

**UNCLASSIFIED**

---

---

**AD 269 189**

*Reproduced  
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY  
ARLINGTON HALL STATION  
ARLINGTON 12, VIRGINIA**



---

---

**UNCLASSIFIED**

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

XEROX  
62-1-6

269189

CATALOGED BY ASTIA  
AS AD No. 269189

# GAS TURBINE AND JET ENGINE FUELS

PROGRESS REPORT NO. 5

NAVY BUWEP CONTRACT NO. (W) 61-0590-D

NOVEMBER, 1961

31

269189



Released to ASTIA by the  
Bureau of NAVAL WEAPONS  
without restriction.

PHILLIPS PETROLEUM COMPANY

ASTIA

PROGRESS REPORT NO. 5

NAVY CONTRACT NO(w) 61-0590-d

GAS TURBINE AND JET ENGINE FUELS

By

W. L. Streets

31

-----  
S U M M A R Y

The fifth bimonthly period under Contract NO(w) 61-0590-d has been spent continuing the study of the effects of sulfur in jet fuels and ingested sea water on the durability of turbine inlet guide vanes. Efforts during this period have included: (1) evaluation of the effect of sea water and the combined effects of sulfur and sea water and (2) preparation toward utilization of the Phillips Microburner, a bench-scale atmospheric pressure laboratory combustor, in future metal corrosion tests as a supplement to the work planned for the Phillips 2-Inch Combustor. It is hoped that the use of this much simpler device will speed up evaluation of various alloy formulations and provide data for correlation with the 2-inch combustor.

The results of tests on sea water alone and in combination with fuel sulfur appear to be inconclusive at this time as a result of marked increases in corrosion of components upstream of the guide vane test pieces. It would appear that metallic ash fragments from these components may have coated the guide vane pieces and protected them from attack. Since previous corrosion tests of flame tubes showed no effect by sea water in the absence of guide vanes it has been considered desirable to investigate the reasons for this sharp increase in flame tube and radiation shield corrosion when test vanes are installed. Such an investigation is in progress.

-----

PHILLIPS PETROLEUM COMPANY  
RESEARCH DIVISION  
BARTLESVILLE, OKLAHOMA

PROGRESS REPORT NO. 5

NAVY CONTRACT NO(w) 61-0590-d

GAS TURBINE AND JET ENGINE FUELS

I. INTRODUCTION

The fifth bimonthly period under Navy Contract NO(w) 61-0590-d has been spent continuing the study of the effects of sulfur in jet fuels and ingested sea water on the durability of simulated turbine inlet guide vanes. Efforts during this period have included (1) tests designed to evaluate the combined effects of sulfur and sea water and (2) preparations toward utilization of the Phillips Microburner, a simple bench-scale 1.25 inch diameter atmospheric combustor, in future metal corrosion tests as a supplement to the work proposed for the Phillips 2-inch High Pressure Laboratory Combustor. It is hoped that the use of this much simpler device will speed up evaluation of various alloy formulations and provide data for correlation with the 2-inch combustor.

II. TEST PROGRAM

The apparatus used in this investigation was the Phillips 2-inch Research Combustor which has been described in complete detail in previous reports (1). Briefly, this is a 2-inch diameter axial flow combustor embodying the principal features of modern jet engine combustion systems. Air is supplied to this combustor from a compression and heating plant described in (1), while fuel is supplied to the swirl type nozzle by nitrogen pressurization. The design of the combustor is such as to allow ready removal of flame tubes and turbine blending test pieces for weighing, inspection, etc.

Test conditions employed were identical to those used for previous investigations of the effect of sulfur and sea water on simulated turbine inlet guide vane durability which have been reported on in (2). Combustor pressure was held at 350 in. Hg. abs., inlet air temperature at 700 F and inlet reference velocity at 100 fps, providing a severity level which is reasonably realistic for high compressor ratio turbojets operating at relatively low altitudes. It will be recalled from Progress Report 3 that operation at a fuel/air ratio sufficient to achieve 1350 F average exhaust gas temperature resulted in the same guide vane metal losses regardless of the presence or absence of sulfur in the fuel. Therefore all subsequent testing has been done at a fuel/air ratio of 0.015 lb. fuel/lb. of air which results in an exhaust gas temperature of approximately 1650 F. Under these conditions it was found possible to observe significant differences in corrosion among the several fuel-contaminant combinations.

For these investigations of the effect of sulfur and ingested sea water on turbine inlet guide vanes no change was made to the combustor section itself. The only change in apparatus was simply to add a six-inch spool piece downstream from the combustor and to cut a suitable holder cavity into its mating flange for the simulated turbine inlet guide vane test pieces illustrated in Figure 1, placing these pieces in a position comparable to that of the real blading in an actual engine. Weight losses

were measured following each of three consecutive two-hour test periods. During this reporting period, in which the major objective was to establish gross trends in corrosion of Fe-Ni-Cr steels by sulfur and sea salts, data have been obtained using only type 304 stainless steel specimens.

Since previous investigations (3) had shown sulfur compound type to be unimportant as compared to gross sulfur concentration, it was decided to continue using ditertiary butyl disulfide as the contaminating agent since it is inexpensive and readily available at adequate purity. As in previous tests this compound was employed at sufficient concentration to realize 2.5 times the jet fuel specification sulfur limit of 0.4 per cent, or 1.0 per cent sulfur. This exaggerated sulfur severity was considered desirable for research purposes. In the tests involving sea salts synthetic sea water formulated according to ASTM D665-60 was used. As in previous tests the synthetic sea water was injected into the combustor at a rate 5000 times that indicated in the literature (4) as representative of the concentration of airborne sea water vapor at an altitude of 50 feet above the ocean surface, since tests at realistic rates had shown no measurable effect of sea water.

The base fuel used in these tests was, as in previous tests, a JP-5 type isoparaffinic alkylate containing 0.005 per cent or less sulfur.

### III. DISCUSSION OF EXPERIMENTAL RESULTS

The results of the most recent tests on the effect of sea water and sea water plus sulfur on the durability of (simulated) turbine inlet guide vanes are shown in Table I and Figure 2 together with the previous data reported in Progress Report 3 on the base fuel alone and with 1 per cent sulfur added. It should be recalled from Progress Report 3 that at the lower exhaust temperature investigated, 1350 F, only very low metal losses were obtained and these losses were about the same regardless of whether sulfur was present or not. This condition seemed too mild and for this reason all subsequent testing has been carried on at conditions producing 1650 F exhaust gas. This discussion will refer only to the data obtained at the higher temperature.

From Figure 2 it may be seen that the test on base fuel with synthetic sea water injected yielded metal losses somewhat higher than the base fuel alone, although much lower than those obtained with sulfur contamination alone. However, when these contaminants were combined the metal loss values fell below the curve established for the base fuel alone. It is indeed difficult to accept these latter results, although a check test did confirm the first test. Of significance in these sea water-sulfur tests, however, is the fact that there appeared to have been an increase (by visual observation) in metal loss from flame tubes and nozzle radiation shields. It is possible that the apparent low metal losses from the guide vane test pieces resulted from protection of their surfaces by metal oxides/sulfides from the flame tubes and radiation shields impacting on them. It would appear that the combined effects of sea water and fuel sulfur contamination on guide vanes bears further investigation and for this reason tests are currently in progress in which flame tube and radiation shield metal losses will be measured gravimetrically while operating with a guide vane test piece in place downstream. At this time the results shown in Figure 2 for sea water plus sulfur are considered inconclusive pending more extensive testing.

#### IV. CONCLUSIONS

As pointed out above, the results of recent tests on the effect of sea water ingestion and the combined effects of fuel sulfur contamination and sea water ingestion would appear to be inconclusive as a result of severe increases in corrosion of radiation shields and flame tubes upstream of the turbine inlet guide vane test pieces. It is believed that the metallic ash particles from these components may have coated the guide vane pieces and protected them from being corroded. Since previous flame tube corrosion tests did not show any pronounced effect caused by sea water in the absence of guide vane test pieces it has been considered desirable to investigate the reasons for this sharp increase in flame tube and radiation shield metal losses when the vanes are in place. Such an investigation is in progress.

#### V. OUTLINE OF PROJECTED WORK

In addition to further investigation of the effect of sea water in combination with fuel sulfur on turbine inlet guide vane durability in the 2-inch combustor, it is intended to begin exploratory testing of the effect of sea water, sulfur and exhaust temperature on actual turbine blading alloys using the Phillips Microburner. This device is a 1.25 inch diameter atmospheric pressure tangential flow bench scale combustor which has been described in detail in previous reports (4). Work is currently underway to modify the exhaust system of this burner to allow placement of test materials in the exhaust stream. Simplified test pieces consisting of 1/16" x 1/4" x 1-1/2" metal strips will be used. It is hoped that by use of this simpler apparatus the acquisition of metal loss data on a wide variety of alloys will be speeded up and at the same time data will be available for correlation with the 2-inch combustor which will yield information as to the advisability of employing such apparatus in future metal durability testing.

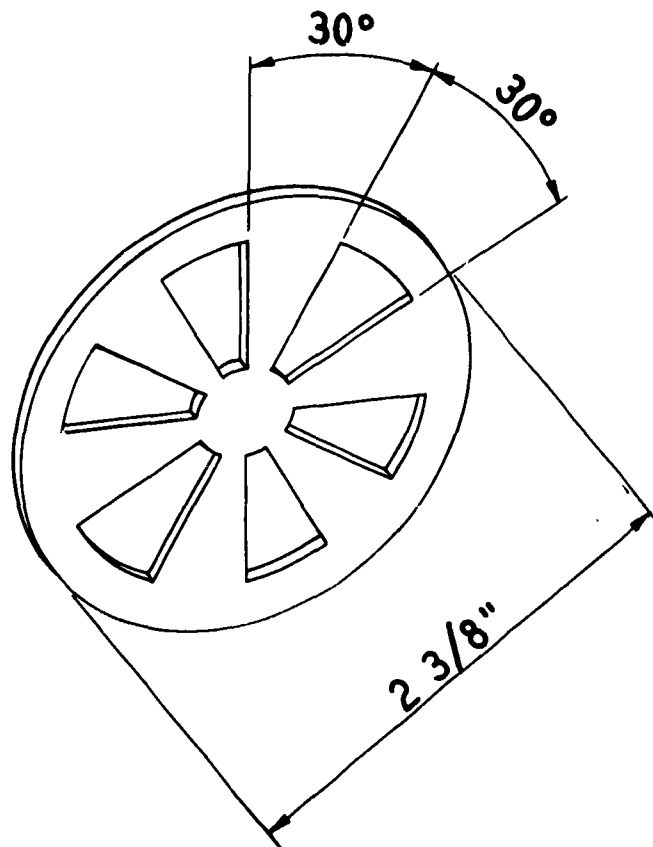
#### REFERENCES

1. Fromm, E. H.; "Design and Calibration of Phillips Jet Fuel Testing Facilities", Phillips Research Division Report 1252-55R, December, 1955.
2. Streets, W. L.; "Gas Turbine and Jet Engine Fuels", Progress Report No. 3, Navy Contract NO(w) 61-0590-d, Phillips Research Division Report 2959-61R, July, 1961.
3. Kittredge, G. D. and Streets, W. L.; "Gas Turbine and Jet Engine Fuels", Summary Report for Navy Contract NOas 60-6009-c, Phillips Research Division Report 2760-61R, January, 1961.
4. Streets, W. L.; "Phillips Microburner-A Tool For Evaluating The Burning Quality of Jet Fuels", Phillips Research Division Report 1793-57R, May, 1957.

TABLE I  
SIMULATED TURBINE INLET GUIDE VANE DURABILITY IN PHILLIPS 2-INCH RESEARCH COMBUSTOR

Combustor Operating Conditions: P = 350 in. Hg abs.; V = 100 ft./sec.; IAT = 700 F

Vane Metal Type	Test Fuel Description	Fuel/Air Ratio	Time, hrs.	Accumulated Metal Loss, mg.	Exhaust Gas Temp., °F
304SS	JP-5 Type Alkylate (BJ61-8-B1)	0.010	2	28.5	1346
		0.010	4	39.5	1382
		0.010	6	68.0	1352
304SS	JP-5 Type Alkylate (BJ61-8-B1)	0.010	2	6.8	1314
		0.010	4	54.8	1326
		0.010	6	66.5	1362
304SS	JP-5 Type Alkylate (BJ61-8-B1) plus 1% Sulfur as Ditertiary Butyl Disulfide	0.010	2	18.9	1346
		0.010	4	32.3	1340
		0.010	6	54.2	1306
304SS	JP-5 Type Alkylate (BJ61-8-B1)	0.015	2	89.0	1660
		0.015	4	242.0	1666
		0.015	6	464.0	1605
304SS	JP-5 Type Alkylate (BJ61-8-B1) plus 1% Sulfur as Ditertiary Butyl Disulfide	0.015	2	121.0	1592
		0.015	4	399.0	1632
		0.015	6	691.0	1625
304SS	JP-5 Type Alkylate (BJ61-8-B1) w/1 lb/hr. Synthetic Sea Water Injected	0.015	2	121.6	1590
		0.015	4	293.7	1578
		0.015	6	501.4	1568
304SS	JP-5 Type Alkylate (BJ61-8-B1) plus 1% Sulfur as Ditertiary Butyl Disulfide w/1 lb/hr. Synthetic Sea Water Injected	0.015	2	66.5	1560
		0.015	4	209.1	1554
		0.015	6	383.0	1544
304SS	Same as above	0.015	2	36.7	1530
		0.015	4	162.6	1546
		0.015	6	370.7	1560



**MATERIAL: VARIOUS TYPES OF TURBINE  
BLADING ALLOYS (16 GA. SHEET)**

**FIGURE 1  
SIMULATED TURBINE INLET GUIDE VANE INSERT FOR MEASUREMENT  
OF METAL LOSSES IN PHILLIPS 2- INCH RESEARCH COMBUSTOR**

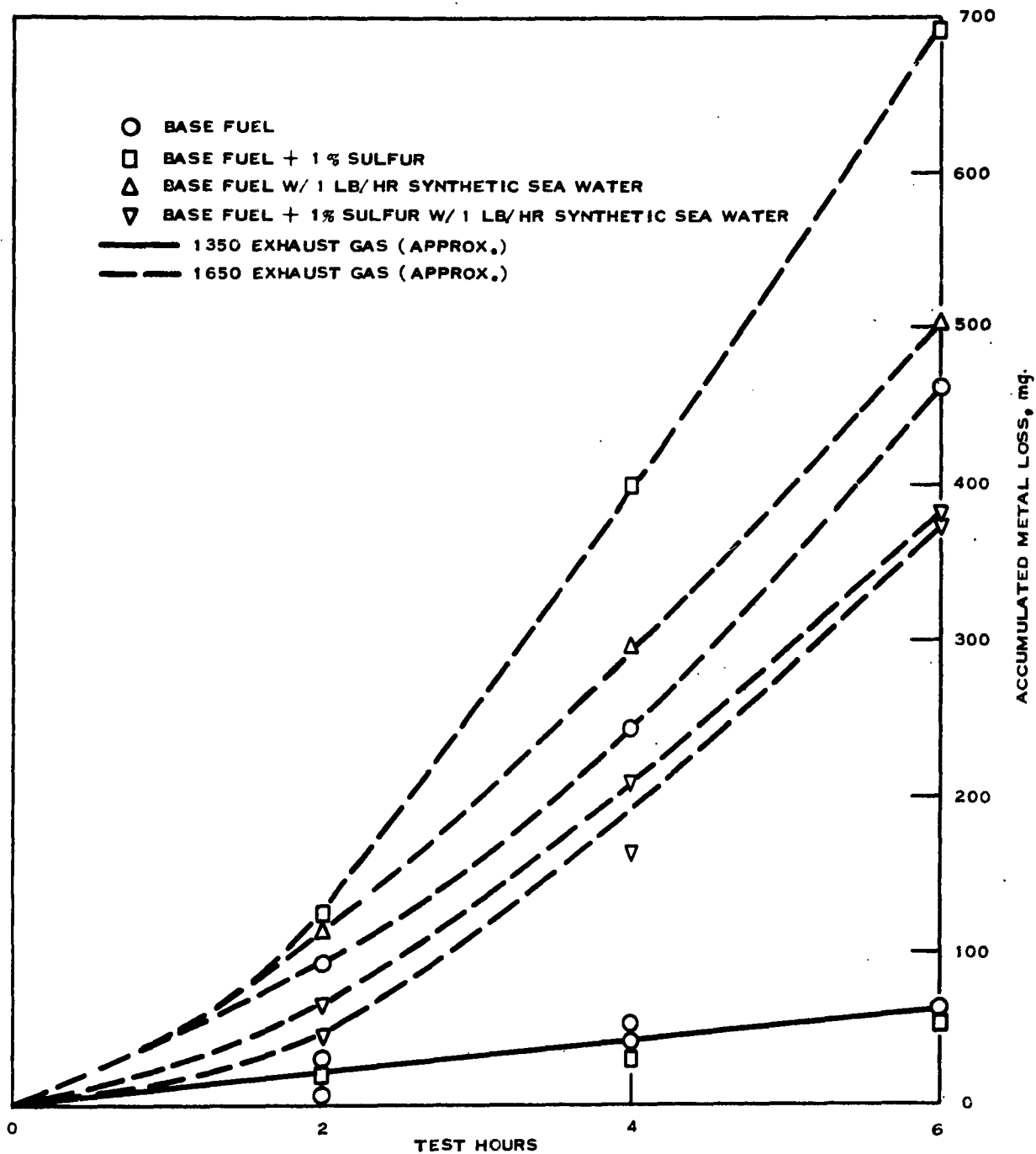


FIGURE 2  
EFFECT OF FUEL SULFUR CONTAMINATION, SEA WATER INGESTION  
AND EXHAUST GAS TEMPERATURE ON THE RATE OF METAL LOSS  
FROM 304 STAINLESS STEEL SIMULATED TURBINE INLET GUIDE VANES