A REVIEW AND ANALYSIS OF THE GOOD FAITH OF THE AUTOMOBILE INDUSTRY IN ATTEMPTING TO COMPLY WITH THE STATUTORY 0.4 NOx STANDARD

a report to

the

Senate Public Works Committee,

U.S. Congress

U. S. Environmental Protection Agency

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INTRODUCTION

This report has been prepared by the U.S. Environmental Protection Agency (EPA) in response to a request (Appendix A) from the Honorable Edmund S. Muskie, Chairman, Subcommittee on Environmental Pollution, U.S. Senate Public Works Committee, on November 18, 1974, to investigate and report on the good faith of the auto industry efforts in meeting the 0.4 gram per mile (gpm) Nitrogen Oxide (NOx) standard established by the Clean Air Act of 1970.*

A letter was sent to the manufacturers on January 6, 1975, (Appendix B), requesting that they submit information on their low-NOx efforts by March 1, 1975. The material received, in addition to other submissions and suspension documents, formed the major body of information used in preparing this report.

The report is divided into six sections. Section 1 summarizes the body of the report. Section 2 provides the history of the "good faith test" under Title II of the Clean Air Act. The remaining four sections analyze the actual level of efforts of the industry as a whole and the major manufacturers - General Motors (GM), Ford, Chrysler, and American Motors (AMC) - with only some brief references to foreign manufacturers. In the opinion of the report team, what the domestic manufacturers have or have not done is of the greatest relevance to

*The 0.4 gpm NOx standard is to be met in conjunction with standards for Hydrocarbons of 0.41 gpm and 3.4 gpm of CO. The designation for emissions used in this report will be such that the above mentioned standards are denoted by 0.41 HC, 3.4 CO, 0.4 NOx.

the issue of good faith efforts; in any case, review of the foreign manufacturers' submittals indicated little difference in basic approach between the foreign manufacturers and the domestic manufacturers.

The submittals of all manufacturers were generally somewhat less than fully adequate. Some foreign manufacturers did not respond at all. However, the short time in which the manufacturers had to reply possibly influenced their submittals, making most of the results just copies of earlier submissions.

In addition to the submittals, the report team has reviewed other documentation, primarily manufacturers' Status Reports and suspension applications.

One obvious characteristic of almost all of the domestic manufacturers' development programs is a fairly recent upsurge of effort.

Section 1 - SUMMARY AND CONCLUSIONS

The state-of-the-art of NOx emission control technology is such that most manufacturers will be unable to certify vehicles at 0.41 gpm HC, 3.4 gpm CO, and 0.4 gpm NOx for the 1978 model year. Most manufacturers have not developed the advanced prototype systems required for certification at the full statutory standards, and inadequate lead time remains for development and testing of a full line of prototypes to meet market demand in 1978.

A comparison of emission expenditures with sales and profits in 1973 and 1974, shows that emissions research in 1974 was not significantly reduced even when profits were substantially lower than those in 1973. Chrysler, which stated that it spent 33-40% of its emission budget on NOx control, only reduced its emission expenditures by 10% at the same time it reported a loss of $52 million and its unit sales dropped 25%. Similarly, both Ford and General Motors reported a substantial drop in earnings while emissions expenditures rose 19% and 46% respectively. The issue of whether the expenditure levels for 1973 and earlier years constitute a good faith effort was essentially dealt with in the 1973 NOx Suspension decision, in which EPA found that the sums spent by the manufacturers were adequate to satisfy a "good faith effort." As a proportion of their total research and development budgets for 1974 the fractions allocated by those companies to emission control development were 16% for GM, 22% for Chrysler, and 24% for Ford. Therefore, based solely on resource commitments, it is difficult to find fault with the auto companies priorities when related to the financial condition of the industry in 1974.

A review of the record of manufacturers' and vendors' research, development, and testing and evaluation programs, however, shows that:

- The automotive industry has not in most cases combined all of their best systems on test vehicles.
- The automotive industry has not vigorously pursued and fully exploited the developments of independent vendors.
- The efforts of some auto manufacturers directed toward the 1978 statutory emission standards have dramatically decreased during the past year.
- Some manufacturers have redirected their alternate engine problems toward a 2.0 NO_x level rather than 0.4 NO_x.
- Some manufacturers have redirected their efforts from dual catalyst systems to 3-way catalysts which appear at the present time to require more research to establish their durability and, hence, longer leadtimes before implementation than dual catalyst systems.

Taken in their entire context, the above conclusions suggest that a maximum effort was not made by the automobile industry to meet the 1978 emission standards of 0.41 gpm HC, 3.4 gpm CO, and 0.4 gpm NOx. The question of whether all good faith efforts were made, however, must also take into account the following considerations:

- As early as 1972, EPA disclosed that an error was made in the Federal Reference Method measurements of ambient NO_2, which formed the basis for the 0.4 gpm NOx emission level, resulting in an overstatement of the number of cities and amount by which cities would violate the 100 ppm NO_2 ambient air quality standard.
- In reconsideration of the need for 0.4 NOx, EPA suggested to Congress in a letter to Senator Randolph dated November 11, 1973, that the timetable for reaching statutory NOx be stretched out with 2.0 NOx required from 1977-1981, 1.0 NOx from 1982-1989, and 0.4 NOx not required until the 1990 model year.
- Congress has not resolved the uncertainty raised by the EPA disclosure and recommendations. Congress has delayed the implementation of the 0.4 NOx standard by one year, but has not dealt with the greater issue of whether or not 0.4 NOx is still required to protect public health.

As explained in Section 2 - Background - this report provides objective information on the magnitude of efforts but refrains from making a conclusive "determination" on good faith. In particular, this report does not conclude whether the complicating considerations just listed provide any justification for lack of adequate efforts, although in a strictly legal sense only an actual change in the statute - not mere recommendations and discussions - would absolve a company of its obligation to make all good faith efforts.

Section 2 - BACKGROUND

The 1970 Clean Air Act Amendments

The 1970 Amendments represented a major change in the legislative approach toward controlling automobile emissions. The Amendments were technology forcing, i.e., when they were passed the technology to meet the requirements was not available and the purpose of the Amendments was to force the needed development.

Under the 1970 Amendments, the EPA Administrator could consider requests from automobile manufactueres for a one-year suspension of the legislated standards. In acting on suspension requests, the Administrator was required to rule on each of four criteria: (1) public welfare or public health, (2) technological development, (3) a report from the National Academy of Sciences and (4) the exertion of all good faith efforts on the part of the manufacturers to meet the standards. Section 202(b)(5)(c).

Before this report was written, there was no published EPA "methodology" that could be used to determine good faith. This is in contrast to the methodology used by EPA to determine the technical capability to comply with the standards. The technical methodology has been the subject of discussion during the various EPA suspension hearings, and also was an area in which EPA received some guidance and direction from the Court of Appeals in International Harvester versus Ruckelshaus. It is more difficult to produce a quantitative "methodology" for a good faith determination. Attempts have been made in the various decisions of the Administrator on manufacturers' requests for suspension of the statutory standards. This chapter will expand somewhat on those previous discussions. This is, of course, an issue on which interested parties are likely to comment, and we invite them to do so.

Ideally, an analysis of the good faith efforts toward meeting any emission standard should start with a universally agreed-to definition of good faith. Unfortunately, such a definition is not available. Therefore a review has been made of what has been previously published on the good faith issue.

EPA has acted four times on applications for suspension. These four decisions in chronological order are for convenient reference referred to on the Original Decision (1972), the Remand Decision (April 1973), the NOx Decision (July 1973), and the Sulfate Decision (1975) in this report.

Listed below are the key good faith aspects of the four decisions:

Decision	Good Faith Implications
Original (HC, CO) (May 1972)	No good faith determination specifically made. The Administrator considered that his denial, based on technological feasibility, did not require a specific decision on the other three issues.

Decision (cont.)	Good Faith Implications (cont.)
Remand (HC, CO) (April 1973)	The "nuclear deterrent" aspect of a non-good faith finding was discussed, and the implication was that a finding of less than all good faith efforts would require a sanction too severe to employ.
NOx (July 1973)	The severe consequences of the "nuclear deterrent" were again mentioned.
Sulfate (HC, CO) (March 1975)	Good faith was considered to be essentially met since the standards could be attained and meeting the standards was considered to be good faith.

What is "Good Faith"?

The Original Decision made the first time the automobile manufacturers applied for suspension of the HC and CO standards. It was a denial, and the resulting judicial review (International Harvester vs. Ruckelshaus) led to the Hearings on Remand and the Remand Decision.

In the Original Decision the Administrator did not make a definitive determination on good faith. His reading of the law was that since the technology was available, in his opinion, he was not under the law required to make a specific good faith determination.

He did, however, provide a discussion of the good faith issue. After a discussion of the monetary expenditures of the applicants, he said:

"that the level of expenditure of the automobile industry as a whole would appear to meet the test of good faith and to be consistent with the intent of the Act."

However, he went on to say:

"It is clear that a substantial financial commitment to emission control research and development is not a sufficient basis by itself for me to find that all good faith efforts have been made by an applicant. In my view, I am empowered to make the required determination on good faith only if a manufacturer's overall program for compliance with 1975 emission standards has been clearly structured with a view to achieving timely compliance with the Act's requirements if possible and has been expeditiously executed. The manufacturer must have or create adequate in-house capability to develop and test necessary components, or he must provide necessary assistance to independent developers and vendors of such components or show why such assistance is not necessary. Equally important, the manufacturer must establish and implement a system which adequately integrates his own development program with those of suppliers on whom he is likely to be dependent. The manufacturer's development program must include adequate provision for promptly testing promising technology as it is developed, and he must react promptly and reasonably to the test results which are forthcoming."

In other words, good faith involves not only the commitments of resources, but also the use of those resources. Conversely, however, the failure to commit substantial resources may constitute, in effect, a prima facie indication of a lack of good faith, and will impose a much heavier burden on the company seeking to show that all good faith efforts have in fact been exerted.

In the court decision to remand the Original Decision to EPA on certain technical grounds, the Court of Appeals for the District of Columbia Circuit also suggested that explicit determinations be made on all four issues before the Administrator (public interest or public health, good faith, availability of technology, NAS report).

In the Remand Decision, the Administrator dwelt at length on the good faith of Chrysler, analyzing both resource commitment and research and development decisions. In the end he found all the applicants in good faith. The difficulty faced by the Administrator on the good faith issue was mentioned in his press conference revealing his Decision where he said:

> "The issue of good faith as it relates to Chrysler Corporation has been particularly troublesome for me in these proceedings. I have covered this issue in some detail in my decision and will not dwell on it here. If Congress had provided me with some sanctions short of the nuclear deterrent of in effect closing down that major corporation, my findings on good faith may have been otherwise."

In a sense, he considered the "punishment", denial of the suspension request and shut down of production) too severe to fit the nature of the "crime" (lack of good faith).

The "nuclear deterrent" issue also influenced the next EPA decision, the NOx Decision. In it, the Administrator said:

> "The good faith question is little changed from prior hearings. As in May 1972, I am disturbed by the apparent lack of adequate coordination between automobile companies and catalyst supplier.
>
> As before, however, the evidence, when weighed with an eye to the drastic consequences of a denial of suspension on this ground, supports the conclusion that the requirements of the statute have been met."

In the most recent decision, the Sulfate Decision, after some discussion of the manufacturers' expenditures, the Administrator said:

> "By the standards of past suspension decisions, these expenditures would be taken as sufficient to satisfy the "good faith" test in its financial aspect. What is more disturbing is the significant decline since 1973 in emission testing of vehicles (except for testing by Ford) aimed at meeting the statutory HC and CO emission standards. This drop-off is clear from the face of the Technical Appendix."

In other words, the Administrator was again looking beyond the mere commitment of resources to the decisions made as to the use of those resources. The Administrator went on to say:

> "There might be some difficulty in making a finding of good faith in the face of such a testing effort but for one factor. The industry, both the NAS and my technical staff agree, has developed the technology to attain the statutory HC and CO standards in the 1977 model year. Since there is no requirement that a company spend more than is needed to meet the standards, the success of the auto industry here warrants a finding of 'good faith' by definition."

This final addition to the approach to evaluating good faith is based on the fact that the primary goal of the statute is attainment of a fixed standard, and efforts are only required insofar as the standard is still unmet. A similar view of the technology forcing aspect of the Act was recently expressed by the U.S. Supreme Court in Train versus N.R.D.C., _____ U.S._____, 7 ERC 1735, 1745, 43 L.W. 4467, 4476 (April 16, 1975).

Finally, it should be mentioned for the sake of completeness that the Administrator has recently made the first "good faith" determination under section 110(f) of the Act - a provision essentially identical to section 202 (b)(5)(c), but applicable to stationary sources. In re: Application of the Governor of West Virginia Pursuant to Section 110(f) of the Clean Air Act for One-year postponement of applicability of standards, pocket no. CAA-1 (April 29, 1975). In that decision, the Administrator found some compliance in good faith and others not in good faith as to their efforts to achieve compliance with the regulations with regard to certain electric plants for the latter be denied extenious of the applicable emission standards.

"Good Faith" and Maximum Effort"

A good faith determination involves both an objective investigation and a subjective conclusion. The remainder of this report will deal with the report team's investigation of the objective facts and to the level of efforts made by the automobile industry. It is believed that this is the information requested by Senator Muskie's letter of November 18, 1974. Since the Clean Air Act does not currently provide for the Administrator making an actual "determination" on good faith with regard to the 1978 NOx standard, the drawing of conclusions amounting to such a determination is in the hands of the Congress.

Section 3-RESOURCE COMMITMENTS

The following analysis deals with resource commitments and does not focus on technological questions. The data presented here is primarily from the February 1975 submissions of the manufacturers in response to EPA's request for data of January 6 and 27, 1975.

Adequacy of the Data

The data on resource commitments submitted by the manufacturers was, with few exceptions, disappointing. Only three manufacturers (Ford, Chrysler and Renault) submitted a detailed breakout of expenditures directed towards NOx control. All others submitted only the expenditures and manpower of their total emission control development program, claiming that their accounting procedures were inadequate to give more detailed information. In addition, differences in both accounting practices and methods of differentiating between NOx control expenditures and all other expenditures make it difficult to compare one company with any other or to analyze expenditure patterns in a meaningful way.

Domestic Manufacturers' NOx Control Efforts

Table 3-1 presents the expenditures and manpower committed by the large domestic manufacturers to efforts for meeting the 1978 statutory NOx standards of 0.4 gm/mi. As shown in the table, there is a wide variation in the estimated percent of total emission expenditures directed towards NOx control, from 7% for Ford in 1973 to 40% for Chrysler in the same year. However, this difference may be misleading. Following EPA's follow-up request on March 28, Chrysler developed its data hurriedly, whereas Ford included the data in its March 3 submission and had time to obtain more exact results. In either case, this data should not be viewed in isolation, but should be considered in conjunction with the technical evaluation to understand its significance.

Ford was the only domestic manufacturer to submit detailed project expenditures for NOx control. In Section II of the March 3, 1975, submission (attached), Ford estimated that 47% of its total 1973 financial commitment to NOx control and 75% of its variable expenditures occurred in only four projects: (1) R&D for systems designed for meeting 1978 Federal Standards, (2) closedloop emission research, (3) catalyst component research, and (4) EGR systems research. Over the four projects, the average proportion devoted to NOx control was 57%. Although no such detailed comparison can be made for Chrysler and General Motors, it is quite likely that projects such as those listed above are also the principal research efforts for NOx control at these companies as well.

The data shown in Table 3-1 and Appendix C show that a substantially higher proportion of Chrysler's emissions expenditures has been for NOx control than has been the case for Ford or General Motors. This is curious, for Chrysler is an aggressive advocate of the non-catalytic approach to emissions control, a system which cannot meet the statutory NOx standard. Thus, the expenditures data submitted by Chrysler seems at odds with its public stance, which has been in opposition to the need to control NOx to statutory levels. Since no detailed project expenditure schedule was submitted which shows NOx vs. HC/CO expenditures, this question cannot be investigated further.

General Motors, while submitting financial data on its expenditures for NOx control, submitted no data on the proportion of its emissions expenditures committed to NOx versus HC/CO control. As justification for this, in its March 31, 1975 submission, Section VIII, GM stated:

> "Segregating expenditures or manpower data to the extent that they are specific to a federally mandated standard (such as the 1978 oxides of nitrogen standard) is exteremely difficult. This is attributed to the fact that the technology itself cannot be isolated. As stated numerous times, standards set for hydrocarbons and carbon monoxide emissions affect the development of the oxides of nitrogen control systems because the control technologies interact. Since the control technologies cannot be isolated technically, they cannot be segregated by cost. Emission devices currently installed in many of our vehicles will continue to be used in both the 1977 and 1978 systems, with improvements being made to these devices where necessary. Consequently, the financial and manpower data filed with our request for suspension of the 1977 emission standards is relevant to the 1978 standard and should be considered as part of our response toward meeting the oxides of nitrogen standard for 1978."

As a consequence, in contrast to Chrysler and Ford, GM did not submit a detailed analysis of its NOx expenditures. The estimates for GM given in Table 1 were based on data submitted by GM in its January 1975 Application for Suspension of the 1977 Emission Standards. Project expenditures for NOx control were estimated for those projects most closely associated with NOx control technology. Those projects and their weighting factors included: catalyst research (50%), Questor system (100%), single catalytic system (100%), air injector reactor system (50%) exhaust gas recirculation (100%), controlled combustion system (50%), and fuel injection (100%). The use of different weighting factors or choices of projects could markedly change the estimates.

Table 3-2 shows the relationship between emission expenditures, total research and development expenditures, and market sales for the three

TABLE 3-1

EMISSIONS RESOURCES FOR NOx CONTROL

Nox Emission Control Expenditures (Million$) 1/

	1973 Expense	Percent of Co. Total	1974 Expense	Percent of Co. Total
Chrysler	$13.7	(40%)	$10.9	(33%)
Ford	14.1	(7%)	17.8	(9%)
General Motors 3/	21.9	(18%)	18.4	(16%)
Total	$49.7	(12%)	$47.1	(11%)

NOx Equivalent Employment 2/

	1973 Employ.	Percent of Co. Total	1974 Employ.	Percent of Co. Total
Chrysler	475	(44%)	381	(36%)
Ford		Not Submitted		
General Motors 3/	987	(20%)	875	(18%)

Note:

1/ The portion of emission control expenditures reported by the manufacturers to be devoted exclusively or primarily to NOx control development (capital expenditures not included).
2/ Man years devoted to NOx control.
3/ Estimated from suspension application project schedules.

TABLE 3-2

EMISSIONS EXPENDITURES COMPARISIONS

	1967	1968	1969	1970	1971	1972	1973	1974[1]	Total 1967-74(%)	Average Share of Market 1967-74
. Total Emissions Expenditures (Million $) (includes capital spending)										
General Motors	$51.2	$39.7	$65.0	$119.9	$181.6	$237.9	$309.5	$450.7	$1,455.5 (53%)	53%
Ford	50.7	35.6	52.7	67.0	131.9	164.9	299.2	357.3	1,159.3 (42%)	30%
Chrysler	2.9	4.4	6.6	9.0	14.4	19.8	47.5	42.8	147.4 (5%)	16%
Total	$104.8	$79.7	$124.3	$195.9	$327.9	$422.6	$656.2	$850.8	$2,762.2	
. Capital Expenditures (Million $)										
General Motors	$27.2	$6.5	$13.9	$39.8	$44.9	$90.0	$123.6	$277.4		
Ford	27.3	9.3	16.4	15.5	41.6	33.0	91.7	151.0		
Chrysler 3	N.A.	N.A.	N.A.	0.3	1.0	1.2	13.4	9.3		
. Total Emissions as a % of Total R&D[2]										
General Motors	3.6%	4.5%	5.9%	9.8%	14.0%	15.6%	17.2%	15.9%		
Ford	7.2%	7.2%	8.5%	11.5%	17.5%	21.1%	25.1%	24.3%		
Chrysler	4.0%	4.7%	6.3%	10.6%	14.9%	15.0%	22.9%	22.2%		
. Total Emissions Expenditures Per Vehicle										
General Motors	$12.02	$8.29	$13.77	$37.59	$34.92	$47.11	$55.67	$111.84		
Ford	29.82	14.24	21.96	29.13	52.76	61.07	106.86	148.88		
Chrysler	2.10	2.77	4.65	6.67	10.00	13.11	31.05	36.27		
. Number of Vehicles Sold (Million)										
General Motors	4.26	4.79	4.72	3.19	5.20	5.05	5.56	4.03		
Ford	1.7	2.5	2.4	2.3	2.5	2.7	2.80	2.40		
Chrysler	1.38	1.59	1.42	1.35	1.44	1.51	1.53	1.18		
. Total R&D (Million $)										
General Motors	$664	$763	$852	$808	$900	$945	$1,077	$1,090		
Ford	325	359	423	453	513	621	826	849		
Chrysler	76	84	95	82	90	124	149	151		

NOTES:
1. 1974 expenditures are estimated
2. Total emissions as a % of total R&D does not include capital expenditures.
3. N.A. -- Not available
4. Passenger vehicles only

Source: Manufacturers' Request for Suspension of the 1977 Federal Emission Standards, January 1975.

TABLE 3-3

U.S. AUTOMOBILE INDUSTRY FINANCIAL DATA, 1974 vs 1973

	1974	1973	1974 over/ (Under) 1973 (Percent)
Unit Sales (000)[1]			
American Motors	354	390	(9%)
Chrysler	1,221	1,629	(25%)
Ford	2,619	2,940	(11%)
General Motors	3,651	5,261	(31%)
Total	7,845	10,220	(23%)
Sales (Million $)[2]			
American Motors[3]	$2,000	$1,739	15%
Chrysler	10,971	11,774	(0.7%)
Ford	23,621	23,015	3%
General Motors	31,550	35,798	(12%)
Total	$68,142	$72,326	(6%)
Profits After Taxes (Million $)			
American Motors[3]	$28	$86	(67%)
Chrysler	(52)	255	(120%)
Ford	361	907	(60%)
General Motors	950	2,398	(60%)
Total	$1,287	$3,646	(65%)
Emission Control Expenditures (Million $)			
American Motors[3]	$4.8	$4.6	4%
Chrysler	42.8	47.5	(10%)
Ford	357.3	299.2	19%
General Motors	450.7	309.5	46%
Total	$660.8	$855.6	29%

ote: 1. Factory sales in the U.S., including those from Canadian plants.
2. Worldwide sales, both automotive and non-automotive.
3. Results given for the AMC Fiscal Year ending September 30.

OURCE: Annual Reports, Motor Vehicle Manufacturers Association Statistics, and Manufacturers' Submissions to EPA.

largest domestic manufacturers. Table 3-3 lists the major U.S. automobile manufacturers' financial statistics and emissions expenditures for 1974 compared to 1973.

Table 3-3 shows that although unit sales decreased 23% and profits fell by 65%, emission expenditures increased 29%. Chrysler, which reported a loss of $52 million in 1974, only reduced its emissions budget by 10%. To show this change in perspective, Chrysler had almost one-half of its work force laid off during the last quarter of 1974 as its production declined precipitously to bring its inventories in line with sales. During one point in late 1974, Chrysler had approximately one-fourth of its engineering staff on leave. As a result, Chrysler's emission expenditures reflect its difficult financial condition more than do the expenditures of Ford or General Motors. The emission expenditures for Ford and General Motors increased 19% and 46%, respectively, from 1973 to 1974, even while profits for the two companies were declining 60%.

Foreign Manufacturers

Except for Renault, foreign manufacturers submitting data in response to the EPA request could not segregate out expenditures for NOx control. In fact, due to deficiencies in their accounting systems, most of the manufacturers state that they cannot separate out emissions expenditures by project. In addition, only thirteen foreign manufacturers responded at all to EPA's request for information relating to their efforts toward meeting the 1978 NOx emission standard.

Table 3-4 lists the total emissions expenditures for manufacturers submitting data. Several manufacturers submitted data on technical achievements but this did not include expenditures data.

TABLE 5-4

TOTAL EMISSIONS RESEARCH AND DEVELOPMENT EXPENDITURES (MILLION $)

	1967-69	1970	1971	1972	1973	1974	Total 1968-74	Estimated 1975	Estimated 1976
DOMESTIC									
American Motors	$ 1.6+[1]	$ 2.0	$ 2.4	$ 3.5	$ 4.6	$ 4.8	$ 18.9+	--[2]	--[2]
Chrysler	16.3	9.0	14.4	19.8	47.5	42.8	147.4	34.8	--[2]
Ford	139.0	67.0	131.9	164.9	299.2	357.3	1,159.3	216.0	196.0
General Motors	155.9	119.9	181.6	237.9	309.5	454.0	1,455.5		
Memo: Domestic	$312.8	$197.9	$330.3	$426.1	$660.8	$858.7	$ 2,780.9		
IMPORTS[3]									
Alfa Romeo	0.6[1]	0.8	1.1	1.2	1.4	1.7	6.8	2.0	2.4
BMW	0.5[1]	0.7	1.3	1.4	2.9	4.3	11.1	4.6	4.9
British Leyland	1.7[1]	2.6	2.9	3.6	5.2	6.8	22.8	9.5	14.3
Citroen[4]									
Daimler-Benz	18.7	19.2	27.4	34.6	43.2	44.2	187.3	45.0	41.8
Ferrari[4]									
Fiat									
Fuji Heavy Industries[4]									
Honda	2.0[1]	4.0	13.0	32.0	35.0	42.0	128.0	45.0	--[2]
Isuzu	0.5[1]	0.7	1.1	2.3	2.5	2.8	9.9	3.5	3.9
Jenson Motors[4]									
Lotus[4]									
Maserati[4]									
Mitsubishi	4.4[1]	5.8	6.6	7.2	7.9	8.3	40.2	8.9	9.5
Nissan (Datsun)	16.0	10.9	16.7	27.9	37.4	54.5	163.4	64.2	--[2]
Peugeot	0.9(est)	0.7	1.2	1.6	2.2	2.4	9.0	2.9	3.3
Porsche[4]									
Renault	0.5	0.6	1.3	1.4	2.0	2.5	8.3	2.5	2.0
Rolls Royce[4]									
Saab-Scania[4]									
Suzuki[4]									
Toyo Kogyo	39.6[1]	49.7	60.1	103.8	127.2	191.4	571.8	229.2	276.7
Toyota	2.8[1]	10.2	22.7	35.8	50.8	63.6	185.9	80.7	93.4
TVR Engineering[4]									
Volkswagen[4]									
Volvo[4]									

1 No data submitted for years prior to 1969

2 Not yet determined

3 All costs relate to Fiscal Year

4 Data on these companies not available

Section 4 - NOx CONTROL TECHNOLOGY

The significance of the NOx emission control technology available currently is most meaningful when put in the context of the historically available technology. To establish the background of NOx control work that preceded the 1970 Amendments to the Clean Air Act, a review has been made of the technical literature available prior to the passage of the amendments. The bulk of the work done in the area of automobile emission control technology development during that time frame was reported through the Society of Automotive Engineers, Inc. (SAE), the professional society which has received the greatest support from the engineers and scientists involved in research and development projects on automobile emissions. Besides the SAE literature, several of the reports of the Inter-Industry Emission Control (IIEC) program were available to the report team. IIEC is a group consisting of representatives of:

Ford Motor Co.

Mobil Oil

American Oil

SOHIO

Mitsubishi

Nissan

Toyo Kogyo

Other organizations have also been represented. The members of IIEC independently work on projects but meet periodically to share the results with, and receive comments from, other members. Beyond 1970, the availability of literature was expanded significantly by the provision of the Act which required manufacturers to periodically report their progress in the emission control technology area to EPA. Annually the EPA's Emission Control Technology Division (ECTD) has requested and received status reports from nearly all automobile manufacturers. These reports, which often are several hundred pages in length, have covered work which is not generally reported through publication. In addition, coverage is given to work which is reported in other technical papers and reports. These status reports formed the basis for the following ECTD reports which summarized the status of automobile emission control technology:

1. Automobile Emission Control - A Technology Assessment as of December 1971.
2. Automobile Emission Control - The State of the Art as of December 1972.
3. Automobile Emission Control - The Development Status as of April 1974.
4. Automobile Fmission Control - The Technical Status and Outlook as of December 1974.

NOx Control Technology Prior to December 1970

SAE publications in the area of automobile emissions first appeared in 1955. In a paper [1] entitled "Automobile Exhaust and Ozone Formation, A. J. Haagen-Smit of the California Institute of Technology and Margaret

1Haagen-Smit & Fox, "Automobile Exhaust and Ozone Formation", SAE 421, Jan. 1955.

M. Fox of the Los Angeles Air Pollution Control District surfaced the need for automobile emission control concluding:

> "Ozone has been found to be a substantial part of the oxidant characteristic of Los Angeles smog. Since automobile exhaust gases are capable of forming ozone in the air, they are considered a definite cause of smog."

Initial activity in the auto emission control areas concentrated on the control of HC emission. As early as 1957, work on catalytic converters with 80% hot efficiency for HC had been reported.[2] Most of the early literature does not include any information of the effect of various HC control measures or other parameters on NOx emissions. The lack of activity in the area of NOx emissions was the result of the singular concern for working on the "smog" problem. NOx by itself was not considered a pollutant but only one of the ingredients in the chain of reactions which result in the formation of photochemical smog. The relationship between NOx and photochemical smog was shown to be such that, for the level of HC and NOx occurring in Los Angeles air, reductions in NOx tended to <u>increase</u> smog formation. As recently as 1966 in a paper [3] by Caplan of GM the following statement was made:

> "The results of studies of atmospheric chemistry of smog formation serve as guidelines for determining a rational basis for control of vehicle emissions. <u>These guidelines indicate</u> the desirability of reactive hydrocarbon reduction <u>and the futility of nitric oxide reductions from vehicles."</u> (Emphasis added)

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2. G. J. Nebel, "Automobile Exhaust Gas Treatment - An Industry Report," SAE 173, Aug. 1957.
3. J. D. Caplan, "Smog Chemistry Points the Way to Rational Vehicle Emission Control" SAE Transactions Vol. 74, 1966.

By 1966 however, more consideration of NOx control began appearing in the literature. The increase in NOx control work was due in part to the adoption by the California State Board of Health of NOx emission standards in October 1965.

Separately NOx control work had appeared in the literature previously:

- R. W. Bishop & G. J. Nebel, "Control of Oxides of Nitrogen in Automobile Exhaust Gases" Industrial Hygiene Foundation, 1957.
- R. D. Kopa & H. Kimura, "Exhaust Gas Recirculation as a Method of Nitrogen Oxides Control in Internal Combustion Engines", APCA, 1960.
- G. J. Nebel & N. W. Jackson, "Some Factors Affecting the Concentrations of Oxides of Nitrogen in Exhaust Gases from Spark Ignition Engines", APCA 1958.

The Nebel & Jackson Paper covered the effect of air fuel ratio and spark retard on NOx emissions. Kopa [5], who reported some of the earliest EGR work, reported in 1966 paper that 60% NOx reductions were possible without economy degradation if EGR was used in conjunction with advanced spark timing, indicating that the shifting of MBT timing that occurs with EGR usage was known and reported in 1966 despite the fact that most manufacturers still fail to take advantage of this effect.

The 1965 Decision by California to go forward with Nox standards generated the most significant industry opposition that had been experienced up to that time. As stated by representatives of the California State Department of Health [6], "Standards for oxides of nitrogen continue to be the most controversial of all possible standards. The Automobile Manufacturer's Association has strongly opposed such standards and has stated that the control of these compounds will negate some of the benefits from hydrocarbon control alone." It was also noted, however, the NOx control was required for more reasons than just the role played in the formation of photochemical smog, "These compounds have a multiple role in air pollution. Aside from being a necessary ingredient in the photochemical reaction, nitrogen dioxide is a toxic gas and it is highly colored. Benefits of reducing possible health hazards and coloration of the atmosphere are expected with the control of oxides of nitrogen."

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5. R. D. Kopa, "Control of Automobile Exhaust Emission by Modifications of the Carburetion System" SAE Paper 660114, Jan. 1966.
6. J. A. Maga & J. R. Kinosian, "Motor Vehicle Emission Standards - Present and Future, SAE Paper 660104, Jan. 1966.

In 1967 the IIEC group also investigated water injection for NOx control. Significant reductions were determined to be possible with high rates of water usage.

Combustion Chamber modifications for NOx minimization were reported by New Hall and EL Messiri in 1970.[7]

Although early emission control work concentrated on HC emissions, prior to the passage of the 1970 Amendments essentially all basic approaches to NOx control had been investigated and reported. The groundwork necessary for a rapid expansion of NOx control research and development had, therefore, aready been completed.

The State of the Art as of April 1975

NOx Catalysts - Since the passage of the 1970 Amendments, the most significant progress in NOx control technology has been made in the area of catalyst refinement. Early NOx catalyst work showed problems with rapid deterioration, attrition and ammonia formation. Some of the so-called catalyst problems were the result of less than desirable control of the basic engine operating parameters (especially air/fuel ratio control). Significant differences have been observed between the performance and durability of various catalysts in laboratory tests and in vehicle tests. Catalyst formulation improvements have, however, resulted in catalysts with greater tolerance for non-ideal operating environments.

7. H. K. Newhall & U. A. ElMessiri, "A Combustion Chamber designed for minimum Engine Exhaust Emissions," SAE Paper 700491, 1970.

A unique approach to the operating environment problem has been developed by the Emission Controls Division of Gould, Inc. With the addition of an oxygen removal catalyst or "getter" to their metallic dual catalyst system, the lean excursions which cause deterioration of the NOx catalyst itself have been eliminated. The Gould system has demonstrated NOx levels close to the 0.4 limit during durability tests of over 25,000 miles. When used in conjunction with advanced engine modifications and EGR systems it is estimated that certification to the 0.41 HC, 3.4 CO, and 0.4 NOx levels may be possible, provided catalyst changes are made at 25,000 miles. An unresolved issue with the Gould system is that of particulate emissions. Preliminary data suggests some attrition of the nickel based catalyst is still occurring. Further data is necessary to assess the degree of this potential problem.

Matching - Catalyst/engine matching has also been significantly improved since the passage of the 1970 amendments with the development of feedback control systems to tightly control air/fuel ratios. "Lambda" sensors, which respond to the level of excess oxygen in the exhaust gases, can provide a signal to a carburetor of fuel injection system for mixture control. The most successful systems to date have relied on fuel injection for more rapid and accurate response. When the excess oxygen content of the exhaust is closely controlled by a feedback system, it is possible to either:

1. Extend the life and efficiency of a NOx catalyst by continually providing an optimum environment for the catalyst, or
2. Accomplish the simultaneous conversion of HC, CO, and NOx in one catalyst bed.

In now appears that exhaust sensors with 20,000 mile life and modest ($5) replacement costs are available, as are the feedback and fuel injection systems with which they are used. Two problems remain with the feedback approach:

1. No 3-way catalyst has as yet demonstrated the capability to maintain 0.4 NOx levels at high mileage in a domestic vehicle.

2. The costs of fuel injection systems are much greater than carburetors and U.S. manufacturers are hesitant to take on this burden.

Oxidation Catalysts - Although not directly associated with NOx control, major improvements in oxidation catalysts have improved the chances of meeting low NOx levels in conjunction with the 0.41 HC and 3.4 CO levels. The state-of-the-art oxidation catalyst technology appears capable of providing 70% HC and CO conversion efficiencies at high mileage over the LA-4 cycle.

EGR - EGR system refinements have been made in the laboratory with the most significant recent work being that of Gumbleton, et. al[8] which reported an EGR/engine calibration optimization technique which resulted in 1.0 gpm NOx levels from full size cars without fuel economy penalties. High HC emissions experienced with this approach reflect the relationship between NOx control and HC control. Low-NOx adjustments can increase HC emissions to the point that the 0.41 HC standard becomes tougher to meet than the 0.4 NOx standard.

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8. J. J. Gumbleton, R. A. Bolton, H. W. Lang, "Optimizing Engine Parameters with Exhaust Recirculation," SAE Paper 740104 Feb. 1974.

It is clear that optimum EGR scheduling will require more sophisticated EGR systems than are currently available on production cars. Work on electronically modulated EGR and spark timing systems has been reported as successful and encouraging in the laboragory, but there have been no commitments on production systems.

Reactor-Catalyst-Reactor - The "Questor" type concept of combining thermal oxidation of HC and CO with catalytic reduction of NOx has shown considerable potential for achieving 0.41 HC, 3.4 CO, 0.4 NOx standards. Tests of the Questor system by several manufacturers have been below the '78 levels even on full size cars. The problems that are yet to be solved are associated with the degree of mixture enrichment and high temperatures necessary to achieve adequate control of HC, CO and NOx. The rich mixtures used with the system cause some fuel economy degradation and result in high exhaust temperatures which have caused some system degradation during mileage accumulation. Over a three year time frame, however, the fuel economy penalty associated with the Questor system has been reduced from a 20% loss to essentially no loss relative to 1974 models (13% lower than 1975 models).

Fuel Metering - Improvements in fuel metering systems have been made since 1970, the most notable example being the Dresser carburetor. The dresser system uses a single fuel circuit and variable area throat to maintain sonic flow conditions over most of the engine's operating range. The ability to accurately control air flow and achieve fine atomization with this concept will benefit any carbureted system, but thus far only lean-burn systems have been considered.

Alternative Engines - A summary of the current state of the art in NOx control would not be complete without mention of several alternative engine approaches.

Honda's CVCC stratified charge engine has been demonstrated to be capable of bringing even full size cars into compliance with 0.41 HC, 3.4 CO, 2.0 NOx levels with essentially no fuel economy penalty. With spark retard and EGR usage NOx levels can be lowered to the .25 gpm level on small cars, providing adequate cushion to meet a 0.4 standard. A problem at this calibration level is fuel economy, which is degraded by about 20%.

Toyo Kogyo has made major improvements in rotary engine control technology in the last 5 years. Current stratified charge rotary prototypes show potential for meeting 0.41 HC, 3.4 CO, 0.4 NOx. Prototypes have achieved .33 HC, .17 CO, .38 NOx with fuel economy superior to current 1974 and 1975 production versions of the engine. (This economy level approaches that of conventional engines.)

Ford has shown that its PROCO stratified charge engine is capable of achieving 0.4 NOx in 4500 pound cars without catalytic NOx control. The combination of stratified charge combustion and high EGR tolerance of the PROCO combustion system makes this possible. Hydrocarbon emissions, rather than NOx, have presented the greatest problem. While the PROCO vehicle can simultaneously achieve 0.41 HC, 3.4 CO, 0.4 NOx with oxidation catalysts, HC levels have exceeded .41 prior to 25,000 miles of durability at the 0.4 NOx calibration. In an uncontrolled state the PROCO engine can deliver substantially better fuel economy than conventional engines, but it has high HC emissions. Achievement of low HC levels has so far required the use of throttling which makes the engine's economy comparable to conventional engines. Once the throttling has been used for control of HC emissions, further control measures such as EGR for lower NOx have little effect on fuel economy.

GM has reported that its latest prototype turbine vehicle has met the 0.4 NOx level in preliminary tests. Such performance potential has been fore-casted in the past but the GM tests are the first actual demonstration of the tubine's potential to meet the '78 standards. Problems with the turbine as an alternative engine remain in the areas of cost, fuel economy and possibly particulate emissions.

Limited data available from Daimler-Benz has indicated that the Diesel engine has also met the 0.41, 3.4 0.4 levels in prototype tests with the use of EGR for NOx control. Potential problems with smoke levels with 0.4 NOx calibrations have been suggested by Daimler-Benz but no hard data quantifying absolute smoke levels is available to EPA. The potential of the light duty Diesel is still largely unknown due to the lack of effort in the Diesel area by industry and government alike.

Summary Current NOx Control Technology

In summary, the current status of NOx control technology is such that prototype certification at the 0.41 HC, 3.4 CO. 0.4 NOx levels may be possible in the near future with any of the following systems:

1. Honda CVCC with EGR in subcompact vehicles
2. Gould Getter metallic NOx catalyst-oxidation catalyst system, all vehicle sizes, catalyst changes possible required.
3. Questor system, small vehicles (large cars may not meet CO levels).
4. Prechamber Diesel with EGR in small vehicles
5. PROCO stratified charge with oxidation catalysts.
6. Turbine

Potential problems with unregulated pollutants need to be further investigated with options 2 through 6. Some of the systems had demonstrated a tendency toward high or possibly harmful particulate emissions.

Potential for Future Development

Assuming funding is available, many areas of development could lead to improvements in NOx control technology. Three areas, however, seem to have the greatest potential: (1) catalyst refinement, (2) improved engine programming and (3) advanced HC control techniques development.

Catalyst Refinement

The progress in the area of catalyst improvements has been such that the successful development of a durable 3-way catalyst is not out of the question. The 3-way catalyst system has so far received a clean bill of health in the unregulated pollutant area. No attrition products have been identified and sulfate formation across the catalyst appears to be extremely low, based on limited testing to date.

Work recently reported to EPA by Exxon indicates that some progress has also been made in the area of noble metal NOx catalysts. Prototype catalysts have shown good low mileage NOx control and substantial HC and CO elimination. Further work is needed to solve persistent durability problems.

Improved Engine Programming

The engine programming area seems to hold considerable promise for future work. Evidence suggests that the optimization of engine calibrations for low emissions is not possible from exclusively steady state engine mapping. Optimum spark timing, EGR rate and air/fuel ratio all appear to be functions of the rate of change of speed and load in addition to the absolute value of speed and load. Very little information is available in the literature concerning transient optimization work. In addition to the basic research needed, spark air/fuel ratio and EGR systems that are fully programmable need to be developed. Many manufacturers who have suffered fuel penalties in meeting emission standards have done so because of crude programming techniques for EGR and spark timing. With electronically controlled fuel, EGR and spark systems, significant emission reductions without fuel penalties may be possible. Chrysler and GM are both known to have worked in the programming area but more is required.

HC Control

Improved HC control techniques offer potential for lower NOx emissions because of the relationship between HC and NOx emissions that exists with some NOx control approaches. High EGR rates and high-turbulence combustion chambers can produce significant NOx reductions without fuel economy penalties, but such techniques cause higher HC emissions which must be controlled. The use of HC control techniques that degrade economy (e.g., spark retard) may therefore cause the achievement of low NOx to be erroneously identified as an inherent cause of poor fuel economy.

Some further improvement in oxidation catalyst efficiency is anticipated but more significant improvements may be possible with other approaches such as:

1. Heat conversion
2. Start catalysts
3. Cold storage

Heat conversion techniques such as port liners, ceramic pistons, etc., would reduce catalyst light off temperatures and increase thermal oxidation in the exhaust system. Both of these effects would lower HC and CO emissions with insignificant effects on NOx. Little work has been reported in this area.

Start catalysts are currently under investigation at GM and Chrysler. Several foreign manufacturers have reported work also. The most effective approach considered to date has been GM's system which directs exhaust through a small volume catalyst located close to the exhaust ports during start up. This catalyst achieves rapid light off and holds emissions down until the larger, main catalyst can take over. When the main catalyst reaches operating temperature, the start catalyst can be switched off stream to prevent the deterioration that might occur if left in this position continuously during all vehicle operating modes.

Cold storage of hydrocarbons is another approach that may warrant further development. Temporary adsorbtion of the cold start HC emissions in a bed of activated charcoal is a complex but effective approach which may be desirable on some engines that would be suitable except for a serious cold start emission problem.

In summary, it is the judgment of the report team that considerable potential for NOx control technology improvement exists. The rate of progress that can be anticipated depends on the motivation of the auto industry to pursue a low-NOx emission goal.

Section 5 - PROGRAM REVIEW

One aspect of considering the magnitude of efforts that have been made by each manufacturer to achieve the statutory standard is a review of manufacturers' research and development programs. The magnitude of efforts has been measured by whether a manufacturer has investigated, evaluated and developed, fairly and with good engineering practice, each and every technique, approach, or combinations of techniques and approaches that have a possibility of meeting the standards in question - in essence, whether each has left no stone unturned.

If a manufacturer is successful in meeting the standards, the question of the magnitude of his efforts is not relevent since there is no requirement that he do more than necessary to meet the standards. Though this may seem to be a small point, it does cover the special case of Honda which can meet 0.41 HC, 3.4 CO, 0.4 NOx with the CVCC approach on Civic-sized vehicles.

The applicable time frame for investigation is December 1970 (passage of the 1970 amendments) to the present. This means that the systems and approaches under consideration include those known in December 1970, and those developed, introduced or discovered since that time.

By its nature, the analysis of the level of efforts lends itself to a qualitative, instead of a quantitative approach. Much effort was expended on investigations of a quantitative rating methodology, but an acceptable scheme could not be designed during the preparation of this report.

Efforts are considered in terms of "programs" and "projects". This breakdown has been used to show the general scope of the efforts (programs) and the details of how the programs were conducted (projects). Projects are discussed in Section 6 of this report.

A program is a general technique, approach or system for achieving low emissions. One or more projects make up a program. A project can be as detailed as a specific vehicle. For example, there is a Metallic NOx Catalyst Development Program, and in it a durability vehicle with a Gould GEM-68 NOx catalyst system would be considered a project.

The following list of programs is considered by the report team to represent an effort of the type that, if conducted diligently and with good engineering practice, would represent maximum efforts.

Programs

1. Cooperative Catalyst Development

When the 1970 Amendments were passed, catalysts of several types for HC and CO control and for NOx control were promising concepts. Some catalysts were known, having been developed by catalyst manufacturers to meet California's early standards. Most, if not all, of the catalyst expertise in 1970 resided with the catalyst manufacturers. A logical approach toward the integration of catalyst control technology with the conventional engine would have been to enter into a cooperative catalyst development program with one or more catalyst manufacturers.

This would involve automobile manufacturers providing financial support, manpower, and development facilities to the catalyst manufacturers and the catalyst manufacturers providing catalyst knowledge and personnel to the joint effort.

2. Combustion Studies

Effort in this area involves the study of the basic pollutant formation and destruction in the engine and in aftertreatment devices. There was much to be learned in this area in 1970.

3. Noble Metal NOx Catalyst

One of the promising NOx catalyst types uses noble metal as the active material.

4. Base Metal NOx Catalyst

Base metals have promise for use as NOx catalyst. This property has been known for years. Efforts in this area could have been intensified in 1971.

5. 3-Way Catalyst

This is an attractive approach for controlling HC, CO, and NOx. This subject could be the subject of a concerted effort, but starting later than NOx catalysts.

6. Fuel and/or Fuel/Air Mixture Additives

One way to reduce emissions could be to modify the fuel and fuel/air mixture.

7. Improved Fuel Metering

This is one of the keys to improvements in emission control. Much room for improvement in this area was apparent in 1970, and an extensive effort would have seemed warranted. Especially important is the sophisticated fuel metering required with NOx catalysts and dual catalyst systems.

8. Advanced Exhaust Gas Recirculation Development

EGR was known as a control technique in 1970. Work could have started then to optimize the systems and to search for effective ways to control EGR rates.

9. Improved HC Control

Control of NOx to low engine-out levels can tend to increase HC emissions. This has been known for a long time. Ways to improve HC control are intimately tied to successful low NOx level control.

10. Ignition System Improvements

The ignition system is another key to emission control. Misfire can be disastrous for catalyst systems, and flexible spark control is desirable for an optimized system.

11. Combustion Chamber and Compression Ratio Studies

Changes in these parameters through cylinder head and piston design can influence emissions greatly and are relatively easy to make.

12. Improved Intake Manifolding

Good mixture distribution and minimum choking are requirements for any low emission vehicle.

13. Rich Thermal Reactor

Rich thermal reactors were known to have good HC, CO, and NOx potential in 1970.

14. Lean Thermal Reactor

A super-lean thermal reactor with EGR or a lean thermal reactor coupled with other NOx control devices could have been a possibility in 1970.

15. Air Injection Studies

Providing the optimum amount of air for catalytic or non-catalytic systems was recognized early as an important area for investigation.

16. Oxidation Catalyst Improvement

This area is important for optimized 0.4 NOx systems, due to the additional HC control necessary to meet 0.41 HC. This also would yield benefits in fuel economy.

17. Alternative Engines

When the 1970 Amendments were passed, there was general agreement that in the 1975-1976 timeframe a complete conversion to an alternate engine was not possible for the domestic manufacturers. Therefore in this report the general area of alternate engines is considered only insofar as the conduct of the programs shed light on the attitude of the manufacturers toward 0.4 NOx.

18. Reactor-Catalyst-Reactor System

This is the Questor or a Questor-like system. This system has demonstrated impressive emission control. The optimization of such a system by the manufacturers in a joint development program with Questor or by themselves would seem logical.

19. Getter-Dual Catalyst System

This is a system like the one developed by Gould. The getter helps control the O_2 transients caused by inadequate fuel control. This system is one of the most promising to date.

20. Chassis and Body Optimization

When the 1970 Amendments were passed there were no guarantees to the industry that the types of vehicles in the future had to be the same as the then current types. It was known that the lighter vehicles theoretically have an easier time meeting NOx mass emission standards, all other things being equal. Improvements that would lower vehicle weight and improve NOx capability (and fuel economy) were therefore an obvious area for investigation.

21. Vehicle System Synthesis Studies

All of the techniques, components and subsystems must eventually be integrated into a complete vehicle package. A maximum effort would investigate ways to predict the likely results from composite systems to aid in vehicle system selection for development and durability testing.

The above general discussions indicate the scope and the breadth of a maximum effort.

The following summary chart gives the report team's estimates of the level of effort exerted by the manufacturers in the 21 program areas considered to be part of a maximum effort.

Summary Chart – Effort Expended

		AMC	Chrysler	Ford	GM
1.	Cooperative Cat. Development	None	Yes, Possibly, with UOP	None	None
2.	Combustion Studies	Little	Moderate	Extensive	Extensiv
3.	Noble Metal NOx Catalyst	None	Little	Extensive, some work with IIEC	Moderate
4.	Base Metal NOx Catalyst	None	Moderate	Little	Moderate
5.	3-Way Catalyst	None	None	Moderate	Extensiv
6.	Fuel and/or Fuel/Air Mixture Additives	Moderate	Moderate	Moderate	Moderate
7.	Improved Fuel Metering	None	Moderate	Moderate, less than adequate with Dresser	Extensiv
8.	Advanced EGR Development	None	Moderate, good systems but not applied to test vehicles	Little	Extensiv
9.	Improved HC Control	None	Moderate, good systems but not applied to test vehicles	Little	Extensiv good syst but not plied to vehicles
10.	Ignition System Improvements	Moderate	Moderate	Moderate	Extensiv
11.	Combustion Chamber and Compresison Ratio Studies	Moderate	Moderate	Moderate, slow to adopt development results to production engines	Moderate

Summary Chart - Effort Expended (Continued)

		AMC	Chrysler	Ford	GM
12.	Improved Intake Manifolding	Little	Moderate, good systems but not applied to test vehicles	Moderate	Extensive, leader in developmer but reluc- tant to ac best syste productior
13.	Rich Thermal Reactor	Little	Moderate	Extensive	Moderate
14.	Lean Thermal Reactor	None	Extensive	Moderate	Little
15.	Air Injection Studies	None	Moderate	Moderate	Moderate
16.	Oxidation Cat. Improvement	Little	Moderate	Extensive	Extensive
17.	Alternate Engines	Little, possible effort on rotary	Adequate, recent low NOx turbine efforts funded by EPA/ERDA	Inadequate, redirected alternate engine pro- gram away from .4 NOx shows Ford does not consider 0.4 NOx a future requirement.	Adequate unsuccessf effort on rotary not primarily NOx problc
18.	Reactor-Catalyst-Reactor System	One successful test with Questor system, no follow-up	Little, minimal assistance to vendor	Little, minimal assistance to vendor	Moderate, provided s assistanc to vendor
19.	Getter-Dual Cat. System	Little, program just starting	Moderate, question- able treatment of test vehicle.	Little, program just starting	Little, system nov being assembled
20.	Chassis/Body Optimization	Moderate	Little, behind in subcompact production	Moderate	Most exter sive in industry
21.	Vehicle System Synthesis Studies	Little Reported	Little Reported	Little Reported	Little Reported

Section 6 - PROJECT REVIEW

The previous section discussed whether certain programs were undertaken. This section tries to answer the question "How well was the effort expended?" The projects considered by the report team are ones that have actually been worked on by the industry. This analysis focuses on what actually was reported and how fair and complete an investigation it was.

Project Evaluation Criteria

The projects were evaluated by considering the following questions listed below which address how the project was run.

1. Were full effort systems tested? Did they contain the components and subsystems known to be effective to reduce emissions or were some components inadequate or missing? An example of a less than full-effort system would be a NOx catalyst vehicle without EGR.

2. What efforts were made to find the cause of failures and solutions? Failures and/or problems are bound to happen in development programs. What was done about failures and/or problems? Was reasonable judgment used to determine whether or not to continue the test? If a problem occured, how many times was it fixed? If an outside developer's system was involved, was an engineering effort made to fix the problem by the manufacturer alone or in conjunction with the vendor? Could the vendor fix it? Considering the vendor's expertise, should he have been expected to have been able to fix it?

3. If a project was terminated or abandoned, why was this done? Were any technical reasons given?

4. How does the apparent level of effort on any given project compare to the apparent level of effort on other projects? In this regard the relative emission control performance of the vehicles in the projects is especially important.

6.1 General Motors (GM)

General Motors is concentrating on the catalytic approach in meeting the 1978 Standard. GM reported durability testing of four categories of vehicles.

1. Dual catalyst vehicles on AMA durability.
2. Dual catalyst vehicles in customer service fleet operation.
3. Three-way catalyst vehicles on AMA durability.
4. Questor system cars on AMA durability.

Tables GM-1 and GM-2 depict the vehicles in three of the four categories. The category not shown is the customer service fleet. These vehicles were omitted because the reported information was incomplete with regard to dates and system descriptions. The emission performance of the fleet vehicles was poor. Twelve of the eighteen fleet vehicles exceeded the '78 Standards at zero miles.

TABLE GM-1

VIN	Family	Control System Type	None	Prop	Non Prop	Air	Fuel Metering EFI	Fuel Metering Carb	Catalyst OX	Catalyst NOx	Highest Mileage within 1978 Standards.	Dates Start	Dates Fin.
ES61315B	Chev 350	Dual Cat.		X		Yes		X	MB RN-2435	UOP HN-1290	2000	6/72	7/7
ES61322	Chev 350	Dual Cat		X		Yes		X	UOP HN 1290	Gulf HN 1575	0	3/72	11/7
ES61322A	Chev 350	Dual Cat		X		Yes		X	UOP HN 1290	GM RLK-8-20-B	11,897	3/72	7/7
ES62356	Chev 350	Dual Cat	X			Yes		X	MB HN 2040	Same	112	9/72	9/7
ES62356A	Chev 350	Dual Cat	X			Yes		X	MB HN 2041	Same	34	9/72	9/7
ES62356C	Chev 350	Dual Cat	X			Yes		X	Grace HN 2029	Same	90	10/72	10/7
ES62369	Chev 350	Dual Cat	X			Yes		X	UOP HN 1646	Gould GEM45	0	8/72	10/7
ES63303	Chev 350	Dual Cat	*			*		X	UOP HN 1646	Gould GEM67	1352	7/73	7/7
ES63307	Chev 350	Dual Cat		X		Yes		X	Nippon Denso	Same	8000	10/73	5/7
ES63339	Chev 350	Dual Cat		X		Yes		X	UOP HN 1646	Grace HN 2182	8163	2/73	5/7
ES63340	Chev 350	Dual Cat		X		Yes		X	UOP HN 1646	Gulf HN-2289	7900	3/73	7/7
ES63341	Chev 350	Dual Cat		X		Yes		X	UOP HN 1646	Gould GEM 45	4393	10/72	12/7
ES63341A	Chev 350	Dual Cat		X		Yes		X	UOP HN 1646	Gould GEM 45	1500	1/73	4/7
ES63343	Chev 350	Dual Cat	X			Yes		X	UOP HN 1646	MS HN 2290	8000	5/73	8/7
ES63344	Chev 350	Dual Cat		X		Yes		X	UOP HN 1646	MS HN 2290	8000	5/73	8/7
ES64346	Chev 350	Dual Cat	*			*		*	HN 2236	HN 2221	2000	*	*
77108	Chev 140	3-Way		X		No		*	HN 2221	Same	114	11/74	12/7
C-3321	Cadi 500	3-Way		X		No			HN 2217	Same	0	*	*
1750-37	Opel 118	3-Way		X		No	X		Deg. OM 721	Same	421	9/72	1/7
1750-37C	Opel 118	3-Way		X		No	X		Deg. OM 721	Same	0	1/73	3/7
1800-39	Opel 118	3-Way		X		No	X		Deg. OM 721	Same	12480	12/72	3/7
1800-41	Opel 118	3-Way		X		No	X		Deg. OM 721	Same	1500	1/73	2/7
1800-39A	Opel 118	3-Way		X		No	X		Deg. OM 721	Same	3190**	3/73	**
1800-41A	Opel 118	3-Way		X		No	X		Deg OM 721	Same	8667**	2/73	**
1800-61	Opel 118	3-Way		X		No	X		Deg OM 721	Same	2648**	3/73	**
4213	Cadi 500	3-Way	X			No		*	HN2217	Same*	0	*	*
2447	Pont 400	Questor	*			Yes		X	*		20,000 (HC&NOx)	*	*
P2483	Pont 400	Questor				Yes		X	*	*	30	8/73	12/7

*Information not supplied by GM
** Testing terminated without explanation.

TABLE GM-2
GENERAL MOTORS 1978 SYSTEMS
ZERO MILE EMISSIONS

CAR NO.	System Type Dual Cat.	HC	CO (Grams/Mile)	NOx	Inertia Weight
61315B		.22	1.1	.22	4500
61322		.42	3.1	.21	4500
61322A		.36	1.7	.27	4500
62356		.30	2.2	.35	4500
62356A		.17	1.3	.35	5000
62356C		.36	3.1	.34	5000
62369		.24	1.8	.31	4500
63303		.28	2.2	.19	5000
63307		.31	2.8	.23	5000
63339		.26	1.6	.32	4500
63340		.30	2.2	.19	5000
63341		.22	1.3	.27	5000
63341A		.19	1.7	.22	4500
63343		.37	2.4	.28	5000
63344		.31	1.3	.34	5000
64346		.25	.8	.27	5000
C-3321	3-way	.28	4.0	.37	5500
77108		.38	2.0	.28	3000
1750-37		.20	2.7	.13	2500
1750-37C		.48	4.7	.26	2500
1800-39		1.4	2.3	.10	2500
1800-41		.19	0.9	.16	2500
1800-39A		.36	2.0	.20	2500
1800-41A		.21	3.1	.09	2500
1800-61		.23	2.5	.29	2500
4213		.26	3.0	2.66	5500
2447	Questor	.10	3.8	.29	5000
2483	Questor	.12	2.3	.36	5000

All of the dual catalyst vehicles were full-sized Chevrolets equipped with 350 cu. in. engines. GM reported that some of these vehicles were equipped with their Triple Mode Emission Control System (T-MECS) but its unclear from the vehicle descriptions as to which are which. The T-MECS was intended to improve catalyst warm up and achieve thermal reactor action at high output by housing the oxidation and reduction catalysts in the exhaust manifolds. The majority of the dual catalyst vehicles were the more conventional configuration with a reduction catalyst mounted close to each exhaust manifold outlet and an underfloor oxidation catalyst. Vehicle No. 63446 was equipped with a closed loop control system for more precise air-fuel ratio control. This vehicle achieved good low mileage emissions, .27 HC, .78 CO, .27 NOx at zero miles, but deteriorated rapidly. The best overall performance was given by car no. ES63341A, which stayed within the 1978 Standards for approximately 15,000 miles. The best NOx control was shown by car no. ES-63307 which remained below 0.4 NOx for approximately 25,000 miles. Unfortunately, the reduction catalyst run on this most successful car (Nippon Denso) was not evaluated on any other vehicle.

Three of the ten 3-way catalyst vehicles were domestic cars: two Cadillacs and one Vega. GM's system descriptions do not specify the type of fuel metering system on these cars but GM does state that most full sized 3-way cars are utilizing servo controlled carburetors whereas the compact sized 3-way development cars are using electronic fuel injection. The closed loop fuel metering control system employs oxygen sensors mounted upstream and downstream of the oxydation catalyst. The use of a downstream sensor is a GM innovation. They report that it is used to guide a logic unit which provides a variable reference to account for vehicle to vehicle variations. All three domestic vehicles exhibited poor emission control durability. The two Cadillacs exceeded the 1978 standard at zero miles, indicating that they may not have even been targeted for 0.4 NOx.

The remainder of the 3-way vehicles were Opels equipped with electronic fuel injection, closed loop fuel metering and proportional EGR. The best performing Opel stayed within the standard only 12480 miles at which time the catalyst monolith became loose and was replaced. All seven Opels were equipped with the same catalyst, the Degussa OM 721.

The remaining two AMA durability test cars reported by GM were Pontiacs equipped with Questor Reactor-Converter-Reactor Systems. Car No. 2447 exhibited excellent HC and NOx control with 20,000 mile measurements of .061 HC and .289 NOx. The CO control was insufficient, however, with levels holding relatively steady at about 4.0 gpm. The thermal reactor on this car failed at about 22,000 miles which ended testing. The second Questor equipped Pontiac, Car No. P2483 did not display the stable, effective, HC and NOx control exhibited by the first. The emission control deteriorated rapidly and the thermal reactors failed at about 15,000 miles.

The following is an evaluation of General Motors efforts to comply with the 1978 standards.

The dual catalyst system development program represents General Motors most significant effort toward meeting the 1978 standards. This can be shown in several ways. In the first place, it represented GM's most viable approach to meeting the standards given the time frame for development and the inertia weight classes GM was forecasing for the 1978 period. Secondly, the dual catalyst program involved a far greater number of durability test cars than the other programs. Out of a total of 46 durability test vehicles reported by GM, 34 were equipped with dual catalysts. Using the premise that the dual catalyst was considered by GM to be the most promising approach, it would stand to reason that a tireless effort would be made in this area, leaving no stone unturned. The reported data, however, show that the level of effort appeared to decline significantly during mid to late 1973, (after GM received a suspension of the then 1976 0.4 NOx standard). Evidence of this is GM's reported AMA durability testing. The reported data shows that in 1972 eight dual catalyst cars initiated testing, in the following year, 1973, seven dual catalyst cars initiated testing, but in 1974 only one vehicle was started. Hypothetical arguments that would justify GM's decrease of testing effort here is that either all of the known techniques for improving dual catalyst systems had been throughly tried and shown unsatisfactory (no stone had been left unturned) or that another area held sufficiently better promise that GM diverted their resources to that area. Dealing with the second argument first, the only alternative area of promise was the 3-way catalyst approach. GM reported testing of ten 3-way systems on AMA durability but only three of these were domestic cars, and only two of these three were the full size variety that GM's marketing plans are commited to in the 1978 time frame. This leaves the first argument as GM's justification for reducing vehicle testing effort on the dual catalyst approach. GM states:[1]

> "Because of the gross lack of durability of catalyst systems using catalytic reduction of NOx, major emphasis has shifted from vehicle durability to basic catalyst research and laboratory and dynomometer evaluation of reducing catalysts."

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1. General Motors progress toward achieving the 1978 Automotive Emission Standard for Oxides of Nitrogen, Vol. 1, Sec. 5, p. 20.

In the opinion of the report team, however, GM ignored several of their own emission control systems which if used in conjunction with their dual catalyst system could have passed or come close to passing the 1978 Standards. The important point here is that GM did not even test them on the dual catalyst cars and, thus, these cars did not represent full effort systems. The systems in mind are the Super Early Fuel Evaporation System (Super EFE), closed loop fuel metering control, cold storage HC control and reduction catalyst replacement.

Super EFE was developed by GM and Table GM-3 shows test results of this system on systems using no catalysts.

TABLE GM-3

Super EFE-No Catalyst (g/mi)

	HC	CO	NOx
4000 # test weight	.37	3.09	1.51
4500 # test weight	.43	3.86	1.86
5000 # test weight	.49	4.27	2.24

Closed loop fuel metering control was used on car No. ES64346 which exhibited outstanding CO control at low mileage. In the opinion of the report team, this control could maintain at high mileage if this system were refined to hold its Air-Fuel ratio control more constant. Along with better CO control this system would give improved reduction catalyst durability because of its control of oxygen spikes during transient operation.

The cold storage concept is effective on HC emissions. As early as 1971 GM reported 30% reductions in HC emissions with the system. GM stopped work on the system because of its complexity but the system was revived for use on their rotary engine when it appeared that HC emissions would keep it from certifying in 1975.

It is hard to reconcile GM's abandonment of dual catalyst development car durability just when Gould was making their advances. GM is, however, building a Gould getter car now.

By using some combination of these advanced systems (but not necessarily all three) in conjunction with their dual catalyst systems, GM could recalibrate spark timing and EGR to improve NOx control and fuel economy.

Reduction catalyst replacement at 25,000 or 30,000 miles is a straight-forward way of circumventing insufficient durability.

6.2 Ford

The vehicles in Table FO-1 are discussed as they are the most recent and representative Ford 0.4 NOx vehicles.

TABLE FO-1

VIN	Eng. Family	Control System Type	EGR Prop	EGR Non-Prop	Air CID	Air drive ratio	Fuel EFI	Fuel Metering Carb	Catalyst NOx	Catalyst Ox	Catalyst Vol	Mfr
10T714	351W	Dual Cat		X					X			Ford
										X		Engelhard
10T718	429	Dual Cat		X				4V	X			
										X		Engelhard
10T719	351W	3-Way+OX							3-Way			
										X		
10T743	351W	Dual Cat						2V				
												Gulf
11A55D	351W	Dual Cat						2V	X			Amoco
										X		Engelhard
2010D	250	Dual Cat	None		19	.92		1V	X		65	ICI
										X	83	
21016D	250	Dual Cat		X	19	.92		1V	X		50	ICI
										X	50	
22C58D	2.6L	Dual Cat	None(?)		X(?)				X			Engelhard
									X			Ford
22P37		Thermal Reactor	None (?)		32/19							
31A74D	400	Dual Cat		X	19	1.4		2V	X			Grace
										X		Engelhard
3055D	351C	Dual Cat						2V	X			Gould
36A57D	351W	Dual Cat		X	19	1.4		2V	X			ICI
										X		
42P25D	2.3L	3-Way+OX			19	1.2	Fdbk		3-Way		72	
										X	48	
46P35D	2.3L	3-Way		X			Fdbk		3-Way			
43206	2.3L						Fdbk					
4A15D	351W		X				Fdbk		3-Way			
14A53D	351W	Dual Cat						X	X			Gould
14A55D	351W	Questor			X			2V	X			
XPU233	2.8L	3-Way	None				Fdbk		3-Way		52	
4W57D	400						Fdbk					

Vehicle 110T714

Vehicle 110T714 was terminated in 1973 due to deterioration of the noble metal NOx catalyst. Emissions were higher than the 1978 levels at zero miles. Insufficient vehicle and catalyst information was provided to complete a full-effort vehicle analysis.

Vehicle 110T718

Vehicle 110T718 was terminated in 1973 due to deterioration in the base metal/noble metal NOx catalyst. Emissions exceeded the 1978 levels at zero miles. Exhaust gas input to the catalyst system exceeded 50 CO. This indicated very poor system selection or calibration. Sufficient catalyst and vehicle information was not provided for a full-effort analysis.

Vehicle 11A55D

Vehicle 11A55D was equipped with different NOx catalysts in each bank. Feedgas levels were very high for all three pollutants, and 1978 emission levels were not achieved at low mileage. Poor system selection or calibration was obvious. A full-effort analysis again could not be made. The vehicle was terminated after significant NOx conversion losses.

Vehicle 2010D

Vehicle 2010D was also terminated due to reduced NOx conversion efficiency. Feedgas levels again were high despite the use of several improved HC/CO control techniques. Had this vehicle been equipped with EGR, it would have been given consideraiton as a full-effort vehicle.

Vehicle 21018D

Vehicle 21018D was reported in the 1973 Ford status report to EPA. It was assembled to evaluate an ICI NOx catalyst. Vehicle 21018D was added and catalyst volumes were reduced. This car probably was a full-effort system in 1973. Initial test results (one test reported .5 HC, 3.8 CO, .45 NOx) indicated that NOx conversion efficiency was not as high as expected. Additional tests were scheduled to find the NOx conversion problem. Vehicle 21018D has never been mentioned again. The problem analysis has never been concluded.

Vehicle 22C58D

Vehicle 22C58D was terminated in 1973 due to the losses in conversion efficiency of the two Ford noble metal NOx catalysts used. EGR was not used and thus 22C58D was not a full-effort system. Zero mile emission levels exceeded 1978 levels.

Vehicle 22P37

Vehicle 22P37 was a thermal reactor car which was reported to EPA in 1973. Ford did not report the use of EGR on this vehicle. Low mileage emissions were quite impressive for an apparently unoptimized vehicle.

TABLE FO-2

Vehicle 22P27 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.26	4.7	.59	---	0		32 CID air pump
.14	4.39	.63	---	5,000		19 CID air pump
.18	6.68	.60	---	10,000		19 CID air pump

No further optimization has been reported on vehicle 22P37.

Vehicle 31A74D

Vehicle 31A74D was used to test three types of NOx catalysts. Two different catalysts from Grace were tested at low mileage, and an Amoco NOx catalyst was durability tested. The Amoco catalyst test was terminated due to the loss of reduction efficiency. The 1973 Ford status report indicated that the best Grace catalyst was to be durability tested. This has not been done in the following year and a half. Vehicle 31A74D may have been a full-effort vehicle; however, a complete description of the vehicle and catalysts was not available for complete analysis. Feedgas emissions for HC and CO were very high.

Vehicle 3055D

Vehicle 3055D was equipped with a Gould GEM 67 NOx catalyst. The testing of vehicle 3055D is a good example of improper treatment of a vendor product. The vehicle had immediate problems with low catalyst temperatures. Ford either installed or modified the air injection system and promptly terminated the testing of the vehicle apparently due to "disappointing" results. The maximum NOx conversion efficiency achieved was 43%. A complete description of the vehicle was not provided to determine if the manufacturer made his best technology available on this car. NOx values of some test results indicate that this car was not optimized for NOx input to the Gould catalyst.

Vehicle 36A57D

Vehicle 36A57D is another example of improper treatment of a vendor product. Ford reported very brief low mileage testing of the catalyst and then terminated testing "until converter designs which allow higher catalyst operating temperatures are completed". A full effort would mandate that Ford work with ICI to develop such a design or provide an existing one for them. The exact nature of the ICI catalyst problem, if any, was not reported.

Vehicle 110T719

Vehicle 110T719 begins the vehicles whose testing occurred in 1974. A detailed description of the vehicle and catalysts was not provided. Extremely high HC and CO feedgas levels indicated that 1974 technology was not employed on the 1972 Ford test vehicle. The 1978 emission levels were not met in brief, low mileage testing.

Vehicle 110T743

Vehicle 110T743 and its emission control system were very poorly described. CO feedgas levels were very high indicating less than current technology. Vehicle termination was said to be due to catalyst deterioration even though one had deteriorated very little over the 9,000 durability miles.

Vehicle 42P25D

Vehicle 42P25D has feedgas levels which are much improved over all previous catalyst vehicles due to the addition of current technology emission control device (feedback controlled electronic fuel injection, improved EGR control). Low mileage emission values were very impressive; however, similar technology could be applied to dual catalyst vehicles as well as 3-way + ox. cat. vehicles such as vehicle 42P25D. The durability of dual catalyst systems is currently greater than that of 3-way catalysts.

TABLE FO-3

Vehicle 42P25D Results

HC	CO	NOx	MPG	Miles	Date	Comments
.14	.70	.15	---	low	---	IW=3500 lb.
.07	.25	.18	---	low	---	IW=3000 lb.

Vehicle 46P35D

Vehicle 46P35D was prepared by Bosch GMBH of Germany to illustrate the potential of feedback controlled mechanical fuel injection systems. Proportional EGR apparently was not supplied to Borch by Ford. The feedgas NOx levels are higher than those of vehicle 42P25D; however, the more effective 3-way catalyst used by Bosch was reducing about 90% of the NOx. Low mileage emissions were .12 HC, 1.26 CO, .13 NOx.

Vehicle 43206

This vehicle program is just beginning. The vehicle was not described completely by Ford so a full effort determination could not be made. Vehicle 43206 is similar to vehicle 46P35D and 42P25D in that they have appeared only recently in the Ford fleet.

Vehicle 4A15D

This vehicle is also very new. Apparently the 3-way catalyst has not even been installed yet. The technology presented on this car is equivalent to that which could have appeared on Ford vehicles in early 1974.

Vehicle 14A53D

Gould prepared this vehicle for Ford's evaluation after the testing of vehicle 3055D disappointed Ford engineers. The engineers at Gould succeeded (which Ford engineers failed on 3055D) in calibrating the vehicle to achieve emission within the 1978 levels. Ford received the vehicle in January of 1974. "During attempts to repeat the Gould (emission) results, the vehicle stalled on a cold start and the NOx catalyst temperatures exceeded 2000° F causing a partial catalyst melt," according to Ford. No reason for the stall was provided, and no vehicle tests have been reported since. New Gould GEM 68 catalysts were provided by Gould in September.

Ford indicated that a feedback controlled Gould car will be assembled in the fall of 1975. The proven durability of the Gould catalyst should be ever better with a good fuel metering system. A full effort system should include Ford's advanced EGR and AIR.

Vehicle 14A55D

The Questor-equipped vehicle was run for 20,000 miles before HC and CO control was lost. Several fixes were attempted by Ford before the vehicle was terminated. Ford noted that air pump deterioration and air system leaks may have been responsible for the failure. There was no indication that any technical advice or improved hardware was provided to Questor to prevent similar problems in the future.

Another vehicle was prepared by Questor for Ford. This one was a 2.3 litre Pinto. After only 360 miles it exceeded the 1978 levels and showed deterioration in both HC and CO. Ford analyzed the problem as being an insufficient air supply. No fixes were attempted. Instead of installing a larger air pump and recalibrating, the vehicle was promptly returned to Questor for repair. Approximately an eight month delay resulted from Ford's fairlure to repair the vehicle.

Vehicle XP4233

Vehicle XP4233 was built for Ford in Europe by Bosch. The absence of EGR indicates that current technology hardware was not provided to Bosch. Shortly after the vehicle arrived in Dearborn, Michigan, it was taken on a "short trip" to Denver, Colorado! Valuable development cars (especially those that are not altituded compensated) seldom are driven between test sights. After the return drive to Dearborn, emission levels exceeded the 1978 levels.

Vehicle 4W57D

This vehicle is another of Ford's recently built vehicles. Very few details of the vehicle and control system were available.

The Alternate Engine Program

Ford told EPA that their alternate engine program had been retargeted from 0.4 to 2.0 NOx in 1973. This would seem to be a problem for the alternate Ford engine as they are not scheduled for introduction until after the implementation of the 1978 0.4 NOx standard. The 0.4 NOx potential of this engine is well known. Its failure has been in HC emissions. Ford also has chosen not to work on their CVCC engines at low NOx levels. The report team believes that Ford technology could provide improvements to the CVCC system should they be convinced that the 0.4 NOx law will be enforced.

Ford Summary

Most test vehicles were poorly calibrated or used less than optimum emission control hardware. Full effort vehicles did not appear until late 1974 or about the same time as this evaluation of industry good faith was announced. Some vehicles were terminated without adequate technical justification. Promising technologies such as base metal NOx catalysts and feedback dual catalyst systems were not pursued. The shift in emphasis from dual catalyst systems to 3-way plus ox. cat. systems may provide long term advantages; however, it will reduce capability to certify at .41 HC, 3.4 CO, .4 NOx in 1978. The Ford alternate engine programs were redirected to 2.0 NOx in 1973. The Ford treatment of vendor's vehicles and products has been questionable. Current technology and technical advice have not been provided to vendors.

6.3 Chrysler

The vehicles in Table CH-1 are discussed as they are the most recent and representative Chrysler 0.4 NOx vehicles.

TABLE CH-1

VIN	Eng. Family	Control System Type	EGR Prop	EGR Non-Prop	Air CID	drive ratio	Fuel EFI	Metering Carb	Catalyst NOx	Catalyst Ox	Catalyst Vol	Mfr
433	360	Dual Cat	None		19	1.67		4V	X			Chrysler
										X		Chrysler
166	360	Dual Cat	None		19	2.08			X			Chrysler
										X		J-M
173	360	Dual Cat		X	19	1.87		2V	X		120	Chrysler
										X		Chrysler
												ICI
219	360	Dual Cat		X	19	1.67		2V	X		120	Chrysler
										X	150	Chrysler
263	360	Dual Cat		X	26	1.67		2V	X		120	
										X	152	Chrysler
352	360	Dual Cat		X	26	1.5			X		120	Gulf
									X		120	Chrysler
										X		Chrysler
476	360	Dual Cat	None		26	1.67		2V	X			Chrysler
										X	150	Engelhard
178	360	Dual Cat			19			Ford	X			Gould
										X		Chrysler
136	360	Questor	None		by Questor			2V	X			Questor

Vehicle 433

The emission control system of vehicle 433 included exhaust port lines and 87 CID, air-gap exhaust manifolds. The absence of EGR was not consistent with either 1973 engineering practice or prolonged NOx catalyst life, due to the increased NOx input to the catalyst system. Under these adverse conditions, Chrysler stated that the NOx catalyst was performing well at 20,000 miles. At the 20,000 mile point the engine failed (the engine in this test car had been used for 30,000 miles of testing prior to the beginning of this NOx catalyst test) and testing was terminated. This noble metal NOx catalyst has not been installed on a vehicle with EGR for reduced NOx input to the catalyst, and was less than a full effort.

TABLE CH-2

Vehicle 433 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.40	4.1	.56	---	low	July '73	
.31	1.7	.99	---	low		Carb. problems
.47	3.8	.67	---	low	Oct. '73	

Vehicle 173

Vehicle 173 most accurately represented the Chrysler first choice control system in the 1973 Status Report to EPA. No advanced HC/CO control was used, but vehicle 1973 more closely approached a 1973 full effort test vehicle. High HC and CO results apparently were the result of either poor vehicle calibration or poor oxidation catalyst efficiency. Insufficient details were provided to make a more precise determination.

TABLE CH-4

Vehicle 173 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.57	6.08	.27	---	low	Aug. '73	
.53	5.40	.29	---	low		
.63	3.71	.50	---	low	Sept. '73	

Vehicle 219

Vehicle 219 was equipped with port liners and enlarged, air-gap exhaust manifolds. Also it included an ICI base metal NOx catalyst. Vehicle 219 was possibly a full effort project in 1973. Complete catalyst details were not presented to permit a full evaluation. Early emission results indicated excellent potential; however substrate breakage problems occurred. Chrysler then prepared a new catalyst with a stronger substrate, and installed it on the vehicle. Emissions again were good; however, catalyst overtemperature problems occurred. Chrysler then removed some exhaust system insulation and modified the intake manifold and spark advance to alleviate the overheating problem. Another catalyst was found to be broken and replaced. All three emissions later deteriorated during durability testing.

TABLE CH-5

Vehicle 219 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.35	2.3	.24	---	low		
.25	3.0	.17	---	low		
.30	3.6	.32	8.58	low		New catalyst
.31	3.7	.32	8.92	low		with improved
.45	6.5	.29	8.60	low		substrate
.50	6.8	.26	8.49	low		replaced one
.87	8.5	.49	---	620		catalyst biscuit
.67	5.4	.49	---	2623		

Vehicle 263

Vehicle 263 included enlarged, insulated exhaust manifolds in conjunction with base metal NOx catalysts. Vehicle 263 may have been a full effort system; however, catalyst detail again were not presented for a full evaluation.

Catalysts efficiencies dropped very rapidly and the catalyst was replaced with "an improved NOx catalyst". No further results were reported with the new catalysts.

TABLE CH-6

Vehicle 263 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.32	2.9	.25	10.34	low		
.51	8.4	.84	9.19	low		
.47	8.6	.35	10.44	1500		
1.1	11.2	.56	9.23	2000		

Vehicle 352

Vehicle 352 was built in 1973. It was not a full effort system as no advanced HC controls were used. It was initially used to evaluate a Gulf NOx catalyst and later to evaluate a Chrysler noble metal NOx catalyst. The Gulf catalyst evaluation appears to have been very brief and superficial.

A new oxidation catalyst is to be installed and durability continued as the NOx catalyst appears to be performing well at 12,000 miles. Mileage accumulations has been slow with the Chrsyler catalyst.

TABLE CH-7

Vehicle 352 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.36	4.68	.65	11.7	low		Gulf catalyst, no EGR
.39	4.33	.80	11.5	low		Gulf catalyst, no EGR
.49	6.07	.37	12.46	low		Chrysler Catalyst
.46	5.25	.47	11.07	low		installed
.57	4.78	.46	10.8	low		
.58	6.31	1.31	---	6000		
.84	9.92	.55	11.4	6000		
.99	11.4	.61	10.7	6000		
.65	13.0	.47	11.0	6000		
1.1	31.2	.46	---	12000		

Vehicle 476

Vehicle 476 was run with port lines and insulated, enlarged exhaust manifolds, but apparently was without EGR. It used a Chrysler metallic NOx catalyst.

Chrysler noted that very painstaking carburetor calibrations were necessary to obtain these excellent low mileage emissions. Chrysler also noted that this difficult calibration would not be possible on production vehicles. The report team is in agreement with that statement, and we hope that Chrysler will soon begin to test vehicles with more sophisticated A/F metering systems similar to those fuel injection or feedback carburetion systems which have been run by many other manufacturers for some time now. If the Chrysler fuel injection system (which has been under development for at least two years) is not ready for vehicle use, then Chrysler could purchase fuel injection systems which are in production from others.

TABLE CH-8

Vehicle 476 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.37	3.9	.34	---	low		
.30	3.8	.29	---	low		
.33	3.0	.34	---	low		
.25	3.1	.27	---	low		
.40	2.85	.21	11.8	low		
.35	2.55	.28	11.3	low		
.26	1.68	.38	11.8	low		
.25	2.56	.38	11.2	low		

Vehicle 178

Vehicle 178 is the Gould GEM-68 equipped vehicle. This car was run without EGR and the larger displacement air pump used on more recent Chrysler 0.4 NOx vehicles.

The catalysts were damaged by ignition failure. In addition, there has been some controversy concerning the exact number of times this vehicle ran out of fuel while being tested. New catalysts were obtained from Gould and durability testing is to be resumed.

TABLE CH-9

Vehicle 178 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.6	2.6	.72	12.3	low	7/12/74	At Gould
.3	.97	.52	12.7	low	7/13/74	At Gould
.3	.72	.62	12.7	low	7/15/74	At Gould
.43	2.5	.71	11.4	low		At Chrysler, add PCV
.35	1.7	.60	11.6	low		
.37	2.7	.69	11.5	low		
.50	3.2	1.31	11.56	496		Prior to ignition failure

Vehicle 136

Vehicle 136 was prepared by Questor for Chrysler. It was equipped with the Questor Reverter system. No EGR was used, and the engine compression ratio was increased thus providing higher engine-out emissions.

The preparation and particularly the testing of this vehicle has been very slow. The vehicle was received by Chrysler on October 9, 1974. Only three sets of low mileage test results have been reported from that time to the present.

TABLE CH-10

Vehicle 136 Results

HC	CO	NOx	MPG	Miles	Date	Comments
.39	3.14	.34	10.1	low	9/74	At Questor
.20	2.18	.38	11.0	low	9/74	At Questor
.31	2.84	.32	9.4	low	9/74	
.15	1.94	.33	9.7	low	9/74	
.24	2.43	.39	10.0	low		At Questor
.13	2.00	.38	10.2	low		At Questor
.22	2.77	.32	10.3	low		At Questor

Chrysler Summary

Chrysler has reported to be developing many effective emission control devices. These include:

- advanced oxidation catalysts
- electric hot spot intake manifolds
- hot well intake manifold
- aluminum intake manifolds
- electric fuel vaporizer
- electronic fuel injection
- sonic induction
- electronic EGR
- electronic spark
- modulated AIR

Virtually none of these devices have been applied to 0.4 NOx test vehicles. Some are scheduled for 1976 production so it must be assumed that they were available for testing. The addition of these items to Chrysler 0.4 NOx vehicles could have had a strong influence on Chrysler's ability to certify vehicles at .41 HC, 3.4 CO, .4 NOx in 1978, in the opinion of the report team. This is a typical example of the less than full effort systems run by many manufacturers.

Other useful approaches have not received much attention at Chrysler. These include:

- high energy ignition
- delayed canister purge
- 3-way catalysts
- feedback A/F metering

Major problems with the Chrysler 0.4 NOx program include:

- Insufficient number of vehicles were tested in 1974
- Very slow, delayed testing of the few vehicles which were tested (very few actual test dates were provided by Chrysler)
- No vehicles which would be considered full effort vehicles in 1974 were tested
- Development programs are moving very slowly - especially advanced fuel metering programs.

- Test vehicles are all very old, the newest being 1973 models. These are poor choices for 50,000 mile emissions durability demonstrations.
- Poor follow-up of potentially good components (i.e., NOx catalyst of vehicle 433)
- Poor or inadequate reasons for apparent project terminations (i.e. vehicle 433, vehicle 166, vehicle 173)
- Questionable treatment of some vendor vehicles. The vehicle 178 was discussed extensively at the sulfate hearings.

6.4 American Motors (AMC)

AMC is the smallest of the domestic manufacturers and, perhaps not surprisingly, has mounted the least comprehensive effort directed toward 0.4 NOx. AMC, however, has an advantage that Ford and Chrysler do not have, through their consulting agreement with GM. AMC, in general, tends to follow the GM approach in many areas, their choice of production oxidation catalysts and some EGR systems are examples.

AMC has reported work targeted toward 0.4 NOx as early as 1971. At that time AMC was considering several approaches, and had indicated that the dual catalyst approach was considered to be one of the more promising systems to meet 0.4 NOx. However, in 1971, none were built and tested. AMC was also aware of the 3-way approach in 1971. The most promising test results for AMC in the 1971 status report came from a Questor system. This is one of the first Questor system tests known to the report team. Low mileage results of 0.01 HC, 2.44 CO, 0.37 NOx were achieved.

In spite of these results, AMC in 1971 indicated that they had no plans to use this system for the 0.4 NOx levels. Although the system certainly was a first generation prototype and had the problems associated with this approach (high temperatures, poor fuel economy, marginal CO control). These problems were ones that could have been attacked in 1971 by AMC. No further testing was planned in 1971, no cooperative development was mentioned, and AMC missed the opportunity to be one of the early leaders in the NOx control technology. This is another example of a corporate decision that used the technical drawbacks of a system to reject it, in spite of its having the best emission control demonstrated to that date at AMC, with essentially no AMC work done to improve the system.

In 1972 AMC had essentially chosen systems to pursue toward 0.4 NOx that were like GM's. Of the tests reported not one met the 0.41 HC, 3.4 CO, 0.4 NOx levels. So in 1972 AMC's project choice was based on what GM was doing.

In 1973 AMC was still planning to use a dual catalyst system. No durability testing was reported, putting AMC in the same position as they were in 1971 and 1972, essentially nothing in the durability area the most serious problem at the 0.4 NOx level. AMC's fall 1973 status report was identical to their suspension request earlier in the year in the area of 0.4 NOx development, an indication that no work was done in the interim. Even though AMC may have not known about the need for precise fuel metering before the NOx suspension hearings they knew about it afterwards, but no plans were reported to put an advanced fuel metering system on a dual catalyst vehicle in their status report.

In 1974, AMC reported only one test of a system that they claimed was a 0.4 NOx possibility. This was the vortex reactor vehicle which achieved 0.48 HC, 10.2 CO, 2.62 NOx. AMC indicated that the purpose of the project was twofold, to obtain data with an eye to eventual integration into a catalyst system, and to examine the possibility for adapting the concept to their rotary engine. The success or failure of this approach is not important. What is curious is that AMC would devote their time and resources to testing a system type whose poor chances for meeting 0.4 NOx were known from the literature several years earlier, when AMC had never been able to find the time and resources to do much at all in the area of their first choice system toward meeting 0.4 NOx.

In contrast to the actual testing and modifications to the thermal reactor vehicle, AMC reported that they were only beginning to construct a Gould catalyst vehicle in their 1974 Status Report.

In their latest submission, AMC reported work in four program areas:

1. Thermal Reactor
2. Gould's Reducing Converter
3. Rotary Engine
4. Pre-Chamber Stratified Charge Engine

No work in other program areas, for example noble metal NOx catalysts, 3-way catalysts, reactor-catalyst-reactor systems, or improved HC control were reported.

AMC indicated that once a generalized set of programs are generated to meet legislative mandates, the proposals are sent to the Engineering Vice President for program approval. This plan includes R&D projects, budget, facilities, timing, potential production tooling impact, and so on. The plans are also submitted to Purchasing and Manufacturing. The three parties determine that the program approved is compatible within all corporate limitations.

AMC stated that this plan submission and or approval has not been done for the 1978 model year. Therefore it could be said that AMC does not even have a plan approved for meeting the 0.4 NOx standard at this time. The lack of decisions on a well defined program for meeting 0.4 NOx is hampering AMC efforts, in the opinion of the report team. It may be that AMC is waiting to see what the Congress will do. AMC also did not indicate what "all corporate limitations" were.

Thermal Reactor

AMC's curious thermal reactor program was discussed above.

Gould Catalyst

The most significant 0.4 NOx work reported by AMC was with the Gould catalyst system. This system which was reported as in the build stage earlier in 1974, was installed in a vehicle in December, 1974. This date is about a month after the letter from Senator Muskie to Administrator Train which specifically mentioned the Gould catalyst. In the opinion of the report team, the impetus provided by that letter probably accelerated the completion of the vehicle. Vendor-based vehicles have a habit of taking a long time to build in the industry.

The vehicle is a 232 cubic inch six-cylinder 3500 pound inertia weight vehicle. The vehicle build list indicates that it includes several components that would tend to make it a full effort vehicle. Possible exceptions are noted below.

The carburetor is a 1975 production unit. While this is better than some manufacturers who have used older 1973-type units, it could be improved. Dual catalysts systems have suffered from poor fuel metering control for several years, and Gould's getter is an attempt to cope with this. AMC did not indicate if the carburetor configuration provided the correct CO/O_2 ratio during transient operation. They also tried some calibrations outside the rich region (15.5 to 1 A/F) which as far as the report team is aware is outside of the region for proper operation of the Gould system.

The ignition and EGR calibrations were not specified. AMC must know of the approach taken by GM and others to optimize EGR and spark timing. If GM can get a full size 5000 lb. vehicle down to about 1.0 NOx with EGR and advanced spark then AMC ought to be able to do as well with a 3500 lb. vehicle. Therefore, the NOx baseline on this vehicle (approximately 1.8 gpm) could be considered too high.

The oxidation catalyst is apparently a 160 cubic inch 1975 production catalyst. Better development catalysts may be available and should have been investigated, especially since AMC indicated that they had an HC and CO problem.

The air injection system included provisions for switching the air injection point from the manifolds to the oxidation catalyst after light-off. AMC indicated that after the 3500 miles of durability, air injection switching using manifold air injection during periods of choke operation would be tried. AMC indicated as early as 1971 that they knew that air injection switching should be used with a dual catalyst vehicle, therefore it is curious that the initial tests did not report using this approach. The high HC and CO reported by AMC may be due to this lack of a known technical approach. AMC indicated that the oxidation catalyst light off was delayed, but Gould has been able to get the Getter to light off (and act as a start catalyst) in 15 seconds, faster than AMC's own oxidation catalyst-only system.

AMC indicated that an EFE-type manifold was part of their first choice 1978 system. This vehicle was not so equipped.

AMC also reported that the exhaust back pressure with the Getter system was almost double that of a system with an oxidation catalyst. This may cause excessive use of the power valve during the test and lead to high HC and CO emissions. However, AMC did not report any discussion or work with Gould to attempt to resolve this problem.

Possibly because of the above-described less than optimum system configuration, the HC and CO performance has exceeded the 0.41 HC, 3.4 CO levels on this Gould catalyst vehicle. NOx has been below 0.4 on several tests, but not as low as AMC's 0.20 low mileage target, 0.37 NOx being the lowest reported. Test results of the vehicle in baseline and modified configuration are shown below:

TABLE AMC-1

System	System Miles	HC	CO	NOx	MPG
Baseline	Low	0.14	3.5	1.87	14.1
Gould	3550	0.51	3.89	0.45	15.1
Gould	3550	0.74	5.91	0.40	14.3

The Gould vehicle fuel economy results are essentially the same as the baseline vehicle.

All in all, the results are promising and if AMC spends a little more time optimizing the EGR and spark calibration and uses switched air injection, they may have their first reported dual catalyst durability car.

Rotary Engine

AMC reported little on their rotary engine program. The only results were a Curtis-Wright RC 2-60 engine with an AC 260 converter and air injection. Low mileage results were 0.80 HC, 2.72 CO, 1.78 NOx, 15.3 mpg at 3000 pounds interia weight.

What is important about this effort is that no EGR was used. In fact the emission control system appears to be targeted toward standards different than 0.41 HC, 3.4 CO, 0.4 NOx. AMC reported no plans to build a system for their rotary that would be targeted toward 0.4 NOx, indicating that their program may be targeted away from 0.4 NOx currently. This is considered odd, since the rotary could only come into production for AMC just about when 0.4 NOx would be a requirement (1978 and later).

Prechamber Stratified Charge Engine

No vehicle tests with a prechamber stratified charge engine were reported. Some engine dynamometer tests have been run showing an 8.2 percent loss in power, a 5 percent gain in ISFC at full power and a 2.7 percent loss in HC control, a 36 percent gain in CO control, a 42 percent gain in NOx control and a 13.5 percent gain in ISFC at part throttle, compared to the conventional engine.

Again no specific plans for making this concept meet 0.4 NOx were presented. Work with main chamber and prechamber EGR should have started concurrently. The best NOx results from this engine type (Honda's) were obtained with EGR and have been reported in the literature.

American Motors Summary

AMC's programs are fairly typical-a low rate of effort, less than full effort systems, and an apparent lack of cooperative development and problem solving with vendors. Unique to AMC is an almost total lack of durability testing of any 0.4 NOx system in the more than 4 years since the 1970 amendments.

APPENDIX ..

United States Senate

COMMITTEE ON PUBLIC WORKS
WASHINGTON, D.C. 20510

November 18, 1974

Honorable Russell E. Train
Administrator
Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Dear Mr. Administrator:

On March 22, 1974, you transmitted proposed legislation to modify the statutory automobile standard for emissions of oxides of nitrogen. This legislation was purportedly based on data which indicated the applicable statutory standard was not justified by current air quality data. More recently in a speech to the New York City Chamber of Commerce and Industry you indicated that the basis for relaxation of the statutory standard for control of automobile emissions of oxides of nitrogen was "that the required technology would not be available in time."

This statement appears to recognize the recent findings of the National Academy of Sciences that strict control of NOX may be needed to assure achievement of health related ambient air quality standards for photochemical oxidants, in that it does not argue for a modified NOX standard on the basis of air quality.

More recently the joint Environmental Protection Agency-Department of Transportation Fuel Economy Report indicated that the required technology to achieve a .4 NOX standard can in fact be available within the time required by current law.

In light of the NAS findings and the conclusion of the Fuel Economy Report it is imperative that there be a determination of the extent to which the auto companies are actively pursuing this requirement of the Clean Air Act. Such a review should include analysis of the level of auto company investment to achieve the statutory NOX standard as well as the extent to which the companies are taking advantage of recent developments by non-industry suppliers. This latter point is particularly important in light of recent information released by Gould, Inc. which indicates that a feasible, fuel-efficient NOX catalyst is now available.

Honorable Russell E. Train
Page Two
November 18,1974

Undoubtedly Congress will be asked to review the 1978 statutory standard for NOX next year. Your review and analysis of the good faith of the industry in attempting to comply with that requirement will be essential to that review.

Sincerely,

EDMUND S. MUSKIE, U.S.S.
Chairman, Subcommittee on
Environmental Pollution

APPENDIX B

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

January 6, 1975

Dear

We have been requested by the Senate Public Works Committee to review and analyze the efforts of your and other automobile manufacturing companies to meet the statutory emission standard for oxides of nitrogen that becomes effective with the 1978 model year, and to report promptly to the Senate Public Works Committee on the results of this review. The information on this issue is required to be reported by the Environmental Protection Agency to the Congress by Section (202)(b)(4) of the Clean Air Act. In the past information for the Section (202)(b)(4) report was obtained from auto company suspension applications and related submissions; this year it is necessary to obtain this information separately since no suspension of the NOx standard is authorized by the Act.

There is enclosed with this letter as a supplement to my request for information of September 20, 1974, an outline of information requested to be submitted by your company which will enable us to make the review and analysis that has been specifically requested by the Committee. To permit timely preparation and submission to the Committee of the requested report, you are requested to provide the information identified in the enclosed outline by February 1, 1975. Please address your response to this letter to the Deputy Assistant Administrator for Mobile Source Air Pollution Control, AW-455, 401 M Street, S.W., Washington, D.C. 20460, room 741, WSMWT, whose office has responsibility for EPA in making this analysis.

Any questions about the information desired should also be addressed to that office.

Sincerely yours,

Roger Strelow
Assistant Administrator
for Air and Waste Management (AW-443)

Enclosure

IDENTICAL LETTERS SENT TO:

Foreign Manufacturers

Mr. Guenter Storbeck
Product Planning Manager
Volkswagen of America, Inc.
818 Sylvan Avenue
Englewood Cliffs, New Jersey 07632

Mr. Bernard Steinhoff
Emission Control Department
Mercedes-Benz of North America, Inc.
One Mercedes Drive
Montvale, New Jersey 07645

Dott. Ing. Andrea Catanzano
Automobili Ferruccio Lamborghini, S.p.A.
40019 S. Agata
Bologna, Italy

Mr. Guy Malleret
Managing Director
Officine Alfiera Maserati, S.p.A.
Viale Ciro Menotti, 322
41100 Modena, Italy

Mr. Guido A. Foggini
Designated Agent (Ferrari)
Fiat Motor Company
560 Sylvan Avenue
Englewood Cliffs, New Jersey 07632

Toyo Kogyo
Suite 423, 2733 Greenfield Road
Southfield, Michigan 48075
Attn: Mr. G. Utsunomiya
Technical Liaison

Mr. Olaf E. Strand
Assistant Engineer
U.S. Suzuki Motor Corporation
13769 Freeway Drive
Santa Fe Springs, California 90070

Mr. Toshitake Mishimura
Manager, USA Office
Isuzu Motors Ltd.
c/o C. Itoh and Company (America), Inc.
245 Park Avenue
New York, New York 10017

Domestic Manufacturers

Mr. Ernest R. Starkman
Vice President
Environmental Activities Staff
General Motors Corporation
Warren, Michigan 48090

Mr. Herbert L. Misch
Vice President
Ford Motor Company
The American Road
Dearborn, Michigan 48121

S.L. Terry, Vice President
Chrysler Corporation
Post Office Box 1919
Detroit, Michigan 48231

Mr. W.J. Martin
Staff Engineer, Vehicle Emissions
International Havester Company
Motor Truck Engineering Department
Post Office Box 1109
Fort Wayne, Indiana 46801

Mr. Daniel Hittler
Manager, Development Department
American Motors Corporation
14250 Plymouth Road
Detroit, Michigan 48232

Outline of Supplementary Information
for Emission Control Status Report

The information requested in the following paragraphs should be specifically addressed to your company's efforts to meet the 1978 emission standard for oxides of nitrogen (0.4 gm/m). To the extent that relevant information has already been submitted to EPA, copies of the previous submission will serve as a response to this request. If a complete response on the issue of your company's effort toward meeting the 0.4 gm/m NO_x standard requires a description of efforts to meet the statutory HC and CO standards, such information should be included in the response.

Please submit an original and four copies of your response, by no later than February 1, 1975, to the Deputy Assistant Administrator for Mobile Source Air Pollution Control, AW-455, 401 M Street, S.W., Washington, D.C. 20460.

Section 1 should contain the company's statement of its total effort to achieve compliance with the established emission standards. The statement should present a discussion of the company's research, development, testing and engineering program(s) in the area of emission control. The statement should include:

a. The overall organization chart for the emission control activity with an indication of the decision-making process in major areas; for example, selection of first choice 1978 system. The names and titles of all responsible personnel in the organization description should include all personnel involved in the light duty vehicle emission control area down to and including the first supervisory level.

b. Engineering goals for the emission levels to be achieved by low mileage engineering prototypes in order to achieve compliance with the emission standards, including assumptions made to arrive at those goals; factors assumed to allow for production variations, prototype-to-production slippages, and deterioration; and change in production variations assumed to occur by 1978 model year production.

c. The composition of the program(s), presented in sufficient detail to include the number and qualifications of professional personnel assigned to emission control activity, and the academic or functional disciplines involved, the type(s) and quantity of major items of laboratory equipment used (e.g., visible, ultra-violet and infra-red spectrophotometers), and the laboratory and testing facilities used. When equipment, projects, and personnel are only partially dedicated to the emission control activities, the company should indicate the percentage portion of such equipment, projects, and personnel so dedicated.

d. The purpose of each program, including the specific technical problem or area toward which the program is directed, the reasons for the program, the date the program was started and its projected or actual end date.

e. Detailed lead time schedule for model year 1978 production, including crucial milestones, commitment and signoff dates, lead time requirements of vendors, and specific lead time schedules for those emission control system components which are most critical. Discuss how much less lead time would be required to produce a reduced number of models or nameplates that will comply.

f. The progress of each program toward achieving the goals set out for it, including information as to: (i) whether the program is ahead or behind schedule, (ii) important milestones that have been met/not met., (iii) the number of times the program's progress has been reviewed (date and specifics) and the personnel responsible for the review, (iv) the outcome of the program reviews, and (v) any changes there have been in the rate of progress for the program as a result of review and redirection.

g. A narrative discussion of the results. Quantitative data should be included here to the extent it is not presented in other sections of the submission.

h. Major problems associated with the most promising system investigated, including fuel consumption, emissions of currently unregulated pollutants, reduc . driveability, other performance penalties, and any safety, maintenace servcing, warranty, development (emission performance, durability and producibility), production tooling, and vendor problems.

i. Plans for resolving the problems identified in h including use of technology developed o .side the company or outside the automobile industry, timetable for developing solutions, critical milestones for meeting this timetable, confidence placed in the schedule, areas of greatest uncertainty, probable or possible breakthrough(s) that would result in a significant reduction in lead time, and consequences of any shortcuts both to the company and to the potential vehicle user.

j. Where an individual project within a program is of significant importance or has not been fully discussed in the program discription, a narrative description providing at the least the following: time of project start/end, level or effort (man hours), reason for starting and stopping the project, results obtained, and how the results of the project were used in the overall approach to emission control program being investigated.

k. The efforts that have been made to identify useful technology developed by other companies.

l. That portion of the program(s) carried out under contracts or agreements with other firms or ad hoc organizations.

m. The efforts, results, and conclusions relative to all alternative power systems considered.

n. The accomplishments of the research, development, testing and engineering program(s) in terms of determination of feasible and non-feasible approaches to emission control, patents obtained or pending, and publications in technological journals, including knowledge and account of any pertinent independent research conducted by facilities not associated with the company.

Section 2 should contain the company's detailed expression of its financial commitment to emission control research, development, testing and engineering activities.

a. A project narrative should be completed for each project or particular phase of a project in research, development, testing and engineering for the years 1969 through 1978. The project narrative should include the following:

1. Project title, number of designation and date started or planned to start.

2. Project description, including objectives, scope, approach, phase and status. Phase refers to research, development, engineering, testing or other areas of the emission control program. Project status should indicate the percentage completion of the project and which phases of the program have been completed for the project and which phases are pending.

3. Description of the project's relationship to the total effort to meet the emission standards for the 1978 model year and relationship to or dependency upon other projects. The description should include whether the project was originated because of the 1970 Amendment to the Clean Air Act, the original objective of the project if they have changed since inception, the percent of direct cost attributed to the present project objectives, and the basis of the percentage attribution.

b. Direct research, development, testing and engineering cost should be summarized in this sub-section. These costs should be presented as shown below - by type of expense and by year of expenditure, including projections for 1975 to 1978, if possible for each project or project phase described in 2(a). Financial data presented in this sub-section must be consistent with the project narratives of 2(a), and should conform to the normal accounting year of the company, with designation of the fiscal year end. Expense classification applied and specifically indicated when a classification change has been made.

The financial commitment for services supplied by outside organizations, i.e., those services financed by the company that can be directly related to its emission control program, should be reported. The following outline should be used to report direct costs for each project identified in 2(a):

Projection Title	Actual Costs 69, 70, 71, 72, 73, 74	Projected Costs 75, 76, 77, 78

Direct project costs

1. Salaries and wages
   (A) Professionals
   (B) Laboratory technicians
   (C) Other technical & clerical
2. Chemicals and gases
3. Laboratory supplies
4. Outside services (identify)
5. Rental expenses
6. Equipment purchases expense
7. Depreceiation expense*
8. Other direct costs (identify)
9. Total direct project costs

Other information

10. Number of personnel directly assigned to project at end of each year.

    (A) Professionals:

        Full Time
        Part Time

    (B) Laboratory technicians

    (C) Other technic-l & clerical

*Submit separate schedule indicating costs of buildings and/or equipment purchased and the respective asset life used to calculate depreciation.

c. Company should indicate in this sub-section all other costs that may be allocated to the emission control projects reported in 2(a). Such costs are to be listed by year of expenditure, including projections for 1975 and 1978, if possible, along with a detailed description of the expenditure and the basis for allocation. The nature of these costs, (e.g., research and development administrative costs, employee benefits, utilities, depreciation of certain research and development facilities) makes it normally not practical to allocate the costs of each project.

d. This sub-section should contain a summary of emission control program costs of each year (69-78). Direct project costs of projects reported in 2(b) should be totaled and added to the total other allocated from 2(c). This total should be the total cost (past and projected) of research, development, testing and engineering by year as applied to emission control systems for light duty vehicles. Total company Research and Development cost by year and total domestic (U.S.) light-duty vehicle sales by year (69-78) should also be presented in this sub-section.

Additional Information

Part V A, First Cost Information, of the "Outline for Emission Control Status Report" has been extended to include the specific costs by major engine family. If this information was not contained in your response to our September 20 request for information, please submit it with the response to this request.

APPENDIX C

Attachment 1

CHRYSLER CORP.

CORPORA

CHARLES M. HEINEN
DIRECTOR
VEHICLE EMISSIONS PLANNING
PRODUCT PLANNING AND DEVELOPMENT OFFICE

April 11, 1975

Mr. Eric O. Stork
Deputy Assistant Administrator
Mobile Source Air Pollution Control (AW-455)
Environmental Protection Agency
401 M Street, S.W.
Washington, D. C. 20460

Dear Mr. Stork:

In response to your letter of March 28, 1975 to Mr. S. L. Terry, I am forwarding to you the requested information regarding Chrysler's commitment of dollar resources and manpower to NOx and HC/CO emissions control for the 1970 through 1975 calendar years.

It is hoped that this information will prove sufficient to satisfy the needs of your Agency and the Senate Public Works Committee in determining the degree of effort that Chrysler has expended in these two areas of emission control. We appreciate the opportunity to clarify the information that we supplied to you in our February, 1975 Progress Report on Chrysler's Efforts to Meet the 1978 Federal NOx Emission Standards.

Sincerely yours,

Charles Heinen

CMH:mn
Attachment
cc: Mr. S. L. Terry

EMISSIONS CONTROL

DOLLAR RESOURCES AND PROFESSIONAL TECHNICAL MAN-YEARS

CALENDAR YEAR 1970, 1971, 1972, 1973, 1974, 1975

(Dollars in Millions)

	1970 Actual		1971 Actual		1972 Actual		1973 Actual		1974 Estimated		1975 Estimated	
	Resources	Man-Years	Resources	Man-Years	Resources	Man-Years	Resources	Man-Years	Resources	Man-Years	Resources	Man-Years
NOx	$ 2.5	109	$ 4.0	145	$ 7.9	340	$13.7	475	$ 10.9	381	$ 9.0	210
HC/CO	5.0	220	8.0	289	8.1	360	16.9	592	19.6	685	19.0	460
Other	-		-		.1	5	.2	8	.1	5	.8	20
TOTAL	$ 7.5	329*	$12.0	434*	$16.1	705*	$30.8	1075*	$30.6	1071*	$28.8	690*
Administrative Support	$ 1.2		$ 1.4		$ 2.5		$ 3.3		$ 2.9		$ 2.4	
Capital Expenditures	$ .3		$ 1.0		$ 1.2		$13.4		$ 9.3		$ 3.6	
Total Resources	$ 9.0		$14.4		$19.8		$47.5		$42.8		$34.8	

Note: These figures have been prepared by using analysis techniques and are not taken from official books of record.
* Does not include Quality Control personnel.

April 11, 1973

SECTION II

FINANCIAL SUMMARY

Chrysler's commitment of its resources to vehicle emission control for the years 1967 through 1975 is shown on Table One on Page I-B-3.

Table Two provides a breakdown of our financial commitment for the years 1970 through 1974 by emission control technology programs. The following list indicates which of the 1974 cost categories the 1975 cost categories are being placed into for the comparisons to 1974 and before cost categories in Table Two.

Table Three provides a breakdown of emissions control resources expressed as a percentage of the total ER&D resources. Table Four details Chrysler's capital costs for labs, equipment, and facilities added for the 1973 and 1974 calendar years for engineering activities engaged in emissions control. Table Five is a detailed breakdown of the emission control dollar resources estimated to be spent in the 1975 calendar year.

1 - Engine Modifications

CN	Evaporative Emission Control
UB	A-406 Long-Life Spark Plug
COG	Improved Carburetion
COH	Advance Carburetion
COJ	Altitude Compensation
UI	Electronic Lean Burn (A-416)
COK	Improved Emission Components
COP	Temperature Control
CP/2	Emissions Certification (1/2 of this in Catalytic Reactors)

2 - Electronic Engine Control

COC	Lean Burn Concept Plus Oxidation Catalyst
SX	Electronic Fuel Metering (A-330)

3 - Thermal Reactors

COB	Air Pump Development

4 - Catalytic Reactors

COA	Oxidation Catalyst Development
COE	Exhaust Heat Conservation (Reactor)
COI	NOx Reduction Catalysts
COM	Production Support - Emissions
CON	Emissions Support Testing
COR	Emissions Cost Reduction
COQ	Engine Dynamometer Durability
CP/2	Emissions Certification (1/2 of this in Engine Modification)

5 - Alternate Power Sources

ST	A-907 Gas Turbine

It can be noted that, unlike its major competitors, Chrysler does not manufacture many of the vehicle components that are important to the control of emissions. Carburetors, spark plugs, air pumps, electronic sensors, thermostatically controlled carburetor air cleaners, catalysts, exhaust systems, and crankcase ventilation valves are all purchased from outside vendors. The cost of the basic research and development of these components is borne by our vendor companies and is not therefore reflected in the Chrysler costs shown in Tables One, Two, and Three. However, Chrysler's share of these component development costs is reflected in the purchase price of such components from our vendors.

Reference should also be made to Section I-B of this report which provides the details of Chrysler's present level of personnel, equipment, and facilities devoted to emissions control activities.

TABLE ONE

EMISSION CONTROL RESOURCES - SUMMARY

CALENDAR YEAR 1967 THROUGH 1975

(Dollars in Millions)

Calendar Year	Total Dollar Resources (Emissions)	Total Dollar Resources (Safety)	Total Dollar Resources (All ER&D)	Professional Technical Man-Years	Light-Duty Vehicle Sales	Profit (Loss)
1967	$ 2.9	--	$ 75.7	140	$3,790	201.0
1968	4.4	--	83.9	172	4,642	302.0
1969	6.6	--	95.1	230	4,189	95.0
1970	9.0	$10.4	81.5	329	4,041	(13.0)
1971	14.4	14.2	90.4	434	4,640	85.0
1972	19.8	13.9	124.0	705	5,296	223.0
1973	47.5	20.9	149.3	1075	5,720	258.0
1974 (Estimated)	42.8	16.6	150.9	1071	--	(52.0)
1975 (Estimated)	34.8	16.0	120.4	690	--	--

NOTE: The ER&D and Man-Year figures have been prepared by using analysis techniques and are not taken from official books of records.

February 21, 1975

TABLE TWO

EMISSIONS CONTROL

DOLLAR RESOURCES AND PROFESSIONAL TECHNICAL MAN-YEARS

CALENDAR YEAR 1970, 1971, 1972, 1973, 1974, 1975

(Dollars in Millions)

	1970 Actual		1971 Actual		1972 Actual		1973 Actual		1974 Estimate		1975 Estimate	
	Resources	Man-Years	Resources	Man-Years	Resources	Man-Years	Resources	Man-Years	Resources	Man-Years	Resources	Man Years
Engine Modification	$3.7	166	$ 4.2	170	$ 5.3	233	$20.0	350	$13.1	458	$11.7	280
Elect. Eng. Control	0.4	12	1.0	38	1.1	48	1.5	50	1.6	58	2.0	50
Thermal Reactors	1.9	79	3.0	101	1.9	84	2.3	80	0.2	7	0.5	10
Catalytic Reactors	1.4	70	3.5	114	7.0	305	13.4	470	13.9	488	12.7	305
Alternative Prop. Systems	0.1	2	0.3	11	0.8	35	3.6	125	1.7	60	1.9	45
TOTAL	$7.5	329*	$12.0	434*	$16.1	705*	$30.8	1075*	$30.6	1071*	$28.8	590
Administrative Support	$1.2		$ 1.4		$ 2.5		$ 3.3		$ 2.9		$ 2.4	
TOTAL	$8.7		$13.4		$18.6		$34.1		$33.5		$31.2	
Capital Expenditures	$ .3		$ 1.0		$ 1.2		$13.4		$ 9.3		$ 3.6	
Total Resources	$9.0		$14.4		$19.8		$47.5		$42.8		$34.8	

Note: These figures have been prepared by using analysis techniques and are not taken from official books of record.
* Does not include Quality Control personnel.

February 21, 1975

TABLE THREE

EMISSIONS CONTROL RESOURCES PRESENTED AS

A PERCENTAGE OF TOTAL ER&D RESOURCES

alendar Year	% Dollar Resources (Emissions)	% Dollar Resources (Safety)	% Dollar Resources (Other)	% Total Dollar Resources (All ER&D)
1967	4%	-	-	-
1968	5%	-	-	-
1969	7%	-	-	-
1970	11%	13%	76%	100%
1971	16%	16%	68%	100%
1972	16%	11%	73%	100%
1973	32%	14%	54%	100%
1974 Est.	28%	11%	61%	100%
1975 Est.	29%	13%	58%	100%

n the months of January and February, 1975, the following percentge of those persons working in the Engineering Office, Product lanning, Research and the Emissions Office were working on the missions or safety areas:

Emissions	-	32.4%
Safety	-	12.3%
		44.7%

t should be noted that the percentage of personnel devoted to missions control projects for these months is at an all-time igh.

TABLE FOUR

CAPITAL COSTS OF EMISSION CONTROL LABS, EQUIPMENT
AND FACILITIES FOR THE 1973 AND 1974 CALENDAR YEARS
($ in Millions)

	1973	1974	Total
:hassis Engineering	$ .7M	$1.8M	$ 2.5M
'ehicle Engineering	2.4	.4	2.8
:missions	7.2	4.8	12.0
esearch	.7	.2	.9
dmin. Services	2.3	2.1	4.4
TOTAL	$13.3M	$9.3M	$22.6M

eference Section I-B of this report for a detailed explanation of the lab equipment or facilities added for emissions control t Chrysler during the 1973 and 1974 calendar years.

TABLE FIVE

EMISSIONS CONTROL
DOLLAR RESOURCES (DETAIL)
CALENDAR YEAR 1975 (ESTIMATED)
($ in Millions)

Cost Category	Project Title*	ER&D
COA	Oxidation Catalyst Development	$ 3.5M
COB	Air Pump Development	.5
UI	Electronic Lean Burn (A-416)	2.3
COC	Lean Burn Concept Plus Oxidation Catalyst	.5
COE	Exhaust Heat Conservation (Reactor)	.7
COG	Improved Carburetion	2.0
COH	Advance Carburetion	1.2
SX	Electronic Fuel Metering (A-330)	1.4
COI	NOx Reduction Catalysts	2.3
COJ	Altitude Compensation - 1977	.2
ST	A-907 Gas Turbine	1.9
CN	Evaporative Emissions Control	.9
COK	Improved Emissions System Components	.8
UB	A-406 Long Life Spark Plug	.2
COM	Production Support - Emissions	1.1
CON	Emissions Support Testing	.9
COP	Temperature Control	.8
COQ	Engine Dynamometer Durability	.7
COR	Emissions Cost Reduction	.4
CP	Emissions Certification	6.5
	Total Calendar Year 1975 ER&D	$28.8M
	Capital and Administration	6.0
		$34.8M

*Reference Pages II-A-3 through A-21 of Volume II of this report for a detailed project description.

Attachment 2

FORD MOTOR CO.

Ford Motor Company

1967-1976 EMISSION CONTROL EXPENDITURES & EQUIVALENT HEADCOUNT a/

Calendar Year Expenditures

Proj.	Project Description	1967 (Mils)	1968 (Mils)	1969 (Mils)	1970 (Mils)	1971 (Mils)	1972 b/ (Mils)	1973 (Mils)	1974 (Mils)	1975 d/ (Mils)	1976 d/ (Mils)
	Research & Engineering										
	Variable Effort										
1	R&D of systems designed for meeting 1975 Federal standards	$	$ -	$ -	$ 0.3	$ 2.0	$ 9.4	$ 34.6	$ 41.8		
[illegible]	R&D of systems designed for meeting 1978 Federal standards	-	0.1	0.3	0.4	1.2	3.3	4.3	6.5		
[illegible]	~~R&D of systems designed for meeting 1974 California~~ Standards		*	*	0.6	3.1	16.1	22.3	-		
[illegible]	Catalyst Component research	0.3	0.5	0.6	0.9	1.9	2.5	4.3	3.1		
[illegible]	[illegible] for Manifold Component Research	0.2	0.4	0.3	0.6	1.3	0.8	0.2	0.1		
[illegible]	[illegible] system test research	0.1	0.2	0.2	0.3	0.9	1.0	1.0	1.1		
[illegible]	Ignition system component research	0.1	0.2	0.2	0.7	0.9	0.5	0.6	0.8		
[illegible]	Other basic engine research	1.0	-	0.8	0.4	0.3	0.3	0.3	0.5		
[illegible]	Induction and fuel system component research	0.9	[illegible]	0.9	1.5	1.9	2.2	3.4	3.7		
[illegible]	Fuels and lubricants research	0.2	[illegible]	0.3	0.4	0.4	0.5	0.4	0.4		
[illegible]	Research in Physics and Chemistry related to HC, CO, NO_x	0.1	0.1	0.1	0.3	0.2	0.1	0.2	0.3		
12	Alternate power source research	4.8	1.3	6.6	8.0	13.0	20.3	31.6	23.1		
13	Research on potential internal combustion engine emissions	*	-	*	*	0.1	0.1	0.2	0.3		
14	Testing and data analysis research	0.2	[illegible]	0.8	1.1	2.4	3.8	3.6	3.9		
15	Evaporative emission research	0.1	1.0	0.7	0.4	0.7	1.2	0.7	0.4		
16	Crankcase emission research	*	*	-	*	0.1	*	-	-		
17	Closed loop emissions research	*	*	*	0.1	0.3	0.8	2.0	2.3		
18	Emission development certification and production emission engineering (cars and trucks)	1.1	1.5	1.7	2.2	8.5	12.4	26.4	32.3		
19	R&D in support of production exhaust emission control components	[illegible]	5.2	9.4	12.7	19.2	18.0	11.7	15.3		
20	Air quality research	[illegible]	[illegible]	0.4	0.6	0.7	0.8	0.9	0.9		
21	Coordination and communication	[illegible]	0.1	0.7	1.3	1.0	0.9	1.0	1.1		
22	R&D of systems designed for meeting 1977 Federal standards	-	-	-	-	-	-	4.5	13.2		
	Total Variable Effort	$ 13.3	$ 17.7	$ 24.0	$ 32.8	$ 60.1	$ 95.7	$154.2	$151.1	$125.0	$125.0
	Support Effort	8.7	8.6	12.3	18.7	29.9	36.2	53.3	55.2	50.0	50.0
	Total Research & Engineering	$ 23.1	$ 26.3	$ 36.3	$ 51.5	$ 90.3	$131.9	$207.5	$206.3	$175.0	$175.0
	Other Emission Control Expenditures										
	Tooling	$ 7.6	$ 6.3	$ 9.9	$ 4.8	$ 10.9	$ 14.7	$ 45.2	$ 82.8	$39.7	$104.0
	Facilities	16.2	2.8	4.2	9.2	27.2	15.2	36.9	51.7	22.3	51.9
	Launching	3.5	0.2	2.3	1.5	3.5	3.1	9.6	16.5	1.1	11.1
	Total Other Emission Expenditures	$ 27.3	$ 9.3	$ 16.4	$ 15.5	$ 41.6	$ 33.0	$ 91.7	$151.0	$63.1	$167.0
	Total Expenditures	$ 50.7	$ 35.6	$ 52.7	$ 67.0	$131.9	$164.9	$299.2	$357.3	$238.1	$342.0

Calendar Year Weekly Equivalent Headcount

Project Description	1967	1968	1969	1970	1971	1972	[illegible]	[illegible]
R&D of systems designed for meeting 1975 Federal standards	-	-		16	79	288	1,105	1,126
R&D of systems designed for meeting 1978 Federal standards	-	3	15	18	47	112	182	254
~~R&D of systems designed for meeting 1974 California~~ Standards	-	1	-	26	113	561	850	
Catalyst Component research	18	27	29	19	79	138	124	94
[illegible] for Manifold Component Research	11	15	15	28	32	[illegible]	6	4
[illegible] system test research	5	12	9	11	31	36	29	32
Ignition system component research	8	11	19	45	27	7	10	21
Other basic engine research	55	32	10	17	12	-	[illegible]	1
Induction and fuel system component research	50	13	18	77	[illegible]	[illegible]	108	100
Fuels and lubricants research	7	17	12	16	13	12	8	8
Research in Physics and Chemistry related to HC, CO, NO_x	6	4	7	13	8	1	6	10
Alternate power source research	191	219	240	253	318	416	162	372
Research on potential internal combustion engine emissions		-		1	1	2	5	8
Testing and data analysis research	7	26	57	61	106	141	134	160
Evaporative emission research	22	59	34	21	29	31	21	[illegible]
Crankcase emission research	-		-	-	1	1	-	-
Closed loop emissions research	-	1	1	3	9	16	56	51
Emission development certification and production emission engineering (cars and trucks)	68	103	101	123	199	51[illegible]	1,153	[illegible]
R&D in support of production exhaust emission control components	[illegible]	[illegible]	[illegible]	681	[illegible]	[illegible]	303	[illegible]
Air quality research	2	4	1	[illegible]	[illegible]	[illegible]	9	8
Coordination and communication	1	10	32	37	[illegible]	28	[illegible]	[illegible]
R&D of systems designed for meeting 1977 Federal standards	-	-	-				122	357
Total Variable Effort	[illegible]	883	1,159	[illegible]	2,315	3,160	1,730	4,662
Support Effort	[illegible]	318	389	[illegible]	752	881	1,138	1,135
Total Research & Engineering	1,070	1,201	1,548	2,018	[illegible]	4,041	5,868	5,797

* Less than $50,000

Note: The uncertainty of the 1977 and 1978 calendar year emission requirements precludes a workload forecast at this time.

a/ Includes non-independent engine/powertrain and related effort to recover fuel economy.

b/ Excludes 1971 model recertification.

c/ [illegible] includes salaried, agency, hourly and overtime equivalent personnel.

d/ 1975 and 1976 calendar year expenditures and headcount represent preliminary estimates.

1978 NOx Suspen
Feb, 1975

Section II: Financial Commitment

Section VIIIA of Ford's Application for Suspension of 1977 Motor Vehicle Exhaust Emission Standards summarizes the allocation of Ford's emission control activities among 22 general project categories. The following Table presents financial data for each of these same 22 project categories relating to Ford's efforts for 1978 low NO_x development.

Total research and engineering expenditures were 17.8 million dollars for calendar year 1974, up 3.8 million from 1973 expenditures of 14 million dollars.

Note:

EPA discussions with Ford staff members revealed that Ford's NOx expenditure data was compiled for efforts directed towards meeting the 1978 standard only and did not include NOx research in meeting earlier standards which could be applied to the 1978 standard.

1973-1974 ACTUAL EMISSION CONTROL EXPENDITURES RELATED TO 1978 LOW NO_x

›ject ıber	Project Description	Calendar Year Expenditures 1973 (000)	Percent of project variable effort	1974 (000)
	earch & Engineering ariable Effort			
1	R&D of systems designed for meeting 1975 Federal standards	$ --		$ --
2	R&D of systems designed for meeting 1978 Federal standards	4,336	(100%)	6,494
3	R&D of systems designed for meeting 1974 California Standards	--		--
	Catalyst Component Research	691	(16%)	294
	Reactor Manifold Component Research	106	(44%)	20
	EGR system research	551	(53%)	278
	Ignition system component research	290	(50%)	380
	Other basic engine research	85	(25%)	241
	Induction and fuel system component research	418	(12%)	499
	Fuels and lubricants research	57	(16%)	16
	Research in Physics and Chemistry related to HC, CO, NO_x	76	(31%)	95
	Alternate power source research	--		--
	Research on potential internal combustion engine emissions	--		15
	Testing and data analysis research	318	(9%)	455
	Evaporative emission research	--		--
	Crankcase emission research	--		--
	Closed-Loop emissions research	1,060	(53%)	1,045
	Emission development certification and production emission engineering (cars and trucks)	407	(2%)	446
	R&D in support of production exhaust emission control components	335	(3%)	625
	Air quality research	40	(4%)	136
	Coordination and communication	--		--
	R&D of systems designed for meeting 1977 Federal Standards	--		--
	Total Variable Effort	$ 8,826		$11,029
	Support Effort	5,245		6,769
	Total Research & Engineering	$14,065		$17,798

Attachment 3

GENERAL MOTORS CORP.

(000's Omitted)

CALENDAR YEAR BASIS
1967 - 1977

Control System Projects

		1967	1968	1969	1970	1971	1972	1973	Projected 1974	1975	1976	1977
	Direct Expenditures	$	$	$	$	$	$	$	$	$	$	$
1.	Catalytic Converters - Converter	50	205	243	1,592	4,089	4,775	15,764	12,279	9,616	11,334	12,[illegible]
2.	- Other	-	-	-	-	-	4,306	2,040	1,781	2,928	4,608	4,[illegible]
3.	Questor System	-	-	-	-	-	414	207	87	43	44	
4.	Single Catalytic System (Combined reduction HC, CO and NO_x	-	-	-	-	-	11	156	320	980	1,540	2,[illegible]
5.	Crankcase Blowby Controls (PCV)	1,342	1,530	494	218	492	380	345	406	453	571	[illegible]
6.	Air Injector Reactor System (AIR)	1,327	1,005	1,016	2,429	3,426	3,913	5,011	4,084	4,397	4,663	4,[illegible]
7.	Exhaust Gas Recirculation (EGR)	13	36	230	1,073	2,988	5,495	5,799	4,401	4,172	3,903	3,[illegible]
8.	Spark Control Systems (TCS, SCS)	338	611	1,018	3,738	3,469	4,299	5,804	4,083	3,761	3,231	2,[illegible]
9.	Manifold Heat (EFE)	19	32	45	-	1,192	979	1,648	1,687	1,971	2,088	1,[illegible]
10.	High Energy Ignition	463	112	217	1,117	2,695	3,270	-	-	-	-	
11.	Electric Fuel Pump	-	-	-	-	-	149	190	151	139	151	[illegible]
12.	Exhaust System (Long Life)	-	-	-	-	-	153	-	-	-	-	
13.	Fuel Filler Neck Change	-	-	-	-	-	131	323	220	180	167	[illegible]
14.	Controlled Combustion System (CCS)	1,192	1,210	1,383	2,792	2,811	1,621	1,239	1,734	1,386	2,025	1,[illegible]
15.	Manifold Reactors	-	111	254	579	894	889	1,724	630	660	1,195	1,[illegible]
16.	Evaporative Emission System	563	958	1,057	3,193	2,796	2,179	2,070	1,784	1,884	1,983	2,[illegible]
17.	Fuel Injection	52	459	1,549	3,055	4,128	1,270	874	1,654	1,340	1,769	1,[illegible]
18.	Asbestos, Rubber, Etc.	-	-	-	-	-	74	131	220	345	381	
19.	Gaseous Fuels - LPG, LNG, CNG	8	-	107	176	139	91	97	19	4	4	
20.	Fuel Specifications	22	95	176	893	2,363	841	624	857	734	815	[illegible]
21.	Smoke, Odor	16	34	115	209	74	117	287	136	147	154	[illegible]
22.	Carburetion - Current Models	2,932	2,532	3,030	5,208	7,785	7,846	6,257	8,743	8,771	9,460	9,[illegible]
23.	- Future Models	1,797	2,334	2,000	2,068	4,186	11,494	12,603	5,752	6,830	7,452	7,[illegible]
24.	Emission Testing and Analysis - End of Line	533	1,550	1,811	3,318	7,322	9,495	8,767	5,775	6,279	7,060	7,[illegible]
25.	- Other	735	1,290	2,385	3,180	7,004	8,047	11,080	12,922	15,680	15,660	17,[illegible]
26.	Alternate Power Sources	1,940	5,086	9,172	12,054	20,106	22,136	35,264	35,017	34,191	26,417	27,[illegible]
27.	Other	1,556	1,309	4,004	2,212	3,622	4,241	6,413	9,262	10,042	12,406	12,[illegible]
	Sub-Total Direct Expenditures	14,898	20,499	30,306	49,104	81,581	98,616	124,717	113,984	116,933	119,281	122,[illegible]
	Facilities	17,872	5,108	6,172	23,451	30,471	41,828	62,963	124,651	18,018*	10,495*	4,[illegible]
	Tools	9,323	1,389	7,749	16,289	25,412	48,165	60,615	152,752	22,819*	7,214*	5,[illegible]
	Total Direct Expenditures Inc. Facilities & Tools	[illegible],093	26,996	44,227	88,844	137,464	188,609	248,295	391,3[illegible]	157,770	136,9[illegible]	132,[illegible]
	Allocated Costs	9,053	12,006	19,584	30,132	44,133	48,515	60,549	58,615	57,230	58,01[illegible]	57,[illegible]
	Total excluding GM Support of MVMA	51,146	39,002	63,811	118,976	181,597	237,124	308,844	450,000	215,000	195,000	190,[illegible]
	GM Support of Motor Vehicles Manufacture Association**	101	708	1,230	957	50	740	662	662	662	662	[illegible]
	Total Expenditures	51,247	39,710	65,041	119,933	181,647	237,864	309,506	450,662	215,662	195,662	190,[illegible]

The above data display a summary for the years 1967 through 1973 and a projection through 1977.

* Capital spending for facilities and tools in 1975 and subsequent years is considerably below the 1974 level due to the uncertainty in our programs resulting from our inability to forecast the technology which will permit us to meet all the requirements of the 1977 and 1978 emission standards on production vehicles. Actual expenditures are expected to be higher when definite programs can be established.

** Forecast of MVMA support is assumed to approximately the same as 1973 since data is not currently available from MVMA.

SECTION VIII

PROGRAM EXPENDITURES, CONSUMER COST AND MANPOWER

Section VIII relates to the financial and manpower commitments made by General Motors toward meeting the 1978 emission standards for oxides of nitrogen. General Motors is devoting financial resources and manpower to attempt to comply fully on a timely basis with federal mandated emission standards. Further, implicit in all our research and development programs is GM's continuing commitment to improve vehicle fuel economy, with current emphasis being directed towards meeting the President's goal of a 40% improvement in fuel economy for the industry by 1980. This will mean a 53% sales weighted improvement for GM.

Segregating expenditures or manpower data to the extent that they are specific to a federal mandated standard (such as the 1978 oxides of nitrogen standard) is extremely difficult. This is attributed to the fact that the technology itself cannot be isolated. As stated numerous times, standards set for hydrocarbons and carbon monoxide emissions affect the development of the oxides of nitrogen control systems because the control technologies interact. Since the control technologies cannot be isolated technically, they cannot be segregated by cost. Emission devices currently installed in many of our vehicles will continue to be used in both the 1977 and 1978 systems, with improvements being made to these devices where necessary. Consequently, the financial and manpower data filed with our request for suspension of the 1977 emission standards is relevant to the 1978 standard and should be considered as part of our response toward meeting the oxides of nitrogen standard for 1978.

As mentioned in previous correspondence and testimony, General Motors does not have the technology to comply with the 1978 statutory requirements of .41 HC, 3.4 CO and .4 NO_x for 50,000 miles. To meet these requirements in emission control system must meet a preproduction certification test for 50,000 miles. In addition, the system must be warranted in customer's use for 50,000 miles or 5 years. We have not yet been able to develop a system hat has adequate durability performance to meet either of these requirements. f General Motors were required to choose a system at this time, it would most ikely include the following components in addition to those on 1975 federal ehicles:

1. Air Injector Reactor Systems
2. Improved Exhaust Gas Recirculation
3. Catalyst Change Reminder System
4. Electric Choke
5. Closed Loop Feedback Control System
6. Reducing Converter

iese components would add approximately $340 to the consumer cost of the 975 vehicles. It should be noted that the two catalysts (oxidizing and re- icing) would require a change every 5,000 to 10,000 miles based on current chnology. The underfloor converter oxidizing catalyst change would cost the nsumer from $60-$70. The consumer cost in effecting the catalyst change in e reducing converters has not been estimated at this time, but it is expected exceed significantly the cost of a change for the oxidizing catalyst.

e facilities required to produce the above hardware will depend on the system osen to meet the 1977 standards. If a warm-up converter is included on 1977 nicles, it would be dropped in 1978. However, some of those facilities could bably be diverted to produce the reducing converter. The additional expendi- es required to meet the 1978 emission standards are presented on two alternate es: i.e., (1) if the 1977 system included the warm-up converter, expenditures $140 million would be required, or (2) if the 1977 system excluded the warm-up verter, expenditures of $270 million would be required.

	Including Warm-up Converter in 1977			Excluding Warm-up Converter in 1977		
	1977	1978	Combined	1977	1978	Combin[ed]
	-$ In Millions-					
Facilities	125	75	200	25	175	200
Tools	60	55	115	25	75	100
Rearrangement and Start-up Expenditures	20	10	30	10	20	30
Total	205	140	345	60	270	330

As mentioned in previous sections of this report, the 3-way catalyst is also being considered as a method of meeting the 1978 standards although, based on current technology, this system does not approach durability requirements. The following components, in addition to the 1975 hardware, are considered integral to this system:

1. 3-Way Catalyst
2. Closed Loop Feedback System
3. Electric Choke
4. Improved Exhaust Gas Recirculation
5. Catalyst Change Reminder System

It is expected that this system would add $150 to the customer cost of the 1975 system. It would cost General Motors in the area of $70 million for facilities, tools, and start-up, etc. if this system were used in 1978. This would be in addition to facilities, tools and start-up expenditures ranging from $60 million to $205 million which would be required to meet 1977 standards, if technology can be developed to permit meeting these standards (see prior tabulation).

It should be recognized that if this system were adopted there would be no need for the additional AIR pump capacity and warm-up converter capacity acquired to meet the 1977 standards. This illustrates the compounding of the problems that occur when standards are frequently revised. If it is assumed that no other use could be made of these facilities, GM would have to idle or dispose of approximately $200 million worth of facilities and tools after one year's use.

it must be pointed out that due to the early stage of development "best guess" type estimates are all that are possible -- clearly, the estimates we are able to make now are not the result of "formal" or "detailed" studies. If the described systems are ever developed and manufactured, the actual costs and expenditures could vary significantly. (All estimates are based on 1975 economic levels.)

It should be noted that at the time total capital expenditures were being compiled for our initial submission for suspension of the 1977 standards, warm-up and reducing converter facilities were not considered due to the preliminary nature of their development. Subsequently, they have been included in our supplemental filing dated February 14, 1975 on a "best guess" basis. These expenditures would be substantially additive to the amounts reported in our January 10, 1975 filing for suspension of the 1977 emission standards. These expenditures will be made principally in the 1976 and 1977 calendar years.

It should be further noted that General Motors recommends a continuance of the 1975 exhaust emission requirements through the 1980 model year in the interests of conserving the fuel economy gained by our current models and to avoid unnecessary "economic hardships" on our customers.

With respect to the 1974 data, information furnished in connection with the 1977 suspension request was developed on an estimated basis. Attached are two schedules compiled for the purpose of replacing 1974 estimates with actual data now available. Actual detailed information pertaining to the 27 project categories listed on Schedule B of our 1977 suspension request is still not available for 1974. However, we expect that spending in those categories will follow the same pattern as our projection of 1974 (submitted with the 1977 suspension request) since total spending under major headings -- research and engineering; reliability, inspection and testing; facilities and tools -- is about the same as projected.

In connection with our 1978 calendar year projection, if a technological breakthrough is achieved then our research and engineering programs relating to 1978 standards should be completed. However, our reliability, inspection and testing programs will continue as will our research and engineering efforts on alternate power sources and other methods of achieving emission standards on a more economical basis. Because of the uncertainties that exist, we are unable to forecast these expenditures at this time.

With respect to our 1978 manpower projection, the uncertainty associated with the 1978 requirements precludes a workload forecast at this time.

Total actual U.S. Research, Development and Engineering expenditures for 1978 calendar year are expected to be about the same level as 1974 which is also about the same level as 1977, as shown on Schedule F of our request for suspension of the 1977 emission standards.

At this time, no reliable projection of unit sales can be made for the 1978 calendar year. This results from uncertainties due to many variables such as economic conditions brought about by inflation and the energy problems, possible increased penetration by overseas manufacturers, federally mandated safety and emission standards and other possible items like gasoline rationing, increased taxes on gasoline and car weight taxes.

The above information and the information submitted in connection with our previous request for suspension of the 1977 emission standards shows clearly that General Motors has made and is continuing to make every good faith effort to meet the 1978 emission standards for oxides of nitrogen.

GENERAL MOTORS CORPORATION
FACTORY SALES OF
U.S. DOMESTIC PRODUCTION AND IMPORTED VEHICLES

	1974 Projected	1974 Actual	1974 Actual Over/(Under) 1974 Projected
ssenger Cars			
Chevrolet			
Domestic	1,977,344	1,905,457	(71,887)
Imports	236,998	236,080	(918)
Total	2,214,342	2,141,537	(72,805)
Pontiac			
Domestic	526,686	503,100	(23,586)
Imports	10,156	9,849	(307)
Total	536,842	512,949	(23,893)
Oldsmobile			
Domestic	561,646	550,529	(11,117)
Imports	9,353	9,747	394
Total	570,999	560,276	(10,723)
Buick			
Domestic	410,509	402,032	(8,477)
Imports*	60,562	62,014	1,452
Total	471,071	464,046	(7,025)
Cadillac			
Domestic	232,639	230,857	(1,782)
Total Domestic	3,708,824	3,591,975	(116,849)
Total Imports	317,069	317,690	621
Total	4,025,893	3,909,665	(116,228)
ucks (6000 GVW or Less)			
Chevrolet			
Domest	548,742	541,801	(6,941)
Imports**	77,604	81,805	4,201
Total	626,346	623,606	(2,740)
GMC			
Domestic	101,261	96,253	(5,008)
Imports	7,245	6,316	(929)
Total	108,506	102,569	(5,937)
Total Domestic	650,003	638,054	(11,949)
Total Imports	84,849	88,121	3,272
Total	734,852	726,175	(8,677)

Includes Opel
Includes LUV

GENERAL MOTORS CORPORATION
U.S. EXPENDITURES AND MANPOWER
(Calendar Year Basis)

Emission Control Expenditures

($ Millions)	1974 Projected	1974 Actual	1974 Actual Over/(Under) 1974 Projected
	$	$	$
Research and Engineering	140	136	(4)
Reliability, Inspection and Testing	33	33	-
Facilities and Tools	277	284	7
GM Contribution to MVMA*	1	1	-
Total	451	454	3

* Estimated -- final data not available.

Research, Development and Engineering Expenditures

($ Millions)	1974 Projected	1974 Actual	1974 Actual Over/(Under) 1974 Projected
	$	$	$
Total U.S.	1,090	1,184	94

Emission Control Equivalent Employment

	1974 Projected	1974 Actual	1974 Actual Over/(Under) 1974 Projected
Full Time	751.0	731.0	(20.0)
Part Time*	622.8	535.1	(87.7)
Laboratory Technicians	950.2	967.2	17.0
Other Technical and Clerical	2,652.0	2,556.8	(95.2)
Total	4,976.0	4,790.1	(185.9)

* Full time equivalent