

Exhaust Emission Analysis of the  
Williams Research Gas Turbine Volkswagen

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### Vehicle Tested

The Williams Gas Turbine, 131-Q, regenerative turbine automotive engine was mounted in a 1965 Volkswagen squareback test bed. The engine utilizes a two stage turbine to develop 70 horsepower. It incorporates the standard VW automatic transmission coupled to the engine through a gear reduction system. Non-leaded gasoline was used as fuel for these tests.

### Test Conducted

The standard 1972 Federal test procedure using the LA 4-S4 driving cycle with constant volume sampling was used.

The 1200 cfm CVS used for this test was modified slightly by blocking off the CVS filters and drawing dilution air from the room with mixing occurring at the vehicle exhaust outlet.

Oxides of nitrogen were measured using both the wet chemical modified Saltzman technique and the chemiluminescence instrument. Carbon monoxide was measured using non-dispersive infrared and hydrocarbons were determined using both the cold and hot flame ionization detector. Concentrations of all pollutants were measured in the CVS bag and hydrocarbon concentration was monitored continuously in the raw exhaust using the hot flame ionization detector.

Emission Results

The normal practice of subtracting the concentration of the background hydrocarbons in the dilution air from the hydrocarbon concentration measured in the CVS bag could not be used in this study. When sampling from low emission vehicles the hydrocarbons in the dilution air can contribute a major portion of the total hydrocarbons and the straight subtraction correction is no longer rigorous. Since the volume flow of the engine was known an alternate more correct calculation procedure could be used.

The concentration ( $C_t$ ) of the diluted sample in the CVS bag can be expressed as follows:

$$C_t = C_e \frac{V_e}{V_t} + C_b \frac{V_t - V_e}{V_t} \quad (1)$$

Where:

$C_t$  = concentration of total sample in bag

$C_e$  = concentration of integrated undiluted exhaust volume

$C_b$  = concentration of background contaminant dilution air

$V_t$  = volume of total sample (exhaust plus dilution air)

$V_e$  = volume of exhaust

Equation (1) can be rearranged solving for concentration of exhaust ( $C_e$ ):

$$C_e = (C_t - C_b \frac{V_t - V_e}{V_t}) \frac{V_t}{V_e} \quad (2)$$

The weight of emission (gm/mi) of each pollutant is obtained from:

$$W = K C_e V_e^1$$

Where: K = constant relating weight of emission to volume of exhaust per mile

$V_e^1$  = volume of exhaust per mile

Four LA 4-S4 tests were run, there was one aborted test because of a leaking exhaust manifold. There is some question to the validity of test #1 due to suspected sample contamination.

In Table 1 comparisons are made of all three tests using the 1972 Federal test procedure. Hydrocarbons in tests #2 and #3 are consistent, but in test #1 the value is considerably higher possibly reflecting the hydrocarbon contamination mentioned above. Carbon monoxide data is inconsistent, and nitrogen oxides also show a slight inconsistency.

In keeping with report policy for tests such as these oxides of nitrogen will be reported as NO<sub>2</sub> and an overall value will be arrived at by averaging two sets of data.

### Conclusions

By averaging two sets of data it was determined that the test vehicle did meet the 1975 standards; however, it should be noted that some slight inconsistencies do exist.

Because a new combustor design had been incorporated in the engine it was unadvisable at this time to perform a larger number of tests. Until such a series of tests can be performed to substantiate the data collected during this short test, a positive determination of emission levels cannot be made.

The driveability of this turbine car did not compare to a conventional internal combustion engine vehicle. Very little engine retardation was evident; acceleration was smooth but not rapid.

Table 1

1972 Federal Test Procedure

	Test #1* 12-1448	Test #2 12-1449E	Test #3 12-1455
HC gpm	.89	.36	.32
CO gpm	1.78	5.4	3.6
CO <sub>2</sub> gpm	1086.5	1094.5	988.4
NO gpm	1.44	1.55	1.27
NO <sub>2</sub> gpm	2.21	2.30	1.95

Average of tests #2 and #3:

HG gpm	CO gpm	NO <sub>2</sub> gpm	NO <sub>x</sub> **
.34	4.5	2.12	1.81

NO<sub>x</sub> corrected for Humidity:

Test #1	Test #2	Test #3
1.92	1.97	1.65

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gpm indicates calculated mass in grams per mile.

\* not used in calculations because of possible effect from the sample contamination on emissions.

\*\* NO<sub>x</sub> corrected for humidity.