system at the Naval Air Station, bypassing their storage, until clean tanks are available.

Since the gasoline in Shell Marine storage meets all of the Navy specifications, the specifications are evidently not broad enough to cover all conditions if the gasoline is partially at fault.

5. Since the 87 Grade is satisfactory and the 73 Grade is claimed not to be, the difference in composition will be given. The 87 Grade is 100% base stock plus a maximum/gal. of 3.00 cc. of tetraethyl lead. Up to April 14, 1936, the 73 Grade consisted of base stock plus approximately 3% of tri-isobutylene. Beginning April 14 and thereafter a blend of di-isobutylene and tri-isobutylene was substituted for T.I.B. Approximately 3% of this blend was also used. The D.I.B.-T.I.B. blend consisted of approximately two-thirds of the former and one-third of the latter. Since no trouble was noticed until about the latter part of June or first part of July, it can be considered that the T.I.B. in the Aviation Gasoline is satisfactory, but that probably the D.I.B. is not, and that perhaps it is the D.I.B. that is the cause of the trouble. It is quite likely that in the presence of D.I.B., the impurities, picked up in storage and under servicing conditions, catalyze gum formation, D.I.B. will be omitted from future blends.

6. The writer wishes to extend his thanks to the personnel at the Naval Air Station at Pensacola, the Naval Research Laboratory at Anacostia, and to Lt. C. E. Ekstrom and Mr. C. E. Earle for their hospitality and hearty

cooperation in the investigation of this problem. It has been a pleasure to work with them.

7. Summarizing - The 87 Grade of Gasoline is satisfactory. All the storage tanks at the Naval Air Station, Pensacola, are being or going to be cleaned. The servicing hose are being tested to determine if they meet Navy specifications. The 73 Grade of Gasoline will be supplied in tank cars from Houston beginning September 28 until a new supply can be delivered to the Shell Terminal tanks at Pensacola. The 73 Grade now in storage at the Naval Air Station will be returned to Shell Marine storage and all this gasoline in Shell storage will be moved to make room for the new supply.

DESCRIPTION

The gasoline is unloaded from barges, through a connecting hose approximately 20 to 30 feet long and 4 inches I.D. to Shell Terminal storage tanks. The hose is a U. S. Rubber Company, Amazon 3800 Hose No. 5-717. It is rubber covered and supposedly metal lined. One 37,000 barrel cone roof tank is in use for the 73 Grade of Gasoline and one 10,000 barrel tank with Wiggins breather type of roof for the 87 Grade. The two systems are entirely independent from each other. Separate lines from the tanks, separate pumps, etc. are used for loading into tank cars. Very old hose connections are used for tank car loading. These are metal lined and canvas covered. Reciprocating steam pumps are used for loading. A graphite asbestos composition packing is used.

The gasoline is delivered to the Naval Air Station in tank cars. Four 10,000 gallon cars are in this service which are used interchangeably for both grades of gasoline. For unloading, a Paranite suction hose, metal lined, rubber covered, is used. This hose is about 20 feet long.

There are three points of Naval storage - one at Corry Field, supplying Squadrons 2 and 5, and one automobile filling station; another supplying Squadrons 1 and 4 and an automobile filling station; and the third supplying Squadron 3. The storage tanks are 90,000 to 100,000 gallon tanks with floating roofs, with the exception of the 87 Grade at Corry Field, which consists of four inter-connected 12,000 gallon horizontal tanks. Another similar 12,000-gallon tank supplies the automobile station with 73 Grade Gasoline at Corry Field.

Centrifugal pumps take suction on the storage tanks and supply pressure on the servicing lines at the airports. All lines are underground. The servicing hose are wound on reels and are all U. S. Rubber Company hose manufactured under Navy Specification No. 33H2A. These appear to be rubber with a possible Duprene lining. One exception to the above, at Squadron 4, a metal-lined, cotton-covered hose, is used for the 73 Grade of Gasoline.

Garlock Packing No. 237 is used at the Naval Air Station for packing all pumps and valves. This appears to be a graphite asbestos composition packing.

The major trouble is experienced with the R-790 engines, Wright Whirlwind Engine (220 h.p.) without blower suction. This type of engine is used in both land and sea planes, which are used mostly as practice planes. They use the 73 Grade of Gasoline. The planes come in every hour for refueling and changing of pilots. Approximately 20 minutes is required. During this

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time the engines have time to cool and any gummy deposits become less fluid and become more sticky. Usually no trouble is encountered in flight; however, the deposit accumulates excessively as already mentioned.

There are other makes of engines in use also, some using the 87 Grade and some the 73 Grade. Most of these engines have blower sections. These will not be described, since no trouble is experienced with the 87 Grade of Gasoline. Trouble is experienced with all engines using the 73 Grade with the maximum in the J-5's or the R-790 mentioned above.

Each morning the gasoline is the service hose is drained on the ground before filling the planes. This precaution is taken to avoid contamination from the hose, which this report indicates takes place. However, in some cases, the gasoline remains in the hose sufficiently long between filling of planes to definitely cause contamination. The results in the attached tabulations led to the testing of this hose to determine if it meets the Navy specifications.

The automobile stations use a hose manufactured by Goodrich Rubber Company under specification No. 22-H-466A for dispensing the 73 Grade of Gasoline to automobiles.

MATERIAL FROM VALVE AND INTAKE PORT OF ENGINE

Material was taken from the induction system, mainly from intake valve and intake port, of an engine that had been using 73 Grade Aviation. This material was taken at the end of the usual overhaul time, namely 350 hours. Quite a heavy deposit was present. This material was analyzed as a matter of interest in the Houston Laboratory, with the following results:

Sulfur	1.9% by wt.
Ash	1.98% by wt.
Lead	0.3% by wt.
Chlorides	Trace

The ash appeared to be mostly iron, although it was not analyzed. A small amount of lead is present, which indicates the use of some 87 Grade Gasoline as well as 73 Grade.

In addition to the above, the per cent soluble in various solvents was determined, with the following results. The extractions were made consecutively on the same charge beginning with hexane.

	PER CENT SOLUBLE
Hexane % by wt.	15.4
Benzene % by wt.	11.2
Chloroform	10.6

This indicates quite a large portion not soluble in these solvents. It was reported that the material when fresh and then removed from the induction system is of a rather soft consistency but it tends to harden upon

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September 25, 1936

73 GRADE AVIATION GASOLINE SAMPLES FROM U.S. NAVAL AIR STATION PENSACOLA, FLORIDA
SAMPLED AUGUST 27 & 28, 1936.

SHELL PETROLEUM CORPORATION RESULTS

Sample Number	Sample	Navy Research Laboratory Glass Dish Gum mg/100 cc.	Color Saybolt	Glass Dish Gum Mg/100 cc.	Ind. Per. Hrs.	Gum After Accel.Aging: No Correction for lead	Gum After Accel.Aging: Correction for lead	Copper Dish Gum & Corrosion Results: Gum Mg/100 cc.	Copper Dish Gum & Corrosion Results: Cu.Dish Corrosion Test	Copper Dish Gum & Corrosion Results: Remarks	Oct. No. C.F.R.
2?	Shell Marine Terminal Tank	8.4	30+	6	4+	7	-	5	Very Good	No discoloration - only slight trace of gum.	73.2
	Squadron 2 Corry Field										
12	Bulk storage tank	5.8	30+	5	4+	7	-	6	Very Good	No discoloration - small streaks of gum.	72.0
10	From servicing hose under usual operating conditions.	6.2	30+	4	4+	5	-	7	Very Good	Ditto	
21	Gas left in servicing hose 24 hrs. Hose in sunlight during daytime.	31.8	16	24	4+	24	-	31	Good	Gum present - not oily.	72.4
4	From tank of Plane No. 9713 (Sample at Anacostia was found to be blue.)	3.9	Blue	6	4+	16	5	7	Good	No discoloration - small streaks of gum.	
2	Automobile Gasoline Station, Corry Field.	13.7-11.8	30+	6	4+	12	-	15	Good	Ditto	
	Squadrons 1 and 4										
17	Bulk storage tank 356	14.8	30+	7	4+	10	-	11	Very Good	Ditto	
14	Pump house No. 407 End of line.	9.4	30+	8	4+	8	-	22	Very Good	No discoloration - gum present.	
13	Outlet of hose, Squadron 1 (Sample was off color -slightly yellowish)	31.8	17	24	4+	21	-	34	Good	Some gum and much oily residue	72.2
19	Plane No. 8190 NY-2 Squadron 1	18.7	28	10	4-/	14	-	15	Very good	Small streaks of gum.	
1	Automobile Gasoline Station, Yard.	12.0-10.1	30+	7	4+	12	-	12	Good	Ditto	

87 GRADE AVIATION GASOLINE SAMPLES FROM U.S. NAVAL AIR STATION PENSACOLA, FLORIDA
SAMPLED AUGUST 27 & 28, 1936.

Sample Number	Sample	Navy Research Laboratory Glass Dish Gum mg/100 cc.	SHELL PETROLEUM CORPORATION RESULTS									Oct. No. C.F.R.
			Color Saybolt	Glass Dish Gum Mg/100 cc.	Ind. Per. Hrs.	Gum After Accel.Aging		Copper Dish Gum & Corrosion Results				
						No Correction for lead	Correction for lead	Gum Mg/100 cc.	Cu.Dish Corrosion Test	Remarks		
	Shell Marine Terminal Tank	0.2	Blue	2	4/	7	-	5	Good	Color mostly dye-no visible gum.		87.5
	Squadron 5* - Corry Field											
5	Tank Car PPX 2666	2.2	Blue	4	4/	15	6	8	Good	Ditto		
11	Bulk Storage	1.8	"	2	4/	10	3	3	"	"		87.2
8	From service hose under usual conditions.	4.0	"	1	4/	9	-	8	V.Sl.Corr.	Slight streaks of gum.		
7	From Plane No. 8621 F4B-2	4.7	"	2	4/	9	-	7	Good	Color mostly dye-no visible gum.		
	Squadron 3											
3	From tank	0.4	"	2	4/	14	2	8	Sl.Corr.	No visible gum.		
6	From service hose under usual conditions (Sample noticed to be greenish in color at Anacostia instead of the customary blue.)	25.4	Green	22	4/	22	No lead present-only oily residue	31	Some Corr.	Gum and much oily residue		87.0
9	From plane No. 8252 02U3	1.1	Blue	3	4/	15	9	4	V.Sl.Corr.	Slight streaks of gum.		
	Squadrons 1 and 4											
	Storage tank No. 402	3.5	Blue	3	4/	23	12	10	Good	Color mostly dye-no visible gum.		
15	Pump house No. 405	2.5	Blue	5	4/	22	6	10	Good	Ditto		
16	Outlet Hose Squadron 4	6.2	"	6	4/	21	13	17	"	Color mostly dye - some gum.		
20	Plane No. 8312 PM-1 Squadron 4	3.5	"	4	4/	17	9	11	"	Color mostly dye - no visible gum.		

*Until about 1 month ago 73 octane gasoline was used; however, this was changed to 87 grade because of some higher compression motors which are now being used.

LA 9-15-36

Houston Lab. Memo. 6072
September 27, 1936

APPENDIX III

FULL PROPERTIES OF AVIATION GASOLINES

The Shell Marine Terminal tanks at Pensacola were sampled on August 27, 1936 and the Navy tanks of 73 Grade Aviation on September 18. Full properties were determined at Houston in the Shell Laboratory with the following results. The Navy Specifications M-222 are given for comparison.

	AUGUST 27 SHELL MARINE TANKS		NAVY SPEC. M-222		SEPT. 18 73 GRADE NAVY STORAGE	
	73 GRADE	87 GRADE	73 GRADE	87 GRADE	STATION TANK	CORRY FIELD TANK
Gravity, °API at 60/60°F	66.5	66.9	-	-	66.4	66.5
Color Saybolt	30+	Blue	25 Min.	Blue	30+	30+
V.P. Reid at 100°F Lb/Sq.In.	6.2	6.1	7.0 Max.	7.0 Max.	5.8	6.0
T.E.L. Content, cc/Gal.	None	3.000	None	3.27 Max.	None	None
Octane No. A.S.T.M.	73.2	87.5	73 Min.	87-89	73.0	73.1
Odor	Sweet	Sweet	Sweet	Sweet	Sweet	Sweet
Doctor Test	Neg.	Neg.	-	-	Neg.	Neg.
Corrosion Copper Dish	Neg.	Neg.	No Gray or Black Corrosion	No Gray or Black Corrosion	Neg.	Neg.
Preformed Gum, mg/100 cc.	6	2	-	-	6	6
Copper Dish Gum,	5	5	-	-	8	7
Accel. Aging Test:						
Ind. Period, Hours	4+	4+	-	-	4+	4+
Gum Glass Dish, mg/100 cc.	7	7*	10 Max.	10 Max.	7	6
Sulfur % by Wt.	0.015	0.015	0.10 Max.	0.10 Max.	0.012	0.015
Freezing Point, °F	Below-76	Below-76	-76 Min.	-76 Min.	Below-76	Below-76
Acid Heat C.F.R. °F	10.5	3.5	20 Max.	20 Max.	14	9
Distillation:						
IBP, °F	119	116	-	-	118	116
5% Rec at °F	144	135	-	-	141	143
10% "	154	145	167 Max.	167 Max.	154	155
50% "	205	196	212 "	212 "	205	204
90% "	256	249	275 "	275 "	260	254
96% "	284	-	-	-	293	280
Dry Point °F.	300	286	-	-	314	304
End Point °F	308	294	-	-	315	305
% Recovery	98.5	98.0	-	-	98.0	98.5
% Residue	1.0	1.0	2.0 Max.	2.0 Max.	1.0	1.0
% Loss	0.5	1.0	-	-	1.0	0.5
Sum 10, 50 & 90% Temp.	615	590	-	-	619	613
Sum 10 & 50% Temp.	359	341	307 Min.	307 Min.	359	359
Acidity of Residue	Neg.	Neg.	-	-	Neg.	Neg.

* No correction was made for lead. Should this have been done, the gum content would have been reduced to about 1 or 2 milligrams.

These results show that both grades of gasoline fall well within the specifications. This includes the gum specification. The color of the 73 Grade Gasoline after the accelerated aging test remained 30+, which is another indication of its stability.

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