PERFORMANCE CHARACTERISTICS OF A MOTOR GASOLINE PRODUCED FROM OIL SHALE

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ABSTRACT

A full-boiling range gasoline produced from shale oil has been experimentally studied to determine emissions, fuel economy, and other characteristics of the fuel when used in conventional automotive engines. Results are reported and discussed.

In brief, neither the emissions nor fuel economy of the automotive engines were significantly altered between conventional gasolines and shale gasoline. In extended use of shale-oil gasoline, abnormal engine deposits were observed; these were anticipated from the characteristics of the gasoline revealed in the inspection data. Characteristics of the fuel that led to undesirable deposits are not necessarily typical of shale-derived fuels and may be readily correctable in the fuel manufacturing process.

INTRODUCTION

Within the foreseeable future, energy available from oil shale most certainly will augument available energy supplies. Precisely how the transportation sector's fuel supply will be affected is not at all clear. However, one thing *is* clear—the development of new and modified engine

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technologies and acceptance of new fuels must involve a sustained effort to insure compatibility of fuels and engines in systems that simultaneously provide good energy economy and minimal environmental penalty. To this end, the Energy Research and Develpment Administration (ERDA) is using technical programs of experiment to obtain information on the behavior of new or different fuels used with engines and accessories that, as systems, represent viable options for continued or future use. As a part of that program, the ERDA Bartlersville (Okla.) Energy Research Center conducted a short experimental program whose objective was to determine the attributes of a shale-derived gasoline, used in conventional automotive equipment representing current engine technology.

With respect to the purposes and value of such a study, three questions are appropraite: (1) will substantial quantities of motor fuel be derived solely from shale? (2) if so, will the fuel be gasoline? and (3) will it be used in anything resembling current engines?

The second and third questions are answered somewhat obliquely but with considerable assurance in the answers:—gasoline will be a primary motor fuel for many years to come and, at least well into the 1990's, will be used in engines much like those in use today. So it is in order to consider gasoline as a potential fuel to be produced from shale. The first question above: will gasoline be derived in quantity solely from shale? is the more problematical of the two. The current outlook is, that within the foreseeable future, gasoline will not be produced from feedstock that is 100 percent shale product. Given that outlook, it is appropriate to question the value of an experiment dealing with a fuel that is 100 percent shale-derived. In my opinion, only a relatively small amount of work with such fuel is justified. The objective of such work should be to reveal characteristics of the fuel that can be related to the source material and thereby identified as potential problem areas in any fuel that may carry the inherent characteristic, or "fingerprint" of the source. At present, however, it is grossly premature to attempt categorical characterization of "shale gasoline." I would reiterate that such a fuel, uniquely shale-derived, probably will not be marketed in quantity during this century; and, if so, its properties could be markedly different from such a fuel produced today. These assessments were kept well in mind as we began experimental work seeking "fingerprint characteristics" of a shale gasoline.

PREPARATION OF SHALE GASOLINE

The gasoline used in the study was a portion of the product of an operation to produce and refine 10,000 bbl of oil shale. Crude shale oil was produced, using the Paraho process; shale feedstock came from the Naval Oil Shale Reserve, Anvil Points, Colorado. Details of this operation, sponsored by the U.S. Navy with participation by others, have been reported.† Briefly summarized, the operation involved retorting about 16,000 tons of shale to yield 12,631 tons of retorted shale, 10,000 bbl of product oil, and 132 MMSCF of product gas. The shale crude was a relatively low gravity product (15.1° API, 0.652 specific gravity) containing 0.65 wt pct sulfur and 1.89 wt pct nitrogen. The crude was refined in a small commercial refinery using a coker/fractionator to yield naphta, light gas oil, heavy gas oil, heavy fuel oil, coke, and gas (table 1). Motor fuel was produced from the naphtha fraction hydrotreating and reforming.

TABLE 1.—*Crude processing yield and shale gasoline properties*

Crude charge, bbl	9,956	*Composition and chemical characteristics:*	
Yield, bbl;		Aromatic, pct.	28(36)
Gasoline	725	Olefin, pct.	14(12)
JP-4	454	Saturates, pct.	58(52)
Jet A	650	Sulfur, wt pct.	0.01-0.03
Diesel fuel No. 2	1,167	Nitrogen, wt pct.	0.03
Heavy fuel oil	2,765	Oxygen	0.52
Phsical properties:		*Stability data:*	
Reid vapor pressure, lb.	10.5	ASTM induction period, min.	1440+**
Gravity, °API	59.7	ASTM existent gum, mg/100ml	25
Octane No.:			
Research	81(87)*	Accelerated gum (4 hr), mg/100 ml: As received	50
Motor	76(79)		
Distillation, °F:		With addition of 10 lb DuPont A0-22 and 2 lb DMD per 1,000 bbl	32
IBP	87		
10%	125		
50%	194		
90%	328		
End point	387		

*Values in parenthesis represent values in samples of the same run of gasoline sent to another laboratory. Analytical data from different laboratories indicate serious non-uniformity in the gasoline as shipped from the refinery.

**40 Lb of pressure was lost during the entire 24-hr period; however, at no time did it lose 2 lb in a 15-minute period.

†Bartick, Herbert, S. ,. Kunchal, D. Switzer, R. Bowen, and R. Edwards, Final Report—The Production and Refining of Crude Shale Oil Into Military Fuels: Contract No. N00014-75-C-0055, 1975.

FUEL CHARACTERISTICS

Discussion

Antiknock quality and stability characteristics of the fuel, as produced, were so poor as to preclude use as a commerical product. However, the deficiencies were such as to be judged correctable by additional or alternative processing using readily available technology. In this connection, the Navy's contractor observed: "these fuels tended to exhibit storage and thermal instabilities. In addition, the fuels contained a high wax content, high particulate matter, and high gum content. It is believed that a higher pressure in the hydrogenation stage (about 2,000-3,000 psi), along with clay treatment of the final products, would reduce or eliminate some or most of these problem areas."

Comprehensive extended engine tests were not run with the fuel because it was felt that the high gum content and poor stability characteristics would cause operational problems. Inasmuch as these fuel deficiencies were judged to be not inherently and unavoidably associated with shale product, there appeared to be questionable value in identifying or demonstrating engine tolerance or, alternatively, associated operational problems. For this reason, service testing was confined to a one-car test over about 7,000 miles to obtain an indication of problems that could develop over very short-term periods. If these emerged precautions could be taken for even the short-duration testing involved in emissions or fuel economy measurement. Additionally, results of the service test would give a basis for deciding on the suitability of the fuel for use in more extended experimental work.

Experimental Results

Emissions and fuel economy measurements were made using shale gasoline in each of two late-model (1974 and 1975) vehicles. Non-catalyst cars were selected so that results, measured at the vehicle tailpipe, would reflect engine-out emissions. Measurements were by techniques widely accepted in the industry for use in connection with automotive emissions control development and engine certification. Results are summarized in table 2.

Except for engine knock encountered when using the shale gasoline, results with the shale and reference fuels were not significantly different.

TABLE 2.—*Emissions and fuel economy–shale gasoline*

Vehicle	Fuel	Emissions, gm/mile				Fuel econ., mpg	
		CO	HC	NO_X	Ald.	Urban cycle	Highway
1974 Model 351-CID	Shale gasoline	25.8	2.2	2.6	0.14	11.2	17.4
	Indolene*	25.9	2.3	2.7	.15	10.9	17.7
1975 Model 318-CID	Shale gasoline	7.4	1.3	2.7	0.18	12.3	21.1
	Indolene**	8.7	1.2	2.5	.17	12.2	20.6

*Values represent results of one test, all other data represent average of 3 replicates.
**Proprietary product widely used as reference motor fuel in the auto and associated service industries.

Thus, there was no evidence of a "shale fingerprint"—good, bad, or benign.

Short in-service testing was done by accumulating mileage in a series of 1-hr drives over an urban route (approximately the driving cycle of the federal emissions test procedure), followed by 1-hr runs over open highway at posted speed limits. Emissions and fuel economy measurements (Table 2) were made at the start of the test, at approximately 1,000 miles, and, thereafter, at about 2,000 mile intervals. The test was terminated at 7,500 miles after sustained elevated hydrocarbon levels indicated probable change in the combustion environment. The engine was then disassembled. Inspection of the engine parts revealed extensive, abnormal coke-like deposits. The severity of the deposit problem was such as to confirm an initial judgment that the fuel was unsuitable for use in engine tests of extended duration. At the same time, however, the relative stability of measurements, made over an approximate 5,000 mile interval, provides a basis for confidence that the short-term tests involved in emissions measurements are not perturbed by virtue of the fuel's abnormal gum and stability characteristics.

CONCLUSIONS

The study was limited by virtue of the shale-derived material being unsuitable for extended engine testing. Comprehensive compositional data on the hydrocarbon component of the engine emissions also were not obtained because modifications of the refining process to correct fuel deficiencies unquestionably would change exhaust composition. Exhaust composition studies should await definition of fully appropriate refinery processing.

For the motor gasoline, as tested, the following were observed:

(1) The gasoline was used satisfactorily in short-term engine tests. As compared with results observed using a reference gasoline widely used in lieu of typical U.S. petroleum-derived gasoline, change to synthetic fuel had no significant effect on emissions, fuel economy, or engine performance.

(2) Stability characteristics and high gum content of the shale-derived gasoline made it unsuitable for extended engine testing, but the fuel deficiency is judged correctable by appropriate choice of available refining technology and/or process adjustment.