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# MANDATORY VEHICLE EMISSION INSPECTION AND MAINTENANCE PART B - FINAL REPORT

VOLUME V

PART 1
SUMMARY

Prepared Under Contract

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with
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Air Resources Board

Approved by

R. L. Gibney, Vice President
Environmental Systems

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NORTHROP CORPORATION
Electro-Mechanical Division
500 East Orangethorpe Avenue
Anaheim, California 92801

in association with

OLSON LABORATORIES, INC.

# FOREWORD

The Second Annual Report of the Air Resources Board, titled "Air Pollution Control in California," published in January 1970, documents the activities of the Board during 1969. In addition to a review of the Air Resources Board's many accomplishments, it was stressed that many problems remained to be solved. One of these was to determine the effects of various maintenance procedures on exhaust emissions and to develop a practical vehicle inspection program. In accordance with a legislative directive (AB76), the Air Resources Board issued a Request for Proposal on July 3, 1970 to conduct a Vehicle Emission Inspection and Maintenance Study that would determine the feasibility of such a program. Northrop Corporation, Electro-Mechanical Division, was selected to perform this study; Standard Agreement number ARB-1522 was consummated on November 30, 1970.

Part A of the study addressed the overall feasibility and public acceptability of a program of mandatory vehicle emission inspection and maintenance. It was completed in June 1971 and documented in four volumes. Volume I, Summary, provided a synopsis of the analytical methodology employed to determine and evaluate the feasibility of a statewide inspection program. The findings and results of the analyses were summarized, and recommendations for further effort were provided. Volume II described the Recommended Vehicle Emission Inspection and Maintenance Program. Volume III, Technical and Economic Feasibility Analyses, described the conduct of the study; provided the findings, results, and conclusions of the analyses; and recommended areas for further investigation. Volume IV included the Appendices of data references, relevant correspondence, instrumentation survey data sheets, and other substantiating documentation.

Part B of the total study was designed to acquire operational data on automotive emission reductions that can be achieved through vehicle inspection and maintenance. Volume V of the total study report documents the results of the vehicle test phase and contains summary information previously reported; thus, Volume V can be utilized without reference to Volumes I through IV. Volume V is presented in two parts, each under separate cover: Part 1 - Summary and Part 2 - Technical Analysis and Results.

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# SUMMARY

This study was requested by the California legislature to determine whether or not a program of mandatory periodic vehicle inspection (PVI) and corrective maintenance is a feasible approach to the reduction of exhaust emissions from automobiles in the State of California.

The conclusions from this study are as follows:

- Mandatory Periodic Vehicle Inspection (PVI) in California is feasible in terms of emission reduction, program costs, vehicle owner costs, and public opinion.
- To be most cost effective, inspection should be performed by the State, with repairs performed by private enterprise.
- Of the inspection regimes studied, Key-Mode conducted in State-owned facilities appears to be the most cost effective when considered over the first 7 years of operation.
- The Idle Test regime was nearly as cost effective as Key-Mode over the same time frame.
- The present program of Certificate of Compliance, as conducted by the service industry, produces the least benefits in terms of emission reduction.
- An inspection program will significantly reduce CO and HC emissions but may increase $NO_x$ emissions somewhat on pre-1970 vehicles.*
- There appears to be a public acceptance of a vehicle inspection program in California as a means to reduce air pollution.
- Instrumentation and equipment which can be adapted to the requirements are available for a network of inspection stations.

*Vehicles tested are equipped with CO and HC control systems. For future vehicles equipped with $NO_x$ control, deterioration and malfunction may cause $NO_x$ emissions to increase. Inspection and maintenance will probably produce a benefit of $NO_x$ emission reduction. The magnitude of this reduction cannot be determined with the data available at this time.

The feasibility of implementing a periodic vehicle inspection program was examined technically, economically, and in terms of public opinion. The effectiveness and costs of five alternative inspection test regimes were analyzed to determine which would be optimum for a mandatory PVI program. These regimes were Certificate of Compliance, Idle Test, Key-Mode Test, Diagnostic Test, and the Annual Adjustment and Maintenance Procedure (AAMP). Other alternate approaches and hybrid test regimes were reviewed and carefully considered. These included the New Jersey vehicle inspection program, cooperative programs sponsored by the Air Pollution Research Advisory committee, and the constant volume sampling (CVS) test procedures specified by the Federal government.

Test regime protocals and rules concerning adjustments and maintenance were based upon best available information and cover a broad range of inspection methods and procedures. Optimization of test regimes and maintenance procedures by the method of operations analysis may improve their cost effectiveness.

A requirements analysis was conducted that considered current trends in State and Federal regulations on vehicle emissions, past and current efforts to reduce and control emissions, the effects of vehicle maintenance on emissions, and other related background information used to formulate the investigation. The five alternative test regimes were analyzed functionally and operationally to define requirements in terms of total facility instrumentation and personnel staffing. Additionally, the requirements for overall program management and administration were defined. The general conclusions from this task are as follows:

- Equipment and technology are presently available to perform vehicle emission inspection for each of the test regimes. A statewide network of inspection facilities will necessitate minor modifications to the equipment. Additional effort will be required to integrate the equipment into a workable and efficient system.

Three of the five test regimes are particularly adaptable to State-owned inspection stations. The following facility and personnel requirements were identified for each test regime.

- Idle Test would require 319 lanes, each capable of processing 127 vehicles per 8-hour day. Each Idle test lane would require two technicians, each with a different technical skill level. Instruction required would be approximately 30 hours per technician.

- Key-Mode Test would require 398 lanes, each capable of processing 100 vehicles per 8-hour day. Each Key-Mode test lane would require two technicians, each with a different technical rating. Instruction required would be approximately 40 hours per technician.

- Diagnostic Test would require 784 lanes, each capable of processing 52 vehicles per 8-hour day. Each Diagnostic test land would require four technicians, comprised of two diagnosticians, and one each of lower technical ratings. Instructions required would amount to 40 hours per technician.

Although the Certificate of Compliance and AAMP test regimes would probably be conducted in existing stations, requirements in terms of State-owned inspection stations are presented for comparative purposes.

- Certificate of Compliance would require 1366 lanes, each capable of processing 30 vehicles per 8-hour day. Each Certificate of Compliance test lane would require at least one technician. Instruction required would be approximately 30 hours per technician.

- AAMP would require 1366 lanes, each capable of processing 30 vehicles per 8-hour day. Each AAMP test lane would require at least one technician. Instruction required would be approximately 40 hours per technician.

To evaluate and compare the candidate test regimes, an effectiveness measure was developed that considered the effects of exhaust pollutants, vehicle population, model-year distribution, average vehicle miles driven, and the anticipated inspection failure rates. This investigation involving 1095 vehicles representative of the California passenger vehicle population was statistically designed to obtain empirical operational data for the calculation of the effectiveness measures. The results of the vehicle testing and maintenance analysis program indicated the following:

- All test regimes are effective in achieving reductions in HC and CO, but to different extents. Listed in order of greatest HC reduction achieved, the test regimes are: Key-Mode, AAMP, Idle, Diagnostic, and Certificate of Compliance. Listed in order of greatest CO reduction achieved, the test regimes are: Key-Mode, Idle, Diagnostic, AAMP, and Certificate of Compliance.

- None of the test regimes was effective in achieving reductions in $NO_x$. Listed in order of least degradation to $NO_x$ emissions, the test regimes are: AAMP, Certificate of Compliance, Diagnostic, Idle, and Key-Mode.

- Additional service beyond the initial repair and adjustment of cars failing the tests was not very effective in further reducing vehicle emissions.

- Approximately 50 percent of total emission reduction achieved will be realized from the South Coast Basin, Air Basin 1. Approximately 80 percent of achievable effectiveness would be realized from the three largest basins, and about 92 percent from the five largest basins.

- Emission changes realized during the vehicle test and maintenance phase are shown in Table S-1.

To determine the emission degradation of test vehicles as a function of mileage, a program was conducted to retest 552 vehicles after 3 to 8 months of their original tests. The changes in emission between the original tests and retests determined the amount of degradation or improvement.

A statistical analysis was utilized to linearize the emission degradation data based on the mileage driven. The general findings of this program are as follows:

- Emission degradation is partially dependent on mileage driven; other factors also contribute to the degradation.

- Analysis of retest data does not show a statistical difference in degradation as a function of test regime. Further data and analysis will be required to resolve this question.

Table S-1. EMISSION PROFILE CHANGES FOR TOTAL FLEET

Note: Total fleet includes vehicles that were serviced combined with those that did not require service.

| Test Regime | HC (%) | CO (%) | $NO_X$ (%) |
|---|---|---|---|
| Certificate of Compliance | | | |
| Controlled Vehicles | -21.8 | -5.6 | 4.68 |
| Uncontrolled Vehicles | -9.6 | -5.53 | 3.72 |
| Idle | | | |
| Controlled Vehicles | -17.0 | -26.0 | 4.45 |
| Uncontrolled Vehicles | -29.0 | -20.8 | 5.65 |
| Key-Mode | | | |
| Controlled Vehicles | -27.8 | -33.4 | 3.92 |
| Uncontrolled Vehicles | -30.0 | -36.6 | 23.4 |
| Diagnostic | | | |
| Controlled Vehicles | -16.4 | -23.0 | 4.53 |
| Uncontrolled Vehicles | -36.6 | -24.9 | 10.7 |
| AAMP | | | |
| Controlled Vehicles | -23.6 | -12.5 | 1.30 |
| Uncontrolled Vehicles | -33.5 | -19.9 | -1.45 |

It is important to note that measured $NO_X$ emissions in this program may not be typical of future years. $NO_X$ control devices are now being installed on newer vehicles and will be required on all future vehicles. None of the tested vehicles for this program had such controls. It is reasonable to expect that an inspection and maintenance program will ultimately be effective in keeping these controls operating properly and thereby achieve reductions in in $NO_X$ emissions.

- The retest phase of the test program indicated that significant increases in hydrocarbons and carbon monoxide (with a corresponding decrease in $NO_x$) occur before accumulation of 10,000 miles in normal service without engine maintenance. Assuming a linear degradation rate, HC emission increased approximately 25 percent per 10,000 miles, CO increased approximately 35 percent per 10,000 miles, and $NO_x$ decreased approximately 25 percent per 10,000 miles.

A detailed cost analysis model was developed that provided a framework for evaluating the program costs associated with each of the five test regimes. This life-cycle cost model categorized cost elements into major submodels of research and development, initial acquisition and investment, and annual operations and maintenance. Results of exercising the model are:

- Least total cost would be a State-managed program, with State ownership and operation of inspection facilities. Second least costly would be a State-regulated network of privately managed, owned, and operated new inspection facilities. Most costly would be a State-managed program comprised of licensed, existing, inspection facilities privately owned and operated.

- Approximately 90 percent of total program cost is incurred by the five largest air basins.

- Research and development costs to implement each test regime are negligible.

- Initial acquisition and investment cost for the test regimes for State-owned facilities would be as follows:

| | Total Cost | Cost per Vehicle |
|---|---|---|
| Idle | $12,084,000 | $1.21 |
| Key-Mode | 19,830,000 | 1.98 |
| Diagnostic | 88,776,000 | 8.88 |

- Annual operation and maintenance costs for these test regimes would be:

| | |
|---|---|
| Idle | $ 9,576,000 |
| Key-Mode | 10,476,000 |
| Diagnostic | 30,688,000 |

- Vehicle annual inspection fee for these test regimes would be as follows:

| | State-Owned, Operated | Private-Owned, Operated | State-Managed, Licensed |
|---|---|---|---|
| Idle | $0.96 | $1.22 | $ 6.00 |
| Key-Mode | 1.05 | 1.33 | 6.00 |
| Diagnostic | 3.07 | 3.90 | 12.00 |

Again, the Certificate of Compliance and AAMP test regimes are presented below for the State-owned option for comparison purposes only.

- Initial acquisition and investment costs would be:

| | Total Cost | Cost per Vehicle |
|---|---|---|
| Certificate of Compliance | $30,263,000 | $3.03 |
| AAMP | 34,458,000 | 3.45 |

- Annual operation and maintenance costs would be:

| | |
|---|---|
| Certificate of Compliance | $23,110,000 |
| AAMP | 23,110,000 |

- Vehicle annual inspection fee would be:

| | State-Owned, Operated | Private-Owned, Operated | State-Managed, Licensed |
|---|---|---|---|
| Certificate of Compliance | $2.31 | $2.94 | $9.00 |
| AAMP | 2.31 | 2.94 | 9.00 |

The following comparisons of service and repair costs, business volume, and fuel savings are independent of ownership options for all test regimes.

- Vehicle owner typical service and repair average costs for failed vehicles would be as follows:

| | Controlled Vehicles | Uncontrolled Vehicles |
|---|---|---|
| Certificate of Compliance (includes inspection fee) | $ 8.65 | $ 8.40 |
| Idle | 36.00 | 33.40 |
| Key-Mode | 26.70 | 32.10 |
| Diagnostic | 27.10 | 53.30 |
| AAMP (includes inspection fee) | 17.10 | 22.00 |

- Service industry annual expected business volume:

| | Controlled Vehicles | Uncontrolled Vehicles | Total* |
|---|---|---|---|
| Certificate of Compliance | $38,900,000 | $ 46,200,000 | $ 85,100,000 |
| Idle | 81,000,000 | 91,800,000 | 172,800,000 |
| Key-Mode | 60,000,000 | 88,700,000 | 148,700,000 |
| Diagnostic | 60,900,000 | 146,000,000 | 206,900,000 |
| AAMP | 76,900,000 | 121,000,000 | 197,900,000 |

*Based on 10 million vehicles of which 55 percent are uncontrolled. Certificate of Compliance and AAMP both require 100 percent service; the other test regimes require 50 percent service.

- Vehicle owner potential fuel savings as a result of service and repair:

| | Controlled Vehicles | Uncontrolled Vehicles |
|---|---|---|
| Certificate of Compliance | $ 1.69 | $ 2.15 |
| Idle | 13.30 | 16.10 |
| Key-Mode | 16.70 | 22.40 |
| Diagnostic | 10.80 | 17.10 |
| AAMP | 3.07 | 10.00 |

To determine the sentiments of the general public regarding the institution of a periodic vehicle emission inspection program, 1000 owners of private passenger automobiles registered in the State of California were interviewed. Opinion Research of California designed the questionnaire in conjunction with members of the Air Resources Board and the Northrop Corporation, selected the interviewees based on a modified probability sample design, tabulated and analyzed the results. In addition, 50 selected individuals representing various business, industrial, legal, governmental, and other organizations were interviewed. The general findings of this survey are:

- Three-fourths of vehicle owners believe a mandatory vehicle emission program is necessary. Primary advantages of inspection program as viewed by vehicle owners would be: (1) reduction in air pollution, (2) force people to repair their cars, and (3) detection of defective vehicles. Disadvantages of program would be expenses and inconvenience.

- More than half of those interviewed believe the program should be conducted by the State of California rather than private garages or service stations. Main reason for selecting the State to run the program was that people do not trust private garages or service stations. Main reason given for those selecting private industry was for the convenience factor.

- Majority of vehicle owners interviewed would continue to favor the program if the following conditions existed:

  a. Inspection took 30 minutes or less
  b. Inspection fee were $1.00 or less
  c. Driving distance to inspection facility were 10 miles or less
  d. Average repair costs were $10.00 or less.

- Acceptable length of time allowed to repair vehicle would be 15 days; majority would prefer 30 days.

- More than three-fourths of vehicle owners believe inspections should be required at least once a year.

A cost-effectiveness index was developed that combined the results of the effectiveness and cost analyses to facilitate the total program evaluation and comparison of the competing test regimes. Based on the yearly effectiveness estimates and the corresponding costs incurred, a ratio of tons emission reduction per dollar spent was calculated and plotted for the program duration of 20 years, beginning 1972. The results of this analysis were as follows.

- Certificate of Compliance and AAMP test regimes would be implemented in the private sector. With respect to the other three test regimes, State-managed, owned, and operated inspection facilities would be the most cost effective. State-regulated, privately administered, owned, and operated newly constructed inspection facilities would rank second. State-managed, privately owned and licensed, existing or modified facilities would be least cost effective.

- Key-Mode would be the most cost effective among the test regimes considered during the first 7 years of total program life. Idle Test would be the next most cost-effective test regime, and would be slightly more cost effective than Key-Mode after the first 7 years of operation.

- Vehicle owner effectiveness measures considering emissions, vehicle performance, direct costs, and fuel economy would rank the alternatives from top to bottom as follows: Key-Mode, AAMP, Idle, Diagnostic, and Certificate of Compliance.

The total program effectiveness and feasibility of periodic vehicle inspection as related to vehicle exhaust hydrocarbons, carbon monoxide, and oxides of nitrogen is estimated to be as illustrated in Figures S-1 through S-4. Due to the fact that this study did not produce sufficient quantitative data on degradation effects, they are not included in these projections. $NO_x$ estimates do not include expected effects on post-1970 model-year vehicles which would have $NO_x$ emission controls.

Revised 12/10/71

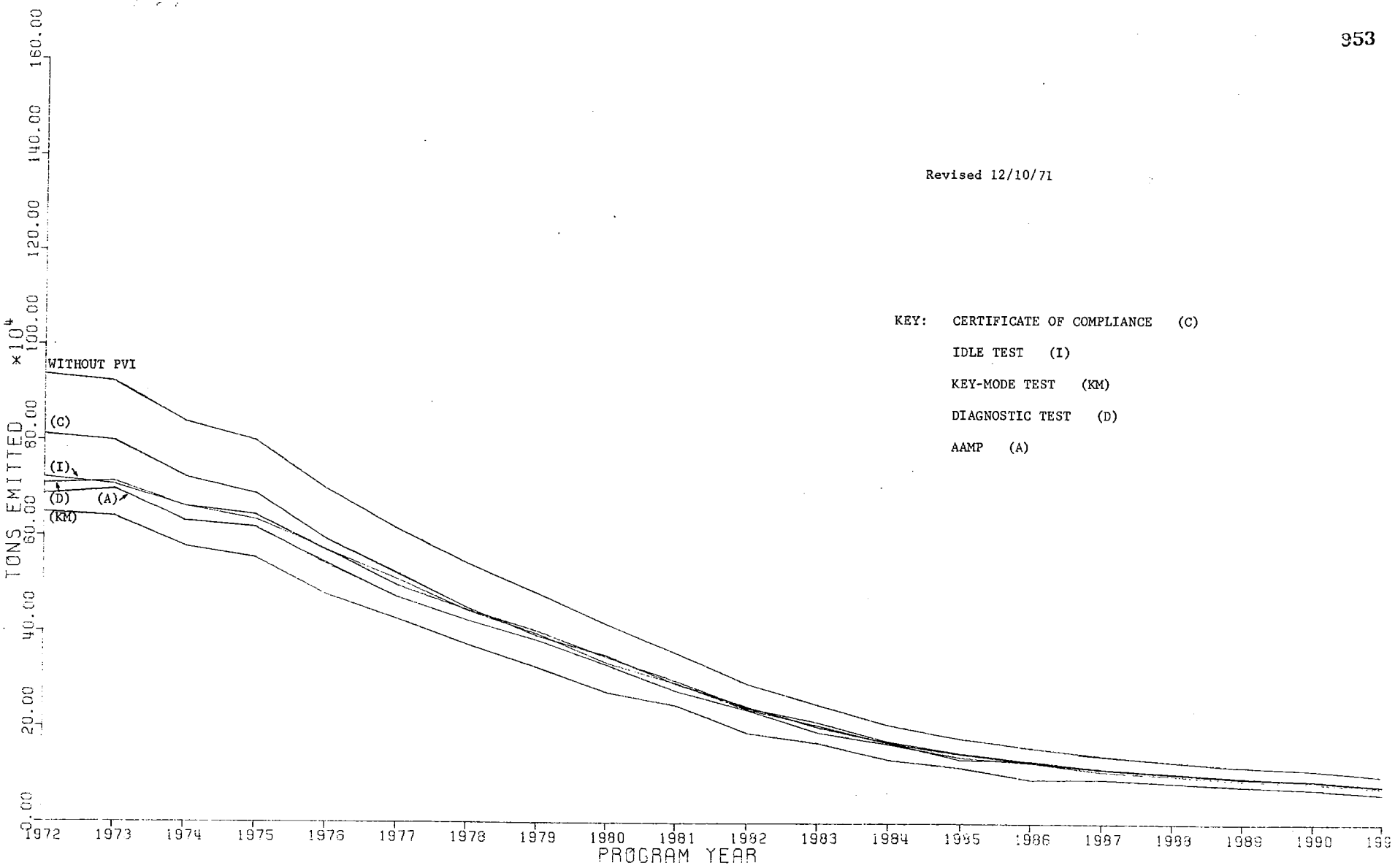


Figure S-1. EXHAUST EMISSION LEVELS OF HYDROCARBONS

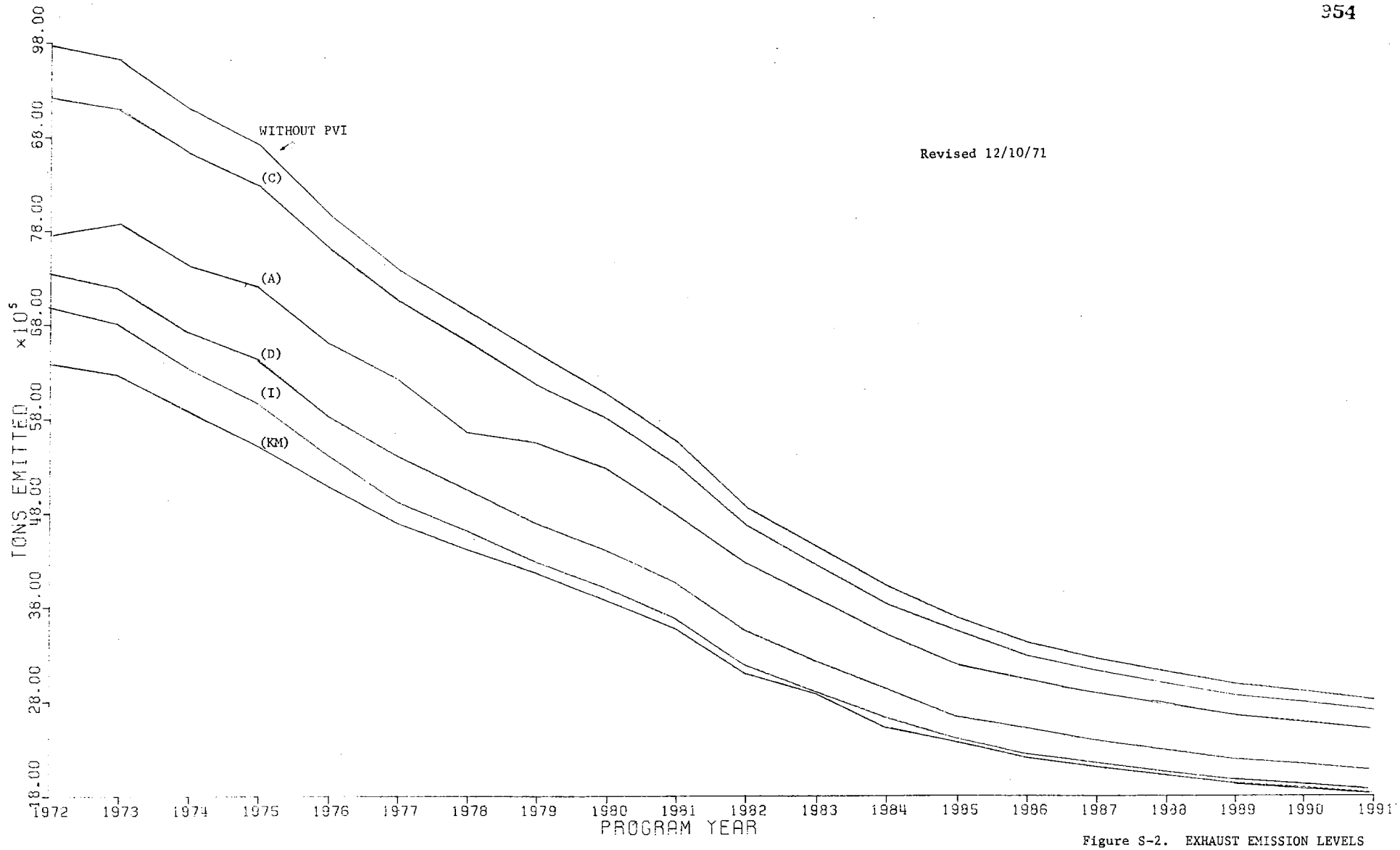


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Figure S-2. EXHAUST EMISSION LEVELS OF CARBON MONOXIDE

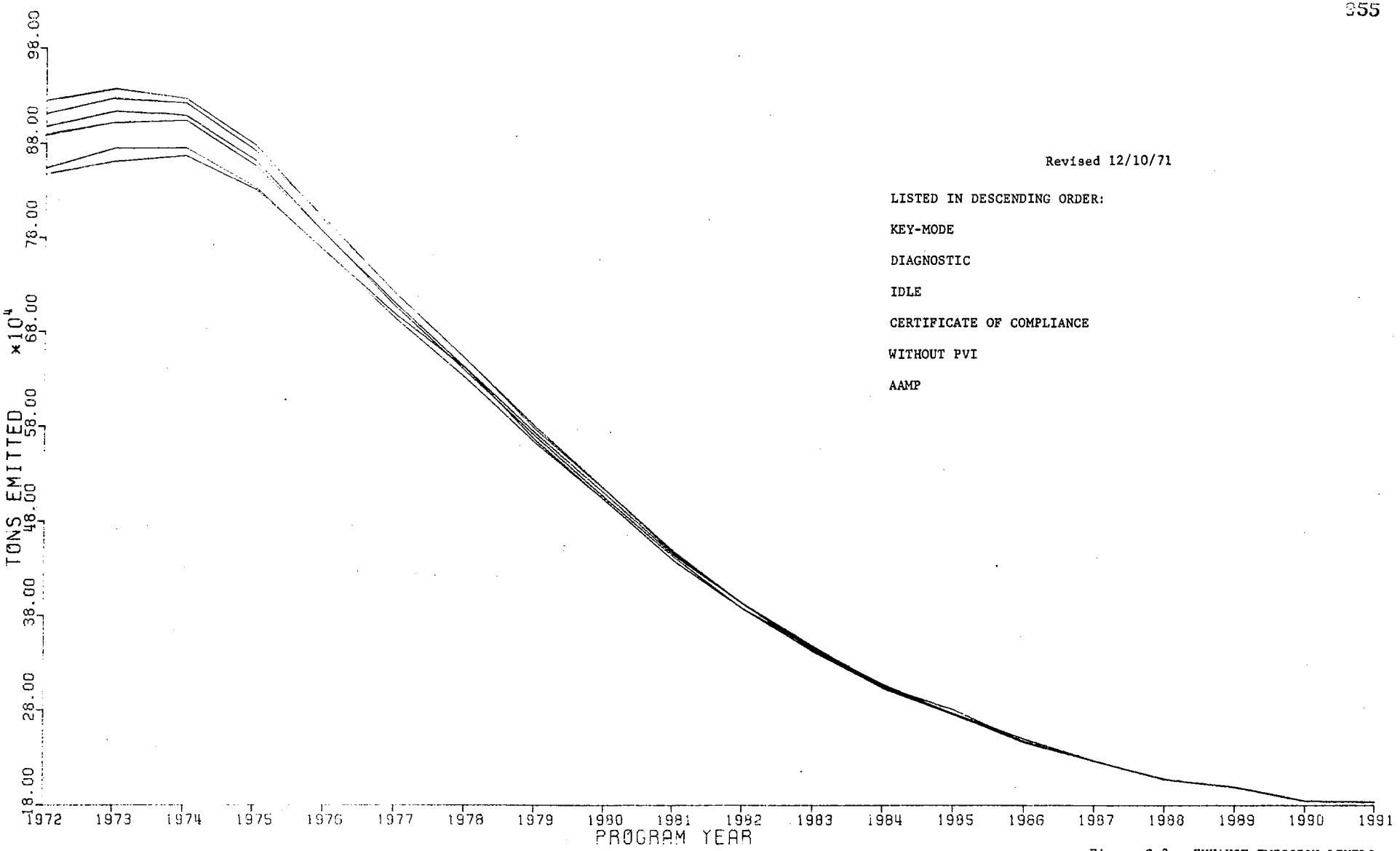


Figure S-3. EXHAUST EMISSION LEVELS FOR OXIDES OF NITROGEN

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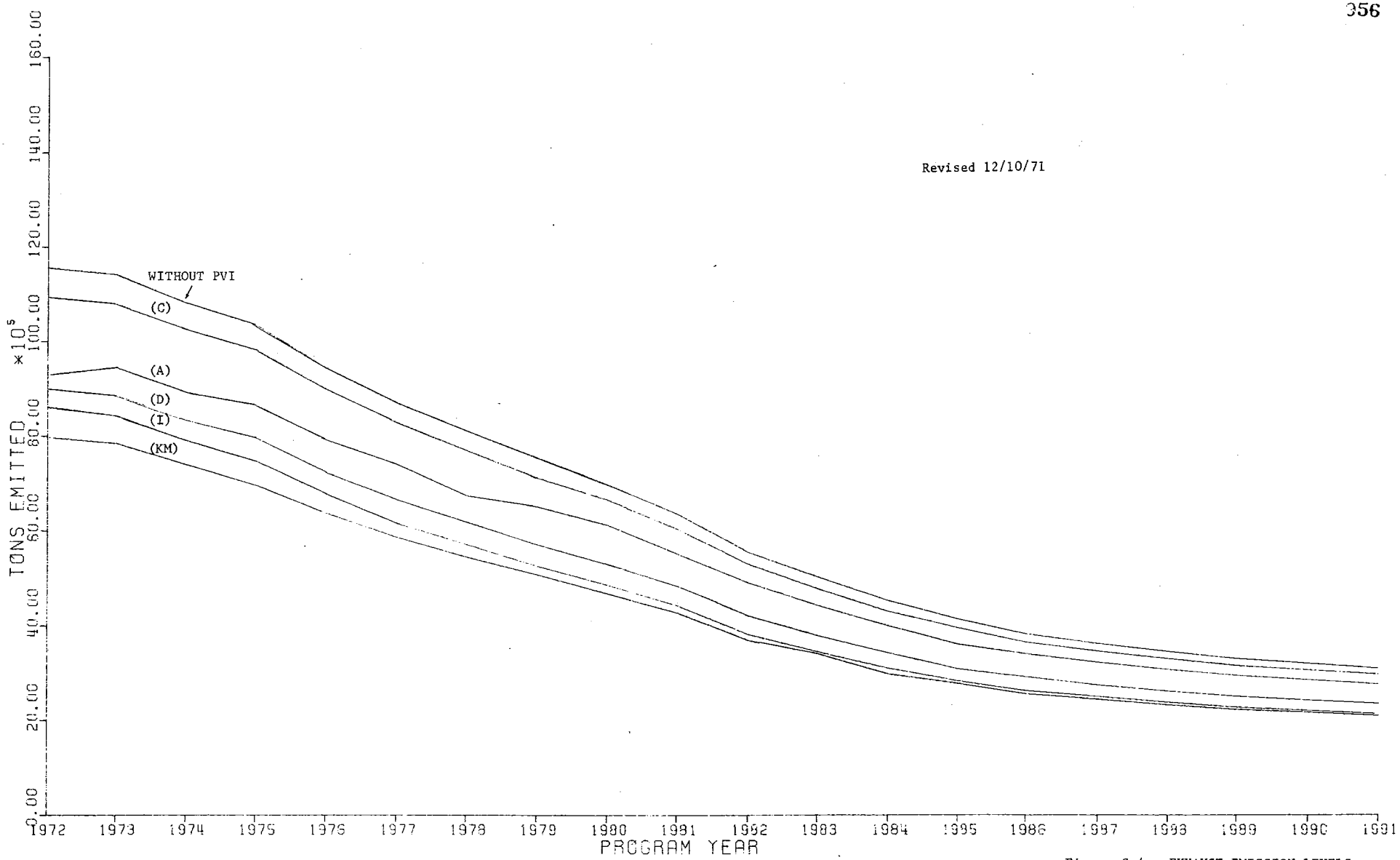


Figure S-4. EXHAUST EMISSION LEVELS OF HC, CO, AND $NO_x$