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Recommendations Regarding the Selection of Idle Emission Inspection Cutpoints for Inspection and Maintenance Programs

by

Douglas Noddings
Inspection/Maintenance Staff

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Notice

Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise, and Radiation
U.S. Environmental Protection Agency

Preface

This report, which was developed as part of EPA's Model Program Guidance, addresses idle HC and CO cutpoints and their resulting failure rates in an Inspection/Maintenance (I/M) program. Recommended cutpoints have been developed for various desired failure rates both at the beginning of I/M and after a year of the program. The analysis applies to I/M programs beginning either 1/1/82 or 1/1/83.

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I. Background

Careful attention should be given when selecting idle emission standards (cutpoints) as this choice will effect several factors of an I/M program. The cutpoints used will determine how many vehicles fail the emission test which in turn will determine the cost or inconvenience to consumers for maintenance as well as the additional capacity needed to reinspect those failed vehicles. With stricter cutpoints, more vehicles will be maintained and the repairs made will result in higher emission reduction benefits. There is also some potential for cutpoints to influence the balance between hydrocarbon and carbon monoxide reductions. Not all I/M programs will be in areas requiring reductions of both Ozone and CO. Some programs may consider selecting cutpoints which would achieve acceptable emission reduction benefits for only one of these pollutants by failing most or all vehicles for that pollutant (e.g. HC for ozone) while keeping the total number of failed vehicles constant. For all of these reasons, simply adopting another area's cutpoints may not be in the best interest of the I/M program if more effective cutpoints can be found to fulfill the program's emission reduction needs.

II. Discussion

A. Policy Considerations and Recommendations In Selecting Cutpoints

Certain policy decisions must first be made by each I/M program before the technical problem of cutpoint selection can be dealt with. It must be determined which groups of vehicles will be classified into the same cutpoint categories subject to identical inspection standards. The desired fraction of the vehicles to be failed both overall and within each cutpoint category is of principal importance. Finally, it must be decided what proportion of these failed vehicles are failed for HC emissions and/or CO emissions. An I/M program could fail all vehicles only for HC or only for CO or distribute the failures in several ways among both emissions with the same overall failure rate.

These policy decisions will affect the emission reduction benefits derived from I/M. Clearly there is a direct relationship between the overall failure rate and the emissions reduction benefits which will be achieved. For a given failure rate these benefits will vary among different emission control technologies represented by different cutpoint categories. Whether vehicles are failed for HC or CO matters because different emission problems will be identified and emission repairs will be performed so that vehicles will be able to pass different cutpoints.

Cutpoint categories may be defined in terms of a single vehicle characteristic or in terms of a unique combination of several characteristics. Characteristics considered in different I/M programs now in operation, include model year, model year groups based on similarities in technology, number of cylinders, presence of an air pump or catalyst, and the make and model of each vehicle.

The cutpoint categories which this report suggests are defined in terms of model year groups based on similarities in the federal emission standards they were designed to meet and/or emission control technologies. These suggested cutpoint categories are pre-1968, 1968-1971, 1972-1974, 1975-1979, 1980, and post-1980. It is believed that a more complex structure of cutpoint categories does not warrant the necessary additional administrative burden. Also, model year failure rates within these model year cutpoint categories (as illustrated in Table 3 and 4, below) do not vary much indicating that finer model year divisions are not necessary.1/ With these model year group cutpoint categories, an I/M program can be assured that virtually all failed vehicles will exceed federal emission standards and will benefit from repair.

1/ MOBILE2 assumes equal failure rates for each model year. Equal cutpoints within technology groups with equal failure rates among groups is close enough to the standard assumption that MOBILE2 may be used. Widely varying failure rates among model year groups require special analysis.

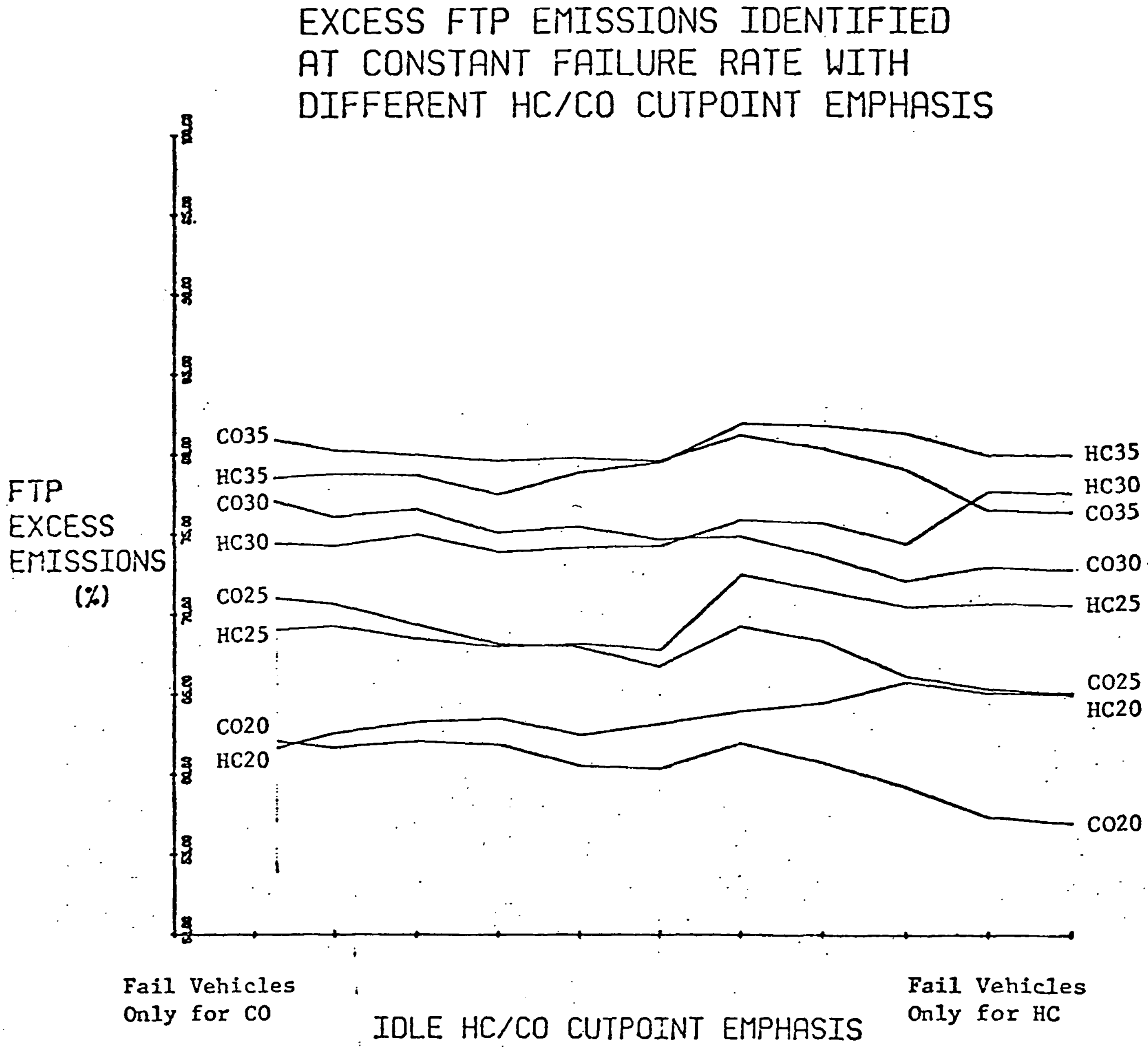
Among pre-1981 model year groups, it is suggested that cutpoints be selected which will result in a failure rate of 35% within each group. This is considered the most effective failure rate for I/M within reasonable limits. This report presents cutpoints for a 35% failure rate and also for other reasonable I/M failure rates.

In the selection of the ratio of HC to CO I/M failures, careful attention must be paid to several factors. As mentioned above, there are many pairs of HC/CO cutpoints which will result in the same total failure rate within a cutpoint category.

There are different approaches to selecting the HC/CO ratio of I/M failures. If a specific pair of HC/CO cutpoints are selected directly, this will determine the HC/CO ratio of failures for a given vehicle population and also the total failure rate. If these results are judged to be acceptable, the cutpoint selection process is completed. If not, further trial-and-error is needed. There are also two other approaches which are more systematic. One is to decide first what the total failure rate, the HC-only failure rate, and the CO failure rate will be (the total failure rate is the sum of the HC-only and CO failure rates); once this decision is made, actual cutpoints that will result in this total failure rate and ratio of HC/CO failures can systematically be selected for any given sample of vehicles' idle scores. A computer program such as the one contained in the Appendix of this report can be used for this final step. The other systematic approach to selecting the HC/CO ratio of failures is to specify first an HC/CO cutpoint relationship, e.g., "HC cutpoint = CO cutpoint x (100 ppm/1%)", and then specify the desired total failure rate. Once these decisions are made, the unique pair of HC/CO cutpoints which satisfy the relationship and result in the desired total failure rate can be found systematically, again using a computer program. EPA prefers this last approach to selecting the HC/CO distribution; the remainder of this report uses it.

In selecting a specific recommended cutpoint locus (HC/CO pairs) for each of the model year groups listed earlier from the great number of alternatives, several factors were considered. Changes in the percentage of excess FTP HC and CO emissions identified in failed vehicles resulting from moderate shifts in HC/CO locus emphasis are negligible. Even shifts to the extreme cases of failing vehicles only for HC or only for CO have little impact as illustrated in Figure 1. Repair effectiveness, however, also determines emission reduction, so excess FTP emissions identified is only a partial indication of the relative emission reductions which would be observed when using such extreme HC/CO cutpoint emphasis. EPA has found that cutpoint sets which emphasize HC are accompanied by high rates of errors of commission (failed vehicles which meet federal emission standards). Due to the resulting high rate of errors of commission and the uncertain though apparently small benefit of extreme HC cutpoint emphasis, it is suggested that I/M programs avoid using extreme HC emphasis cutpoint loci. Also because of uncertain benefits I/M programs which need HC reduction benefits should avoid extreme CO emphasis loci.

Figure 1



EXCESS FTP EMISSIONS IDENTIFIED
AT CONSTANT FAILURE RATE WITH
DIFFERENT HC/CO CUTPOINT EMPHASIS
FTP
EXCESS
EMISSIONS
(%)
CO35
HC35
CO30
HC30
CO25
HC25
CO20
HC20
HC35
HC30
CO35
CO30
HC25
CO25
HC20
CO20
Fail Vehicles
Only for CO
IDLE HC/CO CUTPOINT EMPHASIS
Fail Vehicles
Only for HC

EPA recommends two specific HC/CO cutpoint loci for pre-1981 vehicles, one for pre-1968 vehicles and the other for 1968-1980 vehicles. Suggested loci are listed in Table 1 and illustrated in Figure 2. These loci are believed to be reasonable, moderate, and administratively convenient. They are suitable for I/M programs needing HC only or both HC and CO reductions. Advice for I/M programs requiring only CO reductions will follow this report. I/M benefits predicted by MOBILE2 are based upon these loci. Special help is available for states who wish to depart significantly from them. The 207(b) standards of 220 ppm HC and 1.2% CO are recommended for use in all I/M programs for 1981 and later model year vehicles.

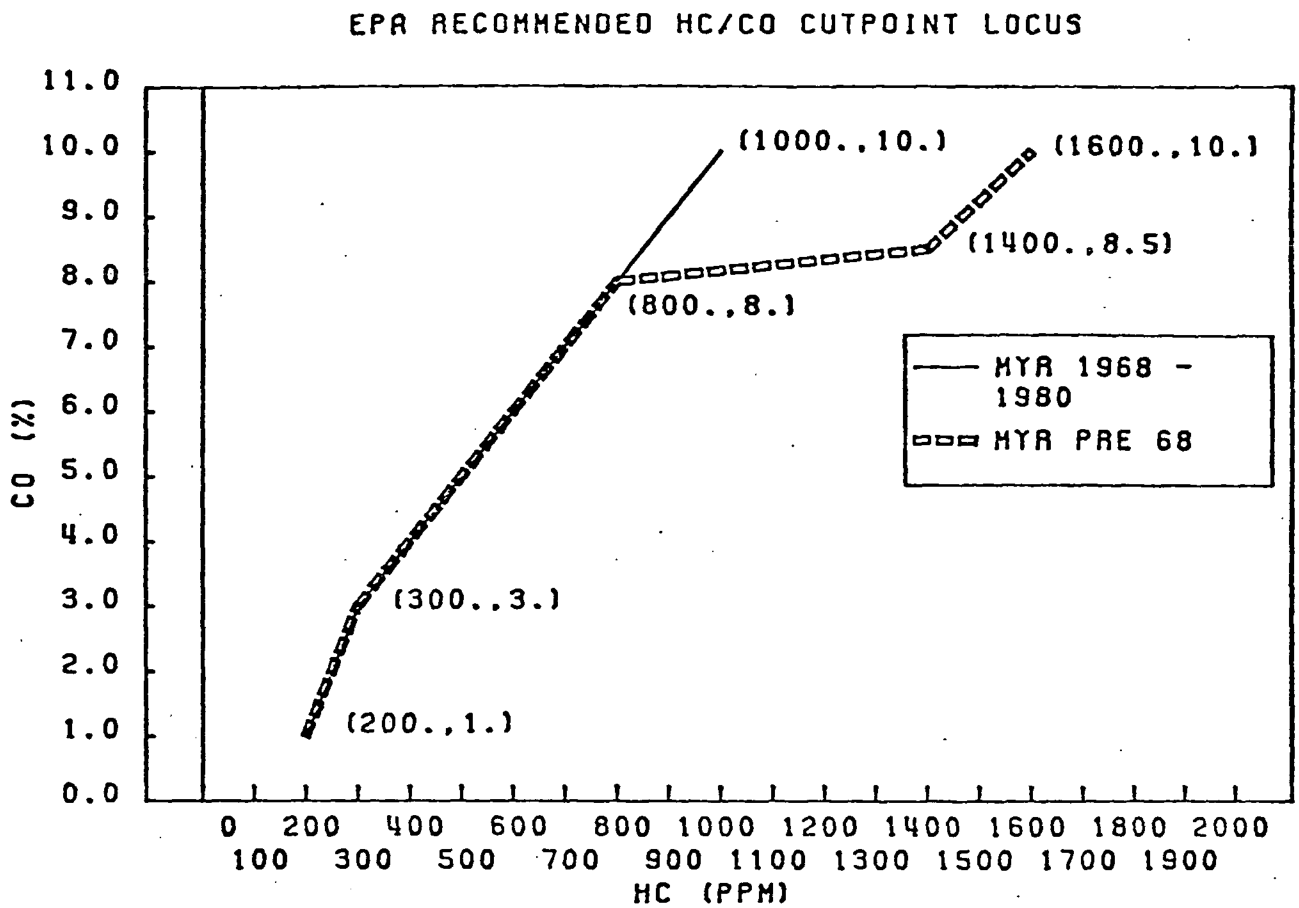
1/ Excess FTP emissions are defined to be emissions above the FTP standard. The percent identified in the fraction of all excess FTP emissions in the vehicle fleet which are accounted for by vehicles failing the short test. The percentage of excess emissions identified is a rough indicator of likely emission reductions possible. If only a small proportion of the fleet excess emissions are identified there is probably not much potential for emission reductions.

Table 1

Suggested HC/CO Cutpoint Loci (Pairs) For Pre-1981 Model Year Vehicles

Model Year			
Pre-1968		1968-1980	
HC (ppm)	CO (%)	HC (ppm)	CO (%)
200	1.0	200	1.0
225	1.5	225	1.5
250	2.0	250	2.0
275	2.5	275	2.5
300	3.0	300	3.0
350	3.5	350	3.5
400	4.0	400	4.0
450	4.5	450	4.5
500	5.0	500	5.0
550	5.5	550	5.5
600	6.0	600	6.0
650	6.5	650	6.5
700	7.0	700	7.0
750	7.5	750	7.5
800	8.0	800	8.0
1400	8.5	850	8.5
1467	9.0	900	9.0
1533	9.5	950	9.5
1600	10.0	1000	10.0

Figure 2


EPA RECOMMENDED HC/CO CUTPOINT LOCUS
CO (%)
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
(1000.,10.)
(1600.,10.)
(1400.,8.5)
(800.,8.)
(300.,3.)
(200.,1.)
MYR 1968 - 1980
MYR PRE 68
0 200 400 600 800 1000 1200 1400 1600 1800 2000
100 300 500 700 900 1100 1300 1500 1700 1900
HC (PPM)

B. Technical Problems in Selecting Initial Cutpoints (Pre-1981 Vehicles)

Once a locus of possible HC/CO cutpoints is selected, selecting specific cutpoints for initial use in an I/M program is simply a matter of estimating the failure rates that will result from different possible cutpoints and choosing the cutpoints that produce the desired failure rate. Estimating the failure rate resulting from a set of cutpoints requires attention to an I/M program's unique attributes. Consideration of the geographic location and starting date of the program are both important.

The same cutpoints may yield substantially different failure rates depending on the geographic location of the I/M program. EPA samples indicate variations in failure rate of as much as 5 percent when identical cutpoints are applied in different states. Altitude, fleet composition and local maintenance habits could be contributing factors to this variation. The use of local data therefore is probably better for failure rate estimation than data collected in other areas, provided enough local data is collected to keep sampling error at an acceptable level. Table 2 gives sample sizes appropriate for sampling one model year group with varying tolerances, confidence levels and estimated model year group failure rates. For example, an I/M program which desires an accuracy of ±2% with 95% confidence for each model year group failure rate estimate and is interested in failure rates of 35 percent should sample 2185 vehicles per model year group in its cutpoint strategy (10925 total if, as is recommended, five model year groups are used for pre-1981 vehicles). The data from this sample should be preserved in the form of one record for each vehicle, the record should consist of the HC and CO scores and the model year or model year group.

Table 2
Appropriate Sample Sizes
for Estimating Failure Rates at Different
Levels of Confidence and Tolerance

Confidence Level	Failure Rate	Tolerance ± 1%	Tolerance ± 2%	Tolerance ± 5%
95%	20%	6147	1537	246
	25%	7203	1801	289
	30%	8068	2017	323
	35%	8740	2185	350
99%	20%	10618	2655	425
	25%	12443	3111	498
	30%	13936	3484	558
	35%	15097	3775	604

The best data to use when estimating the failure rate in an I/M program is data from the operating program itself. However, to select initial cutpoints it may be desired to obtain these estimates before the actual program is in place. Two possible ways of collecting useful data are a pilot program (e.g., shopping center testing) and a mandatory inspection/voluntary maintenance phase.1/ A strong possibility of recruiting or sampling bias in the former makes the latter preferable. For either option, though, test accuracy must be assured by good quality control. Otherwise the sample estimates may be meaningless.

Failure rates observed now for a given set of cutpoints and vehicles are probably lower than they will be in the future. As vehicles age and are driven more miles they get dirtier. For this reason, a given pair of HC/CO standards for a given model year will result in higher failure rates with time. Failure rate estimates derived from a current sample will be less than what will actually be observed in a program beginning a couple years from now. The most recent data is therefore the best sample to use when estimating failure rates.

When the actual I/M program does begin, states should plan to use the actual I/M data to measure the actual failure rate in the initial months. A month or two should be sufficient time to collect enough data to make these measurements.

Once the necessary data has been gathered, estimates for the failure rates resulting from various cutpoints can be achieved using computer software similar to the FORTRAN program attached. This program can test any cutpoint pair input by the user and return the resulting failure rate, or accept as input a desired failure rate and HC/CO cutpoint relationship and return the appropriate cutpoints. With data sets of reasonable sizes, such as mentioned in Table 2, this analysis can be managed on most computer systems once the data has been transcribed into computer usable form.

1/ Either of these approaches may over predict the failure rate which will be observed at the beginning of the mandatory maintenance I/M program. During the mandatory maintenance phase, some vehicle owners will probably have their vehicles maintained anticipating the emissions inspection. No data is available to investigate this further.

For the benefit of states which do not have local data available, EPA has developed a model to predict failure rates for various cutpoints in the future.1/ Data used in creating this model came from 10,450 light duty vehicles of all model years sampled nationwide by EPA's I/M Demonstration Vans during the past year, 2,513 1975-1980 model year vehicles tested in Houston, Phoenix, St. Louis, Chicago and Washington D.C. by EPA's Emission Factor Program between 1975 and 1979, and 10,656 vehicles of all model years sampled in New Jersey's I/M program during the past year. The EPA model accounts for the fact that failure rates will be higher when I/M programs start than when these vehicles were tested.

Tables 3 and 4 present prediced minimum, maximum, and mean failure rates for all pre-1981 model year groups. Table 3 is for programs beginning 1/1/82; Table 4 for those starting a year later. The minimum is the failure rate for the most recent and therefore the youngest and cleanest model year in the group; the maximum is the failure rate for the oldest and therefore the dirtiest model year; and the mean is the average for all the model years in the group, taking the national average registration distribution of model years within model year groups at the projected time into account. As the tables show, there is little variation in failure rates among model years within a model year group, as is usually desired. This verifies the appropriateness of the model year groupings chosen.

1/ Details concerning this model are to be released in a technical paper titled: "Failure Rates in Inspection and Maintenance Programs". Copies will be distributed to state I/M officials and will also be available from the EPA's I/M Staff in Ann Arbor, Michigan (312)668-4367.

Table 3

Initial Model Year Group Failure Rates
Predicted by EPA Cutpoint Model
At I/M Program Start Date 1/1/82

Cutpoints Idle HC (ppm)	CO (%)	Pre-1968 Min1/	Max2/	Mean3/	1969-71 Min	Max	Mean	1972-74 Min	Max	Mean	1975-79 Min	Max	Mean	1980 Mean	1981+4/
200	1.0							86.0	88.7	87.2	58.8	77.9	66.1	48.5	
220	1.2														5.0-10.0
225	1.5							81.2	83.4	82.4	52.0	60.0	56.5	43.0	
250	2.0							75.2	77.5	76.3	47.3	54.8	51.1	36.6	
275	2.5							68.9	71.4	70.1	43.2	50.3	46.9	31.0	
300	3.0	90.0	90.3	90.1	76.8	76.8	76.8	65.3	68.3	66.3	40.0	48.7	44.7	24.2	
350	3.5	86.6	87.2	86.9	71.3	72.0	71.8	58.7	62.1	60.4	35.1	44.1	39.9	19.4	
400	4.0	81.1	81.1	81.1	66.3	67.5	66.5	53.3	56.6	54.7	30.8	39.3	35.4	16.6	
450	4.5	75.4	77.6	76.5	59.9	61.4	60.9	47.9	51.2	49.6	26.3	35.1	31.2	13.9	
500	5.0	69.8	71.0	70.3	53.5	54.2	54.2	42.5	46.5	43.9	22.4	31.2	27.2	11.5	
550	5.5	65.0	65.7	65.5	48.6	49.9	48.9	36.3	39.7	38.0	19.8	27.6	23.7	8.9	
600	6.0	62.2	62.8	62.5	42.6	44.1	43.2	31.4	34.8	33.1	16.7	23.6	20.3	7.2	
650	6.5	56.7	57.8	57.4	37.0	39.4	38.2	27.3	30.1	28.6	14.4	20.7	17.8	5.3	
700	7.0	51.0	52.2	51.7	34.3	35.1	34.4	23.6	25.8	24.5	12.0	18.4	15.4	4.0	
750	7.5	46.6	48.3	47.5	29.1	30.2	29.6	19.4	22.7	20.8	10.2	16.0	13.3	3.0	
800	8.0	41.9	43.9	42.9	24.8	27.4	25.8	16.6	18.9	17.6	8.0	13.9	11.2	1.9	
1400	8.5	26.3	29.0	27.8											
1600	10.0	16.0	16.7	11.4											
Registration Fraction			.038			.110			.184			.449		.095	.124

(1) Minimum model year failure rate within model year groups.
(2) Maximum model year failure rate within model year groups.
(3) Average failure rate in model year groups weighted by projected model year registration fractions.
(4) EPA recommends use of 207(b) short test standards of 1.2% CO and 220 ppm HC.
EPA expects that the failure rate from these cutpoints will never exceed 5-10%.

Table 4

Initial Model Year Group Failure Rates
Predicted by EPA Cutpoint Model
At I/M Program Start Date 1/1/83

Cutpoints Idle		Model Year Group													
HC	CO	Pre-1968			1969-71			1972-74			1975-79			1980	1981+4/
(ppm)	(%)	Min1/	Max2/	Mean3/	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Mean	
200	1.0							87.2	90.3	88.5	60.6	79.8	69.5	51.4	
220	1.2														5.0-10.0
225	1.5							83.0	84.6	83.5	54.8	63.1	58.3	45.9	
250	2.0							76.7	79.2	77.6	49.6	56.6	52.6	39.2	
275	2.5							70.3	73.0	71.4	45.7	51.0	48.1	35.2	
300	3.0	90.0	90.3	90.2	76.8	76.8	76.8	65.7	69.8	67.6	42.6	50.1	46.3	27.0	
350	3.5	86.6	87.2	87.0	72.0	72.0	72.0	60.9	63.5	62.0	37.7	46.2	41.7	23.6	
400	4.0	81.1	81.1	81.1	66.3	67.5	66.7	54.6	57.6	56.0	33.0	41.1	37.1	18.9	
450	4.5	75.4	77.6	77.0	61.4	62.2	61.5	50.1	52.5	51.1	28.7	36.9	32.9	16.5	
500	5.0	69.8	71.0	70.6	54.2	55.2	54.6	43.4	47.8	45.5	25.1	32.3	28.8	13.9	
550	5.5	65.5	65.7	65.6	48.6	49.9	49.1	38.5	40.7	39.5	21.6	28.7	25.1	11.6	
600	6.0	62.2	62.8	62.6	43.2	44.1	43.6	33.7	35.6	34.5	18.8	25.1	21.7	9.6	
650	6.5	57.4	57.8	57.7	38.1	39.6	38.9	28.8	30.7	29.7	16.3	22.0	19.1	7.8	
700	7.0	51.4	52.2	52.0	34.3	35.1	34.6	24.4	27.3	25.6	13.9	19.8	16.7	5.9	
750	7.5	47.2	48.3	47.9	29.6	31.4	30.0	20.9	23.1	22.1	11.4	16.8	14.4	4.4	
800	8.0	42.3	43.9	43.3	25.8	27.4	26.4	17.6	19.4	18.5	9.9	15.0	12.3	3.4	
1400	8.5	27.0	29.0	28.4											
1600	10.0	16.3	16.7	16.6											
Registration Fraction			.027			.084			.152			.447		.073	.217

(1) Minimum model year failure rate within model year groups.
(2) Maximum model year failure rate within model year groups.
(3) Averge failure rate in model year groups weighted by projected model year registration fractions.
(4) EPA recommends use of 207(b) short test standards of 1.2% CO and 220 ppm HC.
EPA expects that the failure rate from these cutpoints will never exceed 5-10%.

C. Cutpoints For Initial and Subsequent Years (Pre-1981 Vehicles)

Because of emission deterioration, failure rates based on data available today are expected to increase up to the time at which the I/M program begins. I/M will thereafter reduce failure rates relative to what they would have been without I/M, since maintenance received to pass the I/M test will still have some effect when vehicles come due for their next annual inspection. How much effect varies with the standards the vehicles were initially required to pass.

During the first twelve months of an annual I/M program, failure rates should remain approximately constant if vehicle inspections fall on vehicle birthdays since the inspected vehicles will be the same age each month. This may not be the case in states which have recently switched to a staggered registration system or still have another registration system in place.

At the second annual inspection, failure rates will probably be different, for a given set of cutpoints, than they were at the first inspection. Two principle factors influence how failure rates will change. Those vehicles which were maintained as a result of the first inspection will still be cleaner at the second inspection than they would have been without emissions maintenance. They may even be cleaner than they were one year earlier at the time of their first inspection, depending on how much cleaner maintenance made them and how fast they have deteriorated. Passing vehicles will have deteriorated during the interim period between inspections thus tending to result in an increase in the failure rate. The change in failure rate will depend upon the balance among these influences. Since sufficient maintenance would have been performed on failed vehicles to enable them to pass the original cutpoints, the failure rate change will largely depend upon the initial failure rate and cutpoints.

EPA's cutpoint model predicts that without I/M, model year group failure rates will increase 1-4 percentage points in the course of a year while with I/M these failure rates will decrease 4-14 percentage points for a given set of cutpoints designed to achieve an initial failure rate of 35% in each model year group.

States have two general options to choose from in selecting their I/M cutpoint strategy. They may leave cutpoints fixed from year to year and let failure rates change, or they may adjust cutpoints from year to year to achieve a constant failure rate or some other desired pattern of failure rate.1/ The second option puts the state in control of failure rate, and thereby also in control of the demand for I/M repair and for reinspection.

1/ Fixed cutpoints with changing failure rates are modeled in MOBILE2. Special help is available if a state wishes to adjust cutpoints during an I/M program.

The effectiveness of an I/M program in reducing emissions from pre-1981 vehicles increases as cutpoints are made stricter, up to the point at which clean cars are being failed frequently. In practice, this only means that failure rates should not exceed 50 percent. If a state allows cutpoints to stay fixed and as a result the failure rate declines (as it generally will between the first and second year), the state is losing an opportunity for greater emission reductions. These greater reductions could be achieved without increasing the failure rate from the rate to which the public, the repair industry, and the I/M employees are already accustomed. All that would be needed to achieve the greater emission reduction would be to tighten the cutpoints just enough to keep failure rates constant. EPA therefore recommends that states plan to adjust cutpoints in this way.

EPA has estimated the initial cutpoints and the revised cutpoints that would be needed at the start of the second year, for a range of failure rates. These estimates are shown in Table 5. By the start of the third year, each I/M program should be able to revise its cutpoints more accurately by using local data than by relying on EPA's general estimates, so third and subsequent year cutpoints are not included. Table 5 gives appropriate cutpoints for I/M programs beginning 1/1/1982 and 1/1/1983. The second year cutpoints shown in these tables should be planned for implementation at the beginning of the second inspection cycle. To insure a program's capability of adjusting cutpoints to maintain a constant failure rate, it is further suggested that the stricter subsequent year cutpoints be on the books and ready to take effect from the start of the program.

Table 5

EPA Recommended I/M Cutpoints

Cutpoints predicted to give constant failure rates among pre-1981 vehicles for I/M beginning 1/1/82 and 1/1/83 in initial and second year inspections by EPA cutpoint model.

I/M Beginning Date	Nominal Failure Rate (%)	Program Sequence	Pre-1968 HC (ppm)	Pre-1968 CO (%)	1968-71 HC (ppm)	1968-71 CO (%)	1972-74 HC (ppm)	1972-74 CO (%)	1975-79 HC (ppm)	1975-79 CO (%)	1980 HC (ppm)	1980 CO (%)	1981+1/ HC	1981+1/ CO
1/1/82														
	20	initial	1550	9.5	850	8.5	750	7.5	600	6.0	350	3.5	220	1.2
		2nd year	1400	8.5	750	7.5	600	6.0	500	5.0	450	4.5	220	1.2
	25	initial	1450	9.0	800	8.0	700	7.0	550	5.5	300	3.0	220	1.2
		2nd year	1400	8.5	700	7.0	500	5.0	400	4.0	400	4.0	220	1.2
	30	initial	1400	8.5	750	7.5	650	6.5	450	4.5	275	2.5	220	1.2
		2nd year	800	8.0	600	6.0	400	4.0	350	3.5	300	3.0	220	1.2
	35 2/	initial	1400	8.5	700	7.0	600	6.0	400	4.0	250	2.0	220	1.2
		2nd year	800	8.0	600	6.0	400	4.0	300	3.0	275	2.5	220	1.2
1/1/83														
	20	initial	1550	9.5	900	9.0	800	8.0	650	6.5	400	4.0	220	1.2
		2nd year	1400	8.5	750	7.5	600	6.0	500	5.0	450	4.5	220	1.2
	25	initial	1450	9.0	800	8.0	700	7.0	550	5.5	350	3.5	220	1.2
		2nd year	1400	8.5	700	7.0	550	5.5	400	4.0	350	3.5	220	1.2
	30	initial	1400	8.5	700	7.5	650	6.5	500	5.0	300	3.0	220	1.2
		2nd year	800	8.0	650	6.5	450	4.5	350	3.5	300	3.0	220	1.2
	35	initial	1400	8.5	700	7.0	600	6.0	400	4.0	275	2.5	220	1.2
		2nd year	800	8.0	600	6.0	400	4.0	300	3.0	275	2.5	220	1.2

1/ All I/M programs should use the 207(b) cutpoints for 1981 and later vehicles for all program years. EPA expects that the failure rate from these cutpoints will never exceed 5-10%.

2/ EPA recommends this failure rate for best effectiveness.

D. Subsequent Cutpoint Revision (Pre-1981 Vehicles)

EPA cutpoint predictions for pre-1981 vehicles are not tailored to specific local conditions such as fleet composition, altitude, and maintenance habits indicating that both initial and subsequent failure rate projections will probably not be completely accurate. For 1980 vehicles in particular, EPA's predictions are based on limited data and consequently may be inaccurate. Thus it is likely that states will find it necessary to revise their cutpoints after I/M has begun. States should be prepared to revise cutpoints within the first one or two months to correct for overall or model year group failure rates which differ from those expected and desired. If a state wishes to achieve a constant or specified failure rate in the second and later years, subsequent revisions become imperative.

In designing an I/M program it may be desirable to specify in advance (by law or regulation) how cutpoints will be revised. One alternative is to give administrators a free hand in cutpoint revision. If this is not preferred, there are other alternatives retaining administrative flexibility while keeping program administrators from having a completely free hand. By law or regulation a state could establish a range (such as $\pm$ 2.0% CO, $\pm$ 200 ppm HC) in which cutpoints may be modified without new laws or time-consuming rulemaking. A variation of this alternative would be an enforcement tolerance or one sided range allowing administrators to tighten but not loosen cutpoints. Conversely, a state could establish by law or regulation a range within which the program administrator would be directed to confine the failure rates, requiring him/her to revise the cutpoints if the failure rates should be found outside of these boundaries for some appropriate length of time.

States should be able to make cutpoint revisions quickly. This will be found to be especially desirable during the first few months at the start of the I/M program when local influences on failure rates become apparent. Similar corrections may be necessary at the beginning of the second inspection cycle. To accomodate this, procedures for data collection, handling, and analysis should be developed. What is necessary is a continuous sample of idle scores and failure frequencies at first inspections identified by model year and test date, and the capability of analyzing these data in a rapid manner.

E. Cutpoints for 1981 and Later Vehicles

The I/M process for 1981 and later vehicles will be different in several ways as compared to earlier model year vehicles. This results from the significantly different technology which will be employed on the 1981 and later fleet. This technology utilizes an on-board computer control system to monitor the operation of the engine and continuously adjust engine parameters such as air/fuel ratio, spark timing, EGR flow rate, etc. This is in contrast to earlier model year vehicles which rely on a combination of fixed internal parameters (passage sizes, spring stiffnesses, etc.) and adjustable external parameters (adjusting screws, variable distributor alignment, etc.) For these earlier model year vehicles, one of the main causes of vehicles emitting excessive emissions in-use is improper adjustment of the external engine parameters (e.g. idle mixture). This occurs in a fairly large percentage of the in-use fleet. (The other main cause of excessive in-use emissions is normal deterioration of replaceable components such as spark plugs, the air filter, distributor cap and rotor, spark plug wires, diaphragms and rubber hoses.) For the 1981 and later fleet, however, the few remaining external adjustable parameters are of minor importance in terms of emissions, and the more critical internal parameters are not adjustable and fall under control of the on-board computer. The main cause of vehicles emitting significantly above the standard is failure of the computer control system. (The other main cause of high emissions for earlier model year vehicles as described above is also still present but plays a secondary role.) Failure of the computer control system can occur in a variety of different ways, but it is not expected to occur very often. When it does occur, HC and CO emissions rise dramatically: hundreds of percent over the design standard. The I/M process for 1981 and later vehicles will focus in on this relatively small group of grossly emitting vehicles[1].

As indicated above, 1981 and later vehicles are also expected to experience a phenomena common to all model years of vehicles: ignition and misfire problems due to deterioration and failure of replaceable ignition parts. These problems are, in a certain way, similar in nature to the computer control system failures described above. That is, they do not occur very often, but when they do they can cause a dramatic increase in HC emissions.

Given the preceding background on the differences in 1981 and later technology and the types of failures which will be encountered, issues related to cutpoint selection and failure rates can now be discussed. There are two issues: the first is that the selection of the short test to be used for 1981 and later vehicles is of more importance than which cutpoints are used. The second is the impact of the 207(b) warranty on cutpoint selection.

The first area listed above stems from the fact that due to the sophistication of 1981 and later vehicles, some I/M short tests will be more capable of identifying the gross emitters than others. For example, a test which simply measures a vehicle's emissions at idle will be slightly less effective than a test which also measures and evaluates (i.e. passes or fails) a vehicle's emissions at either an elevated speed (2500 rpm) or under a loaded condition (30 mph at 9.0 AHP load). Evaluating a vehicle's emissions at modes other than the basic idle mode puts the computer control system more to the test by giving it more than one operating condition to respond to. This conclusion is based upon analyses of data from actual in-use vehicles equipped with technology representative of the 1981 and later model year fleet. While cutpoints still play an important role, their role is secondary in comparison to the choice of which short test will be used. Since the computer control system is assumed to either be operating properly with very low emissions or to have failed with resultingly very high emissions, the in-use emissions picture will

1 A more complete discussion of this subject can be found in a technical report entitled: Derivation of I/M Benefits for Post-1980 Light Duty Vehicles for Low Altitude, Non-California Areas. [EPA-AA-IMS/81-2]

be much more quantized. This is as opposed to the continuous range of emission levels seen among fleets of earlier model year vehicles with adjustable parameters. Thus, varying the cutpoints up and down within reasonable limits will not yield significant changes in the failure rate. Grossly emitting vehicles will for the most part be identified by any reasonable cutpoint.

The discussion so far has focused on vehicles with a failure of the computer control system. The other major source of excessive in-use emissions is vehicles with ignition and misfire problems. These vehicles will have an in-use emissions performance similar to current model year cars. Therefore it is reasonable to conclude that currently available cutpoints (such as the 207(b) cutpoints discussed below) will work equally well in identifying those vehicles requiring maintenance.

The failure rates resulting from the identification of vehicles with computer system failures and of vehicles with severe ignition/misfire problems were combined to arrive at the estimated failure rate of 5-10% shown in Tables 3 and 4. In comparison to earlier model year vehicles, there are not large data bases from 1981 and later vehicles participating in representative I/M programs. Thus, failure rates cannot be more closely quantified as they have been for earlier model year fleets.

The second area of discussion has to do with the impact of the 207(b) warranty upon the selection of cutpoints. The 207(b) regulations established three basic tests as acceptable for use in the warranty process: the basic Idle-in-Neutral test with or without a 2500 rpm preconditioning, the Two Speed Idle test (Idle-in-Neutral/2500 rpm/Idle-in-Neutral) and the Loaded Two Mode test (30 mph @ 9.0 AHP/Idle-in-Neutral). The regulations also provided for a number of variations on test format, that is, which test modes would be used in making the pass/fail decision. Cutpoints were established for each test and are EPA's recommendation for use for 1981 and later vehicles in operating I/M programs. The basic cutpoints are 1.2% CO and 220 ppm HC. The one exception to this is for the Two Speed Idle test where either the 2500 rpm emissions or the lower of the two Idle-in-Neutral emissions are the criteria for failure. For these cases the cutpoints are 1.0% CO and 200 ppm HC. Table 6 lists the basic tests, the variety of formats and the cutpoints for each.

Table 6

207(b) Tests and Associated Cutpoints
(1981 and Later Models)

Basic Test	Mode(s) to be Evaluted	Cutpoints
Idle-in-Neutral	Idle-in-Neutral	1.2% CO, 220 ppm HC
Two Speed Idle (Idle-in-Neutral/ 2500 rpm/Idle-in Neutral)	Lower of two Idles-in-Neutral	1.0% CO, 200 ppm HC
	2500 rpm	1.0% CO, 200 ppm HC
	2500 rpm and Lower of two Idles-in-Neutral	1.0% CO, 200 ppm HC
2500/Idle-in-Neutral[1/]	2500 rpm	1.0% CO, 200 ppm HC
	Idle-in-Neutral	1.2% CO, 220 ppm HC
Loaded Two Mode	Idle-in-Neutral	1.2% CO, 220 ppm HC
	30 mph	1.2% CO, 220 ppm HC
	Idle-in-Neutral and 30 mph	1.2% CO, 220 ppm HC

1/ This test combines the 2500 rpm test and standards from the two speed idle test with the basic idle test, and is EPA's recommended test for 1981 and later models. It differs from the two speed idle in that only one idle-in-neutral is performed. Because the standards are relatively insensitive to failure rates for post-1980 models, 1.2% CO and 220 ppm HC are recommended for both modes for the purpose of simplicity in administration.

Table 7

Vehicle Model Year Groups
Corresponding To Similar Emission
Control Technologies

LDV[1/]	LDT1[2/]	LDT2[3/]
Pre-1968	Pre-1968	Pre-1970
1968-1971	1968-1971	1970-1972
1972-1974	1972-1974	1973-1978
1975-1979	1975-1983	1979-1983
1980	-	-
1981+	1984+	1984+

1/ LDV = Light Duty Vehicle.
2/ LDT1 = Light Duty Truck with GVW less than 6,000 pounds.
3/ LDT2 = Light Duty Truck curb weight greater than 6,000 pounds or Light Duty Truck with GVW between 6,000 pounds and 8,500 pounds.

There are several points which lie behind EPA's recommendation that the 207(b) cutpoints be adopted. First, and perhaps most obviously, a tighter cutpoint should not be used. This would result in problems with warranty coverage. For example, if an I/M cutpoint was set lower than the established 207(b) cutpoint, an auto manufacturer would not need to honor a warranty claim from a vehicle which failed the lower cutpoint since the regulation specifically defines the higher cutpoint as the lowest acceptable criterion. On the other hand, while a state or locality could select cutpoints higher than the 207(b) cutpoints without loss of warranty coverage, there is no good reason to do so since the failure rate using the 207(b) cutpoints is already very low (5-10%). This failure rate is well below the limit necessary for good public acceptance.

F. Cutpoints for Light Duty Trucks

The same considerations apply when selecting cutpoints for light duty trucks (LDTs) as in selecting cutpoints for light duty vehicles (LDVs). LDTs are classified into 2 weight categories for purposes of federal emission standards. Each category is subject to a different set of certification schedules for meeting federal emission standards. LDT model year groups recommended in Table 7 are chosen so that each group has similar emission controls to the corresponding LDV model year groups.

The same cutpoints should be applied to both LDT categories as well as LDVs within similar emission control groups. Further refinements are possible once the I/M program begins.

III. Summary

Cutpoints should be selected and adjusted to maintain a constant failure rate. Appropriate initial cutpoints and revised cutpoints for the second inspection cycle are presented in Table 4. If an I/M program results in a failure rate lower than anticipated, the failure rate should be allowed to climb, or cutpoints should be revised. Whatever the desired failure rate, HC/CO cutpoint pairs should be selected from HC/CO loci in Figure 2 and Table 1.

Attachment

FORTRAN program for automating
cutpoint selection

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC                                                                 CC
CC THE PROGRAM, 8064G-CUT, IS TO STUDY THE  HC & CO CUT POINTS AND CC
CC  DETERMINE THE STANDARDS FROM A DATA BASE FILE.                 CC
CC.                                                                CC
CC  RUN SAQP:8064H-CUT 1=SGWH:EFLINE.T2  5=*MSOURCE*  6=*MSINK*    CC
CC                      19X, F5.0,F5.2                             CC
CC                                                                 CC
CC     WRITTEN BY J.P.CHENG    ON 07-07-80.                        CC
CC     REVISED BY J.P.CHENG    ON 07-14-80.                        CC
CC                                                                 CC
CC                                                                 CC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC
CC
      DIMENSION  HC(5000), VA11(5000),VA22(5000), COM1(20)
      DIMENSION  CO(5000), VA21(5000),VA12(5000),  FMT(10)
CC
      DATA  FMT(1), FMT(10), BLNK,ONO /'(   ','   )','    ','N   '/
CC
  100 FORMAT(//' INPUT IHC AND ICO READ FORMAT ***********',
     +/' XAXAXXXXXXXXXXXXXXXXXXXXXXXXXXX '   )
  102 FORMAT(     20A4 )
  104 FORMAT( 1X, 20A4 )
CC
  106 FORMAT(1H0,' IN THE SAQP:8064H-CUT PROGRAM, THE FUNCTIONS OF ',
     W     'FOUR (4) OPCODES ARE LISTED BELOW : '/1H0,
     W/' 1 = GIVEN CUTS TO PROJECT FREQ. PERCENTAGES.',
     +/' 2 = GIVEN FREQ. PERCENTAGES TO PROJECT CUTS.',
     +/' 3 = GIVEN (F2+F3+F4) % & THE HCCUT/COCUT RATIO TO PROJECT CUTS'
     W/' 4 = GIVEN (F2+F3+F4) % ONLY ( WITH BUILT-IN HC & CO RELATIONS',
     W     ' ) TO PROJECT CUTS '   )
CC
CC
  108 FORMAT('0  INPUT COMMENTS AS THE HEADER OF O/P ( SUCH AS',
     W ' DATA SET NAME, FORMAT ETC. )'/1H ,  20('COMM') )
  110 FORMAT(//' **********************************',
     W//' PERCENTILE      IHC      ICO    '/ )
  112 FORMAT('   P(',I4,' )  ',2F9.3  )
CC
  114 FORMAT(///'& DO YOU WANT TO CONTINUE ? (Y/N) : (DEFLT=Y) ')
  116 FORMAT(  A1   )
CC
CC     READ IN A FORMAT STATEMENT, LIST OPCODES,
CC     INPUT COMMENTS AND READ IN DATA
CC
C
 1007 WRITE(6,100)
C
      READ (5,102) (FMT(K),K=2,9)
      IF( FMT(2).EQ.BLNK .AND. FMT(3).EQ.BLNK ) GO TO 1007
      WRITE(6,104) (FMT(K),K=2,9)
CC
      WRITE(6,106)
CC
      WRITE(6,108)
CC
      READ (5,102)  COM1
```

```
      WRITE(6,104)  COM1                                          20
CC
CC
      DO 10 N=1,5000                                              21
      READ (1,FMT,END=15)  HC(N), CO(N)                           22
   10 CONTINUE                                                    23
CC
CC    " N " IS THE SAMPLE SIZE
CC
   15 N = N - 1                                                   24
CC
CC    SORTING
CC
      CALL   SORTPR( HC,   CO,    VA11,VA12, N, IRTN )            25
CC
      CALL   SORTPR( CO,   HC,    VA21,VA22, N, IRTN )            26
CC
CC
CC    CALCULATE PERCENTILES AND LIST THEM OUT.
CC
      WRITE(6,110)                                                27
CC
      DO 30 IP=2,99,2                                             28
      PERT = ( IP * N ) / 100                                     29
      INT  = ( IP * N ) / 100                                     30
      DEL  = PERT - INT                                           31
      HCTIL = VA11(INT) * DEL + VA11(INT+1) * ( 1. - DEL )        32
      COTIL = VA21(INT) * DEL + VA21(INT+1) * ( 1. - DEL )        33
CC
      WRITE(6,112)     IP, HCTIL, COTIL                           34
CC
   30 CONTINUE                                                    35
CC
      IP = 100                                                    36
      WRITE(6,112)     IP, VA11(N), VA21(N)                       37
CC
CC
CC    MAJOR OPERATIONS BY USING " CUTOUT " SUBROUTINE
CC
  777 WRITE(6,114)                                                38
CC
      READ (5,116)   ANS                                          39
CC
      IF( ANS .EQ. ONO ) GO TO 999                                40
CC
      CALL CUTOUT(    VA11,VA22,    VA21,VA12,   COM1,      N )   41
CC
      GO TO 777                                                   42
CC
  999 STOP                                                        43
      END                                                         44
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC                                                                 C
CC THE SUBROUTINE, SORTPR, IS TO SORT PAIRED DATA DATA LINE        C
CC (BASED ON FIRST VARIABLE) IN AN ASCENDING ORDER.                C
CC                                                                 C
CC   V1IN(N)   -- INPUT VARIABLE 1 FOR  ASCENDING ORDER SORTING    C
CC   V2IN(N)   -- INPUT VARIABLE 2, PAIRED WITH VARIABLE 1.        C
CC   SRT1(N)   -- OUTPUT SORTED DATA OF VARIABLE V1IN(N).          C
CC   SRT2(N)   -- OUTPUT OF V2IN(N) , PAIRED WITH SRT1(N).         C
CC                                                                 C
CC    WRITTEN BY J.P.CHENG   ON 07-07-80.                          C
CC                                                                 C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC
      SUBROUTINE SORTPR( V1IN,V2IN, SRT1,SRT2, N, IRTN )                1
CC
CC
      DIMENSION  V1IN(N),V2IN(N), SRT1(N),SRT2(N)                       2
CC
CC    INITIALIZATION,  FILL SRT1(1) & SRT2(1)
CC
      DO 10 L=1,N                                                       3
      SRT1(L)    = 0.0                                                  4
      SRT2(L)    = 0.0                                                  5
   10 CONTINUE                                                          6
CC
CC
      SRT1(1) = V1IN(1)                                                 7
      SRT2(1) = V2IN(1)                                                 8
CC
CC    ASCENDING SORT WITH V2IN GOING WITH V1IN.
CC
   15 DO 60 NS=2,N                                                      9
CC
      NL = NS                                                           10
      NM = NS - 1                                                       11
CC
        DO 30 NC=1,NM                                                   12
        NL = NL - 1                                                     13
CC
        SRT1(NL+1) = SRT1(NL)                                           14
        SRT2(NL+1) = SRT2(NL)                                           15
CC
        IF( V1IN(NS) .GE. SRT1(NL) ) GO TO 45                           16
CC
   30   CONTINUE                                                        17
CC
      NL = 0                                                            18
CC
CC
   45 SRT1(NL+1) = V1IN(NS)                                             19
      SRT2(NL+1) = V2IN(NS)                                             20
CC
   60 CONTINUE                                                          21
CC
      RETURN                                                            22
CC
      END                                                               23
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC                                                                    C
CC THE SUBROUTINE, CUTOUT, IS TO CALCULATE THE HC & CO CUTOUT POINTS  C
CC FROM GIVEN FREQUENCIES OR VICEVERSA.                               C
CC                                                                    C
CC                                                                    C
CC                                                                    C
CC                                                                    C
CC                                                                    C
CC                                                                    C
CC     WRITTEN BY J.P.CHENG   ON 07-15-80.                            C
CC                                                                    C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC
      SUBROUTINE CUTOUT(    VA11,VA22,   VA21,VA12,  COM1,    N )                1
CC
CC
      DIMENSION VA11(5000),VA22(5000),VA21(5000),VA12(5000),COM1(20)             2
      DIMENSION  SHC(5000), SCO(5000),  KS(5000),   PCT4(4),COM2(20)             3
      DIMENSION  KT(4)                                                           4
CC
      DATA BLNK/'    '/                                                          5
  590 FORMAT('0 INPUT COMMENTS WHICH WILL BE USED AS O/P HEADER',                6
     W /1X,' ( DEFLT = PREVIOUS COMMENT INPUT )', 21X, 6('COMM') )
  595 FORMAT(       20A4 )                                                       7
  596 FORMAT( 1X,  20A4 )                                                        8
CC
  600 FORMAT(//'&(SAOP:8064H-CUT) ****** INPUT OPCODE (1/2/3/4): ' )             9
  601 FORMAT('0 INPUT :                                 ',                       10
     +'            '/'0   HC CUT   CO CUT' /'    XXX.XXX  XXX.XXX' )
  602 FORMAT('0 INPUT :  F2(HC-F,CO-P) & F3+F4(CO-F) IN ',                       11
     +'PERCENTAGES. '/'0    F2 %   F3+F4 %' /'    XXX.XXX  XXX.XXX' )
  603 FORMAT('0 INPUT :'/'0 PERCENT  HCCUT/COCUT  ',                             12
     +'            '/'  F2+F3+F4   RATIO ' /'    XXX.XXX  XXX.XXX' )
  604 FORMAT('0 INPUT :'/'0 PERCENT                ',                            13
     +'            '/'  F2+F3+F4          ' /'    XXX.XXX         ' )
CC
  202 FORMAT( I1 )                                                               14
  212 FORMAT(   2F9.3 )                                                          15
  214 FORMAT(1X,2F9.3 )                                                          16
CC
  220 FORMAT('0 ***** THE NEGATIVE F1 = ', F10.3)                                17
  224 FORMAT(1H0,' ****************************************',                    18
     +/'      H C    H C    H C    H C       SIZE ',
     +/'      C O    C O    C O    C O ',
     +/'      P P    F P    P F    F F ',
     +/ 1X, 4I7,  3X,I7,     '    FREQ.          '
     +/ 2X, 4F7.3, '             FREQ. IN PERCENTAGES ' ,
     +//' ***  HC CUT =', F9.3,' /   CO CUT =',F8.3 // 1X, 40('<>')  )
  244 FORMAT('0  *********  SORRY  CHARLIE  ************'/,                     19
     + '  UNABLE  TO   CALCULATE    WITH     F1 = ', I4
     +/'        HC CUT = ', F7.3,'     &    CO CUT = ', F7.3 )
CC
CC     INITIALIZATIONS AND HEADER FIXING
CC
      DO 110 K=1,4                                                               20
      KT(K) = 0                                                                  21
```

```
CC
CC
      WRITE(6,590)
      READ (5,595)  COM2
CC
      KNT = 0
      DO 114 K=1,20
      IF( COM2(K).EQ.BLNK ) KNT = KNT + 1
  114 CONTINUE
CC
      IF( KNT.EQ.20 ) GO TO 116
      DO 115 K=1,20
      COM1(K) = COM2(K)
  115 CONTINUE
CC
CC
  116 WRITE(6,596)  COM1
CC
CC    MAJOR OPERATIONS START HERE  ******************
CC
  127 WRITE(6,600)
CC
      READ (5,202)  KODE
CC
      IF( KODE.LT. 1 .AND. KODE.GT. 4 )      GO TO 127
      CALL TIME(6,1)
CC
      GO TO(1,2,3,4),KODE
CC
CC    OPCODE = 1  < GIVEN HC CUT  AND  CO CUT   TO GENERATE RESULTS. >
CC
    1 WRITE(6,601)
      READ (5,212) HCCUT, COCUT
      HCCUT = HCCUT + .5
      COCUT = COCUT + .005
      WRITE(6,214) HCCUT, COCUT
CC
      DO 150 I=1,N
      KS(I) = 1
      IF( VA11(I).GT.HCCUT .AND. VA12(I).LE.COCUT ) KS(I) = 2
      IF( VA11(I).LE.HCCUT .AND. VA12(I).GT.COCUT ) KS(I) = 3
      IF( VA11(I).GT.HCCUT .AND. VA12(I).GT.COCUT ) KS(I) = 4
      KT( KS(I) ) = KT( KS(I) ) + 1
  150 CONTINUE
CC
      GO TO  900
CC
CC    OPCODE = 2  < GIVEN F2(%)  AND  F3+F4(%)   TO GENERATE RESULTS. >
CC
    2 WRITE(6,602)
      READ (5,212)  F2PCT, F34PCT
      WRITE(6,214)  F2PCT, F34PCT
CC
CC    DETERMINE  NFCO AND NFHC CUT OFF POINTS.
CC
      NFCO = N * ( 100. - F34PCT ) / 100. + 0.999
CC
      IF(VA21(NFCO).NE.VA21(NFCO+1) )   GO  TO  261
```

```
      260 IF(VA21(NFCO).EQ.VA21(NFCO+1) ) NFCO = NFCO + 1                57
          IF(VA21(NFCO).EQ.VA21(NFCO-1) )   GO  TO  260                  58
CC
      261   COCUT = VA21(NFCO) + .005                                    59
CC
CC
            F1PCT = 100. - (F2PCT + F34PCT )                             60
CC
            IF( F1PCT .GT. 1.0 ) GO TO 270                               61
CC
CC    ERROR, UNABLE TO HANDLE SMALL F1PCT.
CC
            WRITE(6,220)  F1PCT                                          62
CC
            GO TO 2                                                      63
CC
CC
      270 CALL   SORTPR( VA22, VA21, SHC,SCO, NFCO, IRTN )               64
CC
          NFHC = NFCO * ( F1PCT / ( F1PCT + F2PCT ) ) + 0.999            65
CC
          IF( SHC(NFHC).NE. SHC(NFHC+1) )    GO  TO  281                 66
      280 IF( SHC(NFHC).EQ. SHC(NFHC+1) ) NFHC = NFHC + 1                67
          IF( SHC(NFHC).EQ. SHC(NFHC-1) )    GO  TO  280                 68
CC
      281   HCCUT = SHC(NFHC) + 0.5                                      69
CC
CC
CC    TO COUNT F(1) & F(2) WHEN CO PASSES.
CC
          KT(1) = NFHC                                                   70
          KT(2) = NFCO - NFHC                                            71
CC
          IM = NFCO + 1                                                  72
CC
CC
          GO TO 850                                                      73
CC
CC    OPCODE = 3  < GIVEN F2+F3+F4(%) AND HCCUT/COCUT RATIO
CC                  TO GENERATE RESULTS. >
CC
        3 WRITE(6,603)                                                   74
CC
          READ (5,212)  F234, RATIO                                      75
          WRITE(6,214)  F234, RATIO                                      76
CC
          CONST = 0.                                                     77
CC
          GO TO 310                                                      78
CC
CC
CC    OPCODE = 4  < WITH BUILT-IN RELATIONS (I.E. HCCUT=RATIO*COCUT+C)
CC                  GIVEN F2+F3+F4(%)  TO GENERATE RESULTS. >
CC
        4 WRITE(6,604)                                                   79
CC
          READ (5,212)  F234                                             80
```

```
      CC
         310 FIPCT = 100. - F234                                          82
      CC
             NFHC =  N * FIPCT / 100. + 0.999                             83
      CC
      CC
             COLO = VA21(NFHC) + .005                                     84
             COHI = VA21(N)    + .005                                     85
      CC
      CC
             DO 380 NTRY=1,20                                             86
      CC
             COCUT = ( COLO + COHI ) / 2.                                 87
      CC
      CC
             IF( KODE.EQ.3 )  GO TO 340                                   88
      CC
      CC     IF( NTRY.EQ.1 .AND. 3.005.LT.COHI )  COCUT = 3.005
                                   RATIO = 100.                           89
             IF( COCUT .LE. 3.00 )  RATIO =  50.                          90
                                   CONST =   0.                           91
             IF( COCUT .LE. 3.00 )  CONST = 150.25                        92
      CC
         340 HCCUT = COCUT * RATIO + CONST                                93
      CC
               DO 355 I=NFHC,N                                            94
               IF( VA21(I) .GT. COCUT )  GO TO 358                        95
         355   CONTINUE                                                   96
      CC
               WRITE(6,244) NFHC,HCCUT,COCUT                              97
               GO TO (999,999, 3, 4 ),  KODE                              98
      CC
         358   COCUT = VA21(I-1) + .005                                   99
               HCCUT = COCUT * RATIO + CONST                             100
      CC
               DO 360 K=1,4                                              101
               KT(K) = 0                                                 102
         360   CONTINUE                                                  103
      CC
      CC
             IM = I - 1                                                  104
      CC
               DO 370 I=1,IM                                             105
               KS(I) = 1                                                 106
               IF( VA22(I) .GT. HCCUT ) KS(I) = 2                        107
      CC
               KT(KS(I)) = KT(KS(I)) + 1                                 108
      CC
         370   CONTINUE                                                  109
      CC
               IF( KT(1) - NFHC )   373, 800, 376                        110
      CC
         373   COLO = COCUT                                              111
               GO TO 380                                                 112
      CC
         376   COHI = COCUT                                              113
      CC
         380 CONTINUE                                                    114
```

```
      CC
      CC
      CC
        800 IM = IM + 1
            IF(IABS( KT(1)- NFHC ) .LT.  5 )    GO   TO   850
            WRITE(6,244)  NFHC, HCCUT, COCUT
            GO  TO (999,999, 3, 4 ),  KODE
      CC
      CC
      CC    START TO COUNT F(3) & F(4) WHEN CO FAILS.
      CC
      CC
        850 DO 855 I=IM,N
            KS(I) = 3
            IF( VA22(I) .GT. HCCUT )  KS(I) = 4
            KT( KS(I) ) = KT( KS(I) ) + 1
        855 CONTINUE
      CC
      CC    WRITE OUT RESULTS
      CC
        900 DO 920 I=1,4
            PCT4(I) = KT(I) * 100. / N
        920 CONTINUE
      CC
            WRITE(6,224)  KT,  N,    PCT4,  HCCUT, COCUT
      CC
      CC
        999 RETURN
      CC
            END
```

T A B L E O F C O N T E N T S
(ALPHABETICAL)

MODULE	FILE	PAGE
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