# Emission Laboratory Correlation Study Between EPA and Audi - NSU Auto Union

by

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## ABSTRACT

This report presents the results of a laboratory correlation study between EPA and Audi - NSU Auto Union of Germany. An attempt is made to isolate equipment, procedure, and ambient differences which affect the degree of emission result correlation.

A research vehicle tested at both Audi and EPA revealed a good HC emission correlation, but significant discrepancies in measurements of CO and $NO_x$. Differences in dynamometers and ambient conditions seemed to be the most important factors affecting the degree of emission correlation.

# Emission Laboratory
# Correlation Study Between EPA and Audi - NSU Auto Union

## Introduction:

In an attempt to ensure a good laboratory correlation between Audi-NSU and EPA, a program was initiated to exchange information with Audi and relate that information to the emission test results of a research vehicle tested at both laboratories. The findings of that program, including conclusions regarding the factors affecting the degree of correlation, are the substance of this report.

## Organization and Sequence of Testing:

Because Audi's request for correlation information was made during peak demand for EPA certification work, a small scale testing program was a necessity. Also, since OMSAPC's Test and Evaluation Branch had already scheduled the Audi vehicle for evaluation testing, the correlation testing had to be arranged within the limitations of the vehicle's availability. Under these restrictions, EPA and Audi representatives agreed on the following program:

(1) Audi and EPA would exchange information relating to their facilities, equipment, and procedures.

(2) EPA would conduct three valid hot-start emission tests on the Audi vehicle on a certification site. Audi would provide data of similar tests at the Audi - NSU laboratory.

(3) Audi would submit static gases to EPA for analysis and comparison with values generated at the Audi laboratory.

Steps 1 and 2 of the program were initiated simultaneously on May 31. The gases required for Step 3 arrived at EPA on June 17, and their analyses was completed on EPA's Train - 15 on June 24.

## Test Procedures:

The vehicle emission tests conducted for this study were hot-start tests over the LA-4 cycle using only one set of collection bags. Sample collection was begun upon vehicle ignition as is done in 1975 federal tests. CVS flow rates were adjusted to accommodate the usage of only one sample bag. These vehicle tests were run at EPA on certification site #5.

Test Vehicles:

The vehicle used for correlation testing was a modified 1974 Audi Fox equipped with an oxygen - sensor system which controlled air-fuel ratio. The following data apply to this vehicle.

Model: Audi Fox
V.I.D: 8442000011
C.I.D: 97.0
Inertia Weight: 2500 pounds
Transmission: 4-speed manual
No. of Cylinders: 4

In testing this vehicle, dynamometer horsepower was set at 7.0 at 50 mph, a value different than Federal Register specifications. This was done because Audi had supplied appropriate data to EPA's Certification Branch such that their 1975 certification fleet will be tested at that setting.

Analysis of Data:

The analyses of Audi - NSU facilities data reveals the following comparative differences with the EPA facility.

| | EPA | Audi - NSU |
|---|---|---|
| Dynamometer | | |
| Drive Type | Direct | Belt |
| Roll Spacing | 17.25 in. | 20.25 in. |
| Driver's Aid | | |
| Chart Speed | 4 in./min. | 4.72 in./min. |
| Resolution | 60 mph=5.00 in. | 60 mph=4.56 in. |
| Facility Altitude (ft.) | 897.5 | 1276.3 |
| Analyzers | | |
| Span Gases (%Full Scale) | 75-96 | 47-97.5 |
| # Calibration Points | | |
| HC and $NO_x$ | 6 | 2 |
| CO and $CO_2$ | 6 | 8 |

Complete Audi - NSU and EPA facility data may be found in the Appendix.

In general, average emission levels measured on the Audi correlation vehicle were higher at the Audi facility than at EPA. Specifically, comparing average levels of three tests at each facility showed Audi 3.8% higher on HC, 19.3% higher on CO, and 56.6% higher on $NO_x$. No $CO_2$ values from the tests at Audi were available, so no comparison of $CO_2$ levels was possible. Complete vehicle emission test data are summarized in Table 1.

The static gas checks compared measurements of four span gases at EPA, Volkswagen, and two Audi analysis sytems. The largest discrepancies were revealed in HC ($C_3H_8$) measurements, where Audi's values were 5.2% and 4.3% lower than the EPA measurement. All CO and $CO_2$ values obtained at Audi and Volkswagen were lower than correponding readings at EPA, the maximum difference being 3.1%. The NO correlation was quite good, with Audi's Train II measuring the largest deviation from EPA's value, 2.3%. A summary of these calibration gas data is presented in Table 2.

Discussion:

Significant CO and $NO_x$ emission level differences between EPA and Audi-NSU were observed in this program, and several factors were documented which could possibly contribute to this problem. The most important factor is probably the dynamometer roll-spacing difference, Audi's 20.25 inch span vs. EPA's 17.25 inch. This difference significantly affects the tire-roll friction, especially since the test vehicle was equipped with relatively small tires (13" rims; approximately 11" inch rolling radius). The result of this difference is that the work necessary to complete the LA-4 driving cycle is significantly higher on the rolls of wider spacing. Thus the effect of the wider roll span would probably be higher levels of all emittants, the magnitudes of which would depend on the particular vehicle's characteristics. The Audi-EPA $NO_x$ discrepancy, although larger than would be expected because of roll spacing difference, may have been largely attributable to this factor. Perhaps the Audi vehicle was particularly sensitive to the effects of increased loading.

Another factor which may have significantly affected the correlation results is the difference in barometric pressure (facility altitude) between the two laboratories. Although Audi's oxygen - sensor emission control system should compensate for barometric differences, its effectiveness is not certain. A trend toward higher CO and HC measurements at Audi than at EPA would be a result of Audi's lower barometric pressure if the altitude compensation was not effective.

The influence of analyzer calibrations could also have had a significant effect on the emission correlation. The static checks showed that Audi would measure higher $NO_x$ levels (approximately 2%), and lower HC concentrations

(4-5%) than EPA, which would account for a minor portion of the $NO_x$ emission discrepancy. However, it would increase the HC emission difference. The effect of different HC and $NO_x$ analyzer techniques might also be important, since Audi's two point calibrations are not as accurate as EPA's six - point technique.

One other factor may have contributed significantly to the NOx emission differences, that being the test cell relative humidity. Audi typically tests their vehicles at humidity near 75 grains of water per pound dry air, while the EPA test cell measured an average of about 50 grains during testing. If the Audi vehicle was substantially less $NO_x$ sensitive than the correlation factor assumes, then the NOx factor over - corrected EPA results. Other correlation studies with American manufacturers have indicated that $NO_x$ measurements at EPA were frequently over - corrected.

Conclusions:

A comparison of laboratory test equipment and procedures and vehicle emission levels has indicated correlation problems between EPA and Audi-NSU. The most significant problem was revealed by Audi's average measurement of 56.6% higher $NO_x$ on the correlation vehicle. Audi's large dynamometer roll spacing is the most probable cause of the $NO_x$ discrepancy.

The difference in barometric pressures between the EPA and Audi - NSU laboratories did not seem to have a major effect on the degree of correlation on the vehicle tested, but it should be realized that this factor could be of greater importance on other control system configurations.

Differences between EPA and Audi - NSU analysis systems were discovered, but their effect on the emission discrepancies were minimal. However, Audi - NSU should be encouraged to compare the effects of six - point HC and $NO_x$ instrument calibrations to their current two - point technique.

Effects of ambient test cell humidity may have contributed slightly to the $NO_x$ correlation problem. EPA should continue its efforts to improve the consistency of its humidity controls and to bring the ambient condition of its test cells nearer the 75 grains of moisture specification.

TABLE 1

AUDI CORRELATION

Vehicle Audi - Fox 8442000011 Test 1972 Hot - Start

| Test Laboratory | Test No. | HC | CO | NOx | CO2 | Fuel Consumption | Barometric Pressure | NOx Factor |
|---|---|---|---|---|---|---|---|---|
| Audi - NSU | 1 | 1.19 | 13.89 | 3.66 | | | | |
| 3 Dynamometers | 2 | 1.11 | 14.41 | 3.33 | | | | |
| 3 Drivers | 3 | 0.94 | 11.81 | 3.30 | | | | |
| | AVE | 1.08 | 13.37 | 3.43 | | | | |
| | | | | | | | | |
| | 1 | 1.01 | 11.25 | 2.22 | 346 | 24.2 | 28.78 | 0.8872 |
| EPA | 2 | 1.03 | 11.23 | 2.13 | 343 | 24.3 | 28.80 | 0.8792 |
| 1 Dynamometer | 3 | 1.07 | 11.16 | 2.23 | 344 | 24.3 | 28.84 | 0.9289 |
| 1 Driver | AVE | 1.04 | 11.21 | 2.19 | 345 | 24.3 | 28.81 | 0.8984 |

Emission Values in grams/mile
Fuel Consumption in miles/gallon
Barometric Pressure in inches of mercury

TABLE 2

Audi Correlation

Calibration Gas Data

| Cylinder No. | Contents | EPA Reading | Facility Readings and Percent Deviation from EPA Reading | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | VW | % | Audi Train I | % | Audi Train II | % |
| 100 098 | $C_3H_8$ | 116.19 ppm | 114 | -1.7 | 111 | -4.3 | 110 | -5.2 |
| 200 178 | CO | 1874.96 ppm | 1825 | -2.7 | 1855 | -1.1 | 1862 | -0.7 |
| 100 030 | NO | 122.7 ppm | 122 | -0.8 | 124.5 | +1.5 | 125.5 | +2.3 |
| 100 053 | $CO_2$ | 3.538 % | 3.43 | -3.1 | 3.43 | -3.1 | 3.47 | -2.0 |

# APPENDIX

LABORATORY CORRELATION

DATA SUMMARY

TEST FACILITY EPA #6

A. Dynamometer

Manufacturer Clayton Model CTE - 50 Absorber HP 50

Torque Bridge Strain Gage Inertia Style Direct Drive Auto

Loader Not Used Roll Diameter 8.65 in. Roll Spacing 17.25 in.

Calibration Procedure Coast - downs at 4,8, and 14 indicated horsepower used to calculate actual absorbed horsepower vs. indicated horsepower for each inertia weight.

B. Driver's Aid

Manufacturer Varian Control Manual Scaling 5 inches = 60 mph, 4 inches/minute Speed Signal Origin Rear Roll

C. Ambient Monitors

Facility Altitude 897.5 feet

Location of:

Barometer Wall of Test Cell

Humidity Sensors 1) Center of Cell - Ambient, 2) Dilution Air Inlet

Nominal Test Cell Humidity See Test Results

D. Analysis System

1. HC Analyzer

Manufacturer Beckman Model 400

Fuel Used $H_2$ / $N_2$ Zero Gas Air

Ranges Used 50/100

Span Gas (es) 41/89.5

Curve Fit Linear

# Cal. Points 6 Hi 98.05 Lo 10.24

2. CO Analyzers

Manufacturer Bendix Model 850

Ranges Used 500/1000

Span Gas (es) 427/923

# Cal. Points 6 Hi 470 Lo 94

Curve Fit 3 rd Order

Zero Gas $N_2$

Manufacturer Beckman Model 315A

Range Used 2500

Span Gas 2112

3. $NO_x$ Analyzer

Manufacturer Teco Model 10A

Zero Gas $N_2$ Curve Fit Linear

Range (s) Used 100

Span Gas (es) 95.8

# Cal. Points 6 Hi 91.2 Lo 8.5

4. $CO_2$ Analyzer

Manufacturer Beckman Model 315A

Zero Gas $N_2$ Curve Fit 3rd Order

Ranges Used 3.3%

Span Gas (es) 2.5%

# Cal. Points 6 Hi 3.33 Lo .78

E. CVS System

Manufacturer Air Monitoring, Inc. Model 705-G

Calibration Date 5/17/74

Calibration Technique Laminar Flow Element & Propane Injection.

Results of Last 3 Propane Injections:

| | | | |
|---|---|---|---|
| Date | 5/20/74 | 5/21/74 | 5/31/74 |
| % Error | -1.92 | 0.326 | 0.946 |
| P | 8.25 | 8.20 | 5.10 |

LABORATORY CORRELATION

DATA SUMMARY

TEST FACILITY Audi NSU Ingolstadt #3

A. Dynamometer

Manufacturer Clayton Model EC 200 modified Absorber HP 50

Torque Bridge spring loaded coil Inertia Style mech - V - Belt Auto

Loader none Roll Diameter 8.65" Roll Spacing 20.25"

Calibration Procedure Coast down at 4, 8 and 12 indicated hp used to calculate actual hp vs. indicated hp for 2000, 2500 and 3000 lbs

B. Driver's Aid

Manufacturer Withoff Control manual Scaling 120 mm=100 km/hr (63 mph), 2 mm/sec Speed Signal Origin rear roll

C. Ambient Monitors

Facility Altitude 1276.3 feet

Location of:

Barometer Wall of Test Lab

Humidity Sensors Test cell near dilution air inlet

Nominal Test Cell Humidity 50% ± 5

D. Analysis System Train II

1. HC Analyzer

Manufacturer IPM Model RS 5

Fuel Used $H_2$ Zero Gas Air

Ranges Used 200 ppm

Span Gas (es) 94

Curve Fit Linear

# Cal. Points 2 Hi 1 98 Lo 99

2. CO Analyzers

Manufacturer H & B Model URAS II

Ranges Used 750 ppm

Span Gas (es) 472

# Cal. Points 8 Hi 745 Lo 74.5

Curve Fit Linearized

Zero Gas $N_2$

Manufacturer H & B Model URAS II

Range Used 3000 ppm

Span Gas 1895

3. $NO_x$ Analyzer

Manufacturer Teco Model 10A

Zero Gas - Curve Fit linear

Range (s) Used 100 ppm

Span Gas (es) 97.5

# Cal. Points 2 Hi 97.5 Lo 48.75

4. $CO_2$ Analyzer

Manufacturer H & B Model URAS 2T

Zero Gas $N_2$ Curve Fit Linearized

Ranges Used 5%

Span Gas (es) 3.65%

# Cal. Points 8 Hi 5.0% Lo 0.5%

E. CVS System

Manufacturer Audi Model Mk II

Calibration Date last: 4-30-74

Calibration Technique Laminear flow element and propane injection

Results of Last 3 Propane Injections:

| | | | |
|---|---|---|---|
| Date | 8-9-73 | 1-11-74 | 4-30-74 |
| % Error | 0.97 | 1.02 | 0.97 |
| P | 0.5" | 0.5" | 0.5" |