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DIESEL FUEL STUDY

MARICOPA ASSOCIATION OF GOVERNMENTS

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STATEMENT OF PURPOSE AND SUMMARY OF FINDINGS

The purpose of the Diesel Fuel Study is to examine and evaluate the consequences of converting Phoenix Transit vehicles from the fuel source presently used, Diesel Number 1, to Diesel Number 2. In the past, studies have reached the conclusion that, in spite of some beneficial impacts, Diesel Number 2 was not suitable for use in high idling conditions and the resultant volume of exhausted smoke was unacceptable in an urban environment.

The recent development and commercial availability of a catalyst designed to eliminate the excessive smoke associated with Diesel Number 2 has prompted this investigation. The preliminary indications from other southwest transit systems are favorable with regards to the performance of this catalyst.

In December 1982, the Maricopa Association of Governments in conjunction with the City of Phoenix Public Transit Administration and the Phoenix Transit System initiated an experiment in which Phoenix Transit buses were, for purposes of comparison, split into two groups and fueled separately. One group was fueled with Diesel Number 1 and the other with Diesel Number 2 and the catalyst. The experiment was designed to measure fuel cost, fuel economy (MPG), exhaust emissions and engine maintenance.

The preliminary findings from the experiment show that Diesel Number 2, when used with the catalyst tested, is cheaper to purchase and produces better mileage per gallon than Diesel Number 1. Together these two improvements could produce annual savings ranging from $188,000 to $242,000 for the Phoenix Transit System if all the buses were operated with Diesel Number 2 and the catalyst. In terms of exhaust emissions and smoke production, Diesel Number 2 with the catalyst was cleaner burning than Diesel Number 1 and it significantly reduced the harmful exhaust emissions. The test period has not been long enough to measure the impact on engine maintenance. Since Diesel Number 2 has a higher lubricant content than Diesel Number 1, it is anticipated that engine maintenance and down time will be reduced.

In order to allow more time to monitor the engine maintenance program and to observe the smoke production during the hot summer months (when the smoke problem is typically at its worst), the test period will be extended through the summer. At that time, the vehicular performance will again be analyzed. If the findings substantiate the results recorded to date, the entire Phoenix Transit fleet will be converted from Diesel Number 1 to Diesel Number 2 with a catalyst similar to that tested.

BACKGROUND

The two grades of diesel fuel in general use are Diesel Number 1 and Diesel Number 2. The basic difference between Diesel Number 1 and Number 2 is one of viscosity and volatility. The viscosity or "thickness" of a fuel can affect injection spray pattern which, in turn, determines to a degree fuel economy. The volatility deals with the ease of ignition of a fuel. The higher the volatility the quicker it ignites and burns. Fuels with high volatility and low viscosity produce less smoke in high idle situations.

Some of the characteristics of the two grades of diesel fuel are:

Diesel Number 1

- Diesel Number 1, known as white fuel, has a higher volatility and lower viscosity than Number 2.
- Number 1 ignites and burns quicker producing less exhaust smoke in high idle situations than Number 2.
- Number 1 is more refined and, therefore, more clean burning than Number 2.

Diesel Number 2

- Number 2, known as diesel oil or black fuel, has a lower volatility and higher viscosity than Number 1.
- Due to higher viscosity Number 2 will exhibit flowing problems when the temperature falls below 20°F.
- In high idling conditions, Diesel Number 2 tends to produce excessive amounts of exhaust smoke.
- Diesel engines operate more efficiently on Number 2 because it provides more power.
- Number 2 has a high lubricant content and is supposed to reduce engine wear.
- Number 2 is generally more readily available than Number 1.
- Number 2 costs approximately eight cents per gallon less than Number 1.

For many years, the Phoenix Transit System like most other transit systems has been using Diesel Number 1 rather than Diesel Number 2 primarily due to the fact that it smokes less. However, various fuel catalysts and additives have recently been developed and made commercially available in order to reduce smoking. If these claims are factual, the use of Diesel Number 2 with such a catalyst would become feasible and would produce significant cost savings for Phoenix Transit.

DISCUSSION

Productivity improvements and cost reductions are continuing goals for the transit planning efforts in the Phoenix Urbanized Area. On December 1, 1982, the Maricopa Association of Governments in cooperation with Phoenix Transit and the Phoenix Public Transit Administration initiated an experiment to compare the performance of vehicles fueled with Diesel Number 1 to vehicles fueled with Diesel Number 2 and a catalyst called CV 100. Vehicles assigned to the North Maintenance Facility began using Diesel Number 2 with this catalyst. South Facility vehicles continued to use Diesel Number 1.

CV 100 combustion fuel catalyst is an iron-based, organometallic compound, produced by Carvern Petrochemical Company Ltd., which functions as a combustion catalyst at the moment of ignition when mixed with liquid hydrocarbon fuels. According to the manufacturer, the effect of this catalytic reaction is that a more uniform and thorough combustion occurs which improves fuel economy, reduces engine deposits and reduces harmful emissions.

The test comparison study covered three areas: (1) Exhaust Analysis which compared emissions from like type vehicles operating out of the North Facility with those operating out of the South Facility, (2) Mileage (fuel economy) which compared North Facility vehicles using diesel fuel Number 1 from February through April 1982 to the same vehicles using diesel fuel Number 2 from February through April 1983, and (3) Engine Maintenance which examined the maintenance records of the vehicles in the test.

EXHAUST ANALYSIS

Exhaust emission concentrations from a select number of North Facility vehicles using Diesel Number 2 treated with CV 100 were compared to a selected number of similar units from the South Facility which use Diesel Number 1 without CV 100. In addition, smoke levels were monitored and compared on vehicles which were using Number 2 to those which continued to use Number 1.

Methodology

Six similar vehicles from each Facility were used in the comparison: 2 RTS 03's, 2 RTS 04's and 2 M.A.N.'s. Vehicles were selected on the basis of similar maintenance records (date of last inspection, etc.). A Sun Electric Multiple Gas Analyzer (MGA-90) was used to measure exhaust gas concentrations at a fixed RPM and load. The MGA-90 is a non-dispersive, infrared analyzer accurate to $\pm 3\%$ full scale. The exhaust gases measured were Carbon Dioxide (CO_2), Oxygen (O_2), unburned Hydrocarbons (HC), and Carbon Monoxide (CO). Each unit was tested twice and an average for these exhaust gases was established.

Exhaust Analysis Summary

When the North Facility vehicles on Diesel Number 2 were compared to the South Facility vehicles on Diesel Number 1, a reduction of 9.26% in Carbon Dioxide (CO_2), an increase of 5.52% in Oxygen (O_2), a reduction of 41.16% in Hydrocarbons (HC), and total elimination of Carbon Monoxide (CO) had occurred. (It should be noted that CO was minimal in the South Garage units too.) All harmful emission levels were significantly reduced by weight and volume. See Tables I, II and III.

The Sun Electric MGA-90 Multiple Gas Analyzer utilizes a Fram G-12 (25 micron) Filter as the primary filter on the exhaust gas sampler hose. A new Fram G-12 Filter was installed just prior to testing the South Facility vehicles (June 1, 1983). Another new Fram G-12 Filter was installed just prior to testing the North Garage buses (June 2, 1983). Both filters were cut in half on June 2, 1983 upon conclusion of the testing. The filter from the North Facility vehicles unquestionably contained substantially less particulate content. The particulates which did exist were a light grey in color, ash-like, and significantly smaller particle size as compared to the large, black, more voluminous content in the filter which had been used for the South Facility vehicles. Indications are that diesel fuel treated with CV 100 does provide a "cleaner burn".

Visible smoke exhaust from the North Facility vehicles (Number 2 with CV 100), when compared to the South Facility vehicles (Number 1 only) was either the same or less intense. During the test period documentation was maintained by Phoenix Transit System of citizen complaints of bus exhaust smoke. There was not one public complaint received during this time that was not attributable to an engine problem. Excessive smoke, a consistent problem with urban transit vehicles utilizing straight Diesel Number 2, was not a problem for Phoenix Transit when the fuel was treated with CV 100 Combustion Fuel Catalyst.

MILEAGE

The initial approach to the mileage study was to compare the mileage records of vehicles assigned to the South Facility using Diesel Number 1 to vehicles assigned to the North Facility using Diesel Number 2. However, after close scrutiny this was not a feasible approach. Thirty-five percent of the fleet is assigned to the North Facility with many of the vehicles running express routes only. Diversity in the type of routes made a mileage comparison of North and South Facility vehicles infeasible. Therefore, only North Facility vehicles were used in the mileage study.

Methodology

Computerized mileage data was collected from the Phoenix Transit System Vehicle Master File. This data provided the number of miles each vehicle travels per month, the number of gallons of fuel expended and the number of miles per gallon. Buses were readily identified as to type and location assignment by vehicle number. Using North Facility vehicles, a mileage comparison was made

of (1) vehicles operating on Diesel Number 1 from February 1982 through April 1982; to (2) the same vehicles operating on Diesel Number 2 with CV 100 for the three month period of February 1983 through April 1983. Vehicles were deleted from the study which produced irratic results and/or due to out-of-service condition. A total of 88 buses were used in the comparison: 4 RTS 03's, 28 RTS 04's, 48 AM Generals and 8 M.A.N.'s. (See Table IV).

Mileage Summary

The North Facility vehicles have been using Diesel Number 2 with CV 100 exclusively since December 1982. After allowing for a break-in period, mileage data was used for the three-month period of February 1983 through April 1983. Mileage data for this period was compared to February through April 1982 mileage data. This comparison showed a weighted average increase in miles per gallon of 3.46 percent using Diesel Number 2 with CV 100. The MGA-90/Carbon Balance Method showed a 6.53% improvement in fuel efficiency. The latter test removes all variables existing in any MPG comparison and is thus a more acceptable method for the industry in general. Of the 88 vehicles studied, only 5 vehicles, all 1981 RTS 04's, averaged a decrease in fuel economy for the three-month period. (See Table IV). Maintenance records on these five 1981 vehicles were reviewed but no concrete conclusions could be drawn to explain the decrease. While study shows a variance in the amount of increase among bus types, figures indicate a consistent increase in overall fuel economy.

MAINTENANCE

Phoenix Transit has not changed any operational or maintenance procedures since using Diesel Number 2 and has noticed no detectable difference in required maintenance or problems which may be attributed to its use.

Presently, data is being recorded by Phoenix Transit which will provide a cumulative maintenance data base for future consideration. Within six to twelve months, there will be sufficient documentation of engine failures to compare the maintenance records of those buses using Diesel Number 1 with buses using Number 2. Phoenix Transit soon will be capable of rebuilding bus engines and documentation would become part of the maintenance record. This documentation then could be used to establish a base for comparing the effects of using Diesel Number 2 with CV 100.

Even though the testing period has not been long enough to substantiate the advantages of CV 100 in regard to engine maintenance, it is expected that there will be a reduction in engine downtime.

SUMMARY/RECOMMENDATIONS

The test data collected to date shows that the use of Diesel Number 2 treated with a catalyst like CV 100 is superior to using Diesel Number 1 because it is significantly cheaper, it is more readily available, it lowers the level of harmful emissions, it produces a "cleaner burn" thereby reducing smoke and particulates and it raised the overall fleet performance in terms of miles

operated per gallon of fuel used. Through the present time, smoking exhaust has not worsened and there has been no detectable difference in required engine maintenance. It is expected that with the continued use of Diesel Number 2 and such a catalyst engine downtime will be reduced.

Other transit properties have recently found similar positive results with the use of CV 100 and Diesel Number 2. Environmental Protection Agency-approved tests conducted at the Automotive Testing Laboratories, Inc. in Aurora, Colorado showed fuel economy improved by 3% to 10% as well as reduced emissions in all categories.

CONCLUSION

Phoenix Transit System vehicles assigned to the North Facility using Diesel Number 2 with CV 100 showed an increase in fuel economy of 3.46 percent. This, coupled with the fact that a gallon of Diesel Number 2 with CV 100 is approximately $0.062 less than a gallon of Diesel Number 1, would result in an estimated annual savings of approximately $188,000 if the entire fleet were converted to Diesel Number 2 with CV 100. (See Table V). Cost savings could rise to approximately $242,000 if actual mileage improvement achieves the lab results. Due to the limited period of this experiment, testing will continue through the summer (the time during which exhaust smoke is the worst) and an addendum to this report will be prepared in the Fall of 1983. If the conclusions substantiate these initial findings, the entire Phoenix Transit fleet will be converted from Diesel Number 1 to Diesel Number 2 with a catalyst like the one tested.

TABLE I
PHOENIX TRANSIT SYSTEM
PHOENIX, ARIZONA

	SOUTH GARAGE RTS 03 AVG.	NORTH GARAGE RTS 03 AVG.	% IMPROVED NORTH OVER SOUTH	SOUTH GARAGE RTS 04 AVG.	NORTH GARAGE RTS 04 AVG.	% IMPROVED NORTH OVER SOUTH	SOUTH GARAGE P-6 M.A.N. AVG.	NORTH GARAGE P-6 M.A.N. AVG.	% IMPROVED NORTH OVER SOUTH	ALL SOUTH GARAGE UNITS AVG.	ALL NORTH GARAGE UNITS AVG.	TOTAL % IMPROVED NORTH OVER SOUTH
CARBON DIOXIDE (CO_2)	4.33	4.30	-.70%	4.5	3.91	-13.11%	7.375	6.49	-12.0%	5.40	4.90	-9.26%
OXYGEN (O_2)	15.0	15.125	+.83%	14.625	15.515	+6.09%	11.125	12.35	+11.01%	13.58	14.33	+5.52
HYDROCARBONS (HC)	8.67	5.75	-33.68%	14.0	5	-64.29%	11.75	9.5	-19.15%	11.47	6.75	-41.16%
CARBON MONOXIDE (CO) (*)	-0-	-0-	-0-	.001	-0-	-100.00%	.0015	.001	-33.33%	----	----	

(*) CARBON MONOXIDE (CO) WAS MINIMAL IN THE SOUTH GARAGE BUSES. NONETHELESS, WHAT CO DID EXIST WAS, FOR ALL PRACTICAL PURPOSES, ELIMINATED ON THE NORTH GARAGE BUSES.

TABLE II
PHOENIX TRANSIT SYSTEM
SOUTH GARAGE
Diesel Number 1

	RTS 03 8V-71 4510*	RTS 03 8V-71 4527	RTS 04 6V-92T 4407	RTS 04 6V-92T 4411	P-6 M.A.N. 7020	P-6 M.A.N. 7011
Carbon Dioxide (CO_2)		4.33	4.3	4.7	7.6	7.15
Oxygen (O_2)		15	14.8	14.45	10.8	11.45
Hydrocarbons (HC)		8.67	16.5	11.5	15	8.5
Carbon Monoxide (CO)		0	.002	0	.002	.001
Temperature		438	373.5	361	497.5	573.5
Flow		1450	1510	1510	1420	1420

BUS NO. 4510 (RTS 03) WAS DISREGARDED DUE TO LOW TEMPERATURE AND SUBSEQUENT IRRATIC AND INCONSISTENT READINGS.

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TABLE III
PHOENIX TRANSIT SYSTEM
NORTH GARAGE
Diesel Number 2 Treated With FPC-1

	RTS 03 8V-71 4536	RTS 03 8V-71 4537	RTS 04 6V-92T 4402	RTS 04 6V-92T 4406	P-6 M.A.N. 7003	P-6 M.A.N. 7006
Carbon Dioxide (CO_2)	4.65	3.95	3.75	4.07	6.55	6.43
Oxygen (O_2)	14.75	15.5	15.7	15.33	12.37	12.33
Hydrocarbons (HC)	7.5	4	5	5	9.33	9.67
Carbon Monoxide (CO)	.0005	0	0	0	.001	.001
Temperature	429.5	436	355	393	450.33	461.67
Flow	1450	1450	1510	1510	1420	1420

TABLE IV
DIESEL FUEL STUDY
NORTH FACILITY VEHICLES
MILEAGE COMPARISON OF DIESEL NUMBER 1 AND NUMBER 2

Vehicle I.D. Number	Total Number of Vehicles	Feb. '82 - Apr. '82 Average MPG (1)	Feb. '83 - Apr. '83 Average MPG (2)	Percentage of Increase (or Decrease) in MPG Comparing Feb. '82 - Apr. '82 to Feb. '83 - Apr. '83
4401 & 4402				
4404 - 4406 (4)	5	3.83	3.68	(3.92)
(RTS 04)				
4533, 4534,	4	3.13	3.29	5.11%
4536 & 4537 (4)				
(RTS 03)				
4538 - 4560 (3)	23	N/A	3.94	N/A
(RTS 04)				
4756 - 4788	33	3.92	4.03	2.81%
(AM Gen'l)				
5101 - 5115	15	3.90	4.11	5.38%
(AM Gen'l)				
7001 & 7002				
7004 & 7005 (4)	8	3.23	3.25	0.62%
7007 & 7010				
(M.A.N.)				
Weighted Average MPG	65	3.76	3.89	3.46%

(1) Operating on Number 1 Diesel Without FPC-1.

(2) Operating on Number 2 Diesel With FPC-1.

(3) New Buses in July, 1982.

(4) Vehicle I.D. Numbers 4403, 4531, 4532, 7003 & 7006 Deleted Due to Irratic Results and/or Low Mileage on Out-of-Service Condition Since the Addition of FPC-1.

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TABLE V

DIESEL FUEL STUDY

PROJECTED SAVINGS
USING DIESEL NUMBER 2

With no change in fuel economy:

Diesel #1	2,040,509 gallons @.933	=	$1,903,794.90
Diesel #2	2,040,509 gallons @.871*	=	$1,777,283.30
			$ 126,511.60

With a 3.46% increase in fuel economy:

Diesel #1	2,040,509 gallons @.933	=	$1,903,794.90
Diesel #2	1,969,907 gallons @.871	=	$1,715,789.00
			$ 188,005.90

With a 6.53% increase in fuel economy:

Diesel #1	2,040,509 gallons @.933	=	$1,903,794.90
Diesel #2	1,907,264 gallons @.871	=	$1,661,226.90
			$ 242,568.00

*Cost includes .015 for FPC-1

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